Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities

Proceedings of an International Conference

Athens, 11–15 December 2006

IAEA

AEN NEA

World Nuclear Association

IAEA

International Atomic Energy Agency

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (i.e. all these areas of safety). The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Safety standards are coded according to their coverage: nuclear safety (NS), radiation safety (RS), transport safety (TS), waste safety (WS) and general safety (GS).

Information on the IAEA's safety standards programme is available at the IAEA Internet site

http://www-ns.iaea.org/standards/

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at P.O. Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

OTHER SAFETY RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications. Security related publications are issued in the **IAEA Nuclear Security Series**.

LESSONS LEARNED FROM THE DECOMMISSIONING OF NUCLEAR FACILITIES AND THE SAFE TERMINATION OF NUCLEAR ACTIVITIES

PROCEEDINGS SERIES

LESSONS LEARNED FROM THE DECOMMISSIONING OF NUCLEAR FACILITIES AND THE SAFE TERMINATION OF NUCLEAR ACTIVITIES

PROCEEDINGS OF AN INTERNATIONAL CONFERENCE ON
LESSONS LEARNED FROM THE DECOMMISSIONING
OF NUCLEAR FACILITIES AND THE
SAFE TERMINATION OF NUCLEAR ACTIVITIES
ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY,
CO-SPONSORED BY THE EUROPEAN COMMISSION,
IN COOPERATION WITH THE
OECD NUCLEAR ENERGY AGENCY AND THE
WORLD NUCLEAR ASSOCIATION,
HOSTED BY THE GOVERNMENT OF GREECE
THROUGH THE MINISTRY OF FOREIGN AFFAIRS
OF THE HELLENIC REPUBLIC
AND THE GREEK ATOMIC ENERGY COMMISSION
AND HELD IN ATHENS, 11–15 DECEMBER 2006

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2007

Sales and Promotion, Publishing Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
September 2007
STI/PUB/1299

IAEA Library Cataloguing in Publication Data

International Conference on Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities (2006 : Athens, Greece)

Lessons learned from the decommissioning of nuclear facilities and the safe termination of nuclear activities : proceedings of an International Conference on Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities / organized by the International Atomic Energy Agency, co-sponsored by the European Commission, in cooperation with the OECD Nuclear Energy Agency and the World Nuclear Association, hosted by the Government of Greece through the Ministry of Foreign Affairs of the Hellenic Republic and the Greek Atomic Energy Commission and held in Athens, 11–15 December, 2006. — Vienna : International Atomic Energy Agency, 2007.

p. ; 24 cm. — (Proceeding series, ISSN 0074–1884)
STI/PUB/1299
ISBN 978–92–0–106107–2
Includes bibliographical references.

1. Nuclear facilities — Decommissioning — Congresses. 2. Radioactive waste disposal — Congresses. I. International Atomic Energy Agency. II. European Commission. III. Series Proceedings series (International Atomic Energy Agency).

IAEAL 07–00491

FOREWORD

The decommissioning of facilities that use radioactive material is the final step in their life cycles and its objective is the safe termination of the activities at the facilities and the release of associated materials and sites for unrestricted or restricted use. There is an international consensus that decommissioning should be considered at the early stages of facility development. However, for many facilities built decades ago, this was not done and, as a result, insufficient consideration was given to important factors such as spent fuel and waste management and to the financial and social aspects. Internationally, immediate dismantling is recognized as the preferred decommissioning strategy because of its important advantages, such as the availability of knowledge of the facility history, the availability of skilled personnel, and social and financial considerations. However, other strategies have been justified and implemented around the world.

Lessons learned from the planning, performance, termination and regulation of decommissioning of different facilities (nuclear power plants, research reactors, fuel fabrication plants, etc.) have been gathered during the last forty years. They show that properly conducted decommissioning ensures the protection of workers, the public and the environment and allows licences to be terminated safely. Decommissioning is also a key factor in demonstrating to the various interested parties that nuclear facilities can be safely managed throughout their lifetimes. The lessons learned from decommissioning projects can be incorporated in a systematic manner into the design and operation of new facilities to facilitate their own eventual decommissioning. Challenges remain in the achievement of safe and effective decommissioning, in relation to, for example, demonstration of safety, the adequacy of technology, adequate funding for decommissioning, the management of spent fuel and radioactive waste, and social considerations.

It was considered timely for the International Atomic Energy Agency (IAEA) to organize this international conference on the Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities, from 11 to 15 December 2006 in Athens. The conference was co-sponsored by the European Commission (EC), and held in cooperation with the OECD Nuclear Energy Agency (OECD/NEA) and the World Nuclear Association (WNA). It was a follow-up to the conference on the Safe Decommissioning of Nuclear Facilities, held in Berlin in 2002.

The conference was organized with the aim of sharing experience and knowledge between operators, regulators, policy makers, decision makers and technical experts. It also had the goal of identifying areas for international harmonization in the decommissioning of various facilities with different complexities and hazard potentials.

Participants at the conference discussed various aspects of decommissioning in eight technical sessions: global overview; regulation of decommissioning activities; planning for decommissioning; waste management issues; technology aspects; social and economic impacts; and decommissioning of small facilities. This publication, which constitutes the record of the conference, includes the opening and closing speeches, the invited papers, the summaries of the discussions during the sessions and the panel sessions, and a summary of the conference. A CD-ROM containing the presentations made during the conference and the unedited contributed papers of the conference can be found at the back of this book.

The IAEA gratefully acknowledges the support and hospitality of the Government of Greece through its Ministry of Foreign Affairs of the Hellenic Republic and the Greek Atomic Energy Commission (GAEC).

CONTENTS

PLANNING FOR DECOMMISSIONING (SESSION 3)

IMPLEMENTATION OF DECOMMISSIONING ACTIVITIES (SESSION 4)

SOCIAL AND ECONOMIC ASPECTS (SESSION 7)

DECOMMISSIONING OF SMALL FACILITIES (SESSION 8)

CLOSING SESSION

SUMMARY

1. BACKGROUND

Early planning, effective and safe implementation and completion of decommissioning of facilities using radioactive material is increasingly drawing the attention of regulators, operators, the public and other interested parties around the world. Decommissioning started more than forty years ago, covering a wide range of facilities with different hazard potentials, complexities and involving different decommissioning strategies (immediate dismantling, deferred dismantling or entombment). This has resulted to the collection of experience (good and bad) and lessons learned that can be shared with experts involved in ongoing or planned decommissioning projects, as well as in the design and operation of new facilities.

The Athens conference was convened as a follow-up to the International Conference on Safe Decommissioning of Nuclear Activities [1], which took place in Berlin in 2002. The aim of the conference was to share experience and knowledge and to identify areas of international harmonization in the decommissioning of various facilities (e.g. nuclear power plants, fuel cycle facilities, research reactors, mining and mineral processing facilities, research laboratories). A total of 292 participants from 50 Member States attended the conference, of which 92 participants were from 32 developing countries. Forty-six papers were presented by invited speakers during the sessions, followed by discussions during seven panel sessions. Sixty-nine posters were presented, together with exhibits from seven organizations.

The conference was organized by the International Atomic Energy Agency (IAEA), co-sponsored by the European Commission (EC) and held in cooperation with the OECD Nuclear Energy Agency (OECD/NEA) and the World Nuclear Association (WNA). It was hosted by the Greek Atomic Energy Commission (GAEC) and the Ministry of Foreign Affairs of the Hellenic Republic, and was presided over by Mr. Camarinopolous, President of the GAEC.

The conference addressed a wide range of topics namely, the regulation of decommissioning activities, planning for decommissioning; implementation of decommissioning activities; waste management; technology; social and economic impacts and decommissioning of small facilities.

2. MAIN OUTCOMES OF THE CONFERENCE

The main conclusions from the conference can be summarized as follows:

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The existing international mechanisms addressing decommissioning safety, such as the Joint Convention [2] need to be used more effectively to increase the awareness of governments and interested parties of the need for early planning, adequate funding, governmental support and long term strategies for decommissioning, waste and spent fuel management.

International safety framework. With the approval of the new Safety Requirements, Decommissioning of Facilities using Radioactive Material (WS-R-5) [3], by the IAEA Board of Governors in September 2006, the suite of international safety standards for the decommissioning of facilities using radioactive material now covers all relevant areas. However, there is significant experience worldwide that needs to be utilized and reflected in the revision of the existing Safety Guides [4–6].

Enhancing the regular exchange of lessons learned from decommissioning. The IAEA proposal to establish a decommissioning network, which will bring together organizations with specific experience and competence in decommissioning and that are willing to share their experience with other organizations, was enthusiastically received.

Facilitating the decommissioning of small facilities. International support for the decommissioning of small facilities in countries with limited resources through further development of international centres in the different regions, complementing the experience of the Research Reactor Decommissioning Demonstration Project (R^2D^2P) in the Philippines [7] expected to be joined by Australia and China, was strongly encouraged.

Regulation and demonstration of safety. The importance of establishing clear regulatory policy, safety requirements and criteria, record keeping mechanisms, approaches and criteria for the review of safety cases and interaction mechanisms between regulators and operators was clearly recognized. The differences between operational and decommissioning activities and the need for flexible and graded approaches to the application of regulatory frameworks were also recognized. The benefits of international projects, such as the Evaluation and Demonstration of Safety during Decommissioning (DeSa) Project [8] were highlighted and the IAEA was encouraged to continue such initiatives to address areas such as the review of safety cases for decommissioning.

Release of material and sites from regulatory control. There is international consensus on the values for the clearance of material and sites from regulatory control contained in the IAEA safety standards [9–11]. However, further work is required at a national level to implement these values in order to ensure a practical coherence across international borders, and to develop strategies and mechanisms for monitoring compliance with them. Release of sites for restricted use may become a preferred endpoint of decommissioning in some cases, in particular in countries where new nuclear facilities are contemplated. The development of new, profitable options for decommissioned sites is a trend which offers a large potential for workforce redeployment and local revitalization [12].

Implementation of lessons learned from decommissioning in the design, operation and maintenance of new facilities. In view of the recent increase in the consideration of and plans for the development of nuclear facilities worldwide, the conference strongly recommended that the lessons learned from decommissioning to date be used as an input for the design, operation and maintenance of all new nuclear facilities.

Decommissioning strategies. For many facilities and, in particular, for small facilities, the preferred option is immediate dismantling. However, deferred dismantling may be a justified option for some facilities, although more clarity is needed on the concept of entombment, considered in some Member States to be a storage rather than a disposal option [13].

Adequacy of cost estimation and funding. The establishment and management of funding mechanisms supported by realistic cost estimates are of high importance in the majority of countries. Governmental support and funding is particularly important for the successful and safe decommissioning of small State owned facilities and the cleanup of legacy sites. A lack of such funding could be a significant impediment to the decommissioning progress [14].

Management of decommissioning waste. Early planning, together with clear waste management and spent fuel strategies, is vital for the success of decommissioning projects. There was agreement that the lack of waste disposal facilities is not a reason for delaying decommissioning, in particular, in the case of legacy and small facilities [15, 16].

Decommissioning technologies. The conference showed that straightforward, proven and available decommissioning technologies are generally preferable to new and innovative technologies. If new technologies are foreseen to be used, the necessary provisions for the testing and demonstration of their suitability needs to be considered in the planning for decommissioning. It is also important to involve the operational workforce in the application and, as appropriate, in the development of the decommissioning technologies [17].

Preservation and management of knowledge. National and international mechanisms need to be established to preserve and maintain the knowledge gained that is important to the safety of decommissioning. The conference also recognized the important challenges experienced in many countries in retaining and maintaining the necessary levels of knowledge (including the long term maintenance of records) and in retaining skilled personnel during decommissioning, in particular in the case of long term projects. In this regard, recognition of the concept of professional competence in decommissioning was promoted [18].

Addressing social concerns. The early involvement of relevant stakeholders in planning for decommissioning and the definition of a clear endpoint for decommissioning are important, in particular for the release of material from control and the reuse of sites. Such involvement contributes to building public confidence, staff motivation and consideration of the social impacts related to decommissioning.

3. THE FUTURE

The conference highlighted many important lessons for implementation in ongoing and future decommissioning projects. It also identified areas for future international cooperation through the:

- Review and revision of the International Action Plan on Decommissioning of Nuclear Facilities [19];
- Improvement of the peer review mechanisms of the Joint Convention, and increasing the awareness of the Contracting Parties on issues important to the safety of decommissioning;
- Revision of the safety standards on decommissioning to take into consideration the lessons learned to date;
- Development of recommendations and guidance for incorporation into international safety standards and their application for the reuse and recycling of material from decommissioning, with particular focus on monitoring for compliance with clearance values;
- Enhancing international cooperation in developing and testing methodologies for estimating decommissioning costs and providing guidance, in particular for Member States with limited resources;
- Establishment of a network of decommissioning centres to facilitate the sharing of information between Member States, the dissemination of good decommissioning practices, and the development of infrastructure/capabilities, particularly in developing Member States;

- Continuation of work of the DeSa project through a follow-up international project on the development and review of safety cases for decommissioning;
- Presentation and promotion of the outcomes of the conference at international forums.

REFERENCES

[1] Safe Decommissioning of Nuclear Activities (Proc. Int. Conf. Berlin, 2002), IAEA, Vienna (2003).

[2] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546, IAEA, Vienna (1997).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series No. WS-R-5, IAEA, Vienna (2006).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series, No. WS-G-2.1, IAEA, Vienna (1999).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standards Series No. WS-G-2.2, IAEA, Vienna (1999).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. WS-G-2.4, IAEA, Vienna (2001).

[7] http://www-ns.iaea.org/projects/r2d2project/default.htm

[8] http://www-ns.iaea.org/tech-areas/waste-safety/desa/start.asp

[9] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Release of Sites from Regulatory Control on Termination of Practices, IAEA Safety Standards Series No. WS-G-5.1, IAEA, Vienna (2006).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Redevelopment of Nuclear facilities after Decommissioning, Technical Reports Series No. 444, IAEA, Vienna (2006).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Selection of Decommissioning Strategies: Issues and Factors, IAEA-TECDOC-1478, IAEA, Vienna (2005).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Final Aspects of Decommissioning, IAEA-TECDOC-1476, IAEA, Vienna (2006).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Problematic Waste and Material Generated During the Decommissioning of Nuclear Facilities, Technical Reports Series No. 441, IAEA, Vienna (2006).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Low Radioactivity Material from the Decommissioning of Nuclear Facilities,, Technical Reports Series (in preparation).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, State-of-the-art Technology for Decontamination and Dismantling of Nuclear Facilities, Technical Reports Series No. 395, IAEA, Vienna (1999).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Record keeping for the Decommissioning of Nuclear Facilities: Guidelines and Experience, Technical Reports Series No. 411, IAEA, Vienna (2002).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Measures to Strengthen International Cooperation in Nuclear, Radiation and Transport Safety and Waste Management, International Action Plans for Strengthening the International Preparedness and Response System for Nuclear and Radiological Emergencies, and on the Decommissioning of Nuclear Facilities, 48th Regular Session of the IAEA General Conference, GC(48)/RES/10 (2004).

OPENING SESSION

Chairperson

L. CAMARINOPOULOS
Greece

OPENING ADDRESS

L. Camarinopoulos
President,
Greek Atomic Energy Commission,
Athens, Greece

It is a great pleasure and privilege for me to welcome you to this International Conference on Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities.

The Greek Atomic Energy Commission is very pleased to host this conference on behalf of the Greek Government. We were deeply honoured by the request of the IAEA to organize this important meeting here in Athens and we accepted the challenge. After some two years of preparatory work we are happy to now open the conference and we are, understandably, very satisfied by the large attendance.

Strangely enough, planning the decommissioning of nuclear facilities — which may be interpreted as a sign of 'ending' — is actually a future-oriented activity. As you well know, the planning for decommissioning of nuclear facilities and the making of provisions for the orderly conduct of decommissioning, at the time of the conception and building of the facilities, is a sign of foresight and is required by many national legislations. Although its critics may claim the contrary, the closing of the nuclear fuel cycle and the management of the nuclear waste has been considered, studied and discussed from the very beginning of nuclear developments. The notions of life cycle analysis of nuclear activities, of recycling of materials and management of the wastes are familiar to nuclear scientists and engineers. Such considerations are commonplace in the nuclear industry – but this is not the case in other industries that discovered these notions, (life cycle analysis and fuel cycles), much later.

Of course, planning for decommissioning occurred to a lesser extent during the pioneering days of the nuclear industry, but this is understandable: The scientists and engineers working with the great enthusiasm of those times had other concerns in mind. Today, however, we are not only requiring the closing of the nuclear fuel cycle, but also the closing of the life cycle of the nuclear facilities; decommissioning is the last step in this cycle.

Decommissioning is becoming an increasingly important activity internationally, not because the nuclear era has come to an end (as some social actors or stakeholders may have wished), but because the nuclear industry has reached maturity and the older facilities that have fulfilled their mission have been retired.

Now a few reminders about the organization of the conference, its purpose, and its focal points:

As you well know – and I am quoting the IAEA announcement — “the objective of the conference is to foster information exchange on the safe and efficient termination of practices that involve the use of radioactive substances and to promote improved coherence internationally on strategies and criteria.”

This conference aims to bring together the various technical and regulatory experts and the other stakeholders in the complex decommissioning topic, to arrive at a comprehensive assessment of the situation: where we stand today – how much have we already learned, what knowledge is still missing – and to find ways for moving forward in a more systematic, comprehensive, I would say, holistic manner.

May I remind you that the prior IAEA International Conference on the Safe Decommissioning of Nuclear Activities was held in October 2002, in Berlin. That conference addressed the social, regulatory, technical and economic decommissioning issues and its conclusions were the important basis for the International Action Plan on Decommissioning of Nuclear Facilities that was published some time after the Berlin conference. In addition, an international workshop co-sponsored by the OECD Nuclear Energy Agency, the IAEA and the European Commission was held in Rome, in September 2004 to discuss, once again, the decommissioning issues and determine whether all key issues were addressed. The present conference is a natural continuation of the previous discussion, but the IAEA conference this time is addressing the subject from a more pragmatic perspective. ‘Lessons Learned’ is the key aspect of our conference, making the difference and assuring continuity with the previous ones.

It is obvious to me that, today, decommissioning of large or small radioactive facilities, the subject of this conference, cannot be ignored by any country, large or small, developed or developing, with or without a nuclear power programme. The magnitude of the issues may be different in each country, but their national importance is always present. All countries make use of at least some applications involving radiation sources or radioactive materials and will need to terminate these activities safely; the decommissioning issues are therefore universal.

Although the weight of the large installations (nuclear power plants and other large fuel cycle facilities) is evident in the invited speakers’ presentations, you will find a lot about decommissioning of smaller facilities like research reactors and nuclear laboratories in the contributed papers.

From the point of view of a country without a nuclear power programme like Greece, the decommissioning of small nuclear facilities, a focal point in Session 8, is also a very important issue. The absence of large, well equipped nuclear facilities and specialized manpower makes the conduct of smaller decommissioning projects difficult – international cooperation and assistance from the countries with large nuclear programmes is needed. This need was already recognized in the IAEA Action Plan that explicitly addresses the difficulties that small countries without nuclear power programmes are facing. The decommissioning of research reactors is also addressed in the Action Plan that again mentions the particular difficulties encountered, in less developed countries, where not only the technical and human infrastructure, but also funding may be lacking. Problems related to the absence of waste management and disposal facilities and decommissioning in countries with limited programmes are focal points in Session 3 on Planning for Decommissioning.

More specialized issues such as how to maintain the safety culture when the time for decommissioning is approaching and how to manage the decommissioning of a facility on a multi-facility site (with some operating and some retired facilities) are focal points in Session 4, Implementation of Decommissioning Activities.

This brings me to a few remarks about the situation in your host country, Greece.

You are probably aware of the fact that Greece has no nuclear power programme and no plans to start building any nuclear power plants in the foreseeable future.

In Greece there is only one research reactor and we hope that its time for decommissioning is still in the future. At the present time, it is undergoing renovation, and this is the reason why we had, regretfully, to change our plans and not visit the research reactor on Friday afternoon, as originally planned.

However, Greece uses radioactive sources in medicine, industry, research and education. These activities have left us with some radiological legacies (orphan sources, for example, as in all other countries) and these continue to create small decommissioning tasks and radioactive waste that has to be taken care of.

The country is also facing, to a lesser extent of course, some very interesting decommissioning problems from non-nuclear industries that have produced some weak radioactive waste. We are particularly eager to see some international harmonization of the exemption and clearance levels for such waste types, that is, for naturally occurring radioactive materials, the so-called NORM.

The challenges in the harmonized implementation of internationally agreed reference exemption and clearance levels will be addressed in Session 5, Waste Management Issues, while the lessons learned from experiences from involving stakeholders in decommissioning projects are a focal point of Session 7.

The amounts of radioactive materials produced in a small country without a nuclear power programme are very limited. The inventories in question are at the level of the uncertainty or 'noise' in the nuclear material inventories of the nations with large nuclear power programmes. In spite of their internationally very small weight, they still have to be addressed appropriately at the national level and disposed of properly — this is a requirement in all national legislations. We would like to appeal here for an international discussion that could lead to the creation of regional or international repositories, hopefully in locations that already receive large quantities of waste. The additional 'noise' will certainly not overburden these locations.

To give a European perspective, particularly to our overseas participants, I would like to briefly mention the decommissioning related actions at the European Union level. The European Union has clearly recognized the importance of the radioactive waste and decommissioning issues and the need for harmonization at the European level. Harmonization, covered in this conference in Sessions 1, 2 and 6, is the key word here and is to be applied to all the aspects of the problems; technical, regulatory and economic. The European Council has commissioned, through its Atomic Questions Group of permanent representatives in Brussels, the Working Party on Nuclear Safety to produce a report on:

- Achievements reached or foreseen with regard to harmonised safety approaches in various contexts (meaning the two IAEA Conventions, the Western European Nuclear Regulators Association (WENRA), the IAEA safety standards and the work of the OECD/NEA and EC working groups), and on
- The availability of adequate financial arrangements in Member States to cover decommissioning costs.

This report should serve as basis for the foreseen consultation process on harmonization. The report should be ready at the end of this year.

As a measure of the importance that the European Union is giving to the issue of availability of decommissioning funds, I can also mention that, in 2005, the European Commission initiated a broad consultation within its Member States and the (future) Accession Countries, and convened a group of nationally nominated experts in nuclear decommissioning funding, the so-called Decommissioning Funding Group. The purpose of this forum is to exchange experience and build a common understanding between the Member States, the Accession Countries and the Commission.

Let me now briefly remind you of the format of this conference and how the various sessions, discussion panels and other presentations will contribute to achieving its goals.

It is worthwhile mentioning that the conference is attended by 292 participants from 50 IAEA Member States. 46 invited speakers will make presentations during the conference and in addition there are 98 contributed papers.

The Programme Committee has identified a number of topics that constitute the themes of the eight technical sessions, each taking half a day.

The major issues in each session will be introduced by senior experts, with time provided in each session for discussion. The panel sessions, that will follow most sessions, will provide an opportunity for a more intensive exchange of views with the audience sometimes on controversial issues. The Chairpersons will present the conclusions from their respective sessions on Friday morning. I will summarize during the closing session on Friday the principal findings of the entire conference.

The poster session, late this afternoon, which is combined with a reception, will be an excellent opportunity for getting to know each other and each other's work. You will find additional contributed papers in the written proceedings of the conference.

At this point, I would like to take a moment to thank all those who contributed to the organization of this conference: the IAEA, the European Commission, the OECD/NEA, the World Nuclear Association, the members of the Programme Committee, the Conference Secretariat and the Local Coordinators.

My remarks may have confirmed in your mind that the subject of this conference is wide-ranging. You have, I believe, an interesting and very busy week ahead of you, with a very intense programme. I wish to all of us success in our deliberations and I look forward to useful outcomes from this event.

OPENING ADDRESS

T. Skylakakis
Secretary General for International Economic Relations and Development,
Ministry for Foreign Affairs,
Athens, Greece

It is with great pleasure that, on behalf of the Ministry of Foreign Affairs, I welcome you to Greece. I would like to thank the IAEA and the Greek Atomic Energy Commission for the invitation to be present at the opening of this International Conference on Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities.

I believe that this conference serves the important purpose of bringing together experts who will consolidate information from around the world on matters regarding the difficult task of decommissioning nuclear facilities.

The purpose of our endeavour is to contribute to the concerted international efforts to obtain a realistic picture of the scope of the decommissioning task, based on achievements thus far, but also to discuss the challenges that lie ahead. In this regard, the role of the IAEA is to continue the burdensome task of compiling information on the magnitude of this problem, as it is the only safe way of creating a solid basis for an international discussion on the solution of the associated problems. It is through the accumulation and evaluation of information that the decommissioning process over the years has become efficient and refined and, most importantly, safer.

This conference is the second of its kind organized by the IAEA, following the success of the one held in Berlin in 2002.

The IAEA, in collaboration with the OECD Nuclear Energy Agency and other international agencies, has the competency, but also the experience, to engage in activities such as radioactive waste management, radiological protection and the technical evaluation of the nuclear fuel cycle.

The roles of these agencies and the importance of the safe decommissioning of nuclear activities are of particular importance in the post Cold War era of the global threat of terrorism. On a regional level, the European Union has offered support by providing grant-financed technical assistance to the twelve countries of Eastern Europe and Central Asia[1]. The goal of this

---

[1] Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan are the TACIS member states.

undertaking is to enhance the transition process in these countries, and, in this context, to decommission nuclear facilities that have completed their life cycle.

In closing, I want to stress the important objective of this conference, which is to foster information on the safe and efficient termination of practices that involve the use of radioactive substances and to promote improved coherence internationally on strategies and criteria.

I hope that Athens will be an inspiring venue for this undertaking, and will contribute to the momentum initiated at the International Conference in Berlin (2002), and the International Workshop in Rome (2004).

OPENING ADDRESS

I. Tsoukalas
Secretary General for Research and Technology,
Ministry of Development,
Athens, Greece

It is a pleasure for me to welcome you to the International Conference on Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities.

The Greek Government, through the Ministry for Foreign Affairs and the Greek Atomic Energy Commission, undertook the responsibility of organizing the meeting in Athens. I am particularly pleased to see that one of the organizations that I have the honour to direct is part of the conference secretariat and that it has contributed to the challenge of organizing this conference.

Ten days ago we faced an emergency, created in still partly mysterious ways, by the use of polonium-210 for criminal purposes. The scientific community was not specifically prepared to deal with this radiological issue, but the laboratories concerned throughout Europe, including the laboratory of the Greek Atomic Energy Commission — and I am very pleased about that — were able to react within hours and days and to face the technical issues raised, as well as the public concerns and fears.

At the other end of the spectrum of timescales, in relation to future issues and the level of preparedness for addressing them, you are dealing this week with decommissioning topics and issues that will become relevant, for some nuclear facilities, decades from today. It is very satisfying to realize that the nuclear industry and organizations responsible for nuclear safety, such as the IAEA, are taking early steps in meeting the challenges of the future. In fact, the nuclear industry is one of the first, if not the very first, to have addressed future issues sufficiently early during its development.

Considering extremely long timescales, the nuclear industry and the responsible international organizations must also plan for the disposal of nuclear waste, a problem that is associated with the unprecedented time horizon of thousands or even millions of years.

Decommissioning has been conducted for some fifty years now, and although there may be some experience of the decommissioning of small facilities, only a few large nuclear facilities or nuclear power plants have been fully decommissioned. Some mistakes have been made in decommissioning and lessons have been learned; it is extremely important to share this knowledge, and this is the theme of this conference.

International cooperation and learning from the experiences of others is particularly important today as most organizations have limited experience of decommissioning projects. As the industry develops, decommissioning will clearly become more commonplace.

The topics of this conference cover an extremely wide range. Although the weight of the large installations (power plants and large fuel cycle facilities) is evident in the invited speakers' presentations, I was very pleased to notice in the conference programme issues concerning the decommissioning of smaller facilities, like research reactors and nuclear laboratories, or issues concerning waste management, subjects presenting a particular national interest to us.

At this point, I can happily remind you that Greece is also a party to the Convention on Nuclear Safety and to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Undoubtedly, the conference addresses both scientific and technical interests. However, as I am also deeply involved in the political dimension of some subjects, I will follow the proceedings of this conference as both a scientist and a politician. In this respect, I am very much interested in the presentations and positions of the international and European organizations, as well as those of our neighbouring countries.

I know that your task is complex. I am confident that you will carry it out with great responsibility, transparency and certainly with unique expertise and profound scientific knowledge.

In this sense, I am looking forward to your final findings and conclusions.

OPENING ADDRESS

T. Taniguchi
Deputy Director General,
Department of Nuclear Safety and Security,
International Atomic Energy Agency,
Vienna

1. INTRODUCTION

It is my pleasure, on behalf of the Director General, to welcome you to Athens and to formally open the International Conference on Lessons Learned from the Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities.

I wish to use this opportunity to express the appreciation of the IAEA to the Government of Greece, the Greek Atomic Energy Commission and the city of Athens for organizing and hosting this important international event, and to Professor Camarinopolous for accepting the Presidency of the conference.

I would also like to thank the European Commission, the OECD Nuclear Energy Agency and the World Nuclear Association for their cooperation in the organization of this conference.

This conference is being convened as a follow-up to the International Conference on the Safe Decommissioning of Nuclear Activities, which took place in Berlin in 2002. That conference led to the approval of the International Action Plan on Decommissioning of Nuclear Facilities by the IAEA Board of Governors in 2004.

This year, the IAEA marks its 50th anniversary, which corresponds to the 50th anniversary of the peaceful use of nuclear technology in many IAEA Member States. Therefore, as mentioned by the Director General during his opening statement at the General Conference in September this year, this is a time for reflection on international achievements and for the sharing of knowledge, experience and lessons learned. It is also a time to reflect on the continuing need for the enhancement of a common safety culture among all parties involved in the life cycle of nuclear facilities.

With the end of life approaching for many facilities, the development and implementation of a holistic approach to decommissioning and the termination of nuclear activities is essential, not only for large nuclear facilities, but also — and in particular — for small facilities, for which resources and safety and security measures are limited. The holistic approach refers not only to the time dimension of the life cycle of a specific facility, but also to the long-term sustainability of the whole system in the country and the region, including the possible recycling of material and multinational or regional cooperation. It should also comprehensively cover the technical, financial, social and political aspects of decommissioning.

For these reasons, it is extremely important to increase the awareness of operators, regulators, and governmental organizations of the lessons learned to date to ensure that the responsibilities for safe decommissioning and termination of activities are implemented until the release of sites from regulatory control. This is also of particular importance for legacy sites where cleanup is needed and often has to be implemented at times long before decisions are made about the release of the sites from regulatory control and about appropriate arrangements for radioactive waste management.

The decommissioning of facilities using radioactive material has been undertaken for more than 40 years and considerable experience has been accumulated. Decommissioning is the last step in the life cycle of a facility, which — contrary to the previous steps of siting, design, construction, commissioning and operation — does not evoke a positive reaction in facility staff, nor often in other interested parties due to its association with reduced employment opportunities and the generation of radioactive waste and spent fuel, with the concurrent need for their long term management.

Increased public awareness and the growing concern for safety and protection of the environment have amplified these issues, and it is therefore not only important to demonstrate the safe decommissioning of facilities and termination of licences, but also to incorporate the lessons learned during the decommissioning in the design, construction and operation of new facilities, to communicate with the public and media, and to involve the stakeholders.

During the past few years we have also observed strong emerging signs of high expectations for the future nuclear power development, often referred to as a ‘nuclear renaissance’. However, I prefer to use the phrase ‘vita nuova’ from the first Anthology of Dante, written in his national language. Vita nuova may better reflect the new global dimension, improved technologies and new countries that will be involved, hence requiring new ways of thinking and meeting new challenges.

Furthermore, an increasing number of power stations are planned for construction and operation in the near future in countries with existing nuclear programmes, such as, Canada, China, Finland, France, India, Japan, the Republic of Korea, the Russian Federation and the USA, and new research reactors in Australia and China.

Uranium mining activities are increasing worldwide, for example, in Australia, Canada, Kazakhstan, Namibia, Niger, the Russian Federation and Uzbekistan. More than ten countries are planning to expand or resume uranium mining in the future.

It is vitally important that these plans for new and re-invigorated nuclear power development worldwide are complemented by equally ambitious plans for establishing and enhancing effective and sustainable safety and security infrastructures, which include proactive measures to assure the safe decommissioning and termination of nuclear activities.

Decommissioning gives rise to particular safety and security concerns, and the importance of adequate planning, funding, regulatory control and measures to ensure safety and security during and after decommissioning become increasingly important as the number and types of facilities undergoing decommissioning increase.

Of the 442 nuclear power reactors in the world, 88 have been in operation for 30 to 40 years, 200 for 20 to 30 years, 109 for 10 to 20 years and 45 for less than 10 years. This means that 209 power reactors, about two-thirds of that total, are expected to exceed their original 30 year design lifetime in ten years' time.

At present, several large facilities are undergoing decommissioning in a number of countries including Germany, Japan, Spain, the United Kingdom and the USA. Also, several nuclear power plants are to be decommissioned as a result of the end of their lifetime, for example in the Russian Federation, or as a result of their early shutdown in Bulgaria, Lithuania, Slovakia and Sweden.

Decommissioning is not only a matter for the organizations directly responsible, it is a shared responsibility with governments, communities and public officials. The timeframes involved can be decades, emphasizing the importance of knowledge preservation and the transfer of knowledge to future generations. The removal of large amounts of material from sites for disposal as radioactive waste or through clearance mechanisms for recycling and free release also poses a significant challenge to all the parties involved.

2. DECOMMISSIONING ACTIVITIES

In recent years, a significant increase in decommissioning projects and activities has been observed, together with significant progress in those projects. In the USA alone, there are currently 16 nuclear power and early demonstration reactors, 14 research and test reactors, 32 materials facilities, 3 fuel cycle facilities and 12 uranium recovery facilities in different stages of decommissioning under Nuclear Regulatory Commission (NRC) jurisdiction.

The picture in other countries is similar:

- The decommissioning of uranium production, enrichment and fuel fabrication facilities is under way in a number of countries, including:
  - The Korea Atomic Energy Research Institute (KAERI) uranium conversion plant;
  - The United Kingdom's Capenhurst diffusion plant;
  - The Siemens Fuel Element Facility in Hanau, Germany.
- Recent nuclear facility decommissioning activities include:
  - The US Department of Energy Rocky Flats Facility was decommissioned and closed in 2005 to become a wildlife refuge;
  - The decommissioning of the Maine Yankee PWR in the USA was completed in 2005;
  - The José Cabrera-1 Nuclear Power Plant in Spain was shut down this year with plans to undertake preparatory activities for decommissioning;
  - The decommissioning of the Greifswald WWER plant in Germany is continuing, with a target date for completion of 2010;
  - The Stade PWR nuclear power plant in Germany entered the second dismantling phase in February 2006;
  - An application has been made for a licence for the decommissioning of the Tokai Magnox nuclear power plant in Japan;
  - Regulatory consent was given for decommissioning of the Dungeness Magnox plant in United Kingdom.
- Notable progress in the decommissioning of research reactors has been achieved during the last year:
  - Decommissioning of the 2000 W research reactor (DR-1) in Denmark was completed at the end of 2005;
  - Two Triga type research reactors located at the German cancer research centre in Heidelberg were completely decommissioned and released from regulatory control in 2006;
  - A licence application is being prepared for the immediate dismantling of the FRJ-2 research reactor in Jülich (Germany);
  - The decommissioning of the CIEMAT Research Centre (Spain) is being planned, including the JEN-I research reactor, a pilot reprocessing plant, a fuel fabrication facility, a conditioning plant for liquid waste and a liquid waste storage facility.
- Decommissioning of many small facilities has also taken place. Examples of recently finalized projects can be found:
  - In France this year after the successful decommissioning of the Cadarache irradiator installation, the facility was released from regulatory control;

  - In 2005 in the USA, the Nuclear Regulatory Commission completed decommissioning actions at seven non-reactor materials sites.
- Developments have also taken place in recent years on national policies and strategies for decommissioning in several countries including:
  - The French nuclear regulatory authority is fostering immediate dismantling as the preferred option, which has resulted in reconsideration of the planned decommissioning activities for nine of the EDF reactors expected to be decommissioned before 2025.
  - In 2005, the Nuclear Decommissioning Authority was established in the UK with responsibility for managing all nuclear legacy sites.
  - The regulatory approach in France, as revised in 2003, has been implemented this year in the licensing of the decommissioning of the Brennilis 70 MW(e) heavy water reactor and the decommissioning of the first French PWR prototype of 350 MW(e) reactor (Chooz A). At present only one licence for decommissioning is required in France, while in the past a separate licence was required for each decommissioning phase.
  - The Ukrainian Council of Ministers issued a decree establishing a national fund for the decommissioning of its WWER reactors which will facilitate the early planning and future safe termination of these facilities.
  - Canada has taken a decision to invest over US $500 million during the next five years in the cleanup of legacy sites where R&D activities have taken place, some which dated from the period 1940–1960;
  - The Russian Federation is also planning to spend several billions of dollars on the decommissioning of nuclear facilities between 2008 and 2015. More than 100 nuclear facilities in Russia have already been shut down for various reasons and are awaiting decommissioning.

So what have we gained from all thise experience over the past forty years? In the words of the Greek philosopher Aristotle, “What we have to learn to do, we learn by doing”. Indeed, the experience and knowledge gained during the implementation of these and other decommissioning projects worldwide is a valuable source of knowledge that can be gathered and shared among experts from operating organizations and regulatory authorities in order to improve decommissioning projects and increase protection of workers, the public and the environment for ongoing and planned future decommissioning projects. Experience, both good and bad, provides an opportunity for learning, particularly in respect of how to:

— Increase safety during decommissioning;
— Improve processes for the clearance of material from regulatory control;
— Improve site clean-up activities and facilitate the re-use or release of sites from regulatory control;
— Improve the selection of appropriate decommissioning technologies;
— Incorporate lessons learned from decommissioning in new designs and operation of nuclear facilities.

The IAEA has been assisting Member States around the world in sharing their practical experience and the lessons learned from decommissioning projects at facilities with different designs, complexities and hazards, using different decommissioning strategies and within different legal and regulatory frameworks. The IAEA technical reports have documented decommissioning experiences since the 1970s.

The increase in these activities in recent years has resulted in the development of internationally agreed safety standards, the application and use of these standards in national decommissioning programmes, and more recently, the establishment of international legally binding instruments such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention).

3. RECENT DEVELOPMENTS IN INTERNATIONAL SAFETY STANDARDS

With regard to the recent developments in the safety standards relevant to decommissioning, a major milestone in 2006 was the publication of the new ‘Fundamental Safety Principles’. It states that the fundamental safety objective is “to protect people and the environment from harmful effects of ionizing radiation”. The fundamental safety objective applies to all circumstances that give rise to radiation risks. It also stipulates ten associated safety principles, and briefly describes their intent and purpose. The safety principles are applicable, as relevant, throughout the entire life cycle, including decommissioning, of all existing and future facilities and activities.

The Safety Fundamentals are complemented by a new Safety Requirements ‘Decommissioning of Facilities Using Radioactive Material’, that was published just one month ago. This standard establishes clear requirements for the planning, implementation and termination of decommissioning activities. It applies to all facilities and decommissioning strategies — immediate dismantling, deferred dismantling and entombment. It recommends immediate dismantling as the preferred option recognizing, nevertheless, that for some countries deferred dismantling is a justified option. It requires development of a final decommissioning plan at least two years prior to the planned shutdown. The existing Safety Guides on decommissioning of nuclear power plants, research reactors, fuel cycle facilities, and research facilities are planned to be revised in the near future, based on the new Safety Requirements.

A new Safety Guide on the ‘Release of Sites from Regulatory Control on Termination of Practices’ was published in November 2006. It provides guidance on the release from regulatory control of land, together with associated buildings and structures, for either unrestricted or restricted use. It provides recommendations for the cleanup of sites, where this is necessary, prior to site release. The guide also provides recommendations on the introduction of a new practice on a previously released site. This guide complements the Safety Guide on ‘Application of the Concepts of Exemption, Exclusion and Clearance’ that was published in 2004.

The only safety standard related to decommissioning that is presently under development is entitled ‘Safety Assessment for Decommissioning of Facilities Using Radioactive Material’. This guide provides specific recommendations on the approach for the development and review of safety assessments.

4. APPLICATION OF THE SAFETY STANDARDS

According to its Statute, the IAEA also provides assistance to Member States in the use and application of safety standards through a number of mechanisms, including appraisal services, training, research and development, technical cooperation and exchange of information. From the implementation of these mechanisms in the field of decommissioning of various facilities worldwide, a number of lessons have been learned.

Specific areas where assistance is still needed by Member States are:

- The establishment of national policies and selection of strategies for decommissioning;
- Ensuring a proper interface between site specific strategies for management of spent fuel, waste management and site release and national policy;
- The development and review of decommissioning plans for existing and new facilities;
- The establishment of adequate and effective funding mechanisms and performance of cost estimates for decommissioning;
- The implementation of decommissioning strategies in the absence of waste management options and capacities;

— The development and review of safety assessments;
— Human resource development and project management, particularly in countries with limited human and financial resources;
— The maintenance and preservation of knowledge on safety aspects related to the transition from operation to decommissioning, and also during and after decommissioning;
— The development, implementation and review of security measures.

The IAEA is working both at national and regional levels to enhance safety during decommissioning in Member States through its regular programme, its technical cooperation programme and also through a number of relatively new international projects. These projects are supported by participants from a large number of countries willing to share their experience and knowledge on decommissioning. In particular these programmes include:

— The project on Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities (DeSa) that started in 2004;
— The Research Reactor Decommissioning Demonstration Project (R^2D^2P) in the Philippines that commenced in June 2006;
— The decommissioning of the former nuclear complex in Iraq.

The IAEA is also considering the establishment of a network of decommissioning centres in different regions as a tool for sharing of knowledge on decommissioning.

5. THE JOINT CONVENTION

It is important to note that the Joint Convention, as a legally binding international instrument, is relevant to decommissioning. In particular, Article 26 requires that:

"Each Contracting Party shall take the appropriate steps to ensure the safety of decommissioning of a nuclear facility."

"Such steps shall ensure that qualified staff and adequate financial resources are available; the provisions with respect to operational radiation protection, discharges and unplanned and uncontrolled releases are applied, the provisions with respect to emergency preparedness are applied; and records of information important to decommissioning are kept."

During the Second Review meeting of the Contracting Parties that took place in May 2006 in Vienna, 41 Contracting Parties discussed the status of waste, spent fuel and decommissioning safety in their countries. As a result of these discussions, several conclusions related to decommissioning were outlined in the President's report:

- "All Contracting Parties are committed to address spent fuel and waste management in a comprehensive manner. Many Contracting Parties have already developed, or are currently developing, spent fuel and waste management strategies based on increasingly comprehensive inventories, including spent fuel and waste arising, or to arise, from decommissioning.
- Many Contracting Parties, especially those having nuclear power plants, have established funding schemes for decommissioning.
- Contracting Parties' strategies vary from immediate decommissioning (i.e. starting from 0 to about 10 years after final shutdown) to delayed decommissioning after a long safe enclosure phase. Keeping the knowledge and memory of the installation (normal operation, modifications, incidents, etc.) was recognized as being of crucial importance, especially in the case of delayed decommissioning.
- The subject of exemption and waste clearance was discussed. There is, for the time being, no international consensus on the use of clearance levels. Many Contracting Parties are implementing clearance criteria on a generic basis or on a case-by-case basis. Public acceptance and a clear radiation protection concept are key issues for the success of using clearance levels."

I am pleased to inform you that since the Second Review Meeting, China and South Africa deposited their instruments of accession on 13 September and 15 November 2006, respectively, and the number of Contracting Parties to the Joint Convention at present is 43. However, there remain more than 100 Member States that are not yet party to the Joint Convention. All Member States would greatly benefit from sharing experience and enhancing cooperation in the areas of decommissioning through participation in the Joint Convention. I strongly urge those countries that are not part of the Joint Convention to take necessary measures to do so.

6. INTERNATIONAL ACTION PLAN ON DECOMMISSIONING OF NUCLEAR FACILITIES (2004)

Providing for the exchange of information and knowledge sharing, including that from decommissioning projects, are important activities of the IAEA. The Berlin Conference of 2002 provided an opportunity for the discussion of various safety aspects concerned with the decommissioning of different types of facilities, and at the same time it identified areas where the IAEA could assist Member States in the decommissioning and termination of practices.

A number of issues identified at the Berlin conference were reflected in the International Action Plan on Decommissioning of Nuclear Facilities that was approved by the IAEA Board of Governors in June 2004. Since then, the IAEA has been working on the implementation of the ten main areas:

— Review of the magnitude of future decommissioning activities;
— Safety standards on decommissioning;
— Safety assessment for decommissioning;
— Decommissioning of research reactors;
— Management of decommissioning waste;
— Information exchange of lessons learned from decommissioning;
— Funding mechanisms for decommissioning;
— Release and reuse of material, sites and buildings;
— Long term preservation of information;
— Addressing stakeholder involvement and social issues.

Progress on the implementation of these topics will be reported during this conference.

The deliberations of the conference this week are important for the identification of additional potential areas for action related to decommissioning and, for example, I have already noted the importance of using the feedback from decommissioning experience to influence and improve the future design, construction, operation, maintenance and security of facilities. The results of the conference will be taken into account in the review and revision of the International Action Plan next year.

7. MAIN OBJECTIVES AND EXPECTATIONS FROM THE ATHENS CONFERENCE

Based on the wide range of completed, ongoing or planned decommissioning projects worldwide, and international activities related to decommissioning undertaken at national and international levels, extensive experience has been accrued; lessons have been learned and feedback has been obtained from the planning, implementation, regulation and termination of decommissioning activities.

The IAEA, together with the European Commission, OECD Nuclear Energy Agency, World Nuclear Association and the Government of Greece, has organized this international conference to share experience and the lessons learned with the objectives of improving, facilitating and increasing safety and also of improving ongoing and future decommissioning projects.

More specifically, during this week we aim to discuss experience in a number of sessions covering:

- Global Overview: Harmonization of decommissioning approaches (Session 1);
- Regulation of decommissioning activities (Session 2);
- Planning of decommissioning activities (Session 3);
- Implementation of decommissioning activities (Session 4);
- Management of waste and material from decommissioning projects (Session 5);
- Decommissioning technologies (session 6);
- Social and economic aspects (Session 7);
- Decommissioning of small facilities (Session 8).

As one of the contributed papers appropriately quoted, the Mediterranean philosopher Galileo Galilei said "You cannot teach people anything. You can only help them discover it themselves." This conference aims to help each one of us to discover the optimum and most adequate way to the safe decommissioning of nuclear facilities and the safe termination of nuclear activities. I expect that the findings of this conference will lead to the revision of the International Action Plan, reflecting the latest knowledge and rich experience accumulated and giving a clear direction for future international cooperation in the field of decommissioning in the coming years. They may also provide useful guidance for a more effective peer review process of the Joint Convention in the area of decommissioning.

Before concluding, I would like to thank the speakers, panellists, chairmen, rapporteurs, and all participants for attending this important conference and to wish all of you success.

GLOBAL OVERVIEW

(Session 1)

Chairperson

C. MILLER
United States of America

Rapporteur

G. LINSLEY
IAEA

WORLDWIDE DECOMMISSIONING LIABILITIES

D. LOUVAT
Department of Nuclear Safety and Security,
International Atomic Energy Agency,
Vienna
Email: D.Louvat@iaea.org

Abstract

The paper discusses the subject of the responsibilities and liabilities for decommissioning, drawing on the recommendations of the international safety standards. It summarizes the results of a study of the worldwide status of decommissioning in which estimates were made of the eventual costs of decommissioning civil nuclear power stations, research facilities, nuclear fuel cycle facilities, non-nuclear industrial facilities and military production facilities and reviews the implications of the study's conclusions.

1. INTRODUCTION

The term 'decommissioning' refers to the administrative and technical actions taken to allow the removal of some or all of the regulatory requirements from a facility. A facility means a building and its associated land and equipment in which radioactive material is produced, processed, used, handled or stored on such a scale that consideration of safety is required. Decommissioning is increasingly becoming a major issue, since hundreds of facilities with associated sources of radiation will end their operational lifetimes over the next 50 years.

Decommissioning strategies are intimately linked with radioactive waste management strategies and policies, and therefore they imply developments over long time frames. Ideally, the decommissioning strategy for a facility involving radioactive materials is defined during the design of the facility, updated on a regular basis during the operational life time of the facility and implemented after its shutdown. This process can last for decades and, if the strategy includes some deferred dismantling, the period can be a century or more, particularly if the management of radioactive waste up to the time of disposal is taken into account.

The main constraint on the safety of such a long-term process is the sustainability of the liabilities framework, which defines the responsibilities in the decommissioning process and the mechanism to provide funds for the decommissioning activity. The IAEA has assembled a series of publications on decommissioning that its Member States can use to identify these responsibilities, determine the resources needed to support decommissioning activities in the future and identify areas that may need attention.

2. RESPONSIBILITY FOR DECOMMISSIONING

The process of decommissioning typically involves several parties and the responsibilities and the transfer of responsibilities during the decommissioning process has to be defined among them. The specification and assignation of responsibilities is set out in international safety conventions and in the IAEA safety standards. The international convention that addresses decommissioning is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) [1]. This convention entered into force in 2001. Article 26 of the Joint Convention assigns to the Contracting Parties (the States) the responsibility for the decommissioning of nuclear facilities.

The recently published IAEA Safety Fundamentals [2] establishes the fundamental safety objective, safety principles and concepts that provide the basis for the IAEA's safety standards. The fundamental safety objective applies for all facilities and activities involving a radiation source and for all stages over the lifetime of a facility or radiation source, including decommissioning and closure in the case of disposal facilities. In particular, Principle 1, which defines the responsibility for safety, states that "consideration must be given to the fulfilment of the licensee's (and regulator's) responsibilities in relation to present and likely future operations and that provision must also be made for the continuity of responsibilities and the fulfilment of funding requirements in the long term". Principle 7 on the protection of present and future generations indicates that "Radiation risks may transcend national borders and may persist for long periods of time and where effects could span generations, subsequent generations have to be adequately protected without any need for them to take significant protective actions". It also makes clear that "radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations and that the generations that produce the waste have to seek and apply safe, practicable and environmentally acceptable solutions for its long term management".

These principles, when translated into safety requirements in the newly revised IAEA Safety Requirements on 'Decommissioning of Facilities using Radioactive Materials' [3], define the responsibility for decommissioning within a State. The government is responsible for providing an appropriate national legal and organizational framework within which decommissioning can be planned and carried out safely. This includes, inter alia, the requirement that a mechanism is established to ensure that adequate financial resources are made available for safe and timely decommissioning. Adequate financial resources to cover the costs associated with safe decommissioning, including the management of the resulting waste, shall be available when needed, even in the event of premature shutdown of the facility. Financial assurances to provide for the required resources shall be in place before authorization to operate the facility is given. The amount of financial assurance obtained shall be consistent with a facility specific cost estimate and shall be changed if the cost estimate increases or decreases. The cost estimate shall be reviewed as part of the periodic review of the decommissioning plan. If financial assurance for the decommissioning of an existing facility has not yet been obtained, suitable funding provisions shall be put in place as soon as possible. Provisions for financial assurance shall be required prior to licence renewal or extension. If the decommissioned facility is released with restrictions on its future use, financial assurance that is adequate to ensure that all necessary controls remain effective shall be obtained before the authorization is terminated.

From the IAEA safety standards, it is clear that regarding the long term mechanism to secure the funding of decommissioning, the responsibilities rest with the government of a State.

3. ESTIMATION OF DECOMMISSIONING COST

The IAEA publication on the 'Status of the Decommissioning of Nuclear Facilities around the World' [4], issued in 2004, reviews and summarizes the decommissioning activities worldwide performed to date, those currently under way and those projected to be performed in the future, and provides an estimate of the likely costs associated with the overall decommissioning activities.

The IAEA study includes all facilities that use radioactive material and that will require eventual decommissioning. It does not include those facilities that use only sealed sources and can be decommissioned in a direct manner (e.g. by sending the source directly to a disposal site or returning it to the manufacturer). The report includes information on nuclear power plants, research reactors, accelerator facilities, fuel cycle facilities, research facilities and laboratories, manufacturing plants and university facilities. Both commercial and government facilities (including military sites) are included in the study — to the extent that information on them was available at the time of the preparation of the publication (2003). The military production facilities are termed 'Cold War legacy facilities' in the following text. Land areas that require remediation, such as tracts of land with uranium mill tailings and former nuclear weapon test sites, are not included.

The decommissioning cost is assessed for each type of facility taking into account various factors: The size and complexity of the facility; the selected decommissioning strategy (e.g. immediate dismantling, deferred dismantling or entombment); the industrial framework in which the activity is performed (e.g., maturity of the industry, availability of experienced contractors); the general industry conditions (e.g. labour costs, availability of appropriate technologies in the domestic market versus imported technologies); the general technical conditions (e.g. a well established regulatory framework, the availability of proper infrastructure such as waste treatment, storage and disposal facilities, and past experience accumulated in the decommissioning field); the forms and quantities of radioactive material used (sealed sources or powders); and the regulatory oversight and controls.

By using these factors, an average decommissioning cost for each type of nuclear facility has been estimated. The values presented in Table 1 are intended to represent typical examples of the decommissioning cost for each type of nuclear facility, regardless of location. The estimated costs, operational period and time to perform the decommissioning are based on the best estimates of experts in the field of decommissioning planning and implementation.

4. THE WORLDWIDE LIABILITIES

The values presented Table 1 were used in making the projections for future decommissioning costs. The total decommissioning costs by facility type are presented in Table 2 and illustrated in Fig. 1. The table and the figure indicate the costs for the time period 2001–2050. Because of the uncertainties in the assumptions, this period has been divided into 5 year increments and the figure shows the estimated liability for each five year period. The total cost for the decommissioning of nuclear power plants during the reference time period is about \$185 billion; for the decommissioning of research reactors and critical assemblies about \$6320 million; for the decommissioning of fuel cycle facilities about \$71 billion; for the decommissioning of industrial facilities about \$40 million; for the decommissioning of research facilities about \$3360 million; and for the decommissioning of facilities from the cold war legacy about \$640 billion. This leads to a total decommissioning liability for the period 2001–2050 of about \$1000 billion.

TABLE 1. ESTIMATED DECOMMISSIONING COST FOR VARIOUS TYPES OF FACILITY [4]

Facility type	Estimated decommissioning cost (US $\$10^6$ in 2003)	Operational period (years)	Time to decommission (years)
Power reactors	350	40	10, after a 5 year transition period
Research reactors	1 MW	40	3
Critical assemblies	0.050	40	1
Fuel cycle facilities			
Uranium milling	0.800	25	1
Uranium conversion/ recovery	150	30	3
Uranium enrichment	600	30	10
Fuel fabrication	250	30	2
Fuel reprocessing	800	30	15
Industrial facilities	0.200	20	1
Research facilities			
Particle accelerators	0.100	40	1
Medical facilities	0.050	20	<1
Laboratories	0.050	20	1

The situation with regard to sustainable funding of these liabilities differs for each type of facility. Some perspective can be provided for the figure for the estimated liabilities over 50 years for nuclear power plants and fuel cycle facilities by noting that the annual turnover of the nuclear power generation industry is of the same order of magnitude (roughly $200 billion) and that it includes provision to fund the decommissioning of these installations.

The situation for the industrial facilities stands in stark contrast to that for nuclear power plants and fuel cycle facilities as only some of these facilities are regulated as nuclear facilities and therefore only these have financial provisions made for decommissioning. Most of the facilities using naturally occurring radioactive material (NORM) are not required to make the same provisions in relation to the termination of activities as facilities involving radioactive material.

Although the liabilities for research reactors and research facilities seem to be modest in relation to other facility types, the proper mechanisms to

TABLE 2. COST BY FACILITY TYPE AND TIME PERIOD [4]

US $ billions	2001–2005	2006–2010	2011–2015	2016–2020	2021–2025	2026–2030	2031–2035	2036–2040	2041–2045	2046–2050	Total
Nuclear power plants	3000	12 500	13 500	16 300	17 300	24 700	35 000	35 400	18 000	8900	184 600
Fuel cycle facilities	18.200	23.140	11 240	5900	4600	3900	2300	0.800	0.300	0.500	70 880
Research reactors	1.620	2.800	0.710	0.340	0.300	0.080	0.050	0.060	0.030	0.330	6320
Research facilities	0.333	0.336	0.334	0.334	0.336	0.339	0.343	0.337	0.334	0.332	3358
Industrial facilities											0.04
Cold War legacy facilities											640 000

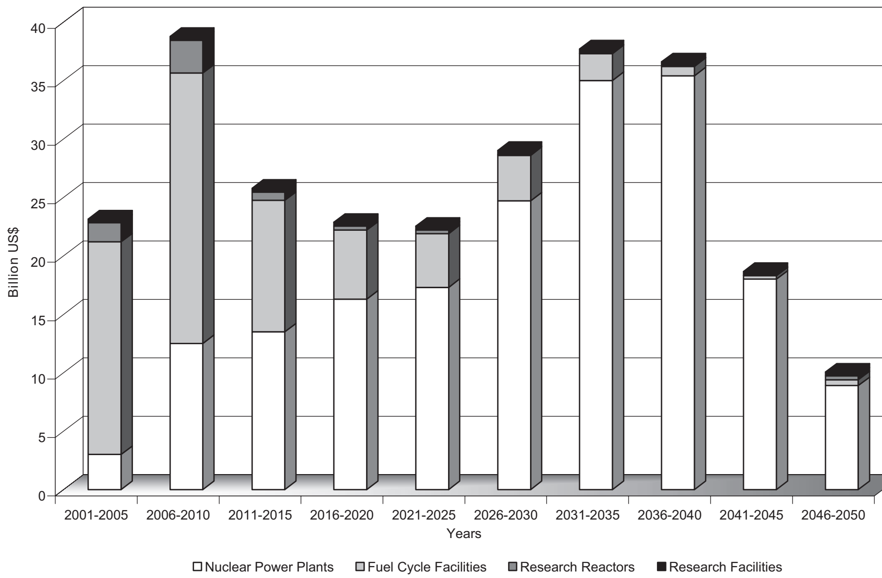

FIG. 1. Decommissioning liability by five year periods [4].

address their decommissioning are not always in place and as a result these facilities have sometimes been abandoned.

By a wide margin, the Cold War legacy facilities represent the largest burden in terms of financial liabilities for decommissioning. Although this type of decommissioning involves, at present, only a few countries in the world, the fact that no mechanism for the provision of decommissioning funds was associated with the development of nuclear weapons (and that the political rearrangement of the world has left the legacy to some States that did not exist at the time of the cold war) can lead to difficult problems in relation to the decommissioning of these facilities and to a persistent radiological threat to the public and the environment.

5. CONCLUDING REMARKS

It is interesting to conjecture what the magnitude of the Cold War legacy might have been had mature regulatory frameworks been in place when the cold war military activities were taking place. The economic advantages of having had a mature regulatory framework for the peaceful applications of nuclear technology are clear.

What do these findings mean for the IAEA? At first glance one might expect that the IAEA would allocate its efforts in a manner proportional to the cost picture presented above. In fact, much of the IAEA's resources will be allocated to the smaller cost areas, namely research reactors and some types of fuel cycle facilities. The reason is quite simple — these are the types of facilities found in countries that request assistance from the IAEA.

The IAEA is preparing a report on the global inventories of radioactive waste [5]. This report is intended to provide global estimates of the amounts of radioactive waste, although the present draft of the report does not provide estimates for disposal costs [5]. The total cost for the disposal of 70 000 t U (tonnes uranium) of spent nuclear fuel at Yucca Mountain has been estimated to be $56 billion (normalized to the year 2000). From this figure, it can be inferred that worldwide costs for spent fuel disposal will be comparable to decommissioning costs for nuclear power plants. To provide a worldwide perspective on the costs of decommissioning and radioactive waste management it would be informative to combine the decommissioning cost estimates and radioactive waste studies, to periodically issue an updated version of this report, and to report on funding mechanisms that Member States develop to manage their decommissioning and waste liabilities.

A central theme of the Joint Convention and the IAEA safety standards is that safety is dependent upon the availability and adequacy of funding for managing the nuclear liability. The greater the period the liability must be managed, the greater the cost uncertainties, not to mention uncertainties arising from economic and financial stability. It is worth noting that the same uncertainties may arise when a strategy of long-term storage of radioactive waste is adopted [6]. Financial uncertainties, and in turn their safety implications, are a compelling reason for society to try to avoid the transfer of undue burdens to future generations.

REFERENCES

[1] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546, IAEA, Vienna (1997).
[2] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006).
[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series No. WS-R-5, IAEA, Vienna (2006).
[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Status of the Decommissioning of Nuclear Facilities Around the World, IAEA, Vienna (2004).
[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Global Inventories of Radioactive Waste and Other Radioactive Materials, IAEA, Vienna (2005) .
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, The Long Term Storage of Radioactive Waste: Safety and Sustainability, A Position Paper of International Experts, IAEA, Vienna (2003).

DISCUSSION

A.J. GONZÁLEZ (Argentina): You mentioned the problem of phosphor gypsum associated with the phosphate industry. Some fuss has been made about phosphor gypsum in Europe, but the main users are in South America, where the activity levels are well below 1 Bq/g.

In my opinion, the greatest liabilities are those associated with the oil industry, about which nobody talks. Oil industry facilities have vast lengths of piping that contain radium and other radioisotopes.

D. LOUVAT (IAEA): I mentioned the problem of phosphor gypsum because the phosphate industry is a practice where improvements could easily be made.

I did not mention the oil industry, but the IAEA is developing decommissioning guidance for that industry and a number of other ones.

CHALLENGES FOR DECOMMISSIONING POLICIES

H. RIOTTE
OECD Nuclear Energy Agency,
Issy-les-Moulineaux,
France
Email: Hans.Riotte@oecd.org

Abstract

In the coming years, OECD member countries will be increasingly faced with the need to make appropriate provisions, in terms of policy, finance and management, for all aspects of decommissioning. Decommissioning requires regulatory approval and oversight, the directions of which are guided by national policy. In several instances, governments have only recently begun to address their approaches to decommissioning policy and regulation in national legislation, and international overviews of such approaches, which may eventually lead to international harmonization, are only now beginning to emerge. In parallel, policy and regulation have been evolving and a broadened competence has developed in relevant regulatory authorities. The challenge lying ahead is to establish a framework that will allow for the growth of nuclear industrial activities in competitive, globalized markets, while maintaining and assuring the safety of decommissioning for the public and for workers. Within this context, institutional arrangements, stakeholder issues, costs and funding, waste management and policies for release from regulatory control, as well as the availability of technologies and skills, need to be reviewed.

1. INTRODUCTION

The record of decommissioned nuclear power plants so far – representing all stages and end points of dismantling, including some projects which have resulted in sites being released under ‘green field’ conditions – clearly shows that, at the industrial level, the processes and techniques for the decommissioning of nuclear installations have advanced greatly over the past 20 years, to the point where most situations arising can now be addressed with feasible approaches. Techniques for decommissioning and dismantling are available, and valuable experience has been fed back for the design of new plants as well as for other decommissioning projects.

However, most of the plants that have been shut down for decommissioning are not fully representive of the challenges to come. The decommissioning of large nuclear power plants, which have been operated until the end of their design lifetimes or beyond, will be more complex and more difficult often more contaminated than for the smaller reactors decommissioned to date.

In addition to these commercial nuclear power plants liabilities, in many countries there are also public-owned liabilities, for example, research and development installations, prototype reactors, fuel cycle facilities, including mining, and – in some countries – from military and weapons programmes. They represent the nuclear legacy from programmes which were largely established in the 1950s and 1960s.

Dealing with these nuclear legacies gives rise to special, and in some cases, unique problems that reflect the nature of facilities that were built and used at a time when regulatory requirements and operational priorities were very different from those of today.

The nuclear industry has to take up these challenges, but it will be the task of governments to adapt the existing nuclear regime so as to avoid the costs remaining from the past and to create a 'level playing field' for a competitive industrial activity.

2. ROLES OF GOVERNMENT AND INDUSTRY

In general, the setting of national policies and the establishment of legislation and regulatory requirements are carried out at the national level by government departments or ministries. Typically, these include ministries for trade and industry, for the environment, for health, and for the economy. The systems for developing legislation and regulatory depending upon constitutional arrangements. Nevertheless, it is generally true that, in matters concerning nuclear power, the primary body for these issues is central government.

The bodies currently in place in countries for establishing policy, legislation and standards; for operating nuclear facilities and managing radioactive waste; and for regulating these activities, are adequate for dealing with decommissioning. Depending upon individual national circumstances, however, it may be convenient to modify the practical arrangements by creating new bodies, such as dedicated liabilities management organizations, to assume responsibility for decommissioning on behalf of operators that are no longer in business and to maintain and further develop the related expertise, and to work to enhance public confidence.

In most countries, the responsibility for implementing decommissioning activities lies with the body that operated the nuclear facility during its operational phase. As regards the practical activities of decontamination and dismantling, various options are being adopted or are being considered. These options include the undertaking of decommissioning by the operator of the facility, or by specialist contactors employed by the operator, or some combination of the two.

Because utility companies are generally plant operators, the tendency is for the decommissioning of nuclear power plants to be carried out by specialist companies from the private sector. On the other hand, the decommissioning of research reactors and other installations of nuclear research facilities is often performed with a significant involvement of the staff and resources of the institution that originally operated the nuclear installation.

As decommissioning has gained focus nationally and internationally, the industry has reorganised itself, by concentrating decommissioning activities, or by the creation of industrial subsidiaries with specific decommissioning responsibilities. The challenge that lies ahead is to establish a framework that will account for growing nuclear activities in competitive, globalized markets, while maintaining and assuring the safety of decommissioning for the public and for workers.

3. DECOMMISSIONING STRATEGIES

It is under this umbrella of political guidance, applicable laws and economic and safety considerations that owners and decommissioners must choose a decommissioning strategy. The main issues are are to determine the intermediate or end-points for decommissioning, the ways that decommissioning is and will be funded, the waste storage and disposal routes. At the same time, it is necessary to implementan efficient regulatory framework that takes into account the specific safety aspects of decommissioning, as opposed to those of a facility operation.

It is generally presumed that the eventual end-point of decommissioning activities is the return of the site to a condition in which it can be released for unrestricted use. Among OECD Nuclear Energy Agency (OECD/NEA) member countries, however, there is a wide range of opinions and policies concerning the most appropriate route and timescale for arriving at this eventual end-point. These opinions and policies are influenced by national positions, or lack of them, on such matters as the future use of nuclear power, the continued availability of trained staff, societal issues associated with the impact on neighbouring communities, possible alternative uses for the facility and the site, e.g. for new nuclear installations, technical and regulatory issues, arrangements for waste management, and economic issues associated with costs and cash flow.

Regarding the timing of decommissioning, the main advantages of immediate decommissioning are seen to be in the availability of working equipment and knowledge about the facility. On the other hand, considerable economic and financial advantages may emerge when dismantling is delayed for a few decades.

Depending on the strategy chosen, decommissioning may take a few years or several decades. Each of these options entails specific problems in decision making, e.g. with respect to the types of licence, the availability of waste storage/disposal sites, public and private structural longevity/evolution, etc. Strategies involving decade-long processes can impact such broad issues as the sustainability of nuclear power, e.g. with respect to inter-generational social, economic and environmental issues, or the preservation of the well-being of local communities.

4. COSTS AND FUNDING

The deregulation of electricity markets has raised new issues related to the means for covering the expenses associated with decommissioning activities. The cost of decommissioning, which has always been recognized and integrated within the cost of nuclear electricity generation, becomes a more important criterion in deregulated markets where competition calls for the lowering of production costs. In this context, national policies and regulations are being adapted or developed in ways that may affect decommissioning costs and the manner in which they are included in the price charged to electricity consumers.

From a governmental viewpoint, particularly in a deregulated market, it is essential to ensure that money for the decommissioning of nuclear installations will be available at the time it is needed, and that no ‘stranded’ liabilities are left to be financed by the taxpayers rather than by the electricity consumers.

It is recognized that provisions for funding decommissioning need to be made during the operating lifetime of a facility and several approaches to achieve this exist. However, each country must develop its own methodology taking into account national regulations and practice and keeping the basic ethical principles in mind. A conclusion from the work so far is that existing funding systems in OECD/NEA member countries are in agreement with widely-accepted ethical principles and, in particular, with the principle of not imposing undue burdens on future generations.

Waste management costs are a significant element of the overall costs of decommissioning and may dominate in some cases. Hence, it is important, not only that waste quantities be minimized, but also that the costs of waste treatment, storage and disposal be separately identified and assigned.

The future challenges are to ensure that decommissioning costs are calculated correctly and that sufficient funds will be available at the time when they are required.

5. RELEASE OF MATERIALS AND SITES AND WASTE MANAGEMENT

Once a facility reaches the end of its useful life, decommissioning usually begins with the aim of releasing from the nuclear regulatory regime both the facility, the associated materials and the site that the facility occupies.

Release of materials from regulatory control and the management and disposal of radioactive waste are key elements in the satisfactory completion of the decommissioning of nuclear facilities, and are the major contributors to its overall decommissioning costs.

It is widely accepted that the route of removing regulatory controls depends on various factors and may involve various stages and interim uses. National policies differ on the detailed objectives to be achieved along the way. Individual countries are influenced variously by such matters as national policy on the future use of nuclear power.

Much of the waste produced during the decommissioning of nuclear facilities is similar to that produced during their operational lifetimes, so a major part of this new challenge is already shared with current activities. The new element — a specific characteristic of decommissioning — is related to the large amount of waste containing only small concentrations of radionuclides. This requires that serious attention is given to the development of environmentally sound but cost-effective means of disposing of these large amounts of lightly contaminated materials, where this proves necessary. The management of specific waste containing materials such as graphite, beryllium, sodium, asbestos, etc., will also need further attention.

The release from radiological control of the sites of nuclear installations is usually one of the last steps in the decommissioning phase of nuclear installations. If the site complies with the appropriate release criteria when a reasonable set of possible future uses have been considered, the site should be released for unrestricted use, which is the preferred option. If this is not feasible, the site may still be released after remediation — but for restricted use.

The free release of sites has been practised in only a limited number of decommissioning projects, and the overall experience is much more limited than that with the release of materials and buildings, as most decommissioning projects have not yet advanced to a state where release of the site has to be considered, or because the sites are — or will be — reused for nuclear activities.

The release of sites is only a mature practice in those countries with a number of completed decommissioning projects.

6. REGULATORY FRAMEWORK

Robust, efficient and independent regulation is vital for achieving public confidence that the nuclear industry is operating to high safety, security and environmental standards and that the risks associated with it are being properly managed. Specific areas that need attention to enhance national readiness to fully address decommissioning issues are legislative and regulatory frameworks, including those for radiation protection, release of materials and sites, waste management, and associated techniques and skills.

Consideration may need to be given to further improving the efficiency of the regulatory regime and to adapting its operation to reflect the change in hazard, in compliance with the principles of proportionality and transparency.Since the public health risks posed by a shutdown facility are substantially reduced from those of an operating facility, the regulatory inspection programme should be tailored to address the new regulatory challenges. For example, many of the challenges involve regulatory policy questions rather than operator performance issues. Those regulatory bodies that utilise resident inspectors at operating facilities may want to replace the resident inspector with periodic team inspections focused on special areas.

As decommissioning progresses, there may be periods of only routine activity on the site and the regulatory inspections can be scaled back accordingly. If the operator chooses to place the facility in a safe storage mode for an extended period, there will be a reduced need for inspections, although they will continue to be needed to ensure that safety and security systems are not degrading.

7. STAKEHOLDER ISSUES

It is widely accepted that openness and transparency are essential for winning public approval of decommissioning plans. The challenge for the future, therefore, will be satisfactory development of systems for consulting the public — local communities in particular — and the creation of sources of information in which the public can have full confidence.

All decommissioning programmes are facing the challenge of developing and implementing a true dialogue between stakeholders and involving the different actors in the decision making process. The following three principles have been found to be relevant for obtaining broad societal support: Decision-making should be performed through iterative processes, providing the flexibility to adapt to contextual changes; social learning should be facilitated; and public involvement in decision making processes should be facilitated.

Societal challenges require important consideration taking into account the risks involved during decommissioning. These challenges will play a role in the decision processes and also in the selection of an adequate form of dialogue between interested parties. Issues of local public concern during decommissioning are partly the same and partly different from those of the preceding phases. As in other phases of the life of a nuclear installation, the building of trust between stakeholders is crucial from the point of view of conflict management, and social lessons learnt from the siting and the development of nuclear facilities are also widely applicable in the field of decommissioning. While in the course of construction and operation, the main challenges include: meeting expectations of a higher quality of life; accommodating a growing population; mitigating construction nuisances; and assuring the safe operation of the facility. The main concerns in the decommissioning phase are: the decreasing employment rate; the eventual reduction of revenues for the local municipality; the future use of the affected land and negative social impacts (e.g. out-migration).

8. TECHNIQUES AND SKILLS

Techniques for decontaminating and dismantling nuclear facilities are already available and have been successfully applied in the decommissioning of many early facilities for development and demonstration of nuclear power. This has provided a substantial body of experience on a wide range of complex applications that is now being used on larger commercial facilities. It is important to ensure that the accumulating experience from applying these techniques to large plants is shared throughout the decommissioning community and that lessons continue to be fed back into new facility designs and decommissioning plans.

The need for totally new decommissioning techniques to be developed through research and development seems to have decreased but there is still room for innovation and improvement. Some areas to mention are:

— Decontamination and effluents management;

— Use of robotics and remote handling techniques;
— Characterization and decontamination of very large quantities of concrete;
— Detection of alpha emitters in concrete.

To solve some specific challenges of legacy management in an effective and cost-efficient way, technologies proven in other areas need to be adapted, and innovative solutions developed. Decommissioning is characterized by a complex interface of civil engineering and radioactive materials management which requires scientific, technical and engineering skills of the highest order. While the nuclear industry has a healthy pool of skills related to the operation of power stations, decommissioning is a new task. Should demand increase for workers with skills that are valuable in both operational maintenance and decommissioning activities, this workforce could become significantly stretched towards its limits. This would require looking to other industries with experience of handling hazardous materials.

There is also the possibility that formerly abandoned techniques considered to be too expensive should be re-examined and evaluated for applicability in a changing technological and economic environment.

9. CONCLUSION

Decommissioning is now a mature and experienced industry which has demonstrated its ability to decommission nuclear installations of various types in a timely, efficient and safe manner. However, the experience has been gained mostly on a case by case basis and new challenges for the industry will emerge as full scale, modern commercial power reactors begin to reach the end of their design lifetimes. The growing decommissioning industry will need comprehensive, purpose-built policy and regulatory frameworks that allow for flexible solutions and optimization. The major issues that need to be addressed to build such frameworks, also at the international level, can be identified today.

BIBLIOGRAPHY

OECD/NUCLEAR ENERGY AGENCY, The Decommissioning and Dismantling of Nuclear Facilities — Status, Approaches, Challenges, OECD, Paris (2002).

OECD/NUCLEAR ENERGY AGENCY, Decommissioning Nuclear Power Plants – Policies, Strategies and Costs, OECD, Paris (2003).

OECD/NUCLEAR ENERGY AGENCY, The Regulatory Challenges of Decommissioning Nuclear Reactors, and Dismantling, OECD, Paris (2003).

OECD/NUCLEAR ENERGY AGENCY,— Strategy Selection for the Decommissioning of Nuclear Facilities, Seminar Proceedings, Tarragona, 1-4 September 2003, OECD, Paris (2004).

OECD/NUCLEAR ENERGY AGENCY, Learning and Adapting to Societal Requirements for Radioactive Waste Management, Key Findings and Experience of the Forum on Stakeholder Confidence, OECD, Paris (2004).

OECD/NUCLEAR ENERGY AGENCY, Releasing the Sites of Nuclear Installations – A Status Report, OECD, Paris (2004).

OECD/NUCLEAR ENERGY AGENCY, Selecting Strategies for the Decommissioning of Nuclear Facilities — A Status Report, OECD, Paris (2006).

PESCATORE, C., VÀRI, A.,, "OECD/NEA lessons learned on stakeholder issues in decommissioning", these Proceedings.

INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series No. WS-G-2.1, IAEA, Vienna (1999).

INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Problematic Waste and Material Generated During the Decommissioning of Nuclear Facilities, Technical ReportS Series No. 441, IAEA, Vienna (2006).

INTERNATIONAL ATOMIC ENERGY AGENCY, Financial Aspects of Decommissioning, IAEA-TECDOC-1476, IAEA, Vienna (2005).

DECOMMISSIONING: IMPORTANCE AND BENEFITS OF LESSONS LEARNED

U. BLOHM-HIEBER, T. KIRCHNER,
R. PASSALACQUA, S. WHITE
DG TREN H2,
European Commission,
Brussels
Email: Ute.Blohm-Hieber@cec.eu.int

Abstract

The paper provides information on the decommissioning activities supported and performed by the European Commission (EC). The outcome and lessons learned from EC programmes on extensive decommissioning research and development, on legal and financial aspects and on decommissioning waste management are discussed. Although decommissioning has reached industrial maturity, there is still the need to address specific regulatory and environmental aspects, in order to ensure safe and efficient decommissioning. The paper describes the steps taken towards achieving the overall goal of a harmonized system of regulations and standards across the European Union (EU) for the purpose of ensuring the safety of the public and the workforce and the protection of the environment. The paper also addresses the specific assistance provided to the new member states of the EU and to acceding countries, in the context of the commitment of some of them to the early closure of nuclear installations, and in relation to the associated social consequences.

1. INTRODUCTION

It is estimated by the World Nuclear Association that, worldwide, there are over 90 commercial power reactors, 50 fuel cycle facilities, 100 mines and more than 250 research facilities that have been retired from operation [1]. Many are currently being decommissioned while others have already been successfully decommissioned. After several decades of the use of nuclear energy, the decommissioning of aging or shut down nuclear installations has become an established and growing industrial field. Considerable experience has been gained, particularly in countries which were early users of nuclear power, or where political decisions have resulted in early closure.

In the EU, 15 of the 25 Member States have nuclear power plants and 13 of them use nuclear energy for electric power generation. Overall, the European nuclear installations are ageing. The number of power plants that are shutdown and undergoing decommissioning is steadily increasing (and this also applies to research reactors and other nuclear fuel cycle installations). It is a fair assumption that more than one third of the 166 reactors currently operating in the enlarged EU will need to be shut down by 2025 — which underlines the increasing importance of decommissioning in the years ahead.

The decommissioning of nuclear facilities and the management of their waste involves environmental, technical, social and financial responsibilities. It is not always clear who will bear these different responsibilities. Until now, decommissioning projects have usually been regulated on a case-by-case basis. To date, EU Member States have chosen markedly different decommissioning strategies.

In view of the increasing number of plants to be decommissioned, the exchange and analysis of experience in the field of decommissioning is of vital importance. The costs at the end of the nuclear plant life cycle can lead to undue financial burdens on the nuclear industry, and subsequently to price increases to be paid by electricity consumers and it is clear that these costs must be better managed. The development of common approaches based on a 'Code of Conduct' within the EU on the decommissioning of nuclear facilities would result in improved protection of the population and of the environment and in a more standardized technological approach resulting in, inter alia, a reduction in the volume of waste produced. Harmonization of decommissioning practices in EU Member States and the development of specific regulations covering decommissioning should make regulatory decisions easier, more efficient and transparent.

With this in mind, the different services of the European Commission (EC) are studying the strategic and policy aspects of decommissioning in the EU, focusing on the following issues, which will be discussed in more detail in the following sections:

- Research and development and the technical approach to decommissioning;
- Legal and financial aspects related to decommissioning;
- Decommissioning waste management.

2. DECOMMISSIONING RELATED R&D ACTIVITIES IN THE EU

Since 1979, the EC has conducted four successive five-year research and development programmes on the decommissioning of nuclear installations, performed under cost sharing contracts with organizations from within the EU [1, 2]. The main objective of these programmes is to establish a scientific and technological basis for the safe, socially acceptable and economically affordable decommissioning of obsolete nuclear installations.

More than €60 million has been spent on the development of decontamination and dismantling techniques for different kinds of nuclear installation, on technologies for waste minimization, (e.g. melting of steel components), on the development of decommissioning strategies and management tools and on the development of remote handling systems for highly activated components.

In the early 1990s, four pilot decommissioning projects were chosen for the purpose of comparing approaches to decommissioning:

— A fuel processing plant (AT1 at La Hague, France);
— A gas-cooled reactor (WAGR at Windscale, United Kingdom);
— A boiling water reactor (KRB-A at Gundremmingen, Germany);
— A pressurized water reactor (BR-3, Belgium).

A WWER type reactor (Greifswald in Germany) was later added to this list of pilot decommissioning projects.

The various projects in Europe have resulted in a great deal of information and experience being obtained. Key points include:

— Improvements to cost estimation methodologies — based on actual experience;
— The development of tools and procedures for radiation dose minimization, reduction of generated waste and cost;
— Improved strategic assessment, particularly in relation to an improved understanding of the significance of equipment deterioration and of the loss of human experience in the case of delayed shutdown regimes;
— For LWRs, the presence of pools and water allows the highly active components of the reactor to be dismantled easily and in a safer manner, using water as a radiation shielding medium.

No significant reduction in the workforce radiation dose commitments and in the amount of waste can be expected from deferring decommissioning for about 30 years. A longer period is needed to obtain significant dose and waste volume reductions.

The experience gained to date is available for future decommissioning operations in a European database.

Since the pilot decommissioning projects (FP5), the supported activities in decommissioning in the EU have clearly shifted from research on technology to:

— Dissemination of results from former research activities;
— Exchange of experience and provision of training;
— Development of decision-support and management tools.

Within the period of FP6 (2002–2006) the EC has decided to support the creation of European Networks of Excellence and the creation of a Network on Decommissioning [3] as an effective instrument for facilitating these objectives.

After more than 25 years of EU R&D programmes on decommissioning, the decommissioning process has reached industrial maturity and the time is now ripe to review the regulatory and environment related issues.

3. LEGAL AND FINANCIAL ASPECTS RELATED TO DECOMMISSIONING

3.1. Regulatory framework for decommissioning

The nuclear safety policy in the EU is to encourage a transparent and harmonized system of regulations and standards across the EU with the aim of providing assurance to the public at large. It enables all players to work effectively towards the common objective of ensuring the safety of the public and the workforce and the protection of the environment both now and in the future. Decommissioning activities must be carried out in a safe and efficient way, in compliance with national and international requirements.

However, there is no common set of rules in the EU for the decommissioning of nuclear power plants. In fact, the only generally applicable legal European requirement [3] that explicitly mentions the decommissioning of nuclear installations is concerned with the need to perform an Environmental Impact Assessment [4].

A draft Directive setting out basic obligations and general principles for the safety of nuclear installations (one of the two Directives in the ‘nuclear package’ of legislative proposals) represents a first attempt to include within legislation important requirements affecting decommissioning funds. Although the legislative proposals were amended and adopted by the EC in September 2004, the Directives have not yet been adopted by the Council of the EU.

3.2. Decommissioning funding

While the decommissioning of nuclear installations is an exclusive national competence, the subject of national decommissioning funds has been discussed in the context of the Directive on the Common Rules for the Internal Market of Electricity [6]. The European Parliament expressed its concerns about the possible adverse effects of the misuse of financial resources earmarked for the decommissioning of nuclear plants and for the management of their waste. As a result, an inter-institutional statement made in July 2003 [7] laid the way for Community action, highlighting the need for adequate financial resources for decommissioning and waste management activities to be available for the purpose for which they were established and to be managed with full transparency. The availability of adequate financial resources by the time a nuclear installation is permanently shut down remains the primary concern when planning the decommissioning of nuclear installations. The creation of the internal market has brought an increased need for transparency and harmonization in the management of financial resources. In this context, it is seen as essential to establish the optimum ways of ensuring that the financial resources set aside for decommissioning will actually be available when needed and that the resources are managed properly.

With this in mind, the EC has prepared a draft recommendation [8], which aims to ensure the safe performance of decommissioning activities without undue risk to the health and safety of workers and of the general public [8].

During the preparation of the recommendation, the EC launched an extensive consultation exercise on the 'Analysis of the Factors Influencing the Selection of Strategies for Decommissioning of Nuclear Installations'. This exercise was welcomed by the EU Member States and, by assembling a substantial amount of related information, has proved to be extremely useful.

The EC recommendation addresses all nuclear installations, with special attention given to future nuclear constructions. While a segregated fund with appropriate controls on its use is the preferred option for all nuclear installations, a clear recommendation to this effect is made for new nuclear installations. In this context, the EC will expect a report to be provided on decommissioning funding aspects under the procedure provided for in Article 41 of the EURATOM Treaty for the construction of new nuclear installations.

The recommendation fully respects the principle in the field of nuclear safety, the responsibility lies with the licence holder ('polluter pays principle'), under the supervision of the national regulatory body. Due to the specificities of the nuclear industry, the effectiveness of traditional auditing methods can be rather limited, especially concerning decommissioning cost estimates. The EC proposes the establishment of national competent bodies, fully independent in their decision making from the contributors to the decommissioning funds, with a specific mandate and the capacity to deliver an expert judgment on decommissioning matters and, in particular, on fund management and decommissioning cost calculations.

As regards the estimation of decommissioning costs, in order to ensure the availability of adequate financial resources whatever strategy is selected prior to and beyond the final shutdown of the nuclear installation, the EC recommends a prudent calculation of costs based on appropriate risk management criteria and external supervision. In this context, the costs should cover all aspects related to safe decommissioning, from the technical decommissioning of the installation (planning, decontamination, dismantling, licensing, etc.) to the long term management of radioactive waste and spent fuel. Furthermore, the cost calculations should be the best available estimates of recurring expenses. Estimates — however accurate — remain estimates. Consequently, the responsibility of the operator should not stop at collecting adequate financial resources in line with the cost estimates. If, in practice, the decommissioning project proves to be more expensive, the operator should bear the real decommissioning costs in their entirety, even beyond the existing cost estimates.

From a financial management point of view, financial resources are in practice accumulated and managed for decades. Therefore, prudent use of the funds should be ensured by seeking a secure risk profile in the investment of the assets, ensuring a positive return over any given period of time.

The EC intends to establish the necessary framework for continued consultation with EU Member States within the scope of the recommendation [8]. In this light, the EC intends to set up a permanent group of experts from the EU Member States. In particular, this group should assist the EC in its proceedings concerning the reports submitted by the competent national body; in the review of the proposed decommissioning funding regime through the procedure provided for in Article 41 of the EURATOM Treaty; and in providing advice within the scope of the recommendation based on the request of the Member State concerned.

3.3. Decommissioning support activities

The European Community has over the last 15 years actively promoted the application of high standards of safety at an international level. The concern of the international community in relation to those Soviet-designed nuclear power plants deemed not to be economically upgradeable to the required level of safety is well known. However, it is recognized that the decommissioning of such an inherited nuclear power plant may represent an exceptional financial burden to a country, not necessarily commensurate with its size and economic strength. In the context of the accession negotiations of

Lithuania, Slovakia and Bulgaria to the EU, the early closure of Ignalina, Bohunice and Kozloduy nuclear power plants have received special attention. Consequently, the treaty of Accession of Lithuania, Slovakia [9] and subsequently that of Bulgaria [10] to the EU introduced specific provisions in the context of the early closure of certain reactors. Lithuania committed to the early closure of Units 1 and 2 of the Ignalina nuclear power plant; Slovakia , for its part, has committed to the early closure of Bohunice V1 (Units 1 and 2); Bulgaria, having already closed, in line with its commitments, Units 1 and 2 of the Kozloduy nuclear power plant, agreed to the early closure of Units 3 and 4.

The EC has committed to provide these states with significant financial assistance in support of their efforts to decommission the respective nuclear power plants and to address the consequences of the early closure and decommissioning. EU assistance is not only foreseen for decommissioning of the reactors but also in relation to issues of security of supply (replacement capacity) and the maintenance of an adequate safety culture through the maintenance of morale and retraining at the plant. The amounts fixed for this assistance (see below) are not based on a specific proportion of the estimated costs, but recognise the extraordinary burden placed on the new EU Member States by the shutdown commitment, and are an expression of solidarity between the EU and the Member State.

The assistance is delivered by three International Decommissioning Support Funds (IDSFs), established for projects relating to decommissioning, security of energy supply and energy efficiency (e.g. through the reduction of the energy production capacity of the country) which are direct consequences of early closure. The three IDSFs for Ignalina, Bohunice and Kozloduy (IIDSF, BIDSF and KIDSF), to which the EU is the major contributor, are managed by the European Bank for Reconstruction and Development (EBRD) under the control of an Assembly of Contributors which is chaired by the EC as the largest contributor.

An alternative mechanism for direct assistance, the ‘Programmed Instrument’, to the beneficiary country is also available, though now it is only used in Lithuania with up to 20% of the annual allocation being provided through this route. This direct assistance to Lithuania addresses safety culture, maintenance and social-related issues, as well as those decommissioning projects which the Lithuanian authorities feel able to manage without external support.

The EC is responsible for the technical evaluation and monitoring of the implementation of the assistance programmes. The assistance has involved the provision (to the three countries concerned) of a total in excess of €1200 million for the period 1999–2006, while for the period 2007–2013, a total of €1488 million is envisaged.

At present, EU decommissioning support to Lithuania is more advanced, than that provided to Slovakia and Bulgaria. This is mainly due to the fact that Lithuania had already closed down its Ignalina Unit1 by the end of 2004 and that the preparation phase for decommissioning is now at an advanced stage. Concerning the financial support to Lithuania, the share of the direct assistance has continuously increased up to the above mentioned 20%. For reasons of national policy and practical expediency, not least being the decision to use the workforce of the plant to perform the dismantling, it is likely that the direct assistance via the Programmed Instrument will expand in the coming years. Recently, Slovakia has also applied for such a direct assistance, complementary to the IDSF. On a more technical level, it appeared helpful to establish contacts and good communications between the decommissioning services of the different plants in order to promote the exchange of respective views and experiences on practices in the field of decommissioning. At the suggestion of the EC, a first workshop was organized in Lithuania at the Ignalina nuclear power plant with participants from decommissioning services from the nuclear power plants in Slovakia, Bulgaria, Ukraine and personnel from the different regulatory bodies. The mitigation of the social consequences is a long and delicate process, in particular with respect to the workers at the plant. Some of the workers still find it difficult to understand the reasons and the necessity for the early closure of their installation. Nevertheless, it is important to keep the staff motivated and to maintain the safety culture at the plant to ensure safe decommissioning, in particular, in the transition phase where there is still an operating unit on the site.

4. DECOMMISSIONING WASTE MANAGEMENT

In the final dismantling of a nuclear installation, the environmental restoration strategy is of great concern to the public. The public is often concerned about what will happen to the management of radioactive waste and about any potential long term duration of decommissioning activities. In addition, there is concern about leaving burdens for future generations. Even if the existing decommissioning regulations and procedures protect workers and the general public, those involved or affected still need to be informed of the preventive measures taken. Decommissioning operations and the related strategy decisions should be undertaken with transparency, the involvement of the public and workers to their concerns.

In September 2004, the EC amended a proposal for two Council directives [11], addressing respectively the safety of nuclear facilities, and spent fuel and radioactive waste management. The latter obliges each Member State to adopt a programme for ultimate nuclear waste management, including an implementation schedule. In spite of the support of the European Parliament, and the subsequent backing of European citizens, this proposal has not yet been adopted and is still under discussion. Nevertheless, the EC has continuously upheld its position, confirming the need for the implementation of safe solutions for radioactive waste at the national level. In line with this position, the EC has provided assistance to new EU Member States and Acceding Countries for the establishment of national agencies (e.g. the ‘State Enterprise for Radioactive Waste’, SERAW in Bulgaria) and continues to contribute in a very concrete way to the funding of nuclear waste repositories or storage facilities. In the context of the decommissioning of the Ignalina nuclear power plant the Commission is providing financial support for the engineering of an Intermediate Storage Facility for Spent Fuel, a Solid Waste Management Storage Facility and a Near Surface Repository.

The concept of waste minimization is part of an efficient waste management strategy for successful decommissioning. The amount of waste can be reduced through a period of safe enclosure as a result of the decay of the radionuclides, the existence and operation of waste treatment facilities for volume reduction, and through the procedures of decontamination, melting, incineration, compaction, clearance, recycle, and reuse.

Directly linked to the concept of waste minimization is the concept of clearance. The amount of waste materials that will be produced depends directly on the level at which the clearance level is set for removing materials from regulatory control.

Following the EURATOM Council Directive 96/29 of May 13, 1996, the principle of clearance has been successfully used in several EU countries, most notably in Germany and Spain, and to a more limited extent in other countries, such as, Belgium and the United Kingdom. Nevertheless, in the absence of an EC approach for harmonized implementation, the remaining inconsistencies cause some difficulty for international trade, or for trans-boundary shipment. These important issues require further discussion within the international nuclear community.

5. CONCLUSIONS

The EC recognized, at an early stage, the need for research and development and the demonstration of effective and safe approaches for the decommissioning of nuclear installations at the end of their operational lifetimes. These efforts have contributed significantly to the capability of the European nuclear industry to manage successfully the final stage of its installations and it is probably one of the few industries that has been able to demonstrate this.

The decommissioning of nuclear installations is challenging on different levels. It is a political challenge, in particular in countries that are planning the construction of new nuclear power plants. The proof that the decommissioning of nuclear facilities is feasible is essential for public acceptance. It is an environmental challenge because the management of decommissioning waste must be shown not to present burdens for future generations. It is also an economic challenge and cost efficient decommissioning is required in order to limit the impact on the price of electricity.

With respect to the above mentioned challenges, the lessons learned can be summarised in the following general statements:

- The nuclear industry is responsible for the nuclear facility up to the end of its lifetime taking all the related financial burdens into account;
- In order to assure the timely availability of the required financial resources, the estimation of the decommissioning costs should be done in a prudent way, based on appropriate risk management and external supervision;
- Special attention to decommissioning considerations should be paid when planning future nuclear constructions;
- Good communication between the different actors involved in decommissioning helps to develop optimal technical solutions and to identify efficient best practices;
- Particular attention has to be paid to the management of decommissioning waste, in particular with respect to cross-border shipment of cleared waste.

Many lessons have been learned from the extensive activities in the field of decommissioning. To make the step from the learning process to future efficient applications, a harmonized regulatory framework is required. This will help to ensure the safe performance of decommissioning activities without undue risk to the health and safety of workers and general public.

REFERENCES

[1] www.world-nuclear.org

[2] EUROPEAN COMMISSION, Decommissioning of Nuclear Installations in the Research Framework Programmes of the EC, http://www.eu-decom.be/introduction/ec&decom.html.

[3] EUROPEAN COMMISSION, Co-ordination Network on Decommissioning of Nuclear Installations, http://www.ec-cnd.net.
[4] EUROPEAN COMMISSION, Assessment of the Effects of Certain Public and Private Projects on the Environment, Council Directive 97/11/EC, EC, Brussels (1997).
[5] EUROPEAN COMMISSION, Commission Recommendation of 6 December 1999 on the Application of Article 37 of the Euratom Treaty, L324, Official Journal of the European Communities, EC, Brussels (1999).
[6] EUROPEAN COMMISSION, Common Rules for the Internal Market in Electricity and repealing Directive 96/92/EC, Directive 2003/54/EC of the European Parliament and of the Council, EC, Brussels (2003).
[7] EUROPEAN COMMISSION, Common Rules for the Internal Market in Electricity, L176, Official Journal of the EU, EC, Brussels (2003).
[8] EUROPEAN COMMISSION, Commission Recommendation of 22 August 2006 on the management of financial resources for the decommissioning of nuclear installations, spent fuel and radioactive waste, C(2006)3672 final, EC, Brussels (2006).
[9] EUROPEAN COMMISSION, Treaty of Accession for the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia to the European Union, EC, Brussels (2003).
[10] EUROPEAN COMMISSION, Treaty of Accession for the Republic of Bulgaria and Romania to the European Union, EC, Brussels (2005).
[11] EUROPEAN COMMISSION, Proposal for two Council Directives (Euratom) setting out basic obligations and general principles on the safety of nuclear installations; and on the management of spent nuclear fuel and radioactive waste, COM/2003/32 final, Brussels (2003).

DISCUSSION

A.M. XAVIER (Brazil): You referred to an ‘external body’. Could you say something about its role?

U. BLOHM-HIEBER (European Commission): We would like the management of decommissioning funds to be assessed by external bodies that are independent of the operators. Such bodies should have not only financial competence but also access to technical competence, in order to judge the adequacy of the funding.

A.M. XAVIER (Brazil): Just the funding — not the safety?

U. BLOHM-HIEBER (European Commission): Of course, safety has to be taken into account. Our recommendation is based on the EURATOM Treaty, which gives primacy to safety.

Only when you have satisfied yourself regarding safety can you talk about competition. Initially, competition was the main concern in the European Parliament, but we said that one should first place emphasis on safety and determine what financial resources are necessary for safe decommissioning.

A.J. GONZÁLEZ (Argentina): I should like to comment on two issues arising out of the presentations of Mr. Riotte and Ms. Blohm-Hieber.

The first issue is the idea of a code of conduct for decommissioning. In this connection, I would mention that concern was expressed at a recent meeting of the IAEA's Commission on Safety Standards regarding the proliferation of codes of conduct in the safety area. The reason for the proliferation of such codes of conduct is that States are reluctant to enter into legally binding undertakings in the safety area, preferring what one might call 'soft law'.

If the European Commission considers the Joint Convention to be inadequate as far as decommissioning is concerned, it could propose an expansion of that convention or perhaps the adoption of a separate convention on the safe decommissioning of nuclear facilities.

If States want 'soft law', I would recall that in September the IAEA's Board of Governors established IAEA Safety Requirements on the 'Decommissioning of Nuclear Facilities Using Radioactive Material'.

The second issue relates to clearance levels. The presentations of Mr. Riotte and Ms. Blohm-Hieber created the impression that there is no international consensus on clearance levels, whereas in fact such a consensus exists. In 2004, the IAEA's Board of Governors approved the use of radiological criteria for radionuclides in commodities, as outlined in IAEA General Conference document GC(48)/8, in the application of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the BSS) — and the IAEA General Conference welcomed that fact (see para. 23 of General Conference resolution GC(48)/RES/10.A). Those radiological criteria are clearance levels.

From discussions relating to Article 37 of the EURATOM Treaty, I have the impression that a few EU countries have concerns about the application of the clearance levels. Such concerns should not be allowed to jeopardize the international consensus on clearance levels — that would be destroying a house that took a lot of time and effort to build.

U. BLOHM-HIEBER (European Commission): I agree that there is an international consensus on clearance levels, but when it comes to implementation there are different interpretations.

As regards the code of conduct issue, we thought that a code of conduct would be useful. We take into account whatever the IAEA does, but one can always refine and do more. When the time is ripe, we may go beyond this idea and come up with a recommendation based on a deeper insight. So I attach a question mark to the idea of a code of conduct.

The IAEA, with its larger family of Member States, should feel free to follow up, in their interest, on anything we do within the European Union.

SAFE DECOMMISSIONING OF CIVIL NUCLEAR INDUSTRY SITES

S. SAINT-PIERRE
World Nuclear Association,
London,
United Kingdom
Email: saintpierre@world-nuclear.org

Abstract

The paper contains the World Nuclear Association's Position Statement on the nuclear industry's perspective and policy on the decommissioning of civil nuclear industry sites. It emphasizes that the restoration of a nuclear site to the full extent practicable for its reuse is fundamental to the sustainable use of resources and is the nuclear industry's guiding goal in decommissioning. Furthermore, it notes that the local public supports the reuse of sites because it will provide opportunities for workforce redeployment and local redevelopment.

1. INTRODUCTION

This paper presents the World Nuclear Association's (WNA's) Position Statement on the nuclear industry's perspective and policy on the important subject of decommissioning of civil nuclear industry sites.

Inevitably, each country and each company adopts a decommissioning strategy appropriate both to the type of site to be decommissioned and also to a specific national, local and technical context. Despite such diversity, this statement reflects an industry consensus that there is a common dedication to sound practices throughout the global nuclear industry and that this continues to enhance an already robust record of safe and affordable decommissioning of all types of civil nuclear industry sites, from uranium mines to nuclear power reactors.

This paper focuses solely on modern civil programmes that contribute to nuclear electricity generation. It does not deal with the sites at which military or early civil nuclear programmes were conducted. These sites fall into the category of 'legacy activities', which are generally accepted as being the responsibility of national governments. Nevertheless, it is noted that the decommissioning of legacy activities has also been conducted safely, and the experience gained in that work has enhanced the process of successful decommissioning of modern civil nuclear industry sites.

2. ESSENTIAL MESSAGES

Decommissioning is a normal and necessary post-operational phase. It is defined as all steps leading to the release of a nuclear site – including facilities, land, buildings and equipment — from regulatory control. These steps include the processes of decontamination and dismantling. The nuclear owner/operator is responsible for all aspects of a site's decommissioning.

The two main objectives of decommissioning are to render the site permanently safe and to restore it, as far as practicable, for reuse. In pursuit of this outcome, no significant health risk may be borne by people nor may any danger be posed to the environment. After proper decommissioning, the degree of control of a site can be reduced or even terminated without cause for concern. The nuclear industry is fully committed to the twin objectives of decommissioning: safety and restoration for reuse.

There is now a wealth of industry experience in decommissioning. Worldwide, over 100 mines, 90 power reactors, 250 research facilities and many other fuel cycle facilities have been, or are being, successfully decommissioned. Throughout the nuclear industry, this experience has been widely shared through exchange mechanisms organized by such international organizations as the International Atomic Energy Agency (IAEA), the OECD Nuclear Energy Agency (OECD/NEA) and the WNA. Such information exchange helps practitioners benefit from the lessons learned by others and to adapt and improve known approaches and techniques. Meanwhile, there has been a steady growth in the appreciation by the public that nuclear sites are being operated safely and with due care for the protection of people and the environment. This confidence is a natural consequence of the comprehensive health, safety and environmental programmes that conform with national regulations. The nuclear industry recognizes that such regulatory standards are indispensable for the successful operation of all phases of civil nuclear activity, including decommissioning.

Sites undergoing decommissioning are intrinsically safer than sites in operation. This is because the high level radiation sources that can pose a significant hazard are, along with radioactive equipment and materials, either removed or secured as decommissioning proceeds. Despite the overall decrease in radiation risk as compared with the operational phase, strict attention needs to be paid to radiation safety during decontamination and dismantling activities. These activities must also be conducted carefully in terms of conventional industrial safety.

The shift from productive operations to decommissioning activities requires transitional planning. Once decommissioning begins, decontamination and dismantling become the primary activities as the site is rendered permanently safe and restored for reuse. This transformation of purpose inevitably leads to significant organizational and cultural changes. Planning is essential to help the workforce prepare for these changes, which potentially involve redeployment or reemployment. As operations move into full scale decommissioning, the requirement for different skills leads inevitably to a shift in workforce composition, usually involving specialized contractors. As established decommissioning practice, the nuclear industry recognizes and fulfils its responsibilities to those who have been employed at the facility being closed.

The restoration of sites for reuse is consistent with the principle of sustainability and is a fundamental industry goal. The first benchmarks of successful decommissioning are: the safety and protection of the workforce, the public and the environment; and the restoration of the site, as far as practicable. The industry's even broader aim is to achieve site reuse wherever possible. A sequence that begins with safe and clean operations, passes through safe decommissioning, and culminates in effective site reuse, represents the fullest possible application of the principle of sustainability.

Fundamental environmental principles — Reduce, Recover, Recycle and Reuse (the 'Four Rs') — are integral to successful decommissioning. Applying these principles means minimizing radioactive contamination and recovering, recycling and reusing materials, equipment, and even waste to the fullest practicable extent. Disposal is used only as a last resort. Typically, over 90% of the volume of waste generated during the decommissioning of a nuclear facility has little or no radioactivity associated with it, and most of the remainder contains only very low levels of radioactive material. Thus, only a small percentage of waste material must be dealt with as low- or intermediate level radioactive waste.

In developing sound end uses for the vast majority of the materials and waste that arise from site decommissioning, the nuclear industry acts in accordance with internationally agreed rules and procedures. These in turn are consistent with the standards governing trade in materials and goods between countries. The WNA Statement on 'Removal from Regulatory Control of Material Containing Radioactivity — Exemption and Clearance' (see www.world-nuclear.org) advocates that national authorities encourage even greater convergence toward a common set of internationally recognized rules;

it argues against any attempts to move away from uniformity of standards and procedure.

Equally as important as the reuse of materials and waste is the reuse of land, water bodies and buildings after site decommissioning. The fact that nuclear facilities usually represent only a small percentage of a site's overall area, means that much of the site can easily be restored and reused. Such reuse often ranks high in public expectations.

Applying the 'Four Rs' represents not only sound environmental practice but also creates opportunities for workforce re-deployment and local redevelopment. In commercial terms, the optimal reuse of a successfully decommissioned nuclear site may well be to build a new nuclear facility there. This option may also be optimal in a broader socio-economic sense — because the nuclear facility would utilize local skills already present in the area and because nuclear sites usually enjoy long-standing local public support. As public appreciation of nuclear energy continues to grow, the expectation of site reuse for further nuclear operations may well become the norm.

Decommissioning requires a sound infrastructure for the management of waste and materials. While the overall volume of waste is relatively small — and the nuclear industry's aim is to minimize this volume – it is essential to successful decommissioning that governments and industry have acted to ensure that sufficient storage and disposal capacity for low or intermediate level nuclear waste is in place. In most countries with major nuclear programmes, storage and disposal facilities of this kind are now operational. The WNA Position Statement on 'Safe Management of Used Nuclear Fuel and Nuclear Waste' addresses this topic (see www.world-nuclear.org). Decommissioning situations involving spent nuclear fuel and other high radiation sources may require interim storage capacity if a suitable disposal site — such as a deep geological repository — is not yet available.

In the decommissioning process, the owner/operator is faced with many compliance steps and milestones. These steps begin with the submission of a decommissioning plan and an application for a decommissioning licence. Regulations apply throughout decommissioning and thereafter, and the owner/operator maintains control after decommissioning until all regulatory requirements are satisfied. At this final stage, authorities can decide to partially or fully discharge the owner/operator from responsibilities and liabilities for the decommissioned site. In the decommissioning process, it is standard practice for the owner/operator to use a quality based management system.

While the overall cost of decommissioning is significant, it is not prohibitive or even dominant compared to the lifetime value of a nuclear facility's output. This cost is normally planned for at an early stage and is recognized as a basic responsibility of the owner/operator. Normal industry practice is to accumulate a decommissioning fund during the lifetime of a facility. Because decommissioning costs are relatively small, the financial resources necessary for decommissioning can be accumulated through a very modest incremental addition to the price of electricity from nuclear power plants or to the supply of nuclear fuel cycle services. Accruing resources sufficient to achieve sound decommissioning is a recognized responsibility of the site owner/operator. The systematic nature and affordability of financing for decommissioning modern civil nuclear facilities should not be confused with the entirely different situation of managing legacy activities. These involve sites from military or early civil nuclear facilities and decommissioning tends to be expensive and complicated.

Building pubic confidence and trust is essential for decommissioning programmes and requires interaction with stakeholders and the transparent presentation of any environmental and socio-economic impacts associated with the decommissioning. The process of obtaining relevant authorizations for decommissioning a nuclear site requires the owner/operator to engage stakeholders in an interactive dialogue. This engagement is not only a necessary hurdle but can be valuable in building community understanding and cooperation. In this process, each side has something to offer. The nuclear industry can build clearer public awareness of the environmental dimensions of decommissioning, while stakeholders can help the owner/operator assess the socioeconomic impact of decommissioning. Properly conducted, this dialogue can contribute to producing a plan for site reuse and for local reemployment and development that enjoys strong public support.

3. DECOMMISSIONING — A NORMAL AND NECESSARY PHASE AFTER THE SAFE SHUTDOWN OF OPERATIONS

Decommissioning is a necessary post-operation phase that marks the end of a site's original use. It also marks the beginning of an important new phase in which the site is rendered permanently safe and restored, to the full extent practicable, for reuse.

A site may be permanently shut down for several reasons. Among the factors are normal ageing/degradation; heavy refurbishment needs; and substantial changes in technologies, regulatory requirements, and markets. In the case of uranium mining sites, the cessation of a site's use often corresponds to the depletion of viable uranium ore deposits.

The IAEA defines decommissioning as "all steps leading to the release of a nuclear facility, other than a disposal facility, from regulatory control. These steps include the processes of decontamination and dismantling." It defines a nuclear facility as “a civilian facility and its associated land, buildings and equipment in which radioactive material is produced, processed, used, handled or stored on such a scale that consideration of safety is required.”

Decommissioning commences with the removal or securing of both high radiation sources that can represent a significant hazard and also radioactive process materials. Such sources include spent nuclear fuel in nuclear power plants (NPPs), radioactive process materials in nuclear fuel cycle facilities and nuclear power plants, and sealed radioactive sources of various uses (e.g. for monitoring and calibration).

4. OVERALL GOAL OF DECOMMISSIONING AND ITS KEY ROLE IN SUSTAINABILITY

During a site’s restoration for safe reuse, no significant health risk may be borne by people nor may any danger be posed to the environment. After successful decommissioning, site control can be substantially relaxed – or, in some cases, safely ended altogether.

The nuclear industry is committed to the twin objectives of decommissioning: safety and restoration. These characteristics underscore the industry’s intrinsic sustainability.

Reuse can apply to various parts of the site, including land, water bodies, buildings, equipment, materials and even waste. The nuclear industry and regulators share a responsibility to develop and implement strategies for safe and effective reuse of these valuable resources. Reuse opens important opportunities for workforce redeployment and local redevelopment. The nuclear industry accepts the obligation to pursue these goals as a high socioeconomic priority.

In summary, the concept of decommissioning entails:

— Rendering a site permanently safe after the conclusion of plant operations;
— Restoring the site for reuse, while maximizing the reuse of all on-site resources, including waste;
— Realizing opportunities for workforce redeployment and local redevelopment.

5. NUCLEAR INDUSTRY EXPERIENCE IN DECOMMISSIONING

The global nuclear industry has developed a wealth of experience in decommissioning. Decommissioning has been successfully accomplished at a variety of nuclear sites, from research facilities to large-scale industrial plants.

As mentioned earlier, worldwide, over 100 mines, 90 power reactors, 250 research facilities and many fuel cycle facilities have been safely retired from operations. Of these, many have been, or are currently being, successfully decommissioned. Much experience has been gained too from smaller-scale decommissioning projects carried out in parallel with normal operations at all types of nuclear facilities.

This professional experience has been widely shared among nuclear practitioners worldwide through conferences, seminars and workshops. These meetings continue to be held under the auspices of international organizations such as the IAEA, the OECD/NEA and the WNA.

Accumulated and shared experience in decommissioning constitutes a knowledge bank of tested techniques, proven standards, and best practices. This knowledge provides a strong foundation for an industry professionalism that helps to build trust among stakeholders in the decommissioning process.

Experience at each facility is also important when the time for decommissioning arrives. Many of the good practices that are essential for safe operations and public confidence during the production phase of a nuclear facility are also a prerequisite for efficient decommissioning. These include complete record keeping on operations, materials, and maintenance; preservation of drawings of facility design and modifications; thorough surveys of contamination and prompt decontamination; and meticulous accounts of any leakages and spills.

6. DECOMMISSIONING APPROACHES

The many types of nuclear sites and facilities and the great diversity of national, local and technical contexts have resulted in a variety of approaches to decommissioning.

For facilities at the front end of the nuclear fuel cycle (e.g. conversion, enrichment and fuel manufacturing facilities), the challenges arise from naturally occurring radioactivity and chemical hazards. For sites at the back end (e.g. reprocessing facilities), the risks are increased by the presence of high level sources containing artificial radionuclides. At all of these sites, decommissioning begins with the removal or securing of high level sources, equipment and materials that can represent a significant hazard. Facilities are then decontaminated by thorough rinsing and cleaning, and finally dismantled. In the process, contaminated materials and waste are sorted and removed.

At nuclear power plants the initial phase — removal of used nuclear fuel, decontamination and sealing — is followed by a deactivation period. This delay facilitates subsequent steps when high level radioactive materials in certain process equipment will have decayed significantly. Within the industry, there is debate as to whether this deactivation period is necessary. Some organizations prefer to proceed to the decommissioning process soon after the cessation of power generation, while others prefer postponement while radioactive decay reduces radiation levels and thereby facilitates decontamination and dismantling activities. In the latter procedure, the facility is placed under surveillance during the interim phase with the highest radiation locations sealed and monitored. A third approach, used in the USA for NPPs, consists of sealing and placing the facility under surveillance for a longer period of time to allow the radiation levels to be reduced to a level low enough to permit termination of the site licence. Among these NPP decommissioning options, the choice depends on specific circumstances; particularly the site's planned end use and the destination of the spent nuclear fuel.

At uranium mines, the decommissioning of mills poses challenges similar to those at other front-end facilities. Due to their large volumes and low radioactivity levels, uranium tailings that result from conventional (mechanical) mining usually remain on site. Decommissioning work includes improving the long term containment of tailings basins; placing a cover on top of tailings to reduce both water infiltration and the emission of radon gas; and collecting, treating and monitoring water discharges from tailings basins and mines. For mining operations using in situ leaching, the decommissioning process centres on the recovery of injection well pipes and process waste, and on the restoration of underground water quality through treatment and monitoring.

For both NPPs and nuclear fuel cycle facilities, the final decommissioning steps are the restoration of the site's landscape and long term monitoring and institutional control. Restoration work for an NPP involves a relatively small area as compared with a uranium mine, where a much wider area has been disturbed.

All decommissioning approaches employ flexibility and adaptability in pursuing the essential objectives of safety and restoration.

7. DECOMMISSIONING TECHNIQUES

Decommissioning work employs a myriad of proven techniques and technologies. These include:

— Measuring and monitoring techniques, which have become steadily more sophisticated over the years;
— Decontamination by applying chemical, mechanical, electrical or a mixture of processes to metal, concrete and other materials;
— Dismantling — for example, by mechanical or thermal cutting;
— Remotely controlled manipulators and robots;
— Treatment and conditioning of wastes and effluents.

Some of the techniques and technologies employed by the nuclear industry are used in decommissioning conventional industrial facilities. Each technique and technology involves a variety of available tools and equipment. The decision of which to employ will always take into account safety and the goal of minimizing any additional generation of waste.

8. PROTECTING PEOPLE AND THE ENVIRONMENT

The public has come increasingly to appreciate that nuclear sites operate safely with due care for the protection of people and the environment. This confidence derives, in part, from rigorous industry adherence to the standards embodied in health, safety and environmental protection programmes.

Such standards continue to apply during decommissioning. When decommissioning begins – and high-level radiation sources and radioactive process materials are removed or secured – a site becomes intrinsically safer for both people and the environment. Nonetheless, health, safety and environmental standards continue to be observed as the owner/operator pursues two aims:

— Maintaining a high level of safety and protection during decommissioning;
— Achieving a permanently high level of safety and protection after decommissioning.

Decommissioning activities differ markedly from the previous operation of a facility. A fundamental difference is that decontamination and dismantling require closer contact with contaminated equipment, materials and wastes. Inevitably, the new tasks represent a significant change in the workplace, often requiring new workers with different skills and experience. Even then, specific training may be needed for the decommissioning workforce to acquire the skills necessary for rendering a particular site permanently safe and restoring it for reuse.

Throughout a site's decommissioning, public authorities monitor the owner/operator's compliance with health, safety and environmental protection requirements. Once decommissioning is completed, acceptance must be obtained from key stakeholders — including local authorities and the general public — that these requirements have been fully met. This acceptance is a prerequisite to gaining official agreement that control over the site can be safely reduced or ended.

9. SITE REUSE — FUNDAMENTAL TO THE SUSTAINABLE USE OF RESOURCES

While the initial benchmark of sound decommissioning is the application of rigorous standards of health, safety and environmental protection, the ultimate aim is to restore the site for reuse to the fullest extent practicable.

Buildings, equipment and materials that are highly contaminated will generally need to be decontaminated and dismantled, and in some cases disposed of after treatment and conditioning. But land, water bodies and many buildings that emerge from successful decommissioning will be available for reuse. Moreover, some 90% of the waste volume generated during decommissioning is, for practical purposes, uncontaminated and may easily lend itself to recycling.

Public expectations attach high value to site reuse because of the potential for workforce re-deployment and local redevelopment. Commercially, the best reuse of a successfully decommissioned site may well be the construction of a new nuclear facility in its place; and this option may also be congruent with national needs and local aspirations. From a national perspective in many countries, nuclear power is gaining increasing policy support as a reliable source of affordable and cleanly generated electricity. From a local perspective, the replacement option draws upon skilled labour already available and is therefore likely to enjoy local public acceptance that is common to communities familiar with nuclear power.

Uniformity in regulatory standards facilitates predictability, planning, and efficiency in all areas of nuclear industry practice, including the decommissioning process. There is thus an increasing effort internationally to develop agreed universal standards that will lend consistency and coherence to national regulatory regimes. Recently, the IAEA adopted international standards on the removal from regulatory control of materials containing trace levels of radioactivity; these standards were particularly designed to govern the use or disposal of bulk quantities of such materials as may occur during decommissioning. These standards — and similar IAEA standards for land and water bodies at decommissioned sites — are milestones in regularizing the process of achieving safe and efficient reuse of decommissioned nuclear facilities.

10. DECOMMISSIONING WASTE MANAGEMENT

The concept of decommissioning suggests an enormous task of decontamination, requiring the dismantling or destruction of many buildings and much equipment and requiring the disposal of a correspondingly large volume of radioactive waste. In fact, over 90% of the total volume of waste generated during decommissioning is non-radioactive and uncontaminated, and most of the remainder contains only a very low level of radioactive material. Thus, only a small percentage of the overall waste generated during decommissioning requires treatment, conditioning and disposal because of its radioactive content.

Because some waste will be generated, decommissioning requires a sound infrastructure and system for waste management. Only with such a system can the owner/operator plan a sequence of activities by which waste and other materials are optimally managed, taking into account costs, risks and benefits. These activities include pre-sorting and collection; control, characterization and sorting; pre-treatment and pre-conditioning; treatment and conditioning; handling; storage and disposal. Sorting is especially important; as costs can be reduced by proper separation of waste types (depend on waste and material concentrations, quantities, forms and types and on the resulting destinations for storage and disposal).

For much of the waste and material, disposal routes have been established, though more can still be done to develop these routes and enhance efficiencies. For the lower volumes of intermediate level waste, the common practice is disposal or storage, as an interim measure. For very low level radioactive material and waste, countries currently vary in practices for exemption and clearance, with some countries permitting unrestricted recycling and reuse. As in other aspects of regulatory practice, this area will benefit from the application of harmonized international standards.

11. OWNER/OPERATOR RESPONSIBILITIES

The owner/operator's responsibility for all aspects of a nuclear facility continues through every phase of the site's decommissioning. Having submitted a decommissioning plan and obtained a decommissioning licence, the owner/operator must complete decommissioning in compliance with all licence requirements and other applicable regulatory requirements. Even when decommissioning work is satisfactorily completed, the owner/operator remains responsible for the site until formally discharged of this obligation by the relevant authorities.

In meeting these responsibilities, owner/operators customarily use a quality-based management system in all phases of decommissioning. Such systems use the well established ‘PDCC’ steps of professional management — Plan, Do, Check, Correct — to meet all regulatory requirements at every stage of decommissioning.

12. A COMPREHENSIVE REGULATORY FRAMEWORK

In all countries, decommissioning is subject to a comprehensive regulatory framework. The initial step — the owner/operator’s submission for a licence — usually triggers a sequence of evaluations and peer reviews to establish clearly what steps will be necessary to comply with the standards and requirements of the relevant authorities. In this process, it is standard practice for the owner/operator to prepare a well-documented supporting case and for the relevant authorities to convene public hearings to facilitate the presentation of all stakeholder views. This interaction will sometimes produce an amendment in the decommissioning plan and the licence application.

Once a licence has been issued, regulatory oversight continues until the decommissioning process has reached the stage of long-term monitoring and institutional control. At this final stage, authorities can decide to discharge the owner/operator, fully or partially, from further responsibility and liability for the decommissioned site.

13. FUNDING OF DECOMMISSIONING

The overall cost for decommissioning is significant, although low in comparison with the lifetime productive output of the facility being closed. Financing for this cost is customarily planned at an early stage of the facility’s life and is recognized as a responsibility of the site owner/operator. Common industry practice is to accumulate a decommissioning fund during the life of a facility by integrating an incremental cost into the price of electricity from nuclear power plants and of the services rendered by fuel cycle facilities. The systematic accumulation and affordability of decommissioning costs for modern civil nuclear facilities is not to be confused with the management of legacy activities — involving military and early civil nuclear facilities — which tend to be expensive and complicated.

Nowadays, for all nuclear facilities, standard international practice includes the preparation of a decommissioning plan at an early stage, often even before the start-up of operations. During a facility's operational life, this plan is regularly updated.

The means by which an owner/operator fulfils the responsibility of accumulating decommissioning funds varies according to national policy. The owner/operator can either: contribute into an external fund controlled by authorities; or make allocations within organizational accounts in compliance with generally accepted accounting principles under the oversight of independent auditors or authorities.

14. ENVIRONMENTAL AND SOCIOECONOMIC IMPACT AND STAKEHOLDER INVOLVEMENT

In many countries, before the formal application for a decommissioning licence, a preliminary process occurs aimed at assessing the environmental and socio-economic impact of the decommissioning project. The result is called an Environmental Impact Statement (EIS). Generally, this process includes public hearings where stakeholders have ample opportunity to influence the conduct of a decommissioning project.

In anticipation of this formal process, the owner/operator often takes the initiative by seeking stakeholder input from the outset of planning. This is efficient from the owner/operator's perspective, and also serves to enhance public trust, confidence, and acceptance. Once decommissioning begins, this interaction usually continues through public meetings, workshops, and debriefings.

15. SUMMARY

The safe decommissioning of civil nuclear sites has been well demonstrated in many countries. The nuclear industry's strong record in this context reflects a high degree of expertise and responsibility towards the well-being of current and future generations of people. Accumulating experience and knowledge will serve to reinforce this already robust record of safety and achievement.

Restoring a nuclear site to the full extent practicable for its reuse is fundamental to the sustainable use of resources and is the nuclear industry's guiding goal in decommissioning. The public recognizes that site reuse will provide opportunities for workforce redeployment and local redevelopment. A well-devised decommissioning plan can combine the fulfilment of environmental principles and of socioeconomic obligations to the local community.

The nuclear industry has, in recent decades, successfully fulfilled its responsibilities for decommissioning its facilities and continues to meet these obligations with professional dedication and technological skill.

DISCUSSION

M. LARAIA (IAEA — Scientific Secretary): I should like to add my voice to what Mr. Saint-Pierre said about the redevelopment of decommissioned sites — something to which we at the IAEA attach considerable importance. Earlier this year we published IAEA Technical Reports Series No. 444, entitled ‘Redevelopment of Nuclear Facilities after Decommissioning’, and we intend to continue working in what we believe will be an increasingly significant area.

REGULATION OF DECOMMISSIONING ACTIVITIES

(Session 2)

Chairperson

G. YADIGIAROGLOU
Greece

Rapporteur

R. FERCH
Canada

LESSONS LEARNED: PAST TO FUTURE

L.W. CAMPER
Nuclear Regulatory Commission,
Washington, D.C.,
United States of America
Email: clm1@nrc.org

Presented by C. Miller

Abstract

The identification, preservation and incorporation of decommissioning lessons learned are critical to the continued expansion of nuclear power. Decommissioning experience will be developed in Europe and Asia over the next several years and that experience will be invaluable for the decommissioning of the next wave of plants in the USA. Industry and regulators will need to work cooperatively to ensure that the information is preserved and included in the design and operation of all new nuclear facilities, as well as in ongoing decommissioning projects. The paper describes the Nuclear Regulatory Commission's efforts to capture the decommissioning lessons learned from the first wave of decommissioning projects in USA.

1. INTRODUCTION

The word 'decommission is defined in Nuclear Regulatory Commission (NRC) regulations (10 CFR 20.1003) as:

> "to remove a facility or site safely from service and reduce residual radioactivity to a level that permits: 1) release of the property for unrestricted use and termination of the license; or, 2) release of the property under restricted conditions and the termination of the license."

On July 21, 1997, the NRC published the final rule on Radiological Criteria for License Termination (the Licence Termination Rule or LTR) as 10 CFR Part 20, Subpart E. The LTR established 0.25 (mSv/year) from all sources of radiation under the licensees control as the decommissioning criteria for NRC-licensed sites. In addition, the LTR requires that radiation doses be as low as reasonably achievable and that all sources (or pathways) be included in dose estimates. Finally, the LTR provides for the release of sites for unrestricted use and for their release from regulatory control with restrictions on future site use.

The NRC regulates the decontamination and decommissioning of materials and fuel cycle facilities, power reactors, research and test reactors, and uranium recovery facilities, with the ultimate goal of licence termination. Approximately 200 materials facility licences are terminated each year. Most of these licence terminations are routine and the sites require little, if any, remediation to meet the NRC unrestricted release criteria. However, some present technical and policy challenges, for example, as a result of contaminated groundwater, restricted release issues and site-specific dose assessments that require large expenditures of NRC staff resources.

2. STATUS OF DECOMMISSIONING FACILITIES

Currently, there are 15 nuclear power reactors undergoing decommissioning. Of these, 11 are in safe storage (SAFSTOR) and four are being actively decommissioned (DECON).

In addition, 14 research and test reactors have been issued with decommissioning orders or amendments and in addition three research and test reactors are in 'possession-only' status, either waiting for shutdown of another research or test reactor at the site, or for the removal of the fuel from the site by the U.S. Department of Energy.

There are 38 complex materials sites undergoing decommissioning. Currently, there are 12 NRC-licensed uranium recovery sites being decommissioned. These include conventional uranium mills and in-situ leach facilities.

The NRC provides licensing oversight and decommissioning project management to fuel cycle facilities, including conversion plants, enrichment plants, and fuel manufacturing plants. Most of these facilities have been in operation for 20 or more years. As technology improves and operations at these facilities change, there are often unused areas on the sites that have residual contamination.

3. DECOMMISSIONING LESSONS LEARNED

In the mid-1990s, it became apparent that the decommissioning of a nuclear facility did not constitute a separate set of actions conducted after the 'life' of the facility had ended, but rather, was an integral stage in the total life cycle of the facility. Planning for decommissioning is now recognized by regulators and the nuclear industry as an activity that must be factored into the design and operation of all nuclear facilities. Because decommissioning is typically undertaken only once in a facility life it is important to identify the associated experiences and lessons, incorporate them into ongoing decommissioning projects and factor them into the design and operation of new facilities so that future decommissioning projects can be conducted in a safe, timely and effective manner.

The NRC has several projects underway to identify, document and disseminate decommissioning lessons learned, including Regulatory Issues Summaries, and an enhanced web page.

4. REGULATORY INFORMATION SUMMARY 2002-02

On July 29, 1996, NRC regulations (10 CFR Part 50.82) were revised to define a new process for decommissioning power reactors. This new process included a requirement for licensees of power reactors to submit License Termination Plans (LTPs), rather than Decommissioning Plans (DPs), when they wanted their facility licences terminated. As a result of these revisions to the regulations, certain licensees are required to submit either DPs or LTPs to have their facility licences terminated. These revisions to the regulations require new information or different types of information than was previously required. Since the implementation of these revisions to the regulations, several licensees have submitted either the required DPs or LTPs for NRC review. As a result of these reviews, the NRC has found common areas that have resulted in it issuing several requests for additional information (RAIs) and for licensees to perform additional analyses to address the RAIs. These additional activities result in delays in completing the reviews. Further, these additional RAIs resulted in increased costs to licensees. The NRC staff has reviewed, or is in the process of completing reviews of several DPs or LTPs. As a result of these reviews, some of the lessons learned are as follows:

— Communications — Early and frequent discussions between NRC staff and licensees are encouraged during the planning and scoping phase in support of the preparation of the Decommissioning Plans (DPs) or Licence Termination Plans (LTPs);
— Groundwater — Additional environmental monitoring data may be needed because there may not be enough operational environmental monitoring of groundwater for adequate site characterization and dose assessments;
— Inspections — ‘In process’ inspections are more efficient than ‘one time’ confirmatory surveys;

— Flexibility — Continued communications between NRC staff and the licensee during the staff's review is encouraged — to help the licensee take full advantage of the inherent flexibility in NUREG-1575, 'Multi-Agency Radiation Survey and Site Investigation Manual,' and NUREG-1727, 'NMSS Decommissioning Standard Review Plan';
— Modelling Issues — The submittal of assumptions and justifications for the parameter values used in developing site-specific derived concentration guideline levels (DCGLs) and in the application of those DCGLs is encouraged;
— Decommissioning Cost Estimate — The discussion should include the relationship between the planned decommissioning activities and the associated updated cost estimate;
— Records — Old records should not be used as the sole source of information for the historical site assessment/site characterization, because these old records may be inadequate or inaccurate;
— Classifications of Survey Units — DPs and/or LTPs should be submitted only after sufficient site characterization has take place;
— Embedded Piping — Some LTPs and DPs contain an inadequate description of the methods that the licensee plans to use when surveying the embedded piping planned to be left behind.

As a result of these findings, the NRC staff has expanded its acceptance review process for DPs and LTPs (typically an administrative review) to include a limited technical review before a DP or LTP is accepted for detailed review. An expanded acceptance review facilitates the identification of significant technical deficiencies early in the review process. This limited technical review focuses on those areas in which experience has shown technical deficiencies in licensees' submittals. In general, these areas are: (1) site characterization (hydrogeological and radiological); (2) dose modelling; (3) final radiation survey; (4) cost estimate; and (5) institutional controls (applicable only to restricted release).

5. REGULATORY INFORMATION SUMMARY 2004-08

NRC staff experience with the LTR has revealed some important implementation issues which have an impact on the decommissioning of sites. In June 2002, the NRC staff conducted an analysis of LTR issues, with particular emphasis on resolving the restricted release and institutional control issues with the goal of making the LTR provisions for restricted release and alternate criteria in 10 CFR 20, Subpart E, more available for licensee use. The staff's analyses were completed for nine issues in March 2004. The nine issues that the staff analysed are:

— Restricted release/alternate criteria and institutional controls. NRC licensees have difficulties arranging for the institutional controls required by the LTR that will ensure long-term protection of public health and safety.
— The relationship between LTR release criteria and the 'unimportant quantities' criterion under 10 CFR 40.13(a). The relationship is unclear between the exemption in 10 CFR 40.13(a) for source material that is less than 0.05 weight per cent uranium or thorium and the criteria in 10 CFR 20 Subpart E (LTR) used for decommissioning and licence termination. In addition, clarification is needed that 10 CFR 40.13(a) is not a decommissioning criterion.
— Appropriateness of developing a separate uranium/thorium unrestricted release standard. Because the LTR cleanup levels for radioisotopes of these elements can be below concentration levels of the isotopes found in nature, the appropriateness of developing an unrestricted release standard higher than the LTR should be considered. In addition, LTR cleanup levels can be lower than those in other NRC regulations or certain State and Federal regulations, and since some sites have large volumes of such materials, cleanup can be complex and costly.
— Relationship between the LTR and on-site disposal under 10 CFR 20.2002. NRC regulations do not establish a clear standard for approving on-site disposals, although on-site disposals need to be reconsidered under the LTR at the time of licence termination.
— Relationship between the LTR and the current case-by-case approach for controlling the disposition of solid materials. The relationship is unclear between the LTR's dose constraint of 0.25 mSv/year (25 mrem/year) for unrestricted use of a site and the existing guidance for controlling the disposition of solid materials on a case by case basis, particularly for instances where materials and equipment containing residual contamination might be removed from an unrestricted-use site after licence termination.
— Realistic exposure scenarios. Clear guidance is needed for selecting more realistic exposure scenarios for estimating potential doses to the public after the termination of the licence.
— Measures to prevent future legacy sites by changes in financial assurance. Because licensee financial assurance risks may cause shortfalls in decommissioning funding, additional measures are needed to ensure that adequate funds are available for the decommissioning of sites.

— Measures to prevent future legacy sites by changes to the operations of existing licensees. Because operations at some sites have a significant potential to cause environmental contamination, additional measures are needed to reduce the likelihood and mitigate the consequences of such events occurring.
— Appropriateness of allowing intentional mixing of contaminated soil. The appropriateness of allowing intentional mixing of contaminated soil to meet release criteria should be evaluated.

The NRC staff is developing guidance, to be documented in a revised NUREG-1784, to address these issues.

6. ENHANCED WEB PAGE

In 2005, the NRC established a ‘decommissioning lessons learned’ page on the new Decommissioning web site. This web page includes a definition of a lesson learned, which is “any item that could be of interest and benefit to many licensees”. Lessons learned include positive or negative experiences that are considered to be worth sharing with NRC licensees and stakeholders for the purpose of improving future efficiencies. The web page provides a short summary of each lesson, its potential benefits, and links to publicly available documents that discuss each lesson learned in greater detail. The web page includes links to existing published sets of NRC lessons learned. NRC lessons learned can be found at: http://www.nrc.gov/what-we-do/regulatory/decommis-sioniong/lessons-learned.html.

7. IMPLEMENTING THE LESSONS LEARNED

7.1. Materials sites

Flexibility and the use of realistic scenarios, supported by adequate justification for the choice of the scenario, are two areas in which the NRC staff has significantly improved the NRC’s Decommissioning Program. Some examples of sites where the NRC has used flexibility and realistic scenarios to establish site specific cleanup levels are described in the following paragraphs.

At one materials site, the NRC staff developed its own dose assessment to support a recommendation to the NRC that no further decommissioning action was needed. The dose assessment included a range of potential scenarios that included two reasonably foreseeable scenarios and two less likely scenarios to bound the uncertainty associated with future land use.

The licensee of another materials site proposed an industrial land use scenario for dose calculation purposes. The NRC staff reviewed the proposal and evaluated land use development in the area and concluded that industrial land use was appropriate for this site. The decision withstood a legal challenge. This decision is important because it is the first case that used the industrial scenario as a reasonably foreseeable land use, and that withstood a legal challenge.

At another site, the licensee used the realistic scenario approach and the flexibility of the LTR to design an engineered barrier for erosion protection to revise and resubmit the DP.

The realistic scenario approach was also used at yet another site to facilitate licence termination. At this site, it resulted in a decision being made not to disturb the contamination; this avoided impacts to workers and the environment as minimized the decommissioning costs.

7.2. Reactor sites

In 2005, the NRC completed decommissioning at two power reactor sites. Two different approaches to decommissioning were adopted at these otherwise similar sites. At one of the reactor sites it was decided to complete decommissioning, terminate the Part 50 operating licence and manage the Independent Spent Fuel Installation (ISFSI) under the 10 CFR 72 (specific license), while at the other site it was decided to reduce the plant footprint to the ISFSI and to continue to manage the ISFSI under the general licence provisions of 10 CFR Part 50. These different approaches identified several lessons, as discussed below.

Stakeholder communications

The NRC LTR requires that the NRC solicits comments from the public, and 10 CFR 50.82 requires that a public meeting be held prior to the License Termination Plan approval for power reactors. This meeting allows the public to present concerns to the NRC staff for consideration of the License Termination Plan. The stakeholder participation can vary widely. It has been observed that this consultation may result in significant actions being taken by the stakeholders that may influence a licensee’s decommissioning plan.

LTP development and implementation

The lesson learned is that licensees need to produce a clear, concise, and detailed LTP, because it results in quicker approval. Further, a clearly written LTP requires less interpretation and allows the NRC to easily verify compliance with approved LTP requirements. The following discussion describes how the two sites' LTPs affected the decommissioning process.

At one site, the licensee took a straightforward approach to the LTP and the decommissioning. In the original site characterization, no groundwater contamination was found, so the licensee adopted the NRC Screening level DCGLs versus the development of site specific DCGLs. This simplified the approach for demonstrating that the residual radioactivity would give rise to radiation doses of less than the 0.25 mSv/year (25 mrem/year) criteria. The goal was to release the site for unrestricted use. The LTP was approved by the NRC in 18 months and over the course of the decommissioning, there were no major revisions to the LTP.

This is in contrast to another site where the LTP was developed using very broad and general methods for demonstrating compliance with NRC requirements and guidance. Although licensees generally believe that a less specific LTP allows for greater decommissioning flexibility, the potential for differing interpretations of the LTP commitments by NRC and licensee staffs is increased. In this case, the different interpretations presented during the LTP review led to numerous meetings and teleconferences to resolve NRC questions. The LTP required 37 months for approval.

Final status surveys (FSS) records and confirmatory surveys

The Final Status Survey Report (FSSR) is used to demonstrate that residual radioactive material at the site does not exceed the NRC criteria for release of the site. The NRC reviews the FSSR to verify that the results of the FSSs demonstrate that the site meets the radiological criteria for licence termination. As part of the FSSR review process, the NRC may review a variety of records associated with the FSSR, such as actual survey data packages, FSS instrument calibration records, and survey technician qualification and training records. The licensee and regulator should agree on the format and content of the FSSR Records that support the FSSR (i.e. FSS data, instrument calibration logs, and technician qualification and training records). These should be readily retrievable for inspection and the FSSR supporting records should be of high administrative quality.

At one site, the licensee submittals following the originally agreed format were consistent and of high administrative quality, which allowed the NRC staff to review the information efficiently. The NRC confirmatory surveys were scheduled with the licensee and were performed as planned.

This can be contrasted with another site where the content of the FSSR consisted of general FSS records. In this case, NRC staff needed to ask for substantially more information and to conduct two additional site inspections. At this site, the NRC review took longer to complete. Further, at this site, the NRC had difficulty in scheduling confirmatory surveys and thus in-process surveys were conducted. In-process surveys can confirm that the licensee is performing the surveys adequately since the surveys are conducted side-by-side with the licensee.

8. CONCLUSION

The NRC is working cooperatively with the nuclear industry on approaches to identify and preserve decommissioning lessons learned because decommissioning knowledge management is critical to the continued expansion of nuclear power. Decommissioning experience will be developed in Europe and Asia over the next several years that will be invaluable to the decommissioning of the next wave of plants in the USA. Industry and regulators will need to work cooperatively to ensure that the information is preserved and included in the design and operation of all new nuclear facilities, as well as on-going decommissioning projects.

DISCUSSION

G. YADIGIAROGLOU (Greece — Chairperson): In your presentation you spoke of ‘intentional mixing’, which could be tempting when one is dealing with low-level radioactive material. Could you elaborate?

C. MILLER (United States of America): ‘Intentional mixing’ does not mean mixing clean soil with contaminated soil or extending a contaminated area into a clean area. In means that, within a contaminated area where there are different levels of contamination, one mixes the contaminated soil so as to achieve a uniform contamination level which meets the standards for decommissioning.

REGULATORY FRAMEWORK AND PLANNING FOR THE DECOMMISSIONING OF THE KOZLODUY NUCLEAR POWER PLANT WWER-440 UNITS

S. TZOTCHEV, G. SIMEONOV
Nuclear Regulatory Agency,
Sofia,
Bulgaria
Email: S.Tzotchev@bnsa.bas.bg

Abstract

Activities for the decommissioning of the WWER-440 power reactors at the Kozloduy Nuclear Power Plant started in the late 1990s. The activities included the development of decommissioning-related regulations and the elaboration of initial strategies for decommissioning the reactors. After 2000, and with the aid of two European Commission funded projects, a technical design for decommissioning of Kozloduy units 1 and 2 was developed. Legislative changes also occurred: A new Nuclear Safety Act was adopted in 2002 and, subsequently, changes were made to the related secondary legislation. Today, Bulgaria has a well developed and complete legislative and regulatory basis for decommissioning and advanced technical and safety documentation concerning the decommissioning of the WWER-440 units. The way in which this framework was developed together with the challenges experienced and the plans for the way forward are presented in the paper.

1. INTRODUCTION

The Kozloduy Nuclear Power Plant is the largest producer of electric power in the Republic of Bulgaria, generating more than forty per cent of the electricity in the country. It has four WWER-440 units, which were commissioned between 1974 and 1982, and two WWER-1000 units, which were connected to the grid in 1987 and 1991.

Bulgaria has been associated with the European Community since 1995 and is expecting to obtain membership of the European Union in 2007. In accordance with the agreements signed by the Bulgarian Government and the European Commission, Kozloduy units 1 and 2 were closed at the end of 2002 and units 3 and 4 are scheduled to be closed by the end of 2006. The decommissioning of the four units is now under consideration. The decommissioning poses a number of safety, financial and planning challenges requiring good organization and continuous efforts both from the side of the regulator and of the licensee.

2. LEGISLATIVE FRAMEWORK

2.1. Past legislation

In the 1980s and 1990s, the main law governing nuclear matters in Bulgaria was the 1985 Act on the Use of Atomic Energy for Peaceful Purposes (amended and supplemented in 1995). According to this law, a Technical Project for Decommissioning has to be prepared by the plant operator at least 5 years before the date planned for initiating dismantling operations. However, no precise guidance is given about the content of this Technical Project.

Detailed requirements on decommissioning planning and implementation and on the content of the decommissioning permit application were established in 2001 with the adoption of the Regulation No. 10 on Safety during the Decommissioning of Nuclear Facilities. This regulation introduced the notion of a decommissioning plan and requirements for the safety assessment of decommissioning operations.

2.2. Current legislation

In 2002, a new basic nuclear law, the Act on the Safe Use of Nuclear Energy was adopted [1]. This Act contains a number of provisions on decommissioning; the most important are:

— Decommissioning can be undertaken only after a decommissioning permit has been issued by Nuclear Regulatory Agency (NRA);
— If decommissioning is to be implemented in stages, a separate permit can be issued for each stage;
— The decommissioning plan, the safety analysis report and a positive Environmental Impact Statement (by the Ministry of Environment and Water) are required before a decommissioning permit can be issued;
— The plant operator must submit a final decommissioning plan to the NRA three years before the closure of the reactor or the nuclear power plant.

The secondary nuclear legislation was completely revised by 2004 in order to be in compliance with the new Act [1]. As a result, twenty new regulations were issued which took into account a number of international requirements and recommendations (e.g. those of European Union, the IAEA and the International Commission on Radiation Protection). The new regulations contain requirements for the early planning of decommissioning (at the design stage) and for the periodic update of decommissioning information; they also contain specifications for the required content of the final decommissioning plan [2]. One of the most important decommissioning-related legislative developments is the definition in the regulations of clearance levels for materials arising from regulated practices.

3. DECOMMISSIONING ACTIVITIES AT THE KOZLODUY NUCLEAR POWER PLANT

3.1. Preliminary studies

In the first study on the decommissioning of the Kozloduy WWER-440 reactors, decommissioning with safe enclosure was proposed as an acceptable option for Units 1 and 2 [3].

In another study, five options for the decommissioning of the Kozloduy units 1 and 2 were assessed taking into account the main factors relevant to decommissioning, such as: safety, environmental protection, radiation protection, radioactive waste management and legal and regulatory considerations [4]. The selected option envisages that the facilities of Kozloduy Units 1 and 2 would be converted into ‘safe enclosures’ and be subjected to continuous monitoring for a period of 70 years.

3.2. Technical designs for the decommissioning of Kozloduy units 1 and 2

After the decommissioning option had been selected ‘in the mid-1990s’, work continued on the development of the more detailed technical and safety documentation needed for the licensing and the implementation of the Kozloduy 1 and 2 decommissioning project. With the support of the European Commission, two consecutive versions of the ’Technical Design for Decommissioning’ were prepared in 2000 [5] and 2001 [6].

The original strategy for deferred dismantling of the units was retained in the technical designs but a more precise timing of the process was developed:

- Phase 1 — including the post-operational activities and the preparation of the safe enclosure (SE) — 5 years;
- Phase 2 — SE period of 35 years;
- Phase 3 — deferred dismantling.

Documents produced during the second PHARE project [6] included a detailed classification of systems for the first and second stages of the decommissioning plan for Kozloduy units 1 and 2, data sheets for every system, an operational handbook, information on radioactive waste management during the decommissioning operations, a preliminary version of the Safety Analysis Report for the preparation of the safe enclosure, preliminary versions of the Environmental Impact Assessment (EIA), the Radiation Protection Concept (RPC) and the Quality Assurance (QA) Plan for decommissioning.

The decommissioning schedule was revised in 2005 to reflect the delay in the implementation of the project for the construction of dry spent fuel store on the Kozloduy site, which is deemed crucial for the start of preparations for the safe enclosure. The new schedule envisages an extension of the post-operational period until 2012 [7].

4. ONGOING AND PLANNED ACTIVITIES

4.1. Revision of the Kozloduy decommissioning strategy

Reference [6] is still the relevant decommissioning guide; however, the changes in circumstances and in the legislative environment have made it necessary to revise the decommissioning strategy. The revised strategy provides a tool for making decisions on further decommissioning activities of the plant and on recommendations for different options, where applicable. The development of a revised strategic document was contracted to a consortium of European (BNFL, EDF) and Bulgarian companies (ENPRO) and the document was submitted to the KNPP management in October 2005 [8]. The Kozloduy management has not yet approved the new strategy document; however, its major features are presented below.

The new strategy [8] identified the following problems associated with the current decommissioning approach [6, 7]:

— It would have a heavy impact on the local community in terms of very low employment during the 35 years of safe enclosure;
— The operational nuclear power plant knowledge necessary for decommissioning would be lost;
— The radioactive waste treatment infrastructure would be idle for the time before the start of deferred dismantling of units 1 to 4.

A new ’continuous dismantling’ approach was proposed for Kozloduy units 1–4, which provides for smooth, even and continuous usage of human and financial resources as well as of the waste treatment facilities. The key features of the new strategy are as follows:

— Dismantling activities commence much earlier (turbine hall — 2011, auxiliary buildings — 2015, etc.);
— The duration of the safe enclosure is flexible and much shorter than 35 years;
— The safe enclosure zone is reduced, e.g. the auxiliary buildings are excluded.

4.2. Regulatory development

The Bulgarian nuclear regulator is receiving assistance in the area of decommissioning from leading Western European regulators and their technical support organizations — as part of the European Commission PHARE programme. Two such projects have been implemented so far, leading to the development of the current decommissioning regulations and the enhancement of nuclear regulatory authority expertise in decommissioning and related topics [9, 10]. The technical design for the decommissioning of Kozloduy units 1 and 2 has also been reviewed within the above-mentioned projects and the results of the review have been communicated to the utility.

Regulatory plans in the decommissioning area mostly concern the development of regulatory guidance on applying decommissioning regulations, which will be done within a new PHARE project. The regulatory guidance planned to be developed by mid-2007, consists of ten documents, the most relevant being:

— The format and content of the decommissioning plan;
— The format and content of the staged decommissioning project;
— The format and content of the safety analysis report for the decommissioning of the nuclear reactors;
— Radiation protection during decommissioning.

5. CONCLUSIONS

When the decision on the early shutdown of the Kozloduy WWER-440 reactors was taken in the mid-1990s, neither the Bulgarian legislative system nor the concerned organizations were prepared for facing the challenges associated with the decommissioning of the units. The first studies on decommissioning [3, 4] were undertaken jointly by the regulator and the operator in the late 1990s. By the early years of this century, these initiatives had led to the development of up to date regulations [1, 2] on one side and technical designs for decommissioning on the other [5–7].

More recently, changing political, social and regulatory environments and the evolving views of both the regulator and the operator have led to the revision and development of the earlier approaches. Thus, the strategy for ‘deferred dismantling’ adopted in the 1990s of the last century has been changed to a ’continuous dismantling’ strategy. In the regulatory field, a number of related regulatory guidance documents have been developed.

Most of the activities related to the decommissioning of the Kozloduy nuclear power plant have been undertaken with the support of the European Commission and with the participation of companies and organizations from EU countries. A number of new regulatory and industrial activities, requiring continuous support from EU countries and institutions, have been planned and are now ongoing. The successful implementation of the decommissioning requires a good coordination between all parties and an adequate and timely reaction to changing circumstances. In this process nuclear regulator has an important role which Bulgarian NRA is ready to take.

REFERENCES

[1] Act on the Safe Use of Nuclear Energy, Promulgated in the State

[2] Regulation for Safe Decommissioning of Nuclear Facilities, Promulgated in the State Gazette No. 73 dated August 20, 2004 (Suspending Regulation No. 10 of 2001).

[3] Decommissioning and radioactive waste disposal - Feasibility study for Kozloduy NPP Units 1-4, Stone & Webster Engineering Corporation, ENERGOPROEKT Plc and DECOM (1994).

[4] Decommissioning Units 1 and 2 at Kozloduy NPP — Feasibility study, DECOM (1995).

[5] Technical design for the decommissioning of Kozloduy units 1 and 2; PHARE contract BG 9608-01-01-L001 (March 2000).

[6] Technical design for decommissioning of Kozloduy NPP Units 1 and 2; PHARE contract BG 9809-02-03 (September 2001).

[7] Updated Technical Design for Decommissioning of Kozloduy Units 1 and 2; Update of PHARE Project BG 9809-02-03 - Detailed Cost Assessment, Enpro Consult; February 2005 (in Bulgarian).

[8] Decommissioning Strategy for Kozloduy NPP Units 1-4, KPMU/DCS/001, Revision C (October 2005).

[9] Assistance to BNSA in the Development of Requirements and Procedures for Decommissioning of Kozloduy NPP Units 1 and 2, PHARE contract BG/TSO/VVER/04 (March 2001).
[10] INSTI building of the Nuclear Regulatory Agency (NRA) — Support on Licensing activity related to the decommissioning of the Kozloduy NPP units 1 and 2, PHARE contract BG 0009.02 (October 2003).

DISCUSSION

G. LINSLEY (IAEA): What were the reasons for the change from a policy in favour of deferred dismantling to one in favour of early dismantling?

S. TZOTCHEV (Bulgaria): We felt that a delay of 35 years would be too long — during that period a great deal of knowledge would be lost owing to, for example, the retirement of personnel.

Also, there was the question of the unemployment that would result from such a delay.

In addition, we would like to make maximum use of the infrastructure that still exists for dealing with radioactive waste.

REGULATION OF DECOMMISSIONING ACTIVITIES

C.O. PHILLIPS
National Nuclear Regulator,
Pretoria,
South Africa
Email: OPhillips@nnr.co.za

Presented by A. Joubert

Abstract

The role of the regulatory body in respect of the protection of the worker, property, and the environment is of central importance. The regulator may, however, be faced with key challenges in ensuring compliance of that decommissioning activities are in compliance with regulations. On the basis of lessons learned from past experiences, the paper provides some insights into areas that a regulatory body needs to pay attention to in the area of decommissioning. They include the resources required by the regulatory body, the safety aspects of decommissioning, and issues related to the review of safety submissions. It is noteworthy that a decommissioning involves the regulatory body in most of its core functions.

1. INTRODUCTION

The decommissioning of facilities is taking place in a regulatory environment that has become more demanding, complex and less forgiving. Our industry is currently going through interesting times. The increasing demands for a viable and environmentally acceptable energy source are challenging our past and present paradigms. The sustainability of planned activities may no longer simply be an option but could soon become an imperative for the nuclear industry. In the middle of competing national priorities the activities of the nuclear industry must still be sensible as well as responsible. This is the background against which activities such as decommissioning are taking place. Regulatory requirements are constantly being made more rigorous, prompted by a growing awareness and scrutiny by the public of developments involving nuclear technology.

2. RESOURCE MANAGEMENT ISSUES

The resources which a regulatory body needs to allocate to control the decommissioning process can be directly linked to its main regulatory functions. It is important for the purposes of resource allocation planning to know: the technologies, the types of facilities, and the physical processes that are intended for decommissioning. For example, the approach taken in decommissioning a uranium processing plant would be expected to be different from that taken for decommissioning a research reactor. The scale of the activities to be undertaken by the operator must also be fully understood. This type of information is an important input for determining the resources that the regulator may need to commit.

The nature of the decommissioning activities and the adequacy with which they are carried out will influence the strategy adopted by the regulatory body. From a planning point of view, the regulatory body will be expected to carry out activities related to its core functions, such as review and assessment, provision of regulatory guidance, public consultation, and approval of the design and safety assessments.

Depending on the technology involved it may be necessary to seek assistance from a technical support organization. For facilities that have remained in safe store for years there may no longer be technical staff at the organization familiar with the processes. Having said this, it is essential that the regulatory body should make use of its in-house technical expertise to control the activities associated with decommissioning. In instances where analytical work is required, the regulator should verify radiological data in its own laboratory. In order to perform confirmatory surveys, the regulator needs to be equipped with the appropriate instrumentation.

Certain activities mentioned here would need to be undertaken prior to the regulatory body granting an authorization for the decommissioning activities. An appropriate level of resources must be applied for the authorization and for the termination of this activity to ensure that regulatory requirements will be complied with. So without being too prescriptive, but taking into account that core regulatory functions need to be performed, consideration of these variables will form part of the assessment required to determine the resource needs of the regulatory body.

3. SAFETY ASPECTS

The regulatory approach to safety is crucial in order to ensure that decommissioning activities are conducted with efficiency and effectiveness. A comprehensive decommissioning plan approved by the regulatory body plays a central role in the overall scheme of ensuring compliance with regulatory requirements. From a regulatory point of view, a phased approach should be adopted for larger decommissioning projects. The phased approach used in South Africa for larger projects has ensured that decommissioning work has been conducted in a structured manner. It is important also to ensure that the operator has planned the activities carefully and can demonstrate that he/she can cope with unintended consequences, if they occur.

The radiation doses that are predicted in the assessment phase of a decommissioning project are based on certain assumptions, which may differ from those that occur during the execution of the project. It is very instructive, therefore, to record and analyse the reasons for these differences.

The criteria for releasing material from regulatory control should be clearly defined. The disposal routes for radioactive waste that arises from decommissioning activities should be identified and be part of a predetermined plan. The disposal strategy should comply with accepted radioactive waste management practices. Government policies for radioactive waste management must be in place and the industry needs to make efforts to implement such policy taking socioeconomic factors into account.

In regard to safety it is necessary that the regulatory body takes a holistic approach that incorporates the determination of best practice, compliance with the letter of the law, while ensuring the protection of property, the worker, and the environment is accomplished.

Prior to the decommissioning plan on a regular basis prior to its implementation, the decommissioning organization should be required to update the plan and to ensure that it captures all events leading to exposures of the type that have arisen during the history of operation of the facilities. Record keeping and configuration control of the organization's management system play an important role in this regard.

The safety requirements for the different decommissioning options need also to be commensurate with the associated radiation hazards. The factors that need to be considered are:

- Cost–benefit and safety considerations;
- The reuse of cleared facilities;
- The opportunity costs and allocation of financial resources;
- Decisions and strategies for effective radioactive waste management;
- The scenarios and criteria associated with clearance, reuse and recycling of materials;
- The impact of deferring decommissioning;
- Use of the appropriate technology and expertise.

4. REGULATORY CONSTRAINTS

In recent times it has become clear that legislative and regulatory requirements have been strengthened everywhere. It is not specific to decommissioning but is general (e.g. ISO 14001) to all types of regulated activity. In South Africa, it is now the case that a larger number of governmental departments than previously have responsibilities related to the achievement of 'green field' sites and this means that the regulatory body must collaborate with these departments in relation to planned decommissioning activities. This can be time consuming for the regulator. All of this indicates the need to have an up-to-date regulatory infrastructure for decommissioning activities involving radiological, non-radiological, nuclear, and conventional safety aspects.

5. ISSUES WHEN REVIEWING DECOMMISSIONING ACTIVITIES

The issues that have arisen in relation to decommissioning activities in South Africa have been mainly concerned with compliance aspects. They have included: the radiological safety methods for demonstrating compliance; the effectiveness of control measures; the need for regular monitoring of radiation doses; the use of appropriate technology that will limit potential exposures, the segregation of large volumes of waste; and some issues of reuse.

From the experience to date the regulatory body must give priority to safety when economic arguments are raised against particular courses of action. This will always be an issue that will arise and one which the regulatory body will have to deal with.

6. CONCLUDING REMARKS

A decommissioning project requires concerted efforts to ensure safety throughout its duration and it can, therefore, can, depending of the decommissioning strategy, to put resource constraints on a regulatory body.

Some important considerations that should be taken into account are:

— Stakeholders, including governmental departments, should be involved at an early stage before the physical activities commence;
— The resources deployed by the regulator should be commensurate with the nature of the decommissioning activity to be undertaken;

— It is important to ensure that the decommissioning strategy is appropriate, that is, it should take into account, inter alia, the available technology, the radioactive waste practices, and the financial constraints;
— The regulator should verify the radiation doses that are projected for the planned decommissioning activities, since predicted doses for certain activities may be on the conservative side;
— There should be a plan to segregate the radioactive waste generated during decommissioning; the absence of such a plan this could lead to the inadvertent release of contaminated material;
— The regulator must recognize the need to take account of the regulatory requirements of different governmental bodies.

DISCUSSION

G. YADIGIAROGLOU (Greece — Chairperson): Does the design of the Pebble Bed Modular Reactor being developed in South Africa take account of decommissioning requirements?

JOUBERT (South Africa): Yes, it does.

FRENCH APPROACH TO REGULATORY REVIEW: LESSONS LEARNED FROM THE EXPERIENCE OF THE LAST 20 YEARS

D. CONTE, O. LAREYNIE, C. MESSIER
Autorité de sûreté nucléaire,
Paris,
France
Email: Dorothee.Conte@asn.minefi.gouv.fr

Abstract

Decommissioning activities have been performed in France since the early 1980s, even though no major decommissioning projects were actually undertaken until after 1990. In the first part of the paper, the regulatory aspects of current decommissioning projects, such as the first-generation nuclear power reactors and research and fuel cycle facilities, are described. The evolution of the regulatory framework since the beginning of the 1980's is also described; this occurred concurrently with the development of the operator's strategies, for example, EDF's strategy change from a care-and-maintenance period of 50 years to immediate decommissioning. The new regulatory framework, introduced in 2003, which allows only one decommissioning licence for the whole project, instead of the previous 2 or 3 licences is described. This system is based on an internal authorization and aims to give the licensee more flexibility and to allow the regulator to concentrate on the most important safety related issues. The licensee is hence enabled, under certain conditions, to authorize internally minor operations within the overall safety demonstration of the facility: The inventories of radioactive and toxic substances, and related hazards must not be substantially increased, design accidents must still be taken account of and the overall defense-in-depth concept should not be jeopardized. The paper gives the first feedback and lessons learned from this new regulatory approach, which emphasizes that the main challenge of decommissioning is not only technical but also organizational. The second part of the paper addresses the topic of safe termination of practices in France. A short introduction to the French approach for radioactive waste management is also presented. The paper explains the principles of the regulatory framework issued in 2006 regarding the complete clean up of facility structures, based on the defence-in-depth concept: understanding of the physical phenomenon (i.e. activation or contamination), modelling of this phenomenon, after-operations radiological controls. The first French examples of declassified facilities and future perspectives are described.

1. INTRODUCTION

In its work on decommissioning, the Autorité de sûreté nucléaire (ASN; Nuclear Safety Authority), to the extent possible, takes account of relevant experience feedback from past decommissioning projects in France and abroad. The ASN encourages complete decommissioning either immediately or after a slight postponement, provided that the operator is able to present and justify the chosen decommissioning scenario before the start of the regulatory process, from the final cessation of production up to the final decommissioning of the installation (end-state). Regulatory practices for nuclear installation decommissioning operations have been continuously updated along these lines, first, in 2003 (unique decommissioning licence) and, most recently, in 2006 (safe termination of practices).

The ASN considers the current decommissioning operations as test cases, providing the opportunity for the operators, on the one hand, to define and implement a decommissioning strategy and, on the other hand, to specify a management policy for the large amount of radioactive waste that will be generated. If carried through to their conclusions, the test cases constitute examples in which the technical and financial feasibility of an entire decommissioning operation is demonstrated.

2. OVERVIEW OF DECOMMISSIONING IN FRANCE

2.1. French regulatory approach and history

2.1.1. Prior to 2003

The general regulatory framework was modified at the end of the 1980s to cope with the need to regulate the decommissioning of the first shutdown power reactors. This general regulatory framework regarding nuclear facilities is contained in the amended decree of 11 December 1963. Before 1990, this decree did not include any provisions for the decommissioning of nuclear facilities. Some small research facilities, located on complex nuclear sites, were decommissioned but this was done by means of a case-by-case licensing process. It has to be noted that, at the end of the 1980s, the general power reactor licensee's strategy was one of deferred decommissioning. This strategy consisted of extracting the fissile material, removing the easily recoverable parts, reducing the contained zone to a minimum and establishing an external barrier. At this time, it was envisaged by EDF (the nuclear power plant operator in France) that complete decommissioning/dismantling of the installation would occur after several decades of containment, in particular, to take advantage of the natural radioactive decay of ^{60}Co in the reactors cores. At that time, the regulatory approach was to license decommissioning as successive modifications of the facility (step-by-step approach); each of these modifications was to be licensed on the basis of a safety report corresponding to the future decommissioning phase. The framework referred to the decommissioning levels defined at this time by the IAEA [1] and required at least a licence to move from phase 2 to phase 3. An approach of this type had its drawbacks, notably in that it could lead to a gradual loss of knowledge of the facility, as its operators departed, which could be prejudicial to the decommissioning operations. The financial cost of the care-and-maintenance period is very high, and the advantage of the natural radioactive decay of ^{60}Co is less important after the first decade (exponential decrease).

After the first applications of this framework in the 1990s, the approach appeared also to have the following regulatory drawbacks:

— Decommissioning of a power reactor would often need to have at least two or three successive licences, whereas only one is needed for the creation of a new facility; this seemed to be out of proportion to the safety hazard presented by a facility under decommissioning.
— The regulatory framework was written for power reactors and was not easily applicable to other types of facilities, in particular smaller facilities — such as prototype or research facilities — where the complicated licensing requirements are clearly not proportionate to the hazard levels.
— The framework did not require the licensee, nor allow the regulator, to have an overview of the overall decommissioning project, that could allow to examine the global optimization of the project.

From the safety point of view, the ASN concluded that there was a need to promote immediate decommissioning approaches, mainly because of potential knowledge loss and ageing management issues at the facilities. The regulatory framework was not compatible, as it did not favour such immediate decommissioning approaches, because of the regulatory burden it involved. Also, it did not contain any provision for the licence termination process, as this problem was assumed not to require consideration before some time, many years into the future. As a result, the ASN asked EDF to review the strategy and to evaluate the feasibility of reducing the time needed to undertake complete decommissioning.

At the beginning of the 2000s, some decommissioning projects had been licensed and had begun. The first licences for power reactor decommissioning contained a licence condition that required EDF to periodically evaluate its decommissioning strategy from the point of view of safety. The studies undertaken in response to the ASN request persuaded EDF to review its strategy and to adopt an accelerated decommissioning strategy for its first generation reactors.

In another area of the nuclear industry in France, the financial difficulties that the Atomic Energy Commission (CEA) had experienced in relation to decommissioning were overcome through the establishment of a dedicated decommissioning fund. Many decommissioning programmes that had been postponed were restarted and this required an appropriate licensing process.

All the preceding considerations led to the need for an in-depth revision of the regulatory framework for decommissioning.

2.1.2. Since 2003

In 2003, the ASN established a licensing framework for decommissioning that responded specifically to the following considerations [2]:

— To provide an overview of the whole decommissioning project, including an intended end-state;
— To issue only one licence for the whole decommissioning project;
— The regulatory activities should be proportionate to the actual hazard presented by the facility (a graded approach);
— To include a regulatory framework for the licence termination process.

All of these new provisions are presented in more detail in Ref. [1]. The advantages of requiring, at the outset, an overview of the decommissioning project are considered to be greater than the associated drawbacks. One important drawback is that the final decommissioning phases cannot be described in any detail at the beginning of the project. However, taking into account the intended end-state from the beginning of the decommissioning project can facilitate its overall optimization, possibly influencing even the very first decommissioning operations.

The licensing process requires that the licensee produces a report on the decommissioning strategy, including a safety assessment of each successive decommissioning phase or main operation. The first phases or operations must be described and assessed in detail, while later phases or operations are to be described and assessed at a lower level of detail, involving only the main safety aspects. The specfic licence for the decommissioning project, based on an in-depth assessment, will identify, if needed, particular future phases or operations that will necessitate regulatory authorizations if it is considered that they are of particular importance from a safety point of view.

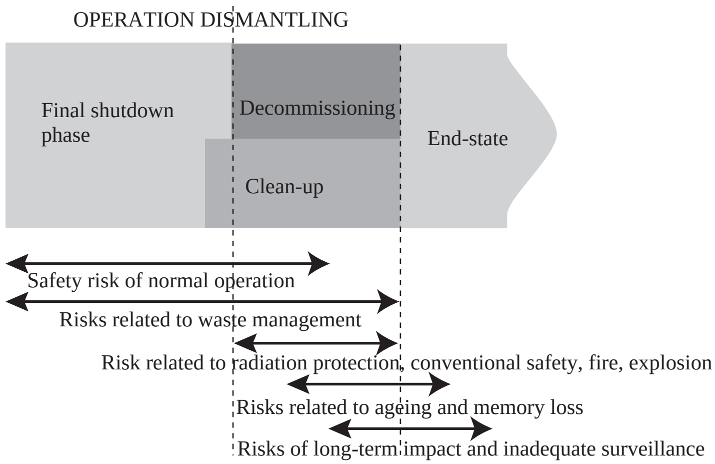

FIG. 1. The new regulatory framework.

Figure 1 is an illustration of the new regulatory framework. It shows the two phases of the life of a facility and indicates the related risks. Each phase is authorized by one decree.

While strengthening the initial licensing process, it was, at the same time, considered necessary to allow the licensee more flexibility in deciding on the details of decommissioning operations. This is consistent with the wish to adapt the regulatory burden to the hazard, but it also reflects the experience that decommissioning always involves unexpected findings that need sufficient flexibility for their management. This is why an 'internal authorization system' has been fostered (see Section 2.3).

2.2. Facilities currently being decommissioned

2.2.1. First generation power reactors

After an initial evaluation in 1999, EDF decided to revise its strategy for the decommissioning of the EL4 reactor, a heavy water moderated 70 MW(e) prototype with carbon dioxide cooling. EDF undertook to carry out complete decommissioning of the reactor after completion of the partial decommissioning operations currently in progress. The authorization for its complete decommissioning was issued by ASN in 2006.

The six gas cooled reactors (GCRs), which were the first generation EDF nuclear power reactors, are currently at various stages of decommissioning. In accordance with the Government decision of February 1998, the fast reactor 'Superphénix', a sodium cooled industrial 1200 MW(e) prototype, is also currently being decommissioned. The authorization for the complete decommissioning of these reactors was issued in 2006. The Ardennes nuclear power plant, Chooz A, was the first French PWR 350 MW(e) plant. EDF is currently carying out operations to prepare for complete decommissioning. EDF's decision to adopt an immediate decommissioning strategy for all its closed nuclear power plants, based on complete decommissioning of the reactors with no care-and-maintenance period, should permit the decommissioning of these nine reactors to be completed by 2025.

In January 2003, EDF presented an overview of the decommissioning programme for the nine reactors to ASN; it included technical justifications which addressed the facility safety cases, radiation protection, waste management (particularly for the graphite), organizational aspects, consideration of workforce skill maintenance, and descriptions of the target end-state. After obtaining the opinion of the Advisory Committee for Laboratories and Plants, which met to discuss this subject in March 2004, the ASN adopted a position in June 2004 about the pertinence of the EDF first-generation reactor dismantling strategy proposed. ASN decided in June 2004 that EDF's strategy and schedule for these reactors was acceptable in terms of safety and radiation protection.

2.2.2. Research facilities at CEA

A wide range of CEA research facilities are currently being decommissioned or are in a final shutdown phase in France; they include: Research reactors (6); a fast breeder reactor prototype; a particle accelerator; various research facilities and laboratories (11). Two research oriented sites are in the process of being completely denuclearized because of the growing urbanization of the surrounding areas. Subsequently, they will be reoriented to non-nuclear activities. There will be a complete assessment of the CEA strategy for the decommissioning of its facilities at the end of 2006 and the Advisory Committee for Laboratories and Plants will be consulted as it was in relation to the EDF decommissioning strategy.

2.2.3. Fuel cycle facilities

Some fuel cycle facilities are currently being decommissioned, or are in a final shutdown phase (two fuel fabrication plants and one fuel reprocessing plant).

2.3. The internal authorization system

The new regulatory framework for decommissioning reaffirms the need for there to be up-to-date and applicable safety documentation at every facility. This is a particular challenge during decommissioning because of the highly changing nature of facilities during the decommissioning process and because some future situations may be difficult to describe in detail because of inherent uncertainties.

To provide this needed flexibility, it has been decided to allow the licensee to authorize internally small modifications provided that they remain within the overall safety case for the facility. The safety authority has provided a clear list of conditions that the operator must respect in order to demonstrate that the intended operations are within the overall safety case.

First feedback of the new The safety authority requires that the internal authorization system implemented by the licensee is auditable (by means of on-site inspections), and that it provides sufficient transparency that the state of the facility and the operations being carried out can be determined at any time.

To achieve this goal, the licensee is asked to establish, within its own organization, a committee of safety experts that includes experts from other national or international licensees, or technical experts from universities or non-nuclear organizations. Particular care must be taken to ensure that the members of the committee charged with the examination of a safety case are different from the persons who prepared the safety case; this is particularly important in the case of small licensee organizations. In the case of the decommissioning of power reactors, this has led to only one national committee of safety experts being established by EDF. The same type of national committee has been established by the CEA. This approach has been followed so that a consistent approach is adopted at all power reactor sites where decommissioning is taking place.

For each document that is examined by the expert committee, a critical report must be prepared and presented to the committee by independent assessors. The critical report and the committee discussions and conclusions must be appropriately documented so as to allow inspection of the overall system by the regulatory authority. The final decision is taken by the representative of the licensee who is legally responsible for safety. To allow the regulatory authority to obtain a good overview of future plans, the licensee is required to make available, and keep updated, a programme of the planned operations and modifications foreseen in the next year.

After each internally authorized operation or modification has been implemented, a feedback document must be prepared by the licensee and sent to the regulatory authority. This allows the regulatory authority to increase its knowledge of the possible problems that might be encountered for sharing with other licensees, if appropriate. This feedback document is expected also to include information such as dosimetry, waste generation and management routes, etc.

In addition, the safety authority is performing inspections of the whole internal authorization system to check whether independent assessments and serious critical reviews are actually being implemented by the licensees. Inspections are also performed, as usual, within the facilities.

2.4. Framework

Numerous decommissioning licence applications are currently being assessed for nuclear power plants and research facilities. The licence termination process has been successfully applied to some small facilities (accelerators, fuel manufacturing plants, etc). The first feedback from the internal authorization system is very encouraging. The safety cases that are internally authorized are often of a very good quality and independent assessors and committees take their roles very seriously because of the responsibilities involved. This has also allowed a much wished for 'safety empowering' of the licensees. While licensees are legally responsible for safety, in the past, they tended to rely too much on the assessments of the regulatory authority. The new system also allows the regulatory authority to focus its attention and resources on a number of issues that are judged to have major importance for safety. Internal authorization systems become a necessity when there are numerous and simultaneous decommissioning projects in the country.

However, some difficulties have been experienced with the implementation (and the application) of the new regulatory system:

— It is sometimes difficult for the operator to have an overview of the overall decommissioning project, especially for large facilities;
— The safety documentation must reflect the actual state of the facilities, which is not easy to ensure, because of the rapid pace of changes within facilities under decommissioning;
— Immediate decommissioning requires routes for the management of all types of radioactive waste.

3. SAFE TERMINATION OF PRACTICES

3.1. The French approach for radioactive waste management

It should be first recalled that in France there is no universal clearance threshold below which a radioactive waste can be considered as no longer constituting a radiological hazard.

The radioactive waste management is based on a zoning system at each nuclear facility. Waste zoning, which is separate from radiation protection zoning, but consistent with it, is done for the purpose of discriminating the zones of a nuclear site where the waste is radioactive or likely to be radioactive.

Waste zoning consists of dividing the buildings and rooms of a facility into two types of zones:

— The ‘nuclear waste zones’ within which the waste produced may be contaminated or activated. Waste from these zones is called ‘nuclear waste’, divided into high level (HLW), medium level (MLW), low level (LLW) and very low level (VLLW) waste.
— The ‘conventional waste zones’ within which the waste produced cannot be contaminated or activated. Waste from these zones is called ‘conventional waste’.

Any premises or parts of premises in which there are physical boundaries or barriers that can be considered to prevent any transfer of contamination between the exterior and the interior of the zone thus defined can be considered as a zone. These provisions are detailed in note SD3-D-01 [3]. In buildings or ‘zones’ where the activation or migration of contamination is suspected, the building structures — concrete walls or metallic structures — are themselves considered to be ‘nuclear waste zones’. The clean-up of these building structures is now covered by a specific regulation.

3.2. Regulatory framework for the complete clean-up of facilities

As already stated, the complete clean-up of facilities being decommissioned is the regulator’s favoured option. The safety authority issued a regulatory document at the beginning of 2006 stating its requirements for the clean-up of building structures (e.g. concrete walls) which may contain artificial radioactivity, mainly due to activation or contamination migration phenomena.

When an operator wishes to remove all the active parts of a building structure in order to declassify a ‘radioactive waste zone’ in a ‘conventional

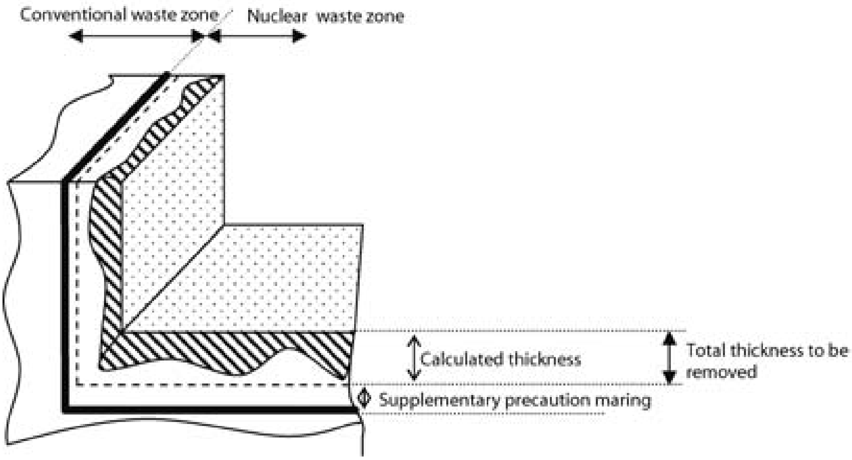

FIG. 2. Strategy for the clean-up of surfaces.

waste zone', he/she must develop a methodology based on the defence in-depth concept.

Three independent and successive defence lines must be implemented:

— Based on a knowledge of the facility (its history, past incidents,) and a knowledge and quantification of the physical phenomena (activation or contamination migration), the operator must define a clean-up depth (within the structure), which will be applied during clean-up operations. Uncertainties must be taken into account by adding a precautionary margin to the clean-up depth (Fig. 2).
— The remaining structure must be checked to determine if it meets the clean-up objectives.
— All waste that is removed from the site must be checked.

As there are no universal clearance levels in France, the clean-up objectives set by the operator may be justified on the basis of residual impact assessment. The clean-up methodology must be presented to the ASN three months before the beginning of the clean-up operation. This methodology should include all relevant information concerning structural stability, the protective measures to avoid the spreading of contamination, the waste management, and the monitoring measures. All of these new provisions are detailed in Ref. [4].

On the basis of a results report, which includes the amount of waste generated, a map of the residual radiological situation, and all relevant information to prove that the clean-up objectives have been met, the ‘nuclear waste zone’ can be declassified to ‘conventional waste zone’. This declassification must be approved by the ASN. When all the ‘nuclear waste zones’ of a facility have been declassified to ‘conventional waste zones’, the facility itself can be declassified (that is, it no longer has the administrative status of ‘basic nuclear installation’). If the remaining building structures are subsequently to be dismantled, the generated waste will be considered as conventional waste. It has to be noted that the ‘green-field’ condition is not required as an end-state by the ASN.

3.2.1. Examples of declassified facilities or buildings

Even though 18 facilities have been declassified since the beginning of the 1980s, only two of them have been declassified under the new regulatory framework. In 2005, a CEA circular particle accelerator was declassified, after 4 years of decommissioning operations. The declassification decision was taken by the ASN — on behalf of the ministries of industry and environment — on the basis of:

— A detailed report of the whole decommissioning project;
— A demonstration that the intended end-state had been reached;
— A residual impact assessment.

The ASN policy regarding declassification of nuclear facilities is to ensure that information about the past use of the site is transmitted to all future landowners. This information is registered in the fiscal land files. If needed, other restrictions may be registered, depending on the end-state of the facility after decommissioning.

Within the framework of the decommissioning of the EL4 reactor, EDF undertook to clean up some specific buildings. The cleanup of building structures of the basement of the STE building was performed according to the methodology described previously. The analysis of the history of the STE building indicated that a past incident involving liquid contamination had occurred. The initial assessment concluded that the incident had only caused the surface contamination of the structures. However, after the first cleanup operations, it was shown that the liquid contamination had migrated into the structures and required a much more comprehensive cleanup. After having had to provide supports avoid the collapse of the building, EDF finally abandoned the clean-up works and chose to treat the remaining structures as nuclear waste.

4. CONCLUSION

Since the beginning of 2003, the nuclear operators in France have submitted numerous decommissioning plans to ASN in accordance with the guidelines of the new regulatory framework. These decommissioning plans are currently being reviewed by the ASN. They deal mainly with facilities that have been closed for several years, but for which the operators had not started the regulatory authorization procedures. This represents a considerable effort on the part of the operators to declassify these closed installations as rapidly as possible.

The coming years will therefore be devoted to intense regulatory and supervisory activity on nuclear installation decommissioning.

The prospect of partial privatization of some of the larger operators (EDF and AREVA) requires a system to be implemented which guarantees that sufficient financial funds will be available to finance the decommissioning of the facilities and provide for waste management. ASN will exercise particular vigilance on this point.

During 2005, extensive work has been conducted on waste management and decommissioning financing both in France and in the European Union. In relation to funding the ASN emphasises the following points:

— The financial resources must be sufficient. The amount of money collected in funds must be available when needed; this implies that the future expenses must be assessed as accurately as possible. The funds must be protected against any other uses.
— The system must be formalized: for this purpose, a legal and regulatory framework to cover the different aspects of the problem must be established.
— The process for the control of the funds must be established and implemented.
— A transparent process for complete and clear communication with the public must be established.

These different points have been introduced into the transparency and nuclear safety law project, currently under discussion by the French Parliament.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Regulatory Process for the Decommissioning of Nuclear Facilities, Safety Series No. 105, IAEA, Vienna (1990).

[2] AUTORITÉ DE SÛRETÉ NUCLÉAIRE, Statutory procedures for the decommissioning of basic nuclear installations, Note SD3-DEM-01 (17 February 2003), http://www.asn.gouv.fr.

[3] AUTORITÉ DE SÛRETÉ NUCLÉAIRE, Nuclear waste study preparation guide (4 September 2001), Note SD3-D-01, http://www.asn.gouv.fr.

[4] AUTORITE DE SURETE NUCLEAIRE, Méthodologies d'assainissement complet acceptables (27 March 2006), Note SD3-DEM-02, http://www.asn.gouv.fr.

DISCUSSION

G. YADIGIAROGLOU (Greece — Chairperson): I assume that in France, with its ambitious nuclear power programme, there are no problems regarding what to do with the operating personnel of plants which have been shut down and are soon to be decommissioned. Are such people transferred to still operating plants or offered jobs connected with the decommissioning?

D. CONTE (France): In France, although nuclear power plant decommissioning is a fairly new field of activity, there are already many people working in that field. As there is a future for nuclear power in France, the operating personnel of plants that have been shut down do not have employment problems.

R. COATES (IAEA): In France, is immediate decommissioning a regulatory requirement or a preferred option?

D. CONTE (France): For the nuclear safety authority it is a preferred option, and we hope that decommissioning operations due to be carried out soon will demonstrate that safe immediate decommissioning is feasible. However, we are adopting a case-by-case approach — if it appears that difficulties are likely to arise, we shall consider whether there is a need to adapt to the particular situation.

N. ARKHANGELSKY (Russian Federation): What was the reason for the decision to 'denuclearize' the Fontenay-aux-Roses and Grenoble sites?

D. CONTE (France): The Fontenay-aux-Roses site is close to Paris and the Grenoble site is almost within the city of Grenoble, so it was decided that new facilities would not be built at those sites but at Cadarache and Marcoule, both of which are far from large population centres.

MANAGING REGULATORY COMPLIANCE FROM OPERATIONS TO DECOMMISSIONING: A CONTRACTOR'S PERSPECTIVE

K.G. SPOONER
British Nuclear Group Ltd,
Warrington,
United Kingdom
Email: keith.g.spooner@britishnucleargroup.com

Abstract

The approaches to the management of the operational phase and the decommissioning phase of nuclear power plants are fundamentally different. The management of operating reactor plant is focused on managing the steady state situation with emphasis on the containment of the nuclear matter in the core, while decommissioning is focused on managing an ever-changing situation comprising a number of projects with the safety emphasis moving from nuclear safety to conventional safety for which the continued use of operational arrangements is regarded as unsuitable. Moreover, these arrangements are not tailored to the new build and commissioning activities required for some decommissioning and waste management activities. Recent changes in the ownership of the nuclear sites in the United Kingdom and the introduction of competition are prompting contractors to look for more innovative ways of decommissioning with the aim of accelerating programmes. Any benefits will be limited if the arrangements under which the projects are managed are not similarly challenged. This paper summarises the approach being taken by British Nuclear Group to improve its arrangements for achieving regulatory compliance in the context of decommissioning programmes. British Nuclear Group is a specialist site management and nuclear clean-up business focused on the delivery of accelerated nuclear clean-up programmes, safely and cost-effectively for its customers in the UK and overseas. British Nuclear Group, (Reactor Sites) is the managing contractor for the Magnox reactor sites, five of which are being decommissioned, and one of which is shut down and being defuelled.

1. BACKGROUND

The regulatory regime in the United Kingdom is essentially based on 'goal setting' with the aim of prompting licensees to make and implement adequate arrangements for compliance. This means that the arrangements are not prescribed and, instead, it is for the licensee to determine how best to meet the requirements [1]. Typically, a licensee develops a compliance matrix, setting out the compliance requirements and the means by which these requirements will be met, identifying those persons responsible for ensuring compliance and referencing the principle implementation documents. In this way, the matrix provides a ‘road map’ for licensee and regulator to manage and inspect compliance, respectively.

Throughout the life cycle of nuclear power plants, the licence requirements remain the same. During operation of the plant, the compliance arrangements remain essentially unchanged, but there is a process of continuous improvement, which usually leads, over time, to improved arrangements. The improvements are generally made as a result of lessons learned from events which have occurred during the life of the nuclear plant. Operational staff follows standard procedures and practices, which are subject to periodic review and are revised only as necessary. The organizational structure may change from time to time and overall staff numbers may vary, but the organizational culture is, broadly speaking, one of familiarity with the ways of doing things as they have always been done. Overall, the operational phase is about the management of a steady state, not about the management of change.

In contrast, decommissioning is about the management of change. The decommissioning of facilities is achieved by means of a set of projects, each a part of an integrated programme. The objective of the programme is to progressively reduce the hazard associated with the facilities and to leave the site either in a benign and quiescent state under a long-term monitoring and surveillance regime or cleared for possible reuse. Decisions are taken as to whether to carry out work ‘in house’ or to put the work out to contractors. In the case of the latter decision, this generally leads to an influx of contractors. There is less need for specialist nuclear skills in the decommissioning phase and, instead, industrial skills are required for removing redundant equipment, machines, etc., from buildings or sites and for demolition activities.

In April 2005, the Nuclear Decommissioning Authority (NDA) was established to take strategic responsibility for the United Kingdom’s nuclear legacy. Ownership of the sites was transferred to the NDA and incumbent owner-operators became contractors overnight. The change also introduced competition into the decommissioning area and is prompting contractors to look for more innovative ways of proceeding and delivering their contractual obligations with the aim of accelerating decommissioning programmes (within given funding constraints). Any benefits will be limited if the arrangements under which the projects are managed are not similarly challenged.

The British Nuclear Group is a specialist site management and nuclear cleanup company which is focused on the delivery of accelerated nuclear cleanup programmes, safely and cost effectively for its customers in the United Kingdom and overseas. British Nuclear Group Management Services, manages operational plants and is carrying out cleanup operations at the Sellafield site in West Cumbria and at various Magnox reactor sites in the United Kingdom.

Management Services, Reactor Sites, which manages the Magnox reactor sites, has responded to the challenge of accelerating programmes not only through innovation but also by enhancing its compliance arrangements to better enable the delivery of these programmes. The changes, which are now being made to the licensee's company arrangements, are focused on the management of changes to plant.

2. PRIORITIZING CHANGE

Managing the transition from operation to decommissioning presents many challenges. The priorities are usually concerned with managing the expectations of the incumbent workforce and with securing the necessary regulatory consents to de-fuel and begin decommissioning. Making discretionary changes to the management arrangements are, by comparison, of a lower order of importance. It could be argued very reasonably that, given the licence conditions remain the same, the arrangements which ensured compliance before cessation of generation are likely to ensure compliance thereafter. However retention of the existing operational arrangements may lead to non-compliance simply because they are overly complex for the purpose of decommissioning and emphasize the wrong type of safety culture. Worse, the arrangements for decommissioning become an obstacle to the delivery of projects because they are not 'fit for purpose'. Some arrangements for controlling operational reactor plant (e.g. operating rules, safety mechanisms) could be totally inappropriate and restrictive in a decommissioning regime. Licensee companies have to address these issues as soon as possible during decommissioning.

3. PROJECT MANAGEMENT APPROACH

Changes to operational plant arrangements are managed through modifications under Licence Condition (LC) 22 (Modifications). This requires classification and the preparation of a safety case. It was under these arrangements that the decommissioning of the Magnox sites was undertaken, i.e. the removal of plant was treated as a modification.

There are two main reasons why this approach is now regarded as unsuitable for decommissioning. Firstly, the same level of rigour used for operational activities at the nuclear reactor was often being applied to decommissioning activities. The high hazard, high risk consequences associated with a hot pressurized reactor at power is very different from the situation during decommissioning activities, where the nuclear hazard and risk consequences are much lower. For decommissioning activities and their lower nuclear hazard and risk consequences, this level of scrutiny should not be necessary. The emphasis should be on the management of other risks. Secondly, the existing arrangements are not tailored to the new build and commissioning activities which are part of some decommissioning and waste management activities. For this type of work, a project management approach rather than a safety case approach is needed. Previously, the work was being driven by the safety case around which the project management arrangements were made rather than the other way around.

The arrangements are also considered to be inappropriate by the Nuclear Installations Inspectorate (NII). Last year, it was agreed with the NII that the work would be better managed under LC 35 (Decommissioning). These arrangements, which had, until then, not been fully developed, now refer to decommissioning plans, regulatory schedules and project management procedures. They do not refer to safety cases. This change of focus from a safety case to a project management approach is acknowledged as requiring a cultural change throughout licensee and regulator organizations.

A project management approach is now being adopted for all decommissioning work. Furthermore, other improvements are being made to simplify the current arrangements. For example, the use of lifetime plans for the purposes of defining the decommissioning programme will remove the need for other types of plan in which the same arrangements for managing projects were used irrespective of the type of decommissioning activity. The safety documentation required is also simplified.

Taken together with the Regulatory Schedule[1], a subset of the life time plan setting out the regulatory deliverables and milestones and providing for a clear understanding of the commitments made by operator and regulator, these changes should greatly improve the delivery of decommissioning programmes.

4. APPLICABILITY AND IMPLEMENTATION

Some illustrations are provided in the following paragraphs to explain how the new arrangements will to be implemented.

---

[1] Effectively a subset of the lifetime plan detailing activities of interest to regulators.

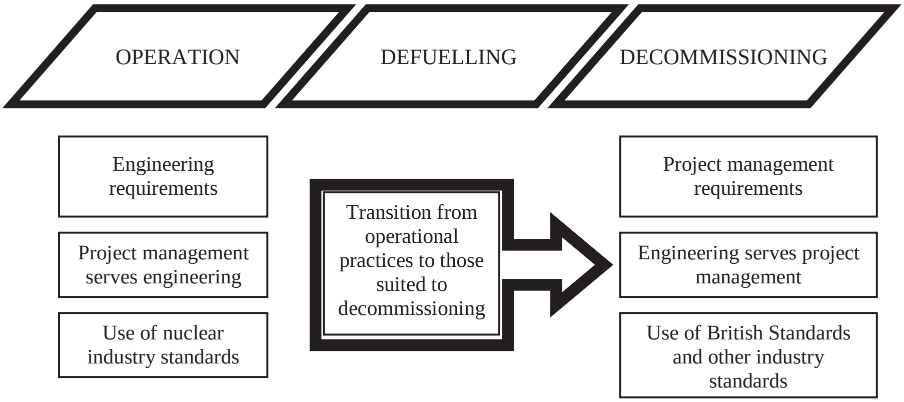

FIG. 1. Changes in the emphasis on engineering during different stages in a site's life cycle.

Figure 1 shows the changes of emphasis in moving from the operational phase to the decommissioning phase (how the emphasis moves from operations, where the nuclear engineering requirements dominate, to decommissioning, where project management requirements become very important). The top of the diagram shows potential overlaps with some work related to defuelling or to decommissioning commencing during an earlier stage. The figure emphasises the increased importance of project management in driving progress in decommissioning and thereby reducing the hazard and risk. It also illustrates changes from the use of nuclear engineering standards to 'fit-for-purpose' standards commonly used by industry as the nuclear hazard is reduced. This change does not affect the standards for radiological protection or for the control of radioactive material which remain valid for all work where there is a radiological hazard or where radioactive material is involved. A common set of criteria for categorizing the nuclear safety significance of proposals will be applied to both generating and decommissioning sites.

Figure 2 shows how the transition from the use of arrangements under LC 22 to arrangements under LC 35 will be made at sites where no new build is involved. As an example, a reactor defuelling machine, once it is no longer required and has been emptied of fuel and of any reactor components, will be isolated from the system (under LC 22) and made available for decommissioning (under LC 35). This removes any ambiguity as to the state of the plant or as to which licence condition the plant activity is being managed under.

Figure 3 illustrates the applicability of different licence conditions to decommissioning projects which have new build components. This again removes any ambiguity as to the state of the plant or as to which licence

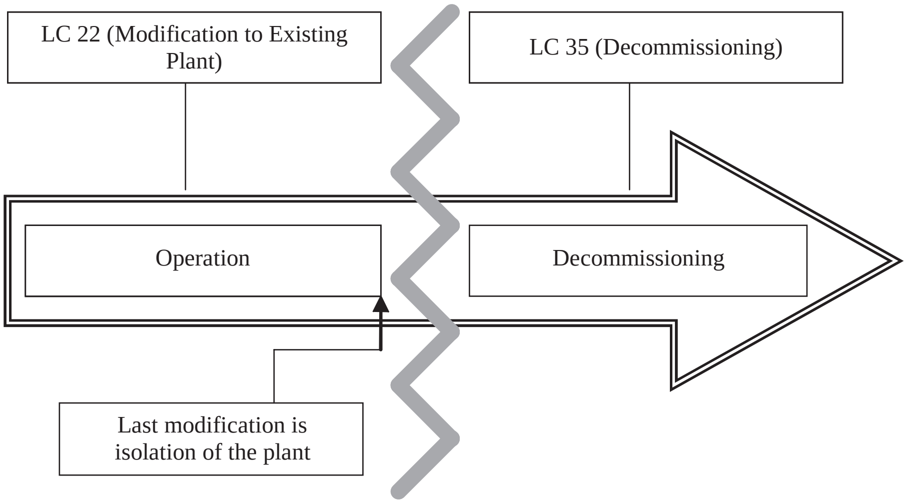

FIG. 2. Proposed use of licence conditions for a decommissioning project confined to deplanting and demolition.

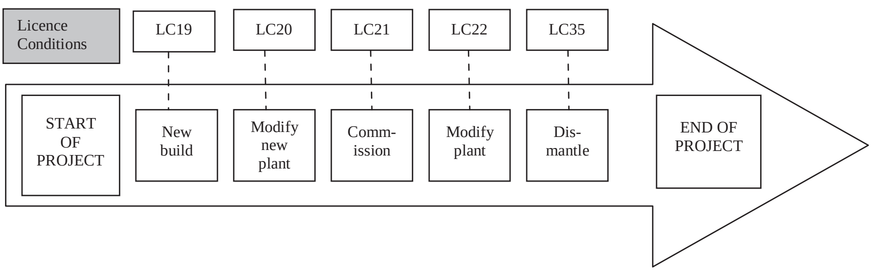

FIG. 3. Proposed use of licence conditions and use of site documents in decommissioning projects, including those involving new build such as the recovery, processing and storage of waste.

condition the plant activity is being managed under. The arrangements for compliance will, however, all use the same set of project management procedures, thereby simplifying the process considerably.

5. HOLD POINTS

The use of ‘hold points’ (points at which the project must be halted to obtain permission to proceed further) in any project is good management practice. Regardless of the safety aspects, a number of internal hold points will be placed in the programme to control the work. For some projects, regulators would expect to identify, from within any set of hold points, those requiring their agreement before work could proceed. For other projects there may be no hold points of interest to regulators.

It is expected that information about all the project-determined hold points would be provided to the regulators at an early stage. Regulator determined hold points would be expected to be targeted at: (i) confirming that all prerequisites are in place before work of particular safety significance proceeds, e.g., gaining access to vaults for operational waste recovery; and (ii) a review of uncertainties existing at the start of a project, e.g. uncertainty as to the nature, amount, and physical condition of waste within a vault. Regulators recognize that decommissioning work is likely to be subject to more initial uncertainties than work to support a site in its operational phase. It is expected that regulators will be primarily interested in projects of safety significance, those that are new or novel, and situations where they have a lack of confidence in the licensees' arrangements, based on previous experience of similar work. If there is a clear understanding in advance of the commencement of work of which aspects of projects the regulator is interested in, and which hold points (if any) are appropriate, both parties should then understand the basis for any intervention. All parties are agreed on the benefits of a 'no surprises' approach.

Regulators would not be expected to formally review the project management arrangements, as they would effectively assess them on the basis of the outcomes of the work programme. They do however see it as very important that the licensee demonstrably complies with his/her own processes. Failure to do so would be expected to prompt action by the regulator.

6. SAFETY ASSESSMENT

The new approach does not negate the need for safety cases but the nuclear safety considerations should be relatively simple given the reduced nuclear hazards, the much reduced schedule of nuclear safety related equipment and the reducing number of interdependencies between different plants on a site as the decommissioning progresses.

The detail of the assessment (and the level of scrutiny) should be proportionate to the level of hazard and risk. This principle is not new; however, the application has varied. There have been instances in which nuclear safety risks have been overstated and, as a consequence, overly detailed safety submissions have been developed. While our processes require review in this respect, it is thought likely that the difficulties have in part arisen from misapplication/misinterpretation rather than the processes themselves. This indicates a need for re-training in the application of the processes. Examples of the management of projects under the new arrangements are intended to help the understanding.

When considering the categorization of work activities, a consistent approach should be adopted throughout the life cycle of the nuclear plant. Nuclear hazards and risks are reduced considerably at the cessation of power generation, further on the completion of defuelling and progressively thereafter. Activities which would have been assigned a low nuclear safety categorization during the early life cycle phases should be assigned the same categorization during decommissioning.

The rigour of the safety assessment will depend on a number of factors. The key factors are: whether the activity is new build, a modification to operational plant or decommissioning; whether the activity involves radioactivity; and whether the activity constitutes a hazard to adjacent plant. For new build, the capital investment and the commercial risks involved must also be considered. Any expenditure on safety related plant and equipment, for which an ‘as low as reasonable practicable’ (ALARP) case cannot be made, should require robust justification.

A ‘holistic’ approach should be adopted where conventional as well as radiological and nuclear safety risks are considered. There has been a tendency for compartmentalization leading, for example, to safety case authors and assessors giving undue attention to nuclear safety considerations whilst paying insufficient attention to the industrial safety aspects.

7. TRANSITION

The transition to the simplified arrangements for decommissioning is intended to be made once it has been demonstrated by means of a revised safety case that the consequences of faults at the plant would be sufficiently low to permit the transition.

The LC 22 (Modifications) arrangements will still be available to sites under decommissioning. This is to allow for changes to continuing operational plant, e.g. active effluent treatment plant, to be managed as modifications just as they would have been managed during the generation phase.

8. CONCLUSIONS

The approaches to the management of the operational phase of nuclear reactor plants and the decommissioning phase of such plants are fundamentally different. The decommissioning of reactor plants is about managing largely discrete projects for which operational arrangements are inappropriate.

Licensees within the United Kingdom may determine how best to make and implement their arrangements to demonstrate compliance with licence conditions. It is incumbent on them to ensure these arrangements remain appropriate for the existing circumstances throughout the life cycle of the nuclear plant.

Any benefits from innovative ways of working will be limited if the arrangements under which the projects are managed are not similarly challenged.

Adopting a project management approach, as opposed to a safety case approach, increases the likelihood that decommissioning programmes will to be delivered according to plan, schedule and cost. There should be no adverse risk to safety provided that the project management arrangements take adequate account of hazard and risk as part of the safety assessment.

British Nuclear Group, within its Reactor Sites business, has responded to this challenge by reviewing its compliance arrangements through a process of consultation with the regulators and is now making changes to improve the implementation of decommissioning programmes.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support and cooperation of the British Nuclear Group in preparing this paper.

REFERENCES

[1] TAYLOR, F.E., et al., Regulation of Decommissioning Power Reactors, BNES Seminar on Nuclear Reactor Decommissioning, Manchester (June 2004).

DISCUSSION

G. YADIGIAROGLOU (Greece — Chairperson): How is financial provision made for decommissioning in the United Kingdom?

K. SPOONER (United Kingdom): Generally, making financial provision for decommissioning used to be a governmental responsibility. With the privatization of the nuclear industry, the Government has endeavoured to ensure that the new private companies have 'ring-fenced' decommissioning funds available to them.

As my company is now a contractor, not an owner–operator, it gets its funding from the Nuclear Decommissioning Authority.

MAIN ISSUES OF RUSSIAN RESEARCH REACTOR DECOMMISSIONING

N. ARKHANGELSKY
Federal Atomic Energy Agency (Rosatom),
Moscow,
Russian Federation
Email: narkhangelskij@uvryo.faac.ru

Abstract

The paper presents the current status of the decommissioning of research reactors in the Russian Federation. Several examples highlight the basic problems for their decommissioning in the Russian Federation, such as: the management of spent nuclear fuel; the management of special coolants; funding issues; ageing of the personnel; social aspects; and the loss of knowledge. The lessons learned from the decommissioning of Russian research reactors are presented in the paper. The regulatory aspects of the decommissioning process, such as the need for good interaction between the operating organization and the regulatory body and the preparation of adequate technical and regulatory rules for all decommissioning stages are discussed.

1. CURRENT STATUS OF THE DECOMMISSIONING OF RESEARCH REACTORS IN THE RUSSIAN FEDERATION

The first research reactor in the Russian Federation reached criticality on 25 December 1946 in the Kurchatov Institute, Moscow. Since then, many reactors have been constructed in the country; the peak of the construction being in the 1960s. The age of almost all of the research reactors that are still in operation is more than thirty years, and some of them have been operating for nearly 50 years.

Research reactor decommissioning began to be given priority in the middle 1980s, when the number of shutdown reactors began to increase appreciably. The reasons for their shutdown were various: failure to meet increasing safety requirements, end of experimental programmes, financing, etc.

The current situation with respect to shutdown Russian research reactors is shown in Table 1 [1].

Although the number of shutdown reactors is large, none of those having a significant power (more than 1 MW) can be considered as being fully decommissioned.

TABLE 1. SHUTDOWN RUSSIAN RESEARCH REACTORS (REACTORS WHICH OPERATED AT STEADY STATE POWER)

Reactor name	Criticality date	Shutdown date	Power (MW)
TVR	1949	1986	2.5
RPT	1952	1962	20
WWR-2	1954	1983	3
AM-1	1954	2002	30
BR-10	1959	2002	8
IR-50	1961	1994	0.05
MR	1963	1993	50
ARBUS	1963	1988	12
Romashka	1964	1966	0.04
RG-1M	1970	1998	0.1
TOPAZ	1973	1986	0.1
IRV-1M	1974	1991	2
GAMMA	1982	2003	0.22
RBT-10/1	1983	1994	10

Decommissioning is a more acute and costly problem for high power reactors. The management of the spent nuclear fuel (SNF) and high level radioactive waste from small power reactors, pulse type reactors and critical assemblies is rather simple and inexpensive, although in some cases there are complexities.

1.1. Features of decommissioning of research reactors

The following important features reflect Russian experience in the area of decommissioning of research reactors:

— The research reactors are situated within large research centres which include other nuclear and radioactive installations (hot cells, charged particle accelerators, etc.).
— In many cases the research reactors are located in the middle of large inhabited districts; this creates difficulties for the transportation of SNF and contaminated equipment off-site and usually means that the decommissioning costs are higher because of the additional safety measures needed.

- The research reactors are very old facilities; they were commissioned at a time when there were secrecy restrictions and demands for high productivity. For these reasons, adequate attention was not paid to the maintenance of accurate and detailed design documentation; such documents are essential for decommissioning.
- The neutron flux density at high power research reactors exceeds that of nuclear power plant reactors. This has created higher levels of neutron induced activity in structures adjacent to reactor cores.
- Design features, the materials used in construction, and power levels differ significantly from one research reactor to another; these factors complicate the development of harmonized approaches.
- Research reactors have many associated experimental devices, some of which present special complexities for dismantling (for example, horizontal experimental channels, loop and rig channels for material testing).

1.2. Basic problems in decommissioning research reactors

The basic problems in decommissioning research reactors are as follows:

- The spent nuclear fuel assemblies of research reactors have variable characteristics. In addition, there are many experimental and exotic fuel elements and assemblies. In many cases, the SNF of shutdown reactors remains in storage at the research reactor sites and the prospects for reprocessing are unclear.
- Despite the fact that a number of formal decisions have been taken, a real financial source for decommissioning funding is lacking.
- The development of dedicated equipment for decommissioning is far from complete. In general, this problem is closely connected to the lack of funding.
- The regulatory standards are incomplete and inadequate for application to decommissioning.
- The different coolants that were used in research reactors: heavy water; sodium (with mercury in some cases); organic materials; (the amount of contaminants, e.g. tritium, caesium in these coolants can be sufficient to determine the selection of purification method).
- The ageing of the personnel is creating social concerns and a problem of loss of knowledge.

The current economic situation in the Russian Federation has resulted in difficulties in identifying financial resources for the decommissioning of research reactors. In the former Soviet Union all research reactors were State property. They received regular funding for the implementation of research activities, capital investments and other works; no financial resources were accumulated for expected or unforeseen works, including decommissioning.

In 'The Federal Law on the Use of Atomic Energy' No 170-FZ, 21 November 1995, the nuclear institutes were given the status of operating organizations which carry out their own programmes of activities, including decommissioning (or with the support of other organizations). The research institutes can now establish decommissioning funds by Law and the Under Legislative Acts of the Russian Government.

The main problem is that these funds are individual funds of the operating organizations. The difficult economic situation of the organizations operating the research reactors means that there is not enough money in these funds. In practice, after the shutdown of a research reactor, the operating organization will not have the financial resources for decommissioning and it will have to find such resources, mainly from the government, i.e., from the public budget.

The solution to the problem could be the creation of consolidated decommissioning funds for the whole nuclear industry.

1.3. Selection of strategy for decommissioning of research reactors

The decommissioning strategy options for research reactors are various. For example, the IAEA has recommended [2]:

— Immediate dismantling;
— Deferred dismantling;
— Entombment.

In the Russian Federation, the following possible strategies have been identified (they are close to those recommended by the IAEA):

— Conversion;
— Liquidation;
— Preservation.

Conversion is the change of the experimental or commercial purpose of the facility to other industrial purposes and the possible use of the buildings, systems and equipment of the facility for conducting other activities in the field of nuclear energy. After completion of conversion, a facility can lose its status as a nuclear installation.

Liquidation is the complete dismantling of the facility and systems, and the subsequent use of the facility site, (this excludes the subsequent storage and disposal of nuclear materials and radioactive substances). After the completion of liquidation, a facility loses the status of nuclear installation.

Preservation is the shutdown and transformation of the facility to a nuclear-safe condition, with subsequent storage of radioactive substances at the facility site and the long-term monitoring of buildings, systems and equipment. After the completion of preservation, the facility will be either converted or liquidated.

In choosing a decommissioning strategy, first of all it is necessary to determine what will be the future use of the scientific centre. Nowadays in Russia, there are practically two answers to this question:

— The centre will be kept as a reactor centre but the size and power of the facilities will be smaller than before;
— The centre will remain approximately the same for the foreseeable future.

New facilities can be:

— Critical or subcritical assemblies;
— Accelerators;
— Storages of SNF;
— Other nuclear or radiological facilities.

The major factors determining the selection of a strategy are:

— The results of preliminary technical and economic assessments;
— The results of the analysis of alternative options;
— The restrictions on the implementation of alternatives are due to nuclear safety, radiation protection and ecological safety considerations;
— The availability of an infrastructure for the management of SNF, high level radioactive waste and other materials generated by the decommissioning work;
— The current and future demands for the use of the territories, structures, equipment and materials of the decommissioned facilities;
— The practical experience obtained from the implementation of alternative decommissioning approaches for similar nuclear and radioactive facilities;
— Estimates of individual and collective radiation doses for the personnel engaged in the decommissioning work;
— The comparative analysis of the volumes and activities of the radioactive waste generated by decommissioning;

— The social concerns of the population living in areas close to the decommissioned facility.

2. LESSONS LEARNED FROM THE DECOMMISSIONING OF RESEARCH REACTORS

Some examples of experiences of the decommissioning of research reactors of different design, power level and experimental programmes are given below.

2.1. Reactor TVR at ITEP (Moscow)

The heavy water research reactor TVR was commissioned in 1949, permanently shut down in 1986 and is now at the decommissioning stage. The power of the reactor was 2.5 MW.

The basic reasons for decommissioning were the impossibility of inspecting the reactor structures due to the high neutron flux density and fluence of the reactor, and also the strong psychological influence of the Chernobyl accident, which drew attention to the safety of old research reactors located in large cities (TVR is located in the middle of Moscow).

The SNF was transported from the reactor to the reprocessing plant 'Mayak' in 1989–1990.

In the reactor building, the heavy water moderator contaminated by tritium is still being stored. The problem of the purification of heavy water is not yet solved.

A decision has been taken to construct a subcritical neutron multiplier in the pool of the reactor TVR to be coupled to a linear accelerator of protons. Consequently, the research reactor TVR — a facility posing both nuclear and radiation hazards — will be replaced by a facility posing only radiation hazards. This is more acceptable in Moscow and does not require the dismantling of the reactor biological shield. As a result, the problem of the heavy water purification is not so urgent, since it is possible to re-use it in the new facility.

As a result of this decision, the decommissioning at the reactor TVR should be completed by the dismantling of only the equipment that will not be used in the new facility.

2.1.1. Lessons learned

The strategy of converting the reactor facility to another type of nuclear or radioactive facility has several advantages for facilities at large nuclear institutes.

The problem of site restoration is very important and requires additional efforts, especially when the facility is located in inhabited areas.

The dismantling of heavy weight equipment having high levels of induced activity is a problem for small operating organizations.

The problem of the purification of specific coolants can create additional difficulties and it is necessary to pay special attention to this problem as early as possible, ideally at the design stage.

2.2. Reactors at IPPE (Obninsk)

2.2.1. Reactor AM

Reactor AM [3] is a water graphite channel type reactor. The reactor power was 30 MW. The date of commissioning was 27 June 1954 and the date of the final shutdown was 29 April 2002.

The development of the decommissioning project began in 1999. At the present time, the reactor is at the stage of "operation under the regime of the final shutdown" according to the licence granted by the regulatory body.

According to "The concepts of decommissioning of the reactor AM with the creation of the State Museum of Atomic Engineering of Russia" (the AM reactor was the prototype reactor for the first nuclear power plant) the work should be implemented in four stages:

— I stage — preparation for decommissioning (2000–2005);
— II stage — preparation for long term storage under monitoring (2006–2010); this stage includes the partial dismantling and other works necessary for the confinement of the reactor and any highly active equipment, the decontamination and dismantling of systems and equipment not intended for museum purposes, inspection, and, if necessary, the upgrading of barriers and the construction of additional protective barriers, and the installation of monitoring systems;
— III stage — long-term storage under monitoring (2011-2080); during this stage, the radioactivity of reactor structures, systems and equipment is allowed to decrease through natural decay to a level that will allow dismantling or unrestricted use;

— IV stage — implementation of the final work needed for the liquidation of the reactor.

The duration of III stage (~70 years) will be determined by the remaining mechanical strength of buildings, the effectiveness of the physical barriers and of the confinement of the structures, systems and equipment and the residual activity of the facility.

The effectiveness of physical barriers at AM is such that, in the case of failure at any decommissioning stage, the radiological impact on the public would still be practically nil.

2.2.2. Reactor BR-10

The BR-10 is a fast research reactor with a sodium coolant. Its power was 8 MW and it was intended for research on the basic technical problems for the development of fast reactor nuclear power plants.

The date of reactor commissioning was 26 January 1959 and the date of shutdown was 06 December 2002. At the present time, the reactor is in the "operation under the regime of the final shut down" according to the licence of the regulatory body. In 1999, the development of the decommissioning project for the reactor began and now the project is well under way.

According to "The concepts for the decommissioning of research reactor BR-10", the work should be executed in four stages:

— I stage — preparation for decommissioning (1999–2007);
— II stage — preparation for long term storage under monitoring (2007–2015); implementation of partial dismantling, which is necessary for the confinement of the reactor and the highly active structures, systems and equipment; the draining, neutralization and recycling of the sodium, sodium potassium coolant and the cold traps containing sodium oxides; and the installation of monitoring systems;
— III stage — long term storage under monitoring (2016–2066); implementation of the long term storage of reactor structures, systems and equipment to allow the decrease of the radioactive contents of the structures etc. through natural decay to a level allowing dismantling or unrestricted use;
— IV stage — implementation of the final work for the liquidation of the reactor.

The actual duration of the III stage (~ 50 years) will be determined by the remaining mechanical strength of buildings, the effectiveness of the physical barriers and of the confinement of the structures, systems and equipment and the residual activity of the facility.

2.2.3. Lessons learned

It is necessary to develop the decommissioning project as early as possible. Special attention should be paid to the history of reactor use during operation and to the issue of coolant cleaning and removal.

Keeping in mind the long period of reactor storage under monitoring (several decades), it is very important to establish regular procedures for the financial support of the operational organization.

In the case of the decommissioning of the very old reactors, the distribution of responsibilities between the State, the operating organization and the regulatory body should be clearly defined.

The problem of site restoration is very important and requires additional efforts, especially when the facility is located in inhabited areas.

The dismantling of heavy weight equipment having high levels of induced activity is a problem for small operating organizations.

The problem of the purification of specific coolants can create additional difficulties and it is necessary to pay special attention to this problem as early as possible, ideally at the design stage.

2.3. RIAR reactors (Dimitrovgrad)

2.3.1. Reactor ARBUS

ARBUS was commissioned in 1963 and permanently shut down in 1988. This reactor is a tank type, organically cooled reactor; its power was 12 MW.

The SNF has been unloaded from the core. Most of the SNF is still in storage at RIAR. Till now the big part of the SNF is still stored at the RIAR site due to insufficient funding for its proper management. RIAR has a centralized system for the storage of SNF from all reactors at the institute (eight reactors, including six in operation and two shut down) and also for the storage of radioactive waste. The SNF storage capacity is now limited and it is necessary to transport the spent fuel assemblies of the reactor ARBUS to the reprocessing plant very soon.

After decontamination and dismantling of the equipment, the reactor building will be used for another type of radiation facility.

2.3.2. Reactor RBT-10/1

Reactor RBT-10/1 was commissioned in 1984 as an experimental installation for materials testing experiments. The reactor used the fuel assemblies discharged from the SM high flux reactor.

Since 1994, with the end of the experimental programme, the reactor was shut down and since then it has been at the stage of ‘extended shut down’. The technical conditions of the equipment and the systems of the reactor are in full compliance with the requirements of the design and operational documentation.

In the absence of new ideas about the possible experimental utilization of the reactor, a decision about the final shutdown of the reactor was taken by Rosatom.

Out of several possible options for the decommissioning of the RBT-10/1 reactor, the most acceptable option appears to be the partial dismantling of the rooms and equipment of the old reactor to allow for the improvement of the operational characteristics and experimental opportunities associated with the other reactor of the same type, RBT-10/2, which is installed in the same building.

2.3.3. Lessons learned

In the case of the RBT-10/1 reactor, the strategy of the conversion of the reactor facility to another type of nuclear facility is attractive because it allows the rooms and equipment of the shutdown reactor to be used for conducting other activities in the field of nuclear energy.

The management of SNF is a costly problem and will require constant and lengthy efforts to reach a solution.

2.4. Some general lessons learned from the decommissioning of Russian research reactors

First of all, it is necessary to develop a system of adequate technical and regulatory rules to cover all decommissioning stages. In Russian Federation, there is such a system especially for the decommissioning of research reactors but it needs to be constantly upgraded taking into account new social challenges, new safety requirements and technological progress.

The interaction between the owner–operator of the reactor and the regulator must be very close keeping in mind that the technical, economical and political situations can change during the very long decommissioning process. The licensing procedure must recognize all aspects of the decommissioning process and the requirements of the regulator must be clear to the operator.

According to the main Russian nuclear law, the operating organization is fully responsible for all aspects of decommissioning. However, the responsibilities of all stakeholders concerned with decommissioning activities and the distribution of responsibilities in the decommissioning process must be defined more clearly. The role and the responsibility of the State, in the case of the decommissioning of research reactors, should be greater than in the case of the decommissioning of commercial nuclear power plants, because the research reactors are state property and, as a rule, have no adequate financial resources.

The creation of a consolidated decommissioning fund within the nuclear industry is a preferable option for the funding of the decommissioning of research reactors rather than the individual decommissioning funds approach used by operational organizations.

Interaction with public organizations is a very important aspect of decommissioning. Without the support of public opinion, it can be very difficult to obtain the necessary funding and to reach an adequate solution.

3. CONCLUSION

The following conclusions can be drawn from the analysis of the implemented and planned decommissioning of research reactors in the Russian Federation.

Many of the research reactor fuel types create technical and financial difficulties. A long time is required to provide safe storage conditions for the fuel and/or to transport it to the reprocessing plant. For some kinds of SNF no technical decisions have yet been made.

The financing of decommissioning is the key problem. The available options are appropriate for profitable enterprises and reactors that are expected to remain in operation for many years. The solution of the problem could be the establishment of a consolidated decommissioning fund for the whole nuclear industry.

In Russian conditions, the most preferable decommissioning strategy is to postpone a final decision or to implement the conversion of the reactor to another type of nuclear or radiation installation. This implies that any viable strategy requires sufficient resources to maintain the installations in safe condition for a long period of time.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Status of the Decommissioning of Nuclear Facilities Around the World, IAEA, Vienna (2004).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Selection of Decommissioning Strategies: Issues and Factors, IAEA-TECDOC-1478, IAEA, Vienna (2005).

[3] KOCHETKOV, L.A., NIKOULIN, M.P., STYFURKO, A.I., "Organization of works and lessons learned from the first stage of decommissioning of research reactors AM and BR-10 in IPPE", Proc. Int. Conf. on Research Reactors in the 21st Century, 20–22 June 2006, Moscow, NIKIET (2006).

PANEL DISCUSSION

Session 2

REGULATION OF DECOMMISSIONING ACTIVITIES

Chairperson: **G. YADIGIAROGLOU** (Greece)

Members: **D. CONTE** (France)
S. KARIGOME (Japan)
A. PERSINKO (United States of America)
K.G. SPOONER (United Kingdom)
M. ŽIAKOVÁ (Slovakia)

G. YADIGIAROGLOU (Greece — Chairperson): I invite the panellists to respond to the question 'How should one grade the regulatory activities related to decommissioning (e.g. according to facility type, the hazard potential, the complexity of the decommissioning activities)?'

D. CONTE (France — panellist): Under a law passed in France on 13 June 2006, the needs associated with decommissioning must be taken into account from the very outset of a nuclear facility project.

As I said earlier, we are adopting a case-by-case approach, so that, although our preferred option is immediate dismantling, what is done depends on the circumstances at the particular facility.

S. KARIGOME (Japan — panellist): I shall start by briefly describing the decommissioning situation in Japan.

Several small research reactors have already been decommissioned, and our first commercial power reactor, Tokai-1 (a gas cooled reactor) shut down in 1998, is currently being decommissioned. In addition, preparations are being made for the decommissioning of the Fugen Nuclear Power Station, which was shut down in 2003. Also, valuable experience was gained during the decommissioning of the Japan Power Demonstration Reactor.

Of the 55 light water reactors currently operating in Japan, four have been in operation for over 30 years, and the intention is to shut them down around 2010. As regards the other ones, their operating lives are to be at least 40 years.

My response to the question put by the Chairperson is that, in my view, the regulatory activities related to decommissioning should be graded according to hazard potential, which will change as the decommissioning operations proceed.

M. ŽIAKOVÁ (Slovakia — panellist): We are already decommissioning our first nuclear power plant, the A-1, which went into operation in 1972 and was shut down permanently in 1977 after an accident. Also, we are planning to shut down our nuclear power plant V-1 (consisting of two WWER-440 units with V-230 reactors).

As regards other facilities, last week a licence was issued for the decommissioning of an experimental incinerator and an experimental bituminization plant.

We shall therefore soon be decommissioning very different types of facility requiring very different approaches. Consequently, I am in favour of the grading of regulatory activities related to decommissioning.

A. PERSINKO (United States of America): I should like to start by asking 'Why grade in the first place?' Grading is done in order to make efficient use of limited resources and to ensure that the site has been cleaned up sufficiently to allow it to be used in the future for some purpose or other.

Conceptually, what we are trying to do is to hold the residual risk at the site at some constant acceptable level across all facilities. By doing so, we would then be applying our limited resources efficiently. In this context, 'risk' is defined as the probability of an event occurring multiplied by the consequences of that event occurring. This means that, as the hazard or complexity of a site increased, more actions would be taken or more controls would be imposed in order to reduce the consequences or the likelihood of a particular scenario occurring, thus keeping the risk at the acceptable level. In the USA, we do not require rigorous risk analyses or probabilistic risk assessments for the decommissioning of facilities.

One method that could be used for sites (and it is a method used in the USA for material sites) is to grade the regulatory aspects of decommissioning on the basis of the amount of residual radioactive material at the site after shutdown, the location of the material and the complexity of the activities needed in order to decommission the site. These factors would help in determining the degree of cleanup necessary in order to achieve a particular residual risk level at the site after the site has been cleaned up.

Put in another way, grading really depends on the material type, the quantity of material and the form of the material when the facility was operating and on the past management of the facility — are the factors that affect the hazard and the complexity and the risk.

In doing this, account would have to be taken of specific attributes, such as fixed versus loose material at the site, the operating history of the site, whether there had been spills and releases and how well they were cleaned up when the facility was operating. The half-lives of the radionuclides in the material would also have an influence. Complexity, in this context, usually means aspects such as groundwater contamination, surface versus subsurface contamination, and buildings contamination.

Also, the desired end state must be considered, because this affects grading as well. The end state specification affects the amount of cleanup needed as well as the complexity, because it is more complicated to achieve restricted release as an end state than unrestricted release.

For material sites in the USA, we have developed a grouping scheme based on the attributes about which I have just spoken. We have come up with seven categories in increasing hazard based on the materials, forms and properties. I mentioned the desired end state. For each group, we have tried to grade the actions that would be necessary in terms of: the type of environmental review that the facility would receive; the details of the decommissioning plan (and whether a decommissioning plan is even needed); the number of inspections to be carried out at the site; whether a site-specific dose assessment is required or whether comparison with some pre-determined approved screening values is sufficient and the level of detail of the review.

For reactors we do not have such a grading scheme. We have differences of approach as between, on the one hand, research and test reactors and, on the other, commercial power reactors. Although we do not have a predetermined grading scheme for reactors, we would establish the level of detail of our review based on factors such as the complexity of the site taking account of, for example, any groundwater contamination.

K.G. SPOONER (United Kingdom — panellist): Grading should take account of all hazards and risks.

During the decommissioning of reactors, it is most unlikely that a worker would be seriously harmed as a result of a radiological event. Clearly, different conditions apply in the case of reprocessing plants, where there may be significant amounts of residual fissile material. During the removal of redundant plant from buildings/sites and demolition, it is the conventional industrial hazards that generally represent the most significant risks to workers.

Thus, a holistic approach should be adopted with all hazards and risk considered. The grading should be proportionate to the hazard and risk levels, otherwise emphasis may be placed on the wrong things.

Also, in grading, account should be taken of the interdependences between different facilities on the site as decommissioning progresses — changes in one part of a site may affect other parts. At the Trawsfynydd nuclear power plant site, for example, we inadvertently cut a low-voltage cable and thereby disabled many of the alarms around the operational waste areas.

The grading of facilities on the basis of their radiological hazard potential in a manner similar to the approach taken by the national regulator might be helpful — sites being classified as high, medium and low hazard sites and regulated accordingly. Such a classification might help local communities to understand the changing status of plants that are being decommissioned.

G. YADIGIAROGLOU (Greece — Chairperson): Mr. Persinko mentioned a large number of criteria. Does the NRC combine them in any particular way?

A. PERSINKO (United States of America — panellist): No, but we use a flowchart algorithm to aid decision making for materials sites – the more complex the site the more attention it receives.

A.J. GONZÁLEZ (Argentina): During this session on the regulation of decommissioning activities, the focus has been mainly on dismantling — on destroying what has been built in the past. It is fortunate that the ancient Greeks knew nothing about decommissioning. Otherwise, we would not be able to enjoy Athens as much as we do.

Perhaps the panellists could say something about what regulatory approaches would be best for recycling in the interests of the sustainability of the nuclear industry, for in my opinion there will be no expansion of the nuclear industry if we simply dismantle.

K.G. SPOONER (United Kingdom — panellist): In response to Mr. González's comment about Athens, I would say that whatever one wishes to leave must be maintained at least to some extent — and maintenance costs money. So, funding arrangements have to be made.

In the United Kingdom, we are required, both by the nuclear regulator and by the environmental regulator, to take account of all aspects of recycling and sustainability in our decommissioning activities.

D. CONTE (France — panellist): Dismantling is the preferred option of the regulator in France, but there is no compulsion to achieve green field status. It is expected that many of the CEA sites are expected to be used for industrial projects after they have been cleaned up and all radioactive waste has been removed.

A. PERSINKO (United States of America — panellist): In the USA, sites are recycled, but deciding what is to be done with a decommissioned site is the prerogative of the operator — not of the regulator. The job of the regulator is to determine whether the site has been cleaned up sufficiently for the chosen future use.

A recent example of site recycling is the recycling of a nuclear site decommissioned earlier this year for use as a petroleum storage facility.

S. KARIGOME (Japan — panellist): In Japan, we apply a green field strategy.

M. ŽIAKOVÁ (Slovakia — panellist): Sustainable recycling is connected to dismantling process and requires good processing technology. In the case of the WWER units that we are going to decommission, a study has shown that, with the right technology, it will be possible to decontaminate them to almost 100% (except for the spent fuel, of course).

There is an economic incentive for operators as the more waste you create the more you pay. Operators therefore proceed very carefully so that there is minimum radioactive waste at the end of the operating lifetime of the facility.

D.W. REISENWEAVER (United States of America): Nuclear power is by now part of our heritage, and I was wondering whether there was any requirement in any decommissioning regulations that certain decommissioned facilities be preserved so that future generations may see what such facilities used to look like. If the ancient Greeks and Egyptians had decommissioned the great structures put up by them, there would be no Acropolis or pyramids now.

A. PERSINKO (United States of America — panellist): I do not know of any such requirement. At the NRC, however, we have extensive historical information about decommissioned facilities, and from that information — which is available to the public — it should be possible to recreate their construction history.

One lesson which we learned from the decommissioning of the Big Rock Point nuclear power plant was that we should have consulted more thoroughly with the Historical Preservation Officer of the State of Michigan.

K.G. SPOONER (United Kingdom — panellist): Consideration is being given in the United Kingdom to preserving one of the Calder Hall reactors and also to creating a national nuclear archive.

S. SAINT-PIERRE (World Nuclear Association): Reverting to the question of sustainability, I would say that sustainability implies the reuse of sites and the reuse of materials, including waste. That does not fit very easily within the rigid regulatory framework applied in the case of construction and operation. You cannot license decommissioning and reuse with the mindset necessary when licensing construction and operation.

G. YADIGIAROGLOU (Greece — Chairperson): I suggest that the panellists bear that comment in mind when responding to the question ‘How much flexibility can be allowed in the regulation of the decommissioning of facilities?’.

K.G. SPOONER (United Kingdom — panellist): In the United Kingdom there is considerable flexibility in the regulation of decommissioning. It is up to licensees to make and implement their own arrangements for compliance — there are no prescribed arrangements. Typically, therefore, a licensee develops a compliance matrix setting out the requirements and the means by which those requirements are to be met.

Reverting to the question of sustainability and reuse, sometimes the best of plans do not come to fruition. For example, a lot of effort has been put into promoting the post-decommissioning conversion of the site of the Berkeley Nuclear Power Station into a business park, but there has been little or no response. Consequently, we are now pressing on with the demolition of buildings and the clearing of engineering facilities.

A. PERSINKO (United States of America — panellist): In the USA there is a great deal of flexibility, although less so for material sites than for reactors.

The NRC tries to achieve a balance between decommissioning efficiently and ensuring that the site is adequately cleaned up for its intended future use. It is concerned about the end state rather than the process of arriving at the end state.

In the case of reactors, a great deal of decommissioning work can be done under the operating licence without NRC approval. In fact, the licensee can decommission the facility completely without NRC approval. The licence to operate is, of course, issued by NRC, but changes in the technical specifications, which are part of the licence; to reflect the change from operation to decommissioning, do not require NRC approval. Before decommissioning begins, the reactor operator is required to submit a post-shutdown decommissioning activities report (PSDAR) dealing with things such as the nature of the decommissioning activities, the schedule for their completion, the estimated costs and the environmental impacts. There is no requirement that the PSDAR be approved by the NRC. The PSDAR is made publicly available, and a public meeting is held on it. NRC regulations contain a so-called '50.59 provision' under which a licensee can make changes to a facility without NRC approval if they will not result in a risk increase or in a new type of potential accident.

However, there are restrictions. The licensee cannot carry out decommissioning activities that would foreclose unrestricted release or result in an environmental impact not previously reviewed. Also, the licensee may not do anything that would result in a shortage of funds for decommissioning. If a licensee wishes to deviate from the PSDAR, the NRC must be informed. But after the lapse of 90 days following submission of the PSDAR, the licensee can withdraw money from the decommissioning fund and start decommissioning.

Later on, a licence termination plan must be submitted to the NRC, and it has to be approved by the NRC before the licence can be terminated. The cleanup levels (the derived concentration guideline levels) are established and the final status survey plan is described in the licence termination plan. When approving a licence termination plan, the NRC does not specify any hold points at which decommissioning must stop pending approval of the next decommissioning step. The results of the final status survey have to be approved by the NRC.

A great deal of decommissioning work has already been done on San Onofre Unit 1 without NRC approval, under the ‘50.59 provision’. In fact, the licensee plans to completely decommission the site before submitting a licence termination plan to the NRC. This is a good indication of the high degree of flexibility that exists in the USA. The licensee still has a an operating licence that has been modified for shutdown.

M. ŽIAKOVÁ (Slovakia — panellist): As we are responsible for fewer facilities than the NRC, our thinking is less general — it is oriented towards specific facilities. Nevertheless, we have some flexibility in the legal framework to take account of the fact that decommissioning can be deferred for a very long time. How can one ask the operator for details when dismantling is due to be completed only in 80 years’ time?

Accordingly, we first require from licensees a preliminary plan for decommissioning with a general description of the approach and a rough estimate of the costs. Later, we require a conceptual plan, in which the decommissioning operation may be broken down into a number of stages. Then, for each stage we require detailed information — about the starting point and the end point, about how the operators intend to proceed from one to the other and about the timing.

In the decommissioning of the A-1 nuclear power plant, we have had a rather negative experience and we are following the company involved in this process almost on a daily basis, using on-site inspectors. But for us it is easy as we have only one facility and we have a special group of people devoted to decommissioning and radioactive waste reprocessing management. The company has the freedom to solve the unexpected problems that arise but the regulator has the possibility to react and to stop operations if it is considered that the safety justification is not appropriate.

S. KARIGOME (Japan — panellist): As an operator, I am very much in favour of regulatory flexibility.

Initially, our regulations were not designed to cover decommissioning — basically, they covered only nuclear power plant operations. However, they were amended in December 2005.

Previously, and without any clear criteria, our competent authority asked us to make a decommissioning plan notification in detail. Here, I would just point out that clear criteria are always necessary for the regulatory body and for the operator.

In Japan we now have three tools — the decommissioning plan, the self-imposed safety rule and the quality management system. The decommissioning plan and the self-imposed safety rule have to be approved by the regulator, but the quality management system does not. However, the performance of the quality management system is inspected periodically.

In my view, this kind of cooperation between the regulatory authority and the operator is one way of solving the problem.

D. CONTE (France — panellist): In France, flexibility was introduced with the decommissioning of research facilities. We established an internal authorization system, the condition being that the safety case is up to date.

The responsibility for review and reassessment of the facility was given to an independent committee within the organization. The results are sent to the safety authority, which can also inspect the system regularly. The results obtained so far have been quite good.

The approach was extended in 2003 to all EDF facilities being dismantled, with the same condition — that they must have an up-to-date safety case. If they stay within the scope of the safety case, they can operate with an internal authorization. There is an internal committee, independent of the project, that can judge whether the safety case and the safety conditions are being respected.

We have also introduced an authorization for decommissioning in stages, if necessary. When operators have an authorization, they can proceed to the end of decommissioning without stopping, unless we decide that there should be some stages in the process.

We have found that the system is more flexible than the previous one and that progress with decommissioning is quicker.

K.G. SPOONER (United Kingdom — panellist): Flexibility relies on trust, and operators who demonstrate high levels of self-regulation and compliance should be rewarded with a ‘lighter touch’ of external regulation, regardless of the stage in the life cycle of the facility. This is what the environmental regulator in the United Kingdom is working towards. Poor operators, on the other hand, warrant a ‘heavy-handed’ approach.

G. YADIGIAROGLOU (Greece — Chairperson): Mr. Spooner is right — if you trust, you can delegate, relinquishing some authority. That is not so easy in the USA, however, where the process is an adversarial rather that a cooperative one.

A. PERSINKO (United States of America — panellist): Because of the way in which the legal system in the USA functions, the process can become an adversarial one, but that is not the norm. We recognize the competency of nuclear power plant operators. In fact, I believe that there is a regulation requiring that we do so.

At the decommissioning stage, once the fuel has been removed, the risk is much less. And even during the operational stage, ‘decommissioning-like’ activities such as the replacement of steam generators have been carried out at some nuclear power plants, whose operators have thereby demonstrated their competency. Recognizing their competency, we grant them greater flexibility, which we can do thanks to a change in our regulations made in the mid-1990s.

G. YADIGIAROGLOU (Greece — Chairperson): Decommissioning is not a high risk procedure, but the general public does not see it that way. Also, members of the general public speak of the heavy burden being passed on to future generations, whereas in reality the burden may not be so heavy.

C. MILLER (United States of America): In the USA, the general public demands that there be no residual radioactive contamination at decommissioned sites. What are the views of the panellists regarding participation of the general public in the decommissioning process?

D. CONTE (France — panellist): In France there are public inquiries at which operators have to explain what they plan to do throughout the decommissioning process and what the end state is to be. Our aim is that every facility should be so decommissioned that the site can be restored to the public domain.

S. KARIGOME (Japan — panellist): We have close contacts with local governments, and we start decommissioning operations only after the relevant local governments have agreed to them.

M. ŽIAKOVÁ (Slovakia — panellist): In Slovakia, the conceptual plan for decommissioning provides for the preparation of an environmental impact statement and for the holding of public hearings.

In view of the fact that a radiological incident in Slovakia — a small country in the middle of Europe — could easily have a transboundary environmental impact, we keep our neighbouring countries informed. Pursuant to the Espoo Convention (Convention on Environmental Impact Assessment in a Transboundary Context), our neighbouring countries can call for a discussion if we do not carry out decommissioning work properly, and, pursuant to the Aarhus Convention (Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters), the public is entitled to participate in such discussions.

The regulatory body reports to the Government and Parliament each year, and its reports are made publicly available on the worldwide web.

K.G. SPOONER (United Kingdom — panellist): The best way to demonstrate to the general public that a decommissioning job has been done properly is to walk about the site without any protective clothing.

I have adopted that approach in the past. At the Berkeley Nuclear Power Station, after we had cleaned out the fuel transfer tunnels we made a large hole in the wall of one tunnel so that we could walk about inside the tunnel together with our stakeholders.

It is probably necessary to clear all buildings from the site in order to really convince the general public that there is no residual hazard.

A. PERSINKO (United States of America): We go to great lengths to keep the general public informed during the decommissioning process, with public meetings on subjects such as our environmental reviews. Also, licensees are required to convene public meetings on their decommissioning plans.

Mr. Spooner talked about clearing all buildings from the site. However, it is not always necessary to clear all buildings. For example, in the case of the Trojan Nuclear Power Plant, the site of which has been released without restrictions, there are still buildings standing. It depends on the intended future use of the site.

Things go fairly smoothly when the aim is unrestricted release. However, difficulties arise when the aim is restricted release. We are facing such difficulties at the present time with a materials site — the public is expressing its concern very vocally.

A.M. XAVIER (Brazil): In my view, ‘flexibilization’ must be done with great care, on a case-by-case basis. In Brazil, for example, there are some operators to whom flexibility should not be granted.

G. YADIGIAROGLOU (Greece — Chairperson): Why are such operators in business?

A.M. XAVIER (Brazil): Because the regulatory authority is lax.

D. CONTE (France — panellist): For us, there are not good or bad operators, but for the internal authorization system it is necessary for them to be ‘mature’ in relation to the decommissioning process.

For example, when we launched the system there was a trial period. The internal committee of the CEA was working, but at the same time the IRSN (Institut de Radioprotection et de Sureté Nucléaire) was also working for us, and we compared the two sets of results. We had a two year trial period before we arrived at a mature system. For EDF there is a period of 18 months for them to bring their system to maturity. When the system is mature within the organization, it works well.

G. YADIGIAROGLOU (Greece — Chairman): France has traditionally had an approach different from that of other countries — a non-adversarial cooperative approach. It works because there is just one utility and just one regulatory body — not many.

PLANNING FOR DECOMMISSIONING

(Session 3)

Chairperson

I. TRIPPUTI
Italy

Rapporteur

A. PERSINKO
United States of America

THE IMPACT OF THE NUCLEAR DECOMMISSIONING AUTHORITY ON THE DECOMMISSIONING OF NUCLEAR FACILITIES IN THE UNITED KINGDOM

J. WILSON
Nuclear Decommissioning Authority,
Cumbria,
United Kingdom
Email: Janet.Wilson@nda.gov.uk

Abstract

The paper describes the work of the Nuclear Decommissioning Authority (NDA) which was set up by the United Kingdom in April 2005 to provide the first ever United Kingdom wide strategic focus on the clean-up of nuclear sites. The NDA establishment enables the biggest change in the structure of the United Kingdom nuclear industry in the last 35 years. This paper describes its mission, its strategy and its intended manner of decommissioning. The NDA mission is to deliver a world class programme of safe, cost-effective, accelerated and environmentally responsible decommissioning of the United Kingdom's civil nuclear legacy in an open and transparent manner and with due regard to the socio-economic impacts on our communities. This mission shapes the NDA values. Safety, security and regard for the environment are paramount to the way in which NDA operates. NDA expects that as it understands the clean-up challenge better, estimated costs will rise but NDA is confident that by introducing competition and through innovation it can, over time, drive these costs down. NDA acts openly and transparently and seeks to generate public confidence in an industry that has, historically, been seen as secretive and opaque. NDA aims to build a United Kingdom skills framework that supports decommissioning and cleanup over the long term, while helping to manage the inevitable socioeconomic change in the communities close to NDA sites as decommissioning gathers pace. The mission covers several decades but, if successful, will deliver huge returns. The NDA Strategy for delivery was approved by the Government of the United Kingdom in April 2006 and is aimed not only to obtain a better understanding of the task faced, but also to get the work done by a well led, competent, motivated and equipped workforce in ways that are smarter. The key messages are that it is important to identify and fund decommissioning costs and learn the lessons from past waste management. The skills dimension is crucial in the United Kingdom. Life cycle thinking is needed and predictable, long term waste management solutions are essential to success.

1. BACKGROUND AND SCOPE

The Nuclear Decommissioning Authority (NDA) was set up by the Government of the United Kingdom in April 2005 to provide the first ever United Kingdom wide strategic focus on the cleanup of nuclear sites. Its establishment has brought about the biggest change in the structure of the United Kingdom nuclear industry in the last 35 years.

The NDA is responsible for the United Kingdom's civil public sector nuclear legacy. It is based in West Cumbria, England and has four regional offices covering 20 nuclear sites across the United Kingdom. It has an annual budget expenditure in excess of £2 billion and currently it has an income in excess of £1 billion each year. The total cleanup programme is estimated to cost over £63 billion and to take around 120 years to complete. Around 20 000 people work on NDA sites.

The 20 sites are diverse; many have facilities on them that were built in the 1940s but there are also some modern commercial plants. Although decommissioning and clean-up is NDA's focus, its activities also include Research and Development, Construction, Reprocessing, Waste Management and Storage, Fuel Manufacture, Electricity Generation and Transport.

2. DUTIES, MISSION AND DRIVERS

The duties of the NDA are laid out in the United Kingdom Energy Act 2004 and include a duty to: ensure that the civil nuclear legacy is dealt with safely, securely and cost effectively in ways that protect the environment, promote competition in the decommissioning and cleanup market, carry out research and development related to decommissioning, ensure the maintenance and development of decommissioning skills, promote good practice and secure value for money and support the social and economic life of the communities around the sites.

The NDA's mission is 'to deliver a world class programme of safe, cost effective, accelerated and environmentally responsible decommissioning of the United Kingdom's civil nuclear legacy, in an open and transparent manner and with due regard to the socio-economic impact on local communities'.

Hence, key drivers for the NDA are safety, security and environmental performance, finding value for money solutions, making effective use of the supply chain, learning from experience both at home and abroad and fully engaging with stakeholders.

3. THE UNITED KINGDOM'S DECOMMISSIONING CHALLENGE

The first question that has to be asked is: 'Do we understand the job to be done?'

To answer this question the NDA has established common Project Controls processes and procedures across all of its sites and a common Work Breakdown Structure. A Lifetime Plan has been developed at each site with the estimated cost, scope and schedule needed to get the job done. For the first time in the United Kingdom, and perhaps even in the world, these plans have been included into a National Lifetime Plan. (See the NDA web site www.nda.gov.uk for details.)

Assuming that the job to be done is understood, the next question is 'Is the money available and can things be done safer, smarter, cheaper, etc?'

NDA intends to use competition and innovation to not only drive down costs but also, where possible, to accelerate programmes and not leave the United Kingdom's nuclear legacy for future generations to deal with.

Even with these answers, the following question must then be posed: has the United Kingdom got the technological and logistical know how to do the job? NDA cannot physically undertake all of the work to be done simultaneously, so how should the work be prioritized?

NDA has worked closely with its stakeholders to jointly develop a prioritization process to balance factors such as hazard potential, environmental concerns, socio-economic factors, etc. and determine the order in which the problem will be tackled in the United Kingdom.

Athough the Government supports the deep geological disposal of higher activity radioactive waste, it is yet known where a disposal facility will be built, or when. Similarly, the United Kingdom's only operational low level radioactive waste disposal facility is rapidly filling up. NDA is currently actively engaged with industry and its wider stakeholders in discussing these issues and developing innovative solutions to deal with decommissioning waste.

The technical challenges NDA faces are significant but Technology Plans have been developed for each site which identify the technology needed to deliver the Lifetime Plans. A National Research Board has also been established to coordinate the United Kingdom's decommissioning and cleanup research and industry-wide review groups to promote good practice.

Finally, assuming that the job to be done is properly understood, that it can be paid for and that the technological and logistic 'know how' exist, will there be people with the right skills available when they are needed and what will be the effect of NDA's programme on local communities?

NDA has developed skills strategies for each of its sites to deliver the Lifetime Plans. These help to identify 'skills gaps' and to assemble a comprehensive strategy to address them. Initiatives are in place to address skills at all levels in the 'Skills Pyramid' with a National Nuclear Institute and National Nuclear Laboratory planned to develop the post-doctoral skills required to undertake the research necessary to support the United Kingdom's decommissioning programme. The NDA is also creating a National Nuclear Skills Academy to provide the all important vocational skills and standards to undertake the work and the scheme includes initiatives to reach into schools to encourage science, engineering, technology and mathematics learning.

4. NDA STRATEGY

The NDA strategy to meet the United Kingdom's decommissioning and cleanup challenge was approved by the Government in April 2006. This strategy addresses the full range of NDA responsibilities and can be found on the NDA website at www.nda.gov.uk. Put simply, it aims, while maintaining high standards of safety, security and environmental performance, to obtain a better understanding of the job to be done, to get that job done by a well led, competent, motivated and equipped workforce and to get the job done smarter.

5. KEY MESSAGES

The key NDA messages are that it is important to identify and fund decommissioning costs and learn the lessons from past waste management. The skills dimension is crucial in the United Kingdom. Life cycle thinking is needed and predictable long term waste management solutions are essential to success.

DISCUSSION

A.J. GONZÁLEZ (Argentina): What is the role of the NDA with regard to the radioactive releases into the Irish Sea from what used to be called the Windscale facility?

J. WILSON (United Kingdom): The levels of the releases into the Irish Sea, which were through authorized discharges, have gone down and down over the years, and, as you obviously know, the Irish Government, with which the NDA has good relations, is keen on their being carefully monitored. Discharge monitoring is the responsibility of the operator, but as the owners of the site we oversee what the operator does.

A.J. GONZÁLEZ (Argentina): How does the strategy of the NDA fit in with the United Kingdom Government's strategy regarding the promotion of nuclear power?

J. WILSON (United Kingdom): The strategy of the NDA was approved by the Government, so that it has become governmental strategy. The two strategies do not conflict in any way.

J.-M. POTIER (IAEA): What is your strategy for dealing with very low level decommissioning waste?

J. WILSON (United Kingdom): One of our site licence companies, Magnox Electric, which operates reactor sites, is consulting with local people in order to elicit their views regarding the on-site disposal of the very low-level decommissioning waste being produced there, and I understand that the response is quite positive. In such cases, of course, much depends on the envisaged future reuse of the site. Certain reuses would completely rule out the presence of even very low level waste. The on-site disposal of very low level waste is not yet policy as far as we are concerned, but we are thinking about it as an alternative to the transport of such waste to a disposal facility elsewhere.

DECOMMISSIONING PLANNING FOR THE RA RESEARCH REACTOR AT THE VINČA INSTITUTE

V. LJUBENOV
Vinča Institute of Nuclear Sciences,
Centre for Nuclear Technologies and Research,
Belgrade, Serbia
Email: vladan@vin.bg.ac.yu

Abstract

The RA research reactor at the Vinča Institute of Nuclear Sciences operated from 1959 to 1984. In 2002, after 18 years of extended shutdown, the final shutdown of the reactor was declared and preliminary decommissioning activities were initiated. In the paper a review of the activities related to the planning for the RA reactor decommissioning is presented. The status of the organizational and technical aspects of the project, as of June 2006, is presented and plans for the forthcoming project phases are outlined.

1. RA RESEARCH REACTOR AT THE VINČA INSTITUTE

1.1. Main technical characteristics of the RA reactor

The 6.5 MW heavy water moderated and cooled tank type RA research reactor [1–4] at the Vinča Institute was bought from the Institute of Theoretical and Experimental Physics, Moscow in 1955. The reactor has been used for different scientific, medical and industrial applications of neutron and gamma radiation.

The RA reactor facility comprises the main reactor building and several auxiliary structures. They include a ventilation building, a pumping station on the River Danube, a water storage pond in Vinča village (for secondary cooling) and a liquid waste system for contaminated effluents released from operational activities in the reactor building.

The main reactor building comprises a reactor block with an active zone, inner and outer reactor vessels, graphite reflector and biological shield (water layers and heavy concrete) and the components of the heavy water primary circuit (pumps, heat exchangers, reservoirs, a system for coolant purification and helium system components). Many horizontal and vertical experimental channels penetrate the active zone, the reflector and the shielding structures.

The interim spent fuel storage [5–7] and the hot cell compartments are located at the main building. Both systems are interconnected with the reactor system. A total of 8030 spent fuel elements are stored at the RA reactor building, almost all of them in the water filled spent fuel pools. These pools were designed as a temporary storage for the irradiated fuel. The 480 high enriched uranium (HEU) fuel elements used during the final operational period of the reactor have been kept in the 48 fuel channels of the drained RA reactor core since 1984. The heavy water was drained from the reactor core and primary cooling system and stored in the heavy water reservoir beneath the reactor hall.

1.2. Operational history

The RA research reactor went critical in December 1959 and was temporarily shut down in August 1984. Its full thermal power was 10 MW, and it was operated at nominal power of 6.5 MW, except for the last several years of operation when it was operated at a reduced power of 2 MW. From its commissioning in 1960 until 1975, low enriched TVR-S type uranium fuel (2% of ^{235}U) from the former USSR was used. From 1976, the original fuel was gradually replaced by HEU fuel (80% of ^{235}U). The reactor was stopped in 1984 for modernization and the partial reconstruction of its control and safety systems.

Several events that occurred during the period of reactor operation had consequences that have strongly influenced the present radiological status of the facility [8]. The most important of the events are: contamination of the primary coolant circuit by ^{60}Co in 1963, a spill of about 300 L of heavy water from the primary cooling system during repair work in 1965, a fuel element failure in 1970 and the dispersion of radioactive dust containing ^{60}Co from the hot cells in the early 1980s.

1.3. Decision to decommission

For a number of technical, regulatory and economic reasons, the reactor was not restarted during the long period of extended shutdown [9]. A proposal for the final shutdown and decommissioning of the reactor was submitted to the Government in 2001 [10] and the final shutdown was declared in July 2002. All fresh HEU fuel was shipped to the Russian Federation in August 2002.

The preparatory activities for decommissioning have been supported by the IAEA through the technical cooperation programme project SCG4004, since 2003. The Serbian Government established regular funding for the RA reactor decommissioning project starting in October 2004. The decommissioning project is part of the Vinča Institute Nuclear Decommissioning (VIND) Program [11] whose main objective is to improve nuclear and radiation safety at the Vinča Institute by repackaging and shipping the spent nuclear fuel back to the Russian Federation, by decommissioning the RA reactor and by improving the radioactive waste storage and treatment capabilities of the Institute.

2. DECOMMISSIONING PLANNING

2.1. Establishing a decommissioning team

During the RA reactor design, construction, operation and extended shutdown there was no planning for the decommissioning phase; as a result, no decommissioning oriented team was assembled and an initial decommissioning plan was not prepared. The RA reactor staff had been significantly reduced during the period of extended shutdown and the decommissioning project was faced with a lack personnel having experience from the operating phase.

The approach chosen to accomplish the RA reactor decommissioning is that the Vinča Institute will be the licensee and will perform the project with in-house resources supplemented by specialist contractors, as needed. The project team has been assembled from available personnel of two Vinča Institute organizational units: the Centre for Nuclear Technologies and Research (NTI) and the Radiation and Environmental Protection Laboratory. The team is organized in two main functional divisions: Planning and Operations. The planning division consists of experts in reactor physics, nuclear engineering, radiation protection and waste management and is in charge for the planning, costing, quality assurance, health and safety, personnel training and administration services. The operations division comprises maintenance, characterization, cleanout, waste management and record keeping groups. The core of the second division has been formed from the existing RA reactor staff in order to gain maximum benefit from their experience gathered during the extended shutdown period and their familiarity with the reactor facility and site.

Support to the RA reactor decommissioning team will be provided by the existing Institute services (health physics, medical protection, fire protection, physical protection, export-import, administration).

2.2. Project goals and decommissioning strategy

The objective of the RA reactor decommissioning project is to implement safe, timely and cost-effective decommissioning of the facility to enable the unrestricted use of the reactor building for other purposes. Immediate dismantling has been selected as the optimal decommissioning strategy.

The short term project goals (before the removal of the spent nuclear fuel) are to:

- Prepare the RA Research Reactor Decommissioning Plan;
- Perform a radiological characterization of the facility;
- Remove all the materials and equipment from the RA reactor building that are not needed during the reactor dismantling;
- Regularly maintain all the systems necessary to ensure safe working conditions inside the building.

The long term project goals (after the spent fuel removal, i.e. transport of the spent fuel to the country of origin or after the adequate long term storage somewhere outside the RA reactor building) are to:

- Complete reactor decommissioning according to the selected decommissioning strategy;
- Remove from the building all the reactor structures, components, systems and all the radioactive and hazardous materials generated and accumulated during the facility lifetime to the extent that will allow unrestricted use of the reactor building for other purposes;
- Conduct all the activities so that the safety of the workers, Institute employees, general public and the environment is assured, according to the requirements of the relevant national legislation, following international recommendations and good practice, in a timely and cost effective manner;
- Document all the activities as required by the legislation and by the quality assurance programme;
- Obtain knowledge and experience in state-of-the-art methods and technologies for research reactor decommissioning and to offer them to the market.

The Decommissioning Plan is assumed to be the main safety related document, which will be submitted to the regulatory body for approval and against which the decommissioning licence will be issued. The content of the Decommissioning Plan has been defined according to IAEA recommendations [12]. During the preliminary planning, a strategy option study was performed in which the advantages and disadvantages of three basic strategies were analyzed (immediate dismantling, deferred dismantling and entombment). Immediate dismantling has been proposed as an optimal strategy for the RA reactor decommissioning [13].

2.3. Main project phases and activities

The main phases of the project include: radiological characterization of the reactor site, preparation of the detailed decommissioning plan, removal of waste and materials from the reactor building, the dismantling and removal of the reactor components and structures, decontamination, the final radiological site survey and the documentation of all the activities in order to obtain the approval for unrestricted use of the facility site.

The MS Project software tool is being used for scheduling the project and for resource management; it involves five levels of detail for earlier phases and four levels for later project phases (before and after spent fuel removal). The duration of the decommissioning project is estimated to be 10–12 years. This time schedule is driven by the progress of the spent fuel and waste management projects, but also by the funding capabilities of the State budget as a main funding source. In the first phase of the project, the main activities are related to the review of the reactor documentation, decommissioning planning, radiological characterization and the removal of existing waste and experimental equipment from the reactor hall.

The dismantling of the reactor components and systems will start after the removal of the spent fuel from the reactor building. At the beginning of this phase, the outer reactor systems and components (located outside the reactor block) will be dismantled. These activities will be performed at the underground level of the reactor building where the components are located, using a ’room by room’ dismantling approach. Dry mechanical cutting is planned to be the main technology used. Mechanical decontamination will be used for the removal of low level surface contamination from the building surfaces and from the materials that can be recycled or reused. In this way, the generation of secondary and liquid waste will be kept to a minimum. After this, the reactor block will be removed starting with the reactor internals, continuing with the removal of the inner vessel, the graphite reflector, the outer vessel, the experimental channels and graphite column and finishing with the demolition of the heavy concrete biological shielding. Underwater cutting is being considered as a possible method for the dismantling of the reactor internals. Remotely controlled tools will be needed for this operation as well as for the demolition of the concrete biological shielding of the reactor.

At the present time, there have been no requests from other organizations to use the hot cell compartment and the ventilation building of the RA reactor. Their decommissioning is included in the preliminary list of the decommissioning activities, but a final decision has not yet been made.

2.4. Main radiological risks

During the implementation of the decommissioning strategy, the main radiological risks will be associated with the dismantling of the reactor block, the primary coolant circuit and the hot cell compartment. A basic assumption of the decommissioning project is that spent fuel will be removed during the transition period, but that the remaining pool water, contaminated structures, sludge at the pool bottom and some of the repackaging waste and tools will have to be managed within the reactor decommissioning project. The used filters from the water purification system in the spent fuel area will also present a significant radiological hazard.

The activation of the reactor internals and the surrounding structures in heavy water reactors may result in a radionuclide inventory equal to or even higher than that in the spent fuel. For example, a CP-5 heavy water reactor (similar to the RA reactor) inventory in the reactor vessel, reflector and bioshield was 32 000 TBq, while in the spent fuel it was 3200 TBq [14]. Particularly high activation is expected in the vicinity of the experimental channels and the thermal column. During the planning phase, special attention is being given to the determination of the trace elements in the shielding structures, which may contribute significantly to the total activation inventory. Heavy water has also to be considered as an important issue. For example, the specific activity of the heavy water of a Russian 2.5 MW research reactor was more than 0.2 TBq/L. The total activity in the 5.5 m^3 of irradiated heavy water in the RA reactor could therefore contain more than 1000 TBq, while the total activity of the spent fuel is about 4000 TBq [16].

As a result of a design error in 1963, the entire primary coolant loop of the reactor was contaminated by cobalt. The heavy water pumps were originally designed for the chemical industry and possible neutron activation was not considered during their design. Thus, the shaft bearings of the pumps were coated with a steel alloy of high cobalt content. During its use in the reactor cooling system, erosion products with a high content of cobalt were activated in the active zone and then spread by the heavy water flow throughout the system. Although the shaft bearings were replaced and the chemical decontamination of the entire primary cooling circuit was performed in 1963, the remaining cobalt activity in all the primary coolant system components is rather high, even after more than 40 years of decay.

The hot cell compartment is located on the underground floor of the main reactor building, giving access to the reactor room and the spent fuel storage room. It consists of one main cell and three auxiliary cells. All the cells are highly contaminated, especially the main one, including the equipment and the devices inside them. Many and various radioactive sources are stored in the cells at the present time, as well as one damaged irradiated fuel element. The removal of the sources should be carried out during the transition period.

2.5. Non-radiological risks

During the implementation of the work, the radiological hazards will decrease but the level of the non-radiological hazards will remain high until the project is completed. The main non-radiological risks are related to the use of cutting devices, materials handling, working at heights, the presence of chemicals, asbestos and other hazardous materials, high voltages, high noise levels, risk of fire due to flammable gases, liquids and combustible materials, hazards from compressed gases, biological materials, degraded or degrading structures, systems and components.

Internal training organized during the transition phase covered the following topics: first aid, radiation protection, working with the radiation sources, industrial safety, characterization surveying, clearance of materials and it included the training and certification of the operators of the overhead cranes and of welding operators. Similar training will be organized during the decommissioning implementation phase on a periodic basis, as well as specific training related to the selected dismantling technologies and tools.

2.6. Safety and environmental protection

Safety and environmental impact assessments are being carried out based on the deterministic analyses of up to a dozen scenarios (both normal and accidental) and considering extreme unmitigated consequences. The safety of the workers, the public and the environment during the implementation of the decommissioning activities will be ensured by careful planning, adequate training of the workers, proper work organization, the use of protective equipment and the regular maintenance of the equipment and tools.

The majority of the dismantling activities will be performed inside the reactor building. The existing ventilation system ensures that zones with higher risks of generating contamination are kept under lower pressure, preventing the spread of contamination in the event of an accident. Portable ventilation and filtration units with temporary tents will be used to isolate working areas and to minimize the possibility that other zones will be affected. All the pathways to the environment will be monitored and the ventilation lines will be filtered. Airborne and effluent monitoring will be established in the working areas and at the ventilation exhaust stack. Proper protective clothing and respiratory protection will be available for the workers. Sanitary admittance areas and whole body contamination monitors will be established at the entrance points of the working zones. Individual thermoluminescent dosimeters (TLDs) and direct reading electronic dosimeters with appropriate alarm levels will be used during the work. Radiation protection specialists will be present throughout the dismantling and decontamination work at the reactor site. All the personnel involved will be properly trained. Detailed working procedures will be prepared and approved in advance to minimize identified radiological and industrial hazards. A graded and phased approach and a policy of defence in depth are being followed in the decommissioning safety assessment in order to define appropriate preventive and mitigating measures, both engineering and administrative. Medical surveillance of the workers will be performed on a periodic basis with additional examinations before and after some operations of higher risk. All the activities will be documented according to the record keeping programme and quality assurance requirements.

2.7. Waste management issues

The Vinča Institute served for many years as the national storage facility for radioactive waste from all institutional (scientific, medical, industrial, etc.) activities. The main fraction of the waste is stored in two metallic hangars (H1 and H2). In addition, underground stainless steel tanks in concrete shields have been constructed to accept all processed liquid waste from the RA reactor. The current situation at Hangar 1 ('old hangar'), with the significant deterioration of the building structures, the presence of contamination inside the hangar and generally bad condition of the waste, is unacceptable from a safety point of view. Hangar H2 does not have enough capacity to accept all the waste from the spent fuel removal and the reactor decommissioning project. Proper treatment, repackaging and storage of the historical waste from H1 in a new storage facility is needed.

The waste management issues of the VIND Program are being addressed in the project 'Safe Management of Waste in the Vinča Institute'. In the first phase of this project, a new waste processing facility for waste characterization and treatment and a new waste storage hangar H3, with secure storage for high intensity sources, are to be commissioned. These new facilities should enable the existing situation in hangar H2 to be improved, the liquid waste in underground VR basins to be treated, hangar H1 to be decommissioned, and the waste from the RA reactor decommissioning and from the spent fuel removal to be properly treated and stored.

Plans for a final repository for radioactive waste do not yet exist in the country. Nevertheless, decommissioning waste should be stored in a form that allows it to be transferred to final storage with minimal further handling and processing requirements. All the radioactive waste generated from the decommissioning activities before the commissioning of the new hangar and the waste processing facility will be segregated, packed according the waste acceptance criteria for the hangers (mainly in 200 L drums) and temporarily stored in one room inside the reactor building that has been cleaned and prepared to serve as a storage place. After the clearance procedure, non-radioactive waste from decommissioning will be transferred for conventional disposal, while valuable materials for reuse or recycling will be placed in a previously adapted storage place in the Institute.

2.8. Funding and cost estimate

The RA reactor decommissioning is being implemented in a scientific institute. In its preparatory phase (transition period), project implementation is funded from the State budget through the Ministry of Science and Environmental Protection based on one year contracts between the Ministry and the Institute. The rules related to the funds from this Ministry are established in a way that is optimal for the needs of research projects, but they are also being applied for the VIND Program projects even though they are not adequate for such projects since they are quite different from projects of the scientific type. Recently, a new Law on Scientific and Research Work was established which introduced further limitations for the projects and implementing organizations.

In contrast, there has been a positive experience in the country, and at the Institute, with the past funding of engineering projects and such an approach might be followed for the VIND program. Funding of the VIND Program directly by the Government might help in overcoming the existing limitations.

Implementation of decommissioning activities (dismantling phase) will be funded from the State budget, with minor involvement of foreign donors. The main part of the principal donor's contribution is planned to be used for the shipment of the spent nuclear fuel and for the construction of the new waste processing and waste storage facilities.

The final cost estimate for the decommissioning project has not yet been prepared. Based on available information for a similar completed project, taking into account the lower labour costs but also some specific technical conditions of the facility (cobalt contamination of the primary circuit, caesium contamination of the spent fuel pool, the expected higher activation of the biological shielding), a first rough cost estimate is in the range of €10–15 million. This amount does not include spent fuel shipment and waste treatment and storage costs.

2.9. Legislative system and regulatory process

The general support of the Government to start the preparation for decommissioning was obtained in 2002. In its early phase, the project was faced with the absence of a legal framework and a regulatory body, a lack of funding and no clear governmental policy regarding radioactive waste management.

The existing Law on Ionizing Radiation Protection [17] does not provide regulations for decommissioning. It establishes measures for ionizing radiation protection, as well as nuclear safety measures, liability for nuclear damages, supervision and authorization, and penalties. There are eleven regulations related to ionizing radiation protection and the safety of radiation sources and five regulations related to nuclear installations.

A temporary regulatory body (the Regulatory Commission for Nuclear Safety) was established in 2005. This Commission is an advisory body of the Serbian Minister of Science and Environmental Protection and is currently responsible for making decisions in the regulatory process.

A draft of the new Law on Ionizing Radiation Protection and Nuclear Safety has been prepared on the basis of the existing national legislation, the safety standards of the IAEA, the European Union (EU) and other international recommendations. It is expected to enter Parliament soon and to be adopted by the end of the year. This law envisages the establishment of the Agency for Radiation Protection and Nuclear Safety as the regulatory body in Serbia.

2.10. Expert and technical support and international cooperation

Expert and technical support has been provided by the IAEA. Several workshops were held at the Vinèa Institute (Basics of Decommissioning, Project Management, Characterization Surveying, Cost Estimation) and two visits made to facilities under decommissioning (ASTRA reactor at ARC Seibersdorf, Austria, SAPHIR and DIORIT reactors at the Paul Scherrer Institute, Switzerland). Project implementation has also been supported by the provision of equipment for sampling, survey, decontamination, cutting and cleanout activities, as well as for ventilation, contamination control and personal safety. This kind of support is expected to continue in the next project phases with the focus on dismantling technologies and tools and the preparation of specific safety assessments for the particular dismantling operations.

Wide international cooperation with the institutions and organizations performing similar projects has been established. The institutions involved in this cooperation up to now are:

— IAEA — support through the technical cooperation programme SCG4004 project, participation in the R^2D^2P, DeSa and RER/059 projects.
— China Institute of Atomic Energy (CIAE) — exchange of visits; the RA reactor and HWRR research reactor in CIAE are very similar facilities.
— Austrian Research Center, Seibersdorf — experience from the ASTRA reactor decommissioning project.
— Paul Scherrer Institute, Villigen, Switzerland — experience from the SAPHIR and DIORIT reactor decommissioning projects.
— Georgia Institute of Technology and CH2M HILL company — experience from the GTRR reactor decommissioning project.
— Slovenian Nuclear Regulatory Body and Jozef Stefan Institute (Triga reactor).
— Bulgarian Institute of Nuclear Research and Nuclear Energy in Sofia, Kozloduy Nuclear Power Plant, Bulgarian Nuclear Regulatory Body.

3. CURRENT STATUS OF THE TRANSITION ACTIVITIES — JUNE 2006

After the declaration of the final shutdown, the transition period from operation to decommissioning started. This is the project phase before the start of the implementation of the dismantling activities [18, 19]. The project has been in the transition phase since 2002 and several preparatory activities for the RA reactor decommissioning project are currently in progress (it does not include preparations for the repackaging and removal of the spent fuel):

— Preparing the Decommissioning Plan and other supporting documents;
— Preparation and implementation of the radiological characterization of the facility;
— Removal of the operational waste from the reactor building;
— Regular maintenance of the reactor systems and reactor building.

In the 2003–2005 period the following preparatory and planning activities were carried out [20, 21]:

— All the available reactor documentation was reviewed and organized in an electronic database and an adequate document control system was established;
— The comparison of the existing facility layout with the reactor documentation was completed;

- A strategy options study was performed and immediate dismantling was selected as the optimal decommissioning strategy;
- The RA Reactor Transition Plan was prepared;
- The following sections of the Decommissioning Plan were prepared: Introduction, Facility Description, Decommissioning Strategy, Decommissioning Activities, Project Management, Surveillance and Maintenance Plan, Waste Management Plan, Physical Protection and Safeguards.

The preparation of the Safety Assessment, Environmental Impact Assessment, Health and Safety Plan, Emergency Plan and Quality Assurance Plan are in progress. These documents and studies will be completed in 2007, when the remainder of the Decommissioning Plan sections are also expected to be completed (Cost Estimate and Funding Mechanisms and Final Survey Plan). The Health and Safety Plan, Emergency Plan and Quality Assurance Plan should be based upon the upper level Institute documents, but should elaborate some specific project aspects. There are three levels of documents that have to be followed in the implementation of the decommissioning project: national laws and regulations, Institute regulations and plans and facility/project rules, regulations and plans. Due to the recent changes in the country that affect the organization and responsibilities of the relevant authorities, the upper level documents (national and Institute) are in the process of amendment. The detailed revision of all of the sections of the RA reactor Decommissioning Plan is planned for 2007 in order to include all the information and data obtained in the meantime, especially the results of the radiological characterization which is still in progress.

In the previous period, a physical characterization of the RA reactor building and systems was performed as well as the comparison of the existing layout with the relevant technical documentation. All the differences noticed have been recorded and appropriate links with the documents have been established in the RA reactor documentation data base. The Characterization Plan [8] for the RA reactor has been prepared. The operating history of the facility was reviewed and the available data on the events with radiological consequences were collected. Detailed three-dimensional reactor models will be used for the numerical calculation of the neutron induced radioactivity in the reactor core components and surrounding shielding structures. Original calculation methodologies based on reference computer codes have been developed and data libraries have been prepared for that purpose. Detailed drawings of the majority of the RA reactor rooms have been prepared for the needs of the sampling and analysis plan implementation. The measurement equipment needed for the radiological survey of the reactor rooms, systems, materials and equipment has been obtained. The training of the workers for the radiological survey has been completed and the relevant working procedures and paper forms have been prepared. A Characterization Database for the efficient organization and management of the wide range of characterization results has been prepared. A radiological survey was started in November 2005, comprising direct measurements, sampling and laboratory analyses of the samples taken. After its completion in 2007, a Characterization Report will be prepared.

After the RA reactor final shutdown, experimental equipment, different kinds of waste, tools and materials were stored mainly around the reactor block inside the RA reactor hall; the majority were contaminated or potentially contaminated. During 2004, a significant part of the clean items was removed from the reactor hall. The valuable materials for reuse or recycling were transferred to a previously prepared internal store in two underground rooms of the RA reactor building awaiting further treatment. The rest of the material located in the reactor hall is either needed for further work or is potentially contaminated.

In 2004 and 2005 an inventory of the materials to be removed was prepared. Due to limited storage capacity in the two existing hangers for low and intermediate radioactive waste it was decided to prepare temporary storage area for radioactive waste inside the reactor building. In the basement of the reactor building one clean room was selected and prepared for the storage of the drums containing radioactive materials. In 2005, building No. 41 of the Institute was selected and prepared for the storage of non-radioactive materials and equipment. Clearance procedures, waste segregation and packaging procedures were implemented according to the waste acceptance criteria for the storage of radioactive waste in the hangers. The reactor staff was appropriately trained for these activities.

In November 2005, the systematic removal of the materials from the reactor hall was started based on the performance of clearance measurements. Radioactive waste is being packaged in 200 L drums while the clean items are being transferred to the storage building. This process is still not completed. Some of the items will require additional consideration regarding the applicability of decontamination techniques in order to minimize the waste generated. This cleanout of the working areas will significantly reduce the existing radiological and non-radiological hazards present inside the reactor building before the beginning of the dismantling activities.

Removal of the operational fluids from the reactor systems was carried out during the extended shutdown but they still have not been removed from the site (they are stored in appropriate storage tanks).

4. CONCLUSIONS AND LESSONS LEARNED

4.1. Organization and team

A new organizational structure and management system were established for the RA reactor transition and decommissioning. The operating organization was found to be inadequate to meet the needs of decommissioning. The transition team was partly extracted from the operating team as it was recognized that operator's expertise and knowledge is vital.

Social aspects and psychological effects must be taken into account during decommissioning planning. One issue is the uncertainty experienced by operating staff about their future employment. The RA reactor decommissioning team consists of the RA reactor personnel from the extended shutdown period and the research staff of the former Nuclear Engineering Laboratory, which was operator of the RB critical assembly. During the last three years it has not been easy to maintain the motivation of the personnel for the 'destructive' work that will close possibilities for research in the nuclear field".

The restructuring of the organization for decommissioning is still not completed. The change from an operating regime with quite different goals to one aimed at demolition, dismantling and disposal is not easy to achieve in a research institute environment.

4.2. Regulatory framework

The lack of adequate national legislation during the initial project phase has led to the use of IAEA guidance and recognized good practice as a substitute. The Vinča Institute as operator has initiated the improvement of the regulatory framework for decommissioning and the re-establishment of the regulatory process in the country.

Changes in legislation should be anticipated in order to limit the impact on projects. (In our case this was possible as member of the decommissioning team was involved in the drafting of the new law.)

4.3. Planning

The Decommissioning Plan is a living document whose preparation has an iterative nature. The planning team should prepare the Decommissioning Plan using the best available data, without waiting for all information considered to be important for the specific topic to be collected.

The extended shutdown period should be used to prepare or update the initial decommissioning plan, even if a restart is expected.

The development of a comprehensive inventory (radioactive and non-radioactive material) is a necessary prerequisite for all planning, especially planning for waste management. The radionuclide inventory in the structures and liquids of a heavy water reactor may exceed the spent fuel inventory.

The radiological characterization of the facility should be performed before the preparation of the detailed decommissioning plan in order to provide information for the selection of the strategy and the technologies, the estimation of waste amounts and the cost estimation. The removal of materials, equipment and operational waste stored on site should be completed before the characterization. Although it is possible, the parallel performance of planning, characterization and waste removal can cause delays due to the interdependence of these activities.

A general safety case covering the common aspects of multiple projects performed on site can be useful when limited human resources are available on both the sides of the operator and the regulator.

MS Project software has been found to be a good tool for scheduling and resource management.

4.4. Experience

RA reactor decommissioning planning was initiated almost 20 years after shutdown and the project was faced with a lack of expertise, reduced facility knowledge and the absence of any decommissioning experience. The lack of appropriate training for both management and workers, the lack of equipment and financial resources at the very beginning of the project and the absence of a regulatory framework, together with the belief among staff that the facility would somehow be restarted, had a negative effect on staff morale. This was resolved by retraining the in-house staff and involving IAEA experts extensively.

4.5. Waste management

Waste management is an essential part of decommissioning planning. Dismantling and decontamination activities can be seriously affected if adequate provisions are not made or are not available at the appropriate time. In Serbia, disposal routes for decommissioning waste are not yet available and even the storage capacities are not yet adequate.

When there is an absence or inadequacy in waste storage capacity, temporary on-site storage for radioactive waste can be provided in empty reactor rooms.

4.6. Funding

Insufficient provision of financial resources for decommissioning is one reason for the start of decommissioning being delayed. The lack of decommissioning funds for the research reactors in State ownership has been observed in many countries. Involvement of foreign donors can help in establishing the decommissioning projects, but the basic funding should be the responsibility of the State.

4.7. Records

Documentation especially important for decommissioning should be identified, sorted, labelled and organized in a way that will enable efficient search by keywords. An electronic database of the reactor documentation with a supporting document control system can be used to efficiently support decommissioning planning activities.

It is almost impossible to obtain accurate information about the facility condition and the material inventory from the records and documentation - even if they are very well preserved and maintained. Comparison of the existing facility layout with the documentation may help in the preparation of a comprehensive facility inventory. It is necessary to perform a visual inspection of components, especially on old facilities where the drawings often do not reflect the ‘as-built’ status. Interviews with the former workers can fill existing information gaps, especially regarding the incidents and contamination spills.

4.8. Public relations

Involvement of the public (including the research staff of the Institute) in the early phase of the project can prevent negative reactions. A Public Relations Plan should be prepared and the positive impact of the decommissioning activities on safety should be stressed. Written information for the media or on the web site is recognized as a very effective communications channel to the public.

ACKNOWLEDGEMENTS

This paper describes results of the work done in the preparatory phase of the project ‘Decommissioning of the RA Research Reactor in Vinča Institute’. The project is funded by the Ministry of Science and Environmental Protection of the Republic of Serbia and is supported by the IAEA through technical cooperation programme project SCG 4004. The author of the paper is grateful to D. Reisenweaver of the IAEA for his expert support and guidance.

REFERENCES

[1] Final Project Documentation of the RA Reactor, The RA internal documentation, IBK, Vinča (1960) (in Russian)

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Directory of Nuclear Reactors, Heavy Water Research Reactor RA, Vol. V, IAEA, Vienna (1964) 217–222.

[3] MILOŠEVIĆ, M., MARTINC, R., "Nuclear reactor RA", Proc. Conf. on The Application of Nuclear Reactors in Yugoslavia, Belgrade, 1978 (1978) 81–97.

[4] ŠOTIĆ, O., et al., Final Safety Analysis Report of the Nuclear Reactor RA, Vol. 1–17, Institute of Nuclear Sciences "Boris Kidrič" Vinča (November 1986) (in Serbian).

[5] Study on Spent Fuel Storage Pool of the Reactor RA, Internal Report Z5.A1.4, Institute of Nuclear Sciences "Boris Kidrič", Vinča (November 1984) (in Serbian).

[6] MILOŠEVIĆ, M.J., PEŠIĆ, M., An Analysis of Burnup Reactivity Credit for Reactor RA Spent Fuel Storage, Nucl. Eng. Design **180** (1998) 29–35.

[7] MILOŠEVIĆ, M.J., VUKADIN, Z., "An analysis of spent fuel characteristics for Reactor RA spent fuel elements", Proc. 3rd Int. Yugoslav Nuclear Society Conference (YUNSC-2000), Beograd 2000 (ANTIĆ, D., Ed.) (2001) 203–216.

[8] MILOŠEVIĆ, M., LJUBENOV, V., Radiological Characterization Plan for the Purpose of Decommissioning of the RA Research Reactor in Vinča Institute of Nuclear Sciences, Contract Initial Planning for the Decommissioning of the RA Research Reactor, Rep. YUG4028-92441A, (2003).

[9] PEŠIĆ, M., et al., "Causes of extended shutdown state of RA Research Reactor in Vinča Institute", IAEA Regional Workshop on Extended Shutdown and Decommissioning of Research Reactors, Riga 2001, IAEA Vienna (2001).

[10] LJUBENOV, V., PEŠIĆ, M., ŠOTIĆ, O., "RA Research Reactor in Vinča Institute — Approach to the decommissioning", Proc. 4th Yugoslav Nuclear Society Int. Conf. Beograd, 2002, YUNSC 2002 (CD-ROM edn), (ANTIĆ, D., Ed.), (2002) 373–382,

[11] PEŠIĆ, M., et al., "Vinča Institute Nuclear Decommissioning Program", Proc. XLVI Yugoslav Conf. ETRAN, Banja Vrućica, 2002, Vol. IV (MILOŠEVIĆ, M., Ed),) (2002) 21–30.

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content of Safety Related Decommissioning Documents, Safety Reports Series No. 45, IAEA, Vienna (2005).

[13] KOSTIĆ, L.J., LJUBENOV, V., Strategy Options Study and the Selection of Optimal Strategy for the RA Reactor Decommissioning, Contract Initial Planning for the Decommissioning of the RA Research Reactor, Rep. YUG4028-92441A (2003).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning Techniques for Research Reactors, Technical Reports Series No. 373, IAEA, Vienna (1994).
[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning Techniques for Research Reactors, IAEA-TECDOC-1273, IAEA, Vienna (2002).
[16] MILOŠEVIĆ, M., Safe Removal of the Spent Fuel of the Vinča RA Research Reactor, IAEA project SCG/4/003, contract SCG/4/003-89102A Determination of Neutron and Gamma Ray Dose Rate on the Outer Surface of Existing Containers with Irradiated Fuel in the Spent Fuel Storage Used in the RA Reactor Building, Final Report.
[17] Law on Ionising Radiation Protection, Sl. list SRJ, Nr. 46/96, Belgrade (1996) 1–16.
[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Transition from Operation to Decommissioning of Nuclear Installations, Technical Reports Series No. 420, IAEA, Vienna (2004).
[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities, Safety Reports Series No. 36, IAEA, Vienna (2004).
[20] LJUBENOV, V., et al., Final Report on the Contract YUG4028-92441A Initial Planning for the Decommissioning of the RA Research Reactor, IAEA TC Programme (2003).
[21] LJUBENOV. V., et al., Radiological Characterization of RA Research Reactor and Decommissioning Planning, IAEA TC Programme, Contract SCG 4004-80400A, Progress Report (July 2004).

DISCUSSION

N. ARKHANGELSKY (Russian Federation): What are your plans regarding purification of the heavy water that was used as a moderator?

V. LJUBENOV (Serbia): Liquids generally are going to be a problem for us as we have no purification capabilities. Besides the heavy water, we will have to purify the water in the spent fuel pools and water from the spent fuel containers. Negotiations are currently under way with Russian partners on how to solve this problem.

PLANNING FOR THE DECOMMISSIONING OF A HEAVY WATER RESEARCH REACTOR

C. HU
China Institute of Atomic Energy,
Beijing, China
Email: cwhu@ciae.ac.cn

Abstract

The Heavy Water Research Reactor (HWRR) was constructed and put into operation in 1958 at the China Institute of Atomic Energy (CIAE), located in the suburbs of Beijing. It was the first nuclear reactor in China. The HWRR is a 10 MW multipurpose research reactor and has been operated for 48 years. Because of its long operating history and aged equipment, it is scheduled to be finally shut down by the end of 2007. It has been decided by CIAE to implement a strategy of immediate dismantling after final shutdown. The paper describes the preparation work for the development of the HWRR decommissioning plan at CIAE. The establishment and organization of the project and the problems encountered are described. Progress and problems are addressed. The paper also discusses the measures needed for the successful planning of decommissioning.

1. INTRODUCTION

The Heavy Water Research Reactor (HWRR) was constructed and put into operation in 1958 at the China Institute of Atomic Energy (CIAE). It was the first nuclear reactor in China and is located in the suburbs of Beijing. The HWRR is a 10 MW multipurpose research reactor that has been operated for 48 years. Because of its long operating history and aged equipment, it is scheduled to be finally shut down by the end of 2007. A decision in favour of a strategy of immediate dismantling has been made by CIAE.

The safe, timely and cost effective decommissioning of the HWRR is an important and sensitive issue. There are many technical issues concerned with the decommissioning of the HWRR because of its complicated structure, relatively high thermal power and long operating history. The HWRR is currently under the IAEA's safeguards system. It will be the first nuclear reactor under the safeguards system to be decommissioned in China. The experience gained through the HWRR decommissioning will be very valuable for the decommissioning of other nuclear facilities and for the further development of the nuclear programme in China.

To prepare for the HWRR decommissioning, the development a decommissioning plan has been initiated. A comprehensive project for the preparation and transition periods of HWRR decommissioning was submitted for inclusion in the Government's five year plan. The lack of decommissioning experience in China, especially in relation to key techniques, is a major problem to be faced. The project has benefited from national supporting investigations and international cooperation.

2. TECHNICAL BACKGROUND

The HWRR core is a tank type structure with graphite as a reflector. Heavy water serves as moderator and coolant. The reactor fuel is ceramic UO_2 with ^{235}U of 3% enrichment. The rated thermal power is 10 MW and the strengthened power is 15 MW. The highest thermal neutron flux is 2.8×10^{14} n/cm^2·s.

In the past decades, a great deal of research and technical applications work has been carried out using the reactor:

— Reactor physics and thermal hydraulics;
— Radiation protection and monitoring;
— Irradiation of nuclear fuel rods;
— Neutron activation analysis;
— Production of radioactive isotopes;
— Technical services for nuclear power plants;
— Reactor operations management;
— Training of reactor operators.

A number of renovation and improvement projects at the HWRR have been carried out. During the period 1979–1982, the inner vessel and two main heat exchangers were changed, chemical decontamination of the primary coolant system was performed, the fuel was changed from metal uranium to ceramic UO_2, and, as a result, the HWRR was significantly upgraded, e.g. its thermal power was increased by 40% and its thermal neutron flux was doubled. In the 1990s, a number of systems were updated, such as, the safety systems, the central control room, the instrument monitoring system and the fire alarm system. The experience gained in all of these operations is valuable for HWRR decommissioning.

3. DECOMMISSIONING PLANNING

At the present time the HWRR is still in operation. The reactor was operated for 11 cycles in 2005 with 21 days per cycle. Because of its long operating history, however, most of the equipment is aged and outdated. As a replacement, the new 60 MW CARR (China Advanced Research Reactor) is under construction and will be put into operation late in 2006 at CIAE. It was decided by CIAE to finally shut down the HWRR by the end of 2007. After final shutdown and a transition period of 2–3 years, immediate dismantling of the HWRR will be carried out. The final HWRR decommissioning goal is to reuse the facility as a educational exhibit for the public.

Four phases are proposed for the HWRR decommissioning. The main activities in each phase are described as follows:

- **Preparation Period (2005–2007):** The national project proposal will be developed, including the preliminary decommissioning plan, the compilation of technical files and history/event records and the planning of the characterization and personnel training.
- **Transition Period (2008–2010):** The fuel will be discharged and the coolant drained, the spent fuel will be transported away from the reactor, special decommissioning facilities (e.g. ventilation and radiation protection systems) will be reconstructed and an application will be made for the decommissioning licence.
- **Implementation Period I (2011–2015):** The systems and equipment outside the reactor will be dismantled and removed, the water in the spent fuel pool will be disposed of and the radioactive structures will be decontaminated.
- **Implementation Period II (2016–2020):** The reactor core, inner components, experimental tubes, graphite reflector and bioshield water tank will be dismantled and removed, the reactor concrete body will be decontaminated and the site will be decontaminated and restored.

In parallel with this project, the China National Nuclear Safety Administration (NNSA) is implementing a project entitled “Safety Criteria and Guidelines for Radioactive Waste Management”. One of its main objectives is to develop a regulatory control programme for the management of radioactive waste generated as a result of the decommissioning of nuclear installations, with emphasis on research reactors.

4. CURRENT ACTIVITIES

The project organizations have been designated and their responsibilities assigned. At the institute level, a steering committee on waste management and decommissioning was established for overall planning, project submission and coordination of departments, such as the Departments of Reactor Engineering, Radiochemistry and Health Physics. At the department level, the HWRR Decommissioning Office has been established for establishing the project and managing it. At present, three working groups have been formed with focus on planning, technology and safety/environmental assessment, respectively.

The HWRR decommissioning at CIAE has been included in the 11th five year plan of the Government and is one of the key engineering projects for the next 20 years of national planning. A national programme on waste management with a financial support of US $44 million from the Government is being carried out at CIAE. A project proposal for the preparation and transition periods of HWRR decommissioning, with total budget of about $6 million, has been submitted to the national authority. The proposed tasks include decommissioning planning, spent fuel transportation and system renovation.

A technical cooperation project has been established by the IAEA to assist the CIAE in the development of the decommissioning plan and for acquiring know-how in state of the-art key decommissioning techniques. The project is composed of expert missions, fellowship training and equipment procurement, and is currently being implemented. It has enhanced the capability for decommissioning planning at CIAE.

Good progress is being made in the development of the HWRR decommissioning plan. The transportation plan for spent fuel has been developed. The reactor operating documents, including operating records, records of events and documentation of previous technical renovations have been collected and organized. The characterization survey has been initiated. Key research projects on decommissioning techniques and waste management are being investigated.

5. SUMMARY

The decommissioning plan will contribute toward minimizing the amount of waste produced, the exposure of personnel, environment releases, project costs, and will help to enhance the reuse rate of equipment. Since the HWRR is still in operation and performing a number of tasks, insufficient funds and labour were put into decommissioning preparations so that the process was slowed. The lessons learned through the preparation work for the HWRR decommissioning are as follows:

- Governmental support for decision making and provision of funds is critical for the establishment and implementation of decommissioning projects.
- Close cooperation with the regulatory bodies facilitates the licensing process.
- The coordinated waste management project carried out at CIAE will provide a good basis for HWRR decommissioning.
- The currently available experienced operators would be able to make a valuable contribution to HWRR immediate dismantling.

Since there is a lack of decommissioning experience and knowledge of key techniques, international cooperation, including IAEA assistance, is very helpful for staff training and capability building. Experience gained by HWRR decommissioning will be very valuable for the decommissioning of other nuclear facilities and for further development of the nuclear programme in China.

PROBLEMS IN PLANNING THE EARLY CLOSURE OF THE IGNALINA NUCLEAR POWER PLANT

B. TESKEVICIENE, P. HARRISON
Ministry of Economy,
Vilnius, Lithuania
Email: B.Teskeviciene@ukmin.lt

Abstract

The Ignalina nuclear power plant is the main electricity generator in Lithuania. Having two RBMK-1500 type reactors has meant that the country has the highest per capita nuclear electricity fraction (more than 70%). The design life of each reactor was 30 years of operation, with fuel channel renewal at mid-life. On this basis, Ignalina Unit 1 should have operated until 2013, and Unit 2 up to 2017 (note that the Russian Federation has already announced a 15 year life extension for the similar type Leningrad-1 nuclear power plant). The early closure of Ignalina was finalized in an additional protocol to the Accession Treaty of Lithuania to the European Union. The protocol committed Lithuania to close Unit 1 of the Ignalina plant before 2005 and Unit 2 by the end of 2009, and committed the European Union to provide appropriate funding. The first unit was permanently shut down on 31 December 2004. Decommissioning planning started with the preparation of the Preliminary Decommissioning Plan in 1999; the preparation of legal acts began at the same time. Several legal documents regulating the decommissioning of the Ignalina nuclear power plant and the management of the resulting radioactive waste have since been adopted. The adoption of the Final Decommissioning Plan and the selection of the decommissioning strategy have their own history and outcomes, as described in the paper. The paper also deals with decommissioning financing, problems encountered in the planning process, social measures and local economic regeneration, and lessons learned.

1. INTRODUCTION

Lithuania is the largest of the three Baltic States and is located at the crossroads of Europe and the Russian Federation. Facing the Baltic Sea, the country has common borders with the Russian Federation (Kaliningrad territory), Poland, Latvia and Belarus.

After fifty years spent as part of the USSR, the country became independent in 1990 following the collapse of the USSR.

Lithuania’s economy and infrastructure were deeply integrated with the economies of the countries of the northwest region of the USSR, comprising

Belarus, the Baltic republics and northwest Russia. This included the integration of the power system; the electricity generating capacity was distributed within each region so as to ensure energy balance at the regional level. A robust high-voltage transmission network interconnected the generating units ensuring a reliable supply throughout the region.

At the break-up of the USSR, Lithuania inherited the electricity generating capacity designed to supply Belarus and the whole northwest Russia region. As part of this capacity, ownership of the nuclear power plant of Ignalina located in the northeast of the country, 130 km from the capital, Vilnius, and close to the borders of Belarus and Latvia, was transferred to Lithuania.

The Ignalina nuclear power plant (Ignalina), with two Soviet designed RBMK-1500 reactor units, is the only plant of its type in the European Union (EU). The first unit of the Ignalina plant was commissioned in 1983 and the second in 1987. Since Lithuania became independent in 1990, the Ignalina plant has typically contributed more than 70% of the national electricity power supply.

The town of Visaginas (population 30 000) was built to serve the nuclear power plant and its operating staff were recruited from throughout the USSR. With 3344 direct employees (this number is decreasing each year), the Ignalina plant remains by far the largest employer in the town. Although there are pockets of Russian language speakers in communities throughout Lithuania, Visaginas is the only example at the level of a town.

In February 1994, as one of the conditions of the grant agreement for the safety upgrading of the nuclear power plant under the Nuclear Safety Account managed by the European Bank for Reconstruction and Redevelopment (EBRD), Lithuania agreed that the operation of neither unit would be prolonged beyond the time when their reactor channels would have to be changed (normally this would be performed at the mid-life of the unit). This was reflected in the National Energy Strategy, approved on 5 October 1999, which stipulated that Unit 1 should be shut down before 2005, "… taking into account the conditions of long-term and considerable financial assistance from the European Union, G-7 countries and other countries, as well as international financial institutions".

Recognizing that without a defined time limit, the further operation of Unit 2 was likely to hinder admission to the EU, the National Energy Strategy was revised on 10 October 2002 in preparation for Lithuania's EU accession negotiations — the revised strategy providing also for the closure of the Ignalina Unit 2 by the end of 2009 "…on the understanding that a programme organising additional financial assistance of the EU to the early closure … will be adequately addressed at a later stage of accession negotiations". Lithuania's commitment to the closure of the plant is reflected in the EU Accession Treaty; Protocol No 4 contains an expression of solidarity on the part of other EU Member States to provide financial support to Lithuania for the decommissioning of the Ignalina plant and certain consequential measures in the energy sector and establishes a financial instrument, the Ignalina Programme, for this purpose [1].

Unit 1 of the Ignalina nuclear power plant was duly shut down on 31 December 2004, and preliminary decommissioning activities are under way.

2. ASSUMPTIONS FOR DECOMMISSIONING PLANNING OF THE IGNALINA PLANT

An initial decommissioning study of Ignalina Units 1 and 2 was finalized in spring 2000 within the framework of the EC PHARE project No. PH4.08/94. The objective of this study was to develop a Preliminary Decommissioning Plan (PDP) and to estimate the related decommissioning cost. The study covered all necessary decommissioning activities before and after permanent shutdown of Ignalina Units 1 and 2 for various dismantling scenarios. It also defined a number of decommissioning support investment packages for pre-decommissioning facilities. These facilities are needed for the treatment and storage of operational radioactive waste and spent nuclear fuel irrespective of the longer term approach to dismantling the plant.

There is limited international experience in the decommissioning of RBMK plants, and in the implementation of facilities to support the preparation for their decommissioning. No other planning documents had been prepared before the law on decommissioning of Unit 1 of Ignalina was adopted on 2 May 2000 [1].

In relation to the Unit 1 decommissioning, in 2001 the Government of Lithuania approved the Ignalina NPP Unit 1 Decommissioning Programme for the period until 2005 [1]. In accordance with this programme, preparations were started on new facilities for the treatment and conditioning of radioactive waste, the construction of an interim dry storage facility for spent nuclear fuel and the preparation of the licensing documents for decommissioning Unit 1; some other decommissioning related projects were also implemented or are still ongoing. A new Decommissioning Programme for the years 2005–2009 was approved in 2005; this reflects the tasks that are already being implemented but also adds new ones, such as preparation for the dismantling of equipment and some dismantling activities.

The Decommissioning Programme is the main planning document and consists of technical, environmental and socioeconomic measures.

The main measures cover:

— The preparation of all necessary planning and licensing documents;
— The preparation of a radioactive waste management strategy and all necessary associated facilities;
— The implementation of urgent measures for replacing the Ignalina nuclear power plant generating capacity;
— Measures related to social issues and the economic regeneration of the local area.

The key bodies in the implementation of the Decommissioning Programme are:

— The Ministry of Economy is the owner of the Ignalina plant and also the institution appointed by the Government to ensure overall coordination and management of the EU and national decommissioning funding;
— The Ignalina nuclear power plant, as the operator of the nuclear facility, according the Law on Nuclear Energy, is responsible for the decommissioning of the nuclear site. The Ignalina plant has established a specialized Decommissioning Service at the plant and will conduct most of the dismantling activities with its own workforce;
— The Radioactive Waste Management Agency (RATA) is responsible for the disposal of radioactive waste generated by the decommissioning. RATA will own and operate the radioactive waste repositories to be constructed;
— The principal regulatory authorities are the nuclear safety regulator, VATESI, and the Radiation Protection Centre (RSC), both of which have formal responsibilities to approve the decommissioning documentation produced by Ignalina;
— The Ministry of Social Security and Labour is responsible for the implementation of social measures in the region, and the local authorities are the main bodies responsible for the economic regeneration of the region.

From this phase, the lessons learned are that: for cost effective nuclear facility decommissioning it is essential to have in place all necessary legal documents covering the future development of replacement energy facilities, local economy restructuring and radioactive waste management.

3. FINANCIAL RESOURCES

Without external support, the decommissioning of the Ignalina plant would represent for Lithuania an exceptional financial burden not commensurate with its size and economic strength.

To finance the pre-decommissioning projects for Ignalina, described in Section 2, the Ignalina International Decommissioning Support Fund (IIDSF) was established, administered by the EBRD. The activity of the Fund was formalized in the Framework Agreement between the Republic of Lithuania and the EBRD relating to the activities of the IIDSF in Lithuania [1]. The Framework Agreement entered into force on 5th October 2001. Contributions to the Fund were made by several European donor countries, but from the outset, the main donor was the EU.

Under Protocol No. 4 of the EU Accession Treaty, the European Community committed to provide Lithuania with financial assistance in support of its efforts to decommission the Ignalina plant and to address the consequences of its closure. The financial assistance under the Ignalina Programme will cover, inter alia: (i) measures to support plant personnel in maintaining a high level of operational safety in the periods prior to the closure and during the decommissioning of the reactor units and measures to mitigate decommissioning consequences; (ii) measures in line with the EU ‘acquis communautaire’ to replace the production capacity of the two Ignalina reactors with modern environmentally sound electricity production plant; and (iii) other measures which are consequential to the decision to close and decommission this plant and which contribute to the necessary restructuring, environmental improvement and modernization of the energy production, transmission and distribution sectors in Lithuania as well as to enhancing the security of energy supply and improving energy efficiency in Lithuania..

Before accession, the EU had already contributed €210 million to the decommissioning of Ignalina (principally through the IIDSF). The Accession Treaty committed the EU to provide a further €285 million (at 1999 prices) in the period 2004–2006 and to continue to provide an appropriate level of funding. In the EU’s next seven year budget plan (the so-called ‘Financial Perspective’ (2007–2013), it has now been agreed that the EU will continue to provide over €100 million per year.

EU financial support under the Ignalina Programme can be provided through two channels:

— **Contributions to the IIDSF:** The EU is now, by far, the major contributor to the IIDSF as other donor countries have not made contributions. Currently around 80% of the annual budget of the Ignalina Programme is allocated via this channel. Funding provided through this channel is mainly directed at large scale pre-decommissioning infrastructure such as the spent fuel storage and waste handling facilities.

— **Directly to Lithuania through the so-called 'Programmed Instrument' managed by the Ministry of Economy:** This funding channel is used to support the staff of the shutdown Unit 1 in the safe maintenance of the reactor (pending removal of the spent fuel) and pre-decommissioning activities (such as radiological characterization and system isolation), small-scale infrastructure, social mitigation measures, and technical assistance to the nuclear regulatory bodies.

In addition to international financing sources, there is funding from national sources (National Decommissioning Fund (NDF)) financed from a levy on the price of electricity. The NDF can be used to finance or to co-finance the decommissioning programme implementation measures. The fund is controlled by an appointed council and managed by the Ministry of Economy.

Each funding source and funding channel operates to its own rules. This added complexity, largely a legacy of pre-accession funding arrangements, leads to further complications in the planning and implementation of decommissioning projects — especially where interlinked projects are financed differently.

A lesson learned is that financing from different sources should be managed by one authorized implementing authority. There should be transparent and clear procedures of control for the spending of the funds.

4. PREPARATION OF PLANNING AND LICENSING DOCUMENTS

During the decommissioning process, safety will be the overriding priority. This will be ensured by the strong safety culture already existing at the Ignalina nuclear power plant, by a clear staff structure and a quality assurance system that will ensure that all staff understand their roles and duties, and by ensuring that the whole process complies with the regulatory framework established in Lithuanian legislation.

Inside its organizational hierarchy, the Ignalina plant has established a Decommissioning Service which is preparing for the closure and decommissioning of the plant; it consists of a fully integrated team of plant staff and consultants.

The Ignalina NPP Final Decommissioning Plan (FDP) was prepared by the Decommissioning Service and adopted by the Minister of Economy according to VATESI requirements [5]. The FDP includes, inter alia:

— The Ignalina nuclear power plant facility dismantling strategy;
— An estimate of the decommissioning costs;
— A statement of the Ignalina decommissioning feasibility;
— An outline of the decommissioning methods and techniques;
— An estimate of the waste that will be produced by the decommissioning;
— A description of the decommissioning organization and necessary resources;
— A conceptual assessment of decommissioning safety and environmental impact.

The most problematic chapter in the FDP was the selection of the decommissioning strategy. Decommissioning strategy, according IAEA guidelines, is a part of the Final Decommissioning Plan. Essentially the decommissioning strategy is mainly dependent on external factors: national policy, the technology of the nuclear facility, financial resources, the economic situation in the local area, the available workforce, and many other external factors. However, there is no legal requirement in Lithuania to prepare a comprehensive feasibility study on strategy selection, nor to adopt the strategy in advance of starting preparation of the FDP.

The Ignalina NPP Preliminary Decommissioning Plan (PDP) included equipment and materials database and an assessment of the cost of different decommissioning options (i.e. immediate dismantling, deferred dismantling and entombment) against various sets of assumptions.

The entombment option was discounted for technical and environmental reasons and because of the uncertainties of cost prediction and of the evolution of the regulatory framework over a period as long as 200 years. The review was therefore concentrated on the deferred dismantling and the immediate dismantling options. Within the deferred dismantling option, different alternatives of safe enclosure were also considered; of these, the small safe enclosure (essentially retention and isolation of the main reactor structures only) was preferred.

For the retained options, in the FDP, corrections and updating of: the Ignalina plant modelling, the waste conditioning techniques, anticipated disposal costs and means, and revised labour costs, as compared with the PDP, were taken into account in updating the decommissioning costs as follows:

— In the FDP, the disposal cost of low and intermediate level waste was taken to be €2400/m^3 for conditioned waste in a near surface disposal site. The use of a landfill facility for very low level radioactive waste (at €240/m^3) with better waste stream segregation and conditioning was also considered.

— The wage costs were assumed to vary from €5 to €40 per hour according to different scenarios for labour cost increases over the period of decommissioning.

After updating, and considering only the deferred dismantling (small safe enclosure) and the immediate dismantling options, the total costs for decommissioning were compared with those in the Ignalina plant PDP review report and in the document on technical and financial considerations required to select an Ignalina dismantling strategy.

Initially the Ignalina plant proposed the deferred dismantling (small safe enclosure) strategy with reactor core cooling for 35 years. However, in reaching a final decision on the Ignalina dismantling strategy, the Lithuanian Government complemented the technical and financial analysis presented by the Ignalina nuclear power plant with consideration of more general social, political and economic factors at the local, regional and national levels so as to encompass the wider Lithuanian socioeconomic situation.

In the discussions, the most significant considerations were the economic situation of the region (heavy dependence on one employer, lack of integration of the Russian speaking workforce into the broader Lithuanian labour market) and the fact that financing is mainly from external sources, principally the European Union (hence the inability to increase funds through investments); however, the overriding factor was the possibility of making use of the existing operational staff of the Ignalina plant for decommissioning activities.

Based on these considerations, in November 2002, the Government issued a statement that: "… in order to prevent heavy long term social, economical, financial and environmental consequences… decommissioning of Unit 1 of the State Enterprise Ignalina NPP shall be planned and implemented in accordance with the immediate dismantling strategy". This decision now applies to the decommissioning of both units.

At the cessation of operation and during the decommissioning period, the final decommissioning plan will be the principal document on which all lower level documentation is based and the decommissioning activities.

Owing to its importance, initially it was foreseen that the FDP should be adopted by governmental decision as a legal document. However, during the adoption procedure it became clear that this document did not corresponded to the requirements for legal acts in Lithuania. Furthermore, the FDP is a 'living' document which should be revised yearly. During the adoption procedure its content has been corrected several times, causing delays in the planning process.

A lesson learned from this process is that the decommissioning strategy should be adopted in the form of a separate document, prior to starting preparation of the Final Decommissioning Plan. The decommissioning strategy must take into account all external factors as well as the technical possibilities.

5. PREPARATION OF RADIOACTIVE WASTE MANAGEMENT INFRASTRUCTURE

Decommissioning of the Ignalina nuclear power plant will give rise to significant amounts of radioactive waste. Furthermore, consideration must also be given to the existing radioactive waste and spent fuel already on the site and that to be produced in the remaining years of Unit 2 operation. This has necessitated significant improvements the legal framework and operational infrastructure for radioactive waste management. According to the immediate dismantling strategy, the decommissioning process for the Ignalina plant will last for 30 years and will result in a 'brown field' site with continuing supervision of the residual radioactive waste storage and disposal facilities. Radioactive waste management is therefore both an immediate and a long term consideration in decommissioning planning.

The basic regulatory framework regarding radioactive waste in Lithuania was established in 1999 under the 'Law on Radioactive Waste Management' [1] (closely linked to the 'Law on Nuclear Energy'). This law sets out principles for radioactive waste management, defines facilities (for storage and disposal), and sets additional (compared with the Law on Nuclear Energy) required fields of competence and responsibilities for the institutions concerned. For the operator of a nuclear facility, the law sets obligations for compliance with specific procedures, standards, rules and conditions of licence and requirements to perform monitoring of the public and the environment, to develop and implement quality assurance programmes, and to prepare accident and incident response plans.

Importantly, this law also provided for the creation of a specialized body, the State Enterprise Radioactive Waste Management Agency (RATA), under the Ministry of Economy. RATA, formally established in 2001, is now conducting investigations into the siting of a near surface repository, which it will in due course operate, for the waste arising from the Ignalina plant decommissioning.

In 2002, the more technically detailed Radioactive Waste Management Strategy was prepared [1] mainly in order to establish the essential infrastructures based on modern technologies and to specify practical measures aimed at implementing the basic principles of the relevant IAEA and EU legislation.

The strategy sets out the basic objectives for the improvement of radioactive waste management in Lithuania. It also elaborates the principles for the management of solid and liquid radioactive waste and spent fuel from the Ignalina NPP, the management of radioactive waste generated by small producers, along with the necessary procedures and systems and the directions of associated scientific research.

As a result of establishing a sound legal framework, a specific strategy for radioactive waste management, and a specialized institution through which the strategy can be implemented, Lithuania is now well placed to proceed with the construction and operation of the required storage and disposal facilities for the decommissioning of the Ignalina plant.

A lesson learned is that before starting decommissioning planning, it is very important to have a clear strategy for radioactive waste management, including treatment, storage and disposal, and to have all the necessary institutions in place to implement the strategy. The absence of these facilities can cause delays in the decommissioning process.

6. MEASURES RELATED TO SOCIAL ISSUES AND REGENERATION OF THE LOCAL ECONOMY

The closure of the Ignalina nuclear power plant will have an economic impact on Visaginas town as well as on the Ignalina and Zarasai districts. However, the greatest social consequences will be for Visaginas, which was purpose-built for the power plant employees. The earnings and jobs of the majority of the population in Visaginas town and Ignalina district, and to a lesser extent in Zarasai district depend on the power plant, which is the major employer and the largest customer in the region.

A study of the consequences of the Ignalina's decommissioning was carried out within a project financed through the EU PHARE programme. The study, entitled 'Technical Support to the Study on the Ignalina NPP Decommissioning Social Costs', was conducted by a consortium of companies from the United Kingdom, Finland and Lithuania. The consortium experts, in their final project report prepared in October 2001, presented an assessment of the social and economic consequences of Ignalina's decommissioning on the region.

The study examined, from social and economic perspectives, three scenarios for the future of Visaginas and the affected surrounding region: balanced redevelopment, controlled run-down, and uncontrolled stagnation. According to the conclusions of the study, the balanced development scenario is the most effective in both the social and economic respects. By comparison, the cost of the controlled run-down of the region would be 1.5 times higher, and that of the uncontrolled stagnation would be 2.1 times higher.

Efforts are therefore being made to restructure and diversify the local economy making use targeted instruments available to EU Member States. For example, with support from the Structural Funds, a large furniture factory is now under construction in the vicinity of Visaginas. This form of redevelopment requires close cooperation with the local authorities in the region affected.

The 'Law on Additional Employment and Social Guarantees for the Employees of the State Enterprise Ignalina Nuclear Power Plant' [1] establishes additional employment and social guarantees for the employees of the Ignalina NPP who will, or have already, lost their jobs as a result of the NPP decommissioning, as well as for their family members. By seeking to mitigate the negative social consequences of job loss, it is intended to ensure the safe and uninterrupted work of the Ignalina plant until the end of its operation.

The principal measures take the form of indirect and direct support to employment:

— 'Indirect support' will include targeted programmes on employment, regional development, and business promotion
— 'Direct support' focuses on the individual and will include the drawing up and implementation of personal plans for providing employment. In addition to the standard measures available to the unemployed under Lithuanian law, measures for those directly affected by plant closure may include: vocational training, retraining, pre-dismissal paid educational leave, subsidized job placements (each placement subsidized to the value of 24 minimum monthly wages), the possibility to learn the Lithuanian language and other active labour market measures (the same additional employment guarantees apply to unemployed family members of those affected by the plant closure provided that they have registered at the labour exchange).

Former Ignalina employees made redundant because of plant closure will also be eligible for additional severance pay (based on years of service) and, if applicable, certain pre-retirement benefits.

The lessons learned are that it is very important to involve local authorities, the public and other stakeholders, up to the level of Members of Parliament, in the preparation of the long term economic development strategy and in the necessary programmes for its implementation.

7. CONCLUSIONS

The closure of any major industrial facility will inevitably create certain difficulties; however, when considering the shut down of the Ignalina nuclear power plant, it is important to highlight the exceptional surrounding circumstances:

— Since independence, the Ignalina plant has been by far the major generator of electricity in Lithuania; its closure will therefore necessitate the complete restructuring of the national electricity supply and the creation of replacement capacity.
— The Ignalina plant will be the first with RBMK reactors to be fully decommissioned to the level of a brown field site, thereby posing significant, groundbreaking, technical challenges.
— During the time of the USSR, there was no plan for the permanent disposal in Lithuania of any radioactive waste originating from the Ignalina plant. The entire legal and regulatory framework for radioactive waste management had to be established in advance of the construction of the infrastructure and facilities.
— Funding for decommissioning and the consequential measures in the energy sector is largely provided by the EU. The EU plans its own budget in seven year periods — much shorter than the timescales for decommissioning — and funding beyond 2013 cannot be predicted. Furthermore, the arrangements for funding are complicated by legacy implementation structures, often ill-adapted to the nature of the projects.
— Nuclear power plants established during the time of the USSR, such as the Ignalina plant, were designed to be operated by a very large staff (typically five times that of a western plant of equivalent output), often accommodated in purpose-built, single-employer towns. In the case of Ignalina, the situation is further complicated by a lack of integration of the Russian-speaking community serving the plant into the broader Lithuanian society.

These diverse problems have had to be tackled at a highly accelerated pace in order for Lithuania to meet its commitments for plant closure and have necessitated a holistic approach, within which the immediate decommissioning strategy is one aspect. Many lessons have been learned in this process and it is hoped that they will be of value in the closure of other nuclear facilities elsewhere.

REFERENCES

[1] SEIMAS OF THE REPUBLIC OF LITHUANIA, Resolution on the Approval of the National Energy Strategy, No. IX-1130 (2002).

[2] SEIMAS OF THE REPUBLIC OF LITHUANIA, Law on the Decommissioning of Unit 1 of the State Enterprise Ignalina Nuclear Power Plant, No. VII-1661 (2000).

[3] SEIMAS OF THE REPUBLIC OF LITHUANIA, Dėl valstybės įmonės Ignalinos atominės elektrinės pirmojo bloko eksploatavimo nutraukimo programos patvirtinimo, No. 17-523 (2001).

[4] Framework Agreement between the Republic of Lithuania and the European Bank for Reconstruction and Development Relating to the Activities of the Ignalina International Decommissioning Support Fund in Lithuania (05/04/2001).

[5] STATE NUCLEAR POWER SAFETY INSPECTORATE, General Requirements for Decommissioning of the Ignalina Nuclear Power Plant, VD-EN-01-99, Vilnius (1999).

[6] SEIMAS OF THE REPUBLIC OF LITHUANIA, Law on the Management of Radioactive Waste, No VIII-1190 (1999 as amended by 26 October 2004 No IX-2506).

[7] RESOLUTION OF THE GOVERNMENT OF LITHUANIA, On the Approval of the Radioactive Waste Management Strategy and the Operational Programme of the State Enterprise Radioactive Waste Management Agency for 2002-2004, No. 174 (2002).

[8] Law on Additional Employment and Social Guarantees for the Employees of the State Enterprise Ignalina Nuclear Power Plant (No. IX-1541, adopted in April 2003).

LESSONS FROM THE DECOMMISSIONING OF THE BN-350 REACTOR IN KAZAKHSTAN

A.J. BAER
Belp, Switzerland
Email: albaer@dplanet.ch

D.W. REISENWEAVER
International Atomic Energy Agency,
Vienna

Abstract

The BN-350 fast breeder reactor at Aktau (in Kazakhstan) on the eastern shore of the Caspian Sea was formally shut down in 1999. The Government of Kazakhstan chose a deferred dismantling strategy and decided that the reactor should be placed in safe storage for 50 years, starting in 2013. In 1999, at the request of that Government, the IAEA constituted an Advisory Committee that, among other things, was to oversee the production of a decommissioning plan. The idea was that this plan should serve as a basis to call a conference of potential donor countries that could find the financing needed for decommmissionning. The decommissioning plan that was submitted to the IAEA in 2002 was, however, judged to be inadequate by the group of experts advising the IAEA. A new plan is due to be presented in 2006. Meanwhile, Kazakhastan has developed a 'plan of priority measures' to prepare the reactor for storage. Considerable progress has been made in the realization of this plan, with financial support and expertise from the USA, the European Commission and the United Kingdom. As a result, and in spite of the lack of a decommissioning plan following the IAEA rules, decommissioning is progressing satisfactorily. This situation is a good example of what should not happen in a decommissioning project. Among the main reasons for this unsatisfactory situation are: misunderstandings about what a decommissioning plan actually is; a lack of understanding about the management of large industrial projects; cultural and linguistic differences; the large number of organizations involved; and the inadequate or insufficient expertise of many of those involved. There is, however, no indication that safety problems have occurred since the shutdown of the reactor.

1. INTRODUCTION

Kazakhstan is the largest republic in Central Asia. It extends from the Caspian Sea in the west to the Chinese border in the east and covers a total area of 2 700 000 km^2, which corresponds approximately to the area of Western

Europe. Its population, with about 15 million inhabitants is slightly smaller than that of the Netherlands. The BN-350 fast breeder reactor is located in Aktau, on the eastern shore of the Caspian Sea. It served a triple purpose: producing energy, desalinating seawater and producing plutonium. Construction started in 1964, the reactor became critical in November 1972, and power operations began in June 1973. It was the first power producing fast breeder reactor in the world. The reactor is a loop type, sodium cooled machine. The primary and secondary circuits are sodium cooled, while the third one is water cooled. The primary and secondary circuits each possess six loops. The reactor, which was designed to operate for 20 years, had a thermal power of 1000 MW but it never operated at more than 750 MW because of limitations set by the steam generators.

Kazakhstan became an independent republic in 1991 and, in 1992, a decision was taken to extend the life of the reactor to 2003. However, an IAEA Operational Safety Review Team (OSART) mission concluded that the available resources were insufficient to maintain a minimum adequate level of safety. It was also realized that upgrading the reactor would take three years during which it would have to be maintained but would not produce any energy.

From 1993 onwards (beyond the end of its design lifetime) the reactor required an annual technical justification from the Russian organizations that had licensed it. In 1998, this justification was refused and the Kazakhstan Atomic Energy Commission (KAEC) decided not to extend the licence. In April of the following year (1999), the Government of Kazakhstan approved a decree requiring the decommissioning of the reactor.

2. 1999 — A CRITICAL YEAR FOR THE PROJECT

The year 1999 was critical for all future developments regarding the BN-350 reactor. On 22 April 1999, the Government signed its decommissioning decree. A delayed decommissioning option was chosen, according to which the reactor would first be prepared for deferred dismantling. It would then be left for 50 years in a safe storage condition (‘Safestore’) and final decommissioning would only occur afterwards. The first (preparation) phase was intended to last until 2013, the second from 2013 to 2063 and the last phase (the final decommissioning phase) from 2063 to 2075. That same decommissioning decree also specified that a ‘Plan of Priority Measures for the Decommissioning of the BN-350 Reactor’ shoul be prepared.

From 10–13 May 1999, a workshop was held in the capital city, Almaty, with the participation of the IAEA and of several States willing to contribute to the decommissioning operations. They were Japan, Germany, France, Italy, and the USA. The European Commission (EC) was also represented. At the meeting it was proposed that an Advisory Committee should be established, coordinated by the IAEA. Its purpose was to help to coordinate the efforts of all parties, to ensure that IAEA safety standards were applied during decommissioning, to help in finding solutions to decommissioning problems and to advise the Government of Kazakhstan on such issues.

The first Plan of Priority Measures was approved by the Government in July 1999. It foresaw the following actions:

- Developing a decommissioning project;
- Ensuring safety during preparations for safe storage;
- Finding a replacement for the heat previously supplied by the reactor;
- Unloading the fuel and draining the sodium from the circuits;
- Reducing the volume of existing liquid radioactive waste to create new capacity for future waste.

From 17–19 August 1999, the first meeting of the proposed Advisory Committee took place in Vienna. Participants from Kazakhstan presented a list of tasks to be accomplished according to the Plan of Priority Measures and indicated a need for foreign expertise and financial support. Other participants explained that to convince their respective national authorities to contribute, they would need to have an overall decommissioning plan and an overall cost estimate. The delegates from Kazakstan undertook to prepare such a plan.

However, before this meeting, in 1997, Kazakhstan and the USA had signed an agreement, according to which, at the time of decommissioning, the reactor fuel would be stabilized and packaged, transported to a safe storage site and left there for 50 years. In other bilateral projects, the USA undertook to support the planning for decommissioning and the decontamination and draining of the sodium. After the formal shutdown decision, the USA also agreed to support the KAEC to develop regulatory oversight of activities related to decommissioning.

Finally, and also prior to 1999, through its TACIS programme, the EC had undertaken to help repair leaks in the fuel storage pond, to supply fire fighting equipment and to help maintain the safety of the reactor during shutdown.

3. COMMUNICATION PROBLEMS

Although nobody noticed it at the time, this year 1999 also marked the beginning of a period in which there were a series of not jusatified assumptions and misunderstandings that were to lead to the strange situation that exists now, in which the reactor is being decommissioned without a decommissioning plan. The confusion started with the lack of understanding of what a decommissioning plan should be. Nobody in Kazakhstan had much experience with preparing such a plan and it was presumably assumed that the existing Plan of Priority Measures could be slightly modified and made into a decommissioning plan. On the other hand, the IAEA Secretariat and the members of the Advisory Committee (other than those from Kazakhstan) insisted on the numerous requirements that belong in a decommissioning plan according to the rules of the IAEA. For its part, KAEC determined that unless a decommissioning plan received IAEA approval, Kazakhstan would not attempt to organize a donors' conference to fund the decommissioning. This made the decommissioning plan a basic prerequisite for future financing in the context of the IAEA coordination. However, the bilateral agreements between Kazahstan and other contributers (USA, EC, and later the United Kingdom) were not affected by the progress of the decommissioning plan.

The company in charge of the decommissioning (KATEP) contracted the drafting of a decommissioning plan to the Kazakhstan Nuclear Technology Safety Centre (NTSC). However, none of the persons involved had had experience of a decommissioning project of the magnitude of that required for the BN-350.

In 2002, a Decommissioning Plan was presented to the Advisory Committee. After a number of improvements, the plan was transmitted to the IAEA for evaluation by a group of selected experts from IAEA Member States. In summer 2003, the expert group gave its view that the plan did not meet international standards and best international practices and recommended that a new plan be prepared.

This negative evaluation discouraged many in Kazakhstan, perticularly in NTSC. It also suggested that the expertise available within the Advisory Committee may not have been sufficient to evaluate a decommissioning plan in detail.

The negative evaluation of the plan in 2003 probably precipitated an evolution that had already started in 1999. The two projects were now moving in parallel, one dealing with an internationally acceptable decommissioning plan and the other dealing with the actual decommissioning of the reactor according to the Plan of Priority Measures, financed in part by Kazakhstan and in part by foreign countries, on the basis of bilateral agreements.

4. PROGRESS OF THE DECOMMISSIONING

Part of a revised decommissioning plan was submitted to the IAEA in autumn 2006, but, in any case, the decommissioning work is progressing on the reactor. The progress to date is:

- The fuel has been unloaded and casks for transport to a repository in Baikal-1 are under construction;
- Sodium has been drained from the reactor and decontaminated through caesium traps;
- A sodium processing facility is under construction and an experimental geocementation plant is being designed;
- A facility to process liquid radioactive waste will soon be under construction;
- The design of a facility to process solid radioactive waste has been approved;
- The reactor building and all facilities that will remain in safe storage for 50 years are being repaired;
- A comprehensive engineering and radiation survey has been completed.

Throughout this work, the KAEC has ensured that the different tasks were carried out according to IAEA safety standards. It is clear that the relevance of a decommissioning plan decreases as the actual decommissioning work progresses. It is also quite possible that once the reactor enters the 50 year period of safe storage, its fate after 2063 will be of little interest to anybody and the motivation to develop a decommissioning plan for the years beyond that date will disappear. For now, it would appear that it is unlikely that an IAEA supported donors conference will materialize. Such a conference had originally been considered to be a major reason for wishing to have a Decommissioning Plan.

As the word ‘Safestore’ implies, the immediate objective of the authorities in Kazakhstan is to place the reactor into safe storage by 2013, at the latest. This means that by that time, all fuel elements should have been removed from the site, the sodium should have been drained from the reactor, cleaned of its radioactive caesium and neutralized and the caesium traps should also have been removed from the site. Buildings that are to remain standing should be repaired, where needed, and services that may be required during the 50 years of Safestore (lighting, ventilation, etc.) should be functioning. Finally, the physical protection of the site perimeter has to be ensured and the necessary human resources should be available for that purpose. According to the present plans, and judging from what has already been accomplished, the chances are reasonably good that these activities will all have been completed in time.

5. LESSONS TO BE LEARNED

What lessons should be drawn from this bizarre situation and, in particular, what can others gain from it?

— **Do not follow the example of the BN-350**

Do not assume that the case of the BN-350 shows that a decommissioning plan is not needed. It would be wrong to assume that Kazakhstan is dismantling the reactor without any control. The operator has written a systematic ‘Plan of Priority Measures’ that has been approved by the KAEC. That regulatory body verifies that work is proceeding according to plan and that IAEA standards are being respected. The analysis of the 2002 decommissioning plan by outside experts has shown that some aspects of the decommissioning are not being treated in sufficient depth to satisfy IAEA rules. In particular, the planning for activities during and after Safestore is not sufficiently detailed so that the actual costs have only been roughly estimated. Even though decommissioning of the BN-350 appears to be proceeding safely, this case should not be taken as an example to be followed.

— **Watch for cultural and linguistic differences**

In retrospect, it is relatively easy to see where mistakes have been made, but at the time it was not so apparent. To people outside Kazakhstan the relations between the national organizations were not clear and their respective roles were only vaguely understood. As is proper, the leadership of the project remained at all times with the organizations in Kazakhstan and the Advisory Committee only made suggestions.

Cultural differences play an important role in a project of this nature. A lack of comprehension or even resentment can easily arise without any partner realizing it. A poorly worded suggestion or a misunderstanding in a particular proposal may create difficulties in communication and an approach that appears quite ‘normal’ to one party may be incomprehensible to another.

Where interpreters have to be used, spontaneous reactions are hardly possible and informality does not develop.

— **Are the blind leading the blind?**

Decommissioning a fast breeder reactor is a very special task. Except for groups in the USA, in the United Kingdom and in France, there is little experience in this particular field. In the case of the BN-350, an added difficulty is that Kazakhstan ‘inherited’ the reactor from Russian organizations. Given this situation, Kazakhstan has done reasonably well considering the nature of resources available in the country. Decommissioning a reactor is a major industrial operation that requires knowledge of specific management techniques, as well as experience with other large operations. It would appear that no suitable person was available in the country to take the lead in decommissioning the BN-350. This meant that whatever the qualities of the people involved, much learning had to take place on the job. As the overall programme involves at least 22 organizations and ministries (eight in Kazakhstan, three in the Russian Federation, eight in the USA and at least three in Europe) leading the programme would have been a challenge even for a highly experienced manager. In spite of well-meaning suggestions, the Advisory Committee does not appear to have found approaches that would have strengthened the team that managed the project.

— **The IAEA follows specific rules**

The IAEA Secretariat can only take initiatives at the request of a Member State. Furthermore, if asked for help, it must insist that whatever support it gives will be done within the constraints of its own safety standards. It was quite natural that in response to a request from Kazakhstan the IAEA would require the preparation of a decommissioning plan before it could coordinate a donors conference. The position of Kazakhstan was evidently delicate. On the one hand it was being offered immediate help to start decommissioning a reactor that presented a certain proliferation risk. On the other hand, it was told to first prepare a decommissioning plan before the start of decommissioning.

— **What could be the role of the Advisory Committee?**

As is common in such cases, the IAEA Secretariat asked Member States to send delegates to the newly created group. Member States were therefore free in their choice of representatives. The Committee had to advise the Government of Kazakhstan on the safety standards to be applied, had to assist in finding final solutions and had to coordinate the activities of potential donor states. It had some expertise in a wide variety of areas besides decommissioning, but it did not have enough experts familiar with practical decommissioning work. In retrospect, the Committee should itself have been more critical of the development of the decommissioning plan and should have suggested to the IAEA Secretariat not to send the 2002 report to outside experts.

— **Possible improvements**

Could things have been done better and how? It is easy to criticize an operation in retrospect. It is now clear that communication between all the partners should have been far more intensive from the very beginning. Ideally, many members of the Advisory Committee should also have been fluent in both Russian and in English. Some fundamental misunderstandings also arose because the same words meant different things to different people. One such term is evidently 'decommissioning plan'. Furthermore, the lack of direct, personal experience in decommissioning operations of many members of the Advisory Committee was definitely a weakness.

6. CONCLUSIONS

Finally, the conclusions to be drawn from our experience with the BN-350 are the following:

— Excellent communication between the major players is critical;
— A good understanding of modern project management techniques is essential on the part of the operator;
— A specialized knowledge of decommissioning techniques must be available to the operator and to the regulatory body;

In the end, the personal qualifications of the people in place and their leadership qualities will make the difference between the success and the failure of such a project.

DISCUSSION

S. LINDSKOG (Sweden): I was pleased to hear what you said about good linguistic skills in various languages helping to improve project quality. In Sweden that view is unfortunately not held at all.

A.J. BAER (Switzerland): Technicians are not expected to be linguists, and they participate in projects using whatever languages they speak. One has to deal with such situations pragmatically. If everyone had the same first or second language, things would be easier.

S. LINDSKOG (Sweden): Yes, but there is a tendency to demand that technicians use only English. We have forgotten languages such as Russian, which is a lingua franca in countries of the former Soviet Union.

HOW TO DEVELOP A DECOMMISSIONING INFRASTRUCTURE TO SUPPORT THE PLANNING PROCESS

S. HARRIAGUE
Comisión Nacional de Energía Atómica,
Buenos Aires,
Argentina
Email: harriag@cnea.gov.ar

Abstract

Argentina´s legal infrastructure defines the Comisión Nacional de Energía Atómica (CNEA) as responsible for the decommissioning planning of all significant nuclear facilities in the country, and for the decommissioning of nuclear power plants. On the basis of related experience from more than 50 years of nuclear activities in the country and international cooperation and assistance, the CNEA started its Decommissioning Subprogram in 2000. The paper presents lessons learned during the development of a structure for decommissioning and the experience arising from decommissioning planning under conditions of constrained resources.

1. INTRODUCTION

Nuclear activities in Argentina started in 1950. Two nuclear power plants are presently in operation and a third one is under construction, six research reactors and critical assemblies remain operational. Significant nuclear facilities include factories for the production of both power and research reactor fuel, ^{99}Mo and ^{60}Co production facilities, as well as a number of fuel cycle installations and facilities for the application of radioisotopes and radiation in industry and medicine. Overall, the Nuclear Regulatory Authority (ARN) has licensed 28 nuclear facilities. Nuclear activities grew until the mid-1980s, then slowed down and no significant growth occurred after the mid-1990s until the recent decision to complete the construction of the third nuclear power plant.

Decommissioning responsibilities fall on the National Atomic Energy Commission (CNEA). Even if no facility is shut down in the near future, decommissioning planning is required for at least two reasons: the regulatory requirement to be consistent with current international practices, and the requirement to make decommissioning waste estimates according to the

National Program on Radioactive Waste Management (also under CNEA). Consequently, in May 2000, the Decommissioning Subprogram was created within the CNEA Technology and Environment Branch.

At the same time, the country suffered the deepest economic and social crisis in its history, a situation peaking at the end of 2001 with events reflected by the world media. This situation has had an influence — by stressing the need to save as many resources as possible, without negative effects on safety, in the proposed decommissioning alternatives and in the planning itself.

The purpose of this work is to present lessons learned during the development of a structure for decommissioning and the experience arising from decommissioning planning under conditions of constrained resources.

2. EXISTING EXPERIENCE

As previously stated, by the time the Decommissioning Subprogram was established there had been 50 years of nuclear activity in the country. Until 1994, when the nuclear utility Nucleoeléctrica Argentina S.A. (NA-SA) was created, basically from the Nuclear Power Stations Branch of CNEA, practically all significant nuclear activities were concentrated within the CNEA. Many decommissioning tasks were performed during these years, and many techniques relevant to decommissioning were developed, including:

- The dismantling of the RA-2 critical assembly and the release of its building (1984–1989);
- The dismantling and change of reactor internal components and other components of the RA-3 radioisotope production reactor (1988–1990);
- The replacement of fuel channels, instrumentation guide tubes and work on reactor internal components of the Atucha I nuclear power plant (1988–1990);
- The replacement of reactor internal components during programmed outages of the Atucha I nuclear power plant (1991–2003);
- Technology development, among other things, in decontamination, cutting and dismantling techniques, and remote operations, usually for purposes not related to decommissioning.

At the present time, these experiences and knowledge are shared by different groups within CNEA and NA-SA.

3. INTERNATIONAL COOPERATION

Argentina has been involved in international cooperation in decommissioning from the very beginning of its deommissioning programme. In fact, a related technical cooperation project with the IAEA started two years before the Decommissioning Subprogram was formally established.

In some cases, existing cooperation agreements with CNEA were extended to include decommissioning (e.g. with Germany, Spain and the USA). In other cases, specific agreements or activities were established (e.g. with the IAEA and Belgium). Activities resulting from international cooperation on the development of a decommissioning infrastructure in CNEA include the following:

— **IAEA:**

— Technical cooperation project providing staff training and experts;
— Regional training course on the decommissioning of research reactors and other small nuclear facilities held at CNEA in 2001, with 33 participants from 14 countries;
— Two expert missions to assist in Atucha I nuclear power plant decommissioning planning;
— Participation in a coordinated research project (CRP) on Disposal Aspects of Decommissioning Waste.

— **Department of Energy (DOE), USA:**

— Specific training course on decommissioning for Argentine staff at the Argonne National Laboratory, 1998;
— Workshop on decommissioning held in Buenos Aires, 2001;
— Technical visits to DOE facilities being decommissioned, 2000 and 2001;
— Financing of a technology development project on mechanical decontamination;
— Equipment donation.

— **Forschungszentrum Karlsruhe, Germany:**

— Workshop on decommissioning held at CNEA, 2003;
— Expert mission on the decommissioning of nuclear power plants;
— Staff training in Germany on the decommissioning of MZFR reactor, the prototype of Atucha I nuclear power plant.

— **ENRESA, Spain:**

— Expert mission;
— Staff training and technical visits to the Vandellos I nuclear power plant when under decommissioning.

— **SCK-CEN, Belgium:**

— Staff training in the decommissioning of BR-3;
— Technical meeting held at CNEA in 2005.

4. ACTIVITIES IN THE PERIOD 2001–2005

Activities promoted by the Decommissioning Subprogram can be classified under three different headings as described below.

4.1. Development of human resources

As already mentioned, during more than fifty years of activities, CNEA had developed, although with other objectives, human resources and capabilities in most of the technologies required for decommissioning. Nevertheless, the application of these technologies to decommissioning required some training in order to switch from an 'operations' mentality to a 'decommissioning' one; for example, components to be decontaminated do not need to remain operational, cutting may require aerosol control or even remote techniques, and the time span for planning may be orders of magnitude longer. The value of sharing this training with staff from the nuclear utility NA-SA and from the regulatory body ARN was also recognized.

International cooperation was a key element in this area; staff training included:

— Training of six staff members from CNEA in radiological characterization, decontamination, dismantling and cutting techniques, quality management and waste characterization at FZK (Germany), SCK-CEN (Belgium) and ENRESA (Spain).
— Specific training course on decommissioning at Argonne National Laboratory (USA) for eight assistants from CNEA, the nuclear utility NA-SA and the nuclear regulator ARN.

— IAEA regional training course at CNEA, involving 11 Argentine technicians from CNEA, NA-SA and ARN, as well as 22 technicians from 13 other countries.
— Eight expert missions from the IAEA, FZK, ENRESA and SCK-CEN.
— Eleven technical visits by CNEA staff to FZK, ENRESA, Argonne and Brookhaven National Laboratoriess, Savannah River and Hanford Sites, SCK-CEN Mol.
— One Master's thesis at Buenos Aires National Technological University on Quality Management in decommissioning.
— Three CNEA fellowships on research into concrete removal techniques and mechanical decontamination.

4.2. Decommissioning planning

Decommissioning planning has concentrated on the Atucha I nuclear power plant (a 357 MW(e) PHWR of Siemens design) and on the RA-1 research reactor. In the second case, participation in an IAEA CRP was extremely helpful and, as a result, a procedure for decommissioning planning and the prediction of the total waste from dismantling was applied to five other research reactors and critical assemblies operating in the country.

The decommissioning planning and cost analysis of Atucha I was developed in a joint effort with the utility NA-SA, and with the assistance of two one-week missions by an IAEA expert. Participation of the operator in decommissioning is generally welcomed; in the Atucha I case, it was of great importance, because of the unique design of the plant and the modifications introduced by the operator over more than thirty years of operation.

4.3. Decommissioning technology

When the Decommissioning Subprogram was created, it was decided that the actual decommissioning would not be based on turnkey contracts. Many tasks would need to be contracted, but the CNEA would keep full control over, and responsibility for, the overall project. This policy implied that it would be convenient to develop local contractors following the CNEA tradition which started during the 1960s with the construction of the first nuclear power plant.

Within the same line of thought, the adaptation and/or development of the technology to be used in decommissioning was decided upon; this includes:

— A review of techniques already developed within the country that may be used in decommissioning;

— A study of the eventual use of some of them in actual decommissioning problems (as an example, electrochemical decontamination was tested in irradiated fuel channels being replaced in the Atucha I nuclear power plant);
— The development of equipment for decontamination by abrasion in vibratory tumblers, partially financed by the US DOE;
— Basic research, including a PhD thesis, on the removal of concrete layers.

5. LESSONS LEARNED ON DEVELOPING AN INFRASTRUCTURE FOR DECOMMISSIONING PLANNING

The following experiences and suggestions resulted from the development of a decommissioning infrastructure under particular circumstances and conditions; these were:

— Nuclear activities developed during half a century, growing steadily during the first thirty years, and then gradually slowing down;
— Qualified staff having little or no experience in decommissioning;
— Severe constraints on resources due to a deep economic and social crisis.

5.1. Lessons learned regarding planning

Establish your priorities carefully in planning

When starting decommissioning planning, the facility selected to begin with should be chosen carefully.

In the Argentine case, due to cost, the impact for waste management and the possibility of having strong cooperation with the utility, it was necessary to begin with a nuclear power plant. As a second priority, research reactors were chosen due to the fact that there are six of them, with a significant probability of an unplanned permanent shutdown. It was decided to learn decommissioning with one of them, chosen on the basis of age, absence of radioisotope production commitments, available staff and geographical location.

Look for decommissioning skills, experience and techniques within your own organization/country

The CNEA and the nuclear utility NA-SA have performed many tasks and developed (and used) many techniques closely related to decommissioning, in non-decommissioning projects. Examples are the modifications and the upgrading of facilities, including a nuclear power plant, where radiological characterization, decontamination, cutting, dismantling and waste management were necessary activities.

It is very useful to investigate your organization and similar ones in your country for relevant skills and experience. In order not to repeat what has been already done, those skills must be identified, and some training provided to make people ‘switch from operation to decommissioning’.

Take benefit from the large amount of existing information

The IAEA, OECD Nuclear Energy Agency (OECD/NEA), national organizations, and regulators have produced a large number of accessible documents covering most aspects of decommissioning, including actual experiences. Time invested in literature surveys and in producing state-of-the-art documents on relevant subjects can be profitable.

Participation of the operator is extremely useful, should be encouraged and, if necessary, the operator should be motivated

In the Argentine case, the operator is not responsible for decommissioning. Nevertheless, the utility NA-SA participates in decommissioning planning on the basis of an agreement with CNEA. This agreement was based on the interest of the NA-SA in knowing the decommissioning costs for its power stations in order to be able to produce an economic analysis of their life extension.

It was also found that the operational staff became more cooperative after a seminar by a foreign expert showing the importance of participation by the operation staff in the actual decommissioning work of a nuclear power plant.

Work from the very beginning with the regulator

In countries lacking decommissioning experience, the regulator must also become acquainted with the subject, develop staff knowledge and a regulatory framework. Working from the beginning in a close relationship with the regulator will help in anticipating regulatory changes that, in some cases, imply additional (and important) costs. This cooperation will add mutual confidence, and will also help to develop a safety culture in the decommissioner, which, in the long term, will also reduce costs.

Work in close relationship with the waste management sector

Decommissioning planning and the selection of a decommissioning strategy are influenced by the waste management system. Our experience is that working in close relationship with the waste management organization can have positive feedback effects, for example, in the elaboration of long term waste management plans.

Benefit from knowledge management projects and techniques

Lack of information on design, construction and operation, especially in relation to old facilities, is a well-known challenge for decommissioners. Interaction with, and results from, a CNEA Project on Knowledge Management [1] was quite helpful, mainly for retrieving data on the construction and early operation of the RA-1 research reactor, which reached criticality in 1958.

State clearly, in a separate referenced document, all assumptions made in the decommissioning plan

It is important to clearly state all the assumptions made when developing the decommissioning plan, if possible, in a separate document referenced in the main plan. This facilitates the updating of the plan whenever some of these assumptions are changed. The time frame for a decommissioning plan may be quite long, and over the years, many changes may occur in the legal infrastructure, regulations, cost definitions (taxes, labour,...), usable technology, site conditions, etc..

Document as much as possible, and be redundant in storing the documents

Work on decommissioning planning may be used in many years from now. Therefore, it is important to clearly document it, and to be redundant when filing copies with different organizations and areas within your own organization. In our case, useful documentation from a 20 year old dismantling project was lost during organizational restructuring, due to the mistake of filing a single copy in a single area.

In future facilities, select materials carefully, mainly concrete aggregates

Most decommissioning waste in research reactors and accelerators is activated concrete rubble, in many cases in the category of low level radioactive waste with long half-lives (due to ^{152}Eu, ^{166m}Ho, ^{3}H, ^{36}Cl), whose disposal is expensive and problematic due to the extremely long times involved. For long-lived nuclides, it is important that both the specific activities in the waste and total inventory are kept below storage/disposal limits.

As the concentration at trace levels of parent isotopes usually falls within a wide range, the activation of long-lived nuclides can be greatly reduced by proper selection of concrete aggregates and cement during the construction of facilities. Work done in Japan may be used as a guideline in this respect [2].

5.2. Lessons learned regarding international cooperation

Use international cooperation while there is time

Labour is the main cost in decommissioning planning projects, and is one of the most relevant cost items in actual decommissioning projects. International cooperation, mainly through the IAEA, but also through some bilateral agreements is an optimal way of obtaining good advice and of benefitting through sharing experiences.

It might be expected that opportunities for cooperation will be gradually reduced as decommissioning consolidates as a commercial activity. This tendency must be seriously considered by Member States having constrained resources.

Look for experts familiar with your conditions and constraints

It is most helpful if the expert on decommissioning planning has had working experience in other Member States having conditions and constraints similar to the local situation.

Use regional networks

To develop regional networks for sharing information and providing help on decommissioning may be another way of operating within the constraints of scarce resources. Experts from the region may be more acquainted with the local problems, and may find it easier to establish an open dialogue regarding a given problem on the decommissioning of small facilities. Technical and financial support may be sometimes be provided by the IAEA or regional organizations.

5.3. Lessons learned on development of human resources

'On the job' training is often more useful than training courses

When training is provided with the help of international cooperation or some other kind of agreement, it is usually more profitable to perform actual work in a decommissioning project than to take courses or make many short technical visits to different facilities. The real world with its hazards is the best teacher.

There is a tendency to provide too much development of human resources

Our experience has shown a tendency for the phase of developing human resources to go on longer than is necessary. Once basic knowledge exists, actual work in decommissioning activities will provide what remaining training is necessary.

REFERENCES

[1] VETERE, C., EPPENSTEIN, M., "Networking for capturing and preserving existing knowledge", in IAEA Technical Meeting on Managing Nuclear Knowledge, Trieste (2005).

[2] KINNO, M., KIMURA, K., NAKAMURA, T., Raw materials for low activation concrete neutron shields, J. Nucl. Sci. Technol. **39** 12 (2002) 1275–1289.

PANEL DISCUSSION

Session 3

PLANNING FOR DECOMMISSIONING

Chairperson: **I. TRIPPUTI** (Italy)

Members: **A.J. BAER** (Switzerland)
S. HARRIAGUE (Argentina)
T. LAGUARDIA (United States of America)
J.L. SANTIAGO ALBARRAN (Spain)
J. WILSON (United Kingdom)

I. TRIPPUTI (Italy — Chairperson): I invite the panellists to respond to the question 'National policies and strategies for decommissioning — is deferred dismantling a justified option?'

S. HARRIAGUE (Argentina — panellist): In my view, IAEA-TECDOC-1478, 'Selection of Decommissioning Strategies: Issues and Factors', is very relevant to this question.

If one does a multi-attribute analysis of all technical and economic factors involved in decommissioning, one will — with some basic knowledge — arrive at a very good strategy, which is usually immediate dismantling. In the real world, however, there are often constraints — such as a shortage of funds, the lack of a proper radioactive waste management system and problems with the local community — that militate against immediate dismantling. So, I would say that deferred dismantling may be a justified option under some circumstances.

In that connection, I would refer you to contributed paper CN-143-65 by J. Nokhamzon, France, and contributed paper CN-143-87 by J.E. Rowling, Australia.

Mr. Nokhamzon says that the CEA has opted for an immediate dismantling strategy so as not to lose the experience of operators, so as to minimize the costs of surveillance and refurbishment and so as to make the public more confident about nuclear power by demonstrating that nuclear facilities can be dismantled immediately. At the same time, he points out that, in the case of France's graphite moderated reactors, it will be possible to dismantle the graphite moderator only in 7–8 years' time, when there is a technical solution for disposal of the graphite.

Mr. Rowling says that, in the case of Australia's HIFAR research reactor, the management team advocated immediate dismantling so as to draw on the experience of the operating staff. However, the Government and the regulatory authority pointed out that work had not yet started on preparing the site for a repository. They also pointed out that a new research reactor was operating at the HIFAR site, so that adequate staff would be available for taking care of the shutdown reactor and for future decommissioning work. They decided on deferred decommissioning.

J.L. SANTIAGO ALBARRAN (Spain — panellist): In my view, deferred dismantling is an option that can be justified.

We opted for deferred dismantling in the case of Vandellós-1 (a graphite moderated, gas cooled reactor) — the first power reactor to be decommissioned by us. The main reason for our decision was the lack of a disposal facility for the graphite waste. Another important consideration was the fact that the radiation dose rates will decline over time, which will make it easier to decommission the reactor vessel. Actually, this is a case of partial decommissioning — all systems outside the pressure vessel have been dismantled and the graphite waste is being stored on site. Final decommissioning is expected to take place in 25–35 years' time.

For our other power reactors, LWRs, we are considering immediate dismantling strategies, but all decisions will be taken on a case-by-case basis.

In the case of José Cabrera-1, which was shut down in April 2006, we are planning to start decommissioning 2–3 years from now. The necessary funding and technology are available and all the waste can be managed on or off the site. It is estimated that immediate dismantling will cost less than deferred dismantling, and it is also considered that immediate dismantling is preferable from the public acceptance and environmental points of view.

A.J. BAER (Switzerland – panellist): I cannot answer 'yes' or 'no' to the question 'Is deferred dismantling a justified option?' The question is a black or white one, but the answer has to be grey.

There are four groups of issues that should be considered before deciding between immediate and deferred dismantling.

First, there are technical issues. For example, what should be done with the waste?

Second, there are financial issues. For example, are there sufficient funds at present? Will sufficient funds be available in 20–30 years' time?

Third, there are social issues. For example, what will happen to the people now working at the facility and to the nearby town that is so dependent economically on the facility? Will former facility employees, with their institutional memory, still be available to advise in 20–30 years' time? What about the burden being placed on future generations?

Fourth, there are political issues. How stable will the State where the facility is located be during the next 20–30 years? How urgent is dismantling of the facility from the nuclear non-proliferation point of view? What is the risk of terrorists gaining access to the facility during the next 20–30 years?

Fortunately, it is not necessary to decide in a hurry. So, it is better to spend an extra year or so thinking about what to do. It is important not to start decommissioning a large facility before having a clear idea of what path is to be followed. Changing direction half-way is not really an option.

I. TRIPPUTI (Italy — Chairperson): In Italy, we have to decommission four nuclear power plants more or less simultaneously, and we are staggering the decommissioning activities so as to optimize the workload. We plan to decommission the four plants over a period of 20 years. I am not sure whether that is immediate or deferred dismantling.

T. LAGUARDIA (United States of America — panellist): I would consider that to be immediate dismantling.

As regards the question put to the panel, the international consensus favours immediate dismantling, but there are situations where deferred dismantling is a justifiable decommissioning strategy.

The simplest such situation is one where there are multiple units on a site, with the newer units having substantial operating lifetimes left. The personnel of the older — shutdown — units can be usefully employed at the newer units and can also spend part of their time planning the decommissioning of the older units, preparing legacy waste for disposal and participating in long-term planning for the decommissioning of the newer units.

Another such situation is one where there is insufficient money available for safe and complete decommissioning. Deferral will allow more time for the accumulation of financial resources, either through governmental disbursements (if the facility is government owned) or in the form of earnings from the investment of the decommissioning trust fund. However, some decommissioning trust fund money will have to be spent in order to retain key personnel until decommissioning can begin. This may cause the overall decommissioning costs to be higher, but there may be no alternative.

Yet another such situation is one where no radioactive waste disposal facility exists and the likelihood of one being built in the near term is very low. Moreover, if the government or the regulator has not developed waste acceptance criteria with specifications for waste containers, early decommissioning may result in significant waste repackaging in order to meet different waste acceptance criteria that are developed later. Deferred dismantling may be justified, but again the overall decommissioning costs may then be higher.

My answer to the question put to the panel is that one should aim for immediate dismantling, in line with the international consensus, but be flexible.

J. WILSON (United Kingdom — panellist): A number of factors have to be considered when one is deciding when — and how — to dismantle a nuclear power plant.

In the United Kingdom, the present strategy for decommissioning our graphite-moderated gas-cooled (Magnox) reactors is to remove all of the fuel from the site, decommission and demolish as many of the buildings and facilities as possible, and retrieve and condition the waste and — where possible — remove it from the site, leaving only an interim intermediate level waste store (pending construction of the United Kingdom's proposed deep geological disposal facility) and the reactor building with the graphite core in safe storage (for about 80 years, to enable substantial radioactive decay to take place before dismantling).

The Nuclear Decommissioning Authority is now challenging that strategy and asking whether a business case could not be made for accelerating the programme for dismantling the older Magnox reactors and clearing the sites.

When we considered how the reactors are to be dismantled after the period of safe storage, we concluded that significant remote dismantling will be necessary even though radioactive decay will have reduced the volumes of intermediate level and low level waste generated during the dismantling operation. We asked ourselves questions such as:

— Should we leave reactors from which we have benefited for future generations to clean up? What about inter-generational equity?
— Will the knowledge and skills necessary for dismantling those reactors exist in 80 years' time?
— Could the socioeconomic effects on local communities not be managed better through a transition from operation and defuelling to prompt dismantling?
— Might tackling the problem today not lead to innovations in the decommissioning field and help to strengthen the United Kingdom's decommissioning capabilities?
— Is discounted cash flow a mechanism appropriate to a business case when no investment provision has been made (the Government will fund the dismantling programme)?
— Could we dispose of very low level and short lived decommissioning waste on the site?
— Are there alternatives to deep geological disposal for dealing with the irradiated graphite (in France, shallow disposal is preferred)?

We are currently considering many factors, and I think the answer may be different for different reactor sites, depending on the proposed reuse and the local drivers for the acceleration or deferral of dismantling.

M. LARAIA (IAEA — Scientific Secretary): The present position of the IAEA, as reflected in the latest safety standard (Decommissioning of Nuclear Facilities Using Radioactive Material, IAEA Safety Standards Series No. WS-R-5), is that preference should be given to immediate dismantling unless another decommissioning option can be justified. Do the panellists consider that position to be sound, or do they think that all options should have equal status and that decisions should be taken on a case-by-case basis?

J. WILSON (United Kingdom — panellist): The aim of the Nuclear Decommissioning Authority is to accelerate decommissioning wherever possible, dealing with the legacy waste now rather than leaving it to future generations. Without a deep geological disposal facility, however, it makes no sense to generate high level waste that you have to store rather than leaving benign structures in place until such a facility becomes available. Of course, when structures are deteriorating fast we have to decommission them with minimum delay. It is a matter of prioritizing.

T. LAGUARDIA (United States of America — panellist): The international consensus in favour of immediate dismantling is based on two main considerations — being able to draw on the knowledge and expertise of the operating personnel of the recently shutdown facility, and being able to use equipment (such as cranes) that is still functioning well and not having to deal with buildings and other structures that have seriously deteriorated.

As regards drawing on the knowledge and expertise of operating personnel, when, in the late 1990s, we tried to start dismantling the Saxton nuclear power plant, which had been shut down in the early 1970s (after which very little had been done to maintain the reactor building), we interviewed some members of the operating personnel. There was much that they could not remember after so many years and they contradicted one another. We realized that, as time passes, it becomes increasingly difficult to draw on people's memories.

As regards structures that have deteriorated seriously, at one facility where the buildings had not been maintained after shutdown, while we were carrying out the site characterization a worker fell through a roof and was killed.

That having been said, there are situations where deferred dismantling makes sense, but decisions must be taken on a case-by-case basis.

A.J. BAER (Switzerland — panellist): If I were asked 'Is immediate dismantling the best option?', I would say that it is except in certain situations of the kind which have been mentioned here. If I were asked 'Should the IAEA state that immediate dismantling is the best option?', I would be more careful in replying, because an IAEA statement in favour of immediate dismantling might unduly influence some countries and induce them to embark on immediate dismantling when that is not the best option in their particular circumstances.

J.L. SANTIAGO ALBARRAN (Spain — panellist): Generally, immediate dismantling is the best option, but sometimes it is not possible or not advisable.

In the case of Vandellós-1, there would have been no point in dismantling the reactor vessel and leaving materials in storage on the site — the reactor vessel is a better storage facility than anything we could build.

S. HARRIAGUE (Argentina — panellist): I agree with what Mr. Baer just said. As someone from a developing country, I would prefer the IAEA not to come out strongly in favour of immediate dismantling, as some developing countries might embark on dismantling prematurely and have to interrupt the process because they have exhausted their resources, or they might devote excessive amounts of resources to the project and do more social harm than good.

I. TRIPPUTI (Italy — Chairperson): The existence of a business plan for the use of the site after release may be an incentive for immediate dismantling.

S. SAINT-PIERRE (World Nuclear Association): International organizations like the IAEA cannot dictate how particular sites are going to be used after cleanup and release. That is a matter for the operators and local stakeholders. Also, account has to be taken of factors such as national energy supply policies. Otherwise, you are just gambling — you may clean up a nuclear site to perfection and then a decision is taken to resume nuclear activities at that site.

T. LAGUARDIA (United States of America — panellist): Mr. Saint-Pierre just referred to local stakeholders. In that connection, I would recall that in the case of the Maine Yankee nuclear power plant the local stakeholders insisted that it be shut down and then that it be completely removed — they would not allow anything radioactive, however slightly, even to be buried on the site. You have to engage with the local stakeholders early in the decision making process relating to decommissioning.

D. LOUVAT (IAEA): The IAEA safety standard on the Decommissioning of Nuclear Facilities Using Radioactive Material, which says essentially that one should dismantle immediately or justify not doing so, was approved by the IAEA's Board of Governors, which was acting on behalf of all Member States of the IAEA. In my view, therefore, the IAEA's Member States have decided to make immediate dismantling a requirement unless an alternative can be justified, and I would not propose a revision of that requirement just now.

A.J. BAER (Switzerland — panellist): The IAEA's Board of Governors may have approved that safety standard, but national governments take decisions in the light of various political considerations. Irrespective of who represented a particular Member State in the Board when the safety standard was approved, for the government of that State the Board's approval is just one political consideration and the government may well say "It would be nice to comply with that requirement, but we are going to do things our way."

U. BLOHM-HIEBER (European Commission): A further argument in favour of immediate dismantling is that, if you defer dismantling, when you do start you may not be able to obtain the international assistance that you would have been able to obtain if you had started dismantling immediately.

T. LAGUARDIA (United States of America — panellist): Reference has been made to the availability or lack of radioactive waste storage possibilities. In that connection, I would recall that in the USA some decommissioning operations were accelerated when it looked as if the Barnwell Radioactive Waste Facility was going to be closed. The people involved in those operations wanted to place as much waste as possible in the facility before closure.

I. TRIPPUTI (Italy — Chairperson): In the light of that comment, I invite the panellists to respond to the question 'How to plan decommissioning in the absence of waste management and disposal facilities/capacities?'

J. WILSON (United Kingdom — panellist): In the case of some old, deteriorating and potentially dangerous facilities (at Sellafield, for example), we are having to carry out dismantling operations and to condition the high- and intermediate-level waste in such a way that it will be accepted at a repository that does not yet exist.

In order to minimize the amount of waste that will have to be disposed of, we are looking into innovative ways of recycling and reusing materials from decommissioning, and we are doing so in cooperation with people in other countries who have the same concerns.

In that connection, I would mention that our old reactors (the older Magnox reactors, for example) produce some 2700 cubic metres of radioactive waste per gigawatts-year of electricity generated. The corresponding figure for the United Kingdom's advanced pressurized-water reactor is about 160 cubic metres. So, the nature of the waste volume issue will change with time.

We intend to consider how lessons can be learned from decommissioning and fed into reactor operation and — perhaps more importantly — possible 'new build' scenarios.

T. LAGUARDIA (United States of America — panellist): A lot of planning and other activities must be carried out before the start of decommissioning, in order to avoid financial, regulatory and other problems, and many of them can be carried out in the absence of waste management and disposal facilities/capacities.

Such activities include realigning one's organization, dealing with licensing and regulatory compliance issues, dealing with contractual and property tax issues, dealing with financial issues, developing new procedures, looking into ways of minimizing the paperwork burden, reclassifying safety systems, dealing with fuel storage issues, characterizing the site, modifying facilities so as to make future decommissioning easier, training personnel for future decommissioning work, selling off clean equipment and liaising with stakeholders.

If the necessary funds are available, existing staff can, using cranes and other equipment still in good working order at the site, start dismantling and — if waste acceptance criteria have been developed — packaging the waste in containers that will be accepted at the disposal facility once it exists. The containers can be stored in, for example, the turbine building, as is being done at Italy's Garigliano nuclear power plant and elsewhere, and in due course transferred to the disposal facility by any contractor with a forklift and a few trucks.

There will almost certainly be plenty of time for all such activities.

A.J. BAER (Switzerland — panellist): Although you may not have a disposal facility, if you have a storage facility that is large enough or can be enlarged, your problems may not be so great. Many countries have no disposal facilities, so a lot of storage is taking place. The absence of a disposal facility is no reason for not planning to decommission.

If you have neither a storage facility nor a waste management system, you should start by establishing such a system, because you should not produce more waste without knowing what to do with it. Much will depend on what you want to decommission. A nuclear power plant will have been producing waste throughout its operating life, so presumably you have a storage facility that you can fill or enlarge.

At all events, before you start decommissioning you should determine what waste material you have, its volume and activity, so as to know what lies ahead. As Mr. LaGuardia indicated, there are many things you can do before facing up to the problems of disposal.

I. TRIPPUTI (Italy — Chairman): Besides nuclear power plants, one has to decommission research facilities which, in some cases, are in a very bad state, with residues that must be dealt with urgently for safety reasons.

J.L. SANTIAGO ALBARRAN (Spain — panellist): Probably there is no country with a complete radioactive waste management system, but planning for decommissioning — even if there is no management system at all — is nevertheless possible. In Spain, we are working towards the establishment of a complete management system. Meanwhile, we must find practical solutions to the problems being encountered.

In the absence of a complete management system, the waste has to be stored on site. There are storage costs, and sometimes a site cannot be released entirely at the end of decommissioning because some waste has still not been shipped out. That is the case with Vandellós-1, as there is not a yet a facility that will accept graphite waste. Similarly, in the absence of a central facility for the storage of spent fuel, ENRESA will have to store spent fuel on site if we wish to proceed with the decommissioning of José Cabrera-1. We are building an on-site dry storage facility to which we hope to have transferred all the spent fuel by 2009.

It is possible to decommission safely if one finds practical solutions to the problems encountered in the real world.

S. HARRIAGUE (Argentina — panellist): In many cases where there is no waste management system, storage is the solution — as at the Ignalina and Krško nuclear power plants, where waste management systems are being established while decommissioning is taking place. There are cases, as at the Vinča Institute, where part of the decommissioned facility can be used for the storage of decommissioning waste.

In developing countries with only small facilities and no waste management system, it is important that the facility operators make the authorities aware that one day those facilities will be shut down and then something will have to be done with them. In my view, such situations can be dealt with only through international cooperation organized by the IAEA or a regional organization. In that connection, I would like to see more being done to promote regional networks for the provision of decommissioning assistance.

J. WILSON (United Kingdom — panellist): Our biggest problems are with the waste management solutions of the past - for example, spent fuel ponds open to the air (which seemed originally a perfectly adequate means of storage) and underground shafts where waste was once legally disposed of. So, a word of caution - if storage with no definite end is being planned, be aware that it may result in problems that you are not, at present, aware of.

J.-M. POTIER (IAEA): In my view, the absence of a waste disposal facility is no justification for the postponement of decommissioning.

About 90% of the waste generated by the decommissioning of nuclear facilities is hardly radioactive and, with application of the exemption and clearance criteria, it can be dealt with without the use of a disposal facility.

At present, there is no licensed geological repository for high level waste, but high level waste and spent fuel account for less than 1% of the volume of decommissioning waste, and storage solutions are available.

Let us say that 10% of decommissioning waste is low level and very low level radioactive waste. For such low activity material there are already a number of disposal facilities available in the world, and the existing facilities could take care of all the low level material arising from decommissioning activities. The problem may lie with the very low level material. At the IAEA symposium on the Disposal of Low Level Radioactive Waste held in Córdoba, Spain, in December 2004, we considered cost effective solutions for its disposal. There are some disposal facilities for very low level waste (for example, in France, Spain and the USA), but more should be built. There might well be less political and social opposition to the construction of such facilities than to the construction of disposal facilities for high-level waste.

The IAEA recognizes that it may have to strengthen its decommissioning assistance to Member States, especially developing ones — helping them to draw up decommissioning plans and strategies. Efforts will be made to reflect this in its future work programme.

IMPLEMENTATION OF DECOMMISSIONING ACTIVITIES

(Session 4)

Chairperson

P. BEELEY
United Kingdom

Rapporteur

Z. SHANG
China

REASONS FOR INCONSISTENCIES BETWEEN ESTIMATED AND ACTUAL DECOMMISSIONING COSTS

T. LAGUARDIA
LaGuardia and Associates,
Sanibel Island,
Florida,
United States of America
Email: tsl8@aol.com

Abstract

Reliable cost estimating is one of the most important elements of decommissioning planning. Alternative technologies may be evaluated and compared based on their efficiency and effectiveness, and measured against a baseline cost as to the feasibility and benefits derived from the technology. When the plan is complete, those cost considerations ensure that it is economically sound and practical for funding.Estimates of decommissioning costs have been performed and published by many organizations for many different applications. The results often vary because of differences in the work scope. Labour force costs, monetary considerations, oversight costs, the specific contaminated materials involved, the waste stream and peripheral costs associated with that type of waste, or applicable environmental compliance requirements. Many of the differences in cost estimates are unavoidable since a reasonable degree of reliability and accuracy can only be achieved by developing decommissioning cost estimates on a case-by-case site-specific basis. The paper describes the estimating methodology and process applied to develop decommissioning cost estimates. A major effort has been made to standardize methodologies, and to understand the assumptions and bases that drive the costs. However, estimates are only as accurate as the information available from which to derive the costs. This information includes the assumptions of scope of the work, labour cost inputs, inflationary effects, and financial analyses that project these costs to year of expenditure. Attempts at comparison of estimates for two facilities of similar design and size must clearly identify the assumptions used in developing the estimate, and comparison of actual costs versus estimated costs must reflect these same assumptions. For the nuclear industry to grow, decommissioning estimating tools must improve to keep pace with changing technology, regulations and stakeholder issues.

1. INTRODUCTION

The quest for accurate decommissioning cost estimates has been under way since the mid-1970s. Up to that point, decommissioning was far from the nuclear power plant designer's and regulator's minds, as the new growing industry of nuclear power was posing other significant challenges on the way to the development of a viable power industry. In time, because of the large physical size of these plants the ultimate liability for decommissioning became of greater interest. Early cost estimates reflected the minimal regulatory requirements in effect at that time, and the issues of radioactive waste disposal, spent fuel disposition, termination of the licences, and stakeholder interests were perceived as relatively simple issues to be dealt with at some time in the distant future when the plants neared the end of their lifetimes.

As plants became more complex and waste disposal costs soared, decommissioning cost estimates also increased sharply. In the early 1980s, certain owners faced bankruptcy in their efforts to complete nuclear plants under construction, and the availability of funds to decommission these plants became of prime concern. Federal and state regulators in the USA demanded assurance that adequate funds would be available when needed, irrespective of the financial condition of the owners. This prompted an international effort to identify decommissioning costs, and regulators and owners devoted efforts to address the issue.

Numerous attempts were made to estimate costs, from simplistic megawatt ratios based upon the costs to dismantle retired fossil fuelled power plants, to the scaling of costs incurred to decommission small demonstration reactors. Such approaches were quickly abandoned when operating plant experience in replacing major components (steam generators, reactor coolant pumps, reactor vessel internals, etc.) revealed that nuclear plants represented a special case.

A more detailed approach was developed to estimate costs using actual plant experience from retrofit, replacement, and maintenance activities during plant operations, and actual cost data from the current plants undergoing decommissioning. Estimates improved, and the documentation necessary to support the estimates increased in volume and complexity. As a result, greater accuracy led to improved confidence in the magnitude of the costs and in the ability of the estimators to predict future liabilities.

To understand the development of a cost estimate, some background on estimating methodology, types of estimates, estimate preparation, and the major drivers that affect the accuracy, validity, and confidence of the cost must be clearly understood. The problems in trying to compare estimates for two similar plants of the same size, or different evolutions of an estimate for the same plant, can be frustrating, to say the least. Yet with a sound knowledge of the scope of work proposed, the assumptions used, the sources of labour, equipment and consumables cost, collateral expenses, and a standardized methodology, reasonably close comparisons of actual costs to estimated costs can be made. There is more work to be done to refine these estimates, but there is a growing database of actual experience from which to learn.

2. COST ESTIMATING METHODOLOGY

There is no universally accepted standard for developing cost estimates, nor a clear unambiguous reference for the terminology used in decommissioning. The Association for the Advancement of Cost Engineering International (AACEI) was founded as a resource for general cost estimating methodology (not specific to decommissioning), and established a programme for the education and certification of cost estimators to lend consistency to the process. The AACEI has published a book to guide cost estimators in the new and evolving cost estimating practices from all facets of industry [1].

2.1. Types of cost estimates and accuracy

To provide guidance on this issue, the AACEI identifies the types of cost estimate and the levels of accuracy expected. These cost estimate types are summarized in the following paragraphs.

- **Order of Magnitude Estimate:** One without detailed engineering data, where an estimate is prepared using scale-up or down factors, and approximate ratios. It is likely that the overall scope of the project has not been well defined. The level of accuracy expected is –30% to +50%.
- **Budgetary Estimate:** One based on the use of flow sheets, layouts, and equipment details, where the scope has been defined but the detailed engineering has not been performed. The level of accuracy expected is –15% to +30%.
- **Definitive Estimate:** One where the details of the project have been prepared and its scope and depth are well defined. Engineering data would include plot plans and elevations, piping and instrumentation diagrams, one line electrical diagrams, and structural drawings. The level of accuracy expected is –5% to +15%.

It is apparent from these estimate types and the levels of accuracy expected that even in the most accurate case, a definitive estimate is only accurate to –5% to +15 %. The cost estimator must exercise his judgment as to the accuracy level that the input data will support. In developing a funding basis for a project, the estimator must include sufficient margin in the budget to account for this level of uncertainty.

2.2. Developing the cost estimate

Costs may be estimated in a number of ways. Recorded experience from other decommissioning projects, estimating handbooks, and vendor equipment catalogue performance data, among other sources, may be used to develop cost data. The techniques used for preparing cost estimates will necessarily vary with the degree of definition of the project, the state-of-the-art of the project, the availability of databases, cost estimating techniques, time, and cost estimators, and the level of engineering data available.

The method widely used in the USA for estimating is the ‘bottom-up’ technique, based on a building block approach known as the work breakdown structure (WBS). Generally, a work statement and set of drawings or specifications are used to ‘take off'’ (extract) material quantities required for executing each task performed in accomplishing a given activity. From these quantities, direct labour, equipment, and overhead costs can be derived. Using this approach, a decommissioning project is divided into discrete and measurable work activities. This division should provide a sufficient level of detail so that the estimate for a specific and repeating activity can apply to all occurrences of the activity. This estimating approach is described in Ref. [2].

3. COST ELEMENT DEFINITIONS

It is constructive to group elements of costs into categories to better determine how they affect the overall cost estimate. To that end, the cost elements are broken down into activity dependent, period-dependent, and collateral costs as defined in the following paragraphs. Contingency, another element of cost, is applied to each of these elements on a line item basis because of the unique nature of this element of cost.

3.1. Activity dependent costs

Activity dependent costs are those associated with performing decommissioning activities of decontamination, removal, packaging, transportation, and disposal or storage. These activities lend themselves to the use of unit factors due to their repetitive nature. Work productivity factors (or work difficulty factors) can be added and applied against the physical plant and structure inventories to develop the decommissioning cost and schedule.

3.2. Period dependent costs

Period dependent costs include those activities associated with the project duration: programme management, engineering, licensing, health and safety, security, energy, and quality assurance. These are typically included by identifying the functions and services needed, including the associated overhead costs based on the scope of work to be accomplished during individual phases within each period.

3.3. Collateral and special item costs

In addition to activity and period dependent costs, there are collateral costs for special items that do not fall into either of the other categories, such as construction or dismantling equipment, site preparations, insurance, property taxes, health physics supplies, liquid radioactive waste processing, and independent verification surveys. Data supplied by the owners is used for costs such as insurance and property taxes.

3.4. Contingency

Contingency is defined by the AACEI as “a specific provision for unforeseeable elements of cost within the defined project scope, particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events that increase costs are likely to occur.”

The cost elements in an estimate are typically based upon ideal conditions where activities are performed within the defined project scope, without delays, interruptions, inclement weather, tool or equipment breakdown, craft labour strikes, waste shipment problems, or disposal facility waste acceptance criteria changes, and changes in the anticipated plant shutdown conditions, etc. However, events occur that are not accounted for in the base estimate. Therefore, a contingency factor is applied.

Early cost estimates included a 25% contingency applied to the total project cost. More recent estimating models apply contingencies on a line item basis, yielding a weighted average contingency for the estimate. One source for the line item contingencies is the AIF/NESP study [2], which discusses the types of unforeseeable events that are likely to occur and provides guidelines for application.

3.5. Scrap and salvage

Scrap is defined as removed materials that are certified to be clean, and may be sold to a scrap dealer for ultimate recycling as a raw material. Examples of scrap materials are copper wire and bus bars, stainless steel plates and structural members, carbon steel and stainless pipe, carbon steel structural shapes, beams, plates, etc. Salvage is defined as removed materials that have an identified market for resale or reuse in their current form at a specific facility. Accordingly, pumps, motors, tanks, valves, heat exchangers, fans, diesel engines and generators, etc., are the types of components that are candidates for salvage. The market for salvageable materials from nuclear facilities is limited.

3.6. Work breakdown structure

The work breakdown structure (WBS) is used to categorize cost elements and work activities into logical groupings that have a direct or indirect relationship to each other. The work groupings are usually related to the accounting system, or chart of accounts used for budgeting and tracking major elements of the decommissioning costs. The WBS elements are generally arranged in a hierarchal format similar to a company's organization chart. The topmost member or level of the WBS is the overall project. The second level is the major cost groupings under which project costs are gathered. Subsequent levels are often used to track details of the component parts of the grouping for a clear understanding of all the cost bases.

3.7. Chart of accounts

The project management or accounting software used on projects identifies categories of costs in terms of a chart of accounts. The chart of accounts is used to budget and control the individual cost items of labour, equipment, consumables, capital expenditures, recycle services, transportation or disposal services. The European Commission (EC), the IAEA and the OECD/Nuclear Energy Agency (OECD/NEA) have prepared a Standardized List of Definitions for Cost Items for Decommissioning Projects [3]. This reference may be used to establish the chart of accounts.

4. COST ESTIMATING PROCESS

The cost estimating process flows from an overview of the project, to the scenarios evaluated or selected, to the assumptions critical to the approach, to the details of the cost elements and the work schedule, and then to a summary of the principal cost drivers. While there are no hard and fast rules for formatting the process, there are logical guidelines to follow so that cost estimates can be easily tracked and compared.

4.1. Scope of work

The scope of work for the project must be clearly stated at the outset of the estimate to ensure the estimator and reader understand what is included in the estimate, and the extent of effort required. The scope should identify assumptions and the extent of the physical removal and remediation of the site.

4.2. Decommissioning strategy

Decommissioning strategies may include safe storage, immediate dismantling, or entombment. Safe storage may be combined with delayed dismantling to take advantage of radioactive decay to reduce exposure to workers and to allow sufficient time for adequate waste disposal facilities to be developed.

4.3. Collection of information

A site specific estimate uses defined engineering data, site and plot plans, general arrangement and architectural drawings, piping and instrument diagrams, one line electrical diagrams, equipment specifications, and reference manuals, etc., to develop the physical inventory for decommissioning. Data collection also includes the site radiological and hazardous material characterization information, a site specific inventory of systems and structures, local labour costs for skilled labour and management, local consumables and materials costs, and taxes, insurance, engineering and regulatory fees.

4.4. Preparation of the cost estimate

The application of unit costs to the inventory of systems and structures for each decommissioning activity provides the activity dependent costs. Project management staff costs for the duration of the project provide the period dependent costs. Collateral costs and contingency are added to obtain the total cost.

4.5. Preparation of the schedule

The overall schedule is developed from a logical and planned sequence of activities. The duration of each activity is estimated from the individual dismantling steps, and the sequence is evaluated to obtain the critical path (longest time) to accomplish the work. Iterations are often necessary to arrive at a reasonable schedule. This work is usually performed using scheduling computer programs.

The cost estimate and schedule are not stand-alone documents; they are linked inseparably, as changes to the schedule affect the time when activities will be accomplished and therefore the associated costs. An accurate cost estimate and schedule provide the ability to track costs and project trends, and to evaluate the impact of changes.

5. WHERE DO COST ESTIMATES GO WRONG?

The differences between estimated and actual costs are due to several factors. These include scope changes, year of reported costs, inflation, discount rate, contingency levels, risk factor allowances, and methodological differences. Some of these are inter-related factors and care must be taken to sort out the reasons for the differences, rather than simply relying on the ‘bottom line’ cost as a basis for decision-making or project performance measurement.

5.1. Scope changes

Probably the greatest factor contributing to variances in cost is associated with the differences in the scope of work used for preparing the cost estimate and that of the actual project. Preliminary estimates are often prepared to compare various decommissioning strategies (safe storage, immediate dismantling, or entombment) and to evaluate and select a proposed approach. The assumptions used in these estimates generally define the scope of work to be performed and the schedule over which the activities will be conducted. When a recommendation is made on a given strategy, the assumptions of scope of work must be clearly understood, and management approval secured before approval is granted. Parametric studies may be performed on the major cost drivers to determine if the results of the recommendation change significantly and for what reason. When the given strategy is adopted by management, any changes made in the scope of work must be reflected in a revised cost estimate. This allows the adequacy of the funding plan to accumulate the necessary funds to accomplish the work to be kept under review.

5.2. Year of reported costs

The estimate should specify the year in which the cost estimate is based, although all too often such details are lacking. The database used for labour costs, purchased or rented materials and equipment, consumables, and other collateral costs must be identified and adjusted for the year of the estimate.

5.3. Inflation

A factor which is strongly related to the reported year of cost is the inflation rate assumed for the estimate. This includes not only the internal inflation factor used to update a previous year's labour rate or equipment cost database, but also the inflation rate used to project future years of expenditure costs for an accurate projection of funding needs. For long term funding planning, the inflation rate will have a greater effect on the funding rate (annual accrual to the decommissioning fund) than any other factor in the estimate. For example, a one-half per cent increase in the estimated future inflation rate (3.5%) over the actual inflation rate (3.0%) will result in a 21% higher estimated future cost over 40 years. If the current cost estimate is $500 million, the estimated future cost at the higher inflation rate would be $1980 billion instead of $1631 billion, a difference of $349 million. Making such projections is necessary for fund planning purposes but must be re-evaluated periodically to reflect actual inflation rate experience.

5.4. Discount rate

A similar situation exists in relation to the estimated discount rate used to estimate the net present value of the future cost. As noted earlier, this factor needs to be re-evaluated periodically to reflect current discount rates.

5.5. Contingency levels

As discussed earlier, contingency amounts are included to account for unforeseeable elements of cost within the defined project scope. Contingency amounts are expected to be fully spent, as the events driving these costs have been demonstrated to occur. The contingency included in the estimate reflects the level of risk the estimator and management are willing to accept. Activities involving work in high radiation areas or in difficult work conditions carry a higher level of contingency. The estimate should identify what levels of contingency have been assumed for each different type of activity or expense.

5.6. Risk factor allowances

Risk factor allowances are often included to reflect events that are not certain to occur (contrary to contingency), but may be estimated by a probability of occurrence. Factors such as severe weather events, the loss of waste disposal availability, transportation routes, organized labour strikes, etc., can cause large increases in the total project cost and quickly deplete the available funds. Management may want to provide additional funding to account for these probabilistic events. Estimates of risk are usually performed using probabilistic computer codes where specific risk factors are evaluated for their low, medium, and high ranges of cost over the entire spectrum of decommissioning activities. The results of such calculations could show, for example, that for a particular activity there is a 60 % probability that the estimated costs will not exceed 20% of the base cost (without risk).

5.7. Methodological differences

As discussed earlier, there are several methods for preparing cost estimates. The degree of accuracy depends on the quality of the input data of the inventory of systems and structures, and the reliability of unit cost factors applied to the inventory. The level of detail used in the Work Breakdown Structure, and the organization of the WBS can have significant effects on the outcome of the estimate. It is virtually impossible to validate an estimate without the details of how the estimate was prepared. At best, a comparison can be made of the total estimated cost to the actual cost with no attempt to correlate individual cost drivers. Often, the cost and schedule tracking system used during decommissioning is not correlated to the cost estimate structure, so direct comparisons are impossible.

5.8. Selected examples of cost comparisons

In recent years, project managers have been conscientious in tracking costs to the estimated values on a line item basis. The early results have been remarkably good compared to the baseline estimate.

Maine Yankee Atomic Power Plant

Table 1 illustrates an example of the 880 MW(e) PWR, Maine Yankee Atomic Power Plant, where actual costs were compared to estimated costs.

TABLE 1. COMPARISON OF MAINE YANKEE 1998 DECOMMISSIONING ESTIMATE TO ACTUAL COSTS AND CURRENT EXPECTED COST (IN 1998 US DOLLARS)

Activity	1998 estimate	Actual cost and current estimate
Staff/staff augmentation	116 467 257	160 255 888
Decommissioning contractors	250 367 727	283 344 667
Decommissioning settlements		(47 982 079)
Other contract services	28 071 200	69 859 700
Fees/property taxes	55 667 103	44 839 376
Insurance	12 108 827	21 503 577
Purchased power	10 317 915	8 107 302
Rentals and leases	1 887 970	3 502 744
Materials and supplies	4 532 364	7 867 222
Other expenses	8 731 875	8 917 398
Contingency	42 099 380	16 502 053
Totals	**530 251 618**	**576 717 849**

The level of accuracy is within 8.8%. As in any estimate, individual line items of costs may be higher or lower than the estimate, but the total costs are within the range of accuracy expected for this project.

For this project a number of significant scope changes occurred which account for the difference in the estimated versus the actual costs. These differences include:

— Increased costs to address post-September 11 additional security measures;
— Relocation of the control room twice to maintain control of operable systems;
— Additional soil removed to meet changed site clearance levels from the US Nuclear Regulatory Commission's 25 mrem/year to the State of Maine's 10 mrem/year criteria (a change that took place after the project started);
— Additional costs to remove and bury all containment building interior concrete as radioactive waste instead of demolition and use as on-site fill;
— Additional engineering costs to analyse containment building demolition by ramhoe and blasting;

— Increased costs for insurance post-September 11;
— Additional costs to self-perform spent fuel dry storage after vendor failed to meet contract requirements.

No specific accounting for the magnitude of these changes is available at this time. These changes in scope were not anticipated when the original estimate was prepared. As noted earlier, contingency is an allowance for events within the defined project scope, and therefore would not be used for scope changes. However, since contingency is spent during every phase of the project, the difference in contingency values reflects the amount that was actually incurred during the performance of the work accomplished.

Big Rock Point

Big Rock Point is a 60 MW(e) BWR located in Charlevoix, Michigan. Table 2 shows the comparison of estimated costs versus actual/expected costs for completion.

The level of accuracy is approximately 6%, which is within the expected range for this project. In this case, the contingency is included in the values listed. Several scope changes were encountered in this case which were not anticipated at the start of the project and together with the different year of the estimate compared with the actual project, this accounts for the differences. These differences include:

— Licence termination activities in 2004 reflect the inflationary effect of the cost of money (approximately 3.1% per year);
— Increased spent fuel management costs incurred as the vendor encountered fabrication difficulties and delays in delivery;

TABLE 2. COMPARISON OF BIG ROCK POINT 2002 DECOMMISSIONING ESTIMATE TO ACTUAL COSTS AND CURRENT EXPECTED COST (IN 2004 US DOLLARS)

Activity	2002 Estimate	Actual cost and current estimate
License termination	299 400 000	318 681 000
Spent fuel management	68 600 000	7 3 018 000
Site restoration	27 300 000	29 058 000
Totals	**395 300 000**	**420 757 000**

— Site restoration activities in 2004 reflect the inflationary effect of the cost of money.

These two examples highlight the importance of accounting for scope changes for events beyond the original planned scope of work and the impact of inflationary effects on the reported actual data.

6. HOW DO WE IMPROVE COST ESTIMATES?

The decommissioning industry needs to build consistency into its cost estimates. A standardized list of decommissioning activities should be adopted internationally so that estimates can be prepared on a consistent basis and to facilitate the tracking of actual costs against the estimate. The international Standardized List [3] incorporates the consensus of international experts as to the elements of cost and activities that should be included in the estimate. A significant effort was made several years ago to promote the universal adoption of this list. Using the standardized list of activities as a template, a questionnaire was distributed to gather actual decommissioning costs (and other parameters) from international projects. Cost estimate contributions from many countries were analysed and evaluated for reactor types, decommissioning strategies, cost drivers, and waste disposal amounts. The results were reported in the literature [4].

The value of a standardized list of activities is the establishment of consistency among estimates from the lessons learned from the past. With appropriate guidelines, methodology, and training, the factors identified earlier of: scope changes, year of reported costs, inflation, discount rate, contingency levels, risk factor allowances and methodological differences can be clearly identified and can lead to reliable estimates.

A standardized list of activities will only be valuable if the underlying cost elements and methodology are clearly identified in the estimate. While no one would expect perfect correlation of every element of cost in a large project estimate versus actual cost comparison, the variants should be visible so that the basis for the difference can be examined and evaluated. International organizations, such as the IAEA and the OECD/NEA, should promote the standardization of cost estimation guidelines, methodology, and training. Similarly, the committee should be directed to continue to accumulate actual decommissioning costs should be accumulated internationally, suitably converted into a form that does not compromise proprietary information. From this data base, consensus can be achieved.

REFERENCES

[1] AACE INTERNATIONAL, Project and Cost Engineers' Handbook, 3rd edn, Marcel Dekker, New York (1993).

[2] LAGUARDIA, T., et al., Guidelines for Producing Nuclear Power Plant Decommissioning Cost Estimates, Vols 1 and 2, AIF/NESP-036, Atomic Industrial Forum/National Environmental Studies Project, Bethesda.

[3] EUROPEAN COMMISSION, INTERNATIONAL ATOMIC ENERGY AGENCY, OECD/NUCLEAR ENERGY AGENCY, Standardized List of Definitions for Cost Items for Decommissioning Projects (1999).

[4] OECD/NUCLEAR ENERGY AGENCY, Decommissioning of Nuclear Power Plants, Policies Strategies and Costs (2003).

DISCUSSION

G. LINSLEY (IAEA): Wages are much lower in some countries than in others. How do decommissioning costs vary from country to country?

T. LAGUARDIA (United States of America): In the USA, on the whole we have high wage levels, but we are currently fortunate in having low waste disposal costs. In other countries, the wage levels may be lower, but waste disposal costs are higher.

So, you have to identify the basis for the cost estimate — that is part of the assumptions for cost estimates. However, the difference due to wage costs can be significant — millions of dollars, tens of millions of dollars or, in some cases, hundreds of millions of dollars. But when you are comparing estimates from one country to another, it is probably better to use something like person-hours than monetary units.

DECOMMISSIONING OF FUEL CYCLE FACILITIES IN SOUTH AFRICA

P.J. BREDELL, G.J. LEUNER, S.W. SMITH
Nuclear Energy Corporation,
Pretoria,
South Africa
Email: pbredell@necsa.co.za

Abstract

Experience gained in South Africa on the decommissioning of uranium conversion, enrichment and fuel fabrication facilities is briefly summarized with emphasis on the lessons learned. The South African Nuclear Energy Corporation (Necsa) has consolidated its nuclear decommissioning and waste management activities at Pelindaba and introduced a comprehensive, all-embracing nuclear liability management approach. The paper describes the experience gained on various aspects of decommissioning and waste management including the social impacts of the decommissioning and waste related activities during the decade from 1995 to 2005. Certain technological difficulties arose during this period and the approaches adopted to resolve these difficulties are also addressed.

1. BACKGROUND

Radioactive waste has been generated at the South African Nuclear Energy Corporation (Necsa) since the early 1960s; it originally consisted largely of research waste, but also included limited quantities of waste from medical and industrial applications of radioisotopes from other parts of the country. Spent fuel and radioactive effluents from the Safari Research Reactor had to be managed from 1965 onwards. Necsa's nuclear fuel production facilities, commissioned during the mid-1980s, generated mostly uranium-based waste. Necsa has been storing all the radioactive waste on the Pelindaba site, which is approximately 30 km to the west of Pretoria.

The South African Government's decision to sign the Treaty on the Non-Proliferation Nuclear Weapons in 1991 and to enter into a safeguards agreement with the IAEA soon afterwards culminated in the eventual phasing out of Necsa's nuclear fuel production capability. As a direct result of these political developments, South Africa regained access to the international nuclear fuel markets with the consequence that the economic viability of

Necsa's nuclear fuel production capability was seriously challenged and its phasing out became inevitable.

The first facility to be permanently closed down was the pilot enrichment plant for highly enriched uranium (HEU) (Y Plant) in 1990, followed successively by the closure of the so-called 'semi-commercial enrichment plant' (Z Plant) in 1995, the PWR fuel fabrication plant (Beva) in 1996 and the uranium conversion plant (U Plant) in 1998. The closure of the entire front end of the nuclear fuel cycles at Necsa left the State with large nuclear liabilities that needed to be urgently addressed. In response to this need, the Government made certain financial appropriations in 1995 for the dismantling and decontamination of the two enrichment plants.

The considerable scope of the liabilities management task as well as the need for policy decisions to guide the entire process became apparent between 1996 and 1998. In addressing this responsibility, Necsa established a new group called Nuclear Liabilities Management (NLM). This group was established in 1999 and was made responsible for all aspects of decommissioning, site remediation and radioactive waste management. Included in its remit was the requirement to establish a reliable assessment of all of the nuclear liabilities on the Pelindaba site in order to enable effective liability reduction to be achieved within the funding resources provided by Government. The overall guiding principle for this new approach was to provide best value for taxpayers' money through the application of cost-effective decommissioning and waste management methodologies.

Now, six years after the establishment of NLM, much has been achieved as a result of this integrated liabilities management approach, i.e. (a) liability assessments have been conducted and reviewed at annual intervals and a sufficiently accurate estimate of the present and past nuclear liabilities has now been established, (b) the second phase of the decommissioning programme involving the two enrichment plants, i.e. decommissioning of plant process equipment, excluding the process buildings, is almost completed, (c) several smaller facilities such as disused laboratories have been fully decommissioned and released for non-nuclear use, (d) suitable waste management processes have been defined, developed and optimized for the various radioactive waste forms presently stored on the Pelindaba site, and (e) much preparatory work has been done in defining and establishing suitable endpoints for these various waste forms.

As a nuclear waste management service provider, NLM has also engaged in external radiological activities, including the decommissioning of sites contaminated with naturally occurring radioactive materials (NORM) previously utilized in the mining and mineral processing industry.

In the following sections, the lessons learned from the South African decommissioning experiences are discussed and highlighted.

2. PLANNING

The planning for the decommissioning of the two enrichment plants initially focused on the dismantling, in situ dry decontamination, size reduction and removal of the process equipment from the process buildings. The planning system was continually adjusted to take account of the changing situation and resulted in satisfactory programme performance. A lesson learned is that planning systems need to be flexible enough to allow for ongoing adjustments to the decommissioning programme.

The rate of disassembly of the process equipment had to be carefully matched with that of the subsequent dry/wet decontamination activities, which took place in a separate facility. This facility had a limited capacity and its throughput was optimized by means of a categorization system that allowed efficient planning and routing of components through the various decontamination processes. The decontamination facility, however, remained a ‘bottleneck’ throughout the decommissioning of the enrichment facilities.

A certain portion of the dismantled process components could, for various reasons, not be decontaminated down to the required levels for free release. These components thus needed to be temporarily stored at a suitable location on site, before being further processed. In the initial planning for plant decommissioning, sufficient provision was not made for the large storage areas required for such partially decontaminated components, so that these components had to be stored outside the facilities where they could not be adequately protected from weather conditions. This arrangement proved to be an unsatisfactory but unavoidable solution and clearly demonstrated the need to take into account, in the planning process, of all the downstream activities which are part of the overall materials management process. The process components were sold as scrap after being cleared from regulatory control.

The consolidation of all decommissioning and waste management activities at Pelindaba into a single nuclear liabilities management group, NLM, made it possible to establish a comprehensive long term plan for the discharge of the nuclear liabilities. This approach required that clear endpoints were determined for the various waste streams, as the liabilities can only be effectively terminated once the waste is finally disposed of. The approach used in the management of nuclear liabilities has been effective in bringing focus to the overall planning, implementation and control aspects of the decommissioning programme.

Establishing project priorities within the long term liability discharge plan presented certain challenges, both at the beginning and in the course of the programme. A system was developed for reviewing, on an ongoing basis, the priorities assigned to the various liabilities, including those for decommissioning. The criteria used for prioritization were based on factors such as maintaining existing facility safety and security conditions, human resource constraints, technology requirements, fund requirements, public sensitivities, facility reuse potential and demand. It was found necessary to review the decommissioning priorities on an ongoing basis to take account of the changing environment.

Experience indicated that the first and second phases of the decommissioning programme, i.e. the safe shutdown of the facility and the removal of the process inventory, followed by the disassembly and decontamination of process equipment could be fairly accurately planned and executed based on available information and experience gained in the past. Difficulties were, however, encountered in the third phase, decontamination of process buildings, where prior experience was lacking. Furthermore, difficulties were also experienced with regard to the termination of the licensing conditions for facilities that had been decontaminated during third phase.

Apart from its nuclear fuel cycle activities at Necsa, NLM has also been engaged in commercial projects for external customers, mostly in relation to the decontamination of redundant facilities and sites in the gold and uranium mining industry as well as other minerals beneficiation processes. The main lesson learnt from this experience is that it is crucial to gain as much information as possible about the sites in order to be able to plan properly. Although some information about the radiological state of the sites could be obtained from radiological surveys, other important information was not always readily available, especially historical information on the previous use of the sites. Having such historical information about the sites to be decommissioned is a major competitive advantage for any contender in the tendering process. Information on the availability of endpoints for the disposal of bulk materials was found to be crucial to the technical and, hence, commercial success of the project. Knowledge of the licensing requirements applying to a project is a vital part of the planning function.

3. INSTITUTIONAL REQUIREMENTS

In South Africa, the Nuclear Energy Act, No 46 of 1999, makes provision for the discharge of certain institutional obligations, including the decommissioning of nuclear facilities belonging to the State. In terms of this statutory obligation, the Government has to provide funds for the decommissioning of redundant nuclear facilities falling under Necsa's control.

The decommissioning of these redundant facilities is performed by NLM under the regulatory supervision of the National Nuclear Regulator (NNR). The regulator's terms of reference are based on the National Nuclear Regulator Act, No. 47 of 1999.

From the perspective of the regulator, the licensee has to put in place certain resources in order to allow sufficient regulatory control of the decommissioning activities being performed. These include the human resources involved in the technical execution of the task and the financial resources to maintain, equip, house and apply the human resources. A lesson learned from past experience is that early involvement of the regulator at the planning stage is necessary to ensure seamless implementation of the regulatory regime. This early involvement has not always been achieved.

As part of the regulatory review of decommissioning projects, the licensee has to submit a pre-agreed licensing strategy. Legislative and regulatory constraints can potentially seriously affect decommissioning projects in a number of ways and it is therefore necessary to plan for such contingencies and to build them into the overall strategy. Some of the most important potential impacts are project delays and, therefore, difficulties in accurately scheduling the projects. The resources of the licensee can also be stretched as a result of such delays.

Necsa has been issued with a single licence for its Pelindaba site, which covers all operations and decommissioning activities. From the regulator's perspective, the removal of fully decommissioned facilities on an individual basis from the licence has been found not to be practical. An agreement has therefore been reached with the regulator that licence requirements would not be terminated, but only temporarily suspended. In retrospect, a licensing structure that allows separate licences to be issued for individual nuclear facilities, with clearly defined boundaries, would be preferable to a single site licence.

The decommissioning work at Necsa has been a learning experience for both NLM and the regulator. As the programme progressed, regulatory requirements have increased in scope and detail, requiring more streamlined work procedures, as well as additional resources. A particularly relevant aspect, from the licensee's viewpoint, is the need for an adequate level of technical competence on the part of the regulator to enable a timely and critical evaluation of licensing submissions. Where such capabilities are lacking, serious delays in obtaining nuclear decommissioning licences can be experienced.

Central to the licensee's strategy for compliance with regulatory requirements is the need to cultivate and maintain a healthy safety culture in the workforce. This requirement should take precedence over all other considerations in the implementation of the liabilities management system, even that of project efficiency.

4. TYPE AND SIZE OF FACILITY

The facilities being decommissioned on the Pelindaba site consist of a variety of redundant structures previously utilized for a research, uranium conversion, uranium enrichment, fuel fabrication and support purposes. The structures vary in architectural design, size and complexity. The radioactive contaminants are mainly uranium isotopes and the contamination levels depend on the nuclear and related processes historically carried out inside these facilities.

The decommissioning strategies for the different redundant structures depend strongly on the unique features pertaining to each structure. As the Pelindaba site is currently still an operating site with an active Necsa workforce, no difficulties have been encountered in obtaining the required information, skills and expertise for decommissioning purposes. Had these facilities been left to future generations to manage, it would be much more difficult for future decommissioning staff to find the relevant information, skills and expertise to perform the task.

The redundant facilities earmarked for decommissioning at Pelindaba can be broadly sub-divided into small (laboratory type) facilities and plant facilities. The decommissioning strategies for small facilities are fairly uniform and rarely present problems. On the other hand, the decommissioning strategies for large plant facilities vary widely and depend on building layout, structure, services, type of process equipment and the existing levels of contamination.

The process buildings on the Pelindaba site are large imposing concrete structures designed to fit into an overall architectural style. These structures, although aesthetically pleasing, are particularly difficult to decontaminate, owing to the adsorption of uranium compounds on the porous internal building surfaces. Special surface cleaning methods had to be applied to these surfaces in order to achieve the required levels of decontamination. The lesson to be learned is that special care needs to be taken in the design of process buildings to facilitate later decommissioning activities.

NLM undertook external contract work from time to time and the nature of the facilities involved varied widely. The NLM teams involved in these activities therefore had to adapt to a great variety of radiological conditions when defining and implementing decommissioning strategies for these commercial projects.

5. PROJECT MANAGEMENT REQUIREMENTS

Project management lies at the heart of decommissioning programme implementation. A decommissioning project management capability at Necsa was created almost ten years ago. Despite the many changes to the project management structure during this period, a core of decommissioning experience and 'know how' has been built up over the years at all levels of the work. This capability was created from a group of people previously involved in operations and maintenance work. These individuals were required to adapt to the decommissioning task, not only by changing their entire job orientations, but also by working in a new organizational structure.

The decommissioning organization had to be versatile and strongly project orientated in order to cope with continually changing working conditions. Adequate levels of efficiency had to be achieved while maintaining a sound safety culture. Among the decommissioning teams there was some prior knowledge of the redundant facilities to be decommissioned. In spite of their basic competencies, staff still needed to be trained and motivated to perform the new project orientated tasks. Apart from the workers, management staff previously involved in plant operations were also absorbed into the decommissioning organizational structure. As many of these individuals had previously worked together, albeit under different conditions, they were easily be moulded into a single efficient and focused decommissioning project team. The need to commence with decommissioning activities as soon as possible after plant shutdown cannot be overemphasized.

The NLM organization is a largely self-sufficient group comprising all the essential elements needed to perform the overall task of liabilities management, including decommissioning projects. It functions in a highly integrated manner and embodies all the resources required to fulfil its obligations as a service provider, with little external assistance. Whether or not such independence produces optimal efficiency is debateable. During the formative years of the new NLM organization, the contracting models employed by other countries in the execution of their decommissioning work were studied. Ideally, subcontracting the different decommissioning tasks on a competitive basis to external contractors should enhance overall efficiency, but in a developing country such as South Africa, the market for these skills does not exist. 'In house' expertise thus became a necessity in this situation.

As there was limited project management expertise available, initially it was necessary to establish an effective project management system to execute the task. This aspect turned out to be a greater challenge than originally anticipated and required a considerable period of time before it was properly established. Although formal project management systems are commercially available, an indigenous system still needed to be shaped on the basis of the particular needs of NLM. A major effort should be made at an early stage to develop an effective project management system that fulfils the particular needs of the decommissioning programme.

The foregoing discussion has centred on the discharge of the State's liabilities at Pelindaba, involving relatively sophisticated and technically challenging project activities. In the case of the external work that NLM performed for customers on a commercial basis, the project work was carried out almost entirely by means of subcontractors. These projects were, however, limited in scope, technically relatively straightforward and could therefore be executed in a more 'conventional' manner.

The success of the project management organization strongly depends on factors such as retaining the operational and maintenance staff after plant closure, having an appropriate blend of technical skills, having the necessary project management capabilities, obtaining detailed knowledge of the facility operating conditions prior to closure, and, last but not least, achieving the effective reorientation and re-motivation of the decommissioning staff towards a new meaningful challenge.

6. TECHNICAL CHALLENGES

The technical challenges in the decommissioning of redundant facilities at Pelindaba are primarily focused on the following problem areas: the final decontamination of dismantled process components not decontaminated to the required levels for free release, the decontamination of building structures as part of the third phase decommissioning, the conditioning of certain kinds of mixed waste not lending themselves to feasible solutions and, finally, establishing disposal endpoints for the different kinds of waste streams on the site. Each of these areas is briefly discussed below to demonstrate the approach taken and the lessons learned.

In addressing the need for the final decontamination of the partially cleaned process components, Necsa decided to install a smelter for melting down these components. The smelter project was initiated almost five years ago, but Necsa has, to date, not been able to obtain the necessary approvals from the environmental and nuclear regulatory authorities to construct this facility. This delay is due to extreme public sensitivity exacerbated by environmentalist intervention. Alternative solutions are being investigated, such as the transfer of the relevant components offsite to be melted at a licensed industrial smelter. Another approach that was considered involved the shredding of these components for packaging and disposal at the Vaalputs National Disposal Facility for low and intermediate level waste. This is an example of a technical difficulty that should have been foreseen at the planning stage of the decommissioning programme and for which a solution in principle should have been provided.

Some success has been achieved in the decontamination of buildings by using conventional methods (washing and scabbling). More sophisticated methods need to be employed or developed for the more severely contaminated areas, especially where raw, porous concrete surfaces are involved. Partial or full demolition of the buildings may be the only options in certain cases in order to achieve free release. This again emphasises the importance of choosing appropriate surface finishes during the design of nuclear facilities and of maintaining these finishes during the operational phase.

The issue of mixed waste, i.e. radioactive and chemical waste mixtures, is a problem commonly encountered in the decommissioning of disused nuclear facilities. In Necsa's case, the following still require feasible technical solutions: the treatment of large volumes of uranium contaminated lubrication oil from the enrichment plants, the separation/drying of large quantities of aqueous sludge containing uranium and chemicals and the conditioning of thousands of waste drums for disposal at Vaalputs. These problem areas are clearly not insurmountable as there are alternative solutions available, but the challenge is in finding the most economically feasible approaches.

Endpoints in general constitute the major challenge in the entire liabilities management programme. In Necsa's case, the potential endpoints in question are firstly, the development of a deep geological repository for research reactor spent fuel that may, or may not require prior reprocessing, secondly, the utilization of the existing Vaalputs National Disposal Facility for the disposal of the large quantities of low and intermediate level waste currently stored at Pelindaba, and finally, the development of landfills on the Pelindaba site to accommodate the large amounts of sludge and building rubble contaminated with only very low levels of radioactive material and for which such disposal methods are recognized as appropriate. The implementation of these endpoints for Necsa's nuclear waste is crucial to the successful realization of the nuclear liability management approach and thus they should be pursued in a systematic and focused manner. The lesson to be learnt here is that the definition, planning and eventual implementation of endpoints, or at least holding points if endpoints are not feasible, constitute an essential element in the discharge of liabilities, of which decommissioning forms an integral part.

7. ECONOMIC DRIVERS AND FINANCIAL REQUIREMENTS

The decommissioning liabilities belong to the State and the NLM group of Necsa is responsible for the discharge of these liabilities. The Government is clearly the customer in this regard and needs to provide the necessary funds. The current financial arrangement with the Government is that funds are annually allocated directly towards the decommissioning of the redundant nuclear facilities at Pelindaba. The allocations for waste liabilities form part of Necsa's annual budget allocations to NLM.

There is currently a scheme in which the Government will financially 'ring fence' all decommissioning and waste management activities at Necsa involving redundant nuclear facilities. It is not clear at the present time what financial mechanisms will actually be put in place to ensure the long term funding of these activities. These developments are very promising in that they demonstrate the Government's resolve to address the decommissioning and waste liabilities in a systematic and predictable fashion. A reliable source of funding for the decommissioning programme is a prerequisite for the systematic discharge of nuclear liabilities in the long term.

The revenues derived from NLM's commercial decommissioning and site remediation activities do not always justify the efforts that go into the planning and implementation of these projects. Experience has shown that they are time consuming, taxing on resources, limited in potential earnings and disproportionately risky. NLM is often approached by customers in the mining and minerals processing industry to tender for such work. Currently NLM will only engage in external work based on invitation where competitive bidding is excluded. Striking a proper balance between the institutional decommissioning activities (the largest portion of the work load) and those performed for commercial purposes (smallest portion) is essential in focusing on the main task at hand.

8. SOCIO-POLITICAL IMPLICATIONS

Necsa has two community based organizations (CBOs) through which the public is kept informed of developments. One CBO is a voluntary organization with limited membership and the other is a statutory body created by regulation through the National Nuclear Regulator Act. In the latter case, Necsa is obliged to keep the public living in the immediate surroundings of the Pelindaba site informed of all relevant safety matters.

At both forums, decommissioning issues are raised from time to time and it appears that the public is generally favourably disposed towards these activities. This reaction is clearly due to the fact that decommissioning is perceived as contributing to the overall safety of the site and hence to the safety of the public at large. When Necsa shut down its nuclear facilities during the latter half of the 1990s, many Necsa staff members living near Pelindaba became redundant. Some of them were re-employed to assist with the decommissioning of the closed facilities and this softened the local reaction to the shutdown decison. Hence, there are no negative sentiments among the public towards Necsa's decommissioning programme.

When communicating to the public on decommissioning issues the point has to be made that the radioactive waste generated on the Pelindaba site will eventually be transferred offsite. For low and intermediate level waste, the disposal endpoint will be the Vaalputs site and this aspect has to be communicated to the local communities at both Pelindaba and Vaalputs.

9. CONCLUSIONS

Decommissioning needs to be treated as an integral component of the overall nuclear liabilities management strategy, comprising all activities involved in the reduction of radioactive waste liabilities.

The waste generated as an inevitable consequence of the decommissioning activities should be systematically processed until it is finally disposed of at approved endpoints.

Decommissioning should be started as soon as possible after the closure of nuclear facilities in order to benefit from the knowledge, skills and availability of the existing operations and maintenance staff.

Despite the importance of aiming for optimum efficiency in the implementation of the decommissioning programme, a safety culture needs to cultivated and maintained at all times.

The potential impact of regulation on the overall performance of the decommissioning programme should never be underestimated and it should be catered for at the planning stage of the project.

DISCUSSION

K.G. SPOONER (United Kingdom): Regarding the Vaalputs repository, has any intermediate-level waste been buried there?

P.J. BREDELL (South Africa): Yes, intermediate-level waste from the Koeberg nuclear power plant is buried there, in concrete drums.

K.G. SPOONER (United Kingdom): Are the drums simply buried, or are there containers in addition to the metal drums for low level waste and the concrete drums for intermediate level waste?

P.J. BREDELL (South Africa): The drums are simply buried. As soon as a trench is completely packed with drums, it is covered with earth, which is compacted, and the surface is returned to its previous state.

K.G. SPOONER (United Kingdom): Is the Vaalputs repository intended to be a final repository?

P.J. BREDELL (South Africa): Yes, it is — with an institutional control period of 300 years. A lot of long term safety assessments have been made, and the regulator is satisfied with the conclusions.

DECOMMISSIONING OF THREE US COMMERCIAL NUCLEAR POWER PLANTS

W.A. NORTON
Connecticut Yankee Atomic Power Company,
East Hampton, Connecticut,
United States of America
Email: Norton@CYAPCO.com

Presented by T. LaGuardia

Abstract

The paper summarizes the lessons learned from the decommissioning of three commercial nuclear power plants in the United States of America: Maine Yankee, Connecticut Yankee and Yankee Rowe. The key lessons are concerned with: maintaining a credible 'safety first' culture while keeping to aggressive cost and schedule goals; developing a clear project plan and focus; developing a strong project team; maintaining a strong focus on the management of project risk and ensuring regulatory compliance.

1. INTRODUCTION

The nuclear power plant decommissioning experience in the USA has been limited to small experimental reactors and research facilities and about eight commercial sized reactors. This paper is concerned with the decommissioning of the commercial nuclear power plants: Maine Yankee, Connecticut Yankee and Yankee Rowe. These plants are briefly described below and key decommissioning statistics are provided in Table 1.

Connecticut Yankee (CY), a 560 MW Westinghouse PWR on the Connecticut River, began commercial operation in 1968 and was shut down for decommissioning in 1997. CY decommissioning was started in 1998 and will be completed next year.

Maine Yankee (MY), an 860 MW Combustion Engineering PWR on the coast of Maine, began commercial operation in 1972 and was shut down for decommissioning in 1997. MY decommissioning was started in 1998 and completed in 2005.

Yankee Rowe (YR), a 165 MW Westinghouse PWR in western Massachusetts, began commercial operation in 1960 and was shut down for decom-

TABLE 1. DECOMMISSIONING PROJECT STATISTICS

Plant	Length (Years)	Cost (million $)	Project ORIR (injuries/200 000 work hours)	Total dose (man-rem)
CY	9	850	1.27	860
MY	7	500	0.26	515
YR	15	750	1.96	594

missioning in 1992. YR decommissioning was started in 1992 and will be completed next year.

All three projects were successful in that the work was accomplished safely, and the sites were (or are being) thoroughly cleaned up to meet State and Federal requirements. While the decommissioning experience for each plant was somewhat unique, the decommissioning processes used for all three were basically the same. Prompt dismantlement was chosen to minimize the time and associated costs without sacrificing safety and dose to workers.

As the decommissioning of the sites progressed, lessons were learned that helped to improve efficiency and thereby shorten the schedule and the costs. We learned, in the course of these projects, that effective planning by a strong management team, both early and throughout the process, was the most critical factor in reducing decommissioning time and project cost.

2. DECOMMISSIONING PLANNING: BEGIN EARLY WITH THE END IN MIND

2.1. Waste management

When a plant shuts down for decommissioning, the entire facility, including the components, becomes waste. Understanding waste streams and how they are handled and disposed of is fundamental to planning how the decommissioning will be done. When starting the decommissioning of Maine Yankee, waste disposal costs were high. This led us to embrace decontamination techniques such as surface scabbling to reduce waste volumes. As decommissioning progressed, we were able to negotiate waste disposal contracts with much lower costs. This change enabled us to employ a ‘rip and ship’ approach. While it is true that waste volumes increased, there were substantial reductions in labour costs and in the time taken.

The approximate total waste amounts for the three plants are listed below:

— Connecticut Yankee: 350 million pounds (163 000 t);
— Maine Yankee: 460 million pounds (210 000 t);
— Yankee Rowe: 170 million pounds (77 000 t).

Despite our best efforts at estimating waste amounts at the beginning of the projects, the waste amounts increased as we remediated areas and generated more soil waste than expected. While the amounts associated with above ground structures can be more readily estimated, it is the below ground remediation that is most uncertain, even with today's characterization capabilities. Land area characterization data were utilized to estimate waste volumes. However, the spread of contamination in soil is unpredictable due to a variety of factors, including inconsistencies in soil/groundwater conductivity, bedrock surface features, and structural impediments to groundwater flow.

Waste disposal contracts were negotiated and renegotiated throughout the decommissioning projects. These changes were the result of new and less expensive disposal facilities becoming available, changes made by waste disposal vendors, changes in our understanding of the waste streams, and regulatory changes. We found that having more than one option for significant waste streams was helpful for keeping costs under control.

Having multiple waste transport options also helped to control costs and ensure that we could continue to ship waste under a variety of circumstances. Railways proved to be the best option for the shipping of bulk waste across the country. Transportation by rail was available on site at Maine Yankee. At Connecticut Yankee and Yankee Rowe the waste was transported by road to the nearest railway. Intermodal containers on road trucks and rail cars were used to ship the waste to the disposal facilities. Barge shipment was only used at Maine Yankee and Connecticut Yankee for large components such as the pressurizer, steam generators, and the pressure vessel.

2.2. Early decommissioning planning

At Maine Yankee, a construction management team started decommissioning planning in anticipation of the decision to shut down for decommissioning. This team embraced performance monitoring, scrubbed the decommissioning cost estimate, and developed a decommissioning plan and schedule with a mission of reaching a 'green field state' in 7 years — from start to finish. The team also invited about 15 leading construction firms (either individually or as teams) to submit firm fixed priced proposals for the entire decommissioning scope. To enable these firms to have the maximum knowledge possible when developing their bids, site characterization was undertaken. The firms interested in submitting bids were invited to participate in the site characterization process to the extent that they were encouraged to attend the daily meetings and to offer suggestions as to what areas should be characterized. The site characterization report then became their bid basis.

Even though the winning firm, to be called a Decommissioning Operations Contractor or DOC, would be responsible for the decommissioning schedule, the utility management team developed a plan and detailed schedule. While many aspects of the schedule became more detailed as decommissioning progressed, MY management realized the importance of having and maintaining a clear understanding of the optimal schedule throughout the project.

As a result of this planning, it became clear that, in addition to site characterization, other activities should also be completed to facilitate the demolition and decontamination scope. The first focus had to be nuclear safety. At the time of plant shutdown, all fuel was stored in the spent fuel pool because no previous dry storage activities had been implemented. The decision was made to address spent fuel storage in parallel with decommissioning. Therefore, a 'nuclear island', including the spent fuel pool and support systems, was designed and developed to maintain protection of the fuel while the decommissioning, including original plant systems removal, was going on around it.

All three plants were shut down before the end of their licensed lives. None of them had an independent spent fuel storage installation (ISFSI). Fuel transfer from the spent fuel pool had to take place during decommissioning and became the critical path. During the fuel transfer phase, maintaining an 'operations-like focus' in the midst of a decommissioning environment was critical to the success of fuel transfer and therefore to the whole decommissioning project. Ideally, plants approaching decommissioning should plan to have their spent fuel pools as empty as possible so that the spent fuel pool island is not necessary and the final fuel transfer operations do not extend the end date of the project.

Another activity that was implemented prior to the start of decommissioning was the transfer of the remainder of the buildings that needed to be decommissioned to a state of 'cold and dark'. Electricity to the buildings was turned off, components were depressurized and drained, and hazardous materials were removed. The DOC was responsible for adding temporary power sources, as need, to perform decommissioning. A system 're-classification and abandonment process' was important for maintaining regulatory compliance while supporting the cold and dark configuration. This process essentially removed the nuclear classification, e.g. 'safety class component', for certain systems that were important to plant operations but which were no longer important to the shutdown facility. Having done this, the decommissioning of these systems had no significance in the regulatory/licence basis for the facility.

2.3. Stakeholder 'buy in'

Another critical key to success in the initial planning is to engage the key stakeholder to ensure that all parties are properly informed relative to the project objectives, regulatory interfaces, clean up criteria, issues important to the local community, etc. These relationships need to be developed early and nurtured during the entire project. Without stakeholder acceptance and confidence in the decommissioning process and activities, it is difficult, if not impossible, to maintain the project schedule and continuity.

3. ESTABLISH A TEAM FOR SUCCESS

3.1. Construction management team

While effective early planning is vital for efficient decommissioning, the team that is doing this planning and implementing the plan is critical to success. Decommissioning is more like construction than a nuclear plant outage. While the scheduling is similar, the planning is quite different. In both cases, industrial safety is a critical consideration throughout the work, however, in the decommissioning process it becomes more important than radiological safety toward the end of the project as radiological sources are removed and radiological risks are virtually eliminated.

A team of construction managers with nuclear experience worked well at Maine Yankee. They were able to get the decommissioning project on the right track at an early stage and maintained project momentum even through unexpected difficulties, such as the bankruptcy of the DOC and the consequent termination of its involvement. The best approach is to obtain a balance between people with plant knowledge who possess the right disposition for decommissioning and new management to aggressively reduce, eliminate, and simplify processes, where practical. A mix, which includes 'change managers' who have clear authority, is essential.

3.2. Downsizing operations workforce

The biggest controllable cost in decommissioning is manpower. It is difficult to downsize the operating workforce as a plant moves into decommissioning — particularly when the shutdown for decommissioning is unexpected, as it was for Maine Yankee. However, the plants that have been slow to efficiently accomplish this downsizing have had higher decommissioning costs. Maine Yankee developed an early de-staffing plan that retained needed workers and released the rest. Severance packages, early retirement, and worker transition services helped workers make the transition. The major downsizing occurred over about a three month period. While downsizing is never easy, workers generally seemed to cope best with the transition when they understood their expected duration of employment and recognized at an early stage that the end was near.

Another advantage of early and aggressive downsizing is that it opens up opportunities to bring in workers with skills that are more suited to a decommissioning environment. Also, if these workers are contractors, they tend to be more accustomed to completing a given scope of work and moving on to another job. They tend to have less of an 'employment for life' mindset.

Of course, some plant operations workers will be needed for some time in the decommissioning operation. Maine Yankee retained a few workers from almost every operating plant department throughout decommissioning, particularly maintenance, radiation protection, licensing, finance, and quality assurance staff. Operators were particularly helpful for identifying equipment and draining systems, and managing groundwater and process water discharges.

Some nuclear plant operations skills are helpful in decommissioning. Compliance with procedures is as essential in decommissioning as it is in operations. This presents two challenges: having credible procedures and teaching construction workers that they must follow them. In general, most plant operations procedures are not applicable to decommissioning. At Maine Yankee and Connecticut Yankee, site characterization, fuel transfer and some decommissioning activities were delayed while procedures were revised or developed to deal with activities that were not anticipated while the plants were in operation. Since verbatim procedure compliance is not optional, procedures vary in terms of the level of required specificity and work controls. For example, activities involving the safety of nuclear fuel require more controls than other industrial work activities where 'skill of the craft' is sufficient to accomplish a given task.

An important part of human resource management is the staffing forecast. All positions should have end dates. We openly communicated the end dates of jobs should be known and updated on a quarterly basis. Everyone should know where he/she stands. This reduces uncertainty and anxiety, and helps foster trust in senior management. It makes good sense for both the company and its workers.

4. DECOMMISSIONING MANAGEMENT: SET CLEAR, REALISTIC GOALS AND MONITOR PERFORMANCE ROUTINELY

4.1. Industrial safety

Decommissioning work can be dangerous, but the safety levels in all three projects which I have been involved in have been high. This includes the industrial and radiation safety of workers, nuclear safety, environmental protection, and public safety. Cost and schedule, although critical measures of success, are less important than personnel safety. It is vital to convince everyone on the project that it takes day-by-day focus and managers walking the talk to establish a strong safety culture. Pre-job briefings involving the workers and project supervisors should occur before each new job. Daily briefings are important in identifying potential changes in conditions. It is important that every worker is empowered to stop a job if he/she feels unsure about the safety. Managers, likewise, are expected to be concerned about safety, to insist that workers are safe, and to get out into the workplace to validate that their expectations are being met. There should be a requirement that all site managers spend time in the working areas every day and, for example, it might be required that at least one manager is in the workplace for every hour of the workday to verify that performance is consistent with the safety requirements. This was one method we used to drive home the safety message.

4.2. Radiological safety

Health physicists who understand the work should allocate radiation dose allowances to each project and monitor its use at least weekly. The dose budgets for all the jobs should be summed up for an overall annual dose goal which is then reduced by 15 to 25% to encourage dose savings. The doses likely to be received vary from one job to another and this has to be taken into account when allocating dose allowances. The dose goals are not considered to be met for a particular job until the entire job is completed.

Total project doses estimated early in the project tend to be conservatively high. As radioactive sources are removed and low dose work practices improve, the actual radiation exposures will tend to drop. Strategic use of special robotic tooling can be helpful in addressing highly contaminated components or structures, thus allowing ‘hot spots’ to be eliminated at an early stage to reduce the exposure of the workers.

4.3. Project approach

4.3.1. Decommission Operations Contractor

Two of the three projects were started with a general or DOC. In both cases the DOC contract was terminated and the remaining work was done by the internal team. The lessons learned outlined above, i.e. good planning by a strong team, should help to ensure the success of either approach.

4.3.2. Firm fixed priced contracts

Firm fixed priced contracting is important for the sharing of financial risks and for controlling costs where project scopes can be well defined by project management. Firm fixed priced contracting is difficult in ‘first of a kind’ activities or when well defined activities are being undertaken in substantially different economic environments for the first time. Here again, good planning, detailed cost understanding, and schedules developed by a knowledgeable management team will lead to more successful firm fixed priced jobs. Even if management chooses not to employ firm fixed priced contracting for the entire scope of the decommissioning, it can be employed successfully in major portions of the work.

4.3.3. Earned value performance monitoring

Comparing actual spending to budgeted or planned spending is not sufficient. In fact, it can lead to the wrong conclusions being drawn. In the three projects, all spending was measured relative to the work being performed. Each scope of work in the decommissioning had an established cost, based on the initial ‘total cost to complete’ estimate, for which performance was tracked. Earned value performance monitoring provided the best understanding of project progress. This method is particularly useful with firm fixed priced contracting when both parties agree to the concept and to the earned value metrics. The management needs to know enough about the project to develop credible earned value/cost metrics. Earned value percent completion also provided stakeholders, particularly the boards of directors, with an understanding of project status and progress.

4.3.4. Project cost control

Project cost control should be integrated from the beginning into project planning and must be continually reinforced. In the three projects, monthly budget meetings were held in which managers of subprojects were held accountable for their performance and given assistance if required. The project cost control professionals need to understand cost estimating as well as the project and field operations and well enough to anticipate potential cost problems.

4.3.5. Financing

Since these three plants were shut down prior to their planned operating lifetimes, the decommissioning funds were initially inadequate to finance the total costs for decommissioning. Through a rate regulatory process, costs were reviewed and generally accepted as allowable to be billed to electricity customers. Success in completing the projects leads to a higher acceptance that ratepayer costs are being minimized. Today, all three projects have substantially paid for their decommissioning costs and are now building reserves to pay for the storage of spent nuclear fuel for years into the future.

5. STAKEHOLDER INVOLVEMENT

The stakeholders we worked with included our employees, contractors, boards of directors, regulators, elected officials, media, and the public. We developed performance indicators to provide a simple measure of project safety and regulatory, financial and schedule performance. These indicators were the same for all groups. As a communications tool monthly reports were provided to the Board of Directors and the project status was discussed at routine Board meetings. These reports included a narrative of progress and issues as well as a monthly update of key performance indicators. Additionally, meetings were held with elected officials and regulatory agencies on a regular basis to keep them appraised of project progress.

In dealing with public and media communications, we found community advisory panels to be particularly effective. These groups were sponsored by the Companies, but made up of credible community leaders. The panels usually met on a periodic basis, but met more frequently early in the project and during busy times. The panels also met when a particular issue of public concern was anticipated and/or raised in the media. The meetings included briefings by project personnel on project status and issues and opportunities for the panel members and public to ask questions and provide input. Initially, the exchanges could be heated, but over time, as the panel members and others became convinced that we would provide responsive information, the tone became more civil. Also, media representatives who attended these meetings provided the information and context to the public.

6. IN SUMMARY: KEY CHALLENGES FOR DECOMMISSIONING WORK

— Managing the transition from operations to decommissioning;
— Managing compliance: develop clear procedures, work instructions, and expectations, and hold workers, supervisors and managers accountable for compliance;
— Developing a strong decommissioning focused project team while maintaining an operations focused fuel storage and transfer group;
— Building the morale of the workers (the goal is job elimination not longevity);
— Planning for managing significant waste volumes with limited waste disposal options;
— Integrating site closure with full resolution of all radioactive, non-radioactive and groundwater remediation issues;
— Securing stakeholder approval for the financing of decommissioning when there are initial funding shortfalls caused by the earlier than scheduled permanent shutdowns;
— Using large scale demolition equipment while still maintaining radiation exposure controls.

DISCUSSION

P. BEELEY (United Kingdom — Chairperson): Why did it take so much longer to decommission Yankee Rowe than Maine Yankee and Connecticut Yankee?

T. LAGUARDIA (United States of America): One reason was soil and water contamination by PCBs (polychlorinated biphenyls) in paint in the containment building. Dealing with it caused delays and additional remediation costs.

KEY ISSUES TO BE TAKEN INTO ACCOUNT DURING THE DECOMMISSIONING OF REPROCESSING PLANTS

G. DECOBERT, T. DEVRIES, T. VARET
AREVA NC,
Vélizy Villacoublay,
France
Email: gdecobert@cogema.fr

Abstract

Careful planning and management is of utmost importance to ensure that decommissioning will be accomplished in a safe and cost effective way under a national regulatory framework while minimizing staff and public exposure. Nuclear facilities decommissioning is not new and a lot of projects are currently being or have successfully managed, from process equipment replacement, installation revamping to dismantling of installations. Nowadays, a change of scale is emerging with industrial operations concerning large nuclear installations within the nuclear fuel cycle such as reprocessing plants. These operations will last over several decades (around 30 years) and cost billions of euros. The paper reports on experience during the first eight years of the decommissioning of UP1, the first French reprocessing plant located at Marcoule and how the experience is being used in the early stages of the decommissioning of the second reprocessing plant, UP2 400 at La Hague that has been shut down at the end of 2003. A few of the key issues which require attention, will be developed in the paper , i.e. the specifics of reprocessing plants, the need for new skills, the need for a change of culture, human resources and project organization, and waste management.

1. SPECIFICITIES OF REPROCESSING PLANTS

1.1. The role of various facilities in the reprocessing

The main modules of a reprocessing plant are shown in Fig. 1 (UP2 400 at La Hague site). Each module plays an important role in the PUREX (plutonium–uranium extraction) process. UP2 400 was commissioned in 1966, at La Hague, to reprocess the first gas cooled reactor (GCR) spent fuel. It operated until 1987. In 1976, a head facility, called HA/Oxide was built to shear and dissolve PWR spent fuel. In 2003, the final shutdown was announced and, at present, the facilities are either under surveillance or subject to post-

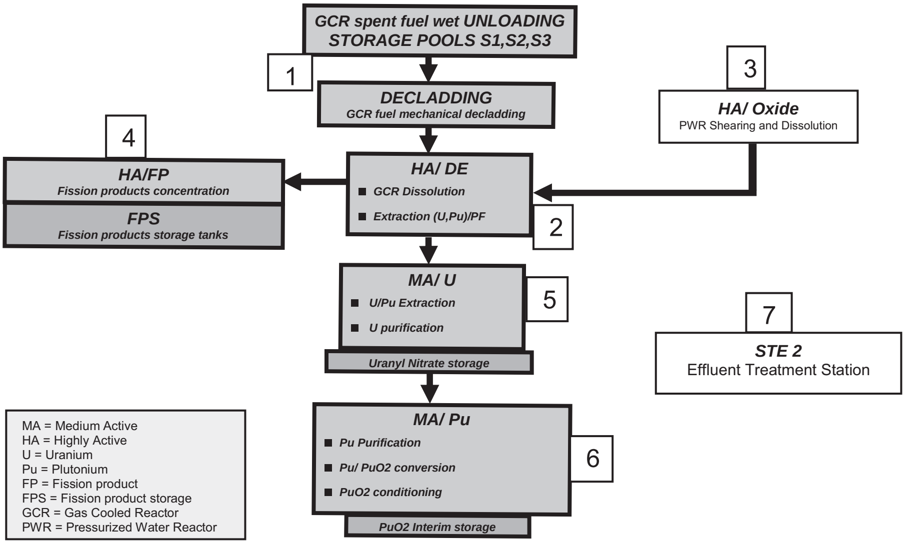

FIG. 1. UP2 400 reprocessing plant modules.

operational cleanout operations. UP2 400 reprocessed 9360 t (of which 4887 t were of GCRs).

It should be pointed out that spent fuel reprocessing facilities, as compared to power reactors, have a number of important and unique features that have to be considered during the decontamination and dismantling programme such as:

— Distinct modules that can be isolated and decommissioned as individual work sites. The construction of a reprocessing plant such as UP2 400 is based on the assembly of processes in seven main distinct modules that can be isolated, such as spent fuel unloading and storage in pools, decladding or shearing units, dissolution, (U, Pu)/fission product extraction, plutonium oxide precipitation and calcination, uranium purification and concentration in uranyl nitrate, fission product concentration and storage, medium and low active effluent treatment.

— A greater variety of potential radiological hazards: beta/gamma irradiation or α contamination, depending on the process being carried out in the cell and its history.

— A greater variety of risks has to be managed during decommissioning because of the diversity of the past reprocessing operations (mechanical, chemical, powder treatment) and the variety of material which has been processed.

1.2. Long term and costly operations

Reprocessing plants are enormous mechanical and chemical plants at the back end of the fuel cycle at which operations are conducted to recover uranium and plutonium. Inside the various buildings are numerous tanks, piping and equipment that have contained highly radioactive material; most of them are inside completely sealed concrete cells that are inaccessible. In addition to the clean up and dismantling of the numerous cells of the plant, a considerable amount of diverse legacy waste from the operation of the plant itself has to be retrieved and conditioned. The overall project for the decommissioning operations in the production facilities and the legacy waste retrieval and conditioning is forecast to extend over the next thirty years and will cost several billion Euros.

1.3. Two major programmes in the decommissioning of a reprocessing plant

Typically, a decommissioning project of the first generation of reprocessing plants, such as UP1 or UP2 400 commissioned in the 1960s, is composed of two main programmes, which are:

- Post operational cleanout (POCO) and the dismantling of the old production facilities;
- Historical waste retrieval and conditioning.

The main objectives of the POCO phase are to decrease, to as low as reasonably achievable, the levels of radioactive contamination and to reach end conditions that will minimize the need for heavy duty remote operations during the dismantling, reduce the volume of waste not compatible with surface disposal (very low level and short lived low level and intermediate level radioactive waste), and minimize personnel exposure and cost. The operations during this phase consist mainly of decontamination by rinsing with various conventional and specific reagents, enhanced where necessary, by mechanical operations to remove ‘hot spots’ or by the dismantling of some equipment. The effluents generated are processed and conditioned in the existing support facilities, which are either the treatment effluent station or the vitrification installation. Most of the liquid waste is concentrated by evaporation and then vitrified. The solid waste generated during the POCO and dismantling phases are treated and conditioned in existing workshops such as compaction, cementation, melting and incineration units. Seven buildings of the UP2 400 reprocessing plant are involved in these operations (see Fig. 1).

In addition to the waste generated as a result of the cleanout and dismantling of the seven buildings, the UP2 400 plant processed mainly GCR and PWR spent fuels and generated a large variety of structural and process waste which was not, in the past, conditioned on-line. The programme for the retrieval and conditioning of this waste comprises the characterization, retrieval, sorting, treatment and conditioning of the waste before it is sent for disposal, or safe interim storage, in the case of long lived intermediate level and high level waste. Table 1 indicates the nature and inventory of the historical waste generated during the operation of UP2 400.

1.4. Immediate dismantling strategy

Spent fuel reprocessing facilities handle long lived radionuclides such as plutonium-239 and caesium-137 and the comparatively small benefits derived from allowing radioactive decay before decommissioning must be weighed against the costs of long term care and maintenance. Therefore, the AREVA NC strategy is immediate dismantling with the objective of making the facilities suitable for conventional use or for use as regulated facilities, depending on the intended use of the site. An advantage of immediate dismantling is that part of the operating staff can continue to be employed and that their knowledge and skills can be used for dismantling. Moreover, the infrastructure needed for the dismantling of the facility is still available.

TABLE 1. NATURE AND INVENTORY OF HISTORICAL WASTE

Nature	Inventory
PWR hulls and ends	880 t in pits under water
PWR hulls and ends	740 t (6300 drums) in pools
Sludge	9300 m^3 in pits
Liquid fission products	235 m^3 in tanks
Resins	362 m^3 in tanks
GCR structural waste (Mg, C)	680 t in pits 540 t in tanks
Solvents (tetrabutyl phosphate + dodecane)	592 m^3 in tanks
Technological alpha waste	2400 drums

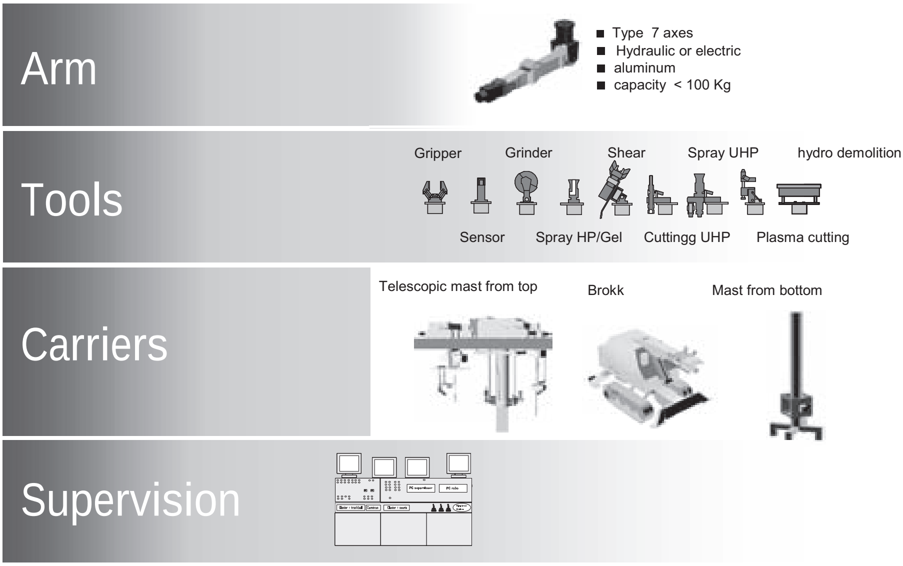

FIG. 2. Remote devices.

2. NEW SKILLS

New skills emerge with decommissioning operations, as discussed in the following paragraphs.

2.1. Remote operations

A considerable variety of commercially available remotely operated handling equipment is used in inspection, nuclear measurement, maintenance and repair that can be used in decommissioning operations. The special environment of the process cells encountered in a reprocessing plant make the development of remotely operated handling equipment necessary. The use of ‘mock ups’ is often a necessary step for operator training. It has been observed that integrated teams with multidisciplinary profiles including maintenance, facility and decommissioning operators are efficient in the use of remote devices.

A field of expertise has been developed for the dismantling of cells in a hostile environment. As illustrated in Fig. 2, remote devices are composed of four main parts, the arm, the tool, the carrier and the control system and each subsystem has required development before reaching its full capacity. Common

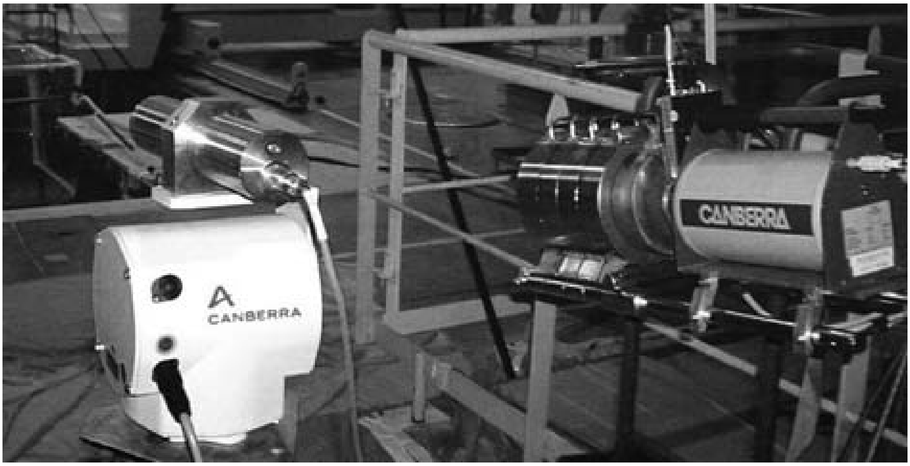

FIG. 3. CARTOGAM and ISOCS for in situ nuclear measurement systems.

availability rates for such systems are around 50% and still need to be improved.

2.2. Investigations

Measurements of various types are often used during the various stages of the decommissioning of a nuclear installation, from the characterization of the initial state to the final monitoring surveillance. The implementation in the project structure of a dedicated trained team for ‘in situ’ measurements and their interpretation is essential. Two main nuclear devices are used (see Fig. 3):

— A real time portable gamma ray imaging system for the detection of source location and radiation intensity. It allows the superposition of a visible image over a gamma radiation map;
— An in situ counting system for qualitative and quantitative analysis of gamma emitters.

Other complementary techniques to in situ measurements are based on destructive analysis and involve laboratory measurements. These are usually used for more in-depth investigations. This field of activity is new compared with the routine analysis carried out during the operating life of the installation.

3. CHANGE OF CULTURE, HUMAN RESOURCES AND PROJECT ORGANIZATION

Beyond the technical challenges, AREVA NC's personnel has a human challenge to face in coping with the transition that will occur in moving from an operating culture to a project management culture.

The decommissioning organization has to be set up well in advance of the final shutdown of the facilities in order to establish precisely the initial state and the overall decommissioning scenario and to prepare all the documentation necessary for obtaining a decommissioning licence.

In this organization several cultures should co-exist, such as project management, facility operator and cleanup services with the common objective of controlling costs and maintaining a high level of safety.

Decommissioning operations have an impact on staffing. The staff to be employed is, to some extent, dependent on the intended future of the site and this can have an impact on staffing. Two main cases can be considered:

— The nuclear site is still operating with other services than decommissioning and key resources are being shared among the different programmes (plants in operation and under decommissioning). This is the situation for the UP2 400 decommissioning project where two other reprocessing plants (UP2 800 and UP3) are continuing in operation.
— Decommissioning is the only remaining activity. In this case the profile of the personnel will evolve towards a multidisciplinary culture and require training in new skills. The site will also have to face the social aspects of the shutdown and decommissioning.

4. WASTE MANAGEMENT

The dismantling of the reprocessing plants at Marcoule and La Hague will lead to the production of several hundred thousand tonnes of potentially contaminated waste. Most of it will be scrap metal and rubble. The management of such large volumes is a key issue because it represents one of the most substantial costs associated with these programmes.

The French regulations require that each category of waste is dealt with from production to elimination according to a pre-assessed and controllable process with waste management routes that are defined in advance. The safety authority excludes the practise of measurement of any unconditional clearance levels for use in managing waste from nuclear zones. In the Ministerial Order of December 31, 1999 (Article 20), the nuclear operator is required to provide a detailed waste management plan for approval, called a 'Waste Study', in which the zoning of the installation into nuclear and non-nuclear zones has to be implemented. The waste generated from the nuclear zones must be managed through regulated pathways and outlets, while the waste from non-nuclear zones can be managed through conventional routes.

During the elaboration of the decommissioning scenario for a reprocessing plant, AREVA NC follows certain strategic rules, some of which are described below:

— All waste compatible with existing surface disposal facilities (very low level and low level waste) should be treated, conditioned and transferred to these disposal facilities in order to minimize the onsite interim storage.
— The existing treatment and conditioning support facilities should be used to the maximum extent by managing the waste flow, taking into account acceptance criteria and facility capacity.
— One of the first important operations to be carried out in preparation for dismantling is to established an optimized waste zoning of the site. This will limit the generation of nuclear waste. Then, particular attention should be given to the physical and radiological inventory of the structures and equipment inside the nuclear zones. This permits the most appropriate route for each waste type to be defined.
— During the life of the decommissioning project, a major objective is waste minimization.

There are important principles to keep in mind when planning and implementing waste minimization:

— Keep the generation of radioactive waste to a minimum. Emphasis should be placed on the segregate the different types of material in order to reduce the volume of radioactive waste.
— Minimize the amount of radioactive waste by applying appropriate treatment technology (e.g., compaction, melting, incineration).
— Open possibilities for the recycle and reuse of valuable material.

5. CONCLUSIONS

The approach to decommissioning has to be prepared well in advance and attention has to be focused, not only on technical, but also on human resource aspects.

The decommissioning team should include staff having all the required skills and experience.

Feedback experience from similar operations has to be considered and evaluated during the elaboration of the overall and, later, the detailed decommissioning scenario.

DISCUSSION

P. BEELEY (United Kingdom — Chairperson): How important is feedback for AREVA NC?

G. DECOBERT (France): It is very important. For example, through OECD and OECD/NEA task groups we have obtained useful feedback regarding the decommissioning of fission product tanks from people working in Belgium and Germany.

DECOMMISSIONING OF AN ABANDONED FERTILIZER PLANT

C. POTIRIADIS, V. KOUKOULIOU, K. KEHAGIA,
S. SEFERLIS, V. STAMATIS, V. KAMENOPOULOU
Greek Atomic Energy Commission,
Athens,
Greece
Email: cpot@eeae.nrcps.ariadne-t.gr

Abstract

The paper describes the decommissioning of an abandoned fertilizer plant in Pireus, Greece. It addresses the particular problems encountered in the decontamination, clean up and disposal of the naturally occurring radioactive material (NORM) at the plant and describes the management solutions eventually decided upon. It records the way in which the public, local authorities and the scrap metal recycling industry influenced the final targets for decontamination and for site clean up.

1. INTRODUCTION

In the area of the port of Piraeus, in Greece, a phosphate fertilizer plant was in operation from 1960 until the beginning of 1999. Because of the location and the high commercial value of the area, the construction of commercial buildings and other facilities for public use in this area, was envisaged. Therefore a plan for the decommissioning of the building and the surroundings was developed.

The decommissioning work was undertaken by a specialized private company. The Greek Atomic Energy Commission (GAEC) was the partner responsible for the radiological aspects. More particularly, GAEC had the responsibility for the radiological survey and the radiological management of the facility. The owner's demand was that the area should be released from any regulatory control related to the presence of radioactive material. Therefore, the contract between the owner and GAEC clearly specified that the region of the phosphate fertilizer plant should be completely released from radiological control and that the area should be 'returned to normality'. In addition, GAEC provided the radiation protection for the workers during the project.

The main objectives of the decommissioning were:

— The dismantling and the categorization of the materials;
— The decontamination of the superficially contaminated materials;
— The minimization of the waste produced;
— The management of the contaminated materials;
— The assessment of the environmental impact.

The contaminated materials were categorized by GAEC according to their physical form (scrap metals, plastic pipes, scales and residues, building materials, etc) and according to their level of radioactive contamination. For each type of material, different decontamination and disposal options were proposed. In order to define the most appropriate technique, the legal framework and the additional demands of the owner and of the involved local authorities were taken into account. The criteria for choosing the most appropriate approach were:

— The optimization of the decontamination;
— The minimization of the environmental dispersion of the contamination;
— The radiation protection of the workers

2. RADIATION PROTECTION CRITERIA

2.1. Legislative provisions

The legislation that implements the International Basic Safety Standards [1] and the European Directive [2] is the Radiation Protection Regulations [3]. It sets out provisions for the radiation protection of workers, the public and the environment. This legislation together with two EC documents [4, 5] has been applied in this project.

In the European Union as a whole and in most countries, there is no specific legislation covering the issues associated with naturally occurring radioactive material (NORM). In addition, the approaches for exemption and clearance are not considered in the same way in the various countries.

Because of the owner's demand to return the area to a natural background level, and in view of other special features of the project (e.g. the 'radiophobia' of local authorities and the population), the clean up criteria which were applied for the decommissioning of the fertilizer plant were stricter than the clearance levels proposed by the European Commission, which are based on specific dose criteria.

2.2. Practice followed

2.2.1. Scrap metals

The radiation protection criteria used for the recycling of the scrap metals with no further restrictions were the following:

— The risk from the radioactive contamination had to be negligible;
— The decontamination activities had to be optimized in order to reduce the contamination as far as reasonably practicable.

Additional parameters, such as the additional cost of decontamination and the demand of the scrap metal recycling industries for 'radioactivity free' material, were also taken into account.

To fulfil the first criterion, a dose criterion of 10 μSv/a was used. This criterion was not directly applicable due to 'in situ' measurements so it had to be converted through dosimetric models to a specific activity, i.e. a specific activity of ^{226}Ra of 300 Bq/kg. If the level was less than this value, the object could be recycled. Even though the decontamination procedure could be terminated when the first criterion was reached, it was continued until the second criterion was achieved. This action was based on the practical observation that the duration of the additional decontamination procedure and the amount of waste produced were negligible compared to the total waste and the work done as a whole. The second criterion was considered to be fulfilled if the surface beta contamination level and the gamma dose rate near the decontaminated object were not distinguishable from background levels.

In most situations in which the first criterion was reached, the fulfillment of the second was achieved very easily. The decontamination of the material was continued until no more contamination was detected. The metallic devices intended for recycling were decontaminated to such a degree that no surface or bulk contamination was detected. This reflects a requirement of the Greek steel factories as a condition for accepting scrap metal. In addition, these factories apply a system of certification and inspection with portal detectors at each foundry entrance.

If the contamination could not be reduced below the limits mentioned above, the scrap metals were exported for recycling to a foreign country with an appropriate infrastructure. The radiological criteria for their exportation were imposed by the recycling company and were in compliance with the national legislations of both countries.

2.2.2. Phospho gypsum

For the management of phospho gypsum, three options were considered:

— The fertilizer plant during the last years of its operation, had a licence to dispose of the produced phospho gypsum in an abandoned quarry, a few kilometres away from the site. The licence expired when the plant shut down. Environmental restoration is in progress at the disposal site and so the attempts to renew the licence were not successful because of bureaucratic problems and the negative opinion of the local authorities. It is noted that it would have been more logical and convenient to end the licence of for disposal after the completion of the decommissioning of the plant.
— Another option was to transfer the waste to the phospho gypsum disposal sites of other operating fertilizer industries. However, it was found that many bureaucratic problems existed in seeking to extend the existing licence in order to permit the disposal of the waste from the decommissioning project.
— The third option was to export the waste to a foreign country with the appropriate infrastructure for recycling.

The third option was followed.

2.2.3. Radiation protection programme for the workers

Specific measures were imposed to keep the radiation doses to workers below 1 mSv/a, even though the regulatory dose limit for occupationally exposed workers is 20 mSv/a. Special protective equipment was used and strict rules were followed. All workers were part of a monitoring programme that included monitoring of the external radiation exposure (with thermoluminescent dosimeters), monitoring for internal contamination (by whole body counting) and the 'in vitro' analysis of biological samples (urine) by means of α spectroscopy. Annual effective doses were kept below 1 mSv.

3. PRELIMINARY SURVEY OF THE AREA

A detailed radiological survey was performed of the abandoned fertilizer production plant and the surrounding areas.

The instruments used for the 'in situ' investigations were the following:

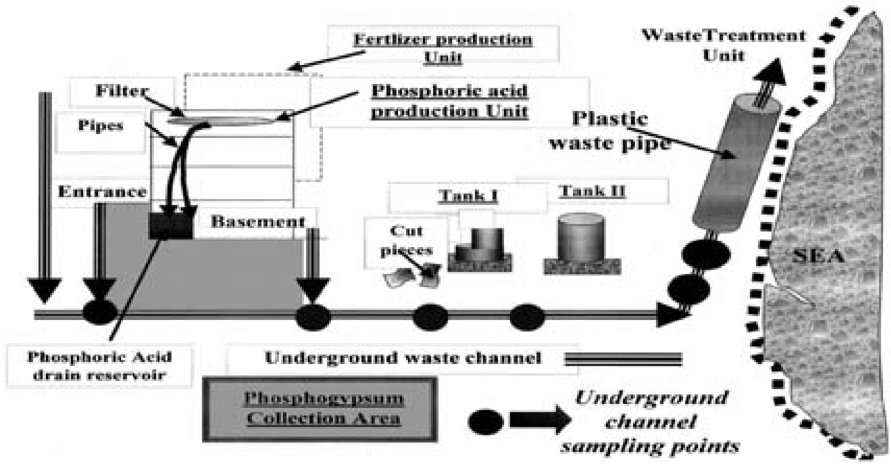

FIG. 1. The fertilizer phosphate production unit.

— Portable gamma spectroscopy unit (HPGe 20%, CANBERRA Inspector);
— Portable gamma spectroscopy unit (NaI, Exploranium);
— Surface contamination monitor (CONTAMAT, ESM);
— Portable gamma radiation survey instruments (ESM, Victoreen);
— Portable large volume NaI detector (2 in × 2 in, ESM).

Based on a detailed radiological survey of the area, the fertilizer production unit as well as some other related constructions (the phosphoric acid production unit, three phosphoric acid tanks and an underground waste channel) were characterized as controlled areas. The maximum measured gamma dose rate was 60 μSv/h. Figure 1 shows a drawing of the fertilizer production unit.

Samples such as scale, dust, sludge, rubber, etc., were collected from several places. All samples were dried, homogenized and covered with epoxy glue in order to prevent radon release from the sample containers. The samples were measured in GAEC's specialized and accredited (ISO17025) laboratory, using three HPGe detectors.

Tables 1 and 2 present the minimum and maximum values of the measured dose rates and specific activity values and surface contamination levels of collected samples.

As a result of the decommissioning of the controlled areas, large amounts of materials such as metallic pieces (iron and stainless steel, brass and sand blast waste), phospho gypsum, phosphate, building materials and plastic pipes,

TABLE 1. RESULTS FROM GAMMA SPECTROSCOPIC MEASUREMENTS IN SAMPLES COLLECTED DURING THE FIRST PHASE OF THE PROJECT (MINIMUM AND MAXIMUM VALUES)

Samples	Dose rate (μSv/h)	Ra-226 (Bq/kg)	U-238 (Bq/kg)	U-235 (Bq/kg)	Th-228 (Bq/kg)	Ra-228 (Bq/kg)
Deposits from phosphoric acid tank I	3–40	2000–13000	280–420	13–20	64–440	75–480
Deposits from phosphoric acid tank III	2–10	560–2800	270–440	13–20	16–100	13–126
PG collection area	0.2–2	550–2500	240–400	12–19	29–68	30–80
Deposits on filter	0.4–40	965–6500	221–303	10–15	31–152	33–154
Deposits from the basement floor of the phosphoric acid production unit	0.38–60	800–1500	600–919	30–43	50–74	55–72
Surface scale from the phosphoric acid transport tubes	0.25–25	400–500	220–900	10–43	20–45	13–48
Deposits and scale from phosphoric acid stir reservoir from the waste treatment unit	2–60	100 000	199	<8	325	362
Sludge from the small cube	0.38–60	35 000	2600	122	104	93
Samples from the overflow of phosphoric acid tank III	2–10	2500–3000	360	17	82	87

TABLE 2. SURFACE CONTAMINATION LEVELS (MINIMUM AND MAXIMUM VALUES)

Sample	Ra-226 (Bq/m^2)	U-238 (Bq/m^2)	U-235 (Bq/m^2)	Th-228 (Bq/m^2)	Ra-228 (Bq/m^2)
Rubber from the phosphoric acid stir reservoir at the waste treatment facility	9000	1330	63	40	38
Rubber from Tank I (Total surface 170 m^2)	4300–11 600	3 460	170	190–270	190–330

with a total volume of 1600 m^3, were produced. The management options for these materials were strongly influenced by the Greek regulatory framework on waste management. The main concern was to restore the area in a way that the public would be reassured and the land value would not be decreased. The value of ^{226}Ra concentration in soil samples from the surrounding area does not exceed 100 Bq/kg and the typical radiation dose rate background is between 50 nSv/h and 120 nSv/h.

4. WASTE PRODUCED

The waste produced from the decontamination procedure was divided into three groups. The first group contained the bulk scale from the tanks, the scale from the underground waste channel (mainly phospho gypsum) and all of the mud removed from the area. The second group contained the scale from sandblasting and some metallic objects (mainly stainless steel) that could not be recycled in the steel industry. The third group included materials for which the dose rate did not exceed the value of natural background dose rate (50–120 nSv/h).

The analysis of the waste is presented in Table 3. The first group of waste, of about 150 t with average specific activity 2500 Bq/kg ^{226}Ra, was exported for recycling to a NORM treatment plant. The second group of waste of about 9 t, with average specific activity 5000 Bq/kg ^{226}Ra, was exported for recycling to a melting plant for radioactively contaminated scrap. Finally, the third group of about 550 t, consisting of materials that did not exceed the natural background radiation dose rate of the area, was disposed of as ordinary municipal waste in waste disposal facilities.

It is noted that the amount of the waste was greater than the amount that would have been produced if the clearance levels had been applied [4].

TABLE 3. ANALYSIS OF WASTE MATERIALS

Groups of waste	Description of waste	Average specific activity ^{226}Ra (Bq/kg)	Quantities (t)		Management
Group 1	Material that simulates phospho gypsum	2500	150		Exported for recycling
Group 2	Contaminated stainless steel	5000	5	9	Exported for recycling
	Sandblast scale		4		

TABLE 3. ANALYSIS OF WASTE MATERIALS (cont.)

Group 3	Iron	150	330	550	Managed in Greece as municipal type waste
	Stainless steel		25		
	Brass		5		
	Debris, wood, plastics		190		

5. FINAL SURVEY OF THE AREA

After the demolition of the buildings and the separation of the debris and the iron bars, a final survey of the restored area was performed (Figs 2(a) and 2(b)). Some hot spots were detected and removed. The area was divided in 22 sectors of $2m^2$ each. The dose rate survey of each sector was performed using a NaI detector. The measured radiation dose rates in the area were at the level of the natural background of the nearby areas.

During the final survey of the area, no residual surface contamination was detected, only some sparsely distributed low level contaminated materials immersed deeply in the soil were detected.

6. CONCLUSIONS

The decommissioning project at the abandoned fertilizer factory was the first project of its kind performed in Greece. It involved legislative, technical and political issues and for these reasons it was of special interest. Detailed records and descriptions of the procedures followed are kept by the GAEC in order to be able to transfer the experience and the knowledge gained.

From the legislative point of view, the radiological clearance levels were determined based on the general directives and recommendations of the EC, IAEA and on the Greek Radiation Protection Regulations. Specific clearance levels were determined and applied for application to the different management options. This project revealed the administrative difficulties in managing, storing or disposing of NORM waste. For this reason, a new challenge for Greece would be the investigation and authorization of new practices involving use of NORM materials, as already applied in some other countries (e.g., reuse for soil improvement, in structural manufacture, road construction, etc.).

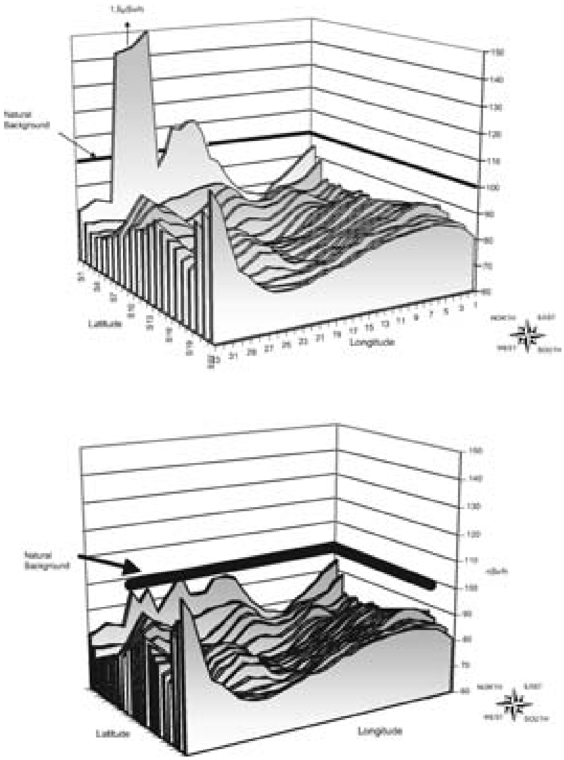

FIG. 2. Results from the final dose rate survey of the area (a) before and (b) after the surface decontamination.

The decontamination strategy was influenced not only by the radiation protection criteria imposed during the decommissioning of the area, but also by the opinion of the public, the local authorities and the owner, and by the conditions required by metal recycling factories. For these reasons, the decontamination of the materials was performed to levels well below the clearance levels, and most of the materials, which were not exported, were decontaminated until background levels were reached.

From the technical point of view, assessment procedures were applied in order to determine compliance with specific clearance levels and to assess the impact of different decommissioning and management options. Measurement procedures were established and verified in order to determine the activities of materials of different amounts, shapes and physical forms.

REFERENCES

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD/NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEATH ORGANIZATION. International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[2] EUROPEAN UNION, Council Directive 96/29/EURATOM 13 May 1996.

[3] EUROPEAN UNION, Joint Ministerial Order 1014 (FOR) 94, Radiation Protection Regulations, Official Gazette No. 216/B/6-03-2001.

[4] EUROPEAN COMMISSION, Radiation Protection No. 122, Practical use of the concepts of clearance and exemption. ¶Part II: Application of the concepts of exemption and clearance to natural radiation sources, EC Directorate-General for the Environment, Brussels (2001).

[5] EUROPEAN COMMISSION, Radiation Protection No. 89, Recommended Radiological Protection Criteria for the Recycling of Metals from the Dismantling of Nuclear Installations, EC, Luxembourg (1998).

DISCUSSION

H. EFRAIMSSON (Sweden): Was the scrap metal decontaminated down to levels below the 10 μSv clearance level recommended by the European Commission?

K. POTIRIADIS (Greece): Yes, it was. The Greek companies dealing in scrap metal insisted that there be no activity measurable by portal detectors or by other such means.

PANEL DISCUSSION

Session 4

IMPLEMENTATION OF DECOMMISSIONING ACTIVITIES

Chairperson: **P. BEELEY** (United Kingdom)

Members: **A. BAEKER** (Germany)
I. TRIPUTTI (Italy)
C. PIANI (South Africa)
F. LOCKHART (United States of America)

P. BEELEY (United Kingdom — Chairperson): I invite the panellists to respond to the question ‘How to maintain knowledge and safety culture during a changing project management environment — from operation to decommissioning, during decommissioning and after the completion of decommissioning?’

F. LOCKHART (United States of America — panellist): Regarding the maintenance of safety culture, at Rocky Flats we found that, with the transition from risks associated with ionizing radiation to industrial risks associated with, for example, the movement of heavy equipment about the site, it was important to focus both management and workers on the new risks. We also found that it was important to strike a balance between the different types of new risks; for example, through the use of anti-contamination clothing the number of cases of skin contamination was reduced almost to zero (in a workforce of about 1000), but there were many cases of heat stress.

In the changing risk environment, we had to modify the authorization documentation setting the limits and spelling out the criteria for the performance of tasks, and we had to ensure that the workforce complied with the new rules precisely. All had to realize that there was no room for casualness or informality.

An important lesson learned by us related to the key role played by the foremen of the work crews in keeping the workers focused on safety. In the light of that lesson, we made sure that the foremen received considerable industrial safety training.

C. PIANI (South Africa — panellist): We are a research reactor operator that has decommissioning plans in place but does not intend to decommission yet. Against that background, I should like to present a managerial point of view regarding what it means to maintain knowledge and safety culture during all phases in the lifetime of a research reactor or any other nuclear facility.

Irrespective of phase, the management must ensure that all members of the staff have the ability to do their jobs efficiently and safely. Most of you, when working around the house, will have been asked by a child whether it may help. The willingness is there, but you know that the child does not have the necessary ability. In my organization, we ensure that people have the necessary ability by putting great emphasis on training. Nobody embarks on a job without first being trained to do it, evaluated and authorized.

As regards the maintenance of knowledge about a facility that has been shut down, it is obviously important to preserve the operating records, but at least 80% of the information about the facility will be in people’s minds. In order to avoid loss of corporate memory, some of the operating personnel should be retained after shutdown, if possible.

As regards the maintenance of safety culture, we urge people to ‘think safety’ irrespective of what job they are doing. The message is ‘If you think that a certain operation is unsafe, don’t carry it out’! They should constantly be thinking ‘Is what I am doing safe?’ If they have doubts, they should stop and ask for advice. We encourage people to observe one another at work and, if necessary, say ‘What you are doing is unsafe. Perhaps you should rethink things’. It is a kind of peer review system that has proved to be very useful in helping to maintain safety culture.

I. TRIPPUTI (Italy — panellist): During decommissioning, the radiological risks are much lower than during plant operations. However, the risks associated with human behaviour may increase, owing to a combination of factors — people tend to pay more attention to radiological risks than to industrial risks; because of a good safety record, people can be too complacent; many years may have elapsed between the end of operations and the start of decommissioning, with a consequent loss of knowledge and skills (young people do not have sufficient knowledge of the plant); with the lower radiological risks, senior people have become over-confident and less alert and tend to bypass necessary procedures; contractors without even a minimum of nuclear safety culture are participating in the decommissioning; and the ‘best’ people have moved to other parts of the organization or left the organization altogether.

Often, the people involved in decommissioning are not regarded by their employers as productive, and the investment in knowledge preservation and the maintenance of safety culture is therefore inadequate. Also, when decommissioning is funded by the State, training and retraining costs are not considered eligible for reimbursement.

The need to maintain knowledge and safety culture is particularly important in a changing environment like a decommissioning project, Consequently, education and training must be maintained at the highest levels, and you need to ask yourself every day whether you are doing the right thing in the right way.

I have one suggestion - that each organization appoint a senior manager with the primary task of monitoring its knowledge management processes and safety culture levels.

A. BAEKER (Germany — panellist): At Greifswald, in the former German Democratic Republic, we were faced with the task of decommissioning five WWER-440s that had all been shut down at the same time. This required the development of a technical strategy and a personnel strategy. We first developed the technical strategy, covering everything from planning through execution to waste management and site reuse. We then developed the personnel strategy on the basis of the main features of the technical strategy.

From the point of view of maintaining knowledge and safety culture, the lessons learned by us have been as follows: the personnel strategy is of key importance; it should be developed before decommissioning starts; for reasons of motivation, maximum possible use should be made of one's own personnel during the decommissioning (no main contractors - just a few subcontractors); before the start of decommissioning, a project structure designed to ensure that the project is carried out safely should be established; for reasons of personnel motivation, the staff reductions should be socially acceptable (at Greifswald, the reduction was from about 4000 to about 1100); special training in dismantling and other decommissioning work should be provided; again, for reasons of personnel motivation, the possibility of site reuse and the creation of new jobs should be included in the provisions for site remediation; and, if possible, the prospect should be offered to the staff of work on decommissioning projects elsewhere.

As regards the last point, thanks to the know-how acquired at Greifswald we have won contracts for three further decommissioning projects in Germany.

C. MILLER (United States of America): How does one induce former operating staff to remain during decommissioning, especially if no future use of the site is yet foreseen?

F. LOCKHART (United States of America — panellist): Former operating staff need to be given reasonable jobs connected with the decommissioning. At the same time, it should be made clear to them that those jobs will not last indefinitely and they should be helped in preparing for the time when the jobs expire.

At Rocky Flats, where there was a strong union presence, the decommissioning contractor worked proactively with the union leadership in redesigning retirement benefit packages, arranging for retraining and supporting entrepreneurial initiatives such as the establishment of small businesses. A commitment was made to the employees in question, and for a year after the end of decommissioning there was a ‘transition office’ helping with the drafting of resumés and the search for new jobs.

C. PIANI (South Africa — panellist): At one point, my organization had almost 9000 people working for it on virtually all aspects of the nuclear fuel cycle. Following its international acceptance in the nuclear technology field, South Africa no longer had to do certain things itself and many types of job became unnecessary. Drastic staff cuts were made, and the present number of staff is about 1500. A lot of assistance was provided to the people seeking new jobs, and psychological counselling was offered to anyone traumatized by the termination of an expected long career.

In my view, if a large nuclear facility had to be shut down in South Africa now, thanks to the current Pebble Bed Modular Reactor project the situation of the workforce would probably be less discouraging. That project is strongly motivating many young people, and there is even a shortage of qualified personnel.

I. TRIPPUTI (Italy — panellist): The most experienced members of the operating staff of a nuclear facility are usually the older ones, and, as decommissioning tends to be a lengthy process, they will probably be too old to participate in the process right through to its completion. What one therefore needs, in my opinion, is a knowledge management system that provides for the transfer of knowledge from those older members of the operating staff to younger people. Younger members of the operating staff may be induced to remain and participate in decommissioning by a plan offering them the prospect of future work at the site after it has been released for reuse or by a promise of employment elsewhere within the organization in due course. What one must avoid is giving people the impression that they are being asked to ‘dig their own graves’. If they get that impression, they will decommission as slowly as they can.

A. BAEKER (Germany — panellist): At Greifswald, in order to retain the most highly qualified people we had to ‘educate’ them so that they realized that decommissioning is a ‘normal business’ requiring a great deal of knowledge and skill. We succeeded, which should encourage those in Eastern Europe who are facing challenges like the ones which we faced at Greifswald.

It is also important to offer prospects going beyond the end of the decommissioning exercise. At Greifswald, we are hoping to create about 1000 jobs through industrial reuse.

P. BEELEY (United Kingdom — Chairperson): I was involved in a decommissioning project ten years ago, where the reactor manager, who was nearing retirement, was made the decommissioning project manager, drawing on his extensive knowledge of the facility and helping to train younger colleagues.

We need to make it clear that decommissioning is a highly responsible scientific and engineering activity involving many technologies and that one can have an entire, satisfying career in decommissioning. That is the best way of attracting people who are just leaving university. We should be thinking of career management in the decommissioning field.

S. SAINT-PIERRE (World Nuclear Association): It is fairly easy to motivate the operating staff of a shutdown facility and involve them in the decommissioning if there are other facilities still in operation at the site. If there are not, they may be motivated by the prospect of ‘new build’, unless the new facilities are expected to be built elsewhere.

P. BEELEY (United Kingdom — Chairperson): We tried to convince former operating staff members who were young enough that they could become decommissioning experts and make a career in decommissioning. Of course, for that approach to work it is necessary that the pay in the decommissioning field be sufficient.

I. TRIPPUTI (Italy — panellist): In Italy, we no longer have any operating nuclear power plants, and at present there is no prospect of ‘new build’. Consequently, there is little to motivate former senior operators. Salaries cannot be increased as there is no income from nuclear power plant operations, and people over the age of about 55 have great difficulty in finding new jobs. So, some former senior operators are staying on and helping with decommissioning simply because they see no alternative. That is a difficult issue, but we are trying to resolve it.

C. PIANI (South Africa — panellist): One lesson we have learned is that you cannot base your hopes on your existing personnel. We have therefore been encouraged by the interest shown by young people in the work being done on the Pebble Bed Modular Reactor. After learning about that work, many are contemplating a career in nuclear science and technology. My organization has hired some of them, although we realize that not all will remain within the nuclear industry after their training.

H. RIOTTE (OECD/NEA): In order to give decommissioning a higher profile, perhaps one could establish ‘nuclear decommissioning engineer’ as a recognized profession.

F. LOCKHART (United States of America): I can see scientists, engineers and safety professionals making a career in decommissioning, but not ‘hard hat workers’ — decommissioning involves difficult, dangerous and dirty work, and only very special individuals would choose to do such work for all their working lives.

At Rocky Flats, the transition from operating to decommissioning created safety challenges and, with a workforce whose median age was 50 years or more, also problems for people wearing anti-contamination clothing.

I. TRIPPUTI (Italy — panellist): With regard to Mr. Riotte's suggestion, the profession of 'nuclear decommissioning engineer' would not be very attractive to young people in a country where — as in Italy— there are not many nuclear facilities to decommission. Perhaps one could establish 'decommissioning engineer' as a recognized profession, with nuclear decommissioning as just one aspect of the activities involved.

P. BEELEY (United Kingdom — Chairperson): In the United Kingdom, a group of 11 universities and other institutions is now offering an MSc degree course in nuclear science and engineering in which one can focus on process engineering, operations engineering or decommissioning engineering. Also, I would recall the reference made by Ms. Wilson in her paper to the National Nuclear Skills Academy. What we need to install into young people is the idea that decommissioning nuclear facilities does not mean being involved in a dead industry.

I now invite the panellists to respond to the question 'How do you manage the decommissioning of a facility at a multi-facility site?'

A. BAEKER (Germany — panellist): First of all, it is necessary to consider, among other things, whether the facility is to be replaced by something similar; whether decommissioning can be deferred and later integrated into a larger decommissioning project; whether there are particular financial or legal requirements; and whether the operating personnel are needed for the operation of other facilities or can be assigned exclusively to decommissioning activities. Those are the main issues, and in order to resolve them the interfaces between the operating facilities at the site and the facility that is to be decommissioned must be defined, and this must be done in respect both of the personnel and of the technical possibilities at the site. As regards the personnel, it must be decided who is to be used for decommissioning and who is to be assigned to a facility that is still operating. As regards the technical possibilities, it must be decided which of the systems and equipment being used in support of operating facilities can also be used in support of decommissioning — with consequent savings.

I. TRIPPUTI (Italy — panellist): In Italy, all our power reactors are single units each on its own site, so we have no experience of decommissioning a power reactor at a site where another power reactor is still in operation.

Let me, however, address the situation where a nuclear research facility is being decommissioned at a site where there are non-nuclear research facilities still operating — a situation that can easily exist at a research centre. In my view, the greatest problem in such a situation is due to the fact that the best former operating personnel will be attracted to the ongoing research activities rather than to the decommissioning activities — the people who become involved in decommissioning being regarded as ‘second-class workers’. Creating a team spirit among those people may be difficult if they meet with the researchers and with other workers on social occasions. We have used the argument that good decommissioning is important for society and the environment, but we have seen that the argument does not carry much weight. Perhaps money would be a better motivator — perhaps decommissioning workers should be paid somewhat more than researchers.

When a nuclear research facility is being decommissioned while other nuclear research facilities are still operating (a situation analogous to that where a power reactor is being decommissioned while others are operating), I suggest that people not be assigned full-time either to decommissioning or to reactor operations. Rather, there should be some form of rotation.

C. PIANI (South Africa — panellist): One lesson we have learned is that the operator should not be allowed to do the decommissioning. Basic dismantling and decontamination may fall within the authorization of the operator, but one must guard against the operator taking significant decisions without authorization. Decontaminating a fuel line that is superficially contaminated with uranium is not the same as dismantling and decommissioning a reactor. The people entrusted with decommissioning should be trained properly and licensed to do the job. Also, for each decommissioning project there should be a project manager with overall responsibility. The role of the operator should be to provide information and assist on request.

F. LOCKHART (United States of America): At Rocky Flats, some 800 facilities, including plutonium processing buildings with floor areas in the range 20 000–40 000 square metres, were decommissioned over a period of about ten years. Some were being decommissioned while others were still in operation.

We found that the most important thing was to have clearly defined boundaries between and within facilities and clearly defined roles and responsibilities within the boundaries. Some of the larger buildings were divided into ‘sets’, with decommissioning activities taking place within certain sets and operational activities still taking place within others. A situation could exist where one point on a pipe passing through a wall was in one set and another point was in another set.

We also found that it was important that the managers of the individual decommissioning projects taking place simultaneously at the site have under their direct control some of the engineering, health and safety, occupational safety, quality control and other professionals available at the site, while leaving enough of them to serve the site as a whole.

In addition, we found that, in order to avoid 'competition' between individual decommissioning projects, it was important that the senior project managers take a close interest in the day-to-day issues and that the senior site managers move about the site balancing priorities and risks.

P. BEELEY (United Kingdom — Chairperson): With regard to the need for clear boundaries and responsibilities, some years ago, work in which I was involved on decommissioning a research reactor at the Royal Naval College in Greenwich, London, coincided with a visit to the College by the Queen. A decision was taken to clean up the main College buildings — by sandblasting — in preparation for the visit, so we had structures erected around the research reactor site so that the sandblasting could proceed. Every morning, those responsible for the decommissioning and those responsible for the sandblasting met and drew up a work plan for the day, in order to ensure that there was no conflict between the two operations.

WASTE MANAGEMENT ISSUES

(Session 5)

Chairperson

Z. PAN
China

Rapporteur

C. PIANI
South Africa

IDENTIFICATION AND HANDLING OF WASTE STREAMS FROM DECOMMISSIONING

A. RODRÍGUEZ
Empresa Nacional de Residuos Radiactivos,
Madrid,
Spain
Email: AROF@enresa.es

Abstract

The paper draws on the experience obtained of decommissioning major nuclear facilities in Spain. It also summarizes the lessons learned with regard to the radioactive waste management aspects, especially those of waste identification and handling.

1. INTRODUCTION

The progress made in the dismantling projects undertaken in Spain has allowed a degree of experience to be acquired and accumulated so that there is now a reasonable understanding of the technical problems involved. Uranium mills (FUA), experimental reactors (ARBI, PIMIC) and commercial power reactors (Vandellós 1, José Cabrera) have been, or are being, dismantled in the country, and this has allowed ENRESA (Empresa Nacional de Residuos Radiactivos), the organization responsible for such activities, to review the experience and to develop working methods for future projects.

The management of radioactive waste in dismantling projects embraces many subprocesses: waste characterization, identification, treatment and conditioning, packaging, transport, storage and disposal.

This presentation will focus on the initial aspects of waste management: waste identification and handling.

The characterization and knowledge of the installation to be dismantled are the starting points for the identification of the wastes to be produced. The techniques and methods used in the decommissioning projects provide information on the decontamination of materials, on the secondary wastes and on the logistics of moving the large amounts of materials that are to be handled.

Radioactive waste is, in terms of quality and quantity, the most relevant aspect of decommissioning, since waste management plays an important role in all activities within the general decommissioning process.

Waste management begins with the initial characterization of the materials that will ultimately become waste and ends with the conditioned waste package and its final disposal. Throughout the process there are different steps, some included within the framework of decommissioning (as the waste producer) and others relating to transport and disposal (as the waste management agency), both responsibilities being separate but inter-related for efficient management.

In decommissioning, waste management tasks inevitably entail the movement and storage of thousands of tonnes of different materials with necessarily different destinations and routes. This is an aspect that requires study.

2. LESSONS LEARNED AND RECOMMENDATIONS

- Characterize, characterize and characterize might be the maxim for efficient and responsible waste management. The characteristics of the waste to be managed must be profoundly understood for such management to be carried out efficiently.
- No conditioning process should be initiated without first having a detailed characterization.
- Sometimes insufficient attention is paid during the phases of the project to details of the characterization and the handling of waste materials; these aspects are not given the importance they warrant often due to their being considered trivial. On other occasions, no detailed consideration is given to the criteria for classification and conditioning specified by the disposal centre that is finally to receive the waste.
- During the project phase, detailed consideration should be given to the radiological and physico-chemical characteristics of all the possible waste streams to be generated as both primary and secondary waste. The present and expected future developments of acceptance criteria to be applied at the disposal facility should be suitably taken into account to ensure the efficient management of the waste generated during the decommissioning project.
- The waste conditioning infrastructures, mainly at older plants, are often obsolete, offer low levels of remote operation and are focused on the most abundant operating waste streams. The organization during the operational phase does not centre its main interest on the area of waste management.
- During the decommissioning phase, the area of waste management and its associated infrastructures are of key importance for the progress of the

work. For this reason, waste management arrangements should be redesigned to take account of future needs, taking advantage of what is of use from the operating phase and implementing whatever else is required for an integral and optimized configuration, considering the different waste types to be treated during decommissioning as compared with the operating phase.

— The capacity of the storage facilities, for both conditioned and unconditioned waste, is a parameter to be kept under review from the design phase onwards. Overcapacity factors may be needed due to excess production or to difficulties in transferring waste to other locations and they make it necessary to consider over-dimensioning of the facilities.
— The capacities of storage facilities should be overestimated in design, with a view to taking account of possible problems resulting from excess waste production or difficulties in decontaminating materials.
— Bearing in mind that declassification may and should be an important management route for the materials generated during decommissioning, a good knowledge of present and past characteristics of the area from where they are generated is required.
— Materials declassification and site restoration practices require accurate identification of materials streams, and in many cases knowledge of the history of the materials is required.
— The minimization of waste volumes during the process is of great economic and strategic importance; however, it should be recognized that this is an aspect that is often not dealt with as carefully as its importance demands.
— From the design phase to the completion of the decommissioning, the instruments required for giving assurance that waste volumes are being minimized should be in place, either through working groups, independent reviews or any other type of supervisory body, analogous to the ALARA philosophy for radiation dose reduction.
— Seen from a broad perspective, decommissioning is a process of ‘transforming’ large amounts of different materials that finishes with different products being subject to rigorous specifications prior to being dispatched to their different destinations.
— Consideration should be given to producing a logistical plan for the different waste packages to be moved — including the transport and maintenance resources needed, the situation of the storage facilities, the most adequate transport routes, avoiding crossover points and optimizing trajectories.

DISCUSSION

J.-M. POTIER (IAEA): In Spain, it is relatively easy to define the necessary level of characterization of decommissioning waste as the purpose of the characterization is to assess the compliance of the waste with the acceptance criteria at the waste repository. In a country without a waste repository, however, how does one define the necessary level of characterization?

A. RODRÍGUEZ (Spain): Characterization is a huge task. It is not just a matter of characterizing the waste for disposal — it starts with a survey of the plant in order to ascertain what problems you face. The philosophy of characterization is 'I prefer a bad solution to a well characterized problem to a good solution to a badly characterized problem.'

The characterization of waste before disposal is another sub-part of characterization, and in Spain, where we are operating a low- and intermediate-level waste repository, we have defined two levels of characterization for the different waste types, and we are starting with the authorities to license the characterization of the waste that will be sent to the very low activity waste disposal facility.

L. VALENCIA (Germany): Regarding Mr. Potier's question, I have had experience with a lot of waste produced in the late 1970s and stored for a long time at the Karlsruhe research centre, and I recommend that one be as precise as possible in doing all characterization work and archive all the information one has.

In the late 1970s and early 1980s, people were declaring only cobalt-60, caesium-137 and a few actinides. Nowadays, characterization for compliance with acceptance criteria for a repository requires the identification of hundreds of radionuclides and, for the historic stored waste, it is impossible to retrieve all this information from the very rough information that you had at the time.

So, bearing in mind the bad experiences of the past, try to preserve as much as possible of the information available now. It does not matter whether you have a repository or an interim solution - such information is always needed.

ASSESSING THE RADIOACTIVE INVENTORY OF A DECOMMISSIONED REACTOR

P. WOOLLAM
British Nuclear Group Reactor Sites,
Berkeley, Gloucestershire,
United Kingdom
Email: paul.woollam@magnox.co.uk

Abstract

The United Kingdom has 40 gas cooled, graphite moderated reactors that, under current plans, will all be closed by 2023. At present, there is no facility in the United Kingdom for the disposal of the waste resulting from dismantling this plant. Because gas graphite reactors are much larger than water reactors, radioactive waste disposal forms a disproportionately bigger part of decommissioning operations. Hence, characterization and validation of calculated inventories, to ensure optimized packaging and minimized disposal volumes, becomes even more important than for other reactor types. Current strategy in the United Kingdom is to defer reactor dismantling; therefore, characterization is also needed to allow safety cases to be developed for the planned safe storage period until the reactors are dismantled. Taking the Magnox reactors as an example, the paper describes the important steps in assessing decommissioned reactor inventories, explains how these are being verified and provides an overview of the magnitude of the United Kingdom's gas cooled reactor decommissioning waste disposal programme.

1. BACKGROUND

There are 40 graphite moderated gas cooled power reactors in the United Kingdom. Of these, 26 are first generation Magnox units, operated by British Nuclear Group under contract to the Nuclear Decommissioning Authority (NDA), and the other 14 are Advanced Gas Cooled Reactors (AGRs) operated by British Energy. Of the Magnox reactors, 18 have ceased generation and the rest will all close by 2010. Published closure dates for the AGRs range between 2011 and 2023, although these dates might be extended if acceptable long term safety cases can be made.

For the Magnox plant, the current decommissioning strategy is to place the sites in a quiescent state of passive safety, deferring dismantling of the reactors for a period of about 100 years from cessation of generation. This strategy has been developed primarily because the United Kingdom currently has no disposal facilities for activated waste arising from the dismantling of large power reactors. However, the NDA has expressed a hope that Magnox reactor site clearance can be accelerated, subject to an appropriate business case being made to the Government.

Following a major stakeholder engagement process, the Committee on Radioactive Waste Management (CoRWM) has recently made recommendations to the Government that a deep geological disposal facility should be constructed in the United Kingdom to allow the disposal of all intermediate level waste (ILW)[1] and high level waste (HLW). CoRWM also recommended that, where the safety case allows, consideration should be given to disposing of the large volumes of waste arising from reactor dismantling on or near the site, primarily to reduce transport impacts.

The Government is expected to respond to these recommendations, which do not include siting proposals, in the autumn of 2006. The Government has been advised that a deep geological disposal facility is unlikely to be available for first waste emplacement significantly before 2045. When the facility does open, some form of national prioritization will be necessary to determine the order in which waste types are disposed of over the repository's expected 65-year lifetime. It should be noted that waste arising from gas cooled reactor (GCR) decommissioning is significantly less hazardous than that from the decommissioning of reprocessing plants.

Even though the current strategy is to defer dismantling, characterization of the United Kingdom GCRs is required in the short term to:

— Facilitate the production of appropriate safety cases for the quiescent safe storage 'care and maintenance' period, during which time the nuclear site licence remains in place;
— Allow development of waste disposal facilities, remembering that GCR decommissioning waste represents a large fraction of the total legacy disposal volume;
— Plan for and cost the liabilities associated with final site clearance.

[1] Intermediate level waste (ILW) has specific activity <12 GBq/te (βγ) and <4 GBq/te (α). Low level waste (LLW) has specific activity below this level, but above the United Kingdom's clearance (free release) level of 0.4 Bq/g. This clearance level is isotope independent. High level waste is ILW that is heat generating; none is produced from Magnox reactor decommissioning.

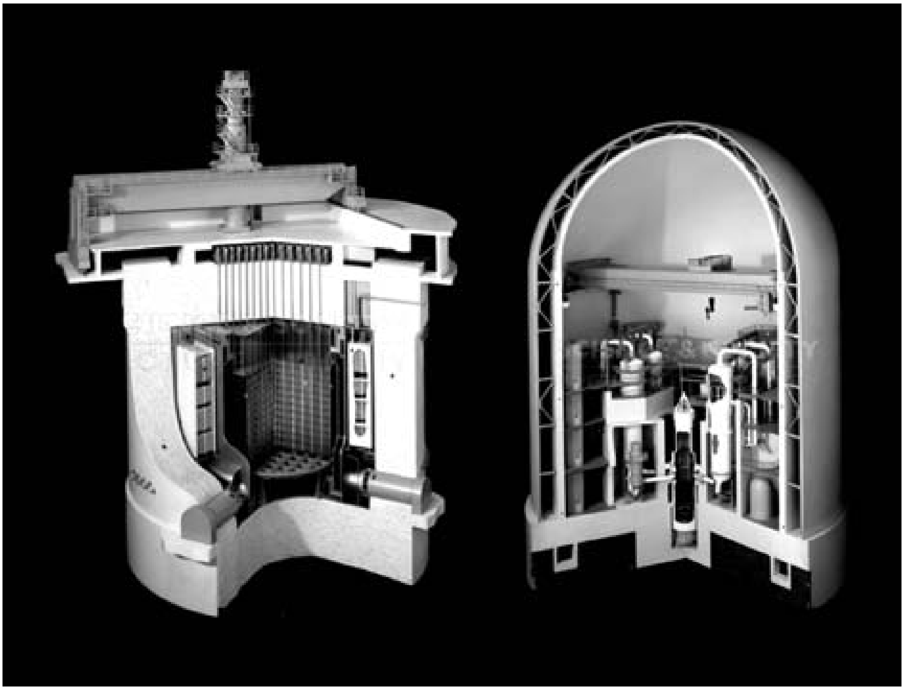

FIG. 1. Comparison between a Magnox reactor and a PWR (both pictures to approximately the same scale) (acknowledgement: www.scienceandsociety.co.uk).

There are currently no plans for further characterization during the safe storage period. However, the local environment will continue to be monitored to ensure the facility presents no hazard to the public.

2. WASTE ARISINGS FROM MAGNOX REACTOR DISMANTLING

The United Kingdom's GCRs are physically very large. Of the 26 Magnox units, 22 have steel pressure vessels and four, in common with all the AGRs, have pre-stressed concrete vessels. The pre-stressed concrete pressure vessels containing each of the Oldbury Magnox reactors are 24 m in diameter and 18 m high. Indeed, Magnox reactor cores would typically fill the entire containment of a 1000 MW(e) PWR. Figure 1 shows the Oldbury pressure vessel and Sizewell B containment on the same scale to allow visualization of the relative amounts of radioactive waste arising from dismantling (Sizewell B is a four loop, 1190 MW(e) PWR).

TABLE 1. AMOUNTS OF WASTE FROM DECOMMISSIONING THE UNITED KINGDOM MAGNOX REACTOR FLEET

Waste type	Mass (tonnes)
Graphite	56 000
Carbon steel — reactor	98 000
Carbon steel — primary circuits	71 000
Concrete	450 000
Total	675 000

The amounts of waste estimated to arise from decommissioning the entire United Kingdom Magnox fleet of 26 reactors are shown in Table 1.

The primary circuits of the Magnox reactors are physically large, like the reactors themselves. There are 115 steam generators in the United Kingdom Magnox fleet, ranging in mass from 310 to 885 te. They are made entirely of carbon steel, which makes them difficult to decontaminate chemically however, in comparison with water reactors, the Magnox steam generator units are only lightly contaminated. It may be possible to reduce their volumes for disposal by melting or compaction. Recycling by smelting may also be an option. These approaches are currently under consideration.

Steel structural components in Magnox reactors are all of carbon steel: there are only a few stainless steel components, although this is not the case for the AGRs. Almost all the steel associated with the reactor structure, plus the pressure vessel, is ILW.

The concrete bioshields on the steel pressure vessel Magnox reactors are ILW at the inside face and, on the basis of activation calculations, below the United Kingdom's free release limit at the outer face. However, tritium diffusion is a potential problem that might result in the whole of the bioshield becoming radioactive. This matter is discussed in more detail below.

Graphite is potentially a special waste management problem because of the presence of two long lived isotopes: highly soluble and mobile chlorine-36 and carbon-14. Table 2 shows that the United Kingdom has, by far, the world's largest amount of graphite for disposal. So far, no country appears to have solved successfully the graphite disposal problem, although Japan has piloted a laboratory scale carbon-14 separation plant and France proposes to build a near surface graphite disposal facility.

TABLE 2. WORLDWIDE ARISINGS OF ACTIVATED GRAPHITE

Country	Core graphite (tonnes)
United Kingdom	80 000
FSU	27 200
France	18 330
Spain	3 330
Japan	1 700
Italy	1 700

3. CHARACTERIZATION OF DECOMMISSIONED REACTORS

Although the United Kingdom's reactors are large, the engineering involved in dismantling them is not considered difficult or novel. Decommissioning is primarily about waste management and, obviously, if the waste was not radioactive, its disposal would not be a problem. Because of the very large volumes involved, it is even more important to characterize Magnox reactors fully before dismantling starts.

Magnox steam generator units are contaminated not activated. Their radioactive inventory has been measured by in situ HPGe gamma spectrometry, combined with removal of samples for laboratory analysis to determine beta activity levels. However, reactor structural component inventories can only be assessed by neutron activation calculations backed up by limited 'in core' sampling and dose rate measurements. To carry out these calculations the following matters must be considered:

- The determination of which isotopes are important for decommissioning and therefore be in the inventory;
- Precursor elemental concentrations for these isotopes in reactor components;
- Adequacy of nuclear physics data;
- Adequacy of reactor modelling and neutron flux calculations;
- Processes affecting the reactor inventory, other than 'in situ' activation.

Because the United Kingdom's strategy is to defer reactor dismantling, the scope of Magnox reactor characterization is greater than would otherwise be expected. For example, it becomes more important to understand the

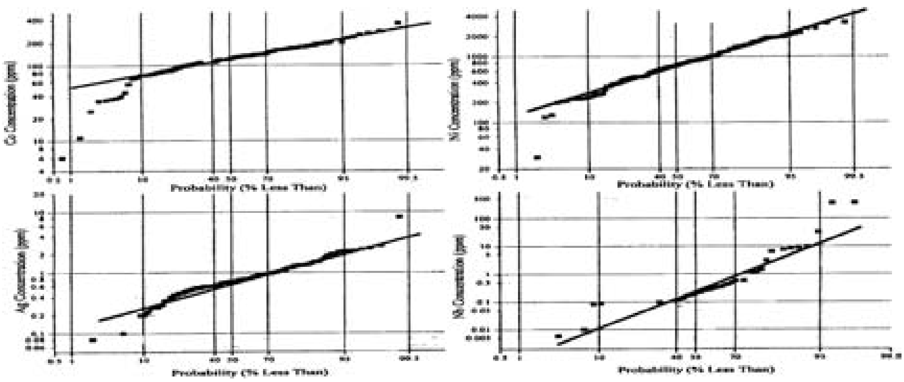

FIG. 2. Log-probability plots showing concentrations of cobalt, nickel, silver and niobium in Magnox reactor steels.

inventory of isotopes that control radiation dose commitments and waste disposal or free release in the longer term.

There are more than 2600 known isotopes. Of these, 79 isotopes have half-lives longer than one year and can be produced in a thermal reactor. However, four of these are gases, 15 also occur naturally and about 35 need more than 10^6 ppm to activate to 0.4 Bq/g (the United Kingdom's clearance limit) in 40 years. A detailed study showed that the isotopes H-3, C-14, Cl-36, Ca-41, Fe-55, Co-60, Ni-59, Ni-63, Nb-94, Ag-108m, Sm-151, Eu-152 and Eu-154 control Magnox reactor decommissioning, either through gamma dose rates or waste volumes. Clearly, different isotopes are more important at different times after cessation of generation.

For the United Kingdom Magnox reactors, there is high confidence that the concentrations of elements in steel and graphite that activate to the isotopes that control decommissioning are well known. Many samples have been taken and analysed, both from the reactors themselves, as activated material, and also from non-irradiated archive materials. For steels, it has been possible to sample materials from components external to the reactor itself, but that are known to be of reactor grade and installed when the power station was originally built.

Figure 2 shows log-probability plots of the concentrations of cobalt, nickel, silver and niobium in Magnox reactor steels. These samples were taken from a number of reactors in the fleet and show, with the possible exception of niobium that statistically, all the samples come from the same distribution. This allows for considerable confidence when interpolating samples within the fleet of Magnox reactors. Silver and niobium are only important as contributors to gamma dose if reactor dismantling is deferred beyond about 80 years from shutdown.

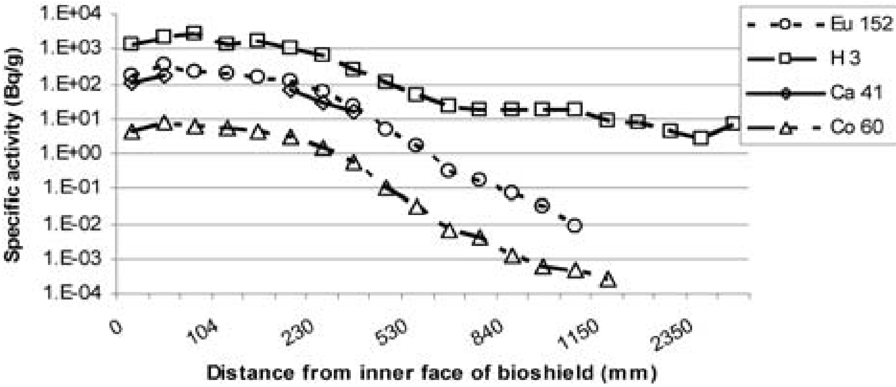

FIG. 3. Data from a core through a Magnox steel pressure vessel bioshield (note that the x axis is not linear to allow detail at the inner face to be more readily seen).

There is also high confidence in cross-sections and half-lives, the anomalies detected in the 1980s having now been resolved.

Three-dimensional Monte Carlo neutron flux modelling has been employed for the Magnox reactors, and is complete for most. The neutron flux is well understood in the cores, but uncertainties arise in modelling the complex geometries at the top and bottom circumferences of the core structure. Bioshield water content is a significant uncertainty in assessing the activation of the concrete structures.

There is high confidence that, for reactor dismantling waste, fission product contamination is negligible compared with activation. However, there is a possibility of significant C-14 ‘contamination’ of graphite via the activation processes N-14 (n, p) C-14 and O-17 (n, α) C-14 from air ingress to the gas coolant during outages. Further work is needed on this matter since just 10 ppm nitrogen increases the carbon-14 inventory in graphite by a factor of three.

Figure 3 shows activation data from a core through the concrete bioshield of a steel pressure vessel Magnox reactor. For cobalt-60 and europium-152, the activation profile follows the neutron flux profile. However, the tritium distribution is very different due; it is believed, to time dependent tritium diffusion down the concentration gradient. The data shown in Fig. 3 imply that the entire thickness of the bioshield has a radioactive concentration exceeding 0.4 Bq/g. Only very limited data are currently available to substantiate (or not) this apparent process; it is planned that a number of cores will be removed from the Magnox reactor bioshields to further address this matter.

In addition, gamma dose rate measurements have been made by lowering a dosimeter into a defuelled Magnox reactor core. These dose rates are

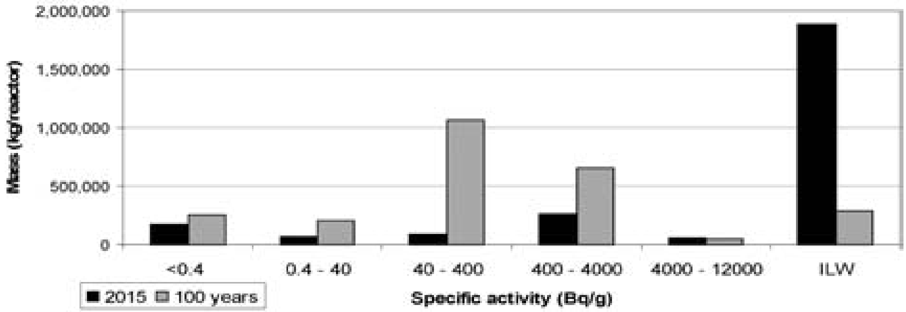

FIG. 4. Typical Magnox reactor steel inventory.

controlled by cobalt-60 at the present time. Comparison between measured and calculated dose rates show that, in general, they agree to within a factor of 2 to 3. Calculations at the top corner of the core overestimate dose rates by around a factor 4, while measurement and calculation agree at the core equator to within 30%. Measurements such as these are quick and inexpensive and can contribute significantly to building confidence in the calculated data.

4. RESULTS FROM ACTIVATION ASSESSMENTS

Each of the United Kingdom's Magnox reactors has been characterized in terms of its radioactive inventory. The following figures show the masses and activities of the three primary material types, steel, graphite and concrete, that arise from dismantling a typical steel pressure vessel unit. Data are shown for early dismantling in 2015 and for dismantling 100 years after cessation of generation, to demonstrate the impact of the United Kingdom's deferment strategy on waste disposal.

Figure 4 shows that most of the steel is ILW soon after shutdown. At this time, the gamma dose rate is controlled by cobalt-60 whereas after 100 years, niobium-94 and silver-108m become dominant, because of the relatively low cobalt content of carbon steel in these reactors (see Fig. 2). At this later time, gamma dose rates have fallen by about a factor of one million. Dose rates due to steel will dominate transport considerations in the United Kingdom, where rail gauges, and therefore transport packages, are small. Figure 5 demonstrates that the graphite inventory is primarily ILW and, because of the long half-life of carbon-14, this does not change on timescales of millennia. Concrete (see Fig. 6) contains a small quantity of ILW soon after shutdown but, 100 years later, none of the bioshield inventory is above 400 Bq/g. A more accurate assessment of the concrete inventory requires better knowledge of water

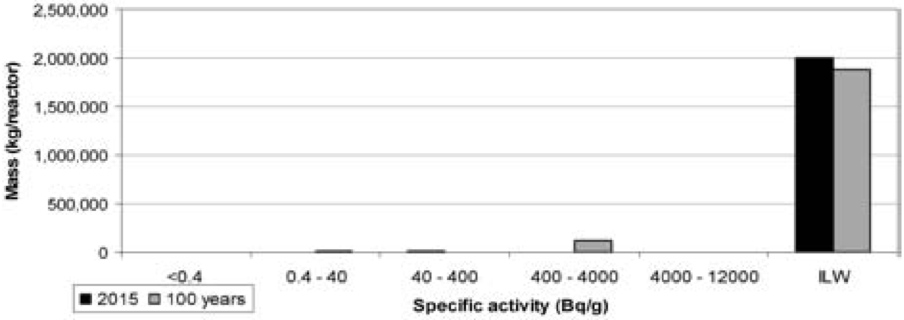

FIG. 5. Typical Magnox reactor graphite inventory.

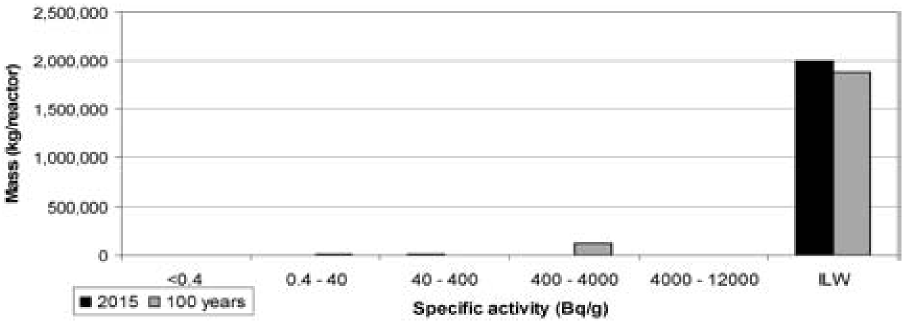

FIG. 6. Typical Magnox reactor concrete inventory.

content and the potential tritium diffusion process. It may ultimately be possible to make a safety case to dispose of the large mass of bioshield concrete on site to avoid the environmental impact of transport through communities local to the Magnox power stations.

5. CONCLUSIONS

The United Kingdom's gas graphite reactors pose a significant challenge for decommissioning because of the very large volumes of waste produced. Therefore, characterizing the reactor cores before dismantling, to ensure optimized packaging and minimized disposal volumes, is even more important than for water reactors. In addition, because the United Kingdom's decommissioning strategy is to defer dismantling the reactors for a prolonged period after cessation of generation, good characterization of the reactors is essential for producing an adequate safety case for the safe storage period. Dismantling is deferred because there is currently no facility in the United Kingdom in which to dispose of decommissioning waste; characterization is vital to allow such facilities to be designed and implemented because reactor decommissioning waste represents a substantial fraction of the United Kingdom's legacy radioactive waste inventory.

For the Magnox stations, work done by British Nuclear Group and its predecessors gives confidence that all important isotopes have been considered in characterizing the reactors, that the elemental concentrations in steels and graphite are known and that the neutron flux calculations are adequate.

For the Magnox plant, limited validation by in-reactor dose rate measurements shows overall agreement with calculation to within typically a factor of three for reactor steel and graphite. Concrete is the least well understood material. A bioshield coring programme is required to improve understanding of its activity profile, particularly the impact of tritium diffusion and the water content of the concrete. Further work is also needed to assess the impact of small amounts of nitrogen on the carbon-14 inventory of graphite.

DISCUSSION

A.J. GONZÁLEZ (Argentina): Obviously, problems are being created by the fact that there are no isotope-dependent release limits provided for in United Kingdom law. However, the United Kingdom is a party to the Joint Convention, which refers to the International Basic Safety Standards, and the limits in those standards are isotope-dependent. In fact, the International Basic Safety Standards contain tables for the calculation of release limits for every radioisotope. Perhaps you could use them in circumventing some of the problems due to the absence of isotope dependent release limits. Moreover, by becoming a party to the Joint Convention, the United Kingdom agreed that the Joint Convention should be incorporated into its national legislation.

P. WOOLLAM (United Kingdom): There are many internationally agreed isotope dependent release limits, but the United Kingdom Government and the governments of many other countries have chosen not to accept them. I wish it were not so. Perhaps you should write to Prime Minister Blair and urge the introduction of isotope dependent release limits in the United Kingdom.

A.J. GONZÁLEZ (Argentina): Perhaps I should write to a clever London lawyer, as the Joint Convention should prevail over the national law of a country that — like the United Kingdom — is a party to it.

B. BATANDJIEVA (IAEA — Scientific Secretary): How much effort should an operator put into the characterization of a facility, particularly when deferred dismantling is the preferred option? When we at the IAEA provide technical assistance to developing countries, we follow the relevant safety standards and require that those countries' facilities be characterized. But how much characterization is necessary?

P. WOOLLAM (United Kingdom): In my view, the amount of characterization needed depends on what is going to be done with the facility. Clearly, it will be necessary to do enough characterization to meet the requirements of the disposal facility, if there is one, or to meet the requirements of the post-closure safety case, if the facility is to be left for some time before dismantling. In all cases, it comes down to the safety case. One must do enough characterization to meet the safety case.

Our experience has been that, however much characterization one does, it is never enough. At Fort St. Vrain, for example, the top head of the reactor was not properly characterized — account was not taken of the neutrons streaming through the standpipes passing through the concrete, which became far more active than anyone had expected. A huge amount of characterization was done, but that one thing was missed.

Moreover, one must look to the future. One can characterize now, but one needs to be very careful that in the future one has characterized sufficiently — particularly for a range of isotopes. It is not good enough to do it just for cobalt-60, caesium-137 and the other obvious ones. It is important to go through all those 2600 isotopes and determine which are important for the facility in question and what is going to happen to them as a function of time, either during the period before the facility is dismantled or after final disposal.

RECYCLING OF DISMANTLED CONCRETE FOR HIGH QUALITY AGGREGATE

T. ISHIKURA, S. FUJII
Nuclear Power Engineering Corporation,
Tokyo,
Japan
Email: ishikura@nupec.or.jp

Abstract

Disposing of dismantled concrete into industrial disposal sites will not be a suitable solution in Japan, especially in the future, because of decreasing site availability. It is, therefore, important to find recycling options for dismantled concrete such as its use as recycled aggregate, because of the decreasing tendency of demand to roadbeds which are most common recycling option of concrete waste. Conventional recycled aggregate is, however, inferior in quality to ordinary natural aggregate. Therefore, its uses are limited to non-structural concrete, bases and roadbeds. If recycled aggregate is available for high structural concrete, the dismantling concrete is recyclable for various uses. With this view, the authors developed techniques for high quality aggregate reclamation and byproduct powder usages for non-radioactive concrete recovered during nuclear power plant decommissioning. Various grinding methods were tested to improve recycled aggregate quality and a heating and grinding method along with some mechanical grinding methods were confirmed to achieve the quality equal to ordinary aggregate. The concrete produced using the recycled aggregates was tested for strength, durability and construction. Real size structural models such as walls, a building and a mass structure were constructed using the recycled aggregate to demonstrate long term soundness and durability, confirming that it is equivalent to ordinary aggregate concrete. In addition, byproduct powder of the aggregate reclamation process was tested for its various usages as raw material mixture. Based on this developed technique, high quality aggregate produced from dismantled concrete has been applied to several new reinforced concrete buildings in industry since 2002.

1. INTRODUCTION

There are 55 nuclear power plants in operation in Japan, most of which will be dismantled by the middle of this century; this includes two already shutdown plants (Tokai in 1998 and Fugen in 2003). The amount of non-radioactive concrete waste produced during nuclear power plant dismantling is estimated to be a half million tonnes for a standard large plant Industrial disposal of the waste is not appropriate, because residual industrial disposal site capacity is quite limited. The demand for roadbeds and backfill tends to be less than the amount of dismantled concrete produced from a single nuclear power plant site. Therefore, it is vital to have more general uses for dismantled concrete as recycled aggregate.

There have been many studies on recycled aggregate. The quality of recycled aggregate in the past, however, was lower than that of aggregate for high strength structural concrete as prescribed in JASS 5 (the Japanese Architectural Standard Specification for Reinforced Concrete No. 5 issued by the Architectural Institute of Japan). So far, application of such low quality recycled aggregate in construction has been quite limited in Japan, because of the inferior strength and durability of the associated concrete.

Concrete from nuclear power plant buildings has good features for recycling aggregate: a large amount of high quality aggregate from the same origin; records of the origin of the aggregate; and few impurities in dismantled concrete, such as woods and plastics.

A technology for producing high quality aggregate from dismantled concrete has been developed, with the aim of establishing of techniques for producing high quality recycled aggregate which can be used for construction. This development was implemented through contracts between the Ministry of Economy, Trade and Industry (METI) and the Nuclear Power Engineering Corporation (NUPEC).

2. RECYCLED AGGREGATE PRODUCTION TECHNIQUES

2.1. Goal

The target of recycled aggregate quality is that prescribed in JASS 5 or JASS 5N, ‘Specification for Nuclear Power Facility Reinforced Concrete’, as shown in Table 1.

TABLE 1. QUALITY OF RECYCLED AND ORDINARY AGGREGATE

Coarse aggregate		Fine aggregate		Reference standard
Dry density (g/cm^3)	Adsorption (%)	Dry density (g/cm^3)	Adsorption (%)	
2.5 min.	2.0 min.	2.5 min.	3.0 min.	JASS5N
2.5 min.	3.0 min.	2.5 min.	3.5 min.	JASS5

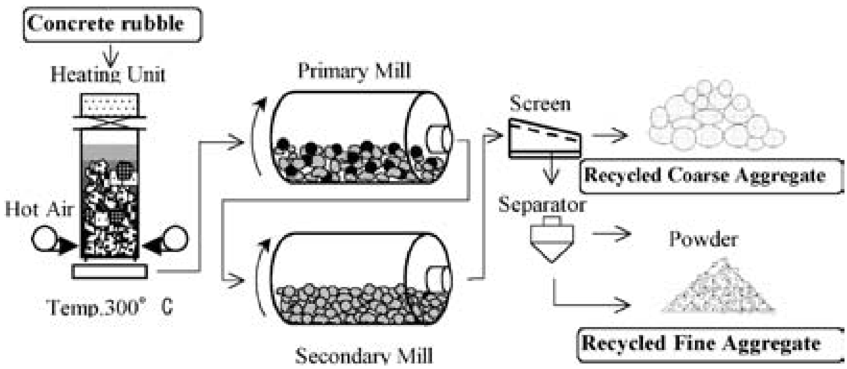

FIG. 1. Heating and grinding method.

2.2. Recycled aggregate production methods

Among the various available aggregate reclamation methods, the heating and grinding method, together with some mechanical grinding methods, was selected and tried for improving the quality of aggregate by changing production parameters [1, 2]. The methods described below deal with concrete rubble that was produced by bluntly crushing the original concrete.

2.2.1. Heating and grinding method

Crushed concrete rubble is heated to about 300°C with hot air. Then the rubble is ground by a primary mill to produce coarse aggregate, and ground by a secondary mill to obtain fine aggregate. Figure 1 shows an outline of this method.

2.2.2. Mechanical grinding method

Crushed concrete rubble is ground to produce coarse and fine aggregate. The process is repeated until the target quality is achieved. This method is similar to the mill process shown in Fig. 1.

2.2.3. Twin corn method

Crushed concrete rubble is pressed between the screw and the corn that reversely rotate against each other (Fig. 2). The process is repeated until the target quality is achieved. This method is only for coarse aggregate, and has the feature of producing high quality aggregate at comparatively low cost.

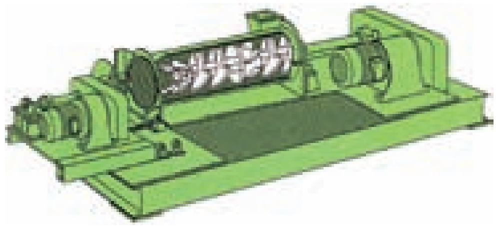

FIG. 2. Twin corn method.

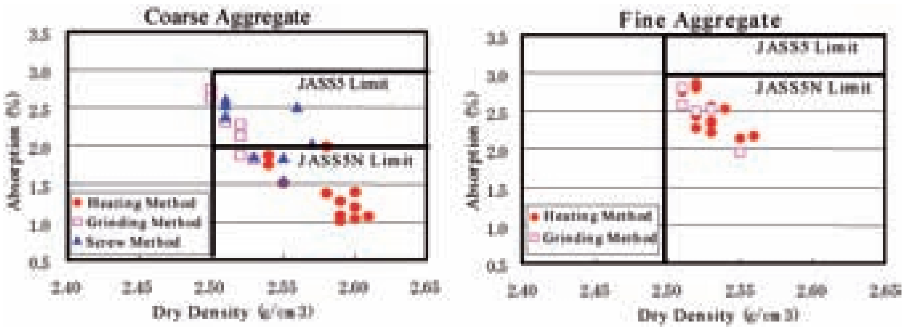

FIG. 3. Relationship between density and absorption of recycled aggregate.

2.3. Recycled aggregate quality

The relationship between oven-dry density and water absorption of the recycled aggregate produced by the three methods mentioned above is shown in Fig. 3. The accepted limits of JASS5 and JASS5N standards are shown as the bold lines in the figure. Recycled aggregates produced using the three methods could meet the target quality. Aggregate of 60–70% of the weight of the original concrete was recovered, which corresponds to 80–90% of the weight of the aggregate in the original concrete. That is, 30–40% of the weight of the original concrete remained as powder.

3. PERFORMANCE OF CONCRETE USING RECYCLED AGGREGATE

3.1. Goal

The following problems exist when low quality recycled aggregate is used for concrete construction:

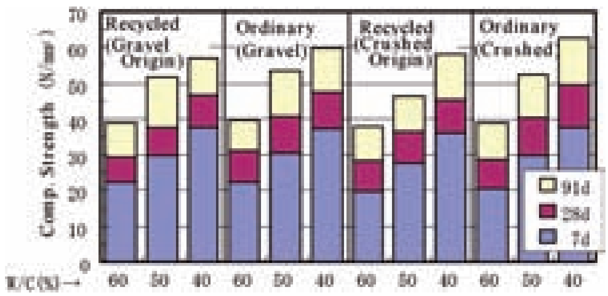

FIG. 4. Compression strength of recycled aggregate concrete and ordinary concrete.

— Low strength;
— Inferior durability, such as drying shrinkage and poor resistance to freezing and thawing.

These are the reasons why low quality recycled aggregate is not applied in major building structures. The goal is to understand the performance of the recycled aggregate concrete compared with that of ordinary aggregate concrete.

3.2. Performance of concrete using high quality recycled aggregate

Concrete using recycled aggregates produced by the three methods was tested for strength and durability. The original concrete of recycled aggregate was taken from the Tokai nuclear power plant building.

The high quality recycled aggregate concrete was seen to have almost equal performance to ordinary aggregate concrete in compression strength, dry shrinkage, and resistance to freezing and thawing. Figure 4 shows the results for compression strength. It is known that cement paste adhered to recycled aggregate tends to reduce the performance of the recycled aggregate concrete. However, the result above suggests that when only a small amount of cement paste adheres to the recycled aggregate, as seen in the other concrete sample tests, the concrete performance is not reduced.

3.3. Demonstration of concrete performance using high quality recycled aggregate

Concrete strength and durability characteristics were studied using actual scale structural models, focusing on the difference between ordinary aggregate concrete. In the model tests, recycled aggregate produced by the heating and

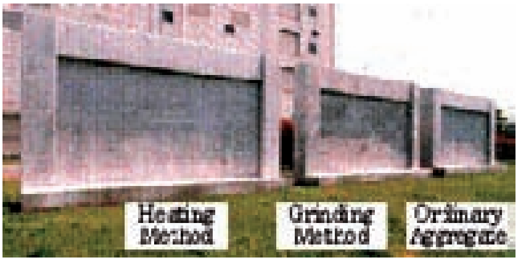

FIG. 5. Walls model.

FIG. 6. Building model.

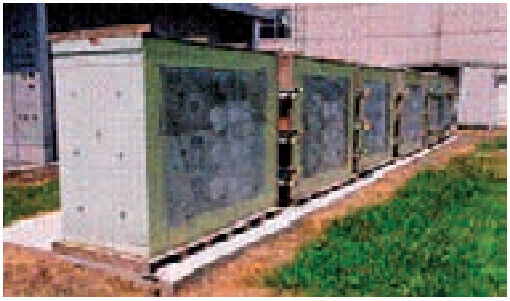

FIG. 7. Mass concrete model.

grinding method was mainly used in three kinds of actual scale models; a wall model, a building model and a mass concrete model. The wall model shown in Fig. 5 consists of a wall (3.1 m × 5.35 m × 0.18 m), columns, and a beam — for each aggregate concrete, simulating a part of a nuclear power plant building. The building model (49 m^2 floor area) shown in Fig. 6 also simulated a part of the plant building. The mass concrete model shown in Fig. 7 consists of walls of three different thicknesses (800 mm, 500 mm, and 300 mm) for each aggregate concrete simulating the thickness of the cylindrical containment vessel wall of a nuclear plant. For these models, original concrete were taken from Tokai nuclear power plant buildings.

The result of these model tests showed that the long term strength and durability of the recycled aggregate concrete is equivalent to those of ordinary aggregate concrete. Cracking of the recycled aggregate concrete was less than that of ordinary concrete in width and length of cracks.

Regarding the effect of temperature on the compression strength of mass concrete, a simulation analysis showed that the high quality aggregate concrete has a little less thermal cracking compared with ordinary aggregate concrete. The reason why recycled aggregate concrete has better cracking performance than that of ordinary aggregate concrete is because the unit volume of the water in the mixture of the recycled aggregate concrete was less than that of ordinary concrete. This is understood to be because the recycled aggregate has a slightly rounder shape as a result of the grinding process, especially compared with crushed aggregate.

4. BYPRODUCT USAGE

It is important to make good use of the byproduct powder produced in the aggregate production process. Byproduct powder represents 30–40% by weight of the original concrete in the high quality aggregate production. Therefore, the byproduct powder characteristics were studied to determine the maximum mixing ratio for materials needed in new nuclear power plant construction.

In the case of high quality coarse and fine aggregate, the byproduct powder is fine and remains active, while for coarse aggregate it is in the form of larger particles and is less active. The use of the byproduct powder for cement raw material (raw material for clinker), cement admixture, paving blocks (Fig. 8), and construction block has been demonstrated.

5. ECONOMIC EVALUATION

The cost of high quality recycled aggregate production was evaluated for nuclear plant dismantling concrete. The high quality recycled aggregate option (option 2) was compared with an option of disposing of it to an industrial disposal site (option 0) and an option of recycling it in crushed concrete for roadbeds (option 1). When there is less demand for roadbeds or backfill within the dismantling site, an option to produce high quality aggregate from dismantled concrete for use within the site can be competitive with the

FIG. 8. *Paving block specimens.*

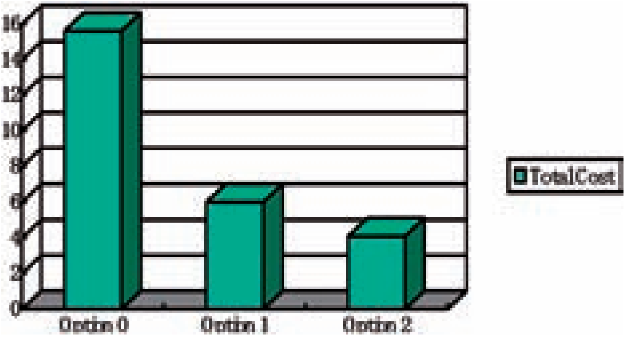

FIG. 9. *Cost comparison.*

roadbed option (option 1), because of the high transportation cost, as shown in Fig. 9.

6. CONCLUSION

The technology for dismantled concrete recycling for high quality aggregate has been developed. Various tests and evaluations have confirmed:

- A high quality recycled aggregate meeting the quality standards of ordinary aggregate for nuclear power plant facility grade concrete can be produced with a high recovery ratio.
- The high quality recycled aggregate concrete showed strength and durability equal to ordinary aggregate concrete.

— The cost of high quality recycled aggregate from dismantled concrete can be competitive with the cost of the roadbed recycling option under certain conditions.

Based on the techniques developed, high quality aggregate produced from the dismantled concrete of ordinary buildings has been applied to several new reinforced concrete buildings in industry since 2002 [3]. This development prompted the development of a new standard publication of the Japanese Standards Association in 2005 entitled 'Recycled Aggregate for Concrete-class H' for high quality recycled aggregate [4]. In the course of this development, it is thought that high quality recycled aggregate produced from nuclear power plant dismantling concrete can attain the level needed for aggregate of new plant buildings. Further, the authors expect that high quality recycled aggregate will be utilized for nuclear power plant building construction in the near future.

REFERENCES

[1] ISHIKURA, T., SAISHU, S., HIRAYAMA, T., SUKEKIYO, M., "Development for production technique of high quality recycled aggregate", ICEM '99, Nagoya (1999).

[2] SUKEKIYO, M., SAISHU, S., HIKURA, T., ISHIGURE, T., "The technical development on recycled aggregate concrete for nuclear facilities", Safewaste 2000, French Nuclear Society, Montepellier (2000).

[3] KURODA, Y., HASHIDA, H., "A closed loop concrete system on a concrete site", CANMET/ACI Int. Symp. Sustainable Development of Cement, Concrete and Concrete Structures, (2005). 371-388

[4] JAPANESE INDUSTRIAL STANDARDS COMMITTEE, Recycled Aggregate for Concrete-class H, Japanese Industrial Standard (JIS) A 5021 (2005).

DISCUSSION

J.J. BYRNE (United States of America): Have you considered placing radiation monitors in the aggregate processing equipment in order to 'clear' concrete in one step?

T. ISHIKURA (Japan): The aggregation process makes use of uncontaminated concrete rubble already segregated by waste category and therefore radiation monitors will not be needed, because the concrete rubble will be segregated during the concrete dismantling process.

EXPERIENCE OF DECOMMISSIONING PROJECTS WITH ON-SITE AND OFF-SITE WASTE TREATMENT

L. VALENCIA
Forschungszentrum Karlsruhe GmbH,
Karlsruhe,
Germany
Email: Luis.Valencia@hdb.fzk.de

Abstract

During the decommissioning of a nuclear facility, the treatment of the radioactive waste is an important aspect. Normally, there are two different ways in which decommissioning waste is managed properly. The first involves the installation of waste treatment facilities on the decommissioning project site. This means, that the management of the radioactive waste is a part of the decommissioning. At the end of the project, the waste treatment facilities have to be dismantled. The other approach is to take the radioactive waste to a specialized waste treatment facility located away from the decommissioning site. The paper will indicate the advantages and disadvantages of the two options and the lessons learned from their application.

1. INTRODUCTION

The decommissioning of nuclear facilities gives rise to radioactive waste that has to be properly treated and disposed of. It may either be treated or conditioned directly on the site of the facility being decommissioned or transferred to an external facility for further conditioning. Each option has advantages and drawbacks, which shall be presented below.

In 1979, the dismantling of the first of the five research reactors of the Forschungszentrum Karlsruhe was started. Two of the research reactors were not located on the premises of the Forschungszentrum Karlsruhe, but at Niederaichbach and Karlstein. At the present time, all of the research reactors are being decommissioned, or have already been completely decommissioned. The dismantling of the Karlsruhe Reprocessing Plant began in 1991 and is still continuing. In the course of these decommissioning projects, it was possible to assess. Within the framework of these dismantling projects, it was studied whether on site radioactive waste conditioning is economically viable in comparison with waste treatment at a centralized facility.

After thorough consideration, it was decided to transfer all radioactive waste and residues from these decommissioning projects to the central waste treatment facility of the Forschungszentrum Karlsruhe, the Hauptabteilung Dekontaminationsbetriebe (HDB, Central Decontamination Department), for further treatment.

2. CHARACTERISTICS AND PECULIARITIES OF DECOMMISSIONING WASTE

Decommissioning waste consists mainly of solid inorganic and organic materials and liquid inorganic substances that have to be treated and conditioned properly. For this purpose, appropriate treatment facilities for combustion, compaction, evaporation, and drying have to be available. As an important objective is the minimization of the radioactive waste volumes, various decontamination methods and facilities are required.

Decommissioning waste differs from operational waste mainly in terms of its dimensions, mass, and radioactive content. This means that the treatment plants have to be designed for the handling and processing of large components of up to 200 t in mass and 15 m in length in compliance with existing requirements. Furthermore, tools, e.g. saws and cutting tools have to be adapted to the dimensions. Apart from the dimensions, the radionuclide content of the decommissioning waste differs from that of operational waste and has a considerable influence on the treatment process. As the components produced during the decommissioning of a nuclear facility are mostly from areas of high contamination and neutron flux, radiation dose rates of up to 200 mSv/h can be encountered. These dose rates make dismantling more difficult, as shielding has to be provided and work performed remotely.

In addition, the decommissioning of research reactors often involves the handling of conventional hazardous materials and chemicals. Examples are asbestos impurities in radioactive waste or sodium residues from the decommissioning of a fast breeder prototype.

3. ON-SITE TREATMENT AND CONDITIONING

As mentioned above, decommissioning waste consists of solid and liquid materials, some of which are burnable. Moreover, it includes large components that cannot be handled by standard methods due to their mass and radioactive content.

Treating and conditioning the waste arising on the decommissioning site means that the necessary decontamination and conditioning methods needed to be available. The decommissioning project must be provided with a separately ventilated closed working area for dry and, if applicable, wet chemical decontamination. As the dismantled components are often are difficult to handle due to their mass and dimensions, they have to be cut into pieces prior to treatment. For this purpose, special workplaces have to be designed in which the components can be cut into pieces without spreading contamination. In addition, a variety of dismantling tools must be available to cope with different material properties, geometries, and types of contamination. Hence, the dismantling method has to be tailored to the given situation.

For volume reducing conditioning, solid inorganic or mixed waste is subjected to high pressure compaction. For this purpose, a mobile or stationary high pressure compaction unit is needed on-site. To avoid the spread of contamination, special containment arrangements and a separately ventilated working area are required.

Since the radioactive content of the decommissioning waste varies, it must be ensured that dismantling facilities and the compaction unit are suited to the treatment of waste producing high radiation dose rates, and that arrangements are in place to minimize the radiation exposure of personnel.

Apart from solid waste, decommissioning also gives rise to inorganic liquid waste that has to be converted into a solid form. For this purpose, an evaporation or drying facility is required on site to bring the waste to a form that is suitable for subsequent storage and disposal.

An advantage of the on site treatment of the decommissioning waste is that transport to an external conditioning facility is avoided. This not only saves transport costs, but also the costs resulting from the procurement of appropriate transport containers. Another advantage is that processing can take place continuously and therefore only a small storage capacity for unprocessed raw waste is required. In order to optimise the number of required shipments of waste to an external facility, the unprocessed waste has to be stored until the volume is sufficient to form a reasonable transport batch. Another advantage of on site treatment is that the personnel having dismantled the components are often also in charge of the conditioning, such that the radiological and mechanical conditions are known exactly. Even if this is not the case, communication between the personnel in charge of the treatment on site and the dismantling staff is easy and direct.

When treating the waste on the decommissioning site, however, the necessary prerequisites have to be established prior to decommissioning. Rooms have to be adapted to the treatment of waste. It may also be necessary for new buildings or facilities to be constructed. In addition, all tools and equipment have to be procured and installed. Due to the limited space, the dismantling project may be delayed, unless separate buildings are available for treatment and conditioning.

4. TREATMENT AND CONDITIONING AT EXTERNAL FACILITIES

An alternative to the treatment of radioactive waste directly on the decommissioning site is its transfer to an external treatment facility. In this case, the waste arising on the decommissioning site has to be sorted, packed into appropriate transport containers, and declared for external treatment. This declaration is important, as it is the means of providing information about the waste in advance of its shipment. The information enables plans to be made at the external facility for the treatment of the waste with minimum radiation exposure and financial cost.

The external facilities are specially designed for the treatment and conditioning of radioactive waste. This means that they are equipped with a variety of treatment methods and tools to cover any possible case.

Usually depending on the equipment of the external conditioning facility, the facility offers methods of wet and dry decontamination as well as various conditioning options, such as a high pressure compaction, a liquid waste treatment and an incineration. Various cutting tools are available for preliminary treatment. The entire infrastructure of the conditioning facility, namely, the ventilation system, transport and lifting arrangements, and workplaces, is designed for the treatment of radioactive waste.

Another advantage of external conditioning facilities is that their staffs are experienced in handling radioactive waste and in operating the treatment systems, such that treatment is efficient and involves the minimum necessary personnel. Due to its regular workload, advance planning is possible such that the external conditioning facility works in an economically efficient manner, which positively affects the budget of the decommissioning project.

To sum up, transfer of the waste to an external conditioning facility is associated with a number of advantages. A drawback can be that not all information about the radiological, physical, and chemical properties as well as about the technical conditions in the originating plant is transferred, such that treatment cannot be planned as thoroughly as is desirable in advance.

In the course of the decommissioning projects of the Forschungszentrum Karlsruhe, the two options of treatment of the waste on site or transfer to the Central Decontamination Department, as an external conditioning facility, were considered. Using the decommissioning of the Multi-purpose Research

Reactor (MZFR) as an example, the results of this analysis are presented below.

5. COMPARISON OF THE TREATMENT OF RADIOACTIVE WASTE ON THE DECOMMISSIONING SITE OR AT AN EXTERNAL FACILITY, WITH THE MULTI-PURPOSE RESEARCH REACTOR (MZFR) AS AN EXAMPLE

The Multi-purpose Research Reactor (MZFR) was a PWR cooled and moderated with heavy water. It was built from 1961 to 1966 and went critical for the first time on 29 September 1965. After nearly 19 years of successful operation, the reactor was shut down on 3 May 1984. The reactor had a thermal output of 200 MW and an electrical output of 75 MW. The purpose of the plant was to obtain experience for the planning, construction, and operation of heavy water reactor systems as well as to provide for the testing of fuel elements and materials. The decommissioning concept for the plant — down to a 'green field' status — comprises eight steps. Six of these eight decommissioning steps were completed successfully by 2002. At the moment, the 7th MZFR decommissioning step is being carried out: the disassembly and cutting of the 400 t reactor pressure vessel (RPV) and its internals. This work is expected to be completed by the end of 2006.

The 6th and 7th decommissioning steps gave rise to various large components and rod shaped components, respectively. The individual components are listed in Table 1.

For the components arising from the 6th decommissioning step, two concepts have been drawn up for cutting and treatment on the MZFR site. In concept A, the dismantled components are cut manually on-site. Concept B envisages the semi-automatic cutting of the components using one of several central cutting facilities in the reactor building. Due to the radiological conditions, only concept B may be applied for the treatment of the rod shaped components from decommissioning step 7. For manual cutting on site, radiation exposure of the personnel is too high and would require extensive automation or remote controlled operations.

5.1. Concepts for waste treatment on the MZFR site

Concept A (manual cutting):

The advantage of concept A is that only low investment costs are involved due to the use of commercially available and simple cutting tools.

TABLE 1. SUMMARY OF COMPONENTS ARISING FROM DECOMMISSIONING STEPS 6 AND 7

	Number	Component	Dimension (m)	Mass (t)
Large components, 6th decommissioning step	2	Steam generators	Ø 2.5 × 10.4	55
	2	Main coolant pumps	Ø 1.2 × 3.9	12.6
	2	Coolers	Ø 0.36 × 4.3	0.8
	2	Moderator coolers	Ø 1.0 × 9.2	17
	1	Accumulator	Ø 1.6 × 11.5	20
	2	Regenerative heat exchangers	Ø 0.25 × 2.5	0.2
	3	Coolers	Ø 0.25 × 2.5	0.2
	1	Loading machine	Ø 0.4 × 8.0	25
	1	Transfer machine	Ø 0.65 × 2.7	1.2
	1	Tilting chamber	Ø 0.2 × 7.0	22
	2	Moderator pumps	Ø 0.7 × 2.1	1.2
Rod shaped components, 7th decommissioning step	17	Control and absorber rods / moveable part	about Ø 0.08 × 6.7	1.4
	121	Fuel element racks and rods	about 0.09 × 1.9	14.5
	17	Guiding tubes	about 0.1 × 6.5	1.1
	121	Spacer tubes	about 0.12 × 6.7	4.8

However, the radiation exposure of the personnel is high, as the time spent in the vicinity of the components is very long. Cutting of the components requires considerable time expenditure, and, for each component, specially designed contamination protection is needed. In addition, the reactor building is blocked by the cutting work, such that a parallel execution of work on the 7th decommissioning step is not possible.

Concept B
(semi-automatic, remote-controlled cutting in the reactor building):

Using this concept, the radiation exposure of the personnel can be reduced, as times spent in the vicinity of the components are shorter than in case of concept A. Moreover, the general contamination protection of the cutting system is sufficient. It is not necessary to provide separate protection arrangements for each individual component.

A drawback of this concept is that, due to the limited space available in the reactor building and the size of the components, several cutting systems are required or the cutting systems have to be transferred or reconstructed. This results in high investment costs for these specially adapted cutting facilities. As in case of concept A, parallel execution of work of the 7th decommissioning step is impossible, as the reactor building is blocked for other uses.

5.2. Estimation of the costs of the cutting options for the 6th decommissioning step at the MZFR site

Concept A (manual cutting):

The components are cut into large pieces on site using saws, rotary pipe cutters, hydraulic shears, etc. For this purpose, temporary enclosures are set up around the components. These enclosures are equipped with mobile ventilation systems.

The cut pieces are transferred to a cutting room (annular gap). There, the pieces are cut further using a band saw or a similar device and packed into transport or storage containers. The containers with the cut pieces are lowered down to the ground level and brought out from the reactor building.

For the cutting operations, the following equipment is required:

— Various hand saws (sabre saws, etc.), disk grinders, hydraulic shears, rotary pipe cutters, rope saws;
— Enclosures for 19 large components (scaffoldings and sheet metal/foil);
— Mobile ventilation systems with filtration units for the enclosures;
— Local suction system (industrial vacuum cleaner with absolute filter);
— Cutting caisson (sheet metal construction) in the cutting room with a crane system, airlock for container loading, both for men and materials;
— Ventilation system for cutting caisson;
— Band saw with cutting table;
— Video technology for band saw;
— Packaging facility.

Execution of the work according to concept A results in the following costs:

• Planning services	€1.6 million
• Equipment	€3.0 million
• Assembly of equipment	€0.7 million
• Execution of the work	€7.0 million
• Clearing of the construction site	€0.3 million
• Additional costs for the longer operation of the MZFR (180 weeks)	€12.1 million
• Less non-incurred costs of the ‘real’ 6th decommissioning licence	€–2.9 million
Total	**€21.8 million**

Concept B
(semi-automatic remote-controlled cutting in the reactor building):

The large components are removed as whole pieces and lowered through the openings in the floors of three rooms. The segment protruding into room 301 is cut off by horizontal cutting. Further cutting and packaging of the cut off pieces takes place using analogy to concept A. For this purpose, a cutting device (band saw or rope saw) for horizontal cutting is installed in the cutting room below the three openings in the ceiling to the three rooms. In these openings, a clamping/holding unit is installed to secure and fix the large components during the cutting. Below the openings, a table is installed to take up the cut-off pieces. This table can be lowered. For lowering the components through the openings in the ceiling a crane is used to manipulate the pieces.

The following equipment is required:

— Crane system (min. 60 t);
— Clamping/holding unit for components;
— Horizontal band or rope saw;
— Table for cut-off pieces that can be lowered;
— Cutting caisson (sheet metal construction) in room 301, with crane system, airlock for loading compaction drums ;
— Ventilation system for the cutting caisson;
— Band saw with cutting table;
— Packaging facility.

Execution of the work according to concept B results in the following costs:

• Planning services	€2.2 million
• Equipment	€5.7 million
• Assembly of equipment	€2.5 million
• Execution of the work	€6.1 million
• Clearing of the construction site	€0.5 million
• Additional costs for the longer operation of the MZFR (145 weeks)	€12.2 million
• Less non-incurred costs of the 'real' 6th decommissioning licence	€–2.9 million
Total	**€26.2 million**

5.3. Estimation of the costs of the cutting options for the 7th decommissioning step on the MZFR site

For the on-site treatment of the rod shaped components in the 7th decommissioning step, only concept B can be applied, namely, the semi-automatic cutting in the reactor building. The rod shaped components are drawn into shielding casks. In the opening from room 401 to room 301, a horizontal cutting facility with a docking adapter for the shielding casks is installed. The rod shaped components are lowered in a stepwise manner from the 'docked on' shielding casks and cut into pieces by the cutting system. The pieces fall into compaction drums that are linked to the cutting system from below via a double lid lock. Full drums are closed automatically and transferred to a high pressure compaction unit via a transport system. The compacted pellets are lowered down to the ground level by means of a crane gripper and packed into repository storage containers (Mosaik casks).

The following equipment is required:

— A second shielding cask;
— Cutting system with docking adapter for shielding casks;
— Double lid lock for cutting system;
— System for transporting the compaction drums;
— High pressure compaction unit;
— Cutting caisson (sheet metal construction) in room 301, intervention access;
— Ventilation system for the cutting caisson;
— Video system for the cutting units;

— Additional equipment, control panel for the operation of the cutting systems;
— Crane gripper for the transport of the compacts;
— Station for closing the repository storage containers;
— Transport rack for repository storage containers.

For the MZFR project, the following costs would have to be considered in addition:

• Planning services	€1.2 million
• Equipment	€4.5 million
• Assembly of equipment	€0.8 million
• Execution of the work	€0.7 million
• Clearing of the construction site	€2.9 million
• Additional costs for the longer operation of the MZFR	€5.6 million
• Less non-incurred costs of the 'real' 7th decommissioning licence	€–2.4 million
Total	**€13.3 million**

5.4. Treatment of the components from decommissioning steps 6 and 7 at the Central Decontamination Department (HDB)

An alternative to the treatment of the components from decommissioning steps 6 and 7 on the MZFR site is treatment at an external conditioning facility. At the Forschungszentrum Karlsruhe, the Central Decontamination Department (HDB) is the competent department for such work. It is equipped with a number of facilities and, hence, offers a variety of treatment options.

After their removal from the MZFR, the components were packed in a contamination-safe manner and transported to the HDB. Here, the components were decontaminated and further dismantled in the existing facilities. Some parts of the material were released from regulatory control after measurement and transferred for re-use. The remainder was conditioned to packages suitable for repository storage. For the cutting of components, HDB is equipped with, among other things, band saws and rope saws, thermal cutting equipment, such as plasma cutting, and mechanical equipment, e.g. disk grinders. Depending on the type and level of contamination, decontamination was accomplished by abrasive methods, such as blasting with steel shots, or by chemical methods, e.g. 'pickling'. To condition the radioactive waste for repository storage, a high pressure compaction system for low level and medium level waste was used.

5.4.1. Conditioning of the steam generators and moderator coolers (as an example of treatment at HDB)

The MZFR was equipped with two steam generators. Each had a mass of 55 t, a length of 10 m, and a maximum width of 2.5 m. The steam generators were disassembled and transported successively to HDB for further treatment. To reduce the radiation exposure of the personnel during treatment and to minimize the contamination in the primary system, in particular, the tube bundle was decontaminated in advance using an acid circuit. By this method, a mean decontamination factor of 3 was achieved. For the dismantling proper, the steam generator was suspended in a shielding device. This device was divided into six segments that could be removed separately. In this way, maximum shielding was ensured during the treatment, as the shielding segment was removed only in the area in which the work was performed. Following the removal of the steam generator jacket, remote dismantling of the tube bundle in the primary system was started. The tubes were cut off largely automatically along the tube guiding plates. After the tubes and tube duct plates had been completely removed and packed into shielding boxes for further treatment, the remaining steam generator parts were dismantled thermally.

The tubes, tube guiding plates, and remaining steam generator internals were subjected to high pressure compaction for optimum volume reduction. The remainder of the steam generator was decontaminated and the material was transferred for melting under a licence granted according to the Atomic Energy Act or for unrestricted re-use. In total, above 40% of the delivered 110 t of steam generators could be reused, while 6% had to be melted. The remaining 54% of radioactive waste was converted into waste suitable for packaging in fifty-three 200 L drums by high pressure compaction.

In addition to the two steam generators, two moderator coolers each with a mass of 12.2 t were transferred from the MZFR to HDB (Fig. 1). The declared dose rate on the outer surfaces of the moderator coolers was 2.5 mSv/h. According to the treatment concept, it was planned to first thermally remove the moderator cooler jacket and then dismantle the water coolers and the plate bases. The free tube bundle was cut into seven segments of approximately 1 m in length using a band saw. Together with the flanges, these tube bundle segments were put into KONRAD-type IV concrete containers and backfilled with inactive concrete. The remaining parts of the moderator coolers (6.5 t/moderator cooler) were decontaminated and transferred for reuse following their release according to the Atomic Energy Act. As a result, more than half of the total mass of the moderator coolers was transferred for reuse.

FIG. 1. Transportation and treatment of the MZFR steam generators.

5.4.2. Treatment of rod shaped components from the 7th decommissioning step

Decommissioning of a power plant always gives rise to core internals that cannot be handled directly, but require a remote treatment. Dismantling of the MZFR resulted in a number of rod shaped components (121 spacer tubes, 120 fuel element racks, 17 control and absorber rods, and 18 guiding tubes) with a maximum dose rate of about 5 Sv/h and a total activity of 1×10^{13} Bq. These rod shaped components were transported in specially constructed shielding casks. The shielding cask was attached and locked with the intermediate level waste scrapping facility (MAW). With the help of manipulators, the rod shaped components were unloaded from the transport cask. The massive head parts of the zircaloy fuel element racks were sawn off and directly packed into 200 L drums that were then backfilled with inactive concrete. Volume reduction by compaction was not possible in this case. The remaining fuel element racks and other rod shaped components were cut into small pieces using hydraulic shears. These pieces were packed remotely into 170 L packaging drums and subjected to high pressure compaction at a force of 2000 tonnes. In total, treatment of the 276 rod shaped components gave rise to 82 drums (200 L) suited for KONRAD repository storage.

5.5. Costs of the treatment of the components from decommissioning step 6 and of the rod shaped components from decommissioning step 7 at HDB

Firstly, the components from decommissioning step 6 were cut, decontaminated, and further processed as described above. The associated activity and radiation dose rate did not require that the work was carried out remotely. Apart from the release measurements for re-use according to Article 29 of the German Radiation Protection Ordinance, the treatment covered all of the conditioning steps, including the packaging into repository storage containers.

For this work at HDB, the following costs were incurred:

• Cutting, decontamination, and backfilling	€10.8 million
• High pressure compaction	€3.5 million
• Release measurement	€0.2 million
• Treatment of liquid radioactive waste	€0.5 million
• Incineration of solid, organic waste	€0.9 million
Total	**€15.9 million**

Due to the high radiation dose rate, the conditioning of the rod shaped components from decommissioning step 7 had to take place almost exclusively in the remotely controlled area of the HDB, i.e. the MAW scrapping facility. The cutting and high pressure compaction of the rod shaped components and the processing of the packaging material resulted in costs of €7.7 million.

5.6. Summary of the comparison of costs, with the MZFR being used as an example

When comparing the costs incurred for the treatment and conditioning of the waste arising in the MZFR, it was found that the transfer of the components to an external conditioning facility was far less expensive than conducting the operation directly on site. In this way, €5.9 million (in case of concept A) or even €10.3 million (concept B) could be saved for the treatment of the components from decommissioning step 6. It must be taken into account that the costs of the HDB cover complete conditioning ready for repository storage as well as services, such as the treatment of liquid waste and the incineration of organic waste. Such items are not covered by the on site costs, as these services cannot be executed on the MZFR site. Hence, the comparable saving potential is increased by another €1.4 million.

For the treatment of the rod shaped components from decommissioning step 7, €5.6 million could be saved by transferring the components to HDB instead of processing them on site.

6. WASTE TREATMENT BASED ON THE EXAMPLE OF THE COMPACT SODIUM COOLED NUCLEAR REACTOR FACILITY (KNK)

The Compact Sodium cooled Nuclear Reactor Facility (KNK) was an experimental power plant of 20 MW electric power. From 1971 to 1974, the plant was first operated with a thermal core as KNK I. From 1977 to 1991, it was run with a fast core as fast breeder power plant KNK II. The plant was shut down in 23 August 1991. According to the decommissioning concept, it is planned to dismantle the plant completely (green field) in ten steps. The first eight steps have already been completed. In particular, the fuel elements and the sodium were disposed of, the facilities and systems no longer required have been shut down, and the cooling towers and machine hall have been demolished. The secondary and primary sodium cooling circuits have been completely disassembled. The rotary shield of the reactor was dismantled in 2002. The particular difficulty in the disassembly of KNK and, thus, in the treatment of the radioactive waste, resulted from the sodium which does not allow the application of wet or thermal cutting methods.

In the course of this project, it was also considered whether the treatment of the waste on site was reasonable and economically efficient or whether they had to be transferred to HDB. Due to the very limited space inside the plant, on site waste treatment would have required the construction of a separate building. This building would have needed to be equipped with a ventilation system that allows for the treatment of radioactive waste as well as with a waste water system, as the chemical conversion of sodium gives rise to a considerable amount of waste water. Moreover, all workplaces would have had to be designed for the treatment of sodium coated components. The radiation doses from the components would require the workplaces to be equipped with remotely controlled tools in order to minimize the radiation exposure of the personnel.

Due to these complex boundary conditions, the construction of suitable new buildings would be very expensive. The new building would have to be integrated with the existing facility, such that treatment of the waste on site would result in project delays that would adversely affect the total project costs. Considering this situation, it is clear that the treatment of the residues and waste on site would not be the cheaper option. Hence, it was decided to transfer the waste to HDB for further treatment without making any detailed cost comparison.

6.1. Treatment of the sodium discharge tank

The problem in the treatment of the KNK sodium discharge tank was not associated with its dimensions (length 9 m, diameter 2.2 m), but with the 150 kg (approx.) of metal sodium that were still contained in the tank (volume 32 m^3) (Fig. 2). In addition, traces of sodium oxide and sodium hydroxide were present in the tank. Due to the operation of the reactor, the sodium is radioactively contaminated, mainly with Cs-137, Co-60, and Na-22. Consequently, all the

FIG. 2. Sodium discharge tank during spray moistening for sodium conversion with continuous monitoring of the hydrogen concentration.

sodium had to be removed from the tank before the latter could be disassembled. The sodium was removed by a controlled chemical conversion of sodium with water into sodium hydroxide solution and hydrogen gas. To facilitate the removal of the sodium hydroxide solution from the tank, a nozzle was installed at the lowest point of the tank. To prevent the formation of an explosive mixture or a sodium fire, an inert atmosphere was created by rinsing with nitrogen. The hydrogen was discharged in a controlled manner. For the controlled conversion of sodium with water, the tank was subjected to video inspection. Then, several injection nozzles were installed such that a fine water vapour mist could be sprayed on to the whole inner surface of the tank. During the spraying, the hydrogen concentration in the tank was measured continuously. In the course of the conversion, the mean hydrogen concentration was limited to 1 vol.%. If this value was exceeded, spray moistening had to be stopped until the hydrogen concentration dropped below the maximum limit set. After the complete 150 kg of sodium had been converted into sodium hydroxide solution, the radiation dose rate due to the tank decreased, such that further treatment was possible without any problems. The tank was then cut thermally into pieces that could be handled and subjected to decontamination and free release for unconditional recycling.

6.2. Treatment of the rotary shield of the reactor

Prior to the transportation of the rotary shield from KNK to HDB, adherent sodium had to be completely removed to avoid any treatment

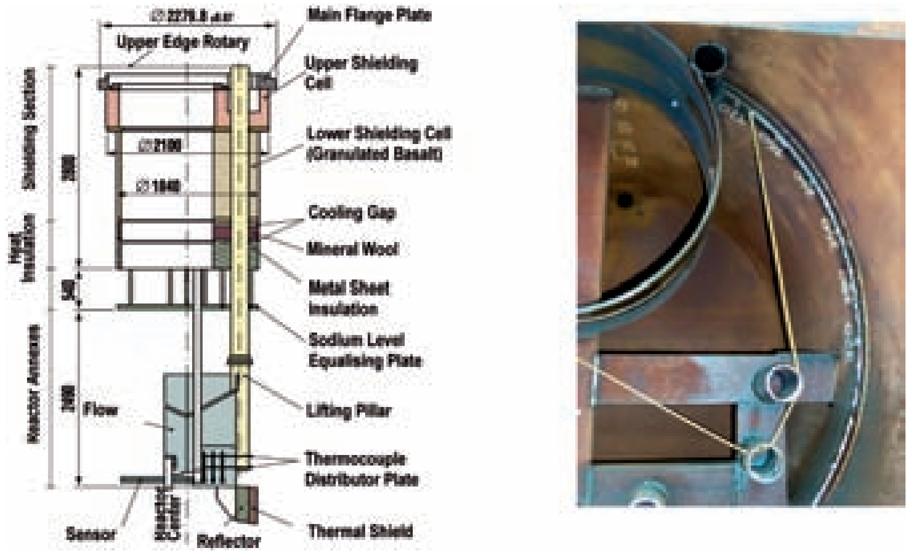

FIG. 3. Schematic view of KNK reactor rotary lid and 'mock up' for dry cutting test with a diamond wire rope.

problems (Fig. 3). The rotary shield of length 6 m, diameter of 2.3 m, and mass 25 t, consisted of several chambers that were filled with various materials to ensure optimum shielding and isolation. Among these materials were super heavy concrete, basalt granules, and rock wool. Since radiation dose rates near the rotary shield reached up to 22 mSv/h, work had to be performed in a shielded area by a minimum number of workers. It was therefore decided to cut the rotary shield into pieces that could be handled and to separate the different sorts of materials (high and low activated) using a rope saw. The problem when dismantling the rotary shield with a rope saw was that the rotary shield contained tubular internals. Consequently, the rope saw had to be designed such that the rope would not tear when cutting through different materials (Fig. 4).

7. WASTE TREATMENT CONSIDERATIONS FOR THE KARLSRUHE REPROCESSING PLANT (WAK)

The Karlsruhe Reprocessing Plant was a pilot plant which was operated from 1971 to late 1990. During this period, about 208 t of nuclear fuel from experimental reactors and nuclear power plants were reprocessed (Fig. 5). In 1991, the dismantling of the reprocessing plant started. The decommissioning

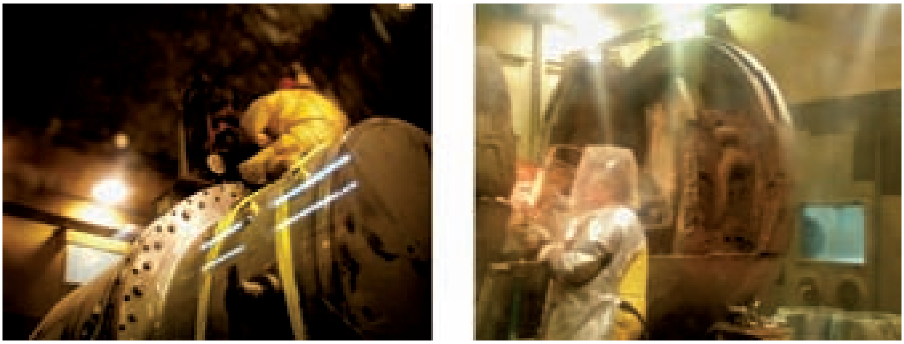

FIG. 4. *Installation of the diamond rope saw in the working caisson and thermal cutting of the low activated part of the KNK reactor rotary lid.*

FIG. 5. *Treatment of the alpha contaminated blocks of WAK with a remote controlled excavator equipped with an adaptor for a pneumatic hammer.*

project deals with a very complex facility, and decommissioning work is complicated by the high levels of alpha contamination and the high radiation dose rates in some parts. Therefore, part of the work had to be carried out remotely. These conditions also apply for the workplaces used for waste treatment; the workplaces have to be designed for the handling of highly alpha contaminated waste. The airlock and ventilation systems have to be adapted accordingly. As a result, no standard components can be employed for the setting up of waste treatment facilities on site. Instead, all facilities have to meet these special requirements. Consequently, high investment costs have been incurred to establish high performance workplaces for waste treatment. In addition, it has been necessary to adapt tools to the requirements or to develop special constructions.

An example of the complex work to be performed is the procedure adopted for the processing of two highly contaminated, high radiation dose rate, concrete blocks, which resulted from the decommissioning of the hot cells. In the course of WAK decommissioning, the walls of the already emptied cells were cut into blocks using a rope saw. The cutting, however, met with the problem that the walls contain a number of ducts and pipelines. These ducts and pipelines served for the transport of supply media and liquid high active waste to the individual cells. The ducts in the wall are inclined slightly and equipped with radiation traps. Prior to the cutting of the walls, the ducts were rinsed, such that no liquids were left inside.

The ducts run from the outer side to the inner side of the cells. Prior to disassembly, they were cut off and closed on the outer side of the cell. On the inner side of the cell, the ducts were closed by squeezing only. On both sides, the ducts protrude from the concrete by about 10 cm. On the inner side, the concrete is coated with epoxy resin.

The concrete blocks resulting from cutting the walls were put into containers and transported to HDB for further treatment. There, the blocks were subjected to another cutting process to ensure that the packaging in KONRAD containers was optimized and that the disposal limits were not exceeded. The containers were then backfilled with loose building rubble. Due to the high alpha contamination level of the blocks, it was impossible to release the material for further reuse or recycling.

Two of the blocks delivered to HDB were highly alpha contaminated, such that they could not be put directly into KONRAD containers due to their high radiation dose rate and activity inventory. For this reason, the highly contaminated block surface had to be subjected to remote decontamination. After unloading the blocks from the transport shielding box, they were placed into a camera controlled shielded processing caisson. There, contamination was removed by means of a loosening chisel fixed to a remotely controlled chisel excavator. The small chips and dust produced were sucked off and collected directly in packaging drums. Subsequently, these drums were subjected to high pressure compaction. After about 10 cm of the surface had been removed, the blocks were packaged directly into KONRAD containers, as planned, and conditioned for KONRAD repository storage.

It is obvious that both the decommissioning of WAK and the treatment of the associated waste are very complex and special operations, such that it is not worth constructing a waste treatment facility on the WAK site. The investment costs would be much too high due to the boundary conditions that would have to be met. The most efficient solution is to package all waste for transport and to transfer it to HDB for further treatment. There, suitable workplaces and tools are available for the low cost treatment of alpha containing, high dose rate waste.

8. CONCLUSIONS

Decommissioning of nuclear facilities gives rise to a variety of radioactive waste types that have to be properly managed. Treatment may be carried out either directly on the site of the decommissioning project or the components may be transferred to an external treatment facility. When treating the dismantled components on site, the necessary structures, equipment, and technical approaches which need to be established result in high investment costs. Moreover, the situation in the building being decommissioned may result in a delay of the decommissioning project, as dismantling cannot be carried out parallel to waste treatment due to lack of space. Transfer of the waste to a central external conditioning facility results in significant cost savings and shortens the project duration, which, in turn, reduces total costs.

DISCUSSION

A.J. GONZÁLEZ (Argentina): I am interested in the MZFR (multipurpose research reactor) because it has characteristics very similar to those of one of Argentina's reactors, and I would welcome your comments on two issues.

First, the tritium inventory of the MZFR was very high. Did you have any problems due to the movement of tritium?

Second, the cobalt levels at MZFR were quite high. How did you deal with the cobalt problem?

L. VALENCIA (Germany): Generally speaking, it is a question of the strategy chosen. We have chosen a green field strategy, so we have to deal with the waste if we want to remove the entire facility with all buildings.

Of course the problem of tritium exists, but the tritium is fixed in the corrosion layer of the metals. We have had to use full suits in the caissons to protect the workers. The air in the caissons is processed by a normal ventilation system connected to the main ventilation system. So that is not a big problem.

Tritium contamination of the concrete is a more serious problem. We shall face that in the future. We plan to heat up the concrete in order to remove the tritium that has penetrated into it — in order to recycle or reuse some of it later.

IAEA APPROACH FOR RELEASING RADIOACTIVE MATERIAL AND SITES FROM REGULATORY CONTROL

B. BATANDJIEVA
Division of Radiation, Transport and Waste Safety,
International Atomic Energy Agency,
Vienna
Email: B.Batandjieva@iaea.org

Abstract

The clearance of material and the release of sites are integral parts of the adequate planning for the successful implementation of decommissioning. Countries have been applying different criteria for clearance and for the release of sites and different strategies for monitoring for compliance with the criteria. During the last few years, international consensus has been achieved on the values for the exemption and clearance of bulk material and on the criteria for the release of sites (land with the associated building and structures) from regulatory control. Work is under way by the IAEA on the development of practical recommendations on monitoring for compliance with clearance and site release criteria.

1. INTRODUCTION

The decommissioning of facilities using radioactive material and, in particular large facilities such as nuclear power plants and fuel cycle facilities, generates large amounts of material with very low concentrations of radioactive contaminants. Such material does not warrant safety consideration or require management as radioactive waste [1–4]. Decisions on the release of such material from regulatory control, based on established criteria and an approved system of monitoring for compliance with these criteria are therefore of particular importance for the optimization of material management and the successful completion of decommissioning. Experience from a number of countries shows that up to 80% of the material arising from decommissioning can be considered for clearance and subsequent disposal or reuse for other purposes.

Recent examples in Europe provide a clear illustration. Of the 96 000 t of material generated during the first phase of the decommissioning of the Vandellos 1 nuclear power plant (NPP) in Spain aimed at placing the reactor in a safe storage mode, 77 000 t of conventional (non-contaminated) material were recycled/reused on site, 15 000 t were recycled, 2000 t were disposed of in conventional disposal facilities, 1800 t were disposed of as low and intermediate level waste and 200 t were recycled in the nuclear industry [5]. As a result of decommissioning activities at the Greifswald NPP in Germany associated with five WWER units, during the period 1996–2004, approximately 41 000 t of material was generated, of which 65% was cleared solid material for unrestricted release; 11% for restricted release (metal for melting and concrete and debris); 23% for waste disposal and less than 1 % was radioactive material for decay and interim storage [6]. Decommissioning of the TRIGA-1 and TRIGA-2 research reactors in Heidelberg, Germany, generated 538 t of waste of which 506 t were cleared from regulatory control, 9 t were sent for processing and decontamination and 23 t were designated for disposal as radioactive waste [7].

These large volumes of a range of materials, e.g., concrete, timber metals, raise significant interest and also provoke discussions between interested parties on the acceptability of the application of clearance, in particular for scrap metal after clearance from nuclear sites. In 2001, the worldwide consumption of scrap metal was of the order of 370×10^6 t [8] and in 2003 it was of the order of 400×10^6 t [9]. For 2006, the scrap consumption in Europe was estimated to have risen 5% to 53×10^6 t [10].

International consensus on the establishment of reference levels for the exemption and clearance of bulk material (above 1 t) was achieved in 2004 after more than ten years of discussions among the Member States of the IAEA. The outcome was presented in the Safety Guide No. RS-G-1.7, Application of the Concepts of Exclusion, Exemption and Clearance, published in 2004 [3]. However, discussion on this issue has continued within various international and national forums, such at the Second Review Meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) held in 2006 [11]; the Fourth Symposium on Clearance of Material from Regulatory Control, held in Hamburg, Germany in March 2006 [12], meetings of working groups of the OECD Nuclear Energy Agency [13–15], the new draft International Commission on Radiological Protection (ICRP) [16], and the Group of Experts on Monitoring of Radioactively Contaminated Scrap Metal, held under the auspices of UN Economic Commission for Europe [8, 9, 17].

In addition to clearance of material, the progress and successful completion of a number of decommissioning projects has also increased attention on the release of sites for unrestricted or restricted use following the decommissioning of the facilities on the sites. Of particular importance, are the criteria for site release, including the approach to their derivation, and the selection and implementation of an adequate strategy for demonstrating compliance with these criteria.

International experience with the clearance of material from sites and the release of sites from regulatory control has provided the basis for achieving international consensus on these issues. Both issues are fundamental for the successful decommissioning of facilities, optimization of material management strategies and for the ultimate task of releasing sites from regulatory control, and deciding on their future use, e.g. development of new nuclear or industrial facilities at these sites.

2. RELEASE OF MATERIAL FROM REGULATORY CONTROL

2.1. Reference values for exemption and clearance

After a careful process of development, international consensus was reached on the application of the concepts of exemption, exclusion and clearance of bulk material from regulatory control, including reference levels for the exclusion, exemption and clearance of bulk amounts. This was presented in the recently published IAEA Safety Guide RS-G-1.7 [3]. The challenges in reaching a common position arose largely as a result of the different radiological criteria related to the matter (10–300 μSv/a) [18–22] and the approaches used by countries for the computation of derived values (scenarios, assumptions, etc.) which led to variation in the values for activity concentrations for specific radionuclides. Another important aspect is the fact that not all countries apply the clearance concept for material in their legislation and in practice.

At the present time, it is possible to state that there is international consensus on activity concentration values for exclusion, exemption and clearance of material containing naturally occurring and artificial radionuclides for bulk material that is generated in amounts greater than 1 tonne in a year [3] and for amounts less than 1 t in a year [1]. The Safety Guide RS-G-1.7 [3] presents internationally agreed reference values for activity concentration and is complemented by IAEA Safety Reports Series No. 44 [23], which outlines the approach adopted for the derivation of these values.

Lessons learned

— The discussions on the clearance of material from regulatory control have continued at an international level in various forums such as the Second Review Meeting of the Joint Convention, the Fourth Symposium on

Clearance in Hamburg in 2006, and the UNECE group of experts. These discussions have shown that there is general agreement on the reference values recommended in IAEA Safety Guide RS-G-1.7, but that there are not yet harmonized approaches to their use and application in national legislation and in practice and this remains desirable;

— At a national level, there is an increased recognition of the need for the establishment of formalized approaches to monitoring for compliance with these values. This is of high importance with respect to establishing effective and optimized control of radioactive material generated during decommissioning. The IAEA is finalizing a safety report on this subject in which specific practical guidance is provided for operators, regulators and other experts involved in the clearance of material [24]. It is expected that this guidance will help in the eventual harmonization of monitoring strategies for compliance at the national and international levels and that it will increase the confidence of future users of cleared material and facilitate the transboundary movement of material.

— A current challenge is the harmonization of monitoring strategies for compliance and verifying the reliability of results internationally. Work in this direction will increase the confidence of future users of cleared material and will facilitate the transboundary movement of material;

— Even when there is harmonization of the approaches to the implementation of the reference values in national legislations, the involvement and interaction with end users of the cleared material still requires specific attention. The metal recycling and steel industries in some countries are not in favour of using any material from the nuclear industry and require material ‘free from radioactivity’. Therefore communication with end users and the definition of routes for cleared material arising from the decommissioning activities is of great importance for the successful completion of decommissioning and the minimization of the radioactive waste to be sent for processing, storage or disposal.

— During the past few years, as a result of the complexity of issues to be resolved in the clearance of material from regulatory control, a tendency has been observed in some countries (e.g. France, Lithuania, Spain, Slovakia) to plan and develop disposal facilities dedicated to very low level radioactive waste as an alternative to clearing material [25].

— It is also recognized internationally that there is a need to develop international consensus on surface contamination values for the clearance of bulk material. In cases where there is both surface and volumetric contamination, clearance levels for both types of contamination are needed. The IAEA is planning work in this area. These surface and volumetric contamination values will need to be reviewed in relation to the values established in the transport regulations [26].

— Some countries have already established clearance values for fixed and removable surface contamination and work is required to relate such values to the activity concentration values established in RS-G-1.7 [3]. Some countries have been working on defining conversion values, but without reaching a consensus. There is a need for generic or facility specific values to be derived for a set of adequate and justified scenarios, similar to the approach used for the clearance values in RS-G-1.7 [3].

2.2. Approach for monitoring for compliance with reference values

Based on these identified needs (also reflected in the International Action Plan on Decommissioning of Nuclear Facilities of 2004), the IAEA has been working on a review of international experience to identify good practice on the development and implementation of monitoring strategies for the clearance of material from regulatory control, with a view to providing practical recommendations for operators and regulators.

Lessons learned

— Monitoring approaches for the clearance of material are being developed on a case by case basis for specific decommissioning projects within the context of national regulatory frameworks. The regulatory approaches for controlling monitoring procedures and their practical implementation also vary from country to country. However, there are basic steps common to all approaches: (i) development of a monitoring strategy and (ii) implementation of this strategy leading to decisions on compliance with clearance criteria. The main steps of the monitoring process are presented in the draft IAEA safety report that aims to facilitate the harmonization of the monitoring strategies in different countries [24].

— There is a strong demand for the international harmonization of monitoring strategies in order to facilitate the transboundary movement of material cleared from regulatory control (e.g. scrap metal). This can be achieved through bilateral discussions, consultations and agreements between regulatory bodies and other competent authorities. Such arrangements can also be supported through international guidance, e.g. work is planned by the IAEA on the development of guidance for the monitoring of potentially contaminated scrap metal that will address the monitoring approaches and responsibilities through the whole chain of scrap metal management.

— Work to date on the development of recommendations for monitoring has identified that one of the difficult areas is the application of a graded approach to monitoring for clearance. It seems clear that a graded approach to the level of monitoring effort expended can be more usefully applied during the previous stages of management of the material (e.g. the sorting of the material) and less so at the stage of final survey of the material. Nevertheless, the graded approach can also be illustrated at the time of the final survey, through the selection of key radionuclides to be monitored instead of monitoring of all the radionuclides identified in the material.
— There is a need for harmonization in respect of monitoring for surface contamination in relation to both non-fixed and fixed types of contamination. (some countries establish levels for both; others recommend that any loose contamination should be removed and criteria should be applied only for fixed contamination).

3. RELEASE OF SITES FROM REGULATORY CONTROL

The release of sites from regulatory control is one of the main objectives of the decommissioning process and one of the key questions in the decommissioning planning process is 'What is the ultimate goal of decommissioning — the release of a site for unrestricted use with or without remaining buildings; or the release of a site for restricted use with or without some or all buildings?'

3.1. Approach to site release

Based on international experience in the field of site release, a new safety standard was published in 2006 entitled 'Release of Sites on Termination of Practices' [28]. The standard provides recommendations and guidance on the establishment of criteria for site release, cleanup; the release of sites for unrestricted and restricted use, and the introduction of a new practice on a released site.

Lessons learned

On the basis of this standard the following lessons can be drawn:

— At present there is international consensus on the radiological criteria for release of sites for unrestricted and restricted use, recognizing also the importance of considering the non-radiological hazards that may exist on

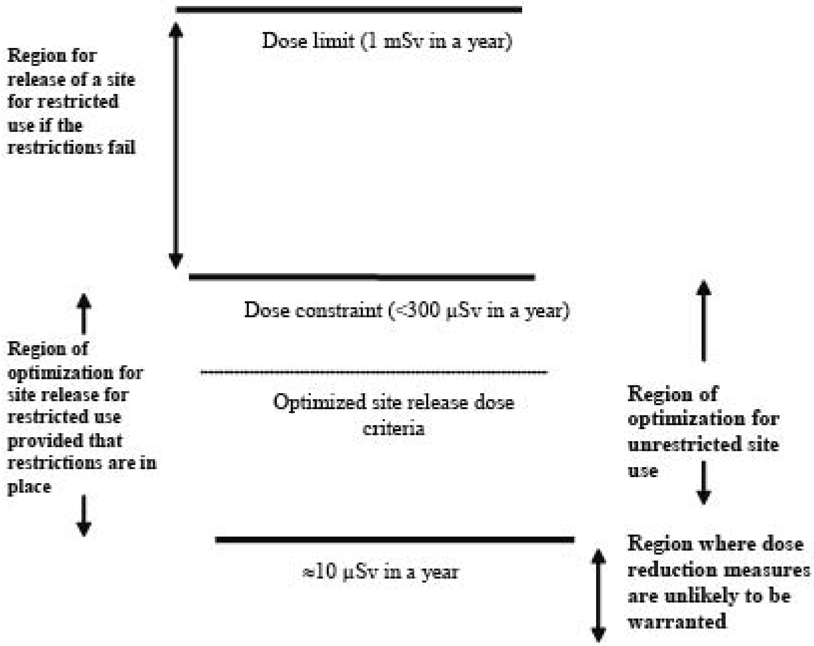

FIG. 1. Constrained optimization and regions of effective dose for members of the critical group in the release of sites [27].

the sites. For the unrestricted use of a site, it should be ensured, through the process of optimizing protection, that the effective dose to a member of a critical group is kept below the dose constraint of 300 μSv in a year. For the restricted use of a site it should be ensured that, with restrictions in place, the effective dose should not exceed the dose constraint of 300 μSv in a year and that if the restrictions were to fail in the future, the effective dose should not exceed 1 mSv in a year. The application of such a dose limitation system to the unrestricted and restricted use of a site is shown in Fig. 1.

— There is international agreement on the radiological criteria for the introduction of a new practice on a released site, where a practice or practices have previously been present. In setting a dose constraint and release levels for any new practice, “the regulatory body should ensure that the exposure of any critical group, from all sources would not exceed 1 mSv in a year above the original background. The maximum value of the annual dose constraint for practices to be introduced on to sites previously released from regulatory control should be of the order of 0.1 mSv in a year but not more than 0.3 mSv in a year” [27] (see Fig. 1).

— Two main approaches for the establishment of site release criteria can be adopted: either the regulatory body may develop generic release criteria for use by the operator; or the operator can derive site specific release criteria, on the basis of the optimization process, which the regulatory body should then approve. The former approach enables the operator to demonstrate compliance with the generic release criteria without deriving specific criteria for the site. However, this approach is likely to result in conservative release criteria because of the need to make generic assumptions in the dose assessment.
— The importance of decisions on compliance and formal authorization by the regulatory body of site release is an important step. If the radiological criteria for site release have been accomplished to the satisfaction of the regulatory body, the regulatory body should formally notify the operator, other relevant competent authorities and interested parties of the decision to release the site from regulatory control. In case of a decision for restricted use, the notification should specify the restrictive measures and their associated time frames, and the entities responsible for the implementation, monitoring and regulatory control of these restrictions.
— Involvement of, and providing information to, interested parties is recognized as a good practice in the site release process, as it can contribute to the adequate selection of scenarios for the possible future use of the site after release and the controls (e.g. administrative or technical) that will have to be implemented for the restricted use of the site.
— Experience shows that specific consideration is needed of the uncertainties associated with the (i) knowledge of the site (level of contamination in soil, underground structures and buried material), and (ii) potential use of the site. This highlights the importance of good record keeping of operational data and knowledge management about the history of the site.
— When a decision is taken for the release of a site for unrestricted use with buildings remaining on the site, consideration should be given to the potential use of material arising from any future modification of the buildings, including demolition after release of the site. The exposure of members of the public from the material from the buildings should not exceed the clearance levels based on the criteria of the order of 10 μSv in a year. It is important that attention is paid to the application of the clearance values (derived on the basis of the 10 μSv in a year) if material is removed from land and buildings from released sites (for which an optimized release level is less than 300 μSv in a year).

— The importance of reference background levels must be recognized. Before commissioning a new facility, therefore, the operator should ensure that a baseline survey of the site, including information on radiological conditions, is performed to define the levels of background radiation for the facility site. These levels will be further used at the end of the practice as a basis for comparison with the levels used to release a site. For existing facilities for which no such baseline survey was done in the past to determine these background levels, data from analogous, undisturbed areas with similar characteristics should be used for this purpose. These analogous areas should be areas that have similar physical, chemical, radiological and biological characteristics to those of the site considered for release but they should not have been contaminated with radioactive material as a result of activities at the site. Such areas are not limited to natural areas undisturbed by human activities. Lessons to be learned for build up of new facilities;
— Bankruptcy and lack of funding during the cleanup process is also an important aspect to be considered. There is general consensus that these aspects need to be addressed in the national legislation and if no funds or insufficient funds are available for completion of the cleanup of the site for unrestricted use, the regulatory body should approve the measures for restricted use and should define procedures and responsibilities for the cleanup of the site, the maintenance of restrictions, the suspension of the authorization and the release of the site. In order to avoid such situations the maintenance of a backup fund is a good practice.
— As there may be more that one site in a country that is released from regulatory control for future use either under or without restrictions, it is important that there is a designated organization in the country responsible for maintaining adequate records of the sites for restricted use. Such an organization should develop and maintain an archive system to ensure the preservation of the records for at least the period of time of restricted use, unless otherwise required by the regulatory body.

3.2. Monitoring for compliance with site release criteria

— A large number of countries have not established criteria for the release of sites or are in a process of establishing regulatory approaches for the release of parts or complete sites from regulatory control. The new IAEA Safety Guide [27] aims to assist these countries in establishing the national approaches and criteria for the final stage of decommissioning.
— Once the criteria for site release are established the next challenge is to define an adequate approach to monitoring for compliance with the

criteria. The IAEA is working on practical guidance on compliance monitoring for the release of sites, which is envisaged to be published in 2007 [28].
— The cleanup of sites as part of the decommissioning process for further use as licensed sites becomes increasingly important if plans are being made to build new facilities on existing sites. In several countries this appears to be an option preferred option over the release of sites, particularly for sites containing nuclear power stations.
— For sites where no future nuclear industry development is envisaged and no disposal facilities exist, a tendency has been observed for the partial release of the site. This is done with a view to reducing the area of the site given to waste management activities or in some cases to spent fuel and waste storage activities awaiting the development of disposal options. This may also enable the size of the regulated site to be reduced.

4. SUMMARY AND CONCLUSIONS

The clearance of material and the release of sites from regulatory control require the establishment of clearance values and site release criteria and the development and implementation of appropriate monitoring strategies for compliance with these values. International consensus has been achieved on reference levels for the clearance of material and on radiological criteria for the release of sites. However, harmonized approaches for demonstrating compliance with these criteria still need to be developed.

Recognition of the importance of having a harmonized approach for the application of the international clearance values for bulk material and the approaches for monitoring for compliance with these values is increasing, in particular in the planning and undertaking decommissioning projects. Difficulties associated with the clearance of materials have led some countries to develop facilities dedicated to the disposal of very low level waste or storage of large amounts of waste on sites.

Achieving harmonized approaches for demonstrating compliance with the reference values of RS-G-1.7 is necessary in order to give confidence to users of cleared materials to be confident in their safety and to facilitate the transboundary movement of material.

Prior to commencing the decommissioning process, it is very important to identify and communicate with interested parties on the potential use of the cleared material and sites after release, and to build confidence in, potential users of cleared material and other interested parties, as these are essential factors for the successful performance and completion of decommissioning projects. The scrap metal recycling industry has been one of the industries that has identified a strong need for cooperation between all interested parties at a national and international level.

The IAEA is working on the development of practical guidance on the development and implementation of strategies for the clearance of material and the release of sites from regulatory control that aims to assist those concerned in the decommissioning of different types of facilities and in the successful termination of practices.

REFERENCES

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Facilities Using Radioactive Material, IAEA Safety Series No. WS-R-5, IAEA, Vienna (2006).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exemption, Exclusion and Clearance, Safety Series No. RS-G-1.7, IAEA, Vienna (2004).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, Draft Safety Series IAEA, Vienna (in preparation).

[5] RODRIGUEZ M., “The dismantling of the Vandellos I Nuclear Power Plant”, World Nuclear Association Annual Symp. 8–10 September 2004, London, World Nuclear Association (2004).

[6] BAECKER, A., Personal communication to B. Batandjieva (2006).

[7] JÜNGER-GRÄF B., “Waste management and decommissioning of the TRIGA Heidelberg research reactors”, German Cancer Research Center (DKFZ), Heidelberg, 3rd Joint DeSa meeting, 13–17 November 2006, IAEA, Vienna.

[8] UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE, Monitoring, Interception And Managing Radioactively Contaminated Scrap Metal, Proc. UNECE Group of Experts on the Monitoring of Radioactively Contaminated Scrap Metal, 5-7 April 2004, Geneva 2004.

[9] UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE, Recommendations on Monitoring and Response Procedures for Radioactive Scrap Metal, Report of an International Group of Experts, UN, Geneva (2006).

[10] BUREAU OF INTERNATIONAL RECYCLING, http://www.bir.org/welcome/welcome.asp.

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Summary Report, Second Review Meeting of the Contracting Parties, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 15–24 May 2006, IAEA, Vienna.

[12] Release of Radioactive Material from Regulatory Control, Harmonization of Clearance Levels and Release Procedures, Proc. 4th Int. Symp., 20–22 March 2006, Hamburg, Germany.

[13] OECD/NUCLEAR ENERGY AGENCY, Releasing the Sites of Nuclear Installations, A Status Report, OECD, Paris (2006).

[14] OECD/NUCLEAR ENERGY AGENCY Comprehensive Report of The Task Group on Activity Measurements at Release Levels, Rep. NEA/RWM/CPD(2006), OECD, Paris (2006).

[15] OECD/NUCLEAR ENERGY AGENCY, The Process of Regulatory Authorization, OECD, Paris (2006).

[16] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Draft Recommendations of the International Commission on Radiological Protection, 02/276/06 (5 June 2006).

[17] UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE, EUROPEAN COMMISSION, INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Radiation Protection Aspects in The Recycling of Metal Scrap, Recommendations to avoid introduction of radiation contaminated material into the recycling stream, UN, Geneva (2002).

[18] EUROPEAN COMMISSION, Radiation Protection, Evaluation of the application of the concepts of exemption and clearance for practices according to title III of Council Directive 96/29/Euratom of 13 May 1996 in EU Member States, (2003).

[19] EUROPEAN COMMISSION, Radiation Protection 112, Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials, (1999).

[20] EUROPEAN COMMISSION, Radiation Protection 113, Recommended radiological protection criteria for the clearance of buildings and building rubble from the dismantling of nuclear installations, Recommendations of the group of experts set up under the terms of Article 31 of the Euratom Treaty, (2000).

[21] EUROPEAN COMMISSION, Radiation Protection 114, Definition of Clearance Levels for the Release of Radioactively Contaminated Buildings and Building Rubble, (1999).

[22] EUROPEAN COMMISSION, Radiation Protection 122, Practical Use of the Concepts of Clearance and Exemption, Guidance on General Clearance Levels for Practices, Recommendations of the Group of Experts established under the terms of Article 31of the Euratom Treaty, (2000).

[23] INTERNATIONAL ATOMIC ENERGY AGENCY, Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, Safety Reports Series No. 44, IAEA, Vienna, (2005).

[24] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Exemption and Clearance Values, IAEA, Vienna (in preparation).

[25] Disposal of Low Activity Radioactive Waste, (Proc. Int. Symp. Córdoba, December 2004), IAEA, Vienna (2005).
[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1996 Edition (as Amended 2003) IAEA Safety Standards Series No. TS-R-1, IAEA, Vienna (2004).
[27] INTERNATIONAL ATOMIC ENERGY AGENCY, Release of Sites from Regulatory Control on Termination of Practices, Safety Series No. WS-G-5.1, IAEA, Vienna (2004).
[28] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Remediation Criteria, IAEA, Vienna (in preparation).

PANEL DISCUSSION

Session 5

WASTE MANAGEMENT ISSUES

Chairperson: **Z. PAN** (China)

Members: **H. HILDEN** (European Commission)
J.S. CARLSSON (Sweden)
P. WOOLLAM (United Kingdom)
A.J. GONZÁLEZ (Argentina)
A. VISAGIE (South Africa)

Z. PAN (China — Chairperson): I invite the panellists to respond to the question 'What are the challenges in the harmonized implementation of the internationally agreed reference exemption and clearance levels?'

A.J. GONZÁLEZ (Argentina — panellist): Let me start by talking briefly about the word 'clearance' in that question. That word was proposed by the 'Anglo-Saxon community' during the drafting of the International Basic Safety Standards to embrace the concept of clearance as being exemption from regulatory control for a source or practice already within the system of control and complementary to the exemption of a source or practice from the regulatory system which would otherwise enter the system. I greatly regret that I went along with the proposal, as 'clearance' - which was translated into French as 'liberation' and into Spanish as 'dispensación' — seems to be able to mean almost anything one wishes.

At this conference, it has been stated that there is a consensus on the criteria for exemption and clearance. That statement is true — there has been a consensus on the criteria since 1989, in a standard co-sponsored by the OECD/NEA and the IAEA (IAEA Safety Series No. 89, Principles for the Exemption of Radiation Sources and Practices from Regulatory Control).

What we have now is a consensus on levels, not on the criteria, and that consensus has a very high legal standing. When a country becomes a party to the Joint Convention, it accepts legal obligations that prevail over its national laws, and I assume that when a country decides to become a party it knows what it is doing.

Clearance levels have been defined in IAEA Safety Standards Series No. RS-G-1.7 (Application of the Concepts of Exclusion, Exemption and Clearance), which was developed in response to a request made by the IAEA's

General Conference. That document has the blessing of the Board of Governors and the General Conference of the IAEA, and I am therefore surprised that the clearance levels are being attacked by some European countries. I can understand that countries may come to the conclusion that they were wrong in going along with the approval of the clearance levels. If they want the clearance levels to be changed, however, they must initiate a sophisticated process similar to the one that led to their approval — perhaps starting with the submission of a draft resolution to the IAEA's General Conference. In other words, there is no problem with the clearance levels internationally — there are just politically motivated difficulties created by a few countries.

As to the technical difficulties of monitoring compliance with the clearance levels, the countries concerned about them could together resolve them, but I see only a few of those countries showing an interest in taking action.

In summary, therefore, the only challenge we have is to respect commitments entered into freely and to persuade others to do the same.

From the technical point of view, the problem we face with clearance is that, if we really want an expansion of the nuclear industry (and if those politicians who say that they want an expansion are telling the truth), we cannot simply just throw material away — there must be recycling. However, very few papers on recycling have been submitted in connection with this conference. If the recycling option is adopted, the issue of characterization will become more complex because, with recycling, there will be a build-up of radionuclides with half-lives of the order of the recycling period (say about 30 years). However, that is the only technical problem we shall have, but at this conference I sense a mood of pessimism, with people focusing on the shutdown of facilities rather than on recycling in the interests of an expanding nuclear industry.

P. WOOLLAM (United Kingdom — panellist): The increasing number of nuclear facilities being decommissioned has led to recognition of the need for well established and internationally accepted policies for controlling the release of materials from decommissioned facilities for subsequent reuse, recycling or disposal. To that extent I agree with Mr. González. The exemption principles are well established — the practice must be justified and inherently safe and the doses in plausible exposure scenarios must be trivial. However, there is no worldwide consensus regarding the application of those principles.

In the United Kingdom, the exemption level — set several decades ago — is 0.4 Bq/g and isotope independent. It is causing us some difficulties in connection with the decommissioning of reactors, because of the high levels of low-radiotoxic isotopes in the concrete in particular.

After Euratom Council Directive 96/29 was issued, the United Kingdom Government of that time consulted widely (with the nuclear industry, green groups, anti-nuclear groups and other stakeholders) on whether to implement that directive, and the Environment Minister decided against incorporating the directive, and the exemption system provided for by it, into United Kingdom law. He took that decision partly in the light of briefings by anti-nuclear groups which claimed that exemption was effectively a 'dilute and disperse' solution. As a result, the aforementioned isotope independent exemption limit remains in the United Kingdom.

As regards the question put to the panel, the nuclear industry in the United Kingdom is continuing to engage with government departments in promoting the concept of isotope dependent exemption limits, and I believe that ultimately it will be successful. However, success will come only through careful stakeholder engagement by the nuclear industry leading the Government to an understanding of the safety issues. It will not come as a result of demands by the nuclear industry that the Government accept some international directive from the European Commission, the IAEA or whoever. There is a need to build stakeholder confidence. That applies to other countries as well, and I think it was the basic message in Ms. Batandjieva's presentation.

In this connection, I would mention that the United Kingdom's nuclear regulator — the Nuclear Installations Inspectorate — recently issued guidance on releasing sites from site licences, and the criterion for that has been set at a risk level of 10^{-6}/a, which is of course roughly equivalent to 10 μSv/a and at effectively the same level as in the International Basic Safety Standards. I would point out that it is not just 10^{-6}/a but also the application of ALARP (as low as reasonably practicable). I am pleased that the Nuclear Installations Inspectorate is promoting the idea of 10 μSv/a, and I believe that through careful stakeholder engagement we shall arrive at something much more realistic in term of isotope dependent clearance limits.

J.S. CARLSSON (Sweden — panellist): In Sweden, there are four reactors that have been shut down and are to be decommissioned — the two Barsebäck reactors, an older power reactor and a research reactor. We have some release limits, but they apply only to the release of small amounts of material from operating facilities — and they are old-fashioned in the sense that they are isotope-independent. They cannot be used for large scale decommissioning projects. In preparation for such projects, the Swedish Radiation Protection Authority has developed the draft of a set of limits and other requirements for the release of material and buildings, and that draft has been sent to the Swedish nuclear industry for comment. Two major questions have emerged in that context.

The first is ‘Which of the two main sets of internationally agreed limits — the IAEA’s or the European Union’s — should Sweden use?’ The European Union’s limits were the basis for the draft developed by the Swedish Radiation Protection Authority, but in some cases the more restrictive limits are given by the IAEA. So, should we always use the most restrictive values?

The second question is ‘If we adopt an internationally agreed set of release limits, should we include in our national limits a safety margin to allow for measurement uncertainties?’ In this connection, I would mention that many of the scenarios being considered are already very conservative.

The Swedish nuclear industry is looking at the code of practice developed by the United Kingdom’s nuclear industry with a view to developing something similar so that there is a common understanding of how the limits should be applied once they have been adopted. I believe that ultimately there will be agreement between the nuclear industry and the Swedish Radiation Protection Authority, as both want release criteria that will ensure that material and buildings can be safely released and — I imagine — neither wants requirements that make it tempting to dispose of material as radioactive waste simply because it is very difficult to measure its activity.

A. VISAGIE (South Africa — panellist): We have cleared significant amounts of waste from the decommissioning of fuel cycle facilities. We did so using clearance levels derived by us specifically for decommissioning and approved — together with the verification methodology — by the National Nuclear Regulator (NNR). The clearance levels and the verification methodology have been revised in the light of experience, and the revised versions have also received NNR approval.

This year, the published international exemption levels were incorporated into our national safety standards and legal system.

One problem we had related to the application of clearance and exemption criteria in the case of bulk waste volumes and although everything was proven technically and accepted by the regulator, public opposition ultimately prevented the transfer of that waste to a conventional disposal site. We at Necsa have not reached the stage of decommissioning that produces significant amounts of bulk waste that could be regarded as cleared waste, but, in the light of what I just described, I think that when we do it will be a challenge.

W. HILDEN (European Commission — panellist): Polls conducted by the European Commission in all Member States of the European Union (EU) indicate that European citizens want harmonization — consistency of Member State legislation — in the nuclear safety and waste management area. At the same time, a poll conducted in 2005 revealed a certain reluctance of European citizens to accept recycled materials in their vicinity.

Thus, if there is a driver for harmonization, it is public acceptance — citizens are easily disturbed and confused by differences between their own country and other countries regarding nuclear safety and waste management requirements. However, that driver may hinder harmonization in cases where national exemption and clearance levels would have to be raised in order to be in line with internationally accepted standards.

Consequently, the present harmonization challenge as seen by the European Commission is first to have exemption values and clearance levels endorsed by all countries, including the EU Member States. Preferably, this should be achieved through harmonization with internationally accepted values.

However, harmonization with the Regulations for the Safe Transport of Radioactive Material would involve problems, and the metals industry and the United Nations Economic Commission for Europe have their own interests and strategies.

Within the EU, we have our own European basic safety standards, which define exemption values to be used by the EU Member States. However, the wording is such that the Member States may exempt practices where the total activity or the activity concentration does not exceed the exemption values. Nothing prevents the Member States from adopting lower exemption values. Also, the standards allow the Member States, exceptionally, to exempt a practice with higher levels provided that the annual effective dose does not exceed 10 μSv.

For clearance levels, no binding quantitative restrictions exist at present. The standards say that materials may be released from reporting, authorization and other requirements if they comply with national clearance levels. These levels must be based on the same basic criteria and take into account technical guidance from the European Commission.

The Commission is currently preparing a revision of the European basic safety standards, in parallel with similar work being done within the IAEA framework. Within the EU there is now a clear intention to harmonize the EU values with the values in IAEA Safety Standards Series No. RS-G-1.7; the general opinion is that this document is now broadly accepted and that nobody wants another lengthy debate.

The main EU expert group in this context, the so-called EU Article 31 Group of Experts, acknowledges the importance of harmonization and has therefore set up a Working Party on Exemption and Clearance with the task of assessing whether the exemption values in the present European basic safety standards can be harmonized with the internationally agreed values. The Commission's aim is to propose one set of values to be used both for exemption and for clearance.

In order to remove any remaining doubts about the harmonization of EU values (in EC Radiation Protection No. 122) and IAEA values (in IAEA Safety Standards Series No. RS-G-1.7), a study is to be made of those cases where the differences are significant. It is expected that the study will shed light on the reasons for such differences and on the possible implications for EU Member States of the envisaged changes in the European basic safety standards.

S. SAINT-PIERRE (World Nuclear Association): With regard to the broad policies on the reuse of sites and material, I am rather confused about the international consensus. It is nice to see that there is an international consensus on working constructively to find viable options for the reuse of sites and material, but it is not so nice to see that there are differences of view about some criteria and/or about how they should be applied.

As regards the release of sites, the nuclear industry does not consider that there is a soundly based international consensus. There has been talk about 0.3 mSv/a and even 10 μSv/a, without any details being mentioned. With a dose limit of 0.3 mSv/a, as compared to the limit of 1 mSv/a in the International Basic Safety Standards, how can one convince the public that one is decommissioning safely? The public will perceive a risk three times as great as what was there before. An international signal that the limit for site decommissioning is no longer 1 mSv/a, but 0.3 mSv/a, will not make the job of the nuclear industry easier.

As regards the release of material, it is important to agree soon on one set of numbers. If the numbers are not perfect, they can undergo international review and revision in due course.

I would add that there is a tendency to say that one should shy away from anything above 10 μSv/a. However, my understanding is that, depending on how one exercises control, IAEA Safety Standards Series No. RS-G-1.7 allows one to go a little higher.

A.J. GONZÁLEZ (Argentina — panellist): I do not share Mr. Saint-Pierre's confusion about the international consensus. In my opinion, there are two incompatible attitudes towards that consensus — the attitude of those who stand ready to abide by it and the attitude of those who, citing stakeholder problems, are not willing to abide by it but nevertheless would like to see others abiding by it.

What is the use of an international consensus by which some abide and others do not? My message to those who are unwilling to abide by the international consensus on the reuse of sites and material is to play the same game.

A confusing aspect of this international consensus is that it derives from a paper submitted by the United Kingdom's former National Radiological Protection Board to the European Commission. That paper provided the basis for the EC's clearance values and subsequently for the IAEA's expanded clearance values for large quantities of material. The criterion was not 10 μSv but '10 μSv plus' — in scenarios of low probability one could go up to about 1 mSv.

The problem is that some people do not want to comply with what has been agreed on but would like others to comply. That simply will not work.

Regarding the release of sites, the guide with the relevant numbers was not approved by the IAEA's Board of Governors and not endorsed by the IAEA's General Conference, and in my view there are contradictions between some of the numbers and the recommendations made by ICRP in its publication No. 82. Hence, the manner in which those numbers have been presented here has given rise to confusion.

P. WOOLLAM (United Kingdom — panellist): The world cannot afford not to have 'new build', and in the United Kingdom we want 'new build'. However, we do not believe that stakeholders will accept 'new build' if they are suddenly confronted with — for example — a change in the exemption level for tritium from 0.4 Bq/g to 10^6 Bq/g, which is the number in the relevant Euratom Directive. Such changes will not be accepted unless there is careful stakeholder engagement, and governments do not comply with an international consensus if they see strong stakeholder opposition.

J.S. CARLSSON (Sweden — panellist): Of course, it would be good to have internationally agreed levels that could simply be incorporated into national regulations. What I fear is that, if the national regulations are more restrictive, then the internationally agreed levels would become more restrictive in the next review step and so on. The country that has the most restrictive levels or requirements tends to be followed — and I do not know where this process would end.

J.-M. POTIER (IAEA): In my view, the purpose of exemption and clearance generally, not just in the nuclear industry, is to permit the reuse of decommissioning materials. As regards the reuse of such materials, however, there seems to be a 'cultural' difference between northern Europe and southern Europe; in northern Europe, over 60% of the materials used in construction are recycled materials, while the corresponding figure for southern Europe is less than 20%. The difference may be due, in part, to greater concern about the environment in northern Europe, where it is consequently more difficult to obtain a licence to — say — open a quarry. However, there must also be an economic incentive to use recycled materials from decommissioning. They will not be used if they have to be transported over very long distances.

A.J. GONZÁLEZ (Argentina — panellist): It makes me nervous to see the nuclear industry moving towards the southern Europe strategy of demolishing and discarding rather than towards the northern Europe strategy of recycling as much as possible.

The strategy one adopts depends to a great extent on one's expectations. It is natural not to recycle if one believes that nuclear power has no future. If one is looking ahead to an expansion of nuclear power, however, recycling as much as possible is the obvious strategy. In the long run, nuclear power cannot expand without recycling.

Z. PAN (China — Chairperson): I invite the panellists to respond to the question 'How to manage most effectively the activities related to waste and material management during decommissioning?'

W. HILDEN (European Commission — panellist): The European Commission believes that for the effective, and efficient, management of decommissioning waste there must be good technical planning, including a national radioactive waste management strategy with clear milestones and end points. Accordingly, in 2004 the Commission published a revised waste directive that requires such planning. The Commission believes that there must also be comprehensive financial planning, based on national legislation. Such planning should ensure that sufficient funds are earmarked for decommissioning activities and for subsequent disposal of the waste.

However, what does 'effective, and efficient, management of decommissioning waste' really mean? Judging by some of the things said at this conference, it can have many meanings. It is clear, however, that effective management requires good information on the amounts and types of waste that will be generated. Obviously, the quantities of primary decommissioning waste and of waste resulting from decontamination and conditioning depend on quite a number of parameters that are know but not easy to structure and quantify — for example, the plant history, the quality of the plant characterization. The records of the OECD/NEA's Rome workshop on 'Safe, Efficient and Cost-Effective Decommissioning' in 2004 contained the conclusion "It is important to have good estimates of the types and quantities of materials and waste that will be generated as a result of decommissioning and dismantling at an early stage. An international project on waste estimating tools would therefore be of great value." In response to that conclusion, earlier this year the EC and OECD/NEA launched a study that is being carried out by an experienced contractor. From that study we expect a detailed understanding of the effects and relative significance of all the parameters influencing the generation of radioactive waste during decommissioning and any interdependencies that may arise. In addition, we hope to gain a good understanding of the interdependencies between the chosen decommissioning strategy and the chosen waste management strategy at the national level and at the level of the implementer. Finally, we expect conclusions regarding whether and, if so, how the effects of those parameters could be used in the development of decommissioning waste estimation models and in the formulation of the consequent waste management requirements. The European Commission stands ready to share the results of the study with the international community.

A. VISAGIE (South Africa — panellist): Waste and materials management actions are an integral part of decommissioning projects. Of course, you must first characterize in order to be able to plan. Decommissioning plans need to address the materials and waste handling aspects mainly in two areas: in strategy and in waste and materials management.

In terms of the strategy, it is important to ensure that decommissioning activities are aligned with waste and materials management, good practices and optimization approaches.

Of course, this is country-specific, depending on the availability of waste disposal options and end points or other decommissioning processes.

When selecting the decommissioning strategy, you should ensure that you do not limit the opportunities for recycling and reuse by mixing different waste and materials types, and you should not allow waste stream mixing that would change the waste class. In the case of uranium, for example, there is a limit on long-lived alpha concentrations in near surface waste repositories and if you mix certain waste streams, you could end up with waste that is not regarded as short lived and for which you do not have an end point.

There are many things you must consider in terms of decommissioning strategy that would impact the efficiency of waste and materials management.

As regards planning, we have found that it is important to be able, in the case of materials, to categorize the different materials — materials categories have to be identified, and you must have provisions in the materials management plans for the segregation and collection of the different materials categories.

In terms of materials, there needs to be a compliance monitoring/verification methodology specified, because that could vary from facility to facility, e.g. recording requirements, the quality assurance requirements.

In waste management plans, the standard things should be done — for example, the identification of waste types and streams and then implementation of the appropriate pre-treatment, treatment and conditioning arrangements. Then, of course, waste characterization requirements need to be specified in each plan and the storage and end point arrangements agreed upon.

J.S. CARLSSON (Sweden — panellist): We will not start any major decommissioning work until we have a repository available for most of the waste.

An important message to all those contemplating or engaged in decommissioning work is ‘Characterize, characterize, characterize! You never know when you will need the information about the waste.’

P. WOOLLAM (United Kingdom — panellist): In my view, the most important aspect of the decommissioning of radioactive facilities is the waste management. In general, there are few engineering concerns with dismantling reactors and reprocessing facilities; the difficulties all relate to what is to be done with the resultant waste.

In the United Kingdom, we have no disposal facilities for decommissioning waste, and, if our reactors were to be dismantled before such facilities became available, we would have to build huge interim storage facilities — facilities much larger than the reactor buildings. That might be unacceptable for environmental, sustainability and financial reasons. So, Magnox Electric is currently assessing options for the on site disposal of low level waste arising from reactor decommissioning. Extensive consultations with a wide range of stakeholders, including local communities and politicians, indicate that the on site disposal concept is broadly acceptable. It is expected that, subject to regulatory approval, an on site disposal facility with radiological performance suitable for most of the decommissioning waste could be made available on a timescale considerably shorter than the time necessary for the construction of a national facility designed to take the entire range of intermediate- and high-level waste.

On site disposal would have additional environmental benefits (particularly thanks to the fact that large volumes of waste would not have to be transported over long distances); it would represent increased value to the customer and the United Kingdom taxpayer, and it would enable the United Kingdom’s Nuclear Decommissioning Authority to accelerate the clearance of the Magnox reactor sites.

This is a good example of what can be done if you consult with people rather than telling them to follow the route which you think is the most appropriate.

A.J. GONZÁLEZ (Argentina - panellist): Like Mr. Woollam, I attach great importance to safe management of the radioactive waste generated during the decommissioning of radioactive facilities. The question is ‘How can we ensure that such waste is managed safely?’

My answer is simple — by respecting international law. Most — if not all — of the countries represented here have freely entered into a serious commitment regarding the safe management of radioactive waste. That commitment is enshrined in a convention that refers to safety standards developed by the only international organization with statutory responsibility for developing such standards — the IAEA, whose standards relating to the safe management of radioactive waste have been adopted by our governments. Nobody forced our governments to adopt them. It takes the opposition of only one IAEA Member State to prevent the adoption of an IAEA safety standard. So, our governments have freely entered into an international commitment and adopted standards for meeting that commitment. All we need to do is respect international law by complying with those standards.

B. BANTANDJIEVA (IAEA — Scientific Secretary): Regarding an earlier intervention by Mr. Gonzalez, I would like to make a clarification concerning IAEA Safety Standards Series No. WS-G-5.1 on Release of Sites from Regulatory Control on Termination of Practices. This publication is a Safety Guide and under the IAEA's rules it was approved for publication by the Commission on Safety Standards (CSS) and by the IAEA's Director General. Unlike Safety Requirements, this category of safety standard is not approved by the Board of Governors.

In order to assure consistency with the documents of the ICRP, the Chairman of the ICRP is a member of the CSS which approved its publication.

The main purpose of the Safety Guide and the reference levels is to ensure the same level of protection of the public during operation, during decommissioning and after release. In other words, if the dose constraint during operation and decommissioning is less than 300 μSv, this is the level that must be maintained and not compromised after the site has been released from regulatory control. This is the main message of the Safety Guide.

I think the discussion in this session has shown that it is very important to communicate with stakeholders and to continue to explain the difference between dose constraints and dose limits, as dose constraints are quite often taken to be dose limits.

TECHNOLOGY ASPECTS

(Session 6)

Chairperson

L. VALENCIA
Germany

Rapporteur

S. HARRIAGUE
Argentina

DECISION MAKING IN THE SELECTION OF DECOMMISSIONING TECHNOLOGIES

M. LARAIA
Division of Nuclear Fuel Cycle and Waste Technology,
International Atomic Energy Agency,
Vienna
Email: M.Laraia@iaea.org

Abstract

Dozens of old reactors and other nuclear facilities worldwide are either in the process of being decommissioned or will be candidates for decommissioning in the near future. A significant number of these facilities are located in institutions and countries that do not have adequate expertise and technologies for the proper planning and implementation of decommissioning projects. The technology selection process is critical in that regard. The overall objective of the activities of the IAEA on decommissioning technology is to promote the exchange of lessons learned, in order to improve the transfer and application of technologies that are important in the planning and implementation of decommissioning. This should be achieved through improving the understanding of the decision-making process for technology selection. The specific objectives of an ongoing coordinated research project (CRP) include the following: (a) to establish methodologies and data needs for developing concepts and approaches relevant to technology comparison and selection in decommissioning; (b) to improve and expand the database on applications and performance of various types of decommissioning technologies; (c) to address specific issues for individual decommissioning technologies and generate data relevant to their comparison and selection. The paper draws on the interim results of the CRP and some examples from the published literature to discuss various topics relevant to the comparison and selection of decommissioning technologies. It is anticipated that the lessons learned from the countries taking part in the CRP will generate valuable data that will be useful to Member States in planning for and implementation of decommissioning of their nuclear facilities.

1. INTRODUCTION

There are dozens of old reactors and other nuclear facilities worldwide that are either in the process of being decommissioned or will be candidates for decommissioning in the near future. Many of these facilities are located institutions and countries that do not have adequate expertise and technologies for the proper planning and implementation of decommissioning projects. The technology selection process is critical in that regard.

A global view shows that most decommissioning technologies are readily available in industrialized countries. This includes, but is not limited to, technologies for characterization, decontamination, segmentation, and related waste management. However, it should be noted, first, that such technologies cannot be deployed without consideration of, and adaptation to, the working environment (layout, radiation and contamination levels, temperature, etc). Secondly, the process for selection of suitable technologies from those available in the market is not a simple one (except for routine, standard applications) in that it involves consideration of a number of technical (performance, speed, waste generation etc) and managerial factors (direct and indirect costs, manpower, skills, hazards, etc). In addition, the individual technologies have various advantages and drawbacks. The final selection of a technology will generally be based on a case by case cost-benefit or multi-attribute analysis. A standardized approach for technology selection can only be applied in a minority of cases. Thirdly, there are a few areas of decommissioning where technologies still have to be further developed to achieve a full maturity. This is the case, for example, in the management of special materials (graphite, beryllium), for the very low level detection of radioactive concentrations, and for some remote operations and the use of robotics. The unique designs of some older prototype facilities can add decommissioning complications that can only be solved on a case by case basis. In this context, those responsible for the decommissioning of nuclear facilities in industrialized countries may be reluctant to promote innovation if they do not see an associated commercial advantage.

The situation is different in Member States having limited resources or scarce expertise in decommissioning. In such circumstances, decommissioning operators have to struggle with constraints additional to those faced in industrialized countries and may have to opt for less than the ‘state of the art’ decommissioning solutions. In many cases, Member States develop their own decommissioning technologies for use in their local circumstances. In part, this is because of the need to understand and predict the potential effects of decommissioning under their own site specific conditions in order to satisfy the nuclear regulators, but it is also due to the fact that many available decommissioning processes are proprietary formulations and are expensive to buy in the open market. In some Member States, it is very difficult to implement full decommissioning for these reasons and the costs associated with such projects are relatively high. Achieving the proper balance between the development of local specific technologies and the purchase of technologies in the open market remains a serious challenge for many countries.

2. OVERALL OBJECTIVE OF THE CRP

Although the state of the art technology for decommissioning nuclear reactors is adequate to cope with most difficulties associated with the dismantling of such facilities, it is important to improve, adapt or optimize technologies for the specific needs of the reactor to be dismantled. It may be possible, in many cases, to develop or adapt simple decommissioning technologies rather than purchase costly equipment, e.g., remote handling equipment. Learning from others rather than 're-inventing the wheel' makes sense in the context of the increasing extent of globalization.

A coordinated research project (CRP) is an IAEA mechanism in which institutions from industrialized or developing countries are able to share a common objective (e.g. the decommissioning of nuclear reactors) and exchange, through consultations and periodical Research Coordination Meetings (RCMs), experience and lessons learned [1].

The overall objective of the CRP on Innovative and Adaptive Technologies in Decommissioning (2004–2008) is to promote research and development activities through the exchange of lessons learned, in order to improve the technologies that are important in the planning and implementation of decommissioning. This should be achieved through a better understanding of the decision-making process in technology selection.

3. SPECIFIC OBJECTIVES AND MEMBERSHIP OF THE CRP

The specific objectives of the CRP include the following:

- To establish methodologies and data needs for developing concepts and approaches relevant to technology comparison and selection in decommissioning;
- To improve and expand the database on applications and performance of various types of decommissioning technologies;
- To address specific issues for individual decommissioning technologies and generate data relevant to their comparison and selection.

The following aspects are considered:

- Planning decommissioning activities with a focus to interactions of relevant technologies;
- Identifying technological needs, constraints and priorities;
- Exploring the market availability of technologies;

— Gathering experience on technologies from other decommissioning projects;
— Evaluating the costs and financing of technology procurement or development;
— Identifying proprietary requirements and their impacts on decision making;
— Conducting cost-benefit or multi-attribute analyses of specific cases of technology comparison and selection;
— Assessing innovative versus adaptive technologies;
— Conducting research and development on innovative technologies;
— Identifying training requirements and carrying out training courses on decommissioning technologies;
— Elaborating on and promoting the transfer of operating experience and lessons learned.

The participants' approaches to the CRP can be grouped into two main categories:

— Research and development work on decision-making approaches for selection of concrete decommissioning technologies in actual projects or national programmes;
— Research and development on decision-making tools of generic usefulness (Norway, Slovakia, and partly Belgium).

Immediately following the approval of the CRP by the IAEA's management, prospective participants were invited to propose research contracts (partly supported financially by the IAEA) or agreements on relevant topics. The process of selecting and awarding agreements or contracts was completed by mid-2004. The following countries are represented in the CRP: Argentina, Austria, Belgium, Brazil, Cuba, Czech Republic, Denmark, the Republic of Korea, Norway, the Russian Federation, Slovakia, Ukraine and the United Kingdom. Norway's Institute for Energy Technology (IFE) agreed to host the first RCM at its Halden facilities (April 2005). IFE performs research in nuclear and other energy technologies. The Halden Virtual Reality (VR) Centre builds on IFE's experience in advanced graphical visualization technologies and human factors. Figure 1 shows how VR helps to simulate and optimize activities in hostile environments, including decommissioning.

FIG. 1. Virtual reality simulation of nuclear activities.

4. LESSONS LEARNED IN TECHNOLOGY SELECTION

The following are selected achievements resulting from the CRP, other IAEA activities, or published technical literature**.**

4.1. Deciding on the need for and the extent of decontamination

In general, decontamination that is carried out during the 'operation to decommissioning transition period' is primarily aimed at dose reduction and is not intended for material clearance. Aggressive decontamination methods can often be applied where the systems are no longer needed for operation. However, decontamination does not solve all problems and requires careful consideration. Advantages should clearly outweigh drawbacks. The decision on whether to decontaminate a nuclear facility (or parts of it) will in general depend on the type of plant, the radionuclide inventory and other constraints such as:

— The decommissioning strategy selected;
— The time available;
— The availability of funds;

— Individual and collective radiation doses to workers;
— Liquid and airborne discharges and their radiological impact on the
— General public and the environment;
— Industrial safety requirements;
— Availability of waste management and disposal options;
— Workforce availability, including contractors;
— The intended reuse of the buildings for other purposes.

Within established constraints, the optimal decision should in general be based on the results of a multi-attribute analysis or an extended cost-benefit analysis. The extent of the decontamination needed will depend on the decommissioning strategy selected. In a delayed dismantling scenario, natural decay will reduce radiation and contamination levels in plant systems and components as well as on surfaces and may render some decontamination unnecessary. After a long safe enclosure (SE) time, the effect of physico-chemical mechanisms may make decontamination less effective, e.g. due to corrosion layers on metals and deeper migration into concrete surfaces. If SE is planned, decontamination should be considered primarily for the areas that will be accessed during the transition period. An alternative in some cases may be to fix contamination in place to reduce airborne resuspension and to facilitate access. However, it is important that surface coatings applied for this purpose do not overly complicate future decontamination and measurement activities [2].

4.2. Selection of dismantling techniques

Among other things, dismantling and segmentation will be needed to complete the decontamination process, as part of the radioactive waste minimization strategy. In this case, specific factors, such as shape, activation level or disposition of the contamination, may limit the effectiveness of the pre-dismantling decontamination. Moreover, even though the use of decontamination methods may not permit the levels of radioactivity to be reduced sufficiently to allow the materials to be returned to the public domain, it is still necessary that components and structures are cut up and size reduced to facilitate storage or disposal as radioactive waste. Dismantling techniques must be applicable to plant equipment and structures of different materials and sizes, for example, metals, reinforced concrete or even masonry, ranging in thickness up to several metres. These various items of plant structure and equipment may have contaminated surfaces, or be activated, or both. This can prevent worker access to the areas where they are located and require the use of remotely controlled machines.

There are many mechanical, thermal, electro-thermal, pyrotechnic and other processes available for cutting up, separating or breaking down the plant, equipment and structures of an installation. When the decommissioning of a nuclear installation is being planned, the selection of cutting tools or equipment should be made taking account of the following points:

— The performance of the equipment should be adequate;
— The equipment should be difficult to contaminate and easy to decontaminate, in order to limit the radiation exposure of maintenance workers and to limit the production of decontamination effluent;
— The equipment components should withstand the effects of radiation;
— It should be possible to remove tools from remotely manipulated systems for maintenance or repair;
— The cutting tools should be compatible with the working environment (e.g. be of a small enough size to allow accessibility to the working area and to the parts to be cut);
— The cutting tools should be compatible with the conditions in the working area, (e.g. for underwater work it should be watertight and corrosion resistant).

Use of the tool should not generate hazards other than those which can be controlled, monitored and treated (i.e. dust, particles, smoke, aerosols and liquid effluent) [3].

Several examples of how dismantling tools were selected at the DR-1 research reactor, Denmark, were made available during the CRP [4]. The dismantling of the reactor recombiner is described below. Contact dose rates at the surface of the recombiner were about 5 mSv/hr (^{137}Cs). This meant that brief contacts with hands in order to place tools or to lift equipment were not excluded. Figure 2 shows the recombiner from the top. Its outside diameter is 270 mm and its height is ~500 mm. It weighs 30 kg. At the bottom a flange connected it to the pipe leading to the core vessel (Fig. 3). The recombiner rested on four feet that were bolted to two beams below, as can be seen in Fig. 2. A number of cooling pipes and cables for the measuring equipment and power supply were attached to the recombiner.

In the initial planning it was intended to cut the connecting pipe between the recombiner and the core vessel by means of an available hydraulic tool. The tool is able to seal the two ends cut away by pressing them before cutting in the middle. In this way the risk of releasing possible contamination would be minimized. However, test cuts on similar piping showed that the tool probably would not be powerful enough to press and cut the 2³/₈ in stainless steel pipe. Since a larger tool would be very expensive and since radiation levels were

FIG. 2. The recombiner seen from top.

moderate, it was considered justifiable to disconnect the recombiner by opening the flange at the bottom and quickly replacing the two open ends with blind flanges. This operation was carried out without any particular problems; the bolts and nuts came apart fairly easily. In order to reduce radiation doses to the technicians, extension shafts were used for the spanners. Whole body doses to the two technicians who carried out the work were measured to be 102 and 30 μSv respectively. The hydraulic cutting tool served well, however, for cutting smaller pipes, such as the one seen in the lower part of Fig. 2. Very small diameter pipes (≤¼ in) were cut with an ordinary wire cutter, as were power and signal cables.

Another example of a decision-making process is illustrated through the dismantling of the Astra reactor, Austria [5]. To take down the inactive structures of the biological shield (400 m^3 of reinforced barite concrete of weight approx. 1400 t) several techniques were under discussion. Finally, wire

FIG. 3. Flange at the bottom of the recombiner.

cutting was chosen, with the biological shield divided into blocks of 7–9 t (limited by the 10 t lifting capacity of the crane). There were several advantages to be obtained from the choice of wire cutting:

— Measurements and calculations had shown that the risk of spreading contamination due to cutting was almost nil. Since wire cutting needs the presence of water, no dust would occur. The local installation of a high power vacuum cleaner following a cyclone unit to reduce dust and fog particles, and absolute filters on the exhaust side proved to be sufficient to control airborne contamination.
— The work would involve few staff; only two technicians were needed for the handling of the cutting equipment, usually supported by two staff of the reactor decommissioning team and a supervisor.
— Last but not least, the use of surface measurements with a higher sensitivity than the traditional 'in barrel' technique allowed compliance with unrestricted release levels to be demonstrated. The 'in situ' object counting system (ISOCS) device was mounted on custom designed gimbals allowing travel along horizontal and vertical guide rails. All surfaces of the blocks could be reached with a minimum of crane work. Figure 4 shows detail of the dismantling work.

4.3. Management of scrap metals

The US Department of Energy (DOE) used a technique called Life Cycle Analysis (LCA) in deciding whether to sell scrap metal and equipment at Oak Ridge National Laboratory (ORNL), or to dispose of it as LLW. The total

FIG. 4. Astra reactor, Austria; the biological shield is being removed.

amount of scrap was over 2400 t. As a result of the LCA, the DOE decided to sell the scrap metal and equipment. The equipment and 223 open top roll off containers (some 40 m^3 capacity) with their scrap metal contents will be sold at their market value to a licensed commercial vendor, who will survey both the scrap and the equipment for radiological contamination, perform decontamination as necessary, and resell the material.

In addition to producing significant cost savings for the Government, this project accelerated scrap metal cleanup efforts at ORNL, thereby avoiding potential soil and groundwater contamination due to the weathering of the radioactively contaminated metal that is in outside storage awaiting ultimate disposal. Sale of the scrap metal avoided the disposal of some 7000 m^3 of LLW and sale of the equipment avoided the disposal of an additional 300 m^3 of LLW.

In general, DOE noted that “currently decisions are typically based on the near term cost of the project. We have found that when this traditional approach is used, the DOE fails to realize potential cost savings, environmental benefits, and health and safety improvements” [6].

4.4. Model calculations

The quality of the decision making process for selecting scenarios and technologies for the decommissioning of nuclear facilities is strongly dependent upon the quality and extent of input data. The contribution to the CRP from DECOM Slovakia is to prepare and to perform a set of model calculations, to analyse the results, and to develop recommendations for supporting the decision-making process. The model calculations address the development of inventory data for shutdown nuclear power plants, typical decommissioning scenarios, and parameters of the decommissioning technologies involved. The results of model calculations will be analysed and cost–benefit/multi-attribute analyses will be performed in order to assess the effects of using various decommissioning technologies, the effect of the radiological state of the NPP after shutdown and the effect of deferred dismantling and other parameters. Advanced costing methods and the newly developed computer code OMEGA for standardized calculation of cost and other decommissioning parameters will be used for model calculations [7].

4.5. Miscellaneous

The following are additional, arbitrarily selected examples of decision making approaches to the selection of decommissioning technologies:

- Reference [8] describes option studies for the treatment and packaging of legacy waste;
- Reference [9] illustrates the cost–benefit assessment of the bio-decontamination of massive concrete structures;
- Reference [10] deals with an application of advanced management techniques and decision support systems for the decommissioning of nuclear facilities.

5. CONCLUSIONS

Given the fact that the need for decommissioning and environmental restoration exists on all continents, cleanup and restoration operations will tend to become increasingly international in the near future. There are three modes of international cooperation that can be utilized in the context of decommissioning technology. The first is through bilateral arrangements between countries and/or organizations. The second is cooperation on a regional level and the third is through the activities of international organizations. The latter form of cooperation, with emphasis on the exchange of lessons learned, including joint research and development and demonstration projects, has been very successful in the decommissioning area. CRPs are the typical mechanisms for implementing such a strategy. Cooperation of this nature has many benefits and is practical for several reasons. First, it makes good economic sense to share and learn from each other‘s experiences and to compare future strategies. It also prevents duplication of efforts. A second point is that projects initiated by any or all of the international organizations tend to be considered credible and therefore generate financial support. Third, joint projects create a support network and a system of formal and informal peer reviews. This external review process enhances and adds technical credibility and validity to national approaches and methodologies. And finally, co-operation and exchange of lessons learned are required and used by countries as a means of checking their own progress — a means of calibration [1].

The CRP on Innovative and Adaptive Technologies on Decommissioning will focus on lessons learned specific to the identification, comparison and selection of technologies for the decommissioning of nuclear facilities, with particular emphasis on the research and development aspects relating to the data needs. The results will be used to improve understanding of the specific characteristics of decommissioning technologies that are important in the planning and implementation of decommissioning. The information will be particularly useful to Member States that are currently planning or implementing decommissioning of their nuclear facilities.

REFERENCES

[1] LARAIA, M., “Achievements and current issues in decommissioning of research reactors”, Environmental Remediation and Radioactive Waste Management, ICEM’03 (Proc. 9th Int. Conf., Oxford, September 2003), ASME (2003). (A summary of this paper was published in Nucl. Eng. Int. December (2003) 34–36).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Transition from Operation to Decommissioning of Nuclear Installations, Technical Reports Series No. 420, IAEA, Vienna (2004).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Methods for the Minimization of Radioactive Waste from Decontamination and Decommissioning of Nuclear Facilities, Technical Reports Series No. 401, IAEA, Vienna (2001).

[4] LAURIDSEN, K., “Experience gained during the decommissioning of Danish Research Reactor DR-1”, Innovative and Adaptive Technologies for Decommissioning (Proc. 1st Research Coordination Meeting of the CRP, Halden, April, 2005.

[5] MEYER, F., et al, “The Decommissioning of the ASTRA-MTR Research Reactor Facility at the Austrian Research Centres Seibersdorf”, ibid.

[6] YURACKO, K.L., et al., Decisions, decisions, decisions…better D&D decision-making through life cycle analysis, Radwaste Magazine, July/August (1999) 31–37.

[7] DANISKA, V., “Comparative Analysis of Decommissioning Technologies Based on Model Calculations and Multi-Attribute Analysis of Specific Decommissioning Cases”, Innovative and Adaptive Technologies for Decommissioning, Proc. 1st Research Coordination Meeting of the CRP Halden, April, 2005.
[8] THOMAS, A., WILKINS, J.D., “An example of a project sanction case – Repacking of Harwell legacy intermediate level wastes”, Appendix. 2 in Nuclear Decommissioning, Waste Management, and Environmental Remediation (BAYLISS, C., LANGLEY, K., Eds), Elsevier, Amsterdam (2003).
[9] HAMILTON, M.A., ROGERS, R.D., NELSON, L.O., “Biodecontamination: Cost-Benefit Analysis of a Novel Approach for Decontamination of Massive Concrete Structures”, Nuclear Decommissioning ’98 (Proc. Int. Conf. London, 1998), ImechE Conference Transactions 1998-12, Professional Engineering Publishing Ltd, London (1998).
[10] ZHU B., YANG Y., “The application of VR-GIS to decommissioning decision support system of nuclear reactor, Nuclear Engineering (Proc. 13th Int. Conf. Beijing, 2005), ICONE13-50612, CNS (2005).

DISCUSSION

L. VALENCIA (Germany — Chairperson): Is it possible to arrive at reliable decommissioning cost estimates that could be used by newcomers to the decommissioning field?

M. LARAIA (IAEA): The OECD/NEA, the European Commission and the IAEA have presented the results of a cost study in a publication entitled ‘A Proposed Standardized List of Items for Costing Purposes in the Decommissioning of Nuclear Installations’. We intend to carry out a further, more thorough, study and to present the results in a more user-friendly form. However, such studies are somewhat hampered by the fact that many organizations tend to regard cost data (especially data on unit costs) as confidential information not to be divulged.

Newcomers to the decommissioning field can draw on the experience of those who have done a lot of decommissioning work, but only up to a certain point. For example, there are big differences between the wage levels in different countries.

EXPERIENCE IN MELTING AND RECYCLING DECOMMISSIONING WASTE

M. LINDBERG
Studsvik Nuclear AB,
Nyköping,
Sweden
Email: Maria.Lindberg@studsvik

Abstract

During the last 20 years, Studsvik has melted and recycled metals from the operation and decommissioning of nuclear facilities. The metals treated are steel (stainless and carbon), aluminium, brass, copper and lead. A large part of the material treated has been subject to clearance for unconditional reuse and has been sold to the metal industry for re-melting. The amount of secondary waste from the melting procedure is strongly dependent on the incoming material. Abrasive blasting is therefore used to reduce the secondary waste from melting. The blasting residues are included in the final amount of secondary waste. During the last ten years, metals from three large decommissioning projects have been melted and recycled at the Studsvik melting facility. The results show that, with good characterization before treatment, and depending on the nature of the contamination, between 98% and 100% of the metals can be recycled. The amount of secondary waste is 3% to 8% of the weight of the metal depending on the contamination and if the material is, for example, painted. From the three example projects, a total 4590 t were melted, 4511 t were, or will be, free released and 3.9% of the weight of the original metal, in the form of secondary waste, has been sent back to the customer together with 49 t (1%) of non-cleared metal.

1. PRINCIPLES OF METAL RECYCLING

The treatment of metals from the decommissioning of nuclear facilities is in principle not different from the treatment of metals from nuclear operations. The metal arrives at the melting facility either as components for decontamination, segmentation, sorting and melting or as scrap pieces. The scrap that arrives in containers may already be decontaminated or the decontamination takes place at the Studsvik site before cutting, sorting and melting. It is important to sort the material for several reasons, one is a safety issue — closed volumes in the scrap may exist that can cause accidents — and the other is that sorted material is likely to produce a melted material that is easier to recycle. The general principle for recycling of metals from the nuclear industry does not depend on the origin of the metals in the reactor system, except for core components that are influenced by neutron irradiation, i.e., activated.

The systems for the clearance of material from regulatory control are country specific, although many are based on the same documents from the IAEA or the European Commission (EC). Several countries are now adopting, or have already adopted, clearance systems based on nuclide specific clearance levels.

In order to recycle as large fraction as possible of metals from operation or from decommissioning, a very important aspect to be addressed is the radiological, preferably nuclide specific, mapping of the system or component. The mapping can be based on both radionuclide specific measurements or on correlation calculations, but it is important that the mapping is done well to facilitate decisions on how to manage the metals before treatment for later clearance. Based on the mapping, a plan is developed in which it is determined whether the material needs to be: (i) decontaminated and melted; (ii) melted; or (iii) measured for clearance and it is important to know what the nuclide profile is.

In Sweden, the appropriate regulation is based on the principle that the metals shall be melted and measured for nuclide content after melting. In order to minimize sampling and to obtain homogeneous ingots, the furnaces at the melting facility at Studsvik are induction furnaces. All the ingots from one melt are kept together throughout the process, including those sold to the non-nuclear industry (Fig. 1).

Since melting is the final and usually irreversible part of the treatment, the pre-melting stage is very important. The pre-treatment, including different decontamination and cleaning procedures, ensures that the metals can be cleared after the final treatment. The method of removal of any surface decontamination is chosen depending on the nature of the object and the metal.

From each melt, only one sample is needed for analysis due to the use of induction furnaces, although triplet samples are taken if the customer or any involved authority wants to measure the sample. From the sample, which has the shape of a hockey puck, shavings are taken for α measurement after dissolution and separation. The puck sample itself is directly measured for γ emitting nuclides. When all nuclide data are registered the clearance ratio is calculated according to:

$$\sum \mathrm{C}_i/\mathrm{C}_{ni}$$

where C_i is the measured activity concentration for radionuclide i and C_{ni} is the clearance limit for the radionuclide i. If the sum is <1, the material can be

FIG. 1. Casting of ingots.

cleared. In Sweden, the radionuclide limits (C_{ni}) used are given in EC Radiation Protection No. 89 [1].

2. EXPERIENCE FROM RECYCLING OF MATERIAL FROM DECOMMISSIONING

2.1. Würgassen nuclear power plant

Since 1997, the Studsvik melting facility has received 3670 t of scrap metal from the decommissioning of the German Würgassen nuclear power plant. The material consisted of both scrap metals in boxes already decontaminated by abrasive blasting and cut into suitable pieces before arrival at Studsvik and components such as heat exchangers which were decontaminated and segmented at the Studsvik facility. The incoming metals were steel (stainless and carbon steel), aluminium, brass and copper; the latter two were in small fractions. All of the incoming material is sorted by hand in order to ensure that there are no sealed compartments which might cause accidents in the facility.

Together with the pre-treated scrap, larger components have also been treated within this project. In total, 12 heat exchangers have been decontaminated and melted. The decontamination was done using tube blasting and the results showed that all of the material from the 12 heat exchangers could be cleared. The total weight of the heat exchangers was about 258 t and the amount of secondary waste was 8% of the original weight of the heat exchangers. One high pressure turbine of 151 t weight has also been treated and the resulting material was cleared and free released.

The incoming material was already classified as a result of the nuclide profile provided by the customer. The material is melted in campaigns so that the classification of the material is conserved during melting. If necessary, a 'worst case' approach can be taken on some 'difficult to measure' nuclides e.g. Fe-55, Ni-59 and Ni-63, since the nuclide profile is known.

According to Swedish legislation, all secondary waste from the melting, as well as from other treatments, has to be returned to the customer within two years of arrival to Sweden. The same legislation also states that no radioactive waste of foreign origin can be stored in Swedish waste repositories.

From the melted metals a mean value of 2.9 % has been returned as secondary waste, i.e., 109 t in total. If the large components are excluded, the fraction of secondary waste is 2.3%.

The secondary waste normally consists of slag from melting, blasting residues, if the material has been blasted, and 'outsorted' material which normally is not meltable, or metals in such small amounts that there is not enough for a full melt. To date, over 2500 t have been recycled outside the nuclear industry and about 1086 t are in storage, some of which awaits radioactive decay before free release, i.e. 593 t (Fig. 2).

Studsvik has a general permit to store ingots to allow for decay to the clearance limit — for up to 10 years, awaiting decay of short lived nuclides, particularly the guiding nuclide Co-60. The ingots belong to the customer during the decay period but the ownership can be transferred to Studsvik just before sale.

In summary, all the metal melted at Studsvik so far, from the decommissioning of the Würgassen plant, has already been free released or will be free released within a ten year period from melting. The lessons learned from this project are: abrasive blasting of metals before melting increases the possibility for clearance and recycling; and blasting also reduces the secondary waste from melting.

FIG. 2. The ingot storing facility at Studsvik.

2.2. Nuclear fuel factory

Between 1996 and 2005, steel and aluminium from the decommissioning of the Siemens fuel factory in Hanau, Germany, was sent for melting at Studsvik. In total, 644 t of steel were melted and 143 t of aluminium. Of the total 817 t that arrived, 740 t have been free released and 47 t have been sent back, mainly aluminium (88%). The residual part is secondary waste, see below for details. The dominating nuclides in this material are those of uranium. The material was cleaned by blasting before arrival in Sweden.

The clearance levels for uranium in Sweden until 2003 were expressed in terms of α nuclide concentrations and were set at <100 Bq/kg. Since then, clearance has been carried out according to EC Radiation Protection No. 89 with a clearance level of 1000 Bq/kg for the uranium isotopes [1].

The residual activity in the material on arrival was too high for direct clearance after melting. Rather than blasting the material again, a method to decontaminate the steel during melting was developed. The method works very well for both stainless steel and carbon steel. This method is based on adding slag-forming chemicals to attract the uranium from the melted metal to the slag and thereafter removing the slag with the uranium from the metal surface. This method is only used for steel but it can be used again and again, either on the same melt or during re-melting of the same material.

Figure 3 shows the results from the first melting and the first re-melting including the application of the melt decontamination process for steel.

In Fig. 4, the results of re-melting with a second and third treatment of the melt decontamination process is shown.

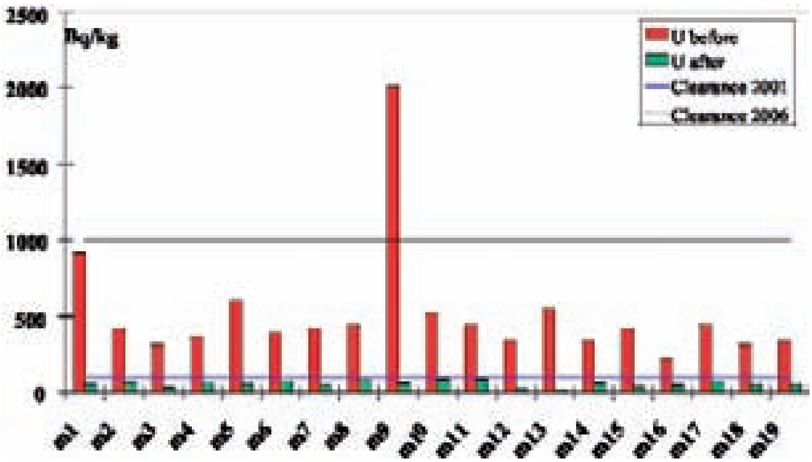

FIG. 3. Results of the melt decontamination process for uranium in steel.

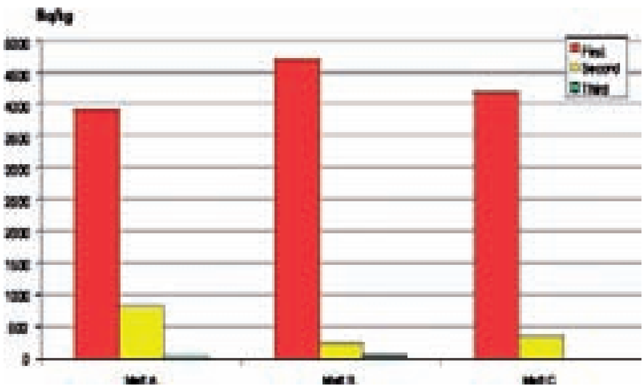

FIG. 4. Results of the melt decontamination process for uranium in steel: first, second and third melting treatments.

In Fig. 4, the bars show the uranium content of the metal after one, two and three applications of the decontamination procedure and it is clearly seen that the re-melting is very effective in reducing the uranium content of the steel. It can also be noted that if the clearance levels of today had been valid at the time of the melting then the third melt decontamination would not have been needed.

The application of the melt decontamination process depends on the uranium content. If the activity level is high, more slag forming additives have to be added and the amount of secondary waste is higher. The amounts of secondary waste for steel were between 3% and 10% depending on the contamination level. The total amount of secondary waste from the steel melting was 61 t.

It can also be noted that since the clearance levels have been adjusted upwards the amount of secondary waste would not be as high today, if contamination levels are comparable

The aluminium cannot be freed of uranium during melting. The aluminium was therefore melted and measured at Studsvik and only the part that it was possible to release for unconditional reuse was recycled.

Since there is no possibility of storing the material for decay, due to the half-life of uranium isotopes, the non-cleared ingots were returned to the customer together with the slag from the melting (Fig. 5). It can be noted that the majority of the aluminium could be cleared if today's limits are applied.

The lessons learned from this project are:

— Uranium contaminated steel can be decontaminated during melting
  - The melt decontamination process is repetitive;
  - The melt decontamination is effective and allows the steel to be cleared.

— Aluminium cannot be freed of uranium by melt decontamination.

FIG. 5. Removal of slag.

2.3. Research laboratory

The Studsvik site was founded as a research site for the nuclear programme in Sweden. One of the large laboratories from the 1950s was decommissioned between 1999 and 2005. During the decommissioning, metal constructions, such as ventilation ducts, were removed and subjected to decontamination, segmentation and melting. Other large painted metallic objects, such as lockers and cupboards, were also removed and decontaminated before melting. All the metal removed during this decommissioning project for melting was painted and sometimes the contamination had been covered with paint in order to fix it in place.

The research laboratory had been in use since the 1950s and, during that time, many different radionuclides were used. Therefore, the material had to be thoroughly decontaminated before melting. The preferred method is grit blasting. In the Studsvik melting handling facility, there are several different types of device used for blasting, such as a grit blaster, a drum blasting machine and a tube blaster (for components such as heat exchangers and steam generators).

The material from the research laboratory was washed and cleaned before arrival but was again thoroughly blasted at the melting facility. Much of the material was ventilation ducts and other large painted structures which also needed to be blasted before melting. This pre-treatment resulted in more secondary waste than normal, due to the special circumstances.

During the years 1998 to 2005, slightly more than 100 t of metals from the research laboratory were decontamination blasted and melted. The material was mainly carbon steel and small amounts of aluminium. Of the 100 t, 82% of the material was released for unconditional reuse, 18% is in storage for decay and 2% cannot be released due to its residual activity content. The lessons learned from this project are that a research laboratory has more differentiated nuclide profile than the other examples and more decontamination may therefore needed.

3. CONCLUSION

Metals from the decommissioning of a nuclear power plant, a fuel factory or research laboratory can, with the correct treatment, be cleared from regulatory control. Important considerations in preparing for the melting process are: the need for thorough radionuclide mapping, the complete sorting of the materials and the relevant legislation on clearance.

The amount of secondary waste from melting is 2–5% of the metal weight. The amount of secondary waste from pre-treatment is often higher depending on the contamination level of the material.

From the three example projects, 4590 tonnes have been melted, 4511 t have been, or will be, free released and 3.9% (by weight of the original metal) of secondary waste has been sent back to the customer together with 49 t (1%) of non-cleared metal.

REFERENCES

[1] EUROPEAN COMMISSION, Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations, Radiation Protection 89, European Commission, Luxembourg (1998).

DISCUSSION

G. LINSLEY (IAEA): Is free released metal really used freely in Sweden?

M. LINDBERG (Sweden): Yes, it is. We have ‘approved customers’ who follow a routine prescribed by the authorities, but such metal is used freely

The steel industry is less sensitive than it used to be, but it is selective in its use of free-released metal. It uses such metal in making, for example, steel mill rollers but not in making, for example, food cans.

R. ANASCO (Argentina): Have there been any problems with public opinion?

M. LINDBERG (Sweden): No — it is only the steel industry that has been slightly concerned.

R. ANASCO (Argentina): Do you keep track of free released metal after it has been released?

M. LINDBERG (Sweden): No, we do not.

S. A. FABBRI (Argentina): Do you include the cost of cutting in your price when you receive big components?

M. LINDBERG (Sweden): Yes, everything is included in the price charged to the customer.

EXPERIENCE IN USING RADIOACTIVE WASTE MANAGEMENT TECHNOLOGIES DURING THE REMEDIATION OF RRC KURCHATOV INSTITUTE FACILITIES AND AREAS

V.G. VOLKOV
Kurchatov Institute,
Moscow,
Russian Federation
Email: vvg@kiae.ru

Abstract

The paper describes the work carried out to remediate the historic radioactive waste repositories at the Kurchatov Institute in Moscow. The sites are located in close proximity to densely populated urban areas and, therefore, special care was required during the work in order to protect the local population. The approaches and technologies applied are described, with particular emphasis on the use of modern techniques for remote waste handling and for remote monitoring and visualization of the most radioactive active materials. Work on disposition of old radioactive waste repositories has been conducted at the site of the Russian Research Centre "Kurchatov Institute" since 2002. These repositories were constructed in 1943-1963 when the Kurchatov Institute was involved in the creation of nuclear weapons and the development of the nuclear power industry. Eight of the ten repositories contained low and intermediate level waste in a form that allowed its easy extraction. In 2004–2005, work was performed on the disposition of repository No.4, which was not easily accessible for the extraction of radwaste since it contained high level waste encased in concrete. From the start of the remediation activities, over 2400 cubic metres of solid radwaste were extracted and removed from the Kurchatov Institute site to the site of the specialized MosNPO Radon enterprise. In specific cases, a technology of electric discharge destruction of concrete structures was used for the demolition of the concrete roofing of the repositories. Intermediate- and high-level waste management operations were performed using remotely controlled robots Brokk-110 and Brokk-330. In the case of high radiation fields, this equipment was used for sorting the waste, and cutting and packing it into special containers. New devices for the measurement of radioactive waste specific activity and the detection of intense gamma radiation sources, and devices for radiation monitoring in working areas and at the radwaste disposal site, as a whole, were developed and tried out. The operations were accompanied by the largescale application of dust suppression methods and the continuous monitoring of aerosol activity in the working area air. Metal radioactive waste was first sorted. The majority of the lowlevel waste was removed to Ecomet-S enterprise (Sosnovy Bor) for remelting. A 'hydroabrasive' decontamination technology was tried out for cleaning up metal

surfaces. All operations concerned with the disposition of repository No.4 were performed inside a specially built shadow shielding. The radiation situation at the entire radwaste disposal site was monitored with gamma locators installed on the roof of the neighbouring building. The main objective of further activities at the site is the clean up of radioactively contaminated soil accumulated within the last repository No.10. The contaminated soil is being cleaned up using a pilot facility for water-gravity soil separation within the working area.

1. INTRODUCTION

In the years when research into nuclear technologies for military and civil application was being conducted at the Russian Research Centre, Kurchatov Institute, considerable amounts of solid radioactive waste and spent nuclear fuel were accumulated [1].

Until the mid-1960s, solid radioactive waste, including that with high specific activity, was put into interim storage at a special site within the Kurchatov Institute. According to initial estimates, 1200 cubic metres of radioactive waste with a total activity of about 3.7×10^{15} Bq (100 000 Ci) (at the time of disposal) were placed in temporary repositories constructed at the site. As a result of the growth of the city of Moscow, the Kurchatov Institute site is now within a densely populated urban area and the radioactive waste disposal site itself adjoins a housing estate. These aspects had to be taken into account in performing the remediation operations.

2. TECHNOLOGIES FOR REMEDIATING THE REPOSITORIES

In view of the lack of accurate data on the design features of the old repositories and on the composition of the radioactive waste they contained, the remediation was performed in accordance with the following sequence of steps:

— Drilling of exploratory boreholes at repository boundary areas and within in the radioactive waste repository, followed by a radiation survey;
— Removal of earth covering layers from the repositories, destruction and removal of the repository covers;
— Extraction of waste from the repositories, waste sorting and loading into certified containers;
— Inspection and remediation of repository structures;
— Sorting of soil and removal of contaminated soil from the repository area;

FIG. 1. Destruction of the in situ concrete cover of repository No. 2 using the electric discharge device.

— Final radiation survey of the repository area and backfilling with clean soil.

The exploratory boreholes were drilled at repository boundary areas and within the radioactive waste repositories in order to determine more precisely the location of the waste repositories, their geometric sizes and design features, and to perform their radiation survey.

The specific activities of gamma emitting radionuclides were measured down the length of the boreholes using collimated detectors. The visual inspection of the boreholes was performed using a specially developed compact video camera which signal was recorded to PC memory.

Operations to remove the earth covering the repositories and the destruction of the repository covers were performed using conventional machines used in the construction industry.

In certain cases, when the repository cover consisted of a thick concrete slab (for example, repository No. 2), it was destroyed by means of a device used for the electric discharge demolition of concrete structures [2] (Fig. 1).

Measures for dust suppression and the monitoring of aerosol activity in the air of the working area were carried out during the remediation work.

The presence of high level waste in one of the repositories (repository No. 4) required the construction of a shadow radiation shield over it.

FIG. 2. Removal of waste using robots.

The extraction of the waste from the old repositories was performed using wheeled and crawler construction machines. Low level waste was extracted by excavators with buckets.

3. HIGH LEVEL WASTE MANAGEMENT EXPERIENCE

Intermediate and high level waste was extracted using Swedish-made ‘Brokk-110’ and ‘Brokk-330’ robots (Fig. 2).

To protect operators against ionizing radiation, the cabs of the construction machines used in the operations were shielded with lead sheets and fitted with lead glass. Both construction machines and robots were equipped with collimated detectors for measuring the specific activity of the radioactive waste being extracted.

During operations at the high level waste repository, colour cameras were installed inside the radiation shielding structure. The images from the cameras were displayed on monitors mounted in the excavator cabs.

To warn personnel of radiation hazards, working areas were equipped with threshold collimated detectors that produced audible and light alarms when the gamma dose rate limit was exceeded.

For the detection of canisters containing high level waste in the broken concrete mass, a gamma camera was used with the image displayed on a

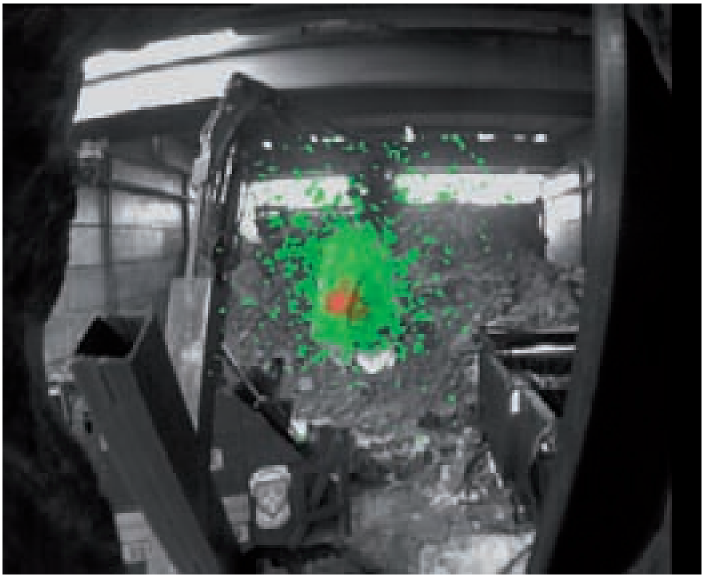

FIG. 3. The moment of removal of a high level radiation source by a robot. The image was obtained with the gamma camera.

monitor viewed by the operator [3]. The extraction of the high level waste canisters was treated as an abnormal situation and was performed by robots (in radiation fields of up to a few tens of mSv/h). When canisters with high level waste were detected in repository No. 4, the shielding cover was completely restored, and operations for extraction, measurement and packing of the high level waste were performed inside the shielding by robots, without any personnel being exposed to high radiation fields. The robots were used to destroy the remains of the waste concrete matrix, pick up the detected high level waste and transfer it to a special sorting area within the radiation shielding. In this area, the robots were used to carry out the separation and cutting of the waste and to pack it in containers. The gamma camera display was used for monitoring operations and for directing the robots to high level radiation sources, and for their extraction, fragmenting and packing in a container (Fig. 3).

4. DEVELOPMENT OF NEW METHODS AND INSTRUMENTS FOR RADIATION MONITORING DURING WASTE RECOVERY

All radioactive waste management operations were carried out under continuous radiation control. The activity of radioactive waste in containers

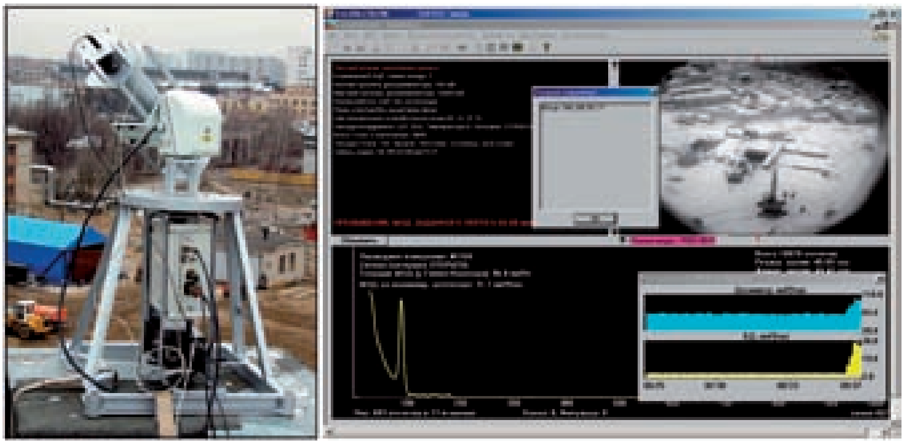

FIG. 4. The image on the gamma locator display during operations at repository No. 4 with the shadow shielding erected.

was measured by means of spectrometric and collimated detectors, with measurement results further refined using custom developed computer codes taking into account the container geometry, thickness and the material of container walls, waste packaging density and the ratio between the activities of the main important radionuclides (^{60}Co and ^{13}Cs) found in the waste [4]. The measurements were performed using qualified procedures, and the collimated detectors used for measurement of the waste specific activity were certified.

The radiation situation was also monitored over the entire radioactive waste disposal site. During operations at repository No. 4, the radiation situation in the working areas and over the entire disposal site was monitored with two gamma locators that measured the ionizing radiation photon flux and its spectral characteristics. One of the gamma locators was used for the continuous monitoring of changes in the radiation situation in working areas at repository No. 4, with the measured data displayed on PC monitors via Internet. The other gamma locator scanned the entire disposal site and measured gamma spectra in individual areas (Fig. 4). The data obtained on photon flux distribution were used for the calculation of gamma equivalent dose rate values at all points of the scanned space. The equivalent dose rate values were presented as a colour palette superimposed on a coordinate image of the object being scanned.

5. TECHNOLOGIES FOR DECONTAMINATION OF RADIOACTIVE SOIL AND METAL

The remediation of the radioactive waste repositories involved the decontamination of large amounts of radioactive soil. Because of the large volumes of radioactive soil it was clear that high capacity (2–3 t/h) soil cleaning technologies were needed. Two radioactive soil treatment technologies were selected: dry radiometric separation and water gravity separation.

Investigations of the radioactive soil have demonstrated that the major part of the radionuclides (over 80–85%) contained in contaminated soil is accumulated in its fine sludge and/or clay fractions. Based on results of the studies, a pilot facility for the water gravity separation of contaminated soil was developed and built at the disposal site. Its operation in the start up and adjustment mode demonstrated its high efficiency. The specific activity of the major part (70–80%) of the initial soil was reduced by four to five times. On average, 180–200 kg of each processed tonne of the initial soil were removed for long term storage. The water remained virtually uncontaminated during several facility runs.

By 2006, the capacity had been brought up to 5 t/h, and a large scale experiment on the decontamination of large amounts of soil was started. To date, more than 4100 m^3 of radioactive soil have been processed, about 700 m^3 of which have been shipped or prepared for shipment to the MosNPO Radon facility for the long term storage of radioactive waste.

Low level surface contaminated metal waste was decontaminated using a hydroabrasive facility developed by VNIITF. The hydroabrasive technology has been demonstrated to have a number of advantages over the conventional techniques of cutting and decontamination of metal structures: there is no thermal action on the material being treated; virtually all natural and artificial materials can be cut (linearly and non-linearly) and cleaned up; and no harmful aerosols or gases are released to the atmosphere. As a result of this work, over 200 t of metal radioactive waste have been removed to Ecomet-S enterprise in Sosnovy B or for remelting.

6. PROBLEMS WITH SUPPORTING TECHNOLOGIES AND EQUIPMENT

Some specific problems related to technological support of the work on remediation of the old repositories arose. One example is the lack of equipment for decontamination and fragmentation of large size metal waste. The use of flame gas cutters or mechanical cutting with disk saws is not allowed due to the large amount of aerosols produced and the lack of standard equipment prevents the use of abrasive hydraulic cutting and decontamination. At present there are plans to set up a special decontamination division in order to define appropriate technology for dealing with the problems encountered.

The use of heavy construction machines in the limited space of the repositories is undesirable; it is necessary use multi-purpose equipment with its own power supplies, allowing various attachments to be easily and quickly replaced. As one of the possible options, Bobcat hoisting and carrying machines may meet the above requirements. This equipment can be remotely operated, which makes it competitive with Brokk robotics equipment.

There are also problems with the measuring equipment. Due to the possible contamination of low background laboratories, organizations licensed to do such work refuse to accept samples of intermediate and high level waste for analytical and spectrometric examinations. This necessitates equipping an ‘in house’ laboratory for radioactive waste control and developing new procedures for rapid measurement of the specific activities of beta and gamma emitting radionuclides of 1 kBq/kg, and greater, in contaminated soil and radioactive waste in containers.

It is necessary to continue work on the development of a new gamma locator modification to provide real time monitoring of the radiation situation over the entire radioactive waste disposal site.

Radiation control issues are closely related to the problems of creating automated dust suppression and a waste sorting system. When the reference levels for the aerosol content of air are exceeded, the system for dust suppression and for attaching radioactive contamination to the surface of waste being handled would automatically turn on.

7. CONCLUSION

To date, work on nine out of ten of the radioactive waste repositories subject to remediation has been completed at the Kurchatov Institute. Over 2400 m^3 of radioactive waste with a total activity of over 1.7×10^{13} Bq (~500 Ci) have been removed to MosNPO Radon enterprise for long term storage. Results of the four year remediation activities have demonstrated that the choice of low, intermediate and high level waste management technologies was made correctly. The supporting organizational and technical measures allowed the work to be completed quickly and in full compliance with the rules and regulations for the safe performance of hazardous operations in the conditions of the built-up city district.

It is anticipated that the operational experience gained during the remediation of the temporary radioactive waste repositories, and the technologies and equipment developed during this period, will find use in operations at other national facilities of the RF Agency for Atomic Energy and Ministry of Defence at which remediation becomes a vital task to be accomplished in the near future.

REFERENCES

[1] PONOMAREV-STEPNOI, N.N., et al., "Rehabilitation of radioactively contaminated facilities and the site of Russian Research Center, Kurchatov Institute", Decommissioning of Nuclear Facilities — Managing the Legacy (Conference Handbook of IBC's 8th International Conference and Exhibition , London, 2002), EA1141, IBC Global Conferences, London (2002).

[2] SMIRNOV, V.P., et al., Creation and application of a mobile facility for electric discharge destruction of rocks and constructions, Moscow, Gorny J. No.11 (1999) 56–58.

[3] VOLKOV, V.G., et al., "Application of new instruments for sorting RW in remediation activities at Kurchatov Institute", Nuclear Technology Safety: Economy and Management of Ionizing Radiation Sources (Proc. 8th Int. ConfSt. Petersburg, 2005) pp. 135–141.

[4] VOLKOV, V.G., et al., "New radiation monitoring instruments and systems and their use in remediation operations at the RRC KI Radwaste disposal site", ibid., pp. 371–378.

DISCUSSION

L. VALENCIA (Germany — Chairperson): What are your decommissioning plans for the near future?

V. VOLKOV (Russian Federation): As I mentioned, there are 12 research reactors at the Kurchatov Institute of which six have been shut down. We are ready to start decommissioning those six reactors. Also, there are about 1000 spent fuel assemblies at the site that have to be removed.

EXPERIENCE WITH REACTOR INTERNALS SEGMENTATION AT US POWER PLANTS

C.J. WOOD, M.D. NAUGHTON
Electric Power Research Institute,
Palo Alto, California,
United States of America
Email: cwood@epri.com

Abstract

The removal and disposal of the reactor pressure vessel and reactor core internals represent major technical challenges during the decommissioning of LWRs. The paper discusses the lessons learned in the segmentation of reactor vessel internals at three PWR plants in the USA: Yankee Rowe, Connecticut Yankee and Maine Yankee. Techniques used included plasma arc metal disintegration machining, underwater mill saw and abrasive water jet cutting. Plant experiences with these techniques, and experiences with water purification, contamination control and the minimization of radiation exposures are discussed. The paper describes how lessons learned were used in the Southern California Edison project at the San Onofre PWR.

1. INTRODUCTION

Decommissioning a nuclear power plant involves a range of tasks of varying complexity. It is generally agreed that the removal and final packaging of the nuclear reactor pressure vessel (RPV) and the management of the waste generated from removing highly activated materials from inside the RPV present major challenges in terms of technology, project management and worker exposure.

1.1. US radioactive waste disposal regulation

Low level radioactive waste (LLRW) classification for land disposal in the USA is defined by the Nuclear Regulatory Commission as follows:

— *Class A waste* is waste that is usually segregated from other waste classes at the disposal site. The physical form and characteristics of Class A waste must meet minimum requirements.

— *Class B waste* is waste that must meet more rigorous requirements on waste form to ensure stability after disposal. The physical form and characteristics of Class B waste must meet both minimum and stability requirements.
— *Class C waste* is waste that not only must meet more rigorous requirements on waste form to ensure stability, but also requires additional measures at the disposal facility to protect against inadvertent intrusion.
— *Greater than Class C (GTCC) waste* is waste that is not generally acceptable for near surface disposal and for which form and disposal methods must be different, and in general more stringent, than those specified for Class C waste. In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository.

1.2. RPV internals classification and disposal

Some of the reactor internal components become highly radioactive due to their proximity to nuclear fuel. Decommissioned RPVs normally contain radioactive materials with a total activity in the range of 2–4 $\times$ 10^{16} Bq (500 000–1 000 000 Ci). Activation of such items as the mid-section of the reactor core barrel and the surrounding baffle support alone can represent as much as 2 $\times$ 10^{16} Bq (500 000 Ci). As a result, these components must be removed from the reactor vessel prior to their disposal.

Removal requires detailed characterization of all of the reactor internal components, removal of the vessel internal movable components, sectioning of the components to remove GTCC waste, removal of internal fixtures and plates of GTCC waste, and packing of the reactor vessel internals material for storage until transferred to the US Department of Energy (DOE).

Most GTCC waste has been stored in canisters similar in design to those manufactured for spent fuel and stored at independent spent fuel storage installations (ISFSIs). The 2005 Energy Policy Act established clear responsibility for the permanent disposal of the GTCC with the DOE and it is expected that the GTCC will be removed from the nuclear sites concurrent with the spent fuel.

1.3. US reactor pressure vessel internals segmentation experience

Several US plants have carried out projects for RPV internals segmentation. Connecticut Yankee, Maine Yankee and San Onofre used very similar approaches in terms of project structure and technologies. The timing of the San Onofre project allowed for the observation of the leading projects, the incorporation of the lessons learned, and the use of experienced vendor teams.

TABLE 1. PRINCIPAL METHODS USED IN RECENT US SEGMENTATION PROJECTS

Plant project date	Cutting method	Reason for selection
Yankee Rowe PWR — 167 MW(e) 1993	Plasma arc. Metal disintegration machining (MDM)	Proven reliability and speed. Greater operating depth and access capability.
Big Rock Point BWR — 67 MW(e) 1999	Underwater hydraulic mill saw. Mechanical clamp-on cutter.	Limited work area.
Connecticut Yankee PWR — 565 MW(e) 2000	Abrasive water jet. MDM.	Worker exposure, airborne contamination, waste form, schedule.
Maine Yankee PWR — 810 MW(e) 2001	Abrasive water jet. Mechanical cutting.	No thermal cutting was performed.
San Onofre 1 PWR — 410 MW(e) 2002	Abrasive water jet. MDM	See below

As a result, the San Onofre RPV segmentation project achieved all of its major goals in terms of results, schedule, and worker exposure, as discussed later.

2. SEGMENTATION TECHNOLOGY

A number of cutting processes have been use in recent RPV Segmentation Projects. Table 1. lists the principal methods used in recent segmentation projects.

2.1. Abrasive water jet cutting (AWJC)

The AWJC process utilizes an ultrahigh pressure stream of water containing an abrasive medium (see Jet Edge, Inc., for more information on the extensive uses for this cutting technology). The AWJC system consists of four basic components. An ultrahigh pressure positive displacement pump referred to as an intensifier pump. This pump pressurizes the water in the range of 40 000–60 000 psi. The pressure is modulated by use of an attenuator located downstream of the intensifier pump that smoothes the pump induced pressure fluctuations. The high pressure water in the range of 1–3 gallons/min (g/min) is forced through a small nozzle orifice in the range of 0.020–0.065 in containing within the cutting head. This high energy stream enters a mixing chamber within the nozzle where it entrains air fluidized dry abrasive material from the abrasive delivery system. The abrasive system utilizes compressed air to provide an even distribution of the media to the cutting head. The resultant supersonic slurry emerges from the nozzle at a small distance from the intended cutting surface.

AWJC offers several distinct advantages over conventional cutting methods including:

— Heatless cutting.
— Claimed elimination of heat affected zones, recast layers, work hardening and thermal stress within the worked material.
— Minimization of dust and fumes.
— Practical elimination of airborne material normally experienced with cutting processes, such as the plasma arc process. This greatly reduces the requirement for off gas collection and processing.
— Finishing operations are not required.
— Proper selection of the cutting parameters, such as, operating pressure, abrasive selection and feed rate eliminates the need for secondary operations.
— Omni-directional cutting.

The cutting profile is only limited by the position control capability of the cutting arm assembly.

2.2. Metal disintegration machining

MDM is frequently used for destructive cutting projects. The MDM process removes metal from the work surface through a series of intermittent electric arcs produced by a vibrating negatively charged electrode against a positively charged workpiece. Each time the electrode breaks contact a high energy arc is created. The resultant molten metal at the workpiece surface is lifted off and quenched by the surrounding liquid. The fine powdered waste material is removed from the coolant by a filtration process.

Electrodes are typically made from graphite and can be fabricated in a wide range of shapes tailored to the application. Normally, electrodes are supplied as either simple cylindrical or rectangular rods. MDM tooling can be delivered to the work location through the use of long poles. The cutting head can then be attached to the workpiece by means of pneumatically operated clamps.

MDM is a relatively slow process with a material removal rate of approximately 4 cubic inches per hour. Even at this rate, the process is well suited for the cutting of brackets and bolts that are inaccessible to other tooling.

3. WATER PURIFICATION SYSTEM

Experience gained in the Connecticut Yankee segmentation project clearly demonstrated the importance of the role of water purification. Waste material from the cutting activities can easily present a severe problem by reducing underwater visibility. Degraded visibility has a direct impact on the conduct of the work and the project schedule. Equally important is the fact that migration of the highly active waste material can produce an increase in the general radiation level on the refuelling floor. An increase in the level of radiation dose rate coupled with the accumulation on waste hot spots in the work area is likely to increase worker exposure. For these reasons, the performance of the water purification system is important to the segmentation project.

A unique design was developed for the waste processing system at San Onofre. Because of the radiation levels associated with this waste and the limited floor space, the processing system was placed underwater. All operations are conducted underwater from a control panel located in the Work Control Centre. To meet the 24 hour/7 day operating schedule, the system utilized two containers. While one of these was collecting waste material, the second was in the ‘dewatering’ mode. The dewatering operation consisted of repeated pumping cycles followed by extended ‘wait periods’.

4. LESSONS LEARNED FROM EARLIER PROJECTS

The approach taken by Southern California Edison Company (SCE) in the San Onofre Nuclear Generating Station Unit 1 (SONGS 1) RPV segmentation project was exemplary. The SCE team made a concerted effort to learn from the preceding projects and to ensure that the relevant information was formally factored into the project. The utility identified the following as key factors to the success of the SONGS 1 project:

— Development of a comprehensive project execution plan;

- Selection of robust equipment, modified as necessary, with required equipment performance testing under simulated field conditions;
- Use of experienced field technicians and machinists;
- Detailed project planning in the phases of the project, concluding in a formal readiness review.
- Diligent attention to detail in the radiation protection programme with respect to field surveys and cleanliness of the work areas;
- Finally, the use of underwater divers where appropriate in support of the work.

The segmentation of reactor vessel internals involves precision cutting, removal and packaging of extremely radioactive sections of internal components from the reactor including:

- Lower core support plate;
- Active fuel region of the core barrel;
- Core former plates;
- Core baffle.

The following are examples of lessons learned (that required corrective actions):

- Evaluate lower core plate removal difficulties;
- Evaluate the use of MDM to remove bolt heads to reduce required rework;
- Evaluate AWJC enclosure problems;
- Evaluate problem of the AWJC producing jagged cuts;
- Evaluate pool activity impact on tooling radiation source;
- Evaluate airborne problems associated with MDM;
- Evaluate water cleanup impact on secondary waste generation;
- Evaluate problems experienced with underwater high integrity containers;
- Evaluate pool activity impact on manipulator bridge and tooling;
- Evaluate the option of locating purification system components underwater;
- Evaluate coordinated schedule for plant staff and contractors;
- Evaluate the duration of scheduled activities;
- Evaluate underwater lighting problems.

5. RADIATION CONTROL ISSUES

Movement of components, sections and waste presents the greatest hazard with perspective of maintainkeeping personnel radiation exposure as low as reasonably achievable (ALARA). The following good practices have been identified from recent plant experiences:

- Nothing should be removed from the spent fuel pool without it being continuously monitored for radiation and undergoing constant flushing of its surfaces.
- A detailed review should be performed of all waste and process hoses. Earlier operations experienced plugging of waste processing hoses. One plant provided protective covers for a number of hoses and electrical cables that were routed through frequently used walkways. Milling chips could have a high potential for plugging process hoses.
- The operation of the filters needs to be coordinated with the segmentation activities to ensure that GTCC waste is not deposited within the filter housing, thereby raising the waste classification of the filter.
- Flow rates for chip collection need to be considerably greater than 100 g/min. Integrated testing would ensure success.
- A thorough cleanup of GTCC chips is required prior to creating core barrel chips — to avoid GTCC chips mixing and creating a radiation dose problem in the waste containers as well as a waste characterization problem.

At San Onofre, the radiation protection group actively participated in the development of a comprehensive Work Control Plan. This plan had as its purpose:

- To identify all the tasks to be performed in radiologically controlled areas;
- To list unique precautions that should be observed during the execution of the task;
- To identify the prerequisites for starting the task;
- To identify the general radiation dose level expected to be experienced during the task;
- To list the specific radiological protection coverage that should be provided in the immediate work area to ensure that the worker is able to work safely.

The total exposure of workers at San Onofre, up to the disassembly and decontamination of the cutting table, was 23.5 man-rem (0.235 man-Sv).

6. CONCLUSIONS

The segmentation of reactor vessel internals presented a major challenge in the decommissioning of US nuclear plants. GTCC waste from internal components is not acceptable for near surface disposal. This means that utilities are required to remove highly radioactive material from their reactors and place in it in storage until an approved national geologic repository is available. As a result, utilities involved in decommissioning had to develop the technology and methods required for this extremely difficult task. The most recent segmentation projects benefited from the lessons learned in earlier projects. The SONGS 1 project was a major success in terms of schedule, safety, worker exposure and final segmentation results.

DISCUSSION

J.J. BYRNE (United States of America): The lessons learned from the plasma arc cutting of Three Mile Island-2 core internals would have been useful at some of the plants to which you referred.

C.J. WOOD (United States of America): I agree. However, the segmentation operations that I described took place many years after the Three Mile Island-2 experience.

Ph. GROJEAN (France): What is the average time necessary for complete segmentation of the internals of a PWR?

T. LAGUARDIA (United States of America): We have found that complete segmentation can take from 6 to 18 months, depending on the time necessary for contamination cleanup.

PRACTICAL TECHNOLOGIES FOR NUCLEAR DECOMMISSIONING: FINDING THE RIGHT TECHNOLOGY BALANCE

F.R. LOCKHART
Rocky Flats Project Office,
Office of Environmental Management,
Denver
Email: frazer.lockhart@fr.doe.gov

A.P. SZILAGYI
Office of Environmental Management,
Washington, D.C.

Department of Energy,
United States of America

Abstract

Nuclear decommissioning is difficult, dirty, and dangerous work that can benefit significantly from technical innovations. The scope of the Rocky Flats Closure Project required the removal of radioactive material, the decontamination and the demolition of over 800 buildings and facilities (a dozen highly contaminated with plutonium or uranium), offsite disposal of all waste, and environmental remediation. The magnitude of the plutonium process decommissioning operation and the nature of the contamination defined how technologies could be applied. It was found that placing the decisions on technology deployment in the hands of the management directly responsible for the execution of the activity ensured that the effort remained focused and accountable, and was more likely to be deployed. The paper describes the various technologies applied and the experience obtained in their use. Generally, the use of simple technology, with continuous improvment, had greater success than highly engineered solutions with long deployment schedules. This is the evolutionary vs. revolutionary mindset which Rocky Flats found to consistently be more effective. The planning process should support the continual re-examination of activities to evaluate how technology improvements can address activity safety, cost and schedule. Rocky Flats found that to seek the right balance for technology, the criteria that improves worker safety often leads to improved cost and schedule efficiency, especially when it focuses on improving methods and tools for achieving work.

1. INTRODUCTION

Nuclear decommissioning is difficult, dirty, and dangerous work that can benefit significantly from technical innovations. An essential element of the Rocky Flats Closure Project strategy was that productivity would improve as the project progressed. The scope of the Rocky Flats Closure Project required the removal of radioactive materials, equipment and sources, decontamination and demolition of over 800 buildings and facilities (a dozen highly contaminated with plutonium or uranium), off-site disposal of all waste, and environmental remediation. The commitment made in 1997 to a 2006 completion within fixed budget limits required a 12% efficiency improvement per year. Executing a strategy to deliver such a level of continuous improvement required identifying and deploying many innovative processes and technologies. The effectivenes of the technologies proved to be dependent on the project characteristics and scope. The principal characteristics of the Rocky Flats Closure Project were the types and location of the contaminants, the relatively large decommissioning scope, and the need to ship all waste offsite for disposal. This paper focuses on the process used to target activities in which new technologies could be effectively employed, as well as on lessons learned about finding the right balance of criteria for technology use.

2. SITE CONDITIONS AND TECHNOLOGY DEPLOYMENT CONSTRAINTS

Several site characteristics influence the technologies that can be effectively employed. The differences between these characteristics and those of other decommissioning projects need to be assessed to determine which technologies might be most beneficial in any given situation.

The Rocky Flats Environmental Technology Site (Rocky Flats or the Site) production activities were narrowly focused on the fabrication of plutonium, uranium, beryllium, and stainless steel weapons components, and the chemical refinement of plutonium for reuse. This resulted in substantial amounts of special nuclear material (SNM), mostly plutonium and uranium, in purified form, sometimes packaged as waste, but often as contamination or 'holdup' dispersed throughout the process systems (gloveboxes, tanks and piping). There were over 1000 gloveboxes and numerous tanks, each with unique geometry, within six major plutonium process buildings, and a substantial amount of large depleted uranium machining and forming equipment in six other major buildings. The remaining few hundred facilities provided administrative and support functions, and contained little or no contamination. Radioactive releases requiring remediation were relatively modest and localized, covering approximately 10% of the approximately 380 acre ‘industrial area’. There were isolated instances of buried radioactive waste on site, but no major burial grounds or contaminated disposal facilities; historically, waste had been shipped elsewhere for final disposal. Although there were some solvent plumes, they were largely contained within the 380 acre ‘industrial area,’ and did not approach the site boundary.

The site characteristics and operating history pointed to technologies for use on a limited population of different materials, and generally involved gloveboxes or tanks. Contamination was generally fixed, but could be dispersed if care was not taken during decommissioning. Since Rocky Flats had no high gamma emitting materials or fission by-products, the radioactive waste from decommissioning consisted of pieces of equipment or facility that had plutonium or uranium contamination (alpha or beta) on their surfaces. All of the decommissioning work could be done on a ‘contact’ basis (i.e. there was no requirement for remote activities as would be the case for reactor or fission product processing facilities). The principal decommissioning effort was in relation to the plutonium facilities, which required simultaneous compliance with Federal and State hazardous material regulations, safeguards, physical and personnel security, nuclear safety, criticality safety, and radiological safety. The layered and sometimes conflicting requirements had to be considered when applying new technology for executing work in these facilities.

3. GENERAL PRINCIPLES FOR TECHNOLOGY DEPLOYMENT

The key measures of success for a new technology were the quantifiable improvements it made in worker safety, in reducing the duration and cost of an activity, and in streamlining waste management. At the beginning of the closure project, choosing which technologies would provide the most improvement was a largely speculative process. Analytical methods to determine optimum technologies were used, but were constrained by limited knowledge of the facility condition, uncertainty in the time required to develop the technology compared to when it was required, and effectiveness once it was employed. Some technologies could not be pursued simply because they could not be deployed in time for a project with a fixed schedule. Early planning for technology would ideally solve much of the schedule concern, but such an approach can be overcome by new data, changed conditions, or competing technologies. Over time, the technology deployment approach which achieved the greatest success was one in which technologies were identified that represented an incremental improvement over those used continuously within an ongoing process — evolution versus revolution.

For short term activities that could not be executed with existing technology, use was made of a ‘top down’ approach. This approach depended on the planning process, and on identifying and assigning project and worker safety concerns to individual execution activities. Early in the planning process the specific work approaches for the execution of technically complex activities were not known. Assigning a risk and contingency cost to activities in which methods to execute the work were unknown or poorly defined allowed the prioritization of technology development to reduce those risks. Also, knowledge of the estimated cost of the activity prevented the investment in technology options that could not substantially improve overall closure project costs. In some instances, several parallel technology developments were initiated in areas of substantial project risk to ensure that at least one suitable method could be deployed. This parallel approach was useful in several instances.

Longer term projects involving many years of labour effort employed ‘bottoms-up’ methods for identifying and implementing technologies. In most cases, commercial methods could be employed immediately, even if inefficiently, and then adapted and improved. The workers quickly became the key focus for technology innovation as about 75% of the project cost was for ‘hands on’ labour. Managers and work crews directly responsible for executing the work were able to identify tangible problems and specific success parameters, often achieving results with ‘off the shelf’ equipment that was applied in a new way for their need. This approach required very little true technology development, but was technical innovation in the truest sense and provided some of the greatest project improvements.

Three general principles were found to be effective in directing the work and hence the technology deployment effort. First, for decontamination or size reduction of highly contaminated equipment with diverse configurations, ‘hands on’ manual work was usually more effective than remote or automated action. The glovebox and equipment shapes were so diverse that automation proved too inflexible to adapt to the unique equipment configurations, and was even less efficient than the expensive and safety challenging process of approaches involving workers in extensive personal protective equipment (PPE) and contamination control enclosures. Complex hardware and software development might have solved this problem, but was not justified by the relatively limited scope of the work. Second, work options such as glovebox size reduction that required the handling of uncontrolled, highly contaminated materials (i.e. not containerized waste) were minimized whenever possible. Finally, the technology deployment programme was expanded beyond physical or engineered solutions. Technology was broadened to include process, management, and system innovations which may or may not have directly involved equipment. Innovation in any form was used to increase safety, efficiency, and/or effectiveness. Through obtaining an understanding of these principles, technology deployment evolved to focus on minimizing or enhancing manual activities for plutonium decommissioning activities, investing effort in activities that had to be done on site, and avoiding overly complicated or automated solutions. This broader perspective and how it helped us find the right balance between practicality and sophistication will be apparent in several of the examples described below.

4. TECHNOLOGIES USED FOR SITE CLOSURE AND AVAILABLE FOR DEPLOYMENT

In the following paragraphs the technologies are discussed first by explaining the drivers for developing the technology, to help the readers decide whether the technology might have application for their site or project. The discussion continues with a brief description of how the technology was deployed. The description is not intended to provide sufficient detail to allow readers to recreate the technology, rather, it is intended to inform readers that the technology exists and has been successfully demonstrated at Rocky Flats.

Plutonium Stabilization System. When the decision was made to cease further plutonium weapons production at Rocky Flats and close the site, the site contained virtually all of the country's inventory of plutonium 'residues'—materials containing a high concentration of plutonium but which had not been refined prior to the cessation of production operations. An automated system was developed and partially fabricated by a consortium to package plutonium residues into containers and weld them for long term storage. The system, known as the Plutonium Stabilization and Packaging System (PuSPS), included substantial automation and complex mechanical devices designed to minimize operator exposure. Development was slow and the automation challenges extensive. To accelerate schedules the technology development was curtailed and the complex system was substantially reengineered and streamlined. Manual glovebox packaging actions were substituted for automated actions, while retaining the final automated welding systems. Even with the re-engineering, the PuSPS system was unreliable and difficult to maintain in an operational state. An 'on call' engineering and maintenance crew, available 24 hours per day, was used to keep the system functional. Although the PuSPS system had worked reasonably well in non-contaminated startup tests, the contaminated environment overtaxed the automated systems. Calibration adjustments and minor mechanical repairs which were simple in a ‘cold’ system, took hours inside a contaminated glovebox. The additional pressure of the production schedule added to the challenge. The early establishment of performance criteria to allow more complete technology testing and deployment would allow better success for automated systems.

Cerium nitrate decontamination process [1]. The driver for use of the cerium nitrate process was to reduce transuranic (TRU) waste volume, reduce residual contamination levels to make size reduction safer, and reduce the amount of size reduction by disposing of more process equipment as larger pieces of low level waste (LLW). The process involved the use of a ‘super-oxidant’ as a solvent to extract the plutonium oxide from the contaminated surfaces (mostly gloveboxes and tanks) and allow it to be readily wiped or washed off. This decontamination enhancement reduced surface contamination and overall radioactivity, in most cases to less than 0.3 kBq/g (10 nanocuries/g) (an order of magnitude below levels previously achieved). The decontamination method was developed and used very successfully in parallel with acid–base decontamination process.

Acid–base (‘three step’) decontamination process [1]. The driver for use of the acid–base process was the same as for cerium nitrate. The process involved the use of a proprietary multi-step process to extract the plutonium contamination from the contaminated surfaces (mostly in gloveboxes) to reduce overall radioactivity, in many cases to below TRU concentrations. Some substrates were better addressed using cerium nitrate, others with the acid–base process.

Plasma arc cutting [2]. The driver for plasma arc cutting of contaminated metal was the need to increase the speed of size reduction in ways that reduced worker stress, fatigue, and potential for injuries (versus hand held reciprocating saws), but retaining the flexibility to cut varied shapes. Plasma arc cutting used hand held plasma arc cutting torches to cut metal at several times the cutting speed of standard hand held saws. Additional fire risk and contaminant dispersal limited the use of this technology to more controlled environments. This technology depended on the ‘birdcage’ containment systems and glovebox and tank decontamination techniques to reduce and control contaminant spread. The plasma arc method performed very well with careful safety controls, however, the ability to perform better decontamination (discussed above) reduced the percentage of contaminated equipment that required size reduction, and reduced the relative benefit of the plasma arc process.

Birdcage containment [3]. The birdcage containment system originated from the need to control radioactive airborne contamination during equipment size reduction. Early in the site’s decommissioning of plutonium contaminated gloveboxes, airborne contamination limits were exceeded for workers in supplied air suits. To provide additional physical controls to reduce the airborne concentrations, Rocky Flats developed 'cabinet' enclosures to provide an additional layer of containment within larger soft sided containment structures. The cabinets had portable cutting tools suspended from retractable load bearing cables to reduce worker fatigue. Tooling configurations went through multiple changes based on worker suggestions. Workers would then reach inside the cabinet to perform size reduction work, hence the name 'birdcage'. These cabinets were large enough to surround the glovebox, and provided airflow control to remove contamination from the worker environment. This improved control of airflow reduced the airborne contaminants such that workers could work in lower levels of personal protective equipment (PPE) and at reduced potential for skin contamination. The birdcage containment interacted with various tooling improvements and the plasma arc cutting to provide an improved method for dealing with large, extremely contaminated equipment not suitable for decontamination.

Ultrahigh pressure abrasive water jet cutting [4]. The driver for using water jet cutting was the need to cut large, moderately contaminated equipment, while suppressing airborne contamination and reducing the need for contamination control enclosures. The process used water jets containing abrasives at pressures greater than 10 000 psi to cut contaminated metal equipment such as tanks and vessels. The equipment had to be used under conditions in which the liquids were contained, and where contamination levels were kept to below those at which criticality was a concern. The water lances were a safety concern — they were difficult to control, and could easily cut flesh, electrical cables, and conduit. Although technically very viable, the constraints and safety concerns limited the use of this technology for manual control. It may be better deployed if combined with automated or robotic technologies to control the water stream.

Vacuum systems for removal of bulk contaminated material. Two systems were deployed at the site that used suction equipment to remove bulk contaminated equipment, one to remove Raschig rings from tanks and one to remove gravel from pits. The driver for the use of the Raschig ring vacuum [5] was the need to remove glass 'rings' (3.8 cm diameter by 3.8 cm long hollow cylinders of borated glass used to prevent nuclear criticality), while preventing contamination uptake by workers and the puncturing of protective clothing, and to package the rings in disposal compliant containers. The process used a special vacuum cleaner with sufficient power, exhaust filtration, and criticality controls such that it could be used as an alternative to hand removal. In one building, pits up to 6 metres in depth containing potentially contaminated gravel inside the building represented a significant and unique technological problem. The site obtained a vacuum system [6] similar to that used in mining operations and modified it to act as its own shipping container. Sufficient HEPA filtration was used to ensure that radioactivity was not spread during the vacuum operation. Both systems were very successful.

Fogging [7]. The driver for fogging was the need to reduce the airborne contamination present in rooms to acceptable levels for workers in more work efficient forms of PPE. Very high air contamination levels were often present in canyon or vault areas, and were exacerbated by work activities that disturbed and suspended contaminated dust. The fogging process involved the use of a device to diffuse an aqueous aerosol (i.e. 'fog') containing glycerol through an opening into the contaminated room or space, effectively 'scrubbing' the air of particulate. Upon drying, the highly mobile contaminated dust was deposited on surfaces, reducing the airborne contamination levels by orders of magnitude. The deposited glycerol was much less susceptible to resuspension, and it was soluble and thus could be subsequently decontaminated from facility surfaces. Dyes that fluoresced in ultraviolet light could also be added to the fogging liquid to allow easy identification of contamination on clothing during removal of PPE. Fogging was very successful and contributed to significant reductions in worker exposure.

Chipless duct cutter [8]. The driver for the development of the chipless duct cutter was the large amount of the highly contaminated cylindrical exhaust duct that had been used to maintain the negative pressure differential for process equipment. The duct was difficult to remove due to its often inaccessible location, the difficulty in fixing contamination within the duct, and the difficulty in erecting contamination barriers. Saw cutting resulted in a substantial spread of contamination and increases in the level of airborne contamination, as well as higher injury rates from the reciprocating saws. The duct cutter used a rotating cutter (similar in principle to a pipe or tube cutter), where knives were rotated around the cylindrical duct until the duct was sectioned off. The cutter could be operated using small, semi-enclosed contamination control structures to minimize contamination spread, due to its proximity to the duct and the relatively low ejection of contamination during cutting (as opposed to a saw blade that moves in and out of the contaminated duct interior). The limited set up area allowed work to take place in confined or elevated areas such as duct or pipe chases. Round duct was removed in sections convenient for packaging, with duct ends sleeved and tied off — the duct interior was not exposed to the working environment during handling. The duct cutter worked very effectively with minimal problems.

Hydrolasing [9]. The driver for the use of hydrolasing was that for the plutonium facilities, most of the contamination on concrete was near the surface, in many cases encased in layers of paint. There was a need to rapidly remove paint and the upper surfaces of concrete without causing contamination spread or airborne contamination. The paint removal was also necessary to allow the survey of the underlying structural surfaces to determine residual contamination levels prior to facility demolition, since the paint also masked surface alpha emissions. The hydrolasing process used an ultrahigh pressure water spray that readily removes the paint and surface layer of concrete without deep penetration and without creating substantial airborne contamination. The decontamination technology was less sensitive to cracks and small variations in surface smoothness than some mechanical decontamination techniques. Initially spray nozzles were hand held which represented a safety hazard. Subsequently, the spray nozzles were mounted within a contained, movable, vacuum supplied enclosure similar in size to a lawnmower housing. The water and solids were vacuumed into a cyclone separator with a filter that separated the solids as a waste sludge and allowed the recycling of the water. The movable enclosure was deployed from a hydraulic boom to decontaminate floors, walls, ceilings, and columns. Results were generally good, although after about three passes contamination appeared to be driven further into the concrete. The technology was dependent upon the liquid waste treatment technology to allow recycling of the water and was used in conjunction with concrete cutting, scabbling or impact hammering for the removal of the 'hot' spots identified after the surface paint has been removed. It competed with cheaper, dry surface techniques like concrete shaving, particularly in uranium buildings, and as a relatively more complex system, hydrolasing use became restricted to those surfaces which dry concrete shaving or scabbling could not address.

Structural foam/encapsulant [10]. The driver for implementing the use of container foaming was to avoid the shifting of cargo container contents in transit and the attendant potential for the container to be breached. Additional benefits were the abilities to meet disposal facility subsidence requirements and to provide additional contamination control. The original procedures for cargo container packaging required custom carpentry to provide wood blocking and bracing to maintain container integrity while in transit to the disposal site. The new process consisted of filling the cargo container, tank, or glovebox with non-expansive foam after the container had been filled with waste, certified, and closed. Foam was inserted through a small drilled hole using a standard industrial foaming system. Foam bracing worked well in smaller spaces up to the size of cargo containers, however, when used in very large room size void areas, heat generation during exothermic curing and the resultant combustion potential became a limiting factor.

Development of the 'InstaCote' process for packaging large pieces of equipment [11]. The driver for developing the 'InstaCote' packaging process was to avoid having to perform the size reduction of large pieces of equipment – pieces too large to fit in a standard cargo container. Some pieces of uranium metal forming equipment had been purchased and received as a single massive unit, and would have taken months to size reduce. Instead of creating custom strong, tight boxes around the equipment, the ‘InstaCote’ process was developed. The oversized equipment was placed on a strong pallet, shrink wrapped, and sprayed with multiple layers of ‘InstaCote’ polyurea coating (similar to truck bed liner) to form a ‘strong-tight’ container. Thousands of man-hours of difficult and dangerous size reduction were avoided by the use of ‘InstaCote’.

Gas generation testing to improve TRU waste characterization [12]. The requirements for shipping and disposing of TRU waste include criteria for limiting the amount of hydrogen that may be present within the waste, and provide a standard formula that may be used to estimate the amount of hydrogen based on the TRU activity and packaging configuration. The requirements also allow for direct testing of the hydrogen levels in the waste drums or other approved containers. Use of the standard formula would have required repackaging materials into containers with as little as 9 g of plutonium per drum, well below the 325 g of plutonium otherwise allowed. The site estimated that repackaging to meet the standard formula criteria would generate 17 000 additional drums. As an alternative, the site developed a programme to test the actual levels of hydrogen in the drums, which included providing the reproducibility and quality assurance necessary to receive appropriate disposal site and regulatory approval. The mobile system allowed drums to be characterized in their storage location with relatively little additional movement. As a result of using this system the site avoided the repackaging, and the transportation and disposal of 17 000 additional drums of TRU.

5. CONCLUSION

The technologies that will be applicable to a closure project will vary — based on the kind and magnitude of the site characteristics and the project scope. The magnitude of the plutonium process decommissioning and the nature of the contamination defined how technologies could be applied at Rocky Flats. It was found that placing the decisions on technology deployment in the hands of the management directly responsible for the execution of the activity ensured that the effort remained focused and accountable, and was more likely to be deployed. This was also an excellent way to engage the workforce and gain their acceptance of the technology, since in most cases it is the workforce that uses the new technology.

Beginning work and creating incentives to deploy new technologies to address specific problems has a greater chance of success than creating new technical systems and waiting for the need to appear. This is the evolutionary versus revolutionary mindset which Rocky Flats found to be consistently more effective. Rocky Flats also came to conclude that the impact of a number of technical innovations was greater than the sum of the individual innovation impacts, due to synergy, compounding, improvement of schedule, and reduction in complexity.

Decommissioning is an inherently crude business that requires flexibility and resists elegant solutions. In general, Rocky Flats had greater success with straightforward technology applications, as compared with highly engineered equipment. The planning process should support the continual re-examination of activities to evaluate how technology improvements can address safety, cost and schedule. It was found that in seeking the right balance for technology, the criteria that improves worker safety often leads to improved cost and schedule efficiency, especially when it focuses on improving methods and tools for achieving work.

REFERENCES

[1] UNITED STATES DEPARTMENT OF ENERGY, Chemical Decontamination of Gloveboxes and Tanks Improves Safety, Reduces TRU, Demonstration & Deployment Summary (2003), http://www.rfets.gov.

[2] UNITED STATES DEPARTMENT OF ENERGY, Plasma-arc Cutting Technology, Demonstration and Deployment Summary (2001), http://www.rfets.gov.

[3] UNITED STATES DEPARTMENT OF ENERGY, Temporary Structures for Remediation of High-Contamination Areas, Demonstration and Deployment Summary (2002), http://www.rfets.gov.

[4] UNITED STATES DEPARTMENT OF ENERGY, Ultra-High Pressure Water Jet Used to Remotely Cut B774 Tank, Demonstration and Deployment Summary (2002), http://www.rfets.gov.

[5] UNITED STATES DEPARTMENT OF ENERGY, Raschig Ring Vacuum System, Demonstration and Deployment Summary (2001), http://www.rfets.gov.

[6] UNITED STATES DEPARTMENT OF ENERGY, Vac and Ship System Removes Gravel from B776 Suspected Burial Equipment Sites, Demonstration and Deployment Summary (2003), http://www.rfets.gov.

[7] UNITED STATES DEPARTMENT OF ENERGY, Passive Aerosol Generator Reduces Worker Risk During Decontamination Activities, Demonstration and Deployment Summary (2003), http://www.rfets.gov.

[8] UNITED STATES DEPARTMENT OF ENERGY, Chipless Duct Cutter, Demonstration and Deployment Summary (2003), http://www.rfets.gov.

[9] UNITED STATES DEPARTMENT OF ENERGY, Hydrolasing Technology for the Cleanup of Radiologically Contaminated Surfaces, Demonstration and Deployment Summary (2002), http://www.rfets.gov.

[10] UNITED STATES DEPARTMENT OF ENERGY, Polyurethane Foam Developed to Block and Brace Waste Container Contents, Demonstration and Deployment Summary (2003), http://www.rfets.gov.
[11] UNITED STATES DEPARTMENT OF ENERGY, Polyurea Coating Becomes Shipping Container for Radioactive Waste, Demonstration and Deployment Summary (2002), http://www.rfets.gov.
[12] UNITED STATES DEPARTMENT OF ENERGY, Gas Generation Testing Technology, Demonstration and Deployment Summary (2001), http://www.rfets.gov.

DISCUSSION

S. SAINT-PIERRE (World Nuclear Association): How did you manage to innovate and at the same time remain in compliance with your licence?

F.R. LOCKHART (United States of America): Although we did not have a licensing regime, we had release criteria and also cleanup standards set both by our federal regulator and by our state regulator. In addition, the Defense Nuclear Facility Safety Board imposed very strict rules regarding occupational exposure control of employees and the techniques that we might be able to use or not use.

Those considerations were included from the start, and all the way through our process, so it was integral to both the planning and the implementation.

In a practical sense, probably the way that it played out the most was with the involvement of the overseers. We invited our regulators to come and see the technologies being used in the buildings, and, when we considered potential changes, something that they had become familiar with that we now wanted to switch to something else or try something else or maybe just change it a little, we would discuss these with them — sometimes right on scene, right in the buildings — in advance and share the results. We shared the data with them as well, so that they could see what was happening — well, what was not happening.

In summary, we developed and applied evolutionary approaches in consultation with the regulator.

G.A. BENDER (United States of America): I know that there are a lot of rail shipments to commercial disposal sites in Utah. Can you say something about how the cost or technology would have been affected if no State would have received the waste from Colorado?

F.R. LOCKHART (United States of America): We kept that as part of the consideration all the way along. The use of commercial disposal sites gave us some options for disposing of much larger volumes of some low level but still contaminated and not free releasable waste forms.

Usually, commercial facilities have strict limits, and below certain contamination levels they will not accept the waste. So, it was a trade-off, and it influenced a number of the technologies that I described. We had to try to make sure that before we did decontamination and demolition work using a particular approach there would be a path for the waste — all the way through to a disposal facility.

However, the use of commercial facilities allowed us to save a lot of money and time by avoiding having to package large volumes of waste.

PANEL DISCUSSION

Session 6

TECHNOLOGY ASPECTS

Chairperson: **L. VALENCIA** (Germany)

Members: **L. NOYNAERT** (Belgium)
W.Z. OH (Republic of Korea)
V.G. VOLKOV (Russian Federation)
C.J. WOOD (United States of America)

L. VALENCIA (Germany — Chairperson): I invite the panellists to respond to the question 'Based on the experience to date, what are the main factors to be considered in selecting decommissioning technologies and how can one improve the exchange of lessons learned internationally?'

L. NOYNAERT (Belgium — panellist): The first factor to be considered is the nature of the problem to be solved. That should determine the pre-selection of technologies. After that, one needs to consider radiological and industrial safety and waste management — with some technologies, one may create waste types that are very difficult to manage. Before a final choice is made, one should consider whether the favoured technique is sufficiently mature and how much it costs.

As regards the second part of the question, there is much information available in the literature and on the Internet, but in my view the best way of exchanging lessons learned internationally is through bilateral contacts and through workshops on very specific topics.

W.Z. OH (Republic of Korea — panellist): The goal in selecting technologies for a decommissioning project is to minimize the overall costs of decommissioning and subsequent waste management while meeting the safety requirements and carrying out the project within a reasonable time and in a manner acceptable to the public. Multi-attribute analysis and cost–benefit analysis can help in attaining that goal.

When considering the project cost, besides the costs of dismantling and waste management, one should take account of the costs of such things as licensing, characterization and decontamination.

In preparation for the decommissioning of two research reactors, the Korea Atomic Energy Research Institute (KAERI) sent three staff members — including me — to the USA in the 1980s to gain on the job experience by participating in the Shippingport and West Valley decommissioning projects. In 1987, a conceptual planning study for the decommissioning of the two Korean research reactors was carried out with the help of a US company, but when we started decommissioning — in 1997 — we were able to do it ourselves, the project team consisting mainly of R&D personnel.

V.G. VOLKOV (Russian Federation — panellist): In my view, when selecting any technology it is important to consult real experts — people who have been working in the field in question for all of their professional lives. At our centre there are over 2000 people who have been working with radioactive materials for years, and I believe in drawing on the experience of such people. In particular, they know and can tell you about the limitations of a given technology — something that you may well not hear about from those who are advocating that technology.

A major factor to consider is whether the favoured technologies will enable you to complete the job, rather than leaving you with unfinished business for which you will need other technologies.

As regards price, you must bear in mind the costs of maintenance and repairs.

Last but not least, if possible you should visit a site where a favoured technique is being applied in order to see it in operation.

C.J. WOOD (USA — panellist): I would first refer you to contributed paper IAEA-CN-143/108 (‘D&D progress at United States Department of Energy sites: Practical implementation of lessons learned from Rocky Flats’), which describes a probabilistic approach to estimating the maturity of a technology and its suitability for use.

The main factors to be considered in selecting a decommissioning technology include the availability of data on field tests and demonstrations carried out under appropriate conditions and of experienced contractors to apply the technology.

The control of radiation exposure during demolition activities has been a major challenge at several nuclear power plants, particularly ones where demolition started immediately after final shutdown. At Big Rock Point, Maine Yankee and Connecticut Yankee, full coolant system chemical decontamination was carried out before the start of decommissioning; at US plants where decommissioning work did not start until several years after final shutdown (including Trojan, Rancho Seco and San Onofre-1), thanks to radioactive decay no decontamination was necessary.

The lessons learned from the chemical decontamination work included the following: evaluate both the performance of the various available chemical decontamination processes and the experience of the vendors or contractors before selection; and apply the selected process as soon as possible after final shutdown, while the necessary equipment is still operational and expert staff is still available.

If carried out correctly, chemical decontamination can reduce worker radiation exposures due to contamination (for example, with cobalt-60) by a factor of ten. However, radiation dose rates from activated materials (for example, reactor vessel internal components) cannot be reduced by chemical decontamination — shielding and remote handling are necessary in order to minimize worker radiation exposures.

As regards the second part of the question put to the panel, the Electric Power Research Institute (EPRI) publishes guidelines on the application of specific technologies. The guidelines are prepared by teams of technology developers, industry specialists and plant operators who have used the particular technology. The recently published guidelines include one on alpha contamination and one on groundwater tritium monitoring.

A. FABBRO (Argentina): One factor that should be considered is the part of the world where the technology is going to be applied. Some technologies are difficult to apply in Latin America because of problems with maintenance and spare parts.

In addition, one must consider whether suitable waste disposal facilities are available in the country where the technology is to be applied.

B. BATANDJIEVA (IAEA — Scientific Secretary): Regarding the second part of the question put to the panel, I would draw participants' attention to the IAEA's Decommissioning Forum.

The IAEA is planning to organize workshops on specific decommissioning-related topics, along the lines probably envisaged by Mr. Noynaert, and is also considering the establishment of an international centre for the exchange of lessons learned, especially lessons relating to decommissioning technology.

C.J. WOOD (USA — panellist): In October 2007, EPRI is holding a workshop on technical developments in the decommissioning field at the IAEA's Headquarters in Vienna.

D.W. REISENWEAVER (USA): The US Department of Energy issues a newsletter on lessons learned in the decommissioning and other fields, and I would like to see the IAEA issuing a newsletter — say, every quarter — on decommissioning lessons learned.

L. VALENCIA (Germany — Chairperson): The OECD/NEA runs an information exchange programme covering many aspects of the decommissioning of all types of facility. The programme is not open to commercial companies, but otherwise all are welcome to participate in it. Within the framework of the programme, visits to decommissioning projects in different countries are organized twice a year.

S. HARRIAGUE (Argentina): I think it would be useful to establish regional networks for the exchange of lessons learned in the decommissioning field. Perhaps the IAEA could help with the establishment of such networks.

W.Z. OH (Republic of Korea — panellist): In 2004, the IAEA published a booklet entitled 'Status of the decommissioning of nuclear facilities around the world'. From that booklet one can see that the decommissioning costs for a reactor of a given capacity may vary by up to a factor of ten. However, the booklet does not give detailed breakdowns of the costs of individual decommissioning projects. Such information would be useful to those who are new in the decommissioning field.

L. VALENCIA (Germany — Chairperson): Regarding Mr. Harriague's comment about regional networks, the IAEA has started to organize regional courses on decommissioning. There has been one course held in Argentina and one in Italy, and one is soon to be held in Germany.

In my view, it is important that the people from developing countries who participate in courses and workshops on decommissioning not hesitate to ask questions — that is the best way to learn. At the same time, they should bear in mind that there is a limit to what developing countries can learn from the experience of advanced countries.

E. WARNECKE (IAEA): I should like to mention the IAEA's Research Reactor Decommissioning Demonstration Project, in which participants from Asian and other countries can follow the decommissioning of the Philippines Research Reactor-1. We are hoping to expand that project through the inclusion of further research reactors.

G. RINDAHL (Norway): On-line information cannot replace courses and workshops, but it is important that the information available on-line be kept up to date.

There are now young people who use computers in their work in ways unknown to us when we were their age.

M. DRAGUSIN (Romania): In my country, where the financial resources for decommissioning are very limited, financing involves major problems. For example, if we receive funds from the European Commission we are expected to use the technologies only of companies belonging to European Union countries. In that connection, I would mention that, in the bids which we receive from various companies, some 60% of the focus is on financial aspects and only about 40% on safety and other technical aspects.

A problem not mentioned so far regarding the selection of decommissioning technologies is due to the fact that in a very long decommissioning project some selected technologies will not start to be used for several years, by which time there may have been important relevant technical developments.

L. VALENCIA (Germany — Chairperson): When choosing between technologies, I consider first the technical aspects and only afterwards the commercial aspects. I prefer to use the best technology even when it costs a little more. There have been very bad experiences with the use of sub-optimal technologies.

L. NOYNAERT (Belgium — panellist): When we invited bids for dismantling the steam generator, the pressurizer, the neutron shielding and other components of the BR-3, we received three involving use of the same technology. They differed in price by a factor of three. We had adequate financial resources, but, in a spirit of economy, we opted for the lowest bid, and the result has been a two year delay. If we were making such a choice now, we would not opt for the lowest bid but for something between it and the highest bid.

If your decommissioning budget is insufficient for the complete job, perhaps the best decision is not to start the job.

L. VALENCIA (Germany — Chairperson): I now invite the panellists to respond to the question 'How do you decide between innovative and adaptive decommissioning technologies?'

L. NOYNAERT (Belgium — panellist): When we were preparing to decommission a steam generator, we were approached by a manufacturer who wished to test a new diamond wire on that kind of component. We invited the manufacturer to carry out a 'cold test' on a representative mock-up provided by us (not a laboratory test). The 'cold test' was successful, so we asked the manufacturer to supply us with some of the new diamond wire and send people to help us use it instead of the cutting technology previously selected. This underlines the importance of testing a new technology before using it.

We need new technologies, if only in order to comply with changing requirements in areas such as radiation protection.

W.Z. OH (Republic of Korea — panellist): I think that in most cases it is sufficient to adapt existing technologies, but there is a need for innovation in some decommissioning areas — for example, graphite dismantling and the management of graphite waste.

A major consideration regarding innovative technologies is uncertainty about their future availability and cost. Developing countries, in particular, should therefore think in terms of adapting the technologies already available (including technologies being used in non-nuclear sectors). The adaptation process will be facilitated if the related basic research and development work is done beforehand. That has been shown by the experience of KAERI in decommissioning two TRIGA reactors and a uranium conversion plant.

IAEA-TECDOC-1476 'Financial aspects of decommissioning' pointed to big differences (of up to the order of ten) in decommissioning costs for reactors of the same capacity. In my view, the differences were due to the lack of a nuclear decommissioning industry in some countries and to differing abilities to adapt existing technologies.

V.G. VOLKOV (Russian Federation — panellist): As a general rule, in decommissioning one should use proven technologies. Sometimes, however, one needs a new technology — and must spend a lot of time and money on developing it. We found that in the case of soil decontamination.

In the case of research reactor decommissioning, it is a good idea to make the greatest possible use of the technologies that were used for reactor maintenance. In the decommissioning of a pool-type research reactor, much of the work can be done under water — something to which the maintenance personnel are accustomed.

C.J. WOOD (USA — panellist): The choice between innovative and adaptive technologies will depend on the need — if existing technologies cannot be adapted, innovative technologies have to be considered.

In the USA, nuclear power plant operators ‘rush to be second’. It is difficult to find someone who will be the first to use new technologies, but once the new technologies have been used for the first time, with satisfactory results, other users soon follow.

Other considerations with new technologies are technical support and flexible procedures for dealing with unforeseen problems. It is all a matter of contingency planning — anticipating the unexpected. For example, during chemical decontamination at one plant we encountered unexpectedly large amounts of corrosion products. However, thanks to the fact that ample reserves of chemicals and ion exchange resins had been laid in, the resulting delays were not too long.

L. VALENCIA (Germany — Chairperson): We had to cut some reactor internals with a thickness of 130–150 mm under water. Techniques such as plasma arc cutting did not work at depths of more than 10 m, so we decided to try the contact arc metal cutting technique. As we had no experience of that technique, we first, together with the regulator, carried out extensive mock-up tests. The test results were satisfactory, so we then used the technique on the actual reactor internals. The cutting was very precise and there was less secondary waste than with other techniques. My message is — if you have a particular problem, rather than trying a sophisticated new technique that has not been thoroughly proven, take a commercially available, well-proven technique and adapt it to your needs.

R.K. CHUGHA (India): A problem we encountered in cutting operations connected with the replacement of power reactor coolant channels was that the personnel who were to carry out the cutting with conventional techniques would have to get very close to the reactor core, thereby receiving a high radiation dose. We developed a plasma arc cutting technique that would obviate the problem, but before using it at the reactor we carried out mock-up tests over a period of several months.

L. VALENCIA (Germany — Chairperson): That underlines the importance of testing new techniques.

J.J. BYRNE (USA): During the Three Mile Island-2 cleanup, we came to realize that the people who were using a given technique and were very familiar with it often had good ideas about how to adapt it to particular situations. In order to encourage suggestions for adaption, we began offering financial incentives — ‘If we save so much time or reduce the dose by so much, you will receive so much money.’ The incentive system worked very well.

C.A. NEGIN (USA): How important is it to involve operator personnel in the development or selection of decommissioning techniques?

L. NOYNAERT (Belgium — panellist): I think it is useful if operator personnel and manufacturers collaborate in the development of such techniques.

C.J. WOOD (USA — panellist): When it is a matter of improving a technique already in use, the experience of operator personnel can be crucial, and one should involve the such personnel as early as possible.

When it is a matter of developing a new technique, one needs to find a ‘champion’ higher up in the organization.

L. VALENCIA (Germany — Chairperson): Further to Mr. Byrne’s comment, at the Karlsruhe research centre we have an incentive system, with prizes for the best inventions and adaptations.

M. DRAGUSIN (Romania): Where possible, we use only proven technologies. If it becomes necessary to use a new technology, we first test it under real conditions — not on a mock-up. It is usually possible to adapt a proven technology during use, and it is often necessary to do so as no research reactor is exactly like another.

T. LAGUARDIA (USA): When planning a decommissioning project, it is necessary to identify the tasks with the longest lead times. Those tasks are usually the ones that will require the use of innovative and adaptive technologies, and it is important to give the contractors enough time to develop and test them.

SOCIAL AND ECONOMIC ASPECTS

(Session 7)

Chairperson

A.J. BAER
Switzerland

Rapporteur

S. SAINT-PIERRE
World Nuclear Association

OECD/NEA LESSONS LEARNED ON STAKEHOLDER ISSUES IN DECOMMISSIONING

C. PESCATORE
OECD Nuclear Energy Agency,
Issy-les-Moulineaux,
claudio.pescatore@oecd.org

A. VÁRI
Hungarian Academy of Sciences,
Budapest,
Hungary

Abstract

Issues of public concern during decommissioning and dismantling are partly the same and partly different from those of the preceding phases (planning, construction and operation). While in the course of construction and operation, the main challenges include meeting expectations of a higher quality of life, accommodating a growing population, mitigating construction nuisances, and assuring the safe operation of the facility, the main concerns in the decommissioning phase are the decreasing employment rate, the eventual reduction of revenues for the municipality, the future use of the affected land and negative social impacts (e.g. out-migration). The decommissioning phase is characterised by the heterogeneity of stakeholder interests and values, the difficulties in reaching consensus or compromise, and the difficulties in connecting with the harmonization of energy production, environmental protection and sustainable socio-economic development considerations. Typically, there might also be tensions between local and regional decisions. As in other phases, the building of trust between stakeholders is crucial from the point of view of conflict management, and social lessons learnt from the siting and developments of nuclear facilities are widely applicable in the field of decommissioning. A review is presented of major lessons to be learned from OECD/NEA activities in the field of decommissioning and stakeholder involvement.

1. INTRODUCTION

1.1. Decommissioning work within the OECD/Nuclear Energy Agency

The OECD/Nuclear Energy Agency (OECD/NEA) is a specialized agency within the Organisation for Economic Co-operation and Development

(OECD), an intergovernmental organization of industrialized countries, based in Paris, France. The mission of the OECD/NEA is to assist its member countries in maintaining and further developing, through international cooperation, the scientific, technological and legal bases required for the safe, environmentally friendly and economical use of nuclear energy for peaceful purposes.

The OECD/NEA has been engaged for over twenty years in helping member countries to find sustainable solutions for the long term management of radioactive waste including decommissioning. Its standing committee on Radioactive Waste Management (RWMC) works on issues related to policy, governance, technical and stakeholder confidence.

The NEA Working Party on Decommissioning and Dismantling (WPDD) brings together senior representatives of national organizations who have a broad overview of decommissioning and dismantling (D&D) issues through their work as regulators, implementers, research and development experts or policy makers. Example study issues include: policies and strategies for the decommissioning of obsolete or phased-out nuclear facilities, funding, recycling, reuse and/or disposal of materials, and the release of buildings and sites. The web page http://www.nea.fr/html/rwm/wpdd.html provides complete information. Within the joint undertaking of currently 11 OECD/NEA member countries and one associated non-member economy, known as the Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD), experience is shared on decommissioning work from 43 ongoing projects.

In close cooperation with the OECD/NEA Forum on Stakeholder Confidence (FSC), the WPDD is concerned with the sharing of experience in addressing the societal dimension of decommissioning and is exploring means of ensuring an effective dialogue with the public with a view to strengthening confidence in decision-making processes. The ability of organizations to communicate and to adapt to the new context has emerged as a critical contributor to public confidence and decision-making. The new dynamics of such processes can be characterized as a shift from a more traditional ‘decide, announce and defend’ model, focused on technical assurance, to one of ‘engage, interact and co-operate’, for which both technical excellence and quality of the decision-making process itself are of comparable importance for a constructive outcome.

1.2. OECD/NEA materials regarding stakeholders and decommissioning projects

Stakeholder involvement issues have been debated within the WPDD since its founding in 2001. Representatives of non-institutional stakeholders attended WPDD meetings and have played a major role in WPDD organized international seminars, namely the Rome Workshop on ‘Safe, Efficient, and Cost-effective Decommissioning’, September 2004, and the Tarragona Seminar on ‘Strategy Selection for the Decommissioning of Nuclear Facilities’, September 2003. At its sixth meeting, in Paris, 14–16 November 2005, the WPDD held a topical session on Stakeholder Involvement in Decommissioning Projects. The topical session was jointly planned and run with members of the NEA Forum on Stakeholder Confidence (FSC). The latter is a major initiative in the field of stakeholder involvement. During a recent workshop in Spain (November 2005), the decommissioning of the Vandellós-I nuclear power plant was discussed in depth. The FSC web page is: http://www.nea.fr/html/rwm/fsc.html. The Topical Session provided a stimulus to review the contributions in the area of stakeholder involvement that the WPDD and FSC have received since their inception. A document has been assembled compiling the papers from the stakeholders’ contributions to WPDD events, and a forthcoming brochure will complete the review by focusing on lessons to be learned. The brochure will be published by the OECD/NEA in Spring 2007. This paper represents an intermediate step to the brochure and provides a portal to NEA documentation on stakeholder issues in decommissioning.

2. INTERESTS VIS-À-VIS THE NATIONAL ENERGY POLICY

2.1. Links with shutdown decisions

The decommissioning of a nuclear power plant may occur because the plant has reached the end of its lifetime, because of an unexpected event (e.g. an accident), or because of a political decision on phasing out. In all of these cases, decommissioning creates environmental, economic and social impacts on the region directly involved and (due, for example, to a resultant change in energy prices or to measures to compensate for a shortage in energy supply) on the whole country. Hence, the shutdown — just as the opening — of nuclear power plants should be preceded by impact studies and should include public debates. While in most countries it is prescribed by law that the affected stakeholders should be heard during the decommissioning phase, local stakeholder involvement is not required in relation to decisions on stopping electricity generation.

By analogy with experience from the establishment of nuclear power plants, it might be observed that when the closing down of these facilities is part of a widely accepted national energy policy framework, decommissioning decisions are more likely to be supported. Open and fair national debates on the preferable mix of various energy sources need to be conducted, in which environmental, economic, social and political impacts are addressed. The question of 'how and from where the diminished electricity supply is to be replaced' requires special attention, since it may affect local, regional, national, and often also international interests. Lack of a timely dialogue with affected communities is one of the reasons for conflicts related to the shutdown of several nuclear power plants. One recent example is Barsebäck [1].

2.2. Link to national radioactive waste management policy

The importance of the interactions between national radioactive waste management policies and local/regional decisions is high. Decisions are made easier if a facility exists for the storage of radioactive waste originating at the nuclear power plant site, or at least a radioactive waste management programme that holds the promise of the establishment of such a facility in the foreseeable future. When these conditions are not met, nuclear power plants may be seen to operate as 'de facto' waste storage facilities [2]. At the same time, decommissioning does produce waste, and decommissioning becomes one of the items in the debate about national solutions for radioactive waste [2].

3. THE LOCAL DIMENSION

3.1. Attention to socioeconomic gains and losses

The local population of candidate sites, the affected local and regional authorities, the operator and the employees of the relevant facility should be involved in making decisions concerning the phasing out (or expansion) of energy production [1, 3]. In such debates, special attention should be paid to the following questions: 'What environmental and socioeconomic gains and losses will accompany the planned shutdown (expansion)?' and 'How and when will the affected communities be compensated and by whom?'

Although decisions on closing down or expansion are similar to the ones associated with choosing a site for a facility, there are also differences. While in most countries, local communities have a say in decisions on siting a new facility (in several countries municipalities have informal or formal right of veto), they have less power in the case of a decision to close a facility (and no municipality has the right of veto). Consequently, it is more difficult for the affected municipalities to negotiate compensation in relation to decommissioning than for the siting of a new facility. Nevertheless, the operator should initiate a dialogue with the affected municipalities and try to find mutually acceptable solutions. These solutions pertain to public information and local control, as well as the mitigation and compensation of negative socio-economic impacts.

In the course of the Vandellós-I decommissioning process, the implementer, ENRESA, tried to mitigate the negative socioeconomic impacts of shutdown by hiring local and provincial companies to participate in dismantling activities. As a result of these policies, about 65% of the personnel were local and provincial workers and a total of 1800 people were involved during the period 1998–2001. Other important contributions to the local economy included revenues from licences and permits, compensation in the form of fees for waste storage, and payments to the administrations of the area to promote economic, cultural, etc. activities [4, 5].

Compensation can also be offered to the employees of the affected nuclear facilities. For example, in the case of the decommissioning of the Barsebäck nuclear power plant, its former owner, Sydkraft Co., gave employees a five year job guarantee after the decision was taken to close the facility [3]. In general, employees of the affected nuclear facilities are among the most important stakeholders when planning decommissioning. They may also constitute an important human resource during the dismantling phase.

3.2. Involving local and regional parties in decisions

The decisions on decommissioning concern the activities to be conducted in the area of the nuclear installation (e.g. the demolition or transformation of buildings, the treatment and storage of radioactive waste), the timing of these activities, and the future use of the land. Regarding the latter, communities typically demand the earliest possible restoration to the original state of the land. An example of speedy execution of D&D operations and the involvement of regional and local actors is the case of the Lubmin nuclear power plant [1, 6].

Theoretically, various possibilities may arise in connection with future land use: industrial versus non-industrial use and, in the former case, establishing nuclear versus non-nuclear facilities. Typically, municipal governments are ready to consider new types of energy installations, since the necessary infrastructure is largely available. Examples of non-nuclear land use also exist. With respect to land use, local municipalities typically have a certain degree of legal control. In Sweden, municipalities have the right to veto any proposal to establish new installations. This may become relevant, for example, for the Kävlinge community, which plans to establish a green field and a new seaside housing area at the place where the Barsebäck nuclear power plant is currently located [1].

4. TRUST BUILDING

Affected communities usually demand safety and security guarantees and therefore it is particularly important to involve the representatives of the communities in monitoring the D&D activities. Transparency and the provision of information to the public are key factors in communicating safety and building confidence. Accurate and accessible information should be provided on a regular basis, and operators/communicators should maintain a continued presence in the community during the decommissioning phase.

Regarding public information, it is suggested that facts rather than partisan information should be communicated, and communicators should avoid the use of technical jargon. Sometimes this is very difficult:

> "Nuclear matters are complex and the nuclear community tends to suggest [that] decommissioning is technically straightforward. Hence we may assume others have understood the technical evidence, even if they dispute it. This is often not the case.
>
> Every strategic decision should have a robust rationale and should have resulted from a detailed options analysis. Anti-nuclear groups want this analysis to be visible and transparent. In some cases commercial considerations make this difficult: public domain reports should be prepared that present as much information as practicable. In some cases, this will never satisfy all objectors" [7].

Building partnerships between stakeholders is essential, and, in particular, the participation of local/regional authorities is of key importance, since they are in charge of public information and they are also the ones facing the local population and the media. Another possible mechanism for collaboration with national and regional/local parties is for the regulator to play an active role in D&D activities, not only by overseeing the process, but also by acting as the expert of the affected communities.

5. SUSTAINABILITY AND FORESIGHT

Building a sustainable host relationship implies addressing the entire life cycle of a facility and site. Where diminishing economic returns are to be expected, attention must be given to creating added cultural and amenity value for the host region.

In the field of long term radioactive waste management, partnership initiatives in Belgium and Spain have called for community sustainability funds as part of the siting ‘package’. Such funds target not only the integration of the radioactive waste management project in the life of the community, but also, increasing community capacity to play a future guardianship role.

The multi-stakeholder research programme, Cowam España, has investigated the role of financial support to host communities in ensuring sustainable development. Moving beyond the concept of short term compensation or incentives, future instruments should enable local and regional development, help the community assume responsibility for waste generated in the benefit of society at large, and serve to create and maintain local knowledge and competence to monitor management over the coming decades and generations. Cowam España suggests that stakeholders, including local and regional authorities, should focus on devising mechanisms for social learning, economic development and environmental protection over the long term; these would be supported by grant funds.

An existing European regulation related to the mining industry in general stipulates that host compensation funds must not all be ‘ear marked’ for short term needs, but must be directed in part to generating economic and cultural resources that will sustain the community over the duration [8].

When creating a new facility, it is necessary to foresee the end of its useful life. If future needs are not anticipated, there is a risk that the facility will become a liability for the community. Proper foresight — on the end use of the facility and site, or technical provisions for quick transitions to other types of facilities — provides assurance to the host community that there will be flexibility in future planning capacity. Several examples can be provided: When mines are closed some have been transformed into mining museums, offering a new tourism industry while providing a memorial of the activity that meant so much to the region and shaped it. In France, a tumulus formed of mining waste has been transformed into a ski site. In the Nord Pas de Calais, France, a mining museum also contains a cultural centre —where conferences and concerts take place. Disused nuclear power plants or facilities are also being considered as tourist sites, e.g. the Dounreay site in the United Kingdom.

6. CONCLUSIONS

Implementing the three pillars of trust, 'safety, participation, local development', is key to stakeholder interests and to the success of decommissioning and dismantling projects.

Safety is necessary for any individual to be able to act, take decisions and make use of his/her freedom. Safety during the whole lifetime of project is paramount and the project should constitute as small a burden as possible on both current and later stakeholders. Assurance of safety, e.g. through the provision of adequate information, including plans for dealing with emergencies, is thus essential for communities in the locality of a nuclear facility.

A 'decide announce defend policy' is not conducive to sustained progress. Participation in decisions is the best way forward. Site operators should involve local politicians or community leaders and co-operate with any local committees set up to oversee the community interests. This means providing them with transparent and valid information about plans and programmes, living up to commitments, and being constantly available to answer questions and hear comments. It also means providing valid information on safety and environmental matters, including radioactive waste management, and giving full consideration to concerns about effects on society, such as loss of employment, the need for alternative economic activity, the future use of the site and compensatory benefits for the community. A communicated, clear structure of interested parties and their roles is helpful to identify national and local responsibilities.

All techniques for communication have their place: conventional meetings, seminars, debates, provision of information packages for local discussions — to television programmes and web sites, supported with 'chatrooms' if appropriate. Timeliness is a key factor. The employees of the facility to be decommissioned are special stakeholders that may become a resource in the subsequent dismantling phase. Communities of sites where facilities are shut down prior to the end of life have additional special communication needs as a result of the unexpected termination of local employment.

At a local level, reflection on all aspects of the process — on technical and socioeconomic aspects, as well as on added cultural and amenity value — is best started from the very first planning stages. The information, concepts and ideas gained will form a part of the basis on which local partners may agree to the final plans.

Many good examples of nuclear decommissioning projects can be presented that show attention to stakeholder involvement and progress to successful outcomes. Important stakeholder involvement lessons can also be drawn from other parts of the nuclear fuel cycle and other industries.

REFERENCES

[1] PALMQVIST, R. The Municipality as a Stakeholder, OECD/NEA WPDD Topical Session on Stakeholder Involvement in Decommissioning, November (2005) NEA/RWM/WPDD(2006)5, see also NEA web page: http://www.nea.fr/html/rwm/docs/2006/rwm-wpdd2006-5.pdf

[2] VILA D'ABADAL, M., Untitled presentation, OECD/NEA WPDD-1 Meeting (May, 2001), OECD/NEA, WPDD: What have we heard within WPDD on Stakeholder Involvement in Decommissioning, 2001-2004. A compilation of texts, NEA/RWM/WPDD (2006).

[3] MODING, P. "Barsebäck after Barsebäck: A case study on the conflicting issues concerning and use after a total clean-up (decommissioning) of a nuclear facility", OECD/NEA WPDD-3 Meeting, (June 2002), OECD/NEA, WPDD: What have we heard within WPDD on Stakeholder Involvement in Decommissioning, 2001–2004, A compilation of texts, NEA/RWM/WPDD(2006).

[4] CASTELLNOU, J., "Local information committee and social repercussions of the closure and dismantling of Vandellós-I", Strategy Selection for the Decommissioning of Nuclear Facilities (Proc. OECD/NEA Seminar Tarragona, Spain, 2003), OECD, Paris (2003).

[5] LANG LENTON, J., "Dismantling of the Vandellós-I nuclear power plant: The implementer's perspective", paper presented at a workshop held in Spain by the OECD/NEA Forum on Stakeholder Confidence, November, 2005 (in preparation).

[6] BÄCKER, A., "Views from stakeholders regarding stakeholder involvement and their role", OECD/NEA WPDD Topical Session on Stakeholder Involvement in Decommissioning, November, 2005. NEA/RWM/WPDD(2006)5, see also NEA web page: http://www.nea.fr/html/rwm/docs/2006/rwm-wpdd2006-5.pdf

[7] WOOLLAM, P.B. "Experience from the Trawsfynyd D&D Public Inquiry", OECD/NEA WPDD-4 Meeting (September 2003), Strategy Selection for the Decommissioning of Nuclear Facilities (Proc. OECD/NEA Seminar Tarragona, Spain, 2003), OECD, Paris (2003).

[8] EUROPEAN COMMUNITIES, Regulation CE 1407/2002 of the European Council, 23 July 2002

DISCUSSION

G. KOROLL (Canada): Nuclear facilities tend to provide the best jobs in the areas where they are located, and the loss of those jobs can be devastating for the local communities. The accelerated decommissioning of nuclear facilities brings with it a continuation of concentrated economic activity, but for only a relatively short time, after which the local communities are left with very little.

C. PESCATORE (OECD/NEA): That is a good point. One needs to think well ahead about the sustainability of the local community and perhaps create a sustainability fund so that the local community does not one day find itself completely 'naked'. Also, one should consult regularly with the local community about how it is developing and will develop over time.

SOCIAL ASPECTS OF THE CHERNOBYL NUCLEAR POWER PLANT DECOMMISSIONING PROCESS

O. MAKAROVSKA
State Nuclear Regulatory Committee of Ukraine,
Kiev,
Ukraine
Email: makarovska@hq.snrc.gov.ua

Abstract

The paper highlights certain social aspects of the Chernobyl nuclear power plant decommissioning process. It describes the process of eliminating the consequences of the accident — a process that was carried out on an 'ad hoc' basis without the support of an adequate financial reserve. The implementation of national legal requirements and the result of the introduction of social oriented state programmes are described. The paper covers the problems which resulted from the termination of operations at the plant and underlines the role of the international community and the public in preserving the specific knowledge and gained experience.

1. INTRODUCTION

The 20th anniversary of the Chernobyl accident led to a thorough review of the associated events and consequences and prompted further discussions within the international community, researchers and the public.

The National Report of Ukraine titled '20 Years after the Chernobyl Accident: The Perspectives' arrived at the following conclusions:

— The management of the systems used for nuclear energy production require an extremely high safety culture from the operators;
— The countries, which use nuclear energy are obliged to establish and maintain a reliable system of training and refresher courses, and to maintain high standards of management and scientific and technical support;
— Well exercised interfaces between all responsible organizations must be established to respond to abnormal situations; governmental agencies, operators, scientific and technical support organizations and local authorities, public organizations and private persons should be involved on the

basis of confidence, clear distinction of responsibilities, competence and mutual respect;
— Lessons learned from the Chernobyl accident must be used to contribute to the international experience in emergency response and the mitigation of psychological discomfort caused by radiation risks.

The role of human factors associated with the causes and consequences of Chernobyl accident is hard to overestimate. And even now major problems are emerging in the social sphere. Certain social aspects of the Chernobyl nuclear power plant decommissioning process which originated directly from the elimination of the accident's consequences and which are now being solved under non-typical conditions are highlighted in this presentation as follows:

— Legislative and administrative;
— Financial and economic;
— Social and psychological.

In accordance with the Memorandum of Understanding between the Government of Ukraine, the G-7 and EU Countries on the Closure of Chernobyl NPP, the power plant was closed on 15 December 2000. It was closed earlier than planned, before the design operating time of units 1, 2 and 3 was over.

Since the beginning of operations in 1977, the Chernobyl plant has produced 308.7 billion kilowatt-hours for the national economy of the USSR and Ukraine, including 158.5 billion kilowatt-hours after the accident at Unit 4. That is, 8 billion kilowatt-hours higher than before the accident.

The annual profit from the operation of the plant provided finance for the staff material incentive fund, the social development fund, the production development fund and social infrastructure fund of the city of Slavutych. The plant allocated funds of about 143 million hryvnias (about €23 million) to maintain and build the social infrastructure facilities of that 'nuclear power plant oriented' city. Until 2000, 99.5% of output of the city of Slavutych was concerned with the Chernobyl plant's energy production.

The closure of the plant as a power generation facility lead to a loss funding to the Slavutych city budget, the loss of about 10 000 jobs, and the possibility of additional funding and support loss for veterans, pensioners and other unprotected strata of the public. It should also be noted that Slavutych city area is under intense radioactive monitoring (according to the CMU Resolution №106 dated 23.07.1991). A total of 17 300 persons out of 24 365, who lived in Slavutych as of 01.01.05 have the status of Chernobyl accident victims under the following categories:

— I Category: 661 persons;
— II Category: 5233 persons;
— III Category: 2209 persons;
— Children, who are victims of the accident: 5847 persons.

2. LEGISLATIVE BASIS

In order to provide social protection for Chernobyl plant workers and the residents of Slavutych due to the early decommissioning of the plant, the President of Ukraine, the Cabinet of Ministers of Ukraine and Verkhovna Rada of Ukraine passed a number of important laws and legal acts aimed at solving problems caused by the closure:

— Law of UkraineNo. 2398-III On Superseding Certain Laws due to ChNPP Closure, dated 26.04.2001;
— Law of Ukraine No. 1907-IV On Superseding Article 12 of the Law of Ukraine On General Principles of Further ChNPP Operation and Decommissioning and the Transformation the Ruined Power Unit 4 into the Ecologically Safe System, dated 29.06.2004;
— CMU Resolution No. 1090 On Assuring Additional State Protection of Workers who are Relieved of Post due to Early ChNPP Decommissioning, dated 21.08.2001;
— CMU Resolution No. 1155 On Additional Monthly Payment to the Pension of the Pensioners, who are Relieved of Post due to ChNPP Closure, dated 13.09.2001;
— CMU Resolution No. 1748 On Measures for Social Protection of ChNPP Workers and Slavutych Residents due to the NPP Closure, dated 29.11.2000;
— CMU Resolution No. 1411 On the Program for Additional Working Places for ChNPP Workers, who are Relieved of Post After ChNPP Closure, and Slavutych Residents, dated 26.10.2001.

According to Law of Ukraine No. 2398-III on Superseding Certain Laws due to ChNPP Closure, dated 26.04.2001, plant workers are entitled to the following:

— Workers of shutdown power units and the Chernobyl Shelter for the period of decommissioning will receive a salary not lower than the average paid to workers of relevant professions and positions at operating Ukrainian nuclear power plants;

— Plant workers who are relieved of their posts due to the early closure of the plant are entitled to the following:
  - Social security and insurance to be placed in a job or have the assistance of the State placement service to find a job;
  - Medical treatment at facilities provided for the staff of the plant;
  - Retention of voluntary medical insurance till the time of expiry of the insurance contract, for a one year period;

— A benefit of the following amount:
  - 100% average salary for 120 calendar days;
  - 75% for next 30 calendar days;
  - 50% for next 390 calendar days.

— A benefit to start a business:
  - A single payment equivalent to the benefit of 540 calendar days of benefit;
  - Welfare during the time of professional re-training.

The procedure was approved by CMU Resolution № 1090 dated 21.08.2001 and superseded by CMU Resolution No.1645 dated 13.12.2004.

According to ‘Law of Ukraine No. 1907-IV On Superseding Article 12 of the Law of Ukraine On General Principles of Further ChNPP Operation and Decommissioning and the Transformation the Ruined Power Unit 4 into the Ecologically Safe System’, dated 29.06.2004, certain pensioners or non-workers, who were relieved of their posts after closure.

The State provides plant workers, who are relieved of their posts due to early closure, with the following additional benefits:

— A one-off benefit of the sum of the monthly average salary in case of the termination of the labour contract (the procedure was approved by CMU Resolution No. 1090 dated 21.08.2001);

— A ‘one-off’ benefit in the sum of 50 individual untaxed minimal salaries in case of resettlement to the different area (the procedure was approved by CMU Resolution No. 1090 dated 21.08.2001);

— The right to early retirement on a pension two years ahead of the term specified by law;

— An additional monthly payment to the pension of pensioners or non-workers, who were relieved of posts due to closure (the procedure and the sum are specified in CMU Resolution No. 1155 dated 13.09.2001):
  - If the work experience is under 5 years — 50 % of the sum of the living wage;
  - For each entire year over 5 years of work experience, the monthly payment is increased by 10% of the living wage and other benefits.

The maximum additional monthly payment shall not exceed the sum of two living wages. At the same time, the total sum of the additional monthly payment and the total pension shall not exceed 70% of the average salary of a worker at the date of his discharge.

3. MEASURES FORESEEN BY SOCIAL PROGRAMMES

Measures, which are foreseen by 'Measures for Social Protection of ChNPP workers and Slavutych Residents due to the NPP Closure' (CMU Resolution No. 1748 dated 29.11.2000), are aimed at ensuring social protection and guarantees for plant workers and Slavutych residents due to the early closure as follows:

— Maintenance and development of the city social infrastructure;
— Efficient human resource management;
— Assurance of payment of social benefits and protection of workers;
— Retaining highly qualified staff for conducting the activities at all plant decommissioning stages and its transformation into an ecologically safe system.

As a part of The Social Protection Programme, the housing fund, auxiliary and social facilities, associated with the plant have been transferred to Slavutych as municipal property. The total sum of the capital fund comes to more than 500 million hryvias (about €7 million). In parallel, housing has been established and infant schools commissioned under the authority of the city educational department; the enterprise Slavutych Chernobyl Trade was established through the plant's procurement department. These initiatives made it possible to mitigate, to a certain extent, the social consequences of the closure, i.e. to keep working places for the residents and efficiently redistribute the manpower.

The centre for training and retraining personnel due to the re-profiling of the plant functions was established in Slavutych.

The reconstruction of the premises of the psychoanalytical building of the Slavutych Medical Centre aimed to serve as the Rehabilitation Centre. Its major objectives are the medical examination and monitoring of personnel involved in the Shelter Implementation Project implementation and rendering first aid.

Currently, the tender for the procurement of major laboratory and diagnostic medical equipment is under way; its purpose is to equip the Rehabilitation Centre.

It is also planned to implement a number of activities for the social protection of plant workers and Slavutych residents:

— To provide collective medical insurance for plant workers and pensioners and non-workers;
— To provide recreation and resort facilities;
— To retain highly qualified personnel for implementation of activities through all plant decommissioning stages (availability of loans for education and improvement of living conditions);
— To construct a 200 flat building.

Measures related to the competence of the plant are foreseen in the 'The Program for Additional Working Places for ChNPP Workers, who are Relieved of their Posts After ChNPP Closure, and Slavutych Residents' (CMU Resolution No. 1411 dated 26.10.2001), and are implemented as follows:

— As a result of the establishment of Atomremontservice under SE NAEC 'Energoatom', 437 workers from the plant were transferred to work at the enterprise. The enterprise made it possible to find jobs for maintenance workers who were relieved of their posts due to a significant reduction in the scope of maintenance;
— Commissioning the heating facility – 106 workers were trained and given jobs at the heating facility;
— As a part of activities for Shelter transformation, the first stage of the change facility was commissioned; 28 workers work there and 122 workers were given training to work at the liquid radioactive waste treatment facility;
— The solid radioactive waste treatment facility is under construction;
— A decision on inexpediency of granting the transportation enterprise the status of an independent entity was made; the SSE plant shipping shop was established (263 workers);
— A decision granting the technical training centre the status of an independent entity was made; now the training centre provides training for the Shelter personnel. Additional schemes are being planned.

4. PERSPECTIVES

Significant experience in international cooperation has been accumulated in Ukraine as a result of the implementation of international projects. After the plant closure, a number of experts became project managers of complicated technical projects, which are funded by the European Bank for Reconstruction and Development (EBRD). This is evidence of efficient retraining and social self-protection.

However, major plant technical programmes, which are funded by the budget (amounting to about 70%) are goal oriented and lack finance for the measures of social protection. Thus, the social protection of plant workers and Slavutych residents is being ensured by plant equity capital, but this is not enough to fully implement the measures in full scope considering that the significant share of the equity capital goes for wage payment of support personnel.

Starting in April this year, the plant decommissioning fund was started, based on a tax on the profits of the operators. It is important for Ukraine to learn from other countries' experience in using such additional financial reserves for solving social problems.

The public hearing on the Conceptual Design for the New Safe Confinement held in Slavutych demonstrates the proactive civic position of the city residents, and their interest in carrying on a dialogue and in cooperating on the basis of knowledge and experience.

VIEWPOINT FROM THE PERSPECTIVE OF A SMALL TOWN

R.A. WELCH
Mayor,
City of Richland, Washington,
United States of America
Email: rwelch@ci.richland.wa.us

Abstract

The historic nuclear reactors on the Hanford site are being decommissioned and for this purpose an interim storage strategy, involving the cocooning of the reactors, has been adopted. The paper describes the work done over the past ten years in relation to the reactor decommissioning and the site cleanup from the perspective of a local community representative and indicates the ways in which the community has been informed and involved in the projects.

1. BACKGROUND

The Hanford Site is a US Department of Energy (DOE) owned, contractor operated facility in southeast Washington State near Richland. The site was established during World War II to produce plutonium for America's defence programme. Today, the 586 square mile site supports programmes in waste management, environmental restoration, science, technology and energy.

Ultimately, Hanford produced over two thirds of the defence or weapons grade, plutonium generated by the USA. Peak production years were in the 1960s, when nine production reactors operated along the Columbia River. One of those reactors (the N-Reactor) was the world's only dual purpose reactor producing plutonium and steam for power production. Connected to a generating plant, N-Reactor steam produced more than 63 billion kilowatt-hours of electricity for the Pacific Northwest power grid.

During 50 years of nuclear material production, Hanford generated a significant amount of radioactive and hazardous waste. Liquid waste from retention basins and from piping has contaminated soil and groundwater in the vicinity of the reactors along the Columbia River. Contaminated soil makes up a sizable percentage of the estimated 10 million tonnes of contaminated material along the river shore – or what we refer to as 'the river corridor'. To date, more than 6 million tonnes of contaminated soil has been cleaned up along the river corridor and disposed of in a huge landfill, the Environmental Restoration Disposal Facility (ERDF), built in 1996 in the central portion of the Hanford Site. The remaining contaminated materials reside in facilities and waste disposal grounds and will also be disposed of in ERDF.

In the early 1990s, the Department of Energy, the US Environmental Protection Agency (EPA) and the Washington Department of Ecology developed a plan to clean up the reactor buildings and hundreds of ancillary facilities adjacent to the reactors.

In 1993, DOE issued a Record of Decision (ROD) on an Environmental Impact Statement for the decommissioning of the Hanford surplus production reactors. The ROD declared that the preferred alternative for the reactors was to place them into interim safe storage for up to 75 years, followed by 'one piece' removal of the reactor cores for disposal in a specially prepared disposal facility in the central portion of the Hanford Site.

In 1994, the Department of Energy hired Bechtel Hanford as the environmental restoration contractor in charge of the cleanup of soil, groundwater and reactors along the Columbia River. Cleanup activities began in 1994 while Bechtel worked with the Hanford Advisory Board, regulators and stakeholders in the region to establish a cleanup strategy and a Long range Cleanup Plan. In 1996, as part of that strategy, the company developed an interim safe storage configuration for the Hanford reactors, referred to as 'cocooning', that met the 75 year interim storage criteria of the ROD.

The cocooning process involves removing all of the reactor building except the five foot thick shield wall surrounding the reactor core. Openings and penetrations are sealed with corrosion resistant materials and a 75 year roof is placed over the remaining structure. The facility is equipped with heat and moisture sensors that are remotely monitored. The intent of cocooning is to keep the building cold, dark, and dry and thereby to establish a safe, environmentally secure and stable structure that will protect the public and the environment from potential contamination while significantly reducing surveillance and maintenance costs. The reactors can remain in the cocooned state for up to 75 years. This time period will allow the DOE, regulators and stakeholders to reconsider the final disposition method for the reactor cores and will allow radioactive materials in the reactor cores to decay to more manageable levels.

2. C-REACTOR — THE FIRST TO BE COCOONED

In 1996, C-Reactor was selected as the first Hanford reactor for cocooning because of the advanced deterioration of roof sections on the reactor building that would have required extensive and costly repairs. Our local Congressman visited the C-Reactor complex in the winter of 1996, along with a group of community leaders. The walls and roof of the main reactor building were in such poor condition that, as they entered the facility, they discovered that snow was accumulating inside the building.

As the cocooning effort got under way on C-Reactor, the project became a reverse construction job. This involved reducing the size of the 60 000 square foot reactor building by more than 80%. Much of the demolition work in the interior of the reactor building focused on removing equipment such as 29 vertical safety rod lifting assemblies. Once the assemblies were removed and the housings penetrating the reactor core were sealed, three stainless steel hoppers containing high efficiency particulate air filters were installed to trap any potential contaminants vented from the reactor core as it naturally 'breathes'. Workers also removed more than 6400 cubic feet (183 m^3) of asbestos, 630 000 pounds (285 t) of low level radioactive materials, 115 t of steel and copper, and 50 000 gallons (190 m^3)of contaminated water.

As the first of the Hanford reactor cocooning projects, the C-Reactor project provided a test bed to demonstrate new and innovative decontamination and dismantling (D&D) technologies that had the potential benefit of lower life cycle costs, accelerated schedules, and reduced worker exposure. The C-Reactor project received supplemental funding from a DOE large scale technology demonstration and deployment programme to identify and demonstrate new and innovative D&D technologies that could benefit cost, schedule and safety, and which could have potential applications in other DOE projects, as well as in the private sector.

Innovative technologies were identified and evaluated in the areas of characterization, decontamination, dismantling, demolition, waste minimization and disposal, facility stabilization, and worker health and safety. The technologies were competitively selected using a 'market search' approach in which the project presented the problems to industry and industry responded with ideas for innovative technologies and/or new application of existing technology. A team of international D&D experts reviewed more than 200 identified technologies and selected 20 to be demonstrated and compared to existing baseline technologies. Of those demonstrated technologies, 13 were successful for deployment. These have been added to the Hanford decommissioning toolbox and have been deployed on other DOE projects, both in the USA and in the former Soviet Union.

3. C-REACTOR PROJECT SUCCESS

With the benefit of the newly demonstrated technologies, Bechtel Hanford completed the cocooning of C-Reactor in 1998 in just over two years for $27.8 million. The reactor footprint was reduced by 81% . One remaining door was welded shut, to be opened only once in every five years for internal physical inspection. In the meantime, sensors and a television camera monitor the interior.

In 2003, workers entered C-Reactor to make the first five year inspection and found it in the same condition in which it had been left. The team used high resolution digital cameras with newly developed software that enabled the creation of 360° photographs. These photographs will be used to develop a virtual tour of the interior for future comparison. The inspection confirmed that cocooning creates a safe, environmentally secure structure while significantly reducing the surveillance and maintenance costs.

Following completion of the C-Reactor project, Bechtel Hanford applied the lessons learned and the technologies successfully demonstrated on C-Reactor, together with a management plan to accelerate the cocooning of the next four Hanford reactors. The cocooning of each of the next four reactors (F, DR, D and H) was scheduled in the Long range Cleanup Plan to be completed in 2003, 2005, 2007 and 2009, respectively. By using a multiple reactor cocooning schedule instead of the planned series schedule, and managing the multiple reactor cocooning as a single project, the cocooning of these four reactors was completed by the end of 2005, four years ahead of the original schedule.

In addition, the cost of cocooning the four reactors was only slightly more than the original cost estimate for cocooning three of the reactors using the series schedule. Cost savings resulted from operating efficiencies achieved by eliminating unnecessary duplication of management at multiple project sites, subcontracting for multiple scopes of work, and by retaining an experienced workforce. Cost avoidances were also realized from not requiring demobilization, remobilization, workforce reductions, and retraining of a new workforce when the next project is resumed. To date, five of the nine Hanford retired production reactors have been successfully and cost effectively cocooned.

4. COMMUNITY OVERSIGHT AND INVOLVEMENT IN THE HANFORD CLEANUP

The four cities and the counties surrounding Hanford followed and influenced progress on the work in a number of ways. First, each of our jurisdictions has representatives on the Hanford Advisory Board. The HAB, as it is known, is a Federally chartered advisory body. The Health Safety and Waste Management Committee of the Board was chaired by the Executive Director of the Hanford Communities organization. This inter-local organization, with representatives from each of the communities, coordinates all local government involvement in the Hanford cleanup. The Administrative and Governing Boards of the Hanford Communities, comprising elected officials and city and county managers, meet monthly in order to maintain current knowledge about cleanup activities and to determine the positions our communities will take in working with the DOE.

A major function of the Hanford Communities organization is to keep the public informed about cleanup activities and to promote public participation in the decision making processes. Over the years, we have learned that there is tremendous regional interest in the Hanford cleanup; however, people are not inclined to attend public meetings in the evenings, even on topics of significant interest. What has proven to be very effective for us is the development of programmes that are shown on local cable television channels. Funding from the Washington State Department of Ecology makes it possible for the Hanford Communities to produce at least two programmes a year. In the past ten years, two of the many programmes we have produced focused on cleanup along the river and reactor cocooning.

Also, I mentioned previously that early in the C-Reactor cocooning process, we were fortunate to receive funding for a technology demonstration. During that period of time, the DOE had ‘Site Technology Coordination Boards’ at most of their cleanup projects around the country. Our city staff participated actively on the local Board and provided ongoing briefings to city managers and elected officials regarding science and technology needs and the progress of demonstrations. The technology coordination boards provided the only avenue for local community leaders and stakeholders to learn about the technology needs of the cleanup and to provide input on which technologies should be prioritized and put forward to the DOE for funding. Unfortunately, all of the boards across the country were abolished at the beginning of the current Administration. Funding for technology development has also dramatically declined in recent years.

5. CLOSURE CONTRACT

As work began on the interim stabilization of the fifth of Hanford's reactors, the DOE determined that remaining work along the river corridor would be put out to bid as a 'Closure Contract'. Ultimately, Bechtel teamed with CH2M Hill and Washington Group to put forth a successful proposal for cleaning up the remaining waste sites, reactors and soil along the river corridor. The two K-Reactors, which until recently held 2100 t of spent nuclear fuel, and the N-Reactor will be the next to be cocooned. In September of 2005, an eight year, $2.2 billion contract was awarded to Washington Closure Hanford. The new contract was structured differently from previous Hanford Management and Operation contracts. It has a specific 'Scope of Work' with a fee linked to that work. It provides incentives for saving time and money. For example, the Washington Closure contract is a cost plus, incentive fee contract. For each dollar saved over the target cost, the DOE keeps 80 cents and Washington Closure gains 20 cents up to a set amount. In all, 486 facilities will be decommissioned or demolished in the 100, 300, 400 and 600 Areas of the Hanford Site. High radiation dose rates, contamination levels inside the hot cells and the heavy concrete walls preclude traditional approaches to demolition. Current plans are to fill the cells with grout and then use diamond wire saws to cut the grout cells into large chunks for removal and disposal at the ERDF facility in central Hanford.

The goal of field remediation in the project is to clean up 370 liquid and solid waste sites and disposal grounds. The largest volume of contaminated liquid waste in the river corridor came from leaks in the reactor effluent piping systems and retention basins, as well as from liquid waste disposal cribs and trenches. Some of the remaining solid waste sites and disposal grounds will be particularly challenging. Radioactive and hazardous materials were buried with little or no documentation. One of the disposal grounds is located adjacent to the parking lot of the Energy Northwest commercial nuclear reactor and another disposal ground of concern is directly across the road. These two facilities are about 15 miles from the city limits of the City of Richland.

6. COMMUNITY INVOLVEMENT IN REMEDY SELECTION

In a recent Federal court decision in a lawsuit filed by the City of Moses Lake, Washington, the judge upheld the community's contention that under CERCLA or Superfund cleanup requirements, local governments have the opportunity to review documents and have input into remedy selection. The Hanford Communities have written to the DOE and the Environmental

Protection Agency requesting to be involved in remedy selection for the 618-10 and 11 disposal grounds, as well as in any cleanup decisions pertaining to the 300 Area of Hanford, which is directly adjacent to the Richland city limits. The response of the Federal agencies was less than encouraging. They said they would take our request 'under advisement'. Our meetings with DOE and EPA on this topic have been enlightening. The DOE was much more willing to consider the opportunity for us to share our views prior to remedy selection.

The regional EPA office has advised us that they have had strong direction from EPA headquarters about how to handle our request. It is our guess that they have been asked to not provide any opportunities that might be 'precedent setting' for other parts of the country. All the fuss is somewhat amusing. The DOE clearly has the authority to make the determination about remedy selection. We have simply requested the opportunity to review technical information and provide comment before the selection decision is made. Although we do not anticipate that the ownership of the Hanford Site will be transferred out of federal control, as the local government adjacent to the land where cleanup is occurring, we may ultimately have the responsibility for managing the institutional controls.

7. CONCLUSION

I would like to summarize our response to the questions proposed by the conference organizers. 'How do you keep the public informed during the entire decommissioning process?'

I have indicated a number of opportunities to keep the public informed. Our inter-local organization, the Hanford Communities, meets monthly, and our staff make arrangements for city and county managers and elected officials to be briefed by the DOE, its contractors and regulators on ongoing cleanup activities and challenges. With the information that has been gathered, we develop an issue agenda each year, prioritizing issues of most importance.

We develop two half-hour programmes for cable television each year focusing on current cleanup challenges in order to provide basic information to people in the region and also to inform them of ways they can become involved in discussions about cleanup decisions. The Hanford Communities also prepare issue papers on current cleanup questions and produce several newsletters each year. These methods have proved to be much more successful than the alternative of public meetings.

We also meet with our members of Congress and Congressional staff who deal with the DOE at least once, if not several times, each year. We have been very successful in seeing funding restored for programmes that had been cut or eliminated by the DOE.

Who are the stakeholders during the decommissioning process?

We believe that the successful cleanup of Hanford is essential for the long term economic viability of our region, as well as the health and well-being of the region's residents. Therefore, stakeholders include: all of the region's residents, the Hanford workforce, as well as communities along the Columbia River and other individuals in Washington and Oregon who have a particular interest in the environmental cleanup of the site. As an elected official, I believe it is my task to be sure that our community and others in the region are working closely together to keep our residents informed and to represent their interests in dealing with the DOE, the regulatory agencies and Congress. We must ensure that the Hanford cleanup is carried out on schedule and in accordance with stated objectives.

What disasters have we experienced?

Fortunately, none come to mind. However, one potential challenge remains. It is the desire of residents of our region to see the B-Reactor, Hanford's first reactor, preserved as a museum. Of course, some cleanup must occur so that the facility is safe for visitors. Fortunately, in this year's budget, we have secured funding to replace the roof of the facility. We successfully lobbied for funding for an options analysis that is currently being undertaken by the DOE. We have also secured funding for a US National Park Service evaluation of the facility's potential as a museum. We are hopeful and optimistic that these studies will draw the right conclusion, and we hope that a decision will be made during the next year.

Finally, what were the economic impacts to the community of the D&D project?

Hanford's production reactors were shut down in the late 1980s. Beginning in 1996 with the cocooning of the C-Reactor, the DOE spent approximately $20 million a year to decommission the reactors. The new River Corridor contract calls for $180 million of funding in 2006, going up to over $400 million a year in the later years of the contract. It includes the cleanup of waste sites and the operation of waste disposal facilities, in addition to the decommissioning of the facilities. The work is planned to be completed in 2013.

Federal dollars coming into the community for this project have provided jobs and have benefited our regional economy.

EXPERIENCE IN THE PREPARATION AND IMPLEMENTATION OF THE FIRST SOCIOECONOMIC PLAN AT THE DOUNREAY NUCLEAR SITE

A.F. McWHIRTER
United Kingdom Atomic Energy Authority,
Dounreay, United Kingdom
Email: Sandy.Mcwhirter@ukaea.org.uk

Abstract

The Nuclear Decommissioning Authority in the United Kingdom has required the management and operations contractors of its sites to prepare annual socioeconomic development plans. The paper discusses the first socioeconomic development plan, prepared for the Dounreay Nuclear Establishment in the far north of Scotland, and identifies the lessons learned from it which will be taken into account in the preparation of future plans for the sustainablity of the area around the site.

1. BACKGROUND

In the United Kingdom, the Energy Act (2004) [1] established a Nuclear Decommissioning Authority (NDA) responsible to the Government for the management of the decommissioning of 20 civil nuclear sites in the United Kingdom. An important inclusion in the Energy Act is the requirement for the NDA to consider the social and economic implications of the decommissioning programme on the communities around the nuclear sites.

The NDA responded to this by providing funding for projects and initiatives using savings derived from the decommissioning budgets of the sites and also by requiring the incumbent contractors to prepare annual socioeconomic development plans (SEDPs).

Most of the nuclear facilities in the United Kingdom are located in remote areas. Often, the site is the major employer in the area and the local economy has grown to support the facility. In some very remote sites there is little non-site related employment in the area and when the site decommissioning programme is complete, there will be little or no alternative employment.

The sustainability of such communities requires action now to identify new employment opportunities and to encourage the development of these in such a way as to ensure the gradual transfer of staff from the management and operation of the decommissioning sites to new businesses in the area.

One example of such a site is the former fast reactor development site at Dounreay in the far north of Scotland. This was established in the 1950s and attracted a large number of highly qualified scientific and engineering staff to the area. The nature of the community reflects the presence of the plant and, in its absence, the number and technical content of the remaining jobs would fall dramatically.

Work has been initiated by the NDA and other agencies to identify and encourage new employment prospects for the area. These will be needed by 2036, although the programme may well be completed before this date

The impact of the NDA has been very significant in influencing the pace of developments. Firstly, its requirement for the development of SEDPs has required the incumbent contractor, the United Kingdom Atomic Energy Authority (UKAEA) to consult widely in the community. Secondly, the requirement of NDA for the incumbent Management and Operations contractors to produce baseline programmes for site decommissioning, has enabled the community to understand very clearly, the impact of the decommissioning programme in a way that was not possible hitherto. This realization has had the effect of causing a number of community organizations and individuals to take immediate action in planning for the loss of jobs at the site on a timescale consistent with the decommissioning programme.

This paper describes the first Dounreay SEDP [2], produced by UKAEA. This plan was issued in 2005 and the activities of the first year of the plan have been implemented. Many lessons have been learned as a result and these are identified and discussed.

2. THE FIRST SEDP

2.1. Establishing a framework for the plan

When the first plan was being prepared, it became clear that background information would be required. A socioeconomic development plan, by definition, is a series of activities aimed at moving from one situation to another. Before such a plan becomes meaningful, it is necessary to have a clear picture of the current socioeconomic status of the area, and then a vision of what the members of the community would wish to have after the completion of the decommissioning.

Neither of these existed, although various bodies had, from time to time, suggested new industries that might be located in the area and some plans had been produced to extend existing non-nuclear related sources of occupation, such as tourism and farming.

A socioeconomic baseline had been prepared for UKAEA by consultants DTZ Pieda for another purpose [3]. The terms of reference for this baseline were not ideally suited to the preparation of the SEDP however, but the report was the best definition available at the time of the preparation of the first SEDP. It was therefore used as a basis upon which a plan for the future could be constructed.

The NDA has funded a project, to produce a 'fit for purpose' baseline report. This has yet to be published but a draft is available and this is described and discussed in Section 4 of this paper.

Having established a baseline, albeit with some flaws, it was then necessary to have a vision of how the community might look in the future. This is a more difficult task as it requires the opinions of many to be elicited. The best available information was contained in the Annual Plan of the local enterprise company – Caithness and Sutherland Enterprise (CASE) — and this was used to guide the thinking as to what the community might want.

Reference was also made to a number of central government policy documents such as 'One future, different paths' [4], representing the United Kingdom's policy on sustainable development and 'A Smart, Successful Scotland' [5], the Scottish Parliament's vision of economic development for Scotland.

These high level policy documents provided valuable guidance as to the direction that new developments might take, however, an understanding of the current socioeconomic baseline and a vision, compliant with the policies and acceptable to the local community, were essential before any SEDP could be successfully created and implemented.

The first SEDP therefore suggested that the first year of the plan should include establishing the baseline and eliciting a strategy by which the vision might be obtained, in addition to any actual projects or initiatives aimed at new job creation.

2.2. Existing skills available from the Dounreay workforce

It was also suggested that to be successful, any vision for the future should make maximum use of the available assets that the community currently possesses. These include fixed capital assets, infrastructure and, of course, the skills available from both the site and the local community.

In the preparation of the site's decommissioning plan, 28 separate skills were identified and each staff member on the site was allocated to one of these (Fig. 1). It was decided that this list of skills could be used to form a matrix to

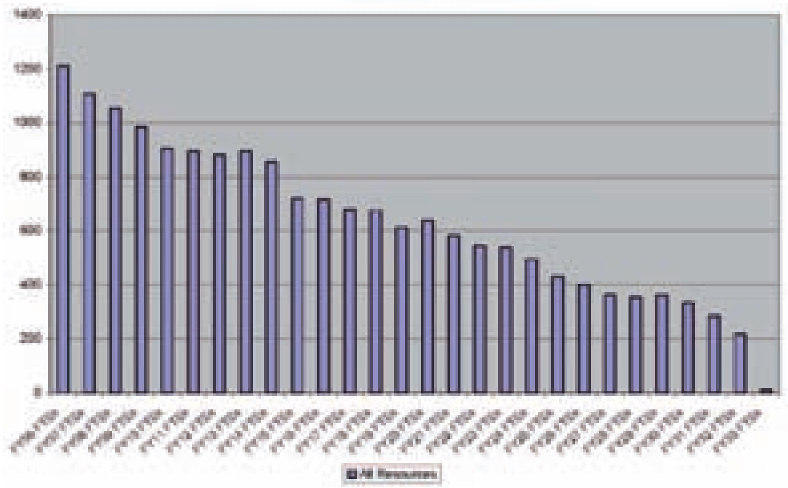

FIG. 1. Profile of skill sets at Dounreay

show a person in one skill set, what opportunities might be available to transfer to another and would enable the person to access the training programme necessary to effect the transfer.

It was also arranged that each skill set could be interrogated to display the profile of numbers of staff over the decommissioning period. By this means, it was intended that staff could see how many people shared their skill set and to see how quickly the numbers required might fall. It would then be possible to look at the profiles for other skill sets and to select one or more to which the individual might be able to transfer after suitable training.

As an adjunct to this process, it was appreciated that the UKAEA as a contractor, would be considering operating in new markets. Staff who could not find an alternative job on the site decommissioning programme could therefore identify a new skill set, not currently needed as part of the Dounreay decommissioning plan, and be trained in this in advance.

Only those staff for whom there was no suitable redeployment or reuse within the new business of the company, would be at risk when their jobs on the site were terminated. The skills available, and the potential numbers, were then proposed to be made available to the Caithness and Sutherland Enterprise (CASE) and updated as every new site plan was produced. This would enable CASE to try to match incoming industries with the staff being released from Dounreay. This should simultaneously provide potential for new jobs for the staff, while being an attractive proposition to companies seeking a new location as the availability of skilled staff near to the facility would seem beneficial.

2.3. The original socioeconomic baseline

The socioeconomic baseline showed that 19% of the local workforce were directly employed at Dounreay. In addition, a similar number were employed in support of the operations of the site. The conclusion was that the community, in the absence of the Dounreay facility and the money that it injects into the community, would be unsustainable and, without intervention, there would inevitably be a downward spiral of economic activity and an increase in the migration away from the area.

In effect, the reliance of the community on one very large dominant employer is intrinsically unsustainable as its loss, for whatever reason, will result in the economic decline described above.

For remote communities to be sustainable, the area should contain a larger number of technologically diverse, small to medium scale enterprises (SMEs). This would ensure that the loss of one company or the decline of one technology, would not, of itself, result in the demise of the whole community.

This means that, in addition to the need for the UKAEA to identify redeployment opportunities, it is also necessary for the community itself to identify new industries that could be attracted to the area, ideally using the skills available from Dounreay to support it.

The demographics of the area show a bias towards older people. If the new business of the community were to be, for example, nuclear decommissioning on a world wide basis, this would mean that most family breadwinners would be working away from home. This would create a further skew towards older retired people and wives looking after young children.

These conclusions meant that two separate approaches to the problem would be needed. The first of these was to identify ways in which the loss of staff from the Dounreay site could be effectively managed by tuning the decommissioning programme and by re-training staff on the site. In addition to this, however, it would also be necessary for the community to identify the types of new industry that they would wish to have in the area after Dounreay and to find ways to attract them.

The Management and Operations Contractor and the NDA can take the lead in the former activity whereas the responsibility for the latter, identifying and attracting new businesses to the area, can be influenced by many but the principal support should come from the local enterprise company, CASE.

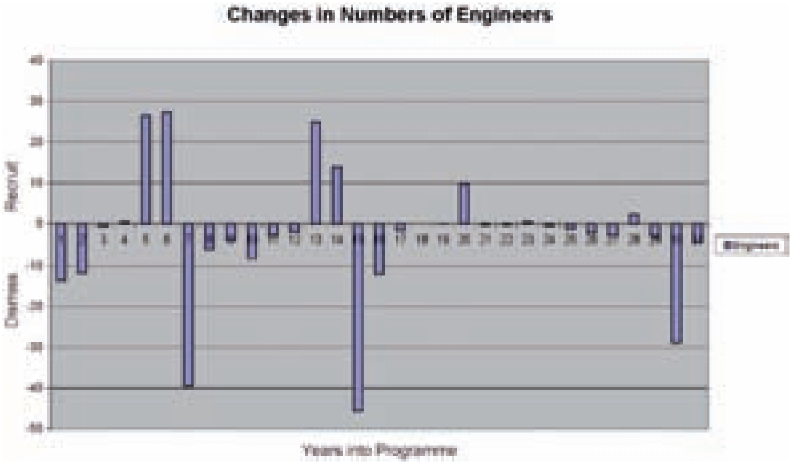

FIG. 2. Predicted variation of skill set requirements for engineers during the decommissioning programme.

3. EXPERIENCE WITH THE PERFORMANCE OF THE FIRST PLAN

The first plan was widely acclaimed as being a very useful starting point, however, in practice, it had a number of flaws which made some elements of it unworkable. Both of these are discussed in detail below.

Firstly, the data on which the resources needed for the decommissioning of the site were based were not sufficiently accurate to be used for long term planning. The reason for this was that the Life Time Plan for the site was a very new concept and as a result, it contained many assumptions. The reality was that when each skill set was examined in detail, significant swings in needs for specific skills over time were noted. As an example, the numbers of one skill set showed the need to recruit 27 staff one year but for 39 of the same skill set to be dismissed the following year. The data for one skill set – engineers – are shown in Fig. 2. While the underlying concept was sound, the absence of accurate, mature data was such that it was considered unlikely that the existing data could be used as a practical, planning aid.

It was also found that the improved planning processes introduced by NDA, resulted in the UKAEA being able to identify ways of accelerating the decommissining programme and if this happened, the skills profile was likely to change dramatically. While this seems negative from an employment perspective, the availability of the detailed baseline plan and its use to enable the prediction of the size of the workforce necessary to implement the plan, represents a very useful tool for managing both the decommissioning programme and its socioeconomic consequences.

On the positive side, the identification of the need to have an accurate baseline and a vision were agreed by all commentators as being worthy of pursuit and a great deal of work in these areas was carried out during the year.

Of particular note was the interest in the problem shown by the local Member of Parliament. He offered to chair a working group to develop a strategy by which a vision of the area in the future could be prepared. Following an inaugural meeting, the representation on this group was agreed as shown in Table 1.

The SocioEconomic Working Group met over a period of six months. Discussions were very wide ranging and were gradually focused towards the production of a draft strategy, through which a vision for the community after Dounreay decommissioning, could be prepared.

The strategy document, will be circulated to every home in the area and comments from recipients will be incorporated. A final strategy will be developed and used to produce a vision for the area.

TABLE 1. MEMBERSHIP OF THE DOUNREAY SOCIO-ECONOMIC WORKING GROUP

Member affiliation	Role
Local Member of Parliament	Chair
Caithness and Sutherland Enterprise	Secretariat
Highlands and Islands Enterprise	Member
Scottish Parliament	Member
The Highland Council	Member
The Dounreay Stakeholder Group	Member
The Trade Union	Member
UKAEA	Member
Nuclear Decommissioning Authority	Member
The local educational institution	Member
Local business representative	Part-time member
House of Lords	Part-time member

4. INITIAL OBSERVATIONS FROM THE NEW BASELINE STUDY

The terms of reference of this study were closely aligned to the production of the SEDP and this has made the interpretation of the results much easier.

Over the decade for which national statistics are available (1991–2001), the population of the area has fallen by some 3.9% while at the same time, the population of the Highland Region as a whole has risen by 0.8%. The areas has a population structure that is, in general, older than the average for the Highland Area and Scotland as a whole.

In the Highland Area, there has been a significant amount of inward migration. In the Caithness Area, the percentage population increase as a result of such inward migration is lower than for most areas of the Highland Region at 2.5% compared with the highest rate (in the Inverness Area) of 6.6%.

The Economic Activity Rate for the area is 66% compared with 68% for the Highland Area in general and 65% for Scotland as a whole. The Highland Area is generally higher than for 'all Scotland' but, within the 10 areas of the Highlands, Caithness and Sutherland is 8th.

Self employment, while potentially an indicator of entrepreneurialism, can also reflect the absence of other large employers. In the same ten areas, Caithness is ranked 6th for self-employment. The data here may, however, be skewed due to the significance of self employed farmers in the southern areas of the highlands region.

A further metric is the number of business start-ups; in this, Caithness is the lowest in the Highland Region. The highest for the region is 7.4, the average figure is 5.03 and Caithness scores 3.6.

In summary, although the study is not yet complete and further analysis will be necessary when the final report has been issued, there is an indication that there is a migration of people away from the area and a reluctance of new people to move to it.

Economic activity, by all metrics, suggests that the area is less active than other areas of the region and that the rate of new business start ups is significantly lower. It is possible that the relative security of the employment offered by the Dounreay site for the past 50 years has produced a population that has not had to find new business and is therefore ill equipped to do so.

5. CONCLUSIONS

The first Dounreay SEDP, while a valuable starting point, had a number of flaws that reduced the extent to which it could be implemented.

It is not possible to create a viable SEDP unless a 'fit for purpose' socioeconomic baseline is prepared.

Re-training and re-deployment of staff within the decommissioning site is a useful way to manage the short term impacts but the nature of the task is such that inevitably, all current and future decommissioning jobs on the site will be lost.

The Dounreay community has a lower than average rate of business growth. This may be as a result of the security offered by the existence of the long term major employer which is now disappearing.

The conclusions reached will need to be reviewed when the final socioeconomic baseline report is available and the vision, to be created from the strategy, will need to be kept under constant review as external factors, in particular technology, change during the decommissioning period.

In areas with a need to re-generate to the extent that is necessary at Dounreay, an individual or organization must be identified with the responsibility to prepare the plan and to drive it to completion.

REFERENCES

[1] HM GOVERNMENT, The Energy Act (2004).

[2] UNITED KINGDOM ATOMIC ENERGY AUTHORITY, The Dounreay Socio-Economic Development Plan – 2005/6, UKAEA, Harwell, (2005).

[3] UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Dounreay Socio-Economic Baseline Study, DTZ Pieda Consulting, Edinburgh (2004).

[4] HM. GOVERNMENT, One future, different paths, Department for Environment, Food and Rural Affairs, London (2005).

[5] SCOTTISH EXECUTIVE, A Smart, Successful Scotland, Scotttish Executive, Edinburgh, (2004).

DISCUSSION

C. GRIFFITHS (United Kingdom): How does one deal with the concerns of local communities when a decision is taken to accelerate decommissioning?

A.F. McWHIRTER (United Kingdom): We used to have for every nuclear site in the United Kingdom a 'local liaison committee' — a forum in which local people could listen to the site operator being questioned by the regulators and find out what was happening at the site. The focus at local liaison committee meetings was invariably on safety and environmental issues.

Now, the Nuclear Decommissioning Authority organizes 'stakeholder meetings' which are dominated by social and economic issues. That is certainly so in the case of Dounreay, where the site management uses the local stakeholder meeting as an opportunity to explain — for example — why decommissioning is going to be accelerated and what it is likely to mean for the local community.

BRAZILIAN EXPERIENCE IN THE DECOMMISSIONING OF A NORM FACILITY: SOME LESSONS LEARNED

D.C. LAURIA
Institute of Radiation Protection and Dosimetry,
Rio de Janeiro, Brazil
Email: dejanira@ird.gov.br

Abstract

Two sites located in a big city were contaminated by the careless management of radioactive waste, residues and materials from monazite processing. The paper describes the radiological aspects of the decommissioning and site restoration process at one of the sites. The subsequent requirement for site resurvey to take account of new laws on non-nuclear pollutants highlighted the need for the involvement of State agencies for both nuclear and non-nuclear aspects in such operations from the beginning. The concerns of the local stakeholders and the approach used to involve them is described. An important conclusion is that experts in commnication should be involved to assist and advise the radiation protection staff and to help reassure the public. Although international regulations would allow the use of higher dose levels for releasing of the site for unrestricted use, the lack of national regulation for intervention together with public anxiety led to the use of lower dose levels resulting in higher costs. Five years after the facility had been released for use the State established regulations for contamination by conventional contaminants and the site had to be resurveyed for non-radioactive contaminants. This experience highlights the importance and value of non-radiological State agencies' involvement both in the decommisioning and in the decision making processes. Public concern and a general lack of information regarding nuclear radiation shows the need for clear explanations and the demystifying of its potential hazards. Dialogue with stakeholders should be truthful, clear and simple, avoiding the use of highly technical jargon, beginning at the planning stage of the process, in order to provide transparency of intentions and to increase trust. Experts in public communication should be deeply involved in order to improve the exchange of information among the radiation protection staff and the public. The Public Ministry is a Brazilian institution dedicated to the enforcing of law concerning public interests. It plays a very important role in the decomissioning process and should be clearly and precisely informed at all steps of the process. Finally, a legal base related to naturally occurring radaioactive material and intervention is necessary.

1. INTRODUCTION

Decommissioning is defined as the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility [1]. Hence, in the context of nuclear facilities, the term is usually used for facilities that are controlled by a nuclear safety or radiation protection regulatory framework. Nevertheless, there are industries that process raw materials containing thorium and uranium that have been excluded from the scope of radiation protection regulatory control. In some of these, the activity concentrations of naturally occurring radioactive material (NORM) are significantly elevated above normal values and the processing of the materials may concentrate the radioactive nuclides in products, by-products, and waste leading to potential occupational exposures and/or environmental impacts. In addition, the facilities associated with these industries may become contaminated and when these industries cease operation a 'radiological' decommissioning strategy may be required. In recent times the presence of NORM has been highlighted in many industries, such as the phosphate, coal, oil, monazite, and ceramic industries and, with the growth of public concern, international regulations for NORM are beginning to be promulgated [1, 2]. Recently, safety and radiation protection requirements for mining, milling, processing and the storage of NORM containing materials have been established in Brazil [3]. Nevertheless, because some industries started their production a long time ago a large amount of NORM waste and contaminated equipment, buildings and land has accumulated and remain to be dealt with. This is the case for the facilities of the monazite industry in Brazil, which are located in a large metropolitan area, and have been operating for more than 60 years — outside of the control of the nuclear regulatory authority. As a result of public pressure, but also for technology obsolescence and economic reasons, it was decided to close the operation of one of the facilities, to decommission the buildings and to cleanup the site.

2. THE SITE

Monazite is basically an orthophosphate of the rare earth elements (REE) containing thorium and uranium. A typical Brazilian monazite contains approximately 39% of cerium oxide, 5% of yttrium, 6% of thorium oxide and 0.3% of U_3O_8. The heavy mineral sands were mined in the southeast coastal area of Brazilian and after some physical separation steps, the monazite was sent to the Santo Amaro mill (USAM) in São Paulo to be purified and chemically processed to obtain a solution of rare earth chlorides. This solution of chlorides was then sent to another facility, also located in São Paulo city, the Interlagos mill (USIN), where light rare earth elements were separated from heavy rare earth elements. The classical monazite alkaline digestion process produces different kinds of waste. At the Santo Amaro mill the management of the waste was less than ideal and resulted in contamination of the site [4].

Santo Amaro Mill was located in a densely populated residential district of São Paulo City, the largest city in Brazil, encompassing and area of 16 503 m^2. When it was built in 1942, the area was sparsely populated, situated far from downtown São Paulo City. However, as time went by, the city surrounded the mill. USAM stopped its activities in 1992 and decommissioning started in 1994 and finished in December 1998.

3. DECOMMISIONING

Firstly it should be noted that technical knowledge available in the country regarding the decommissioning process is limited. The technical expertise for radiation safety during the decommissioning activities was provided by IRD (Institute of Radiation Protection and Dosimetry) which is part of the regulatory body CNEN (Brazilian Nuclear Commission). A manager was chosen to be in charge of the CNEN team, which included experts in environmental and occupational radiation protection and radioactive waste management. The operator's organizational team included a decommissioning manager, radiation protection workers, a safety engineer and various contractors. In this team there were some former employees, whose knowledge of the site proved to be of signifiant value. The decommissioning process was discussed step by step in meetings of the two teams. The operator was responsible for the decommisioning activities under the guidence and supervision of CNEN.

The decommissioning was carried out in four stages: (i) packaging and removal of waste remaining at the plant; (ii) decontamination and dismantling of the equipment; (iii) decontamination of floors and walls and demolition of the buildings (built area of 13 000 m^2); and (iv) radiological survey and cleanup of the site. The last step, carried out by CNEN, consisted of a final survey to check if the cleanup process had reduced levels to values that met the established criteria. The adopted limits for the decontamination and dismantling of equipment and the decontamination of floors and walls were those established in the Brazilian waste standards [5]. Materials with contamination levels higher than the established levels were submitted to different processes of decontamination. Those materials in which contamination remained higher than the limits were segregated as waste. As a result, approximately 6900 m^3 of

FIG. 1. USAM site before and after the cleanup action.

radioactive waste was segregated (metallic material, wood, clothes, papers, etc.). At present, Brazil does not have a disposal site for low level waste and, due to public opposition and the positions taken by the State legislatures, the transference of radioactive waste from one State of the Federation to another is very difficult. As a result, the waste generated in the decommissioning of the USAM facility was stored in an adapted building at an already contaminated USIN site.

After the demolition of the buildings at the USAM site, the area was surveyed and a radiation dose criterion for the unrestricted use of the site was adopted. The cleanup actions at the USAM site could have been treated as an 'intervention' situation and, consequently, the radiological protection principles for intervention could have been applied. The International Commission on Radiological Protection (ICRP) recommends a level of existent dose of 10 mSv/y, below which intervention is optional, but not likely to be justified, and above which it may be necessary [6]. However, at that time the Brazilian radiation protection standards did not include the concept of intervention and the dose limits for practices (1 mSv/y) had to be applied in all situations. In addition, public concern about a site so centrally located was influential and it also led to the dose release criteria of 1 mSv/a. The concentration levels were then derived by pathway analysis [7]. Soil with concentrations higher than 30 Bq/g was sent to the USIN storage facility, while soil with concentrations lower than 30 Bq/g, but higher than 0.65 Bq/g of ^{228}Ra, was sent to a municipal landfill site. Soil with concentrations below 0.65 Bq/g of ^{228}Ra could remain at the site. Thus, as a consequence of the site cleanup, about 2300 m^3 of soil was removed from the site, of which 60 m^3 was stored at USIN and 2240 m^3 was disposed of at a municipal landfill. Pictures of the USAM site before and after the cleanup activities are shown in Fig. 1.

The total cost of the decommissioning of the USAM site was estimated to be around 20% of the sale value of the site. Soon after the release of the site for unrestricted use, the area was sold to a big construction company. The company is building six high residential towers at the site.

4. COMMUNICATION ISSUES

No formal public communication procedure was established during the decommisioning of USAM. People who were interested to know what was going on at the site could ask for a visit and interview the manager of the site and the CNEN officials. The inhabitants of the residential buildings located in front of the site visited the site on occasions. However, a meeting prompted by the shopkeepers association of the district, which happened soon after the sale of the site, showed the high level of public anxiety caused by a misunderstanding of the potential radiation risks, concerns about the level of contamination remaining at the site and about the potential for the spreading of contamination. Communication between radiation protection staff and the public was difficult, as the technical terminology used was frequently interpreted as being used as a way to confuse the public. In addition, some individual interests were evident: part of the local community would have liked to see a playing field in front of their windows, instead of high buildings, some politicians were seeking opportunities for getting public attention and some people were lookinng for ways to find advantage from the potential problem. This situation showed the need for the involvement of communication professionals. These professionals could have given some trainning to the radiation protection staff in order to help in communications with the stakeholders. They could have also been effective in mediating public meetings and in dealing with the press attending the public meetings.

The Public Ministry is a Brazilian institution for the defence of citizens in relation to their collective rights and for the enforcement of the law concerning issues of public interest. Any citizen can directly contact the Public Ministry and request apropriate legal action. The office of the State Public Ministry in São Paulo is an approachable and reliable institution and, from time to time, there have been public requests to the Public Ministry concerning the USAM decommissioning. CNEN has had many meetings with the Public Ministry to explain the details of the cleanup processes adopted at the site.

Six years after the site release, the State of São Paulo enforced a law concerning contaminated soils in industrial areas. According to this law, the owner of the site is responsible for the cleanup of the site. Because of this new law, the USAM site had to be surveyed again, on this occasion for other types of contaminants, such as oils and heavy metals. At the request of the Public Ministry, the new survey of the site was performed by CNEN which was seen as clear evidence that the organization had gained credibility from its earlier activities.

5. SUMMARY AND CONCLUSION

Industrial activities which have been outside of the scope of nuclear regulations can be associated with radiological hazards. The contamination of such sites is making the regulation for NORM facilities necessary. Recognizing this need, CNEN has established requirements concerning NORM facilities, but the regulations do not encompass all types of NORM industries and there is some conflict of interest with other Brazilian State agencies which will have to be resolved.

To avoid additional costs and the creation of additional public anxiety due to the need for site re-surveys, the involvement of the State agencies responsible for conventional pollutants should be promoted.

Despite public pressure being one of the reasons for the decommissioning of the USAM facility, a public communication strategy was not properly established and the public was not appropriately informed about decommissioning procedures. As a result, public concerns about radiation risks, the extent of site contamination, the potential for the spreading of contamination from the site to neighborhood areas and for radionuclide migration into groundwater were not properly dealt with. Public meetings showed that the communication between radiation protection staff and members of public without proper guidance from experts in communication can be ineffective.

The Public Ministry is an important interested party and should be clearly and precisely informed of all of the steps of the decommissioning process. The technical support provided by an institute of the regulatory authority could be perceived by the public as representing a conflict of interests. However, it proved to be possible to increase the credibility of the process as a whole by showing the similarity of the proposed actions with the ones taken by international counterparts.

The cleanup costs could be decreased if optimization within higher intervention levels were considered. The new Brazilian Basic Standards include an intervention level of 10 mSv/a and this level will be considered in the optimization of the cleanup of USIN site.

The demolition of an old facility and the construction of new and high-priced residential apartments will bring hundreds of wealthy consumers to the region increasing property values and improving the local commerce.

REFERENCES

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[2] EURATOM 1996. Basic Safety Standards for the Protection of the Health of Workers and the General Public from the Dangers Arising from Ionizing Radiation. Council Directive 96/29 Euratom of May 13, 1996.

[3] BRAZILIAN NUCLEAR ENERGY COMMISSION (CNEN), CNEN-NE-4.01, Requisitos de Segurança e Proteção Radiológica para Instalações Minero-Industriais, Rio de Janeiro, (2005).

[4] LAURIA, D.C., ROCHEDO, E.R.R., The legacy of monazite processing in Brazil, Radiat. Prot. Dosim. **114** 4 (2005) 546–550.

[5] BRAZILIAN NUCLEAR ENERGY COMMISSION, CNEN-NE-6.05, Gerência de Rejeitos Radioativos em Instalações Radiativas. Rio de Janeiro (1985).

[6] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Protection of the Public in Situations of Prolonged Radiation Exposure. ICRP Report 82, ICRP, London (1999).

[7] LAURIA, D.C., ZENARO, R., SACHETT, I.A., "Restoration of an urban site affected by a monazite processing plant", Site Characterization Techniqes used in Environmental Restoration Activities, Final Report of a Coordinated Research Project: 1995–1999, IAEA-TECDOC-1148, IAEA Vienna (2000).

DISCUSSION

A. J. BAER (Switzerland — Chairperson): In the light of your experience, what is the main recommendation that you would make to someone faced with the problems which you encountered?

D.C. LAURIA (Brazil): Take the concerns of the local community seriously and respond to them. When decommissioning a nuclear site in an urban area, you must communicate with the local community, and for that you need a public communication strategy.

PANEL DISCUSSION

Session 7

SOCIAL AND ECONOMIC IMPACTS

Chairperson: **A.J. BAER** (Switzerland)

Members: **R.A. WELCH** (United States of America)
B. HANSSON (Sweden)
D.W. REISENWEAVER (United States of America)
C. PESCATORE (OECD/NEA)

A.J. BAER (Switzerland — Chairperson): I invite the panellists to respond to the question 'What are the challenges of and the lessons learned from site restoration and the reuse of sites after the completion of decommissioning?'

In doing so, I wonder how much one can learn from other people's experiences given the fact that situations can differ so much. The facility may be 1000 miles from the nearest population centre or in the middle of an urban area, public pressures may be considerable or negligible, and so on. Perhaps the owners of the site will not wish it to be released into the public domain after decommissioning as they envisage its being used for something similar to what it was used for originally, such as another nuclear power plant (for example, if ever a further nuclear power plant is built in Switzerland, it will, I am sure, be built at the site of one of our existing plants). The transport of vast amounts of contaminated soil to a disposal site may entail road accident risks greater than the risks involved in leaving the soil where it is and letting people walk about on it. Given considerations like those, how much can we learn from one another?

I. TRIPPUTI (Italy — panellist): One challenge is gaining sufficient stakeholder trust to allow unrestricted use of the decommissioned site, especially when soil contamination exists or is suspected. That challenge calls for transparency and for dialogue with the stakeholders. Who should engage in that dialogue — senior company officers, company representatives who live within the local community, communication experts? At all events, a communication plan should be developed.

A further challenge is deciding what to do when the conditions exist for partial site release but the rules are unclear. In such a situation, it is necessary to agree on the rules with the safety authorities as early as possible. I would mention in that connection that the partial release of a site can help in gaining stakeholder trust.

Then there is the challenge of deciding on the monitoring and other controls necessary after site release — how long should they last and who should be responsible for them? As regards the latter point, if the controls are to last a long time, they should, in my opinion, be the responsibility of a public institution rather than a private company.

Lastly, I would mention the challenge of planning for site reuse in the interests of the social and economic well-being of the region. Should that be the responsibility of the decommissioning organization or of the local communities?

C. PESCATORE (OECD/NEA — panellist): The purpose of decommissioning a nuclear site is to secure the removal of some or all of the regulatory controls. Basically, there are three possible end points — unrestricted use of the site (green field), reuse of the site for non-nuclear (for example, conventional industrial) activities, and reuse for nuclear activities (for example, the storage of radioactive materials or the construction of a new nuclear facility).

If the envisaged end point is reuse of the site (with buildings) for non-nuclear activities, it is important to verify well in advance that there is sufficient interest within the business community (enough companies interested in renting or buying space) or that, if something like a museum is to be established at the site, the necessary financial resources will be provided for. At all events, there must be a 'business model', which should, if possible, be worked out with local and regional development boards.

Once decommissioning has been completed to the satisfaction of all, the most important challenge is to ensure that the decommissioning records, which should be sufficiently detailed, are preserved in case a subsequent intervention proves to be necessary or liabilities arise. This is widely recognized. The question is 'How to preserve the records in a readily accessible form for a sufficiently long time?'

R.A. WELCH (United States of America — panellist): As an elected official of the city of Richland, located near the Hanford site, I have a responsibility to help ensure that the city's economy remains strong. This is, in the first place, a matter of credibility as regards safety — there must be justified confidence that the cleanup of the Hanford site is proceeding as it should. Otherwise, people living within the Richland community will have doubts about remaining and people living outside it will have doubts about moving in and investing.

As the Hanford site cleanup progresses, well paid jobs will be phased out. We are therefore trying to create alternative employment opportunities for scientists and engineers. For example, we are lobbying for an expansion of the national laboratory that is located in Richland.

We have learned lessons from what happened in the early 1980s, when the construction of new facilities at the Hanford site ended abruptly and many local people lost their jobs and moved away, leaving empty homes — a situation that might be characterized by the request 'Would the last person to leave please turn out the light!' We realize that we must be proactive. So, in order to attract new businesses we are offering low-interest loans where possible, cheap power (the city has its own electrical utility) and low cost land (parts of the Hanford site, with infrastructure, have already been handed over to the city).

We have been very successful in creating opportunities for new businesses in Richland, which last year was ranked the best city in the State of Washington for doing business in.

B. HANSSON (Sweden — panellist): I shall respond to the question put to the panel by focusing on Sweden's Barsebäck nuclear power plant, which was closed for political reasons.

Barsebäck Unit 1 was shut down in 1999 and Unit 2 in 2005, and we have been learning how to deal with the social and economic consequences. We have changed our organizational structure in order to fit in with the transition from power reactor operations to site care and maintenance.

We are sure that the Barsebäck site will be reused in some way or another, and we intend to clean it up so that it will be free from regulatory requirements. The site could be developed into an industrial park or, as the local community wishes, used for family homes built near the sea.

Commercially, the best reuse of a successfully decommissioned nuclear site may well be the construction of a new nuclear facility. That is what we would like, but we are currently thinking of the Barsebäck site being used as an industrial maintenance training centre or a centre where new tools can be tested (on the reactor vessels) — or even as a visitors' centre where people can learn about the history of the nuclear era in Sweden.

One challenge we are facing is the local community's dissatisfaction due to the fact that, as there is not yet a final disposal facility for the dismantling waste, dismantling of the two power reactors at Barsebäck will not start before 2020.

D.W. REISENWEAVER (United States of America — panellist)): I have problems with the words 'site restoration' in the question put to the panel. In many dictionaries, you will find 'restore' defined as 'return to a former condition'. That is something we cannot do with a nuclear site, and we should not mislead the public into believing that a nuclear site will one day be as it was originally. In my view, we should speak of 'site remediation'.

One challenge connected with the prospective reuse of a site after decommissioning is proving that the site is safe for reuse, especially if the site has not been cleaned up in accordance with present-day clearance values or if buildings or other structures remain on the site. No new owner will want to accept liability for possible future cleanup.

I shall illustrate the point by recalling the case of Nuclear Lake, a lake in the State of New York near which there used to be a nuclear fuel testing and research facility containing a research reactor and fuel handling cells. The facility was closed in the 1970s and decommissioned. The buildings were decontaminated as part of the decommissioning project, but not demolished. The land changed hands a couple of times, and ultimately it was donated to the National Park Service for public recreation purposes.

In the 1980s, members of the public discovered that there was residual plutonium at the site, especially in and around the old fuel research building, from which a plutonium release had occurred during an incident when the building had been in operation. A second decommissioning project was carried out and the site was again released for unrestricted use. At the end of the second decommissioning project, all the buildings were removed and the site remediated to park-like conditions. The area is now part of the Appalachian Trail system and the public has unrestricted access to it.

One lesson learned was that it is important to make sure that the criteria for the release of a site are fully understood. Another lesson was that limits may change in the future, so one should document the results of final surveys and ensure that the records are maintained in an accessible location and form. The records of the first decommissioning project were not available, so that much time was spent on determining the location of the plutonium contamination. The original owner of the site was no longer in business, so a subsequent owner — not the current owner — was called upon to pay for the remediation (the second decommissioning project). Fortunately, that subsequent owner, a very large corporation, was willing to pay, so legal actions were not necessary. The issue could have come before the courts, and reuse of the site might then have been restricted for a long time.

A.J. GONZÁLEZ (Argentina): In a discussion on the social impacts of the decommissioning of nuclear facilities, we who are not sociologists can only scratch the surface of the issues. At conferences of chemical industry representatives that I have attended, the technical experts have discussed technical issues, the sociological issues being referred to the sociologists. We have very few sociologists, if any at all, at this conference. Also, I would recall that decommissioning is not an invention of the nuclear industry — the chemical industry and other industries regularly encounter decommissioning problems and solve them.

In many of the presentations made here, I have detected a kind of 'eurocentrism', and that troubles me, because Europe is not the entire world. In Europe, it is not uncommon for a few young people who band together and make a lot of noise about some environmental issue to be regarded as 'stakeholders'. That is a distortion of the system of representative democracy. Mr. Welch described himself as "an elected official of the city of Richmond". He is a true stakeholder, democratically representing people who have a genuine stake in what is happening at a nearby nuclear site.

The IAEA has not done much with regard to the social impacts of the decommissioning of nuclear facilities. In my opinion, that is because the IAEA's Statute does not envisage the involvement of the IAEA in social issues and because decommissioning is not an activity exclusively of the nuclear industry.

A.J. BAER (Switzerland — Chairperson): The IAEA's Statute was drawn up in the 1950s, and the world has changed a lot since then — hence the difference between what the IAEA is authorized to do and what it perhaps ought to be doing. I should like the IAEA to become more involved in social issues relating to the peaceful utilization of nuclear energy.

One impediment is the fact that technical issues tend to be universal whereas social issues tend to be local, national or regional. Mr. González spoke of 'eurocentrism'. It is true that the way in which some things are done in Europe is not the way in which they are done in, say, North America or South-East Asia, but we have to live with that — and it makes life more interesting.

C. PESCATORE (OECD/NEA — panellist): In response to Mr. González's comment about stakeholders, I would mention that under the Aarhus Convention it is not just elected officials who are stakeholders. The concept of 'stakeholder' is a broad one, and experience has shown that environmental and related issues tend to be dealt with more successfully if a large number of people are consulted.

S. SAINT-PIERRE (World Nuclear Association): I agree with Mr. González that Mr. Welch is a true stakeholder, and I hope that more people like him will be at future IAEA conferences similar to this one.

Mr. Welch talked about being proactive. When you want a decommissioned nuclear site to be reused, you certainly have to be proactive — and optimistic. Safety is very important, but if you emphasize only the safety aspects of a decommissioning project you probably will not get very far in creating interest in site reuse.

C. PESCATORE (OECD/NEA — panellist): The concept of 'safety' is very broad — it is more than just compliance with certain numbers relating to risk. Such numbers change from time to time, and what was once 'safe' comes to be considered unsafe.

Important aspects of safety are familiarity with and control over a situation. That is why many people advocate the development of repositories in easy stages.

I. TRIPPUTI (Italy — panellist): Mr. González referred to 'the system of representative democracy'. One problem with that system when you have a decommissioning project which is taking a long time is that a local election may lead to the creation of a new local government, with views about your project very different from the views of the previous local government. That can happen even if the views of the local community as a whole have not changed.

R.A. WELCH (United States of America — panellist): With regard to safety, there are frequent reports in our local media about the safety of the Hanford decommissioning project. Many of them are inaccurate, especially ones appearing in the media in the western part of the State of Washington, which is strongly anti-nuclear power. We regularly contact the media in order to correct 'facts' that are simply opinions.

B. HANSSON (Sweden — panellist): Mr. Tripputi referred to 'the views of the local community'. In our experience, they can change quite drastically. When the Barsebäck nuclear power plant was being built and operated, the local community was very supportive, but now it simply wants to be rid of the two shutdown reactors.

G. RINDAHL (Norway): Some people from our Institute for Energy Technology, during a visit to a decommissioning project in Japan a few years ago, were very impressed by the way in which the local community was being kept informed about the project through three-dimensional visualization. In my view, such an approach is likely to be more effective than the presentation of documents that most local citizens — especially the young ones — do not want to read.

A.J. BAER (Switzerland — Chairperson): Mr. Welch talked about being proactive, and I should be interested to hear whether the city of Richland has to rely entirely on itself or receives outside support.

R.A. WELCH (United States of America — panellist): We do not have to rely entirely on ourselves. Completion of the Hanford site cleanup is a goal of the State of Washington as a whole — there is no east-west disagreement on that issue. We and the leaders of other cities potentially affected by the decommissioning of the Hanford site come together in the Hanford Advisory Board, exchange views and agree on what matters to raise at what political level, perhaps going right up to Congress. In addition, the decommissioning contractors are very supportive. Things tend to work well because there is normally a partnership among all those involved.

S. BARKER (United Kingdom): In the United Kingdom, the Nuclear Decommissioning Authority (NDA) supports the activities of site stakeholder groups and has established a National Stakeholder Group, in whose activities the representatives of site stakeholder groups can participate, sharing their concerns with one another, with the NDA and with site managers. The aim is to build trust through openness.

A.J. BAER (Switzerland — Chairperson): I now invite the panellists to respond to the question 'Is stakeholder involvement in decommissioning overemphasized, and what is the role of stakeholders?'

The panellists' responses will probably differ according to what they understand by 'stakeholder'. I looked the word up on the Internet recently and found 21 definitions. Views regarding the meaning of 'stakeholder' vary within the nuclear industry. For example, some say that regulators are stakeholders, whereas others say that they are not. Probably all agree that local communities are stakeholders, but they may well disagree about the meaning of 'local' — is a community 300 km away from a nuclear site a 'local community'?

D.W. REISENWEAVER (United States of America — panellist): I do not like using the word 'stakeholder' in this context. I prefer to speak of 'interested parties' — people who have an interest in the decommissioning project. In my response, however, I shall talk about stakeholders.

The number and types of stakeholders will vary depending on the location of the site and the kind of facility that is being decommissioned. If it is a small manufacturing plant, the general public living in the vicinity may not be interested at all. That was so in the case of a decommissioning project I was involved in, even though the manufacturing plant was located in the middle of a large city. The local businesspeople were interested, but only in whether the project would affect their businesses. No one except the local government was really interested.

In the case of a large nuclear facility, there may be contradicting views among the stakeholders. For example, one group may not want the facility to be decommissioned as that would mean the loss of their jobs, whereas another group wants it to be decommissioned immediately as it constitutes a 'nuclear hazard'. How does one resolve such issues?

One group of stakeholders that we have encountered in the State of New Mexico is the local Indian tribes. Often, when we start remediating an area we find Indian artifacts, and even graves, which the local Indian tribes want to be preserved. Also, there are local historical societies that believe that some of the buildings at Los Alamos should be preserved, or at least documented, because they were involved in the Manhattan Project. Such issues are not the conventional ones that decommissioners are used to dealing with.

Among the lessons that we have learned are: identify all possible stakeholders early in the decommissioning process; be prepared for conflicts of views between stakeholder groups; listen to the conflicting views and try to make the groups understand each other and the purpose of the decommissioning project; and, as a minimum, fully document what is done during the decommissioning project and identify whatever you think should be preserved for historical reasons.

B. HANSSON (Sweden — panellist): I agree with what Mr. Reisenweaver said about ‘stakeholders’ and ‘interested parties’.

One very interested party is usually the workforce members who are ultimately going to lose their jobs. In our case, where there is to be a workforce cut from 450 to 40, we have given people time off to prepare for the future, so that they do not have the feeling that they are ‘working themselves out of a job’. Also, we have invited people to participate in the planning of necessary organizational changes.

In communicating with our workforce and the local community, we have been very open, passing on information as soon as it is received in order to prevent rumours from developing because of a lack of information.

As regards the local community, it will be affected in a number of ways — for example, the local volunteer fire brigade will no longer receive support from the Barsebäck site fire brigade. The local community is urging the Government to move some State-owned or State-administered enterprises to the area, but so far without success.

Most political groups that have visited the Barsebäck site have left with a very positive impression, but we nevertheless feel that we could be doing more.

R.A. WELCH (United States of America — panellist): For me, with my business background, the primary stakeholder is the customer, the person who is — say — going to buy the house that you are building if it meets the specifications. Other stakeholders in such a case may be, for example, the neighbour whose view is going to be partly obstructed by the house and the local school that will be attended by the children living in the house. In such a situation, I do not believe that all stakeholders should have ‘an equal seat at the table’.

As far as the Hanford site cleanup is concerned, the contractor is doing an excellent job — within the budget and in a timely manner. Nevertheless, there are people who would welcome a switch to another contractor because they would like the job to be done cheaper. We are resisting that. We do not get involved in the technical aspects of the project, but we are sufficiently knowledgeable technically to understand what is going on at the site, and we pass on what we learn to the local community as a whole.

C. PESCATORE (OECD/NEA — panellist): We use the definition of ‘stakeholder’ given in the Aarhus Convention, which is a broad definition that says basically ‘everybody who is an interested party’.

I do not think that stakeholder involvement in decommissioning is ever overemphasized. It will be counterproductive if there is no genuine desire to accommodate the views of the people consulted. There must be a mechanism for ensuring that words can be followed by actions.

Regarding Mr. Reisenweaver's comment about things of historical interest, we are looking into that issue and will be releasing a report soon.

I. TRIPPUTI (Italy — panellist): In the decommissioning of a nuclear facility the main issue is not safety or environmental impact, but the perception of safety or environmental impact. In my opinion, therefore, we should not overemphasize the role of national and international environmental groups, which may well be pursuing general political objectives of no interest to the local community.

I agree with Mr. Reisenweaver's comment about conflicting stakeholder views. We have experienced situations where some stakeholders wanted the spent fuel to be sent away for reprocessing and others were opposed to its being reprocessing and situations where some stakeholders wanted the decommissioning project to be completed as soon as possible and others wanted it to last as long as possible.

Decommissioning workers are important stakeholders, because they are local citizens and they understand the technical issues. If they are not convinced that the decommissioning plan is a good one, it is very difficult to convince the other local stakeholders.

A.J. GONZÁLEZ (Argentina): I am glad that the Chairman has triggered comments about the meaning of 'stakeholder', a word that has given rise to much confusion.

A few months ago, the IAEA's Board of Governors adopted a safety standard containing a very broad definition of 'stakeholder' (The Management Systems for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3 (2006)). Brazil and Argentina opposed — unsuccessfully — the adoption of that safety standard because 'the authorities of neighbouring countries' constituted one stakeholder category. The inclusion of that category in the definition might make sense as regards Europe, a continent with many small countries, but not as regards a continent like South America, where a facility being decommissioned could be thousands of kilometres from any neighbouring country. It is as if the Libyan Arab Jamahiriya were being invited to state that it is a 'stakeholder' in respect of a decommissioning project taking place in Austria.

The problem is that this safety standard may come to be regarded as an integral part of the Joint Convention. If that happens, the countries party to that convention will have to consult with their neighbours whenever they want to embark on a nuclear site decommissioning project regardless of where the project is going to take place.

I look forward to seeing the impact of the definition of ‘stakeholder’ in that safety standard within Europe.

C. PESCATORE (OECD/NEA — panellist): In Europe we are already living quite comfortably with such a broad definition of ‘stakeholder’, especially in the waste management area. For example, a Finnish environmental impact assessment report has recently been translated from Finnish into a number of other languages so that stakeholders in other countries can examine it.

As regards the Libyan Arab Jamahiriya and Austria, if they are both parties to the Joint Convention they could put questions about each other’s nuclear facility decommissioning activities at review meetings of the contracting parties.

B. HANSSON (Sweden — panellist): We have held stakeholder meetings in Denmark, a neighbouring country, in order to learn the opinions of people living there.

R. COATES (IAEA): When organizing stakeholder consultations, one must make the nature of the process clear to the stakeholders very early on. The stakeholders must know whether they are going to be able to participate in the decision-making or their role is only advisory. One must avoid arousing false expectations.

C. PESCATORE (OECD/NEA — panellist): I fully agree with Mr. Coates.

M. LARAIA (IAEA — Scientific Secretary): In an exercise aimed at identifying all possible categories of stakeholder in IAEA Member States, we arrived at a total of over 30 categories.

In my view, it is risky to exclude anyone who considers him/herself to be a stakeholder. Whether you like it or not, anyone who wishes to be ‘part of the game’ should be allowed to be ‘part of the game’. The involvement of many stakeholder categories complicates matters, but that is something you should learn to live with.

Three stakeholder categories not yet mentioned here are the shareholders of the company whose facility is to be decommissioned, countries that have donated funds for decommissioning activities in other countries, and site redevelopers (we are currently preparing a document on the redevelopment of nuclear sites).

As regards Europe, pursuant to Article 37 of the Euratom Treaty, all countries belonging to the European Union are stakeholders, regardless of geographic location, when a nuclear facility decommissioning project is taking place in a European Union country.

B. BATANDJIEVA (IAEA — Scientific Secretary): With regard to Mr. González’s comments, we tried to develop a definition of ‘stakeholder’ that took account of views expressed in the Board of Governors, as we realized that different countries defined ‘stakeholder’ in different ways. Finally, we decided to leave it to individual Member States to define ‘stakeholder’ for themselves.

There is now a tendency to use the the expression ‘interested party’ rather than ‘stakeholder’ in IAEA documents.

S. HARRIAGUE (Argentina): I wish there had been a few social scientists at this conference, as the input of social scientists can be important. There was no input from social scientists when the decision was taken in Argentina to dismantle most of the railroad system. From a narrow economic point of view, the decision was a sound one, but it led to the ‘death’ of hundreds of villages. When we suggest fantastic ‘green field’ solutions, it might be useful to have a few social scientists there to point out that in most countries the necessary financial resources will have to be diverted from — say — the public health sector.

A.J. BAER (Switzerland — Chairperson): That is a very good final comment.

DECOMMISSIONING OF SMALL FACILITIES

(Session 8)

Chairperson

A. YOUTSOS
Greece

Rapporteur

C. PESCATORE
OECD/NEA

LESSONS LEARNED IN DECOMMISSIONING LABORATORY FACILITIES

C. GRIFFITHS
Griffiths Consultancy Services,
Newark, Nottinghamshire,
United Kingdom
Email: cathygriffiths@f2s.com

Abstract

The misconception that the decommissioning of small facilities is a trivial, low priority activity often results in unnecessary costs, delays and possible safety issues, e.g. the loss of radiation sources, which in some countries has led to the death of members of the public who came into contact with them. Much of the existing technical literature on decommissioning addresses the technological and other aspects of the decontamination and dismantling of the larger nuclear facilities, such as nuclear power plants and relatively large prototype, research and test reactors, although an increasing number of documents focusing on decommissioning of smaller facilities have been published in the last decades. Furthermore, the infrastructure for sharing the knowledge and experience gained in the decommissioning of large nuclear facilities is already well established in many parts of the world, but this is not generally the case for smaller facilities. The paper aims to identify some of the lessons learned when decommissioning laboratory facilities in the United Kingdom. Much of the information is generic and is equally relevant to a whole range of the smaller facilities that exist worldwide. It is anticipated that the sharing of knowledge gained from the decommissioning of laboratory facilities will be directly relevant to others faced with similar projects in the future, such that they can benefit directly and achieve safe, cost-effective completion of a well considered decommissioning project.

1. INTRODUCTION

The past fifty years has seen a rapid global escalation in the use of radioactive substances in small medical, industrial, research and education facilities. A wide range of radionuclide sources (both sealed and unsealed) are used worldwide in such facilities. In most, if not all countries, the number of larger nuclear facilities is well known and an outline decommissioning plan for each of them will have been drafted and submitted to the licensing authority before the facility commenced operation. The situation is not so clear for the much greater number of small facilities, which vary in size and complexity and usually present a lower radiological risk in decommissioning. It is common for decommissioning not to have been considered at the time of the original construction of the smaller facilities and rarely, if at all, would a decommissioning plan or resources for its delivery have been provided. The problems of obtaining adequate financial provisions for the safe and satisfactory decommissioning of small radionuclide laboratories is exacerbated when there are challenged with unforeseen problems that have the potential to rapidly deplete an already small budget. The sharing of international experience and knowledge and the establishment of a network of decommissioning colleagues worldwide is seen as an important step in optimizing the task of decommissioning of smaller facilities for the benefit of those who have to do such work and for all persons concerned with the subject.

2. LESSONS LEARNED IN PLANNING FOR DECOMMISSIONING

It is important at the outset to establish the level of knowledge and expertise that exists within the organization to aid the decommissioning project. Early identification of any training needs is essential. Whereas training may be considered to be an expensive overhead when faced with a limited decommissioning budget, the costs of ignorance are much higher. Unfortunately, this is a lesson that has been all too well learned when establishments have started to decommission small facilities with inadequately trained and experienced staff, leading to problems with legislative compliance and often costly delays because of the need to train staff after the project has started in order to be allowed to proceed further.

Often a small nuclear laboratory engages the services of a specialist decommissioning company to carry out some aspects of the decommissioning plan, but this is dependent on the overall size and complexity of the facility. Smaller laboratories, in which the only work carried out was radioimmunoassay, using iodine-125 and cobalt-57, should be able to plan and deliver a decommissioning strategy using existing expertise of their staff with reference to published documents as appropriate [1, 2]. One radioimmunoassay laboratory informed that they had satisfactorily completed a waste characterization and monitoring survey, decontaminated and decommissioned the laboratory. However, it failed to manage the disposal of the laboratory refrigerator and the gamma sample counter. An assumption had been made that the refrigerator would not be contaminated — as radionuclide kits had been stored in sealed boxes. Both items had to be retrieved from a disposal skip prior to the arrival of a scrap metal merchant to remove them from site. Monitoring revealed trace iodine-125 contamination and a higher level of cobalt-57 contamination in the refrigerator, that exceeded the levels for free release [3]. Although the gamma sample counter had been monitored and declared free from contamination, the loss of the equipment manual and lack of understanding of the construction of this twenty year old piece of equipment had led to the in-built calibration source being overlooked [4]. A telephone call to the manufacturer could have prevented this omission. The decommissioning plan needs to be all inclusive if simple, yet significant, errors of this sort are to be avoided [5].

The benefits of early discussion with the regulator should not be overlooked. Whereas owners sometimes delay discussions with the regulator until the decommissioning is imminent, discussions even up to several years ahead of the project commencing can result in the regulator providing historical records of the facility that present day workers did not know existed [6]. Furthermore, the regulator can provide useful early guidance on the demonstration of regulatory compliance and can identify any holding points required as decommissioning proceeds at which he/she wishes to be satisfied that the project is proceeding in compliance with legislative requirements, including the application of ‘best practice’. The regulator is best placed to be aware of the implementation schedule for any national or international requirements that may trigger revisions of regulations which may influence the decommissioning project. It is always easier to build in flexibility when forewarned of impending change. The collective experience of the regulatory authority can be a valuable source of available advice which the operator should use to the best advantage. Further information can be found in publications of the IAEA, through contacts with colleagues who may have experience of decommissioning similar facilities or through web sites and email discussion groups of worldwide learned and professional societies, such as the International Radiation Protection Association (IRPA).

Early communication should not be restricted to the regulatory body. Often owners of small facilities do not see the need to inform residents living close to the laboratory of their plans for decommissioning, as they fail to perceive how it may affect them. A harsh lesson was learned by adopting this approach by one site owner who was decommissioning radionuclide laboratories prior to their conversion into offices. The erection of a contamination control tent external to the building where contractors were observed to be cutting up demolition waste, coupled with staff in protective clothing using radiation measuring instruments caused alarm to local residents who observed these events from the windows of their homes. The absence of any communication about the decommissioning plan had caused residents to assume that a radiation leak had occurred from the laboratory which the owners were now seeking to control. The adverse publicity surrounding this event, and the subsequent public relations exercise to provide retrospective information to local residents almost halted this project. Early communication and provision of information could have avoided the problem.

The possibility that naturally occurring radionuclides might be present should be considered. If the walls of the laboratory are tiled, a check to rule out the presence of a uranium glaze finish could avoid later problems. Uranium glaze may not be restricted to wall tiles: uranium glaze on hand washing sinks is not unknown. Naturally occurring thorium may be incorporated into the linings of high temperature laboratory equipment, such as furnaces used for sample preparation in destruction analysis. The total laboratory inventory might also include a radionuclide that has not been utilised in the laboratory but was incorporated during the original laboratory construction as a design feature. Examples of such items are gaseous tritium light devices, ionizing radiation smoke detection devices containing Americium-241 or long half-life small sealed sources (typically isotopes of radium or strontium) incorporated in lightning conduction devices, installed on the roof of the laboratory.

The provision of adequate funding for the decommissioning of radionuclide laboratories is often identified as a major problem. This is exacerbated if the contents of the laboratory include equipment containing a high activity sealed source and there are no financial provision for its disposal, recycling or return to manufacturer [7]. In 2005, there was a revision of the IAEA regulations for the safe transport of radioactive material [8] and such changes occur periodically internationally and nationally. In one case, even though the original transport container in which the sealed source was delivered to the site was still available, it was unwisely assumed by the owner that it met the requirements of present day transport legislation. Omitting to discuss the transport proposals with the relevant regulatory body during the early planning stage caused severe difficulties when the problem was recognized. By then, the owner of the laboratory had signed an agreement with a private developer for the sale of the land. The late realization that the original packaging no longer met the United Kingdom's transport legislation resulted in a one year delay while alternative packaging was type-tested and approved by the regulatory body. The laboratory demolition was delayed until after the source was transferred from the site. The vacated site owner incurred costs for employing a security firm to oversee the site until the source could be removed. This delay caused the site owner to default on the agreement for the sale of the land, with consequent heavy financial penalties. All of these problems could have been avoided with adequate forward planning.

Where long half-life radioactive material has been discharged from the laboratory as aqueous waste, typically carbon-14 or tritium, time spent studying site drainage arrangements, especially where roots from trees external to the building may have invaded the pipes and caused leakage should be investigated. Video telemetry devices can be used to trace the routing of drainage pipes to check their integrity. The retrospective investigation of drainage arrangements identified as necessary by the regulator once decommissioning was already underway at a laboratory resulted in the decommissioning project substantially exceeding its projected budget, as no provision had been made for land remediation. This error could have been avoided if early discusssions with the regulator had taken place.

A further consideration in establishing a comprehensive decommissioning plan is to identify hazardous material other than radioactive materials that may constitute part of the overall laboratory waste inventory, e.g. asbestos, chemicals or biologically hazardous materials. Where uncertainties exist as to whether or not asbestos could be present, and a pilot survey cannot resolve them, it is better to err on the side of safety and ensure the availability of suitably qualified and experienced staff to deal with asbestos and its subsequent disposal [9]. The inappropriate exclusion of asbestos containing materials from the inventory of one laboratory caused unprojected costs and delays. The demolition work had to be stopped while specialist asbestos contractors were employed to complete the removal. It was difficult to obtain a competitive price quote for the work as the contractor was aware that his services were in high demand. The original risk assessment had taken no account of the possibility of asbestos and hence had to be revised.

3. LESSONS LEARNED DURING IMPLEMENTATION OF THE DECOMMISSIONING PLAN

Lack of funding should not be an excuse for failing to make progress with a decommissioning project because it will never be as inexpensive to do the task tomorrow as it is today. Evidence for this view comes from the worldwide increases in costs for radioactive waste disposal, particularly over the last decade, and in the increasing costs of labour. Furthermore, it is beneficial for decommissioning to be undertaken while there is ‘in house’ knowledge and expertise of the range of radionuclide uses that have occurred in the laboratory over its lifetime. For commercial laboratories, it is often possible for the costs of decommissioning to be considered as part of an integrated business plan, with costs recovered through product sales. For government funded laboratories, financial provisions at the outset often fall short of the required budget and a mechanism to carry forward money into the next financial year, when additional funds may be available, might not exist. In such circumstances, a staged approach to decommissioning should be adopted, taking due account of the relative hierarchy of risks and their reduction as the phased decommissioning progresses. In this context, it may be possible to raise money from the resale of free-released recyclable materials during the decommissioning, such as scrap copper pipes. In the case of phased decommissioning over a number of years, the screws and bolts in the fixtures and equipment scheduled for dismantling at a later stage should be maintained. In one laboratory where the dismantling of fixtures and installed equipment was delayed for several years, the absence of periodic oiling/greasing of screws and bolts, seals and joints had resulted in dry and rusted joints which required an extended period for the purpose of dealing with this problem through the use of cutting techniques when dismantling operations commenced. This costly addition to the project could have been avoided.

When a project is considered to be beyond the expertise of existing staff employed at the facility, the services of an external consultant should be sought, who ideally will coordinate the completion of the various stages of the decommissioning plan. Prior to selecting and appointing a consultant, it is essential to research his/her relevant experience in the decommissioning of small laboratory facilities. Inappropriate selection of a consultant can lead to the project being halted while the services of a more appropriate expert are secured, often with a resultant financial penalty from premature termination of a contractual arrangement. It may be necessary to engage the services of a suitably experienced decommissioning contractor to undertake dismantling and stripping out/demolition works, and the cutting up of dismantled materials into manageable pieces for further characterization and radionuclide activity quantification. When considering the options for decommissioning a facility, the many benefits that result from employing an expert to oversee the delivery of a comprehensive decommissioning plan should not be overlooked. Such experts can provide training to the existing workforce as appropriate, so that they develop new skills and contribute to keeping the overall costs of decommissioning as low as possible. Such an approach can deliver cost effective decommissioning of the laboratory, while also providing the benefit of a more skilled and knowledgeable workforce. Further benefit may be gained from ownership of new instrumentation purchased to enable existing staff to characterize and quantify the waste, especially those that are suitable for free release.

The clear specification and assignment of roles and responsibilities is essential for the effective and optimized delivery of a decommissioning plan. The logical progression of the decommissioning project relies upon the completion of specific tasks at the appropriate time. The plan should ideally be progressed with frequent briefing meetings of those involved, to verify that actions have been successfully completed. In parallel, it is important to keep persons who will be involved at a later stage of the overall plan fully informed of the progress made to date, especially highlighting any learning experience gained. For those who have never decommissioned a laboratory before, any opportunity that becomes available to visit a facility that is already undertaking decommissioning activities should not be refused because of the valuable first hand knowledge that can be gained. A review of publications on decommissioning of laboratories can provide valuable knowledge but the benefits of actually observing a project in progress and talking to the workforce about their experiences cannot be overstated. Of particular value are discussions surrounding any safety issues that have occurred during the tasks so far completed and how these have been eliminated or mitigated through effective work planning and procedures. Where problems have occurred, a review of the comprehensive nature of the risk assessment might identify problems that perhaps could have been avoided. A comprehensive, carefully planned and executed decommissioning strategy should progress without difficulties, or at least without unanticipated difficulties that cannot be accommodated within the contingency arrangements built into the decommissioning strategy. It is considered appropriate to include a financial contingency provision within the overall decommissioning budget as part of sound financial planning. While the contingency fund can be utilised to meet price increases or to finance minor additional costs not identified at the planning stage, a contingency provision cannot rescue a decommissioning project faced with escalating costs due to inadequate planning. The careful retention and review of records, and a thorough knowledge of past activities undertaken at the laboratory, and their incorporation into the decommissioning plan, will make the chance of a major omission less likely.

At an early stage, before demolition commences, the methods to be used for the minimization, accumulation, characterization and segregation of the resultant waste streams and the planning for their disposal to the most appropriate route should be established and any necessary regulatory permission/licence should be sought. This is particularly relevant where the acceptance criteria for the facility destined to receive some or all of the waste requires the production and approval of a documented quality plan. This plan may need to include data on the proposed verification of the radionuclide inventory of the waste and the methodology used for activity quantification including the calibration of the instrumentation used to make the measurements. Where existing staff at the laboratory are to actively participate in the decommissioning, especially in relation to the further management of waste for disposal, the purchase of suitable radiation detection equipment, such as a germanium detector, coupled with the training of staff in its use, might be required. The confidence to decide that waste can legitimately be free released to a landfill site or scrap metal for recycling can dramatically reduce the overall radioactive waste disposal costs of a project. Conversely, the inappropriate free release of decommissioning waste to landfill can result in prosecution and fines, loss of reputation and substantial costs in attempting to recover inappropriately released waste. Whereas a strategy of delay and decay is cost effective for short half-life radionuclide waste, the accumulation of decommissioning waste on the premises of a small laboratory where space is limited can hinder further progress being made.

It is worthwhile validating the specifications of any specialist equipment being hired to facilitate completion of a given task in the decommissioning plan. While the specifications may be clearly stated in the catalogue of the hire company, the time taken to visit the establishment and verify the factual accuracy of the data provides additional reassurance. The removal of a sealed source from an irradiator located in a basement laboratory had to be halted when the specifications of the hired ‘A frame’ stand and hoist equipment were found to differ from those published in the literature. The hoist was being used to lower the empty shielded source container through a hatch from the ground floor above, setting the container down onto the floor below to receive the removed sealed source. Unfortunately the over-specification of the hoist resulted in the type B source container hovering almost one metre above the ground, with no way of lowering it to the floor. This temporary halt in the schedule for the source removal could have resulted in serious financial implications for the decommissioning project budget had the contractors been unable to find a prompt resolution. However, a visit to the hire company to explain the problem resulted in the immediate issue of a suitable block and tackle assembly such that the task could be successfully completed. The consequences of failure could have resulted in a protracted delay if it had been necessary to fix another date for the source removal contractors, bringing with him the hired type B source container, having agreed The routing by road of the low loader vehicle with the police and regulatory body would also have had to be rearranged. In this case the failure to verify the specification of the hired equipment almost had serious consequences for the decommissioning project.

The end stage of any decommissioning project is the release of the laboratory from regulatory control, which often involves the issue of documentation by the regulator to revoke the regulatory permissions. For a well planned and executed decommissioning plan, this usually presents no difficulties. The main difficulties encountered that have resulted in the regulator being unwilling to revoke regulatory permissions can typically attributed to one of several causes; these were due to a failure to adequately communicate and agree the decommissioning plan in advance with the regulator, a failure to addresss adequately inadequacies in the strategy that the regulator had identified as decommissioning got underway, or due to the late provision of information to the regulator. One laboratory that only provided the regulator with the characterization survey information at the time of the final decommissioning monitoring survey was refused revocation of the regulatory permission because the instrument calibration and its limits of detection were inappropriate and inadequate for the task. These problems could have been avoided if an effective dialogue with the regulator had commenced sooner and had been maintained throughout the project, coupled with a willingness to act on the advice and concerns voiced by the regulator.

4. CONCLUSIONS

A comprehensive plan is necessary even for the decommissioning of small facilities if costly delays and errors are to be avoided. It is never too soon to consider the need for decommissioning and the records that will facilitate such action. Lessons learned from past projects have identified how making assumptions without validating them can result in protracted delays and escalating costs not originally envisaged. Lack of finance should not be used as an excuse to avoid making progress with decommissioning. A staged approach making full use of the opportunity for training and skill development of the existing workforce is to be encouraged so that it can participate in the project under the supervision of an experienced consultant, hence reducing the overall costs. Early discussions with the regulatory bodies are to be encouraged, as their input can avoid costly errors that may lead to a breach of regulatory compliance. Effective communication is essential at every stage of the project. It is important to consult stakeholders that may previously not have been considered as relevant during the operational lifetime of the laboratory, such as residents living in homes adjacent to the boundary of the facility, to avoid generating unnecessary concern. The clear assignment of roles and responsibilities at the outset, including their periodic review as decommissioning progresses, closely aligned with the review of the risk assessments, should frequently be highlighted and discussed with all those involved. Attention paid to even the smallest of details relevant to the effective delivery of the project is worthwhile, as it is often the simplest of omissions that results in contingency funds being exceeded long before the project is completed. The owners of small laboratories scheduled for decommissioning often have no previous relevant experience, so that any initiatives to establish a 'lessons learned' programme to promulgate such advice is to be welcomed. Whereas publications are widely available to provide the basic principles to facilitate development of a decommissioning strategy, supported by technical and safety documentation to optimize the implementation and delivery of the project, there are benefits from promulgating the knowledge obtained from lessons learned. These lessons learned might rescue another decommissioning project faced with a similar problem and facilitate the achievement of a cost-effective and timely solution. Wherever possible, tried and tested techniques should be adopted throughout the decommissioning project, especially when decontamination techniques are adopted as part of waste minimization. The use of novel equipment or techniques should be avoided unless a validated alternative can not be found.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standards Series No. WS-G-2.2, IAEA, Vienna (1999).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Small Medical, Industrial and Research Facilities, Technical Reports Series No.414, IAEA, Vienna, (2003).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Clearance of Materials Resulting from the Use of Radionuclides in Medicine, Industry and Research, IAEA-TECDOC-1000, IAEA, Vienna (1998).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Methods to Identify and Locate Spent Radiation Sources, IAEA-TECDOC-804, IAEA, Vienna (1995).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Planning and Management for the Decommissioning of Research Reactors and Other Small Nuclear _Facilities, Technical Reports Series No. 351, IAEA, Vienna (1993).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Record Keeping for the Decommissioning of Nuclear Facilities: Guidelines and Experience, Technical Reports Series No. 411, IAEA, Vienna (2002).

[7] NUCLEAR REGULATORY COMMISSION, Technology, Safety and Costs of Decommissioning a Reference Large Irradiator and Reference Sealed Sources, Rep. NUREG/CR-6280, PNL-10167, prepared by Pacific Northwest laboratory, NRC, Washington, DC (1996).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 2005 Edition, IAEA Safety Standards Series No. TS-R-1, IAEA, Vienna (2005).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Problematic Waste and Material Generated During the Decommissioning of Nuclear Facilities, Technical Reports Series No.441, IAEA, Vienna (2006).

THE RISØ DR 1 DECOMMISSIONING PROJECT AND LESSONS LEARNED

K. LAURIDSEN
Danish Decommissioning,
Roskilde,
Denmark
Email: kurt.lauridsen@dekom.dk

Abstract

Based on the experience gained during the decommissioning of a 'zero power' reactor, DR 1, some lessons learned are presented that may be helpful to other small decommissioning projects. The reactor was the first one of six nuclear facilities to be decommissioned in Denmark and was used as a 'learning exercise' for the decommissioning organization as well as for the nuclear regulatory authorities. Initial planning for the dismantling of DR 1 was done by the project leader and others from the engineering staff, while the detailed planning of individual dismantling operations was done in collaboration with all staff that were to participate in the operations. Concrete demolition was carried out by an external contractor and special care was taken to inform his staff about working in a potential radiation environment. Similar care was taken to educate the 'old' staff to be aware of conventional industrial hazards and to use appropriate personal protection means. Waste handling and documentation was a weak point in the project, partly because intermediate storage facilities and a waste documentation system were not operational at the time that the project produced waste. During the clearance measurements of the building, measurable levels of ^{137}Cs from either fallout or the Chernobyl accident were found; it took some effort to demonstrate that these were the sources of the contamination and not DR 1.

1. INTRODUCTION

Risø National Laboratory (RNL) [1] was established in the late 1950s as the Danish nuclear research centre. Three research reactors and a number of supporting laboratories were built. Following problems with a leaking drainpipe in the largest reactor it was decided in 2000 to close all remaining facilities and to initiate decommissioning. In March 2003, after thorough preparations, including an Environmental Impact Assessment, the Danish parliament gave its approval to fund the decommissioning of all nuclear facilities at the laboratory to 'green field' status within a period of up to 20 years. The decommissioning is to be carried out by a new organization, Danish Decommissioning (DD) [2], which is independent of the Risø National Laboratory, thus avoiding any direct competition for funding between decommissioning and the continuing research activities at Risø. The majority of DD's staff are former operational staff of the facilities, thus securing, as far as possible, the maintenance of knowledge of the design and peculiarities of the individual facilities. However, some new competences, e.g., in project management, have been added to the organization.

In the overall decommissioning plan it was decided to decommission the facilities sequentially, beginning with the smallest and least radioactive reactor and leaving the largest reactor (a 10 MW MTR) until last in order to benefit, as much as possible, from the decay of ^{60}Co in this reactor. Thus, the decommissioning of DR 1 became a 'learning exercise' for DD as well as for the nuclear regulatory authorities. The decommissioning approach chosen was to let DD's own staff dismantle the facilities as far as possible and to only use external contractors for tasks for which no or insufficient internal expertise exists, such as concrete demolition. In particular, for the dismantling of radioactive parts, it is considered advantageous to use staff who have a prior knowledge of the facilities and of radiation work.

2. DESCRIPTION OF THE REACTOR

DR 1, shown in Fig. 1, was a 2 kW thermal homogeneous solution type reactor, which used 20% enriched uranium fuel and light water as moderator. The first criticality was obtained in August 1957. During the first ten years of operation the reactor was used for neutron experiments and thereafter mainly for educational purposes. The reactor was in operation for the last time in 2001.

The reactor core consisted of a spherical vessel with an outer diameter of 32 cm containing a solution of 15 litres of uranyl sulphate dissolved in light water, which was drained from the vessel in December 2002. The core vessel was positioned at the centre of a cylindrical reflector consisting of 13 layers of graphite bars stacked in a steel tank, which was placed inside a shield of magnetite concrete. A recombiner tank was installed in order to recombine hydrogen and oxygen produced by radiolysis. The reactor had a number of horizontal irradiation facilities. Four stainless steel control rods containing boron carbide controlled the reactor. In addition to these major reactor components, there were connecting pipes, lead shield, cooling coils etc. Fig. 2 shows a cutaway view of the reactor.

The reactor vessel, the recombiner, and the 60 mm pipe connecting the two were the most active components due mainly to ^{137}Cs and small amounts of

FIG. 1. DR 1 during operation.

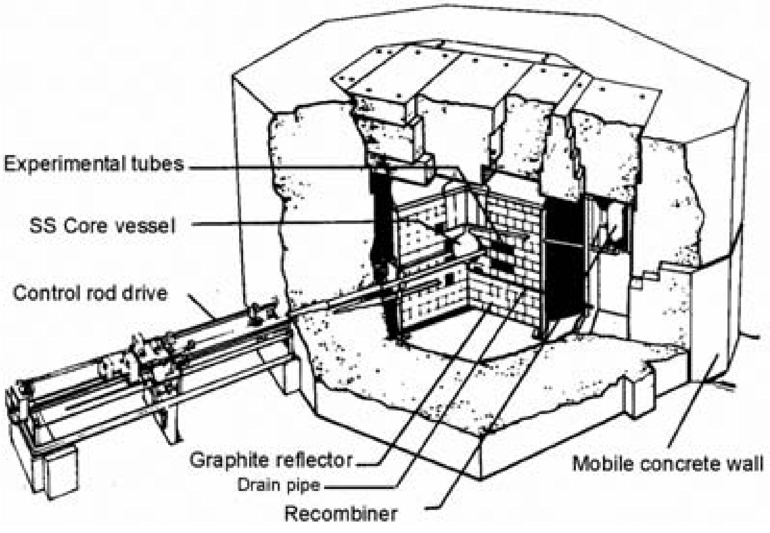

FIG. 2. Cutaway view of DR 1.

actinides, deposited on the inner surfaces, and ^{60}Co. Although not very active, these components required some degree of remote handling, the detailed planning of all operations and consideration of the risks involved in order to minimize radiation doses to personnel and occupational injuries. Small amounts of activation products such as ^{14}C, ^{60}Co, ^{63}Ni, ^{133}Ba, ^{152}Eu and ^{154}Eu were also found in the reflector, the reflector tank and the concrete shield.

3. THE REGULATORY PROCESS

The documentation to be submitted to the nuclear regulatory authorities before decommissioning could start comprised an overall plan for decommissioning of all the nuclear facilities at the Risø site, safety documentation and a specific project description for the DR 1 project. In addition, an Environmental Impact Assessment was prepared. The overall decommissioning plan described common aspects, such as the general strategy, the order in which the facilities were to be decommissioned, waste handling arrangements, environmental monitoring and radiation protection. The safety documentation contained detailed descriptions of the organization, the site and the facilities, as well as accident analyses and contingency measures. The project description for DR 1 covered the approach to be used for dismantling and demolition of the facility as well as aspects of waste handling and radiation protection specific for this project; but it did not go into the details of working plans and procedures. The structure and contents of the overall plan and the DR 1 project description were based on the recommendations given in IAEA Safety Standards Series No. WS-G-2.1 [3]. However, it was an agreed principle between the authorities and DD that references to other documents should be used rather than repeating information in all documents submitted. Therefore, several chapters in the DR 1 report were replaced by a reference to the overall plan or the safety documentation. This greatly facilitated both the writing and the review of the documents.

Once the project was finished, the required documentation for the authorities were: a final report describing the dismantling and demolition process and the waste produced [4], and a clearance report describing the clearance measurements for the building and surrounding land [5].

During the operation of the facilities, the relations between Risø National Laboratory and the nuclear regulatory authorities were good and based on mutual trust and respect for the professional capabilities of the each other. Because the facilities at the Risø site are the only nuclear facilities in Denmark and, consequently, the first ones to be decommissioned, the regulators are also facing a new set of problems. From the outset of the decommissioning planning it was therefore agreed – more or less formally — between the regulators and DD that there should be an open dialogue between the parties in planning, regulatory acceptance and execution of the decommissioning projects. In particular, the first project, decommissioning of DR 1, was seen as a 'learning exercise'. DD has sought to be open even about matters that did not work out so well, and it is felt that this openness has consolidated the trust of the regulators.

4. DISMANTLING AND DEMOLITION

Detailed planning of the individual tasks was done with the participation of all those who were going to take part in the work. A spreadsheet with the individual steps of the work on one axis and all the aspects to consider on the other axis, served as the planning and safety analysis tool. Aspects to consider were, for instance, tools to be used, the waste container to use, anticipated doses and the particular risks to consider. The work plan also contained references to relevant drawings and photos.

The majority of the dismantling work was carried out by two technicians, generally supervised by either the project leader or his deputy. For some operations one or two additional technicians assisted. In general, existing or 'off the shelf' tools could be used, since there was no need for robots or other sophisticated remote handling equipment. In some cases special tools or modifications of existing tools were made in DD's workshop.

4.1. Dismantling the recombiner

Contact dose rates at the surface of the recombiner were of the order of 5 mSv/h. So, brief contact with the hands in order to place tools or lift equipment was by no means excluded. The flange to the pipe connecting the recombiner with the core vessel was opened easily and replaced by blind plates. Other connecting pipes and wires to the recombiner were cut by means of an ordinary wire cutter or, for thicker pipes, a hydraulic cutting tool. After this, the recombiner was lifted out and placed in a shielded drum that was transferred to a shielded cell made of concrete blocks in a corner of the reactor hall. The lifting gear was disposed of together with the recombiner in order to save radiation dose.

4.2. Dismantling the reflector and the core vessel

As can be seen from Fig. 2, the core vessel was positioned in the middle of a tank, surrounded by the reflector. The reflector consisted of more than 300 graphite bars measuring 10 × 10 cm in cross- section and having varying lengths between a few cm up to 126 cm. There were 13 layers, and the direction of the bars in each layer was perpendicular to that of the layers above and below.

There were three pipes connected to the core vessel which had to be removed before the vessel could be pulled out: the 60 mm pipe leading to the recombiner, a 6 mm drainpipe going from the bottom of the vessel and out through the reflector to the space below the recombiner and a 25 mm aluminium pipe going through a steel pipe that was welded into the core vessel. The aluminium pipe served to place small items in the centre of the reactor core for irradiation. This pipe could be pulled out fairly easily.

It was evident that in order to remove the core vessel, at least seven layers of graphite would have to be taken out, and that, in the course of this action, the connecting pipe to the recombiner could be cut loose. The drainpipe at the bottom of the vessel was disconnected by drilling a 50 mm circular core through the graphite around the pipe by entering from the recombiner vault. This somewhat delicate operation was successful; the drill followed the correct direction all 75 cm to the centre and the drainpipe was cut exactly where it was supposed to be cut.

Since the graphite bars had a very smooth surface and were not very heavy (the longest ones weighed around 23 kg) it was decided to use suction pads for lifting out the elements. Three suction pads each with a diameter of 75 mm were mounted on a beam. Two technicians operated the system: one stood at the top of the biological shield and manoeuvred the beam into position by means of a long rod, and the other operated the air supply for the suction pads and the swinging crane used for lifting out the graphite bars. The whole operation went surprisingly smoothly. On the average it took about 1½ hours to take up one layer, consisting of about 30 individual bars. No bars were dropped during the removal.

After the removal of seven layers of graphite and parts of the eighth layer, the 60 mm pipe was be cut loose from the core vessel and a mounting was fixed for lifting out the core vessel. After the removal of another layer, the vessel was lifted out and transferred to a shielded waste drum.

After being emptied and cleaned, the reflector tank was lifted out and placed in an open space in the reactor hall. It was slightly activated and had to be classified as radioactive waste. In order to reduce its volume, it was cut into smaller pieces by means of a nibbler. This method was chosen because it does not produce any sparks or dust. Only the top flange had to be cut with a right angle grinder.

4.3. Demolishing the concrete shielding

DD chose to hire an external contractor to do the demolishing, instead of acquiring equipment and educating its own staff. The external staff required some extra instruction and the work had to be supervised in order to ascertain that the rules for work in radiologically classified areas were adhered to and no material taken away from the site without having been cleared. In general, the contractor's staff performed the work without any safety problems.

The walls of the control rod house were ordinary brick walls, which were easily torn down by means of a small ‘Brokk’ demolition robot. The biological shield was made of magnetite concrete and was cut into blocks by wire cutting. The maximum size of the blocks was determined by the 5 tons lifting capacity of the crane. Thus the largest blocks were a little over 1 m^3. The inner 10–20 cm of the biological shield was activated to levels above the clearance levels. Slabs were therefore cut off the blocks in order that the majority of the concrete could be released as ordinary building waste.

Wire cutting was performed using water as a lubricant. This method was chosen, partly because it was cheaper than dry cutting and partly because it was assumed that handling cutting water would be easier than handling the dust coming from dry cutting. It must be acknowledged that handling the cutting water was not all that easy; on one occasion, for instance, water penetrated cable ducts in the concrete and appeared in the basement. Also the surveillance of air contamination during the cutting was disturbed by many false alarms due to moisture entering the air monitor. Therefore, DD may prefer dry wire cutting in the future and accept the drawback of having to establish tents with filtered ventilation around the working area.

5. WASTE HANDLING

Denmark does not yet have a repository for radioactive waste. When the parliament decided that decommissioning of the facilities at Risø could start, it also initiated preparatory work for establishing the requirements for a repository. This work is still ongoing. Therefore, an intermediate storage facility has been built at the site. However, this facility was not ready when DR 1 started to produce waste. So, the waste had to be stored temporarily in other existing storage facilities or at DR 1. This situation was far from ideal, but the problems were overcome because the amounts and the activity of the waste were modest. It was also unfortunate that DD's electronic Waste Documentation System was not operational at the time of the DR 1 project. This made the recording of the waste more difficult and eventually resulted in double work when the details of the waste had to be entered into the the electronic system. The lesson here is that it is very important to be able to carry out waste documentation as soon as the waste is produced — and that it should be recognized in the planning phase that preparing a documentation system takes time.

6. OCCUPATIONAL SAFETY

All DD personnel working in radiation fields wore TL dosimeters as well as digital dosimeters. In addition, the technicians performing the dismantling work wore special dosimeters at fingertips, around the wrists and at the front of the head, as appropriate. For the removal of the recombiner and the core vessel and reflector, the total collective dose was about 800 man Sv. Minor doses were incurred through other operations so that the total collective dose was not much more than 1 man mSv.

All contracting staff who carried out the concrete demolition wore TL dosimeters. They were given a half-day introduction to radiation protection and, mainly for their personal reassurance, they were asked to deliver urine samples before the demolition work started and after its completion. They all did so, and the analysis of the urine samples did not show any signs of intake of radionuclides as a result of the work. It was our impression that the contractors appreciated this extra precaution.

While the 'old' DD staff were very much aware of the potential radiation hazards, their awareness of conventional industrial hazards was not high at the outset. So, some education and change of habits was necessary and protective clothing and helmets were worn as required. No major incidents have occurred although a couple of minor accidents are worth mentioning in order to learn from them. One of them happened during the dismantling of pipes in the primary system when the technician cut his hand on the protruding end of a 6 mm pipe that had been cut with a wire cutter and thus had a rather sharp edge. The technician, who was one of DD's own staff, was aware that there was a contamination risk and went to the nurse at Risø National Laboratory who cleaned the wound and checked it for contamination without finding any. A somewhat similar accident happened to one of the contractor's wire cutting operators who cut his hand on the wire. He, however, wrapped a piece of (dirty) cloth around the hand and continued working. Fortunately, DD's health physics technician observed the improvised bandage shortly afterwards and ordered the man to go to the nurse to have the wound cleaned and checked for contamination. Also, in this case no contamination was found, but the incident underlines that special care should be taken to ensure that external staff members are aware of the particularities in work in classified areas and that they should follow the rules.

7. CLEARANCE OF MATERIALS, BUILDING AND LAND

Clearance levels for materials were established by the Danish nuclear authorities in July 2005. The levels are based on EC and IAEA recommendations. Materials that had not been activated and had a regular surface were cleared at DR 1 on the basis of measurements with hand held contamination monitors. Materials, which were assumed to be below the limits, but which had been slightly activated or were contaminated and had a geometry which did not allow direct measurement, were cleared in DD's clearance laboratory. This laboratory received its permit to operate in May 2006. A special procedure was applied for the concrete from the biological shield. The thicknesses of the slabs to be cut off from the individual blocks in order to clear the main part were determined on the basis of analysis of cores drilled out of the concrete before cutting started. The analyses were described in a report [6], which was scrutinized and accepted by the authorities before any concrete could be released from the site.

The clearance measurements for the building and the immediate surroundings took about 2½ months. They were carried out by means of a combination of contamination measurements on surfaces with hand held instruments and measurements of entire walls or large portions of a wall with highly sensitive Ge detectors and ISOCS ('in situ' object counting system) software. A particular problem encountered was ^{137}Cs from weapons test fallout or from the Chernobyl accident (or both); it took some time to find suitable places to carry out measurements to establish background levels. The authorities granted the clearance of the building and land on the basis of a report describing these measurements [5] and spot checks of the detailed measurement records.

8. CONCLUSIONS

The DR 1 project was a small and rather straightforward decommissioning project. Nevertheless, some lessons were learned and some assumptions confirmed that may be important to bear in mind for other projects. The mutual trust between the operator and regulators greatly facilitated many things and therefore a lesson is that the operator should be open and honest at all times — even when things do not turn out so well. All staff participating in the work should be involved in the planning; they will feel more committed to the work and they sometimes have good ideas. The proper classification and documentation of the waste produced — both active and cleared — is very important and should be carried out immediately when the waste is created. Clearance measurements can take a long time, in particular if the building is to remain and be used for other purposes.

The DR 1 project serves as inspiration to a test case on safety assessment for the IAEA project DeSa [7].

REFERENCES

[1] http://www.risoe.dk

[2] http://www.dekom.dk

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series No. WS-G-2.1, IAEA, Vienna (1999).

[4] DANISH DECOMMISSIONING, Decommissioning of DR 1, Final report. DD-18(EN) (January 2006). http://www.dekom.dk/publikationer/Decommissioning_of_DR1_-_Final_Report/.

[5] DANISH DECOMMISSIONING, Final survey report for DR 1. Clearance of building and land. DD-19(EN) (December 2005).

[6] DANISH DECOMMISSIONING, Aktivitetsindhold i betonblokken på DR 1. Måleresultater som dokumentation for frigivelse (Activity contents in the concrete block at DR 1. Results of measurements as documentation for clearance), Rep. DD-16, June 2005 (in Danish).

[7] http://www-ns.iaea.org/tech-areas/waste-safety/desa/start.asp

DISCUSSION

R. ANASCO (Argentina): What was the total collective dose?

K. LAURIDSEN (Denmark): About 900 man-Sv. The maximum dose to an individual was 450 Sv, and most of the collective dose was distributed over two people.

R. ANASCO (Argentina): What decontamination method did you use?

K. LAURIDSEN (Denmark): The only decontaminating we did was to cut off the active part of rods that had been activated.

In other projects, we have decontaminated by means of glass blasting and high pressure water jetting.

V. SEYDA (Ukraine): You said that in the graphite moderator the main radionuclide was europium-154. What about carbon-14? In any reactor graphite structure the main radionuclide is carbon-14.

K. LAURIDSEN (Denmark): Europium-154 was the determining gamma-emitting radionuclide. There was so much europium-154 in the graphite that we had to store the graphite as radioactive waste. Of course, there was also carbon-14.

EXPECTED PROBLEMS IN THE DECOMMISSIONING PLANNING OF A SMALL RESEARCH REACTOR IN A NON-NUCLEAR COUNTRY

A.G. YOUTSOS, S. MESSOLORAS, K. MERGIA,
C. HOUSIADAS, A. SAVIDOU, I.E. STAMATELATOS
National Centre for Scientific Research 'Demokritos',
Attiki,
Greece
Email: youtsos@ipta.demokritos.gr

Abstract

A 5 MW materials testing research reactor is operational in Greece. The operator of the reactor, while carrying on planning for its continued use, is formulating a decommissioning strategy. In the paper the issues and problems related to the future decommissioning of the reactor are discussed and the steps to be taken now for successful future decommissioning are outlined.

1. INTRODUCTION

It is good international practice and a requirement of the regulatory authorities that decommissioning planning should start as early as the design stage of a nuclear facility. Operators of research reactors have to address the decommissioning issues now rather than later even if a long operational period is foreseen. A number of factors make this exercise of paramount importance. The operation of a research reactor should have high acceptability by the general public and the existence of a decommissioning plan aiming at the restoration of the site will enhance its acceptance. This is of particular importance for the public in Greece since the research reactor is the only nuclear facility in the country. A decommissioning plan will provide the operating organization with information on the technological issues, costs and liabilities that must be considered. In addition, the required inputs from the regulatory authority and the modifications or extensions needed to the existing law will become apparent and the preparations to address them can start long before the actual decommissioning. An early recognition that the reactor will eventually have to be decommissioned will make the reactor users more conscious of the problems that can be created by producing waste and may result in future cost reduction and the minimization of technical difficulties. The ideas outlined above reflect the current thinking of the operating organization of the Greek Research Reactor, GRR-1, and steps have already been taken to begin decommissioning planning. In the initial stages, a decommissioning strategy has to be decided upon and issues connected with this strategy have to be addressed and resolved. In the future, the detailed technical aspects of decommissioning planning will have to be decided upon. Also, the question of who will bear the cost of the decommissioning will have to be addressed and whether resources should be set aside from now onwards. These and related issues will require discussions between the operating organization, the regulatory body and the government.

2. DESCRIPTION OF GRR-1

The GRR-1 is a 5 MW open pool type reactor with materials testing reactor (MTR) type fuel elements, cooled and moderated with demineralized light water.

In line with the international Reduced Enrichment for Research and Test Reactor (RERTR) programme, the core has been recently fuelled with low enriched uranium (LEU) elements of U_3Si_2_Al type. The fuel enrichment is 19.75% and the fissile loading is 12.34 g of ^{235}U per plate. The equilibrium LEU core contains 23 standard fuel elements and 5 control fuel elements. The control fuel element is of the same size as the standard element but consists of only 10 plates, thus providing an inner gap for the insertion of the control blades. The core is reflected by beryllium blocks on two opposite faces and is surrounded by a practically infinite thickness of pool water. A graphite thermal column is adjacent to one side of the core. The core is suspended in a water pool that is 9 m deep. The fuel elements are cooled by the circulation of the water of the pool at a rate of 450 m^3/h. The water flows downward through the core, through a decay tank and is then pumped back to the pool through the heat exchangers. A weighted flapper valve, attached to the bottom of the core exit plenum, enables natural circulation through the core in the absence of forced flow circulation. Irradiation devices for isotope production, neutron activation analysis and irradiation damage studies are located at specific core lattice positions. Six radial horizontal beam tubes are available, of which three contain in pile collimators for neutron scattering instruments.

3. CURRENT STATE OF GRR-1 AND FUTURE UTILIZATION PLANS

The operator and owner of the GRR-1 is the Institute of Nuclear Technology and Radiation Protection, one of the eight Institutes of the National Centre for Scientific Research ‘Demokritos’. Demokritos is a public body supervised by the General Secretariat of Research and Technology, a department under the Ministry of Development. Renovation of the reactor operational facilities has been carried out recently and the renovation of the building is planned to start shortly. The policy of Demokritos, the Institute and the Greek government is that the reactor will operate for a long time into the future.

There is extensive planning for the future utilization of the reactor which is expected to bring societal and economic benefits. The irradiation facilities of the reactor are used for radioisotope production, for research purposes and for material studies for the European Fusion Programme. There are facilities for neutron activation analysis — enabling the study of short and long lived radioisotopes, as well as large volume sample multi-element non-destructive analysis. The neutron activation facilities are used for bio-medical, environmental, material and cultural heritage studies. The neutron diffractometer is used for investigations of magnetic, superconducting and technologically advanced materials. A neutron reflectometer, to be used in the study of polymers, biological systems and thin film materials, is being commissioned. In addition, small angle and ultra small angle instruments have been designed and are expected to be operational in the very near future. These instruments will be used for the study of macromolecules, porosity, alloys, etc.

4. DECOMMISSIONING STRATEGY

It is worthwhile examining the available decommissioning strategies under current conditions in order to identify the most probable one to be adopted for GRR-1 in the future.

Strategy I: Care and maintenance under regulatory control

This approach could be implemented initially after the reactor shutdown. During the care and maintenance period, short and medium lived activation products will decay and this could reduce the subsequent decommissioning effort. Within this period, the future use of the building would be decided and a detailed plan made for the decommissioning programme.

Strategy II: Safe enclosure under regulatory control

This strategy could be implemented either immediately after reactor shutdown or after strategy I, when a definite decision on the future use of the building has been taken (i.e., its use as a radiological laboratory or for other types of nuclear activities). Nevertheless, radioactive materials would have to be removed from the reactor pool and the experimental facilities. These materials could be temporarily stored in the hot cell within the reactor building, thus, a national repository would not be necessary.

Strategy III. Entombment – termination of regulatory control

Since the site is now within a densely populated area, this strategy would be unacceptable. Furthermore, this strategy is not a real solution to the problem and would impose costly or difficult tasks on future generations related to the management of the radioactive waste inside the tomb.

Strategy IV: Full decommissioning – termination of regulatory control

This strategy is the final solution and its implementation could start after the initial period envisaged under strategy I or after the termination of the building use discussed in strategy II. Strategy IV, i.e. the eventual restoration of the area to 'green field' status, would be the most acceptable strategy to the public and has to be central in the decommissioning policy. The adoption of this approach would require that future reactor operations and use are planned in such a way as to make the future full decommissioning easier and less costly. Further, a full radiological assessment of the present state of the site and of the facilities would have to be undertaken as soon as possible.

Thus, in summary, initial implementation of Strategy I would reduce the cost of any next stage and would also provide the necessary time for decisions to be taken on the future use of the building. It would also provide time for the development of a detailed plan for either partial or full decommissioning. However, present and future decommissioning planning has to be conducted within the basic premise that, at some future time, the site will be released for unrestricted use. This approach is likely to be the most acceptable to the public and to the Greek authorities.

5. DECOMMISSIONING ISSUES

To move to a more detailed decommissioning planning stage, three general elements have to be addressed: (a) detailed documentation (radiological, composition, engineering plans, etc.) of building structures, biological shield, other infrastructure and experimental facilities; (b) revision of infrastructure, when possible, to minimize future radioactive waste production; and (c) new infrastructures or innovated infrastructures to be implemented to take account of the needs for decommissioning.

The main issues for designing the decommissioning, taking into account the present state of the facility and its envisaged future operation and utilization, are as follows.

5.1. Spent fuel

So far, all spent fuel has been shipped to the USA, and there is an agreement with the US Department of Energy (DOE) that spent fuel will be taken — up to 2019.

5.2. Reactor pool and biological shield

The present radioactivity levels of the reactor components in the pool and biological shield have to be determined and an appropriate radioactive components inventory produced. This inventory would enable the radioactivity production during the future reactor operation to be assessed and permit the final categorization of the waste material at the decommissioning stage. It is noted that, since the reactor has not been operated for the last two years, there is an opportunity for this assessment to be carried out now with a minimum of difficulty.

5.3. Radioactive material in the hot cell

In the reactor hot cell a number of active components have been stored over the years of reactor operation but which are not adequately documented. This issue is now being addressed and the appropriate procedures for radiological assessment are being carried out.

5.4. Material irradiation for experimental purposes and applications

The existing irradiated materials and irradiation rigs within the reactor facility do not pose a major problem for decommissioning, since appropriate waste minimization and disposal procedures have been implemented in collaboration with the Institute's Radioactive Waste Management Laboratory. It is important that low activation materials are used for the construction of future irradiation rigs in order to minimize the amount of radioactive waste produced. Concerning materials to be irradiated, requests come from four customers: the Institute, the Demokritos research centre, hospitals and Greek universities. Since, under the current legal rules, the reactor operating organization is responsible for the final disposal of the materials, the need to produce long lived isotopes should be closely scrutinized, and in the case of commercially produced isotopes, the charge made should include disposal costs.

5.5. Experimental apparatus using the neutron tubes

The 'in pile' collimators are the radiologically most important components of the experimental facilities using the neutron beams. These components are exposed to high neutron fluxes and although particular care has been taken to use low activation steel and other shielding materials, the large mass of the components may result in the production of a significant amount of radioactive waste material. The remainder of the 'in beam' components, taking into account that the relevant neutron beam flux is six orders of magnitude lower and that they are of low activation materials, will impose a minimum problem for decommissioning. The same applies to the shielding materials used for neutron beam experiments. This practice of waste minimization by selection of materials will be continued in the future and will always be applied for new experimental facilities for which decommissioning needs have to be taken strongly into consideration.

6. DISCUSSION AND CONCLUSIONS

The basic concept for the design of the decommissioning plan for the GRR-1 must take into account the fact that Greece is not a nuclear country and that the public wishes to be assured that, at the end of the research reactor operations, the site will be released from regulatory control for unrestricted use. These issues have been taken into account in the policy making of the operator. The most important item for decommissioning that of the spent fuel, has been successfully addressed. The agreement with the DOE provides assurance that any spent fuel up to 2019 will be taken away from Greece. The remaining decommissioning items are within the capabilities and expertise of the reactor operating organization. If the reactor continues to operate after 2019, as the Greek law stipulates, a 'take back' agreement has to be incorporated into any purchase contract. It is apparent that in the full decommissioning process, highly radioactive material will be produced. Within the operating organization there is expertise in radioactive waste management and there are facilities for waste storage. However, the requirements for the decommissioning of the GRR-1 have to be carefully examined to determine whether additional expertise and different types of storage facilities are required.

Experience from the decommissioning of other facilities has shown that, besides the spent fuel, there are a number of items which could result in a technically demanding decommissioning project, exposure of the decommissioning personnel and the general public to radiation hazards and the acceleration of costs. Several such items and the means for avoiding the associated problems have been discussed in this paper, for example, the need for comprehensive documentation, the need to assure that all the future reactor operation and utilization should be carried out so as to minimize radioactive waste production and the need to have a clear definition of the methodology for decommissioning.

Although the arrangements for the future decommissioning of GRR-1 appear to be adequate, no-one is complacent since many problems would be encountered if, for any reason, the decommissioning process was required to start in a short time. There would be problems on technical, legal and finance levels. These potential problems have to be pinpointed and the best approach is through the formulation of a detailed decommissioning plan, after the assessment of the present situation with the actions outlined above.

Finally, a successful decommissioning programme for a research reactor facility, such as GRR-1, depends on several factors, such as, advanced planning, learning from the experience of others, the thorough assessment of the hazards involved, a radioactive waste management programme to meet not only the existing but also the final waste requirements, maintaining staff with the necessary skills and expertise, and a close collaboration with the regulatory body.

DISCUSSION

C. PESCATORE (OECD/NEA): What is your estimate of the financial resources that will be necessary for the decommissioning project when you embark on it?

A.G. YOUTSOS (Greece): We are in the process of drawing up an estimate. I would not like to hazard a guess here.

A.J. GONZÁLEZ (Argentina): A calculation of the radioactivity would probably give you the best idea of what to expect. In his presentation, Mr. Lauridsen did not mention the activity concentration, but the total activity was of the order of 10^9 Bq, so I assume that the activity per unit mass was very low. Maybe you will find something very similar, so I suggest that you make the calculation now that the reactor has been refurbished. If there are no problems with the fuel, it is strange that you would expect to have activities of real concern.

USING A RISK INFORMED, GRADED APPROACH FOR DECOMMISSIONING SMALL FACILITIES

A. PERSINKO
Nuclear Regulatory Commission,
Washington, D.C.,
United States of America
Email: axp1@nrc.gov

Abstract

The decommissioning of small facilities is different from the decommissioning of large facilities in that small facilities are generally less hazardous and require comparatively limited actions or controls than large facilities to keep risks to an acceptable level after decommissioning. Such actions or controls should be commensurate with the hazards posed by the facility, i.e. a graded approach should be applied. This graded approach should be based on the associated risk and complexity of the decommissioning task, and should be used to accommodate the risks posed by small facilities. It should provide a clear and consistent approach for both safe and cost-effective decommissioning. Although small facilities generally pose lower risks, some small facilities may be significantly contaminated because of the type and form of the materials used. Unlike large facilities (e.g. commercial nuclear power plants), licensees of such facilities may not possess sufficient financial resources to provide for the clean up of their sites. Therefore, attention should be paid to ensuring that small facilities possess sufficient financial resources to adequately clean up and decommission.

1. INTRODUCTION

Facilities to be decommissioned include commercial nuclear power plants, materials facilities of varying sizes, laboratories, users of sealed sources, research reactors and irradiators. Generally, commercial nuclear power plants are considered to be 'large' facilities, regardless of the rated power output. Materials facilities can range from 'large' to 'small', depending on their sizes. Laboratories, users of sealed sources, research reactors, and irradiators are generally considered to be small facilities. The decommissioning of small facilities differs from the decommissioning of large facilities in that small facilities are generally less hazardous and require comparatively limited actions or controls to keep risk to an acceptable level. Such actions or controls should be commensurate, or 'graded', with the hazards, which are related to the potential consequences (e.g. radiation doses) posed by the facility. In this paper, the term ‘small facilities’ refers to small manufacturing facilities, laboratories, research reactors, irradiators, and users of sealed sources.

Although large facilities generally present higher hazards and thus higher potential consequences than small facilities, this is not always the case. The type, amount, and form of the radioactive materials used at the facility when it was operating and the past management practices together determine the hazard of the facility after it is shut down and before cleanup. Small materials facilities can pose higher hazards and consequences than large facilities because of the type and form of the materials used at the site.

In the USA, commercial nuclear power plants have been able to clean up their facilities to allow unrestricted release, even in cases where there was significant residual radioactivity. In those cases, the licensees possessed the financial resources and technical capabilities to clean up the contamination to a level that allowed the unrestricted release of the site. On the other hand, some relatively small materials facilities in the USA were extensively contaminated after shutdown and required substantial cleanup efforts, but the licensees did not have sufficient financial resources to perform the cleanup. Thus, the size of the facility is not the only factor in determining the complexity and cost of decommissioning. Large facilities may pose low consequences and small facilities may pose high consequences. Grading the approach to decommissioning and the extent of cleanup should be based on the type, amount, and form of the radioactive materials that the facility used and the amount of contamination after shutdown, and not on the size of the facility.

2. GRADED APPROACH

The US Nuclear Regulatory Commission (NRC) applies a risk informed approach to regulatory decision making. According to this philosophy, risk insights are considered, together with other factors in the regulatory process, to better focus licensee and regulatory attention on design and operational issues, commensurate with their importance to public health and safety. The process is considered risk informed rather than risk based because the decision making takes into account a number of factors and does not depend solely on the numerical results of a risk assessment.

Risk can be defined by the ‘risk triplet’ of: (i) a scenario or set of scenarios with a combination of events and/or conditions that could occur; (ii) the probability or likelihood that the scenario(s) could occur; and (iii) the consequences (e.g. the dose to an individual) if the scenario were to occur. Quantitatively, risk is defined as the likelihood of an event times the consequences of the event. Conceptually, the graded approach attempts to achieve approximately the same level of risk for each event or group of events, in order to achieve an efficient application of resources. To achieve a desired level of risk if the current level is deemed to be excessive, actions must be taken to either lower the potential consequences of an event(s), or to lower the likelihood of the event(s) occurring. The actions that are taken should be graded to the potential consequence — the higher the potential consequence, the more stringent the actions. The foremost decision is whether a site will be released with or without restrictions on future site use. If a site seeks unrestricted release, then a reduction of the hazard (i.e., radioactivity level) that is related to the potential consequence may be necessary. This can be accomplished by cleaning up the site. If a licensee seeks to obtain the restricted release of a site, they must demonstrate that further cleanup is neither necessary nor feasible and then take actions, such as establishing institutional controls or engineered barriers, to reduce the likelihood that an unacceptable consequence will occur. Whether for unrestricted or restricted use, actions may need to be taken to reduce risk (i.e. the consequences or the likelihood) and to achieve an acceptable level of risk. In decommissioning, both NRC staff and licensees use risk insights, along with the results of dose assessments. However, rigorous risk analyses are not the norm.

The NRC applies a graded approach in decommissioning materials facilities by binning or grouping facilities (i.e. 'decommissioning groups') based on the nature and extent of the radioactive material present at a facility. The groups are generally related to the potential hazards associated with the facility; less 'complex' facilities with limited distributions of radioactive material may pose lower hazards to individuals and populations during and after decommissioning. The decommissioning process, which may include taking action to reduce risk, proceeds down a path commensurate with the hazard posed by each group.

Activities to decommission a facility depend on the type of operations that the licensee has conducted, the residual radioactivity after shutdown, and the complexity of the contamination and cleanup. The NRC has divided facility conditions into seven decommissioning groups with the following characteristics:

— *Group 1 facilities* — Facilities at which licensed materials have been used in a way that would preclude their release into the environment, would not cause the activation of adjacent materials, and would not have contaminated work areas above a decommissioning screening level. Examples include: (a) licensees who possessed and used only sealed sources, such as radiographers and irradiators; and (b) licensees who possessed and used relatively short lived radioactive materials in an unsealed form.

— *Group 2 facilities* — Facilities that may have residual radiological contamination present on building surfaces and in soils. However, licensees in this group are able to demonstrate that their facilities meet unrestricted release criterion (i.e., radiation doses are less than 0.25 mSv/a (25 mrem/a)) by applying the screening criteria dose analysis. Examples include licensees who used only quantities of loose radioactive material that they routinely cleaned up (e.g. research and development facilities).
— *Group 3 facilities* — Essentially Group 2 facilities that require the development of a decommissioning plan because the licensee did not incorporate remediation procedures into the licence before licence termination. Examples include licensees who may have occasionally released radioactivity within NRC limits.
— *Group 4 facilities* — Those that have residual radioactivity present on building surfaces and in soils, but the licensee cannot meet screening criteria and the groundwater is not contaminated. Licensees are able to demonstrate that residual radioactive material may remain at the facility, but within levels for unrestricted release (i.e. less than 0.25 mSv/a (25 mrem/a). Examples include licensees whose facilities released loose or dissolved radioactive material within NRC limits and may have had some operational occurrences that resulted in releases above NRC limits (e.g. waste processors).
— *Group 5 facilities* — Group 4 facilities that have groundwater contamination. Examples include licensees whose facilities released, stored, or disposed of large amounts of loose or dissolved radioactive material on site (e.g. fuel cycle facilities).
— *Group 6 facilities* — Those that have residual radioactive contamination present on building surfaces, in soils, and possibly in ground water. The licensees are able to demonstrate that the proposed residual radioactivity exceeds the criterion for unrestricted release (i.e., 0.25 mSv/a (25 mrem/a)), but is within levels for restricted use (i.e. 0.25 mSv/a (25 mrem/a) with institutional controls in effect to restrict land use). Examples include licensees whose facilities would cause more health and safety or environmental impact when cleaning up to the unrestricted release limit than could be justified (e.g. facilities where large inadvertent releases occurred).
— *Group 7 facilities* — The same as Group 6 facilities, except that the residual radioactive material remaining at the facility exceeds the level for restricted use (i.e. greater than 0.25 mSv/a (25 mrem/a) with institutional controls in effect). Examples include licensees whose facilities would cause more health and safety or environmental impact when cleaning up to the unrestricted release limit than could be justified (e.g. facilities where large inadvertent releases occurred).

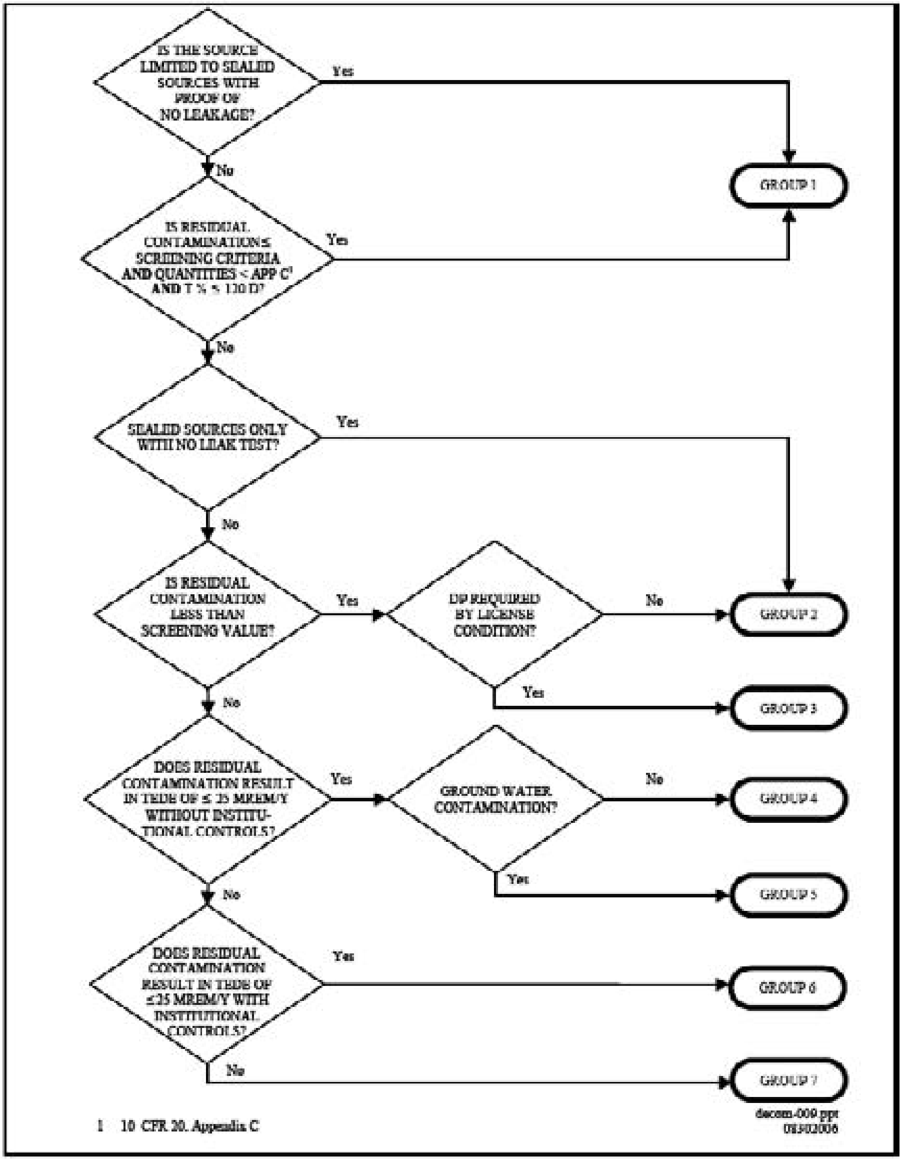

FIG. 1. Determination of the decommissioning group

The simplified flowchart in Fig. 1 shows the key characteristics of each group and the placement of a facility into a group.

The graded approach, both in terms of the review process and the necessary cleanup, is affected by binning facilities into groups and by the application of actions as described below.

3. HOW SMALL FACILITIES BENEFIT FROM THE APPLICATION OF A GRADED APPROACH

Unrestricted release versus restricted release — Facilities in Groups 1–5 are eligible for unrestricted release if it can be demonstrated that residual contamination results in a dose rate of less than 0.25 mSv/a (25 mrem/a) without restrictions on future site use. Facilities in Groups 6–7 are restricted release facilities that require institutional controls to restrict future site access and land use. The institutional controls must ensure that a dose limit of 0.25 mSv/a (25 mrem/a) is achieved with the controls in place. Furthermore, the licensees must show that a dose limit of 1 mSv/a (100 mrem/a) is achieved if the institutional controls fail. A gradation is applied to restricted release facilities, depending on the consequences if the controls were to fail. This gradation is such that if the estimated dose is greater than the 1 mSv/a (100 mrem/a) dose cap when institutional controls are not in effect, then additional, durable institutional controls must be in place to provide further protection for these higher risk facilities. The graded approach allows the use of conventional deed restrictions for lower risk facilities and durable institutional controls (e.g. government ownership or NRC monitoring or licensing) for higher risk facilities. It also allows the duration of the controls and specific-use restrictions to be tailored based on expected hazard duration and dose estimates.

Screening criteria versus dose modelling — Facilities in Groups 1–3 may be evaluated by comparing residual contamination to predetermined conservative screening values, issued by the NRC, for site specific radionuclides instead of performing a site specific dose assessment. A site specific dose assessment must be performed for facilities in Groups 4–7.

Decommissioning plan — Facilities in Groups 1–2 are not required to submit a site specific decommissioning plan because the decommissioning activities will not pose a potential risk to the public or workers. Groups 3–7 must submit a site specific decommissioning plan because they will pose a potential risk to the public or workers.

Environmental review — Group 1 facilities are not required to perform an environmental review. Groups 2–5 must perform an environmental review, referred to as an environmental assessment. Groups 6–7 are required to perform an environmental review and prepare an environmental impact statement. An environmental impact statement is a much more detailed environmental review than an environmental assessment, with more extensive public involvement.

As described above, both licensee and NRC actions are graded according to the hazard, which varies by group. By means of a graded approach, based on risk and complexity, the aim is to achieve approximately the same level of risk for each event or group of events by requiring less stringent actions for lower risk facilities. A graded approach to decommissioning allows facilities to be decommissioned in a safe and cost-effective manner.

4. LESSONS LEARNED FROM DECOMMISSIONING SMALL FACILITIES

Most of the licence terminations in the USA are routine and fall into Groups 1–3. For example, the NRC terminated approximately 900 licences between 2003 and 2006. Of these terminations, most would be considered small, and less than 30 would be considered to be complex (i.e. requiring regulatory review before beginning decommissioning). Most terminations were routine not because of the size of the facilities, but because of the type, amount, and form of the radioactive materials used at the facility when it was operating.

Although many lessons learned apply to both large and small facilities, one that applies particularly to small facilities relates to having sufficient financial resources to clean up a site. Although most licence terminations of small facilities are routine, some are complex and require extensive cleanup. When such cases occur, the licensee may lack the funds and sufficient financial assurance to accomplish the cleanup unlike large commercial power reactors that have sufficient financial resources to clean up facilities for unrestricted release. When the private company has exhausted all avenues for obtaining funds, Federal and State agencies often become involved. At the Federal level, the Environmental Protection Agency (EPA) serves as one potential source of cleanup funding through the Comprehensive Environmental Response, Compensation, and Liability Act, also known as ‘Superfund’.

In some cases in the USA, relatively small manufacturing facilities required extensive cleanup but lacked the funds to do so. For example, the site of a relatively small manufacturing facility was contaminated due to manufacturing operations associated with self-luminous watches and instrument dials and other items involving ^{226}Ra, ^{137}Cs, ^{90}Sr , and ^{241}Am. Primary soil contamination included ^{226}Ra and ^{137}Cs, with small amounts of ^{241}Am. The groundwater on-site was also contaminated with tritium, ^{90}Sr, and ^{137}Cs. The licensee estimated the cost of cleanup to be approximately \$29 million. The NRC estimated that it would cost between \$94 and \$120 million, and \$50 and

$78 million, to decommission for unrestricted release and restricted release, respectively. The licensee's decommissioning fund falls far short of the amount needed to clean up the site, and the licensee had not been contributing to the decommissioning trust fund for some time. The site has since been turned over to the EPA for remediation.

In another example, a small uranium mine and mill that ceased operations more than 30 years ago has buildings and soils contaminated with uranium and thorium. The company that owned the site sold it to private persons who plan to live on the site, but possess insufficient resources to adequately clean it up. The NRC estimates that it will cost approximately $6.6 million to adequately clean up the site so that the persons can live there. This amount far exceeds the financial resources available to the private persons. EPA is also considering this site for remediation.

The NRC continues to revise its financial assurance regulations to better ensure that sufficient resources exist to accomplish decommissioning and to prevent future legacy sites. Revisions may include: (i) requiring licensees to provide, for NRC approval, a decommissioning funding plan based on unrestricted release; (ii) requiring licensees to re-evaluate their decommissioning cost estimates and, if necessary, provide additional financial assurance to cover higher costs after an operational event (e.g. spills) that indicates a potential for increased decommissioning costs; and (iii) providing collateral for undefined guarantees.

5. CONCLUSION

A graded approach based on risk and complexity should be used to accommodate the low risk posed by most small facilities. This provides a clear and consistent approach for both safe and cost effective decommissioning.

Although most small facilities pose low risks, some small facilities may be significantly contaminated and thus represent higher risks that make them more complex to decommission. Unlike large facilities (e.g. commercial nuclear power plants), small facilities that are contaminated may not possess sufficient financial resources to provide for the clean up of their sites. Attention should be paid to ensuring that small facilities possess sufficient financial resources to provide for adequate clean up and decommissioning.

REFERENCES

[1] NUCLEAR REGULATORY COMMISSION, Status of Decommissioning Program — 2004 Annual Report, Rep. NUREG-1814, NRC, Washington, DC (2005).

[2] NUCLEAR REGULATORY COMMISSION, Consolidated Decommissioning Guidance, Decommissioning Process for Materials Licensees, Rep. NUREG-1757, NRC, Washington, DC (2006).

DISCUSSION

T. ISHIKURA (Japan): Obviously, the risk will decrease as decommissioning progresses. Perhaps the IAEA could produce guidance on the reduction of inspection requirements as the risk decreases at large nuclear facilities such as nuclear power plants.

A. PERSINKO (United States of America): I agree.

In 2000, we proposed a phased approach to decommissioning, with inspection requirements declining as one moved from phase 1 to phase 2 and then to phase 3. The proposal was not acted upon officially, but we now carry out inspections on an ‘as needed’ basis in major decommissioning projects.

D. LOUVAT (IAEA): I do not see the virtue of a safety standard on the graded approach to decommissioning, but we could produce a document or organize a forum on what ‘graded approach’ means. In that connection, it would be useful to clarify the meanings of expressions like ‘restricted release’ and ‘conditional release’.

J. LUX (United States of America): I should like to compliment the Nuclear Regulatory Commission on NUREG-1757 (Consolidated Decommissioning Guidance, Decommissioning Process for Materials Licensees, USNRC, Washington, DC, (2006)). It is extremely comprehensive, and I recommend that all decommissioning professionals download it, although it is a massive document.

A. PERSINKO (United States of America): Thank you — we are quite proud of that document, which was recently revised (up to 30 September 2006). The nuclear industry has found it very useful.

DECOMMISSIONING OF SMALL NUCLEAR FACILITIES: PROBLEMS ENCOUNTERED AND LESSONS LEARNED

J.C. BENITEZ-NAVARRO, M.M. SALGADO-MOJENA
Centre for Radiation Protection and Hygiene,
Havana,
Cuba
Email: bentez@cphr.edu.cu

Abstract

The decommissioning of small facilities may present a lower radiological risk and easier planning and implementation than the decommissioning of large facilities but some practical difficulties, lack of strategies, regulatory considerations and financial resources can create serious problems in the decommissioning of small facilities that should be solved properly. In past years, the Radioactive Waste Management Service of the Centre for Radiation Protection and Hygiene has been involved in different decommissioning projects involving small facilities, including laboratories and medical facilities, in which radioisotopes were used for research, diagnosis and treatment. For different reasons, some of these facilities became contaminated. The facilities were closed for a long time and no actions were taken. The decommissioning was not considered during the useful life of these facilities and therefore no plans were in place and no decommissioning related records were kept. Despite these problems, the decommissioning projects were carried out and successfully completed. Several difficulties were overcome and the safety issues received the adequate priority. The paper gives special emphasis on the problems encountered, the solutions, and the lessons learned from each situation.

1. INTRODUCTION

Many countries have facilities in which radioactive materials and sources are used for medical, industrial and research applications. These facilities need decommissioning at some stage; either at the end of their useful lives or when they are no longer required [1]. Decommissioning of small facilities is expected to commence shortly after shutdown, but in many cases, due to several constraints and factors (including limited human, technical and economic resources), decommissioning may be deferred for long periods (e.g. several years or decades) if there are no resources, expertise, etc.

This paper gives four examples that describe the approach taken to solve, in a safe manner, some of the situations encountered. The situations described are typical of those which can arise during planning or implementing decommissioning activities and also enable the following two questions to be answered: (i) what are the experiences with decommissioning of small nuclear facilities in countries with limited resources?; and (ii) what lessons learned from our practices might be applied to other decommissoning projects?

2. DECOMMISSIONING PROJECTS

2.1. Case No.1: Decommissioning of a brachytherapy facility contaminated with ^{226}Ra

In May 1997, the National Institute of Oncology and Radiobiology (INOR) requested the Centre for Radiation Protection and Hygiene (CPHR) to evaluate the radiological situation and to carry out decommissioning activities at a former brachytherapy facility in order to achieve the unrestricted release of the facility [2]. The facility was contaminated with ^{226}Ra, as the institution had used ^{226}Ra radioactive sources for brachytherapy purposes and some of them were leaking. The decontamination of the rooms and the decommissioning of the facility took place in June 1999, once all the necessary regulatory conditions were met. In order for this work to be performed, the hospital received authorization from the National Centre for Nuclear Safety (CNSN) (Cuba's regulatory body) in the form of a licence for decommissioning. This licence included the criteria for the unrestricted release of the brachytherapy facility: the residual ingrained surface contamination should be fixed and the surface contamination should be =0.04 Bq/cm^2. The initial radiological survey showed that contamination could be found in unexpected places — even though the contamination levels were rather low. The decommissioning project was successfully completed. An appropriate project management approach was applied to provide safety assurance, radiation protection and waste management. Several disused ^{226}Ra sources were recovered from the facility and safely stored. The Oncology Institute received an authorization from the regulatory body for the unrestricted use of the facility upon the successful completion of the decommissioning. At present, the four decontaminated and cleared rooms are used as offices.

2.2. Case No. 2: Decommissioning of improvised storage facility — contamination caused by a leaking source

A small redundant facility within the INOR was used to store medical, research and disused industrial sealed sources. One of the ^{137}Cs sources in the store was leaking. Serious contamination on some areas of the walls and floors was found in 1980. Due to the lack of waste management expertise, infrastructure and financial resources, the contaminated areas were simply locked up and left unattended. In 1986, in a decontamination attempt, the walls and floors were washed using pressurized water jets, but the contaminated water spread the contamination to other areas. A second decontamination attempt was made in 1999. Items inside the contaminated area were carefully monitored and segregated. Physical and chemical methods of decontamination were used. For different reasons, the requirements established by the regulatory authority for decommissioning could not be achieved, and therefore, the facility could not be released from regulatory control. A Radiological Status Report was prepared explaining the high cost of the decontamination that would be required to meet established clearance levels. New alternatives were then proposed to the regulatory authority for the final decommissioning of this facility. A new strategy based on the annual dose limit to members of the the public was prepared and agreed with the regulator [3]. The third and final decontamination attempt was carried out in 2004 and, following this, the INOR received the authorization for the unrestricted use of the site.

2.3. Case No.3: Decommissioning of a brachytherapy facility contaminated with ^{137}Cs

In the past, the Dr. Heriberto Pieter Oncology Hospital in Santo Domingo used ^{226}Ra and ^{137}Cs sealed sources for brachytherapy. One of the ^{137}Cs sources leaked and caused contamination of some areas, including equipment and devices (e.g. beds of the patients, bathrooms, containers, medical materials and instruments). The facility was shut down because of safety concerns. The National Commission of Nuclear Affairs (CNAN) of the Dominican Republic requested the IAEA to evaluate the radiological situation in the contaminated areas of the hospital and to carry out the decontamination of the rooms and the decommissioning of the brachytherapy facility for unrestricted use [4]. The decommissioning project was successfully completed within a month. An appropriate project management approach was applied to provide safety assurance, radiation protection and waste management. As a result, tens of disused radiation sources were recovered and properly managed,. The volume of radioactive waste generated during the decommissioning was 3.4 m^3 (i.e. 17 standard 200 L drums). Upon the successful completion of the decommissioning, the Oncology Institute received an authorization for the unrestricted use of the facility.

2.4. Case No.4: Decommissioning of a laboratory contaminated with ^{14}C

The International Center for Neurological Restoration (CIREN) used ^{14}C for the purposes of radiochemical research. For different reasons, this practice concluded and the institution requested the release of the radiochemical laboratory from the regulatory control. For the decommissioning activities, the CIREN contracted the services of CPHR, which initiated the radiological survey and characterization of the facility. It was fortunate that the historical record keeping of the ^{14}C operation was very good. A thorough revision of the available documentation (authorization, source inventories, inspection reports, radioactive waste collection reports) revealed that the main radionuclide used in the past years was ^{14}C but that between 1993 and 1996, other radionuclides, such as ^{3}H, ^{51}Cr, ^{125}I and ^{32}P, had been used. The material containing very short lived radionuclides had decayed to negligible levels, and the ^{3}H material was of very low activity and most of the material had previously been collected as radioactive waste. Therefore, from the decommissioning perspective, only ^{14}C was considered in the radioactive inventory. The reference levels used for decommissioning were only in terms of fixed and removable surface contamination.

3. PROBLEMS ENCOUNTERED, SOLUTIONS AND LESSONS LEARNED

3.1. Case No.1 Problem (01): Lack of regulatory requirements for decommissioning

The licensing of the process for decontaminating an installation to a final end state had not previously been done in Cuba. This caused delay in deciding on a licensing strategy for implementing the decommissioning. Before 1999, there was no regulation specifically related to decommissioning activities. The regulatory framework on decommissioning was restricted to general considerations.

Solution: The first decommissioning activities were planned and managed on a case by case basis in consultation with the regulatory authority. The national infrastructure to support the decommissioning activities was

FIG. 1. Non-radioactive PVC pipes.

strengthened by the entering into force of regulation No. 25/98 on authorization for practices associated with the use of ionizing radiation [5]. In this regulation, in Article No. 46, the regulatory requirements for decommissioning are established.

Lessons learned: Legal and regulatory aspects related to decommissioning need to be established as soon as practicable. The legal framework should include the allocation of the necessary funding for the final decommissioning of the facilities.

3.2. Case No.1 problem (02): Management of non-radioactive waste

A particular problem was experienced during this decommissioning project concerned with the management of decommissioning waste. The contractor was not prepared to deal with the relatively large amount of non-radioactive waste materials (a few m^3 of sand and 5 m^3 of PVC pipes — Fig. 1).

Solution: An additional working group was created to manage the generated non-radioactive materials. The material was removed from the controlled zone and transported outside the facility.

Lessons learned: During decommissioning there will, be compared to the normal operations of the facilities, large amounts (and probably new types) of waste materials. The management of non-radioactive waste during decommissiong should be considered in advance and therefore a coordination team should be established to handle the waste.

3.3. Case No.1 problem (03): Undefined reuse for the site

The old brachytherapy facility which is located in a large hospital was shut down and for different reasons kept closed for more than ten years. Besides a lack of funds, there was no motivation for reusing the site.

Solution: Once a potential reuse of the site had been decided upon, the 'new' users became active and they insisted that the directorate of the institution provide the necessary funds for decommissioning. This was achieved

FIG. 2. Removing floor tiles and concrete slabs.

and the decommissioning was performed taking into consideration the intended future use of the installation.

Lessons learned: Immediate decommissioning is the best solution for small facilities. Decommissioning should commence immediately after operations cease in order to make full use of the available personnel who operated and maintained the installation. The decision on the facility reuse accelerated the interest in having it decommissioned.

The reuse of the site compensated for the negative impact of the facility being shut down. Some systems and utilities of the old facility were reused in the new one.

3.4. Case No. 2 Problem (01): Improvised Storage Facility

As explained in Case No. 2, due to the lack of a national storage facility for radioactive waste in the country, a redundant room at an old brachytherapy facility was used as a centralized storage facility for disused sealed sources. This area was not designed for such purposes and as a result, the contamination caused by a leaking radioactive source had unimaginably serious consequences. The floor was rough and absorbent and became radioactively contaminated. The ^{137}Cs became fixed on the tiles and concrete materials of the floor.

Solution: The disused sources were removed from the facility. The facility was decontaminated and decommissioned, generating a large amount of radioactive waste. The contaminated surfaces were cleaned several times using detergent solutions, followed by chemical decontamination. Specifically, K-Alum acidified with HCl and Prussian blue solutions were used [7]. Chemical decontamination was not effective and most of the floor surface of some rooms had to be removed (Fig. 2).

FIG. 3. Recovering of disused radioative sources.

Lessons learned: The facilities for radioactive waste storage should be designed and constructed according to ‘state of the art’ safety standards and requirements. The surfaces of walls and floors of small nuclear facilities should be easy to decontaminate. The use of smooth, seamless and non-absorbent work surfaces and flooring (or removable coatings) in areas likely to be contaminated should be considered [1].

3.5. Case No. 2 Problem (02): Loss of relevant documentation

In each of the first three cases described in this paper, the documentation relevant to decommissioning was not available. There was no information on the construction details, water supplies, drainage systems, the existence of sealed sources or other radioactive materials, etc. Important reports, drawings, technical designs had disappeared from the archives of the facility.

Solution: The only solution was to conduct a detailed characterization (physical and radiological) of the facility. During radiological monitoring in the garden, two disused radium needles were found in the ground. The needles were collected and processed (Fig. 3).

Lessons learned: Knowledge of the status and history of the radioactive facility is essential for successful decommissioning planning, decommissioning strategy selection and execution. The rigorous control and registration of sources during the operational life of the facility should be mandatory.

It is crucial to have a monitoring plan for all areas of the facilities.

3.6. Case No. 2 problem (03): Drainage systems

During decommissioning of an old brachytherapy facility (case No. 2) radioactive contamination was found in a drainage system below the ground.

FIG. 4. Recovering and monitoring of underground. pipes

This drainage system was not designed for the collection of radioactive effluents. Contamination was absorbed and accumulated in the pipe construction material. Site drainage plans or drawings were not available.

Solution: Radiation monitoring of all accessible manholes on existing drainage pipes was undertaken to find underground pipes. Some of the pipes had to be removed, as shown in Fig. 4. Since equipment for the characterization of the underground pipes was not available, the activity was estimated using a lineal source model [3]. It was verified that the dose rate measured was only coming from the pipe and not from other contaminated materials (such as floor tiles or filling). Using a dose rate monitor with a collimator (Fig. 4), the dose rate was measured over all surfaces of the floor, where the pipe was supposed to be. Having achieved the criteria for clearance (0.1 μSv/h), it was assumed that the pipes were not contaminated or that the contamination levels were very low. For this reason it was decided to leave the pipes in the facility. Another reason was that the pipes were being used by other facilities in the hospital for drainage, and it was not possible to remove them until a new drainage system is available.

Lessons learned: Proper drainage systems to prevent the accumulation of radioactive materials should be designed and constructed. Decisions at the design stage of the facility could help or complicate the future decommissioning activities if decommissioning is not properly considered. Early consideration during the facility design phase should be given to the need to decommission them.

3.7. Case No. 2 problem (04): Inadequate record keeping, before and during decommissioning

When CPHR received the request to decommission the contaminated rooms, no answer was received to any of the following questions: (i) How did the contamination occur?; and (ii) How were the previous decontamination attempts conducted? Not only were the records missing, but also the key personal had retired. For planning the decommissioning activities conducted in 1999, the initial decontamination strategy was derived based on some data (on contamination levels and dose rate measurements) that was obtained 15 years ago. While characterizing the facility, it was realized that the contamination levels were much higher and and widespread than the existing data indicated.

Solution: This discrepancy in the initial data led the CPHR to quickly redefine the characterization programme and consequently to change the decontamination and decommissioning plan.

Lessons learned: Record keeping at the facility (since commissioning) is essential to support decommissioning activities [8]. The lack of contamination records can be a major issue in the decommissioning of older facilities and can have significant impacts on costs and schedules. Problems can be encountered due to poor knowledge of the initial state of the facility, mainly because of a lack of records or due to erroneous information. In such cases, a careful characterization of the facility is needed.

3.8. Case No. 2 problem (05): Inappropriate selection of decontamination method

During the first decontamination attempt (in the 1980s), the walls and floors were washed using pressurized water jets. This method was ineffective however since the contamination was only reduced by about 20% and the contaminated water spread the contamination into two other rooms, the drainpipes and the soil in the garden of the facility. The facility had to be closed because of the remaining contamination.

Solution: New alternative strategies were selected and proposed to the regulatory authority for the final decommissioning of this facility, which took place 16 years later.

Lessons learned: The selection of adequate and appropriate techniques is an important part of a decommissioning project. The use of water jets for the decontamination of walls and floors in small nuclear facilities should be carefully considered, as the water can spread the contamination. The amounts and types of waste created during decommissioning is an important factor to be considered in the selection of a decommissioning strategy.

3.9. Case No.2 problem (06): Lack of adequate facility maintenance

No attention was given to maintenance at the facility during the closure period. Because of this, the decommissioning was made more difficult. For example, because of a broken pipe in the laboratory and a broken window, the water (from the pipe and rainwater through the window) dissolved and transferred the ^{137}Cs to different places at different depths. Additionally, the doorframes (corners) were in bad condition, which facilitated the Cs transfer.

Solution: During the initial survey, the discovery of contamination under doorframes led to comprehensive sampling being carried out at various depths. The gamma spectrometric analysis revealed a potential contamination to be present under the doorframes. Excavation of the floor around and under the doorframes areas with subsequent removal of material filling up to 50 cm depth was carried out. This work caused a delay of two weeks in the schedule.

Lessons learned: During facility construction and maintenance, special attention should be directed to areas were the accumulation of contamination can occur. Even after the shutdown, during the closure period, maintenance of the facility is required.

3.10. Case No. 3 problem (01): Inadequate infrastructure and funds for decommissioning

As a result of the contamination in a government owned medical facility in a developing country, the facility was shut down and closed for a long period of time while a solution was sought. The facility personnel were completely unfamiliar with decommissioning activities. Furthermore, there were no qualified personal with adequate knowledge and experience to carry out the decommissioning activities in the country. The infrastructure for decommissioning and the resources needed for implementation were not available.

Solution: As a Member State of the IAEA, the country requested technical assistance. External experts went to the country and carried out the decontamination of the facility.

Lessons learned: Experience is essential in order to reduce the risk and cost during decommissioning. In some countries there is a shortage of staff qualified and trained to carry out decommissioning activities and therefore there is a need for the facility operators or other national staff to be appropriately trained. The possibility of obtaining technical and financial support for decommissioning from international organizations should be explored. The IAEA is a source of international experience on suitable regulatory frameworks that might be adopted for decommissioning purposes.

3.11. Case No. 3 problem (02): Cross-contamination caused by ants

During the decontamination of a small medical facility it was found that ants had scattered radioactive contamination. Two ant mounds were discovered.

Solution: The solution was to remove the anthill.

Lesson learned: To avoid the presence of insects in controlled areas.

3.12. Case No. 3 problem (03): Lack of waste management infrastructure

The decommissioning activities produced seventeen 200 L drums of non-compactable radioactive waste. No national storage or disposal facilities for radioactive waste were available in the country.

Solution: A buffer storage room was created where the waste could be stored temporarily in the hospital.

Lessons learned: The decommissioning plan should address the question of the availability of appropriate capacity and capability to manage the waste arising during decommissioning activities. Decommissioning should not commence until storage or disposal facilities are available.

3.13. Case No. 4 problem (01): Deriving clearance levels for decommissioning a laboratory that used ^{14}C

The clearance levels for materials containing radionuclides are established in a national regulation in terms of activity concentration [6]. For ^{14}C the clearance level is 30 Bq/g. For radiological survey and decommissioning purposes, it was necessary to derive clearance levels for surface contamination, in order to determine the risk due to removable and/or fixed surface contamination. It was also necessary to define how to measure the derived surface contamination values.

Solution: The derived clearance level values were 4 Bq/cm^2 for removable contamination and 2 kBq/cm^2 for fixed contamination. Wipe testing was used for assessing removable contamination in the most probable contaminated areas. The samples were measured in a liquid scintillation counter. The existing surface contamination monitor (Mini Instruments Ltd., Model 1500, with probe DP2R/4) was not calibrated to measure ^{14}C. The equipment was calibrated using a reference surface sample at the derived contamination limit, prepared to simulate the surface contamination. Once the response limit for the specific monitor was defined, the surface contamination survey could be carried out.

Lessons learned: Because of the difficulties in directly measuring weak beta emitters such as ^{14}C, it was necessary to agree on a practical approach with the regulator, which included monitoring and decontamination methodologies. By means of a mixture of direct monitoring and wipe testing (with liquid scintillation counting) it was possible to accomplish the monitoring tasks. Practical solutions were used to solve problems resulting from a lack of specialized equipment and tools.

4. CONCLUSIONS

— Existing constraints associated with funding, the waste management systems and human resources imposed deferred decommissioning on the facilities. Several unexpected problems were encountered and overcome during the implementation of the decommissioning projects.
— In the case of small nuclear programmes with limited resources, international involvement and cooperation is needed to help in planning and conducting decommissioning projects.
— The projects have strengthened national capabilities for conducting decommissioning activities and have led to increased cooperation between decommissioning operators, regulators and the users of radioactive materials.
— The lessons learned were seen as ‘good working practices’ for solving the problems and are being shared in this paper to help colleagues with similar problems. Some of the identified lessons learned are ‘adverse work practices’ and these experiences are described and shared to help avoid their recurrence.
— Even relatively small projects at small facilities can yield significant lessons. The experience and lessons learned and summarized in this paper will reach their full value by being shared, debated and implemented in similar future decommissioning projects.

ACKNOWLEDGEMENTS

The authors would like to thank the IAEA and particularly M. Laraia of the Division of Nuclear Fuel Cycle and Waste Technology for the invitation to present this paper at the Conference.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standards Series No. WS-G-2.2, IAEA, Vienna (1999).

[2] BENITEZ, J.C., SALGADO, M., MADRAZO, S., CASTILLO, R., "Decommissioning of a brachytherapy facility at the Oncology Hospital in Havana", Management of Radioactive Wastes from Non-Power Applications: Sharing the Experience (Proc. Int. Conf. Malta, 2001).

[3] SALGADO, M.M., et al., "Decommissioning activities in an area contaminated with Cs-137 at the National Institute of Oncology and Radiobiology, in Havana, Cuba", Environmental Remediation and Radioactive Waste Management, ICEM '05/DECOM '05, (Proc. Int. Conf. Glasgow 2005).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Small Medical, Industrial and Research Facilities, Technical Reports Series No. 414, IAEA, Vienna (2003).

[5] CITMA Resolution No. 25/98 — on "Authorization for practices associated with the use of ionizing radiation". Publication in Spanish. Havana, Cuba, 1998.

[6] CNSN Resolution 1/2004, Guide on the unconditional clearance levels for solid materials with very low radioactivity and discharges of liquid and gaseous materials to the environment, CNSN, Havana (2004) (in Spanish)

[7] SALGADO, M., et al., "Decontamination activities at the National Institute of Oncology and Radiobiology in Havana, Cuba", Safe Decommissioning for Nuclear Activities: Assuring the Safe Termination of Practices involving Radioactive Materials (Proc. Int. Conf. Berlin 2002), IAEA, Vienna (2003).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Record Keeping for the Decommissioning of Nuclear Facilities: Guidelines and Experience, Technical Reports Series No. 411, IAEA, Vienna (2003).

PANEL DISCUSSION

Session 8

DECOMMISSIONING OF SMALL FACILITIES

Chairperson: **A.G. YOUTSOS** (Greece)

Members: **H. LIU** (China)
K. LAURIDSEN (Denmark)
G. YADIGLIAROGLOU (Greece)
M. LARAIA (IAEA)

A.G. YOUTSOS (Greece — Chairperson): I invite the panellists to respond to the question 'Is the dismantling of small shutdown facilities always the safest option?'

H. LIU (China — panellist): Before responding to the question, I should like to mention the small facilities that we have in operation — 18 research reactors, four nuclear fuel cycle facilities, three plants for the manufacture of radioactive sources, 150 irradiation plants and ten research laboratories with operational radioactivity greater than 0.1 Ci/d (Grade A).

The small facilities decommissioned in the past have included radiochemical laboratories, a radioactive source storage facility, an isotope production line, an irradiation plant, a Grade A laboratory, a 30 kW neutron source reactor, research reactors and critical facilities.

Most of those facilities are located in large cities, so the decommissioning of small facilities is considered to be very important — maybe more important than the decommissioning of large facilities.

As regards the question put to the panel, I cannot answer simply 'Yes' or 'No'. Everything depends on the particular circumstances. For example, we dismantled one critical facility because it had been severely contaminated during an accident, while we dismantled a radiochemical laboratory and the 30 kW neutron source reactor not because they were severely contaminated, but because, in both cases, the land was wanted for other purposes and therefore had considerable commercial value. However, the usual practice in China is to decontaminate and reuse, especially in the case of small facilities at multi-facility sites. Also, in order to minimize decommissioning waste we usually decontaminate and reuse or recycle equipment. This practice is conducted in accordance with our safety criteria and is considered to be very safe.

So, my answer to the question is that the dismantling of small shutdown facilities is a good option, but each situation must be analysed in the light of various factors.

K. LAURIDSEN (Denmark — panellist): Like Mr. Liu, I cannot answer simply ‘Yes’ or ‘No’ to the question that has been put to us. In general, however, I would say that the answer is ‘Yes’, particularly if the alternative to dismantling is just to leave the facility.

The factors to be considered in deciding on a decommissioning strategy include — the physical state of the facility; the radioactive inventory (nuclides, half-lives); the availability of knowledgeable staff to plan and carry out the dismantling; the continued existence of a nuclear programme in the country/at the site; and the economic situation of the country.

If the physical state of the facility is good and there are to be further nuclear activities at the site, in may be best to leave the facility in a state of ‘care and maintenance’, particularly if the radioactive inventory is so low that there is a possibility of clearing all or most of it while those further nuclear activities are taking place. One must be sure, however, that the physical state of the facility will not deteriorate.

When no continued nuclear activities are foreseen in the country, as in the case of Denmark, the safest option will be to dismantle the facility while some knowledge of it still exists — that is to say, immediate dismantling. However, borderline cases may exist where the radioactive inventory is so low that it will fall below the clearance limits in the foreseeable future, so that deferred dismantling is the safest option.

The economic situation of the country may be such that there are no or only very limited resources available for dismantling. Then, leaving the facility in safe store may be better than embarking on a dismantling project. This dilemma underlines the importance of preparing financially for dismantling at the time when the facility is being installed.

G. YADIGIAROGLOU (Greece — panellist): I would start by saying that there are countries which are highly developed in the nuclear field and countries which, although not highly developed in the nuclear field, have nuclear facilities which need or ultimately will need to be decommissioned. This is an area where international cooperation — especially through the IAEA — is going to be very important.

My answer to the question put to us is similar to that of Mr. Liu and Mr. Lauridsen — it all depends.

What are the risks from a small shutdown facility that is not dismantled? One is the risk of a release of radioactive material, due to corrosion, overheating or something less obvious (the presentation from Cuba described how radioactive material had been spread by insects!). What are the risks from dismantling? One is the transport risk associated with moving material, especially large amounts, from one place to another, and there is also the risk of radioactively contaminating a hitherto uncontaminated area.

A major consideration is whether one can safeguard all relevant information about a facility if dismantling is going to be deferred. If the site is to continue being used for nuclear activities, this may not be such a big problem.

M. LARAIA (IAEA — panellist, Scientific Secretary): Following the shutdown of a nuclear facility, a hazardous situation may arise if no further action is taken. While it is recognized that ‘no action’ is in principle different from a long term safe enclosure strategy, the two have a number of potential risks in common. Although in principle a strategy of safe enclosure implies protection against hazards, the reality, especially in countries with very limited resources, may be that the protective measures are not reliable in the long term. Ultimately, safe enclosure could come to mean ‘no action’ and loss of control. I shall therefore use the expression ‘no action’ when referring to a lack of active decommissioning.

Unfortunately, the ‘no action’ strategy is common in the case of small shutdown facilities, often because small facilities are shut down for periods of non-use or maintenance and then, because of obsolescence or for commercial or other reasons, never restarted. ‘No action’ is often the result of the erroneous perception that the risks associated with the shutdown facility are trivial and can therefore be disregarded. In other cases, ‘no action’ may be due to a lack of funds for decommissioning. Ultimately, ‘no action’ may lead to abandonment of the facility.

There are various risks associated with the ‘no action’ strategy. The loss of records can be a particularly serious problem. Knowledge regarding the design and the operational features of the facility may fade away quite soon, owing to dispersal of staff familiar with the facility and to a loss of documentation. The memories of key staff play an important role in decommissioning, particularly of facilities constructed and operated in the 1960s and 1970s, when records were rarely archived properly. However, assembling a team of competent former staff some years after facility shutdown may well be impossible. Moreover, long periods of ‘no action’ inevitably result in higher costs when the decommissioning is finally undertaken.

During a period of ‘no action’ there may be inadequate maintenance, allowing systems and components to deteriorate, contaminated fluids to leak and drain pumps and sumps to become inoperative, with consequent risks to workers and the general public. Rainwater or groundwater may find a way into and out of the facility. Still more serious — owing to inadequate surveillance, contaminated material and even radioactive sources may be stolen. Failure to protect the radioactive sources in shutdown facilities has already resulted in fatal accidents.

Decommissioning implies positive management action, with adequate resources, particularly in the case of small facilities. For decommissioning projects to be successful, the duration of any period of ‘no action’ following shutdown should be kept to a minimum. During that period, planning for decommissioning should be initiated as soon as possible, while the operational staff is still available, and high priority should be given to systematically collecting all decommissioning-relevant information.

S. HARRIAGUE (Argentina): How about the risks of intrusion in the case of abandoned facilities, especially in poor countries? From what Mr. Laraia just said, I got the idea that in situations where facilities were practically abandoned there was potential for participation from another country in the same area, and that can be a solution in many cases.

M. LARAIA (IAEA — panellist, Scientific Secretary): This is one of the most serious concerns in the nuclear community at present.

I believe that, with time, maintaining adequate surveillance and protection at small shutdown facilities will become increasingly difficult and intrusion will become a likely event.

K. LAURIDSEN (Denmark — panellist): One should consider the risk of intrusion when deciding whether to dismantle a shutdown facility. If one decides not to dismantle immediately, one should take measures to prevent intrusion and to ensure that the consequences of intrusion, if it did occur, would not be serious.

A.G. YOUTSOS (Greece — Chairman): If the shutdown facility is ‘embedded’ among similar facilities that are still operating, in may not be absolutely necessary to dismantle it immediately in order to avoid a loss of decommissioning-relevant knowledge and to prevent intrusion. However, such happy situations are rare.

From what we have heard here, I would say that it is almost certainly advisable to start dismantling immediately provided that a dismantling plan has been drawn up and the necessary funds are available.

C. GRIFFITHS (United Kingdom): When we decontaminate a laboratory prior to its being taken over by a new research group with the necessary funds, we upgrade the laboratory benches and equipment so as to make decontamination easier next time it becomes necessary.

M. LARAIA (IAEA — panellist, Scientific Secretary): In that connection, I would mention that the prospect of a decommissioned site being reused can attract financial resources and thereby accelerate decommissioning.

H. LIU (China — panellist): That would not happen in China. Under our regulations, a site can be taken over by a new user only after decommissioning has been completed to the satisfaction of the regulator.

B. JUENGER-GRAF (Germany): After the decommissioning of a TRIGA research reactor, we have been discussing whether it would have been legally permissible to leave the shutdown reactor as it was. What are the views of the panellists?

K. LAURIDSEN (Denmark — panellist): I do not know whether specific legislation relating to that point exists, but in Denmark you would certainly not be able to leave a shutdown reactor as it was.

H. LIU (China — panellist): I do not think that you would be able to leave a shutdown reactor as it was in China either.

G. YADIGIAROGLOU (Greece — panellist): There may be a legal vacuum here. I have never seen any regulations stating that what has been shut down must be decommissioned.

M. LARAIA (IAEA — panellist, Scientific Secretary): Many shutdown facilities are in a kind of 'limbo', and that is a serious situation. In the case of operating facilities, the regulators can apply sanctions if they see something wrong — for example, they can order a facility to be shut down. When the facility is already shut down, however, the regulators have virtually no 'weapons'.

D. LOUVAT (IAEA): It would not have been legally permissible to leave the reactor referred to by Ms. Juenger-Graf as it was — since Germany is a party to the Joint Convention.

E. WARNECKE (IAEA): As regards the question put to the panel, is there a safer option than dismantling?

G. YADIGIAROGLOU (Greece — panellist): As I indicated earlier, in my view there are cases where dismantling and transporting large amounts of radioactive material to another location may be less safe than leaving the shutdown facility as it is.

A.G. YOUTSOS (Greece — Chairman): That would not apply in the case of a typical small reactor or of a hospital facility.

G. YADIGIAROGLOU (Greece — panellist): I was thinking of a facility involving a large area where the ground is contaminated by an industrial by-product of low activity and where the ground is fairly stable.

E. WARNECKE (IAEA): I doubt whether such an area would be really safe, given factors such as the weather and intruders.

In my view, one should first remediate the most unsafe parts of such an area and then consider what to do next. I would call that 'prioritization', which is always a wise course of action.

A.G. YOUTSOS (Greece — Chairperson): I think we can all agree with that.

I suggest that our tentative conclusion be that for all practical purposes the dismantling of small shutdown facilities is almost always the safest option.

I now invite the panellists to respond to the question ‘Is entombment an acceptable decommissioning option?’

H. LIU China — panellist): In my opinion, the purpose of entombment is to leave something for the education of future generations. To that end, in the case of a [power] reactor we remove the fuel and the primary system, decontaminate the equipment and keep the control room and the [reactor] building, with photographs and documents from which the visiting public can learn something about the former operational activities.

Entombment involves at least two challenges — that of the responsibility for safety and that of cost. As regards the responsibility for safety, entombment is not a final decommissioning option and there may be radiological hazards. Maintenance and monitoring will be necessary.

K. LAURIDSEN (Denmark — panellist): The acceptability of entombment will depend on many factors, including the economic situation of the country, the suitability of the site as a final repository and the decay times of the radionuclides in the facility.

The availability of only very limited economic resources may cause a country to opt for entombment. If the facility is small and contains mainly short lived radionuclides, entombment may be acceptable — and definitely preferable to doing nothing.

In the case of wealthy countries, entombment should generally not be considered acceptable. Such countries should opt for dismantling of the facility and disposal of the waste in dedicated repositories — if only to demonstrate, for psychological reasons, that nuclear facilities can be decommissioned safely just like non-nuclear facilities.

G. YADIGIAROGLOU (Greece — panellist): In my view, entombment is a temporary solution unless you are entombing something within a final repository, in which case it is disposal.

Entombment in the sense of simply pouring concrete over a facility and leaving it for 50—100 years complicates the final solution — at the end of the waiting period, someone will have to break up the concrete and dispose of all the radioactive material, and that will be more difficult to do than dealing immediately with the challenges posed by the facility.

If, however, you have a large accumulation of some low activity industrial byproduct that is in a stable state, some form of entombment may be the best solution.

M. LARAIA (IAEA — panellist, Scientific Secretary): I would say that entombment is acceptable in some cases.

To illustrate my point, I would refer you to contributed paper IAEA-CN-143/24, titled ‘On results of the decommissioning of Georgian nuclear research reactor IRT by grouting and its conversion into a new low power nuclear facility’. The Georgians did not have the cutting tools and other equipment necessary for dismantling or the money to buy them (and only very slim prospects of obtaining enough money in the future). Moreover, the operating staff were elderly (many were over 60 and some over even 70 years of age). In addition, Georgia lies in a region of high seismicity. The decision to opt for entombment was endorsed by the IAEA, which provided support.

Currently, the IAEA is providing support for the dismantling of the peripheral systems around the reactor monolith.

D. LOUVAT (IAEA): In the paper referred to by Mr. Laraia, it is stated that the ‘Proposed plan for decommissioning was approved by IAEA’. To me, this suggests that the IAEA has regulatory powers, and I should like to make it clear that the IAEA does not have such powers.

K. LAURIDSEN (Denmark — panellist): Nobody has said that entombment is unacceptable, so presumably it is considered acceptable. Sometimes it may be the best option under the circumstances.

C. PESCATORE (OECD/NEA): I am rather confused — is entombment being discussed here as a decommissioning/dismantling option or as a waste management option? I am the Rapporteur for this session, and I would welcome some clarification on that point.

K. LAURIDSEN (Denmark — panellist): As I see it, entombment creates a repository, so it is a waste management option.

H. LIU (China — panellist): In China, which is a big country with a number of repositories, we do not need entombment as a waste management option.

G. YADIGIAROGLOU (Greece — panellist): If entombment is the equivalent of final disposal, it is acceptable. However, if you are entombing something because you cannot dismantle it at the moment and the site is to be revisited at some point in the future that is a bad solution.

A.G. YOUTSOS (Greece — Chairperson): In a civilized society, when a nuclear facility is built, there is an implicit intention that the site will ultimately be returned to society in its original ‘virgin’ state. Accordingly, I do not consider entombment to be an acceptable option under any circumstances - the facility was never meant to be entombed.

There are exceptions to the rule; that is why the rules are there. My answer is that the rule must be observed almost always, and then, in an extraordinary situation where it cannot be observed, it will be an exception — if we can come up with a rational justification.

G. YADIGIAROGLOU (Greece — panellist): It is only the nuclear industry that places so much emphasis on restoring sites to ‘green field’ status. Are there any plans to restore — say — Manhattan Island, Athens or the sites of airports to ‘green field’ status? In my view, the nuclear industry is bowing to those who, for political or social reasons, are determined to put an end to it and eliminate all traces of its existence.

A.G. YOUTSOS (Greece — panellist): Of course, there is no question of restoring Manhattan Island to the condition it was in when it was bought from the Indians.

During the next 50–100 years, we are going to have to depend very heavily on nuclear power — to the extent of 30–35% in Europe according to all credible scenarios. For that to be possible, people will have to trust the nuclear industry, and they will not trust the nuclear industry if it leaves entombed facilities behind. The nuclear industry must act more responsibly.

H. FORSSTRÖM (IAEA): With regard to Manhattan Island, every day parts of it are being decommissioned so that the sites can be used safely for other purposes. Much the same thing is happening within the nuclear industry worldwide.

For me, entombment forever means waste disposal, and a waste disposal facility must fulfill certain requirements so that it is safe as far as both people and the environment are concerned which means that it is either under some kind of institutional control for a period of time or that it can be released.

C. GRIFFITHS (United Kingdom): I am worried about the fact that some people have said ‘Yes, entombment is an acceptable decommissioning option’ and then qualified that statement. This session is about the decommissioning of small facilities, and there are thousands of small nuclear facilities in the world, so I would prefer to hear people saying ‘No, entombment should not even be considered for at least 90% of the small facilities worldwide.’ In the case of ‘larger small facilities’, such as research reactors, entombment may be considered, but only under very special circumstances.

M. LARAIA (IAEA — panellist, Scientific Secretary): I agree with Ms. Griffiths.

D.W. REISENWEAVER (United States of America): Entombment is a decommissioning option that leads to a waste management strategy. However, when we start talking about Manhattan Island and Athens, we should bear in mind the IAEA’s definition of ‘decommissioning’ — namely ‘the removal of some or all of the regulatory controls from a facility’. Are the small stores on Manhattan Island and in Athens under regulatory control? If not, they do not have to be decommissioned.

A. ORSINI (Italy): As to whether entombment is part of decommissioning or part of waste management, some time ago, in a Department of Defence building in the middle of a city, there was a piece of equipment containing a large cobalt source that could not be used any more as the source was stuck outside of its shielding. It was impossible to dismantle the equipment, so we entombed it. Later, when the cobalt had decayed sufficiently, we decided to decommission the equipment. Although the activity of the cobalt was very low, the price quoted for waste management was very high. Until we have sufficient funds to pay for the waste management, the entombment will have to continue.

A.G. YOUTSOS (Greece — Chairperson): In the case just described by Mr. Orsini, entombment is a form of waste management, but things were not planned to be that way. For me, ‘waste management’ means that you have a plan for managing the waste and you implement it.

G. YADIGIAROGLOU (Greece — panellist): In my opinion, one must be clear in one’s mind about what one is trying to do — the purpose and the time horizon. Without clarity on those points, it is difficult to distinguish between entombment, decommissioning and waste management.

K. LAURIDSEN (Denmark — panellist): The Chairperson seems to be implying that decommissioning was foreseen in the past when nuclear facilities were built. However, the people who have carried out decommissioning projects have the impression that no provision was made for the decommissioning of the facilities in question.

In my view, entombment is a waste management strategy, because the entombed facility is not released from regulatory controls — it becomes subject to the regulatory controls appropriate for a waste repository.

H. LIU (China — panellist): The decommissioning of small facilities is very important as there are many of them and they tend to be close to the public. It should start as soon as possible after final shutdown and be carried out in a single step.

A.G. YOUTSOS (Greece — Chairperson): I invite the Rapporteur, Mr. Pescatore, to read out his conclusion regarding the entombment question.

C. PESCATORE (OECD/NEA): I propose the following answer — ‘Entombment requires continued regulatory oversight. It is not a final waste disposal solution, but a form of active waste management. I think the general view seems to be that ‘Entombment is a last resort option. It requires special and convincing justification’.

CLOSING SESSION

Chairperson

L. CAMARINOPOULOS
Greece

Rapporteur

G. LINSLEY
IAEA

SUMMARY OF SESSION 1

GLOBAL OVERVIEW

Chairperson

C. MILLER
United States of America

The purpose of this session was to provide a background or framework for the conference by reviewing the worldwide decommissioning situation and the related activities of the international organizations. It comprised invited papers from the IAEA, the OECD Nuclear Energy Agency (OECD/NEA), the European Commission (EC) and the World Nuclear Association (WNA).

In the first paper an assessment of the global liabilities associated with facilities and sites in need of decommissioning or cleanup was given by the IAEA based on a study published in 2004. Estimates were given of the cost of the decommissioning and/or cleanup of all types of facilities and sites at which radioactive material is used, including military sites, but excluding non-nuclear industries and areas affected by the Chernobyl accident. In terms of 2003 values, the total global cost was estimated to be around $1000 billion. More than half of this cost is associated with the clean-up of 'cold-war legacy sites', that is, sites involved in the production of military materials. The next largest component is associated with the decommissioning of civil nuclear power stations (about one sixth of the total). It was noted that for nuclear power reactors, sustainable funding mechanisms for decommissioning are usually in place but that for other facilities and sites, such as research reactors and sites, non-nuclear industries and cold war legacy sites, established mechanisms for decommissioning and/or cleanup usually do not exist.

The presentation from the OECD/NEA recognized that the scale of decommissioning in OECD member countries will increase in the coming years and that decommissioning is likely to become a more complex process. With this background, the policy challenges to be faced were reviewed. It is expected that the associated industrial structure for decommissioning will change — with specialist companies emerging to do the work rather than the existing site workforces as in the past. The specific policy challenges associated with decommissioning were reviewed, they included strategies (noting the trend towards early decommissioning), costs and funding (the establishment of national funds for decommissioning), regulatory frameworks (the extra elements to be added to the basic operational regulatory requirements), the release or disposal of materials (involving large volumes of low activity materials) and technologies and research and development.

The presentation from the EC summarized the extensive programmes of research carried out in the past by the EC on decommissioning and noted the shift in recent times to programmes focussed more on the dissemination of results, the exchange of experience and decision support and management tools. There was a call to the international community to consider mechanisms that would facilitate a broader exchange of experience between countries. On funding aspects, recommendations have been issued in the European Union (EU) on the need for appropriately controlled segregated national funds for decommissioning and, amongst other things, for independent expert bodies to advise governments on the use of the funds. Examples were given of the support given to certain EU States on specific decommissioning projects.

The final presentation was from the WNA, giving its position statement on decommissioning. The WNA considers that the abandonment of facilities and sites after their decommissioning is not acceptable. Instead, it favours the recycling and reuse of facilities and sites and considers that the disposal of materials from decommissioning should be a last option. The main drivers of decommissioning are considered to be the potential that it creates for workforce redeployment and for the redevelopment of the local area. At a time of nuclear renaissance, the WNA notes that the possibilities for the reuse of facilities and sites are increasing.

In addition to the presented papers, there were three contributed papers for this session. The papers deal with various aspects of the DeSa (Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities) project launched by IAEA in 2004. The project is a forum in which methodologies for performance and review of safety assessment are shared and developed related to the application of safety assessment techniques to the decommissioning process. The first paper discusses the development of an internationally harmonized approach to the safety assessment of decommissioning — which many Member States evidently wish to use. The second paper focuses on the regulatory challenges associated with decommissioning and specifically with decommissioning safety assessments. One key lesson learned is that it is important to ensure that the regulatory approach changes to reflect the changed circumstances in decommissioning. The third paper identifies the need for a graded approach in the safety assessment of decommissioning, that is, to reflect the relative complexity and risk associated with different decommissioning tasks. The paper notes that significant resource savings that can be made in this way. Overall, these papers illustrate how the DeSa project is attempting to provide a helpful set of safety related tools for those involved in decommissioning activities.

Some of the common views and general points which emerged from the presentations and the associated discussions were as follows:

- *Responsibilities*: The responsibility for the costs associated with decommissioning should, in the first instance, be with the operator or licensee. However, governments have responsibilities to provide a framework within which the decommissioning can be managed; this includes a regulatory framework and a funding mechanism.
- *International structures*: An international framework for the safe decommissioning of nuclear facilities and sites exists in the form of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) supported by the IAEA safety standards on decommissioning.
- *Harmonization*: The international harmonization of approaches to decommissioning is to be encouraged through the sharing of experiences and methodologies.
- *Release from regulatory control*: Clearance policies are being used in most Member States and the recent IAEA guidance on clearance levels is generally accepted as a good basis for the setting of national values.

The main point for international organizations is as follows:

- There was a call for a more broadly based sharing of experience in the decommissioning area, especially in relation to funding schemes and technology sharing. The Joint Convention is an existing global mechanism for promoting safety in radioactive waste management, including the area of decommissioning, and it may be appropriate for such an initiative to be launched through its auspices.

SUMMARY OF SESSION 2

REGULATION OF DECOMMISSIONING ACTIVITIES

Chairperson

G. YADIGIAROGLOU
Greece

The session on regulation of decommissioning activities consisted of six invited papers from the USA, Bulgaria, South Africa, France, the United Kingdom and the Russian Federation, followed by a panel session.

The importance of knowledge management was identified throughout the session, as well as in several of the contributed papers. Mechanisms for knowledge retention are needed because of the long timescales of many decommissioning projects and because of the loss of the knowledge of plant configuration and operating history when workers retire or leave for other employment. This is a developing subject on which international cooperation could be useful.

It was clear from the invited and contributed papers that the regulation of decommissioning requires a different approach from that used for the regulation of the operational phase (project management versus process management). In this context, a number of regulatory issues were identified: (i) the need for a graded approach to regulation to reflect the declining hazard level as decommissioning progresses; (ii) the need to adapt regulatory decision making to the developing project rather than to a fixed calendar; (iii) the need to reflect the increased focus on operational management rather than on mainly technical issues; (iv) the importance of contamination control rather than accident analysis; (v) the importance of industrial safety as well as radiological safety; and (vi) the management of changing situations. International advice on these subject areas may be useful, especially to countries with less well developed decommissioning programmes.

The need for a flexible and graded approach to the application of the regulatory framework to reflect the varying levels of hazard associated with different types of facilities and different phases of decommissioning was identified in several of the invited and contributed papers and was one of the topics of the panel discussion. Most participants agreed that such an approach is essential in decommissioning although there were some expressions of concern about the possible negative perception by the public of a flexible regulatory approach. It was emphasized that the application of the graded and flexible approaches should not compromise the ultimate goal of ensuring safety during decommissioning. As with the previous point, advice and international consensus and in this area would be appreciated by many regulators.

Problems associated with securing funding for decommissioning were identified. A particular problem is funding the decommissioning of small facilities and research laboratories. There is a risk that, without proper funding, decommissioning will not occur and that these facilities will ultimately be abandoned. Governments therefore have an essential role to play in relation to the funding of the decommissioning of small facilities. This aspect was one of the most common issues mentioned in the contributed papers and may be an area where further international cooperation could be helpful.

The deferred decommissioning option can result in local unemployment and in problems of loss of knowledge, as well as in reduced public acceptance; however, in some cases, deferred decommissioning may be justified for financial and other reasons.

A number of other points were raised in the invited papers:

- It is important to have an agreed regulatory clearance regime in each country.
- Close and effective communication between the operator and the regulator is important.
- The management of spent fuel remains an issue for many research reactors.
- The minimization of radioactive waste from decommissioning is important.
- There should be clearly defined disposal pathways for radioactive waste.
- A phased approach to decommissioning may be preferable, especially for large and complex projects.
- Some of the challenges in decommissioning may be more organizational than technical in nature.

From the discussions of the panel on the grading of regulatory activities, it was generally agreed that the degree of regulatory control to be applied should reflect the risk associated with the decommissioning (on the grounds of effective use of resources). Factors such as the hazard potential and the complexity of the decommissioning tasks, the location and accessibility of the facility being dismantled, the past history of the equipment or material, the half-life of the radionuclides in the material should play a role in decision making on this issue. There was discussion on whether a formal hazard-based grading system would aid public communication and understanding.

In relation to the issue of flexibility of regulation, the panel discussed the concept of 'internal regulation', as used in France, in which a degree of freedom is given to the operator in regulating the decommissioning work. Views on this varied, but there was an agreement that the operator is responsible for safety and that the primary interest of the regulator should be to ensure a safe outcome of the operator's decommissioning work. The successful application of the internal regulation concept requires that the regulator is able to trust the operator and to rely on the operator to comply with the relevant safety requirements. It is relevant to note that in most decommissioning tasks the risk to the public is low, thereby allowing the regulator to give consideration to the use of this approach. In this respect, the history of the operator is a factor to be considered and operators with a poor record of compliance require appropriately closer regulatory supervision.

In relation to a question to the panel on whether reuse and recycle are part of the regulator's mandate, the general response was that it is primarily an issue for the operator to decide upon. The operator decides on matters such as the intended end use of the site after decommissioning. The regulator's role is to ensure that the end state will meet the relevant requirements and that it will be achieved safely.

In response to a question on whether there should be regulatory requirements to preserve nuclear knowledge and heritage, the general view seemed to be that while it is important to preserve knowledge as a part of the measures taken to reduce the burden on future generations, and in particular after site release, it is not strictly a regulatory concern. Finally, the panel agreed that it is important to have public participation in the decision making process.

The following additional points were identified from the 16 contributed papers in this session:

— The sufficiency of the regulatory framework was identified as an issue in several papers. Countries that have numerous large installations to decommission have generally established the necessary regulatory framework, but often there is a recent change, and in some countries the regulatory framework for decommissioning is still lacking.
— The importance of life cycle planning is now widely recognized, but in relation to the decommissioning of legacy facilities this recognition has often come too late and the regulatory framework has to be modified to 'catch up'.
— The regulatory approach to decommissioning should be different from the approach to routine operations, as discussed above.

- The issue of clearance is important and clearance levels must be agreed between the operator and the regulatory body at an early stage of decommissioning planning.
- Keeping documentation up to date and consistent was noted to be a challenge.
- Several of the papers describe unique ‘one of a kind’ situations (e.g. ‘exotic’ reactors or facilities) occur in many countries and require special considerations for their decommissioning.
- A lack of real life experience with decommissioning and evaluation of compliance with safety requirements and criteria are seen as a problem for countries with small programmes and the absence of this experience makes decision making difficult.
- The advanced age of the existing workforce at many facilities is a growing challenge, for example the average age of staff at research reactors in the Russian Federation is more than 60 years. Since, for financial and other reasons immediate decommissioning is unlikely, this will soon lead to a problem of loss of knowledge about the facilities that in turn will make safe decommissioning more difficult.
- The absence of adequate funding not only has an impact on the choice of decommissioning strategy and the timing of decommissioning, it may also leave the regulatory body in a situation where it is powerless to ensure that decommissioning is carried out safely.

Areas where future international guidance and advice would be useful are: (i) mechanisms for knowledge management, appropriate regulatory approaches to decommissioning (and how they differ from that used for the operational phase); (ii) the concept of flexibility in regulation, including reliance on the operator for his/her own regulation; and (iii) advice on managing the funding of decommissioning.

SUMMARY OF SESSION 3

PLANNING FOR DECOMMISSIONING

Chairperson

I. TRIPPUTI
Italy

In this session on planning for decommissioning, there were six invited papers, from the United Kingdom, Serbia, China, Lithuania, Switzerland and Argentina, followed by a panel session. From the invited paper presentations and the general discussions during the session, the following general conclusions can be drawn.

It was generally agreed that in planning for decommissioning, it is important to first develop a strategy and then a detailed, yet flexible, plan to implement the strategy. The approach of addressing and coping with specific isolated priority issues can be effective in maintaining an acceptable safety level, but it cannot replace a comprehensive plan. A lesson learned from the experience obtained to date is that it is important to develop, maintain, and update a plan that takes account of the entire life of the facility.

Issues which have major influences on the strategy and the plan include: (i) spent fuel management; (ii) waste management; and (iii) the availability and adequacy of funding. Many other technical elements, and also social, political, environmental and even ethical considerations, play a role. The decision making process is so complex that no single solution can be applied generally. A plan which extends from the start to the end of decommissioning is needed, since ‘end states’ and possible reuse options for materials and sites can influence both the schedule and the choice of technical solutions.

It is important that the following elements are adequately considered in the decommissioning plan:

— *Past experience*: It is recognized that any plan must be built on past experience, developed internally or acquired externally (from external contractors or through associations and cooperation agreements).
— *Skills*: It is important to systematically identify and ensure the right skill mix for the planning and implementation of decommissioning. The skill mix should include the experience and skills of the plant operational workforce to the extent possible, even if it has been recognized that re-training of operators in decommissioning skills may not be the most

effective solution because of different attitudes, mindsets and psychological constraints. Additionally, since decommissioning is a fundamentally different activity from facility operation and is mainly a project management challenge, it may be important to have an external (e.g. not involved with previous facility operation), experienced project manager to lead the decommissioning workforce with a proper mix of internal workers and external contractors.

— *International cooperation*: Where national experience and/or infrastructure for decommissioning are not well developed or are judged to be insufficient, assistance and support should be sought. In this context, there is much information and assistance available internationally, for example, from the international and regional organizations (e.g. the IAEA). International assistance is also available in some cases to support national funding for decommissioning projects of general interests. This should not prevent operators, organizations managing decommissioning projects or national governments from trying to provide all necessary financial support for domestic decommissioning projects. In projects involving cooperation between various parties, experience has shown that efficient and effective communication among all parties at each project step is of paramount importance in order to overcome, inter alia, problems due to cultural and linguistic differences.

Additional discussion points included:

— The strategy for decommissioning requires input and coordination with the government. Government support is needed for small, State owned facilities.
— The decision concerning disposal of very low level waste (i.e. on-site vs. off-site) depends on the end use of the site after decommissioning.

The panel discussed the question of deferred dismantling and agreed that immediate dismantling is generally preferred but that there are situations where deferred dismantling can be justified for technical, financial, social and political reasons. Some of the most compelling of these reasons are:

— *Waste Management*: For some waste types, waste management technologies are not yet fully mature and, in some cases, this may influence a decision to defer dismantling. Governments should commit themselves to providing for the ultimate disposal of radioactive waste and recognize that storage is only a short-term measure.

— *Funding*: Inadequacy of funds for decommissioning may force an organization to defer decommissioning until funding can be assured. If decommissioning is started without the assurance of sufficient funding and subsequently halted before the decommissioning is completed, the decommissioning problems may be exacerbated.

It was emphasized in the panel discussion that deferred dismantling does not mean doing nothing in the short term. There should be an active transition phase involving various activities in the preparation for 'safe-store', such as materials and waste characterization. Additionally, measures must be taken to secure and codify the knowledge of the current workforce.

On the subject of how to plan decommissioning in absence of waste management and disposal facilities/capacities, all panellists agreed that, although this is not an ideal situation, decommissioning can be started without the existence of waste disposal facilities, since waste can be safely managed in on-site or off-site interim storage facilities. However, it was emphasized that waste storage should be clearly recognized as an interim step to disposal. The availability of waste storage is important but one needs confidence in the waste acceptance criteria for storage that should be established taking account of future disposal plans so as to avoid the need for waste repackaging or reconditioning at some time in the future. In some cases, safe interim storage can be provided by using existing nuclear facilities, (e.g. graphite storage in the reactor building), until disposal is available. However, attention must be paid to legacy sites where decisions for decommissioning cannot be delayed.

There were 26 contributed papers from 18 countries related to this session, where the following additional points were highlighted:

— Decommissioning planning should be started early, mainly to ensure that adequate funds are in place;
— Advance planning, involving detailed technical and safety considerations, should follow;
— Preparations for decommissioning can be helped in various ways, for example, by gaining experience from the decommissioning of small reactors or research reactors as a training ground for larger projects and collecting data from maintenance and refurbishing activities during the operational phase of facilities;
— Planning for decommissioning through the facility lifetime must be flexible in order to cope with possible changes of boundary conditions, such as new end states;
— Government may have a role to play in some countries in providing financial and strategic support to small state owned facilities;

— It is also essential to have adequate funding in order to plan well for decommissioning.

From the discussions during the session, it was clear that further international guidance on subjects such as decommissioning funding and disposal options for waste types from decommissioning would be appreciated. In addition, increased international cooperation and assistance to countries in the decommissioning process, including detailed planning, cost assessment and knowledge management, would be valuable. Finally, there was encouragement to strengthen the role of the Joint Convention in ensuring the safe decommissioning of facilities that use radioactive material.

SUMMARY OF SESSION 4

IMPLEMENTATION OF DECOMMISSIONING ACTIVITIES

Chairperson

P. BEELEY
United Kingdom

The session on implementation of decommissioning activities consisted of five invited papers, from the USA, South Africa, France and Greece, and a panel discussion. The papers covered a broad spectrum of topics: the decommissioning of fuel cycle facilities (South Africa), of commercial nuclear power plants (USA), of reprocessing plants (France) and of a fertilizer plant (Greece), and the inconsistencies between estimated and actual decommissioning cost (USA).

A common theme in the invited paper session concerned the need for engagement of the key stakeholders in planning for decommissioning, including those involved in managing the projects. The use of both operational staff and contractors for decommissioning is usually necessary due to the lack of suitably qualified and experienced contractors in some countries. Therefore, there is a need to provide proper education and training for existing facility staff. The paper dealing with the decommissioning of a non-nuclear facility showed that many of the same issues arise in both nuclear and non-nuclear facilities decommissioning.

Some of the key points from the panel discussion on maintaining knowledge and safety culture during decommissioning are as follows:

— Success in maintaining a safety culture is achieved through having a clear specification of safety requirements, work boundaries, and work authorizations. The shift from operational to decommissioning activities should not imply a reduction in safety requirements. There should be a clear understanding of the changing work scope and nature of the risks in moving from the operational phase to the decommissioning phase (which involves a shift from mainly radiological to conventional safety).

— Decommissioning responsibilities should be clearly defined and followed according to an established organizational structure for decommissioning.

The following aspects were given particular attention in the course of the session:

- Decommissioning knowledge is not always sufficient for the successful completion of decommissioning. There is also a strong need for willingness of the operator and its staff to perform decommissioning activities. An important aspect of managing a decommissioning project is concerned with personnel development, knowledge improvement and the maintenance of a motivated workforce. Senior staff will often be required to keep the focus on decommissioning goals and to motivate young personnel in relation to the decommissioning challenges and to emphasize that the expertise gained in decommissioning has long term value, i.e. that there is a future for their activities.
- An educational and training framework for decommissioning personnel needs to be established.
- The reliable estimation of decommissioning costs is important for the successful planning and implementation of decommissioning. The work of the international organizations in developing a standardized list of cost items was very useful and further practical guidance would be useful.
- The decommissioning of small facilities in countries with limited resources usually has to be planned and, to a large extent, implemented by the operator because of the lack of available competent companies with experience in the country. An alternative is to seek regional or international assistance.
- Adequate planning and implementation of the transition phase from operation to decommissioning is one of the critical factors for the successful implementation of decommissioning.
- For decommissioning activities at a multi-facility site, experience shows that it is necessary to have: (i) clear boundaries between the facilities; (ii) well defined responsibilities in relation to the decommissioning tasks as distinct from any other functions; (iii) a clear structure for the decommissioning of individual facilities; and (iv) consideration of interfaces between the facilities on the site. The involvement of senior management in the daily decommissioning works on site is essential for the effective completion of the work.
- During decommissioning projects there is a need for a regular review of the measures for optimizing the radiological and industrial risks to workers.

Thirty contributed papers from 17 different countries were relevant to this session. From these papers the following additional points can be highlighted:

— If adequate training and supervision are provided, some decommissioning activities can be successfully and safely outsourced.
— The reliability of the technology is an important factor to consider in the selection of a decommissioning process. The tools and deployment systems must be easy to decontaminate and before any new tool for dismantling and decontamination operations is used, appropriate cold tests must be performed.
— The continuous changes of organization and the development of new methodologies for decommissioning project or programme management is a constant concern for the successful implementation of the decommissioning strategy.
— An unreasonable delay in the implementation of cleanup activities may result in undesirable consequences. Prior to any decommissioning activity, efforts should be made to improve communication on radiation matters with members of the public living near the nuclear sites and other stakeholders. Serious consideration should be given to complying with the non-radiological requirements established by environmental regulatory bodies, before releasing the site for unconditional use.
— In order to achieve successful decommissioning of facilities, it is important to coordinate all relevant aspects of decommissioning — management, contractual, regulatory, and technological.
— Technological developments have led to mature methods and improved equipment. Therefore, the exchange of information on such developments should be encouraged.
— In order to predict decommissioning costs, a methodology for collecting data on decommissioning costs should be developed.
— Funding profiles, cost estimation, risk management and commercial strategy cannot be considered separately. With careful planning, decommissioning can be achieved safely and give good value for money to the funding authority. It is necessary to make progress with the technology at hand while pursuing the improvements that will be needed to achieve the targeted budget.
— Waste volumes can be decreased by improved compaction and packaging technologies, as well as improvements in pre-dismantling sampling and measurements, the latter leading to more precise nuclide vectors and thus a better separation of materials for clearance.

— The development of an integrated safety management system supports the safe and cost effective decommissioning of nuclear facilities.
— The licensee needs to prepare a detailed decommissioning plan in order to satisfy regulations and conditions set by regulatory authorities. There is a need to have good cooperation between the relevant government agencies, regulators and licensees to facilitate the completion of the decommissioning project.
— The definition of a clear end state for decommissioning is necessary in order to establish the decommissioning conditions for a permanently shutdown contaminated facility, in a systematic and logical way.

A number of areas were suggested for further international initiatives, they were:

— A ‘safety culture for decommissioning’ should be developed that embraces a radiological safety culture with an industrial safety culture. The establishment of a recognized decommissioning profession is to be encouraged.
— The decommissioning experience database should be broadened to include facilities from the naturally occurring material industry; highlighting the common aspects based on the experiences from all types of nuclear facilities, including medical and mining facilities.
— Further guidance on decommissioning cost estimation should be provided.

SUMMARY OF SESSION 5

WASTE MANAGEMENT ISSUES

Chairperson

Z. PAN
China

The session on waste management issues consisted of five invited papers from Spain, the United Kingdom, Japan, Germany and the IAEA, followed by a panel discussion. It was evident from the papers presented that the key elements for successful decommissioning involve a clearly defined decommissioning strategy, a decommissioning plan and a systematic waste management approach.

In relation to decommissioning and the subsequent waste management, there should always be a strong emphasis on characterization. The characterization of the facilities being decommissioned and the characterization of the waste generated are important irrespective of the decommissioning strategy adopted. This facilitates the accurate identification of the various radionuclides present, the determination of the characteristics and the amounts of decommissioning waste expected and enables plans to be made for the most appropriate means of waste storage and disposal prior to the implementation of decommissioning activities.

In the presentation and discussion on the release of materials and sites from regulatory control, it was noted that although international policies, guidelines and levels are now well established, there are often difficulties in implementation at the national level. These can arise due to the reluctance of the various concerned parties to move from pre-existing national regulatory values for clearance. In addition, the reluctance of some parts of the metal recycling industry to accept material that has been cleared from regulatory control persists. The paper from the IAEA identified harmonization at the national level as one of the areas in which progress would be sought in coming years and noted that further guidance is needed on methods for monitoring for compliance and on clearance levels for surface contamination.

It was highlighted that in the management of material during decommissioning (i.e. characterization, handling, treatment, packaging, transport, disposal and/or reuse), several factors were relevant for consideration during planning and implementation of decommissioning — establishment of a clear methodology for clearance, cost–benefit analysis, regulatory limits and criteria, and public acceptance.

Experiences of providing waste management arrangements for the various and different types and geometries of waste from decommissioning were described and the importance of knowing the history of the waste was emphasized. Experience of the day to day handling of waste and its control by regular evaluation and input from radiation monitoring was also highlighted.

Examples were given of the difficulties experienced in managing some of the special waste forms from national decommissioning projects, e.g. large volumes of activated and contaminated graphite. These problems were one of the reasons for the United Kingdom to adopt a strategy of deferred decommissioning to allow time for the development of appropriate waste disposal facilities.

Emphasis was placed on adequate planning of measures for special material processing and the expense and delays involved, for example, in processing large volumes of activated and contaminated graphite, carbon and stainless steels.

Waste reprocessing, volume minimization, the recycling and reuse of material, together with on-site storage are approaches which can be used by countries where no disposal options are available.

The intention to establish a harmonized (international) approach to monitoring for compliance with the clearance values that would be universally implemented was considered as a challenging one. This would also require consensus between the various national stakeholders. In the panel discussion addressing the issue of achieving harmonization of clearance levels, it was noted that countries, through their formal approval of the relevant IAEA safety standards, had already effectively accepted the international levels. Despite that, and the publication of IAEA Safety Guide RS-G-1.7, technical difficulties in implementing and monitoring the levels are still evident.

Success in gaining acceptance of international clearance levels is most likely to be achieved through obtaining the trust of stakeholders at the national level by gradual and open approaches involving discussion between the proponents and the stakeholders. In a statement, the European Commission (EC) panel member indicated his organization's intention to implement the IAEA clearance level values in the EC legislation. There was general agreement that, since so much of the decommissioned material from nuclear reactors is inactive or contains very low levels of radionuclides, a recycling option is necessary and therefore a mechanism for releasing very low activity level materials from regulatory control is essential.

On a question concerning the activities needed to manage the radioactive waste and material from decommissioning, the panel members emphasized the importance of: (i) good strategy and decommissioning planning; (ii) a clear end point for materials management; (iii) accurate estimates of the required costs, time and human resources; (iv) good communications and training; and (v) waste characterization as the basis for planning and selecting the most appropriate storage and disposal options. There was also agreement that radioactive waste management is the key element in decommissioning. Incentives were encouraged to be generated to motivate the recycling of decommissioned materials.

Finally, the international organizations were encouraged to organize more workshops to inform and train responsible persons in countries with limited resources regarding the principles and practices of decommissioning, including strategies, characterization, decommissioning technologies and radioactive waste management.

SUMMARY OF SESSION 6

TECHNOLOGY ASPECTS

Chairperson

L. VALENCIA
Germany

The session on technology aspects consisted of five invited papers, from the IAEA, Sweden, the Russian Federation and the USA, followed by a panel discussion.

The IAEA paper outlined the available approaches for selecting the most appropriate technologies for decommissioning and indicated a need for more accessible information on decommissioning costs. It highlighted that in selecting decommissioning technologies it is important:

— To identify key factors;
— To develop and implement a formalized decision making process to help structure the problem and arrive to justified conclusions; and
— To use methodologies such as financial, cost-benefit and multi-attribute analysis.

It indicated the need for more accessible and updated information on costs by means of an international cost database. In addition it was pointed out that the IAEA started a Coordinated Research Project to analyze technology selection and comparison processes and experiences between 13 Member States.

An example of the success achieved in melting and recycling metal from nuclear decommissioning was presented in the Swedish paper. It was highlighted that metal melting can be considered a mature technology and, by this means, a high percentage of free released material has been achieved. Size reduction, sorting and measuring for radiological characterization are important steps in this process. Surface blasting is also considered as a very effective technique in increasing the fraction of material that can be cleared. This method is effective for contaminated metals, not for activated components. Steels, both carbon and stainless, can be decontaminated from uranium, but this is not the case for aluminum.

In contrast to indications from earlier sessions of the conference concerning the attitude of the steel industry to recycled metals from the nuclear industry, the steel industry in Sweden and some other countries accept the recycled metal from this source. The key element in this seems to be the existence of trust between the recycler and the steel industry customer.

In many countries, a legacy from the early years of the nuclear industry is the disused nuclear facilities located in close proximity to populated areas. The Russian paper described the experiences of work on the remediation of waste repositories and land areas located very close to buildings in an urban area. The experience shows that different technologies have been used in this large project, including electric discharge destruction of concrete, remotely controlled characterization, cutting, sorting and packaging, large scale application of dust suppression and remote continuous monitoring of the working area. Techniques for contaminated soil washing have proved to be effective and 88% of the soil volume has been free released.

The papers from USA described experiences from the many decommissioning projects at civil and cold war legacy sites which have been successfully completed. It is apparent that many lessons can be learned from the US experience of applying and developing different decommissioning technologies. Some of the general lessons learned are: that testing technologies thoroughly before their application is essential, that ‘simple is usually best’ and that it can be beneficial to involve the workers in selecting the technology. It was highlighted that abrasive water jet cutting was among the most effective methods.

Equipment reliability in decommissioning also presents a challenge and needs to be considered in the planning and implementation of decommissioning. The periodic testing of equipment and use of mock-ups to the greatest possible extent are very important factors for successful decommissioning. The selection of decommissioning techniques also needs to take into account the generation of small particle debris which should be minimized. Other important factors for the successful and safe decommissioning are a good radiological characterization of the facility and its systems and components, as well as a clear definition of the final disposal options and associated waste acceptance criteria, e.g. size of packages.

The session emphasized that technology selection needs to be taken into account improvement of workers safety, while optimizing the associated costs and duration of decommissioning activities.

A common view was shared that ‘Simple is the best’ decommissioning technology option. Starting with a simple technology, then continually improving it as experience grows, generally has greater success than highly engineered solutions with long deployment schedules. In high risk activities where new technologies are needed, several parallel efforts, if possible, are beneficial, in order that at least one method can be deployed.

A general agreement was also expressed during the conference on the importance of the IAEA/NEA project on decommissioning cost itemization to produce an international database on decommissioning cost values. However, the difficulty of overcoming proprietary concerns was noted.

In addressing a question concerning the main factors to be considered in selecting decommissioning technologies, the panel concluded that the following factors are most relevant: correct definition of the problem to be solved, the maturity of the technology, that is, that it should ideally have been demonstrated on the type of facility under consideration, and that ‘simplest is best’. Other factors are often relevant, for example, the local availability of maintenance and technical assistance for the proposed technology and the experience of the contractor with the technology. Finally it was noted that the cheapest option may not be the most effective one. Quite often, an evaluation of the advantages and disadvantages for a technology is vital to the optimal choice of decommissioning technologies.

On the question of improving the international exchange of lessons learned, various suggestions were made by the panel and the conference participants. They included: workshops and networks on specific topics (e.g. regionally based), as an alternative to large generic conferences, expert groups to produce guidelines on particular topics, international newsletters, websites or other forums where information on technologies could be exchanged and advice given on request, especially to developed countries. It was pointed out that some of these ideas have already been implemented, such as the IAEA’s Decommissioning Forum, a website through which information can be exchanged, and through other regional and national initiatives.

Finally the panel addressed a question concerning the choice between innovative and adaptive technologies and concluded that existing and proven technology should be used as far as possible. Innovative techniques should only be used if there is no relevant existing technology. When an innovative technology is used, local technical support should be available and contingency plans should be prepared. In case of new technologies it was emphasized that enough time must be allowed in planning to develop and test this technology. There was agreement that, whatever technique is used, the general maxim should be: ‘test, test, and test once again’.

Further suggestions for international cooperation were discussed during the session and in particular: (i) improvement of regional cooperation for discussion of technology sharing; (ii) enhancement of international mechanisms for experience exchange through for example promotion of an IAEA Quarterly Newsletter and/or the IAEA website or establishment of an IAEA International Exchange Center.

SUMMARY OF SESSION 7

SOCIAL AND ECONOMIC IMPACTS

Chairperson

A.J. BAER
Switzerland

The session on social and economic impacts consisted of five invited papers, from the OECD/Nuclear Energy Agency, Ukraine, the USA, the United Kingdom and Brazil, followed by a panel session.

Socioeconomic issues are vitally important to decommissioning, but this is not well recognized at present. There is a parallel with the development of the approach to waste management, where it eventually became recognized that social issues were of overriding importance. It is important to increase awareness of this issue. The session showed good examples of socioeconomic engagement at the Dounreay and Hanford sites.

There are considerable differences in cultural approaches across the world and across facilities. The world is not uniform in this context. This makes it very difficult and challenging to learn from the experiences of others and to transfer the experiences to other situations and facilities. Furthermore, it is better to learn from doing than from being taught. In summary, ‘technology is universal, social is local’.

The early involvement of the local community (including the workforce) in establishing the vision for the future use of the site is a vital first step.

Socioeconomic issues must be an integral part of the overall decommissioning plan.

There needs to be an emphasis on the preservation of the future quality of life of the community. Particularly for those sites which are remote and/or which have a major local economic impact, there will be a desire within the community to preserve a similar level of economic activity. This involves consideration of:

— The reuse of the site;
— Attracting alternative economic activity;
— The retraining of the workers.

Negative consequences may not be fully avoided, but they can be minimized through early engagement with the community.

Stakeholders need confidence in the safety of the site, and, in particular, confidence in the end state of the site. They should be involved in the ongoing cleanup and final closeout in order to develop this confidence. Safety perception issues need to be actively addressed, with involvement of the public authorities.

It is important that all parties (particularly the local community and its representatives) display a positive and confident tone. Local communities should proactively contribute to success through active involvement and leadership. They have a major influence on securing eventual success.

Successful stakeholder engagement requires that clear rules are defined and agreed in order that the expectations of all of the parties are managed.

An important message in relation to the engagement of stakeholders is, ‘involve, involve, involve!’

International organizations such as the IAEA can help by:

— Raising awareness of the importance of socioeconomic factors;
— Establishing a framework to integrate socioeconomic factors into the decommissioning process;
— Providing a platform for discussing case studies, recognizing cultural/geographical/system differences.

Only one paper had been contributed to this session, which led the Chairperson to ask why of a total of about one hundred papers contributed to the conference, only one dealt with social and economic impacts.

He proposed the possible explanation that although the importance of social and economic issues was well recognized, technologists did not need any help in handling them, should they occur. This possibility, however, reminds of the situation in the field of disposal of high level radioactive waste of 10 or 15 years earlier. The most important lessons presented in the paper is that training of personnel to undertake decommissioning projects is an integral part of a long term vision in the management of human resources.

However, since social aspects are site specific, there is little merit in seeking to develop standards in this field.

SUMMARY OF SESSION 8

DECOMMISSIONING OF SMALL FACILITIES

Chairperson

A.G. YOUTSOS
Greece

The session on decommissioning of small facilities consisted of five invited papers, from the United Kingdom, Denmark, Greece, the USA and Cuba, followed by a panel discussion.

The key points from the invited papers are summarized in the following paragraphs.

Small facilities (laboratories, small research reactors, medical facilities, etc.) may be considered as 'orphans' (because they are not part of the larger nuclear industries). They often have technologies and physical housings that are obsolete and date from the early years of the nuclear industry. In many facilities chemically hazardous materials are present which complicates the planning and performance of decommissioning.

Decommissioning, if possible, should not be delayed.

As with all decommissioning projects; good planning is a key element.

If a strategy for the reuse of the facility after decommissioning is clearly identified, this heightens interest in its decommissioning.

Failure to plan results in unnecessary costs, delays, and possible safety issues. When planning for the decommissioning of small facilities:

— All sources of relevant information should be found and any uncertainties identified;
— Regulators should be involved at an early stage of decommissioning planning;
— Relevant literature and expert networks should be consulted;
— A characterization survey is key element in the decommissioning planning and should be carried out;
— An external review of the decommissioning plan can provide additional assurance.

A staged approach should be adopted for decommissioning with specific milestones and decision points.

Delays and additional costs can be caused by changes in regulation, not involving stakeholders, inadequate training, and taking poor advice.

Procedures for the subsequent management of radioactive waste should be established and clearance levels agreed by the regulatory body before decommissioning begins.

Local staff should be involved in decommissioning as much as possible, starting at the planning stage.

The performance of all contractors should be carefully monitored, especially those who do not have nuclear experience.

Attention should be paid to conventional safety aspects, as these become the dominating hazard when the radiological risks decline.

In designing or upgrading a facility, materials and samples that do not become significantly activated should be chosen, to ease future decommissioning.

For developing countries there are a set of specific decommissioning challenges, they include: lack of funding, lack of equipment and appropriate staff, and the unavailability of technologies. For these countries, international guidance, technical advice and direct assistance are important both to operators and regulators.

For a country with a large number of facilities to be decommissioned, it may be worthwhile to make a classification of the facilities taking account of the views and the expectations of the regulators.

While the use of well-proven approaches and technologies is preferable, new approaches may have to be used for problems specific to the facility.

The panel discussed whether the dismantling of shutdown small facilities is always the safest option. It discussed the many factors to be considered in such a judgement. It noted that such facilities often have to be decommissioned because they are located in city neighbourhoods. In these circumstances, there may be public concerns about safety but there is often also the desire to reuse valuable land.

Considerations which are in favour of prompt decommissioning action are: doubts about maintaining adequate human resources to carry out the decommissioning, the increasing likelihood with time of releases occurring to the environment, and the need to preserve records and knowledge of the facility.

However, for sites on which new nuclear facilities will be constructed or on which there are other nuclear facilities, immediate decommissioning may not be a priority. The panel noted that if a strategy of ‘no action’ is decided upon now, it cannot necessarily be assumed that others in future will take action. On balance, it seems that the decommissioning of small facilities should commence as soon as possible unless there are strong reasons to the contrary.

The longer the delay before decommissioning a facility the more likely some form of radionuclide release will occur. Also it was questioned as to whether all the necessary facility-specific information can be retained, especially for older facilities.

The panel discussed entombment as a possible decommissioning option. It was noted that entombment requires continued monitoring, continued regulatory oversight, involves long lasting costs, and raises the question of 'who is responsible and when?' Entombment seems to be an intermediate solution in the wait for final decommissioning and waste disposal. It can be viewed in a similar way to near surface disposal facilities, which are monitored until their radioactive contents decay to acceptable levels. It is a better option than doing nothing, and may be appropriate for countries with limited resources provided that the major contaminants have short radioactive half-lives. It was noted that in special circumstances the IAEA has helped a country to implement the entombment approach. The panel considered that entombment should be seen as a last resort option that requires special and convincing justification.

The following additional points were raised in the contributed papers for this session:

— As for all other types of decommissioning, the importance of a determining a final destination for the radioactive waste generated in the decommissioning of small facilities and the need to have an established policy for the free release of materials was emphasised.
— The potential risks involved in handling large sealed sources encountered during decommissioning was noted and the need to have prior information about them, their location and nature.
— There can be difficulties in finding suitable capable contractors for decommissioning small facilities especially in countries with no nuclear industry and the assistance of the international organizations can be helpful in such cases.

SUMMARY BY THE CONFERENCE PRESIDENT

L. CAMARINOPOULOS
Greece

1. BACKGROUND

A significant fraction of the world's nuclear facilities has now entered the decommissioning phase; this includes nuclear power plants, fuel cycle facilities, research reactors and other research facilities, uranium mines and military facilities. It was therefore appropriate that international attention was focused, through this conference, on learning lessons from the significant amount of decommissioning experience that has been obtained.

In recent years, the international community began to anticipate the increasing importance of decommissioning with a series of international workshops and conferences. The IAEA used the findings of its international conference on Safe Decommissioning for Nuclear Activities, held in Berlin in 2002, to develop an International Action Plan on Decommissioning, and it is expected that the outcome of the present conference will be used to update that plan.

The successful decommissioning of many types of facility has provided valuable experience and this has encouraged the belief that there are lessons to be learned from these projects. Experience is much greater in some countries than in others and so events such as this conference can bring real benefits to countries that are just beginning to engage in decommissioning. In this context, there was a call during the conference for a more broadly based sharing of experience in the decommissioning area, especially in relation to funding schemes and technology. It may be appropriate for such an initiative to be launched through the auspices of the international organizations or through the existing global mechanism in this area, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention).

2. INTERNATIONAL SAFETY FRAMEWORK

At the Berlin conference, the international framework that exists for managing the safety of decommissioning was set out — with the legally binding Joint Convention as its focal point. The Joint Convention is supported by the safety standards of the IAEA and during this Athens conference it was shown that the framework of standards is now almost complete — with new Safety Requirements and Safety Guides covering all important areas of decommissioning.

3. EARLY PLANNING FOR DECOMMISSIONING

A fundamental lesson learned from past experience is that it is essential for there to be early planning for decommissioning. Unfortunately, this is a lesson which has been learned as a result of the inadequate planning for decommissioning in the early years of the nuclear activities. This early planning should take account of the lessons learned from decommissioning experience and cover issues such as designing for ease of decommissioning and arrangements for providing decommissioning funds.

4. DECOMMISSIONING STRATEGIES

It seems that the original target of decommissioning projects, of returning sites to a ‘green field’ status, may be modified by the prospect of a renewed interest in nuclear energy and the possibility that existing sites will be reused for new nuclear facilities.

The discussions at the conference have shown that, while the generally preferred strategy for decommissioning is ‘immediate dismantling’, there are many situations where ‘deferred dismantling’ can be justified, because of lack of funding, lack of waste management arrangements, social and political reasons.

One advantage of immediate dismantling is that the existing workforce, with its skills and knowledge of the facility, can be employed for the decommissioning work. However, this workforce may not always be capable of such work, and there is a trend in countries with many nuclear facilities for key parts of decommissioning operations to be done by specialist companies or organisations with experience and skills in decommissioning planning and implementation.

5. REGULATION OF DECOMMISSIONING

The decommissioning phase, unlike the operational phase, is dynamic in nature, and there is a need for continuous changes and adjustments to be made in the regulatory process. In addition, the hazards associated with the various decommissioning operations are usually less than those in the normal operation of the facility and do not require the same degree of regulatory rigour. The experience obtained in this area has shown the need for flexibility in the way in which the decommissioning process is regulated. Various examples of this were shown during the conference, including the French approach of giving flexibility to the licensee through the 'internal authorization' process, but with a proper oversight being maintained by the regulator. A graded regulatory approach may be used to take account of the different hazards presented in decommissioning and to appropriately utilize regulatory resources. Further international guidance on these aspects may be useful to harmonize regulatory approaches in this area.

6. FUNDING OF DECOMMISSIONING

The funding of decommissioning is a key issue and for many facilities it is the main reason for the lack of progress in decommissioning. Ideally, arrangements should be made for funding decommissioning before a facility becomes operational. Unfortunately, this was often not done in the past and while decommissioning funds usually exist for civil nuclear power plants, for other types of facility they do not. One example presented at the conference concerned the many shutdown research reactors for which no provision has been made to cover the decommissioning costs. In view of the long-term potential hazard to the public and to the environment presented by these facilities, they should be decommissioned and, in this context, the funding issue warrants serious attention. Of course, the responsibility lies with the operators and ultimately with national governments but the international organizations should consider what help they can offer in this area.

7. MANAGEMENT OF RADIOACTIVE WASTE FROM DECOMMISSIONING

There is an absence of suitable repositories for intermediate level waste in many countries but the clear view of the conference is that this is not normally a reason to prevent decommissioning going forward. Most waste types from decommissioning can be stored safely until repositories become available.

8. CLEARANCE OF MATERIALS FROM DECOMMISSIONING

The vast majority of the material resulting from the decommissioning is inactive or below clearance levels and the use of clearance has the potential for saving considerable waste disposal costs. For this reason, the conference recognized that it is very desirable for clearance levels to be harmonized so as to avoid misunderstandings and transboundary problems. A step forward in achieving harmonization was achieved when the IAEA published in 2004 its Safety Guide on clearance levels. The clearance levels are accepted internationally and are gradually being introduced into national regulatory schemes, but it remains to be seen as to whether a complete harmonization between countries will be achieved in the coming years.

9. DECOMMISSIONING OF SMALL FACILITIES

Small facilities, such as research reactors and research laboratories, often present unique technical decommissioning problems. The financial and technical support available for the decommissioning of these facilities is usually limited and in countries with few or no other nuclear facilities this presents particular difficulties. This is an area in which the international organizations can be effective in providing advice and in facilitating the transfer of knowledge.

10. TECHNOLOGY FOR DECOMMISSIONING

The sessions on technological aspects showed that there are many lessons to be learned from the decommissioning experiences obtained to date, especially from those in the USA, where many large scale decommissioning projects on nuclear power reactors have already been completed. It is evident that substantial savings of money and time can be achieved through learning from the experience of others. Various proposals were put forward on means to facilitate this transfer of knowledge between countries.

11. KNOWLEDGE MANAGEMENT

The timescales for many decommissioning projects are long and important knowledge may be lost, for example, of plant configuration and operating history, as experienced members of the workforce retire.

Mechanisms for saving and managing this knowledge are required and this may be an area in which international cooperation can be effective.

12. DECOMMISSIONING WORKFORCE

The conference recognized that there are often problems in retaining a knowledgeable and skilled workforce to do decommissioning work. Various ideas were put forward to help resolve this problem. They included ways of positively motivating the workforce through education and other means. One proposal was to promote the concept of professional qualifications in the decommissioning area – a ‘decommissioning engineer’ — and to establish an internationally accepted curriculum for such a speciality.

13. SOCIAL ASPECTS

The decommissioning of nuclear facilities usually has a major impact on local communities due to a loss of quality employment and, possibly, a decline in the local economy. While the negative consequences cannot be fully avoided, they can be reduced through the involvement of concerned parties. An important lesson learned from decommissioning experiences is that plans to involve the concerned parties should be made early — at the same time as the decommissioning plan is developed.

CLOSING ADDRESS

H. FORSSTRÖM
Director,
Division of Nuclear Fuel Cycle
and Waste Technology,
International Atomic Energy Agency,
Vienna

1. INTRODUCTION

Thank you Professor Camarinopoulos for an excellent summary of the salient points coming out of this conference. I am very impressed by the high quality of the conference and the presentations that have been made. Over the years I have participated in many international meetings about decommissioning. Actually, my first IAEA meeting was on decommissioning almost 30 years ago. At that time only a few installations had been decommissioned and dismantled and many of the discussions were rather theoretical. Today, the situation is quite different. Many installations, ranging from small laboratory facilities, e.g. glove boxes to large commercial sized nuclear power plants, have been decommissioned and many of them dismantled. The list of lessons learned presented in papers and posters at this conference is impressive.

A first conclusion is that adequate technology is available for decommissioning, but there are still challenges for specific tasks, not least to ensure a proper and cost effective waste management.

Second it can be noted that strategy, organizational and planning issues have been very prominent in the presentations and are key to the success of decommissioning projects.

Third, waste management issues remain a concern in many countries, both at the very low level end of the spectrum, e.g., concerning clearance levels, recycling and reuse, and at the higher end of the spectrum, e.g., how to take care of the intermediate level waste.

Fourth, more emphasis is being put on the social aspects and stakeholder involvement, bearing in mind that large decommissioning projects have a great impact on the local society, both from the point of view of reducing the risks and of changing dramatically the employment situation.

2. IAEA ACTION PLAN

In his opening address, the Deputy Director General for Nuclear Safety and Security, Mr. Taniguchi, made reference to the International Action Plan on Decommissioning of Nuclear Facilities that was approved by the IAEA Board of Governors in June 2004. This plan covers many aspects of decommissioning, including the setting of safety standards and the provision of guidance on their application, as well as information exchange on technical developments and lessons learned. The progress of the implementation of this plan has been reported during this conference.

Now it is time to revisit the Action Plan taking into account the information provided and the discussions held during this week and to identify what new actions are needed or what ongoing actions need to be reinforced. I will not pre-empt this work, but only mention a few points from the long list of topics that have been discussed.

3. JOINT CONVENTION

I will start with the international safety framework. Decommissioning is one of the topics that is covered by and should be reported under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention). Very good experience has been gained from the first two review meetings that have been held, primarily concerning strategies and implementation activities for radioactive waste management. The need for reporting in a structured way and the review of the reports and the activities in one country by peers in other countries has been very much appreciated. Learning from each other and being exposed to a critical, in the positive sense, review is seen as an important tool to improving national approaches.

So far, however, the decommissioning activities, although reported under the Joint Convention, have had a lower profile in the discussions. There is a need to consider how the positive experiences of the review mechanisms for waste management can also be transferred to the decommissioning field. The IAEA will work together with the Contracting Parties to the Joint Convention to explore how this can be achieved for the next review meeting, within the existing framework.

4. FLEXIBLE AND GRADED APPROACHES

Another important point raised during this conference concerns the discussion on a flexible and graded regulatory approach. Experience shows that the international cooperation provided by the IAEA through its decommissioning safety project — DeSa — has been very useful in clarifying some of the aspects in this connection. The IAEA will look into the mechanisms for, and the suitable content of, a follow-up project to DeSa to keep this positive momentum alive.

5. SHARING OF EXPERIENCE – ESTABLISHING A DECOMMISSIONING NETWORK

A common theme during this conference has been the need for information and experience sharing, not least between those countries and organizations which are conducting large and important decommissioning projects and those countries which are facing decommissioning challenges but still lack experience. Several mechanisms exist internationally for the exchange of experiences between the well developed projects, e.g., within the OECD/NEA Co-operative Programme on Decommissioning, which has been active for more than 25 years and within the collaborative programmes of the European Commission. However, there is no mechanism for sharing information and experience with the less experienced countries. Such a mechanism is very important to ensure that decommissioning will be performed safely and effectively worldwide.

To fill this gap the IAEA is considering establishing a Decommissioning Network, which will bring together organizations with particular experience and competence in decommissioning work and who are willing to share their experiences, with organizations — primarily in developing countries — that are starting decommissioning activities. To be effective, the network will be centred around a number of case studies and demonstration projects, e.g. a research reactor in the Philippines, and regional reference centres. The issues that will be addressed will cover a large spectrum of activities; they include: strategies, organization and planning (both for regulators and operators), methodologies, cost assessment and funding mechanisms, characterization activities, decommissioning techniques, waste and materials management and including ‘hands-on’ experiences.

The decommissioning network will provide opportunities to support Member States with less developed decommissioning industries by providing access to decommissioning skills, knowledge and practical experience. It could provide possibilities for secondments, training courses and technical visits. The use of coaching and mentoring techniques could be developed. Also it might, on a more technical level, provide the possibility for sharing or transferring redundant instrumentation and equipment.

Positive discussions with interested experienced organizations about the network had already started before this conference and there have been even more positive reactions during this week. A first consultancy is planned for February 2007 to discuss the organization and functioning of the network. It will be followed by a Technical Meeting with a broader participation of Member States. The positive experiences from a similar network on radioactive waste disposal, which has been operating for several years, will be utilized. In this network, organizations operating underground research facilities are members and countries entering the field of geological disposal are associates.

6. TECHNOLOGY

I mentioned earlier that adequate technology is available for decommissioning. The approach to decommissioning and the techniques used are in essence straightforward. Decommissioning is not ‘rocket science’ and there is no reason why it should not be managed in the same way as any other project. However, as with other projects, experience and proper planning and organization are essential in order to reduce risks and costs while ensuring safety. Also, technology will continue to be developed and new specific technical approaches will be used. The IAEA will continue to provide a forum for the exchange of experiences and applications. In particular, it will be important to find simple and economic solutions for use in the developing countries with limited resources.

7. WASTE MANAGEMENT AND SITE REUSE

I will now turn to the issues of waste management and the reuse of material and sites. The overall objective of decommissioning is to reduce the potential risk of a redundant installation and, preferably, to remove the radioactive materials so that the site can be released for productive reuse, be it for industrial purposes, which is the most probable, or for leisure purposes. IAEA Safety Guides have been published on the release of sites from regulatory control after termination of practices and on clearance levels for materials. Still, it has been reported at this conference that there is a need to ensure harmonization of application of these rules across Member States. Also, the difficulties in getting public or industrial acceptance for the recycling of cleared material have been reported. More activities in this area are needed.

Further work is also needed to define realistic end states for both waste and sites. In reality, full site release might not be the optimal, or even preferred or achievable, solution. A nuclear power site is a very valuable site for future power production, given that the infrastructure already exists there. It might be acceptable, in some cases, that a certain part of the site remains under regulatory control. The same can be valid for some types of material recycling. Further work on these aspects is needed in order to develop appropriate safety guidance, taking into account the many practical experiences noted at this conference.

Another aspect of waste management discussed during the conference is whether lack of waste disposal facilities is an excuse for delaying decommissioning activities. It was agreed that immediate decommissioning is the preferred option, but that waste management needs to be considered in good time. In this context, the best options for storing the waste while waiting for disposal, have to be determined. It is also important that the waste management community is made aware and requested to work on the management of all types of waste from decommissioning as soon as possible, i.e. to find adequate solutions for the management of special types of decommissioning waste, such as graphite waste, large size components and intermediate level waste. The situation is not very different from the situation for spent fuel management, for which interim storage facilities have been built at plants to be decommissioned.

8. FUNDING

Throughout the conference, the issue of ensuring adequate funding for decommissioning has been raised. This concerns how to assess the funding needs, but also, more importantly, how to ensure that funding will be available for decommissioning, not least in countries with limited resources. There is a need to raise the awareness of governments of this issue also in those Member States that are not Contracting Parties to the Joint Convention.

It is also clear that some countries might not be able to afford extensive decommissioning work. For these cases, it would be of interest to seek international solutions for financing. An example of this is the decommissioning and waste management work done in the former Soviet Union with financing from the G8 countries and the European Bank for Reconstruction and Development, which is coordinated in a Contact Expert Group operated by the IAEA.

9. DECOMMISSIONING OF FUTURE REACTORS

Finally, I will say a few words about the future. We are facing an increasing interest in the development of new nuclear facilities and new types of nuclear power plants. This is the time to ensure that the experiences of decommissioning are taken into account in the design of new plants. As practically all power plants are rebuilt several times during their lifetimes through the replacement of components, etc., including decommissioning experiences in design will also be a tool for improving the maintainability of the plants and with the resultant lowering the operational radiation doses to the staff.

In the new designs, recycling should also be taken into account. Perhaps the car industry could serve as a good example in this context, where nowadays, a large percentage of the material used in the cars is designed to be reusable.

10. CONCLUDING REMARKS

To summarize, I think that this conference has been very timely and has brought up a large number of issues to be considered. The IAEA is preparing to follow up on the recommendations given. Although I started by saying that decommissioning is a mature activity, we have identified many areas where further advice is needed.

I believe that this conference has been an excellent forum for the exchange of experiences and lessons learned.

In his introductory remarks Mr. Taniguchi quoted Aristotle by saying “What we have to learn to do, we learn by doing.” I will not question the wisdom of Aristotle, but I also believe that we do not have to learn everything through our own experience, but that we can also learn from each other. I hope that the follow-up of this conference will prove that to be true.

Once again, I would like to thank the Government of Greece, the Greek Atomic Energy Commission and the city of Athens for hosting this conference and for the warm welcome that has been given to us all.

CHAIRPERSONS OF SESSIONS

Opening Session	L. CAMARINOPOULOS	Greece
Session 1	C. MILLER	United States of America
	G. LINSLEY *(Rapporteur)*	IAEA
Session 2	G. YADIGIAROGLOU	Greece
	R. FERCH *(Rapporteur)*	Canada
Session 3	I. TRIPPUTI	Italy
	A. PERSINKO *(Rapporteur)*	United States of America
Session 4	P. BEELEY	United Kingdom
	Z. SHANG *(Rapporteur)*	China
Session 5	Z. PAN	China
	C. PIANI *(Rapporteur)*	South Africa
Session 6	L. VALENCIA	Germany
	S. HARRIAGUE *(Rapporteur)*	Argentina
Session 7	A.J. BAER	Switzerland
	S. SAINT-PIERRE *(Rapporteur)*	World Nuclear Association
Session 8	A.G. YOUTSOS	Greece
	C. PESCATORE *(Rapporteur)*	OECD/NEA
Closing Session	L. CAMARINOPOULOS	Greece
	G. LINSLEY *(Rapporteur)*	IAEA

PRESIDENT OF THE CONFERENCE

L. CAMARINOPOULOS Greece

SECRETARIAT OF THE CONFERENCE

B. BATANDJIEVA	Scientific Secretary
M. LARAIA	Scientific Co-Secretary
K. MORRISON	Conference Services
R. PERRICOS	Conference Services
H. EASSON	Secretarial Support
L. GEWESSLER	Secretarial Support
S. MOORE	Secretarial Support
J. WHITTAKER	Secretarial Support
M. DAVIES	Records Officer
G. LINSLEY	Proceedings Editor
G.V. RAMESH	Coordinating Editor

LOCAL COORDINATOR

V. KAMENOPOULOU	Greece

PROGRAMME COMMITTEE

S. HARRIAGUE	Argentina
Y. KANG	China
V. KAMENOPOULOU	Greece
C. PIANI	South Africa
G. BROWN	United Kingdom
A. PERSINKO	United States of America
T. ENG	OECD/NEA
W. MEIJST	European Commission
S. SAINT-PIERRE	World Nuclear Association
B. BATANDJIEVA	IAEA
M. LARAIA	IAEA
D.W. REISENWEAVER	IAEA (until May 2006)

LIST OF PARTICIPANTS

Akhmetov, Y.	Institute of Nuclear Physics, National Nuclear Center of the Republic of Kazakhstan, Ibragimova Str. 1, 050032 Almaty, Kazakhstan Fax: +83272 546455 Email: erbolat@inp.kz
Ambar, D.	Nuclear Research Centre, Negev, P.O. Box 9001, Beer-Sheva 84190, Israel Fax: +972 8 656 8611 Email: ambard@zahav.net.il
Anagnostakis, M.	Nuclear Engineering Department, National Technical University of Athens, Zografou Campus, 157 80 Athens, Zografou, Greece Fax: 0030 217722914 Email: managno@nuclear.ntua.gr
Anasco, R.	National Atomic Energy Commission, Avenida del Libertador 8250, C1429BNP Buenos Aires, Argentina Fax: +5411 67798330 Email: anasco@cnea.gov.ar
Anastasova, E.	Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy (INRNE), 72, Tzarigradsko Chaussee Boulevard, 1784 Sofia, Bulgaria Fax: 0035927144274; 0035929743955 Email: elkaana@inrne.bas.bg

Andersson, I.	Prizztech Oy, Tiedepuisto 4, 28600 Pori, Finland Email: iiro.andersson@prizz.fi
Aparkin, F.	Concern Rosenergoatom, Bolshaya Ordynka 24/26, 119017 Moscow, Russian Federation Fax: 007 495 7105367 Email: aparkin@rosenergoatom.ru
Arkeholt, P.	Swedish Nuclear Power Inspectorate, Klarabergsviadukten 90, 10658 Stockholm, Sweden Fax: +4686619086 Email: peter.arkeholt@ski.se
Arkhangelsky, N.	Federal Atomic Energy Agency, 24/26 B.Ordynka, 119017 Moscow, Russian Federation Fax: 0074952392000 Email: narkhangelskij@uvyro.faae.ru
Askounis, P.	Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +30 210 650 6748 Email: paaskrun@eeae.gr
Bacsko, G. G.	Public Agency for Radioactive Waste Management (PURAM), P.O. Box 12, 7031 Paks, Hungary Fax: 0036 75 519589 Email: gabor.bacsko@rhk.hu

LIST OF PARTICIPANTS

Baecker, A.	EWN Energiewerke Nord GmbH, P.O. Box 1125, 17509 Lubmin, Germany Fax: +49 38354 48058 Email: axel.baecker@ewn-gmbh.de
Baer, A.J.	Hohlestrasse 24, 3123 Belp, Switzerland Fax: 041318191574 Email: albaer@dplanet.ch
Barker, S.	Nuclear Decommissioning Authority, Herdus House, Westlakes Science Park, Moor Row, Cumbria CA24 3HU, United Kingdom Fax: 00441925802095 Email: stephen.barker@nda.gov.uk
Batandjieva, B.	Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety and Security, International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria Fax: (+43) 1 26007 Email: B.Batandjieva@iaea.org
Beckitt, S.	UKAEA, Dounreay, Thurso, Caithness KW14 7TZ, United Kingdom Email: steve.beckitt@ukaea.org.uk
Beeley, P.	Nuclear Department, DCEME HMS Sultan, Military Road Gosport, Hampshire PO12 3 BY, United Kingdom Email: sultan-dnd@nrta.mod.uk

Beer, H.-F.	Paul Scherrer Institut, OBG/101, 5232 Villigen, Switzerland Fax: 0041 56 3104726 Email: hans-frieder.beer@psi.ch
Benali, A.	Nuclear Research Centre of Birine, B.P. 180, 17200 Ain Oussera, Djelfa, Algeria Fax: +213 27 87 42 80 Email: Abder_Benali@yahoo.fr
Benda, G.A.	StudsvikRACE, 2550 Channel Ave, P.O. Box 13143, Memphis TN 38113, USA Fax: +1901 775 0629 Email: gbenda@studsvikrace.com
Benitez-Navarro, J. C.	Center for Radiation Protection and Hygiene, Calle 20 No. 4113, Miramar, Playa, P.O. Box 6195, 10600, Havana, Cuba Fax: 005372041188 Email: benitez@cphr.edu.cu
Berglund, T.	Swedish Nuclear Power Inspectorate, Klarabergsviadukten 90, 106 58 Stockholm, Sweden Fax: 0046 8 661 90 86 Email: thomas.berglund@ski.se

LIST OF PARTICIPANTS

Bilyk, A.O.	Chernobyl Nuclear Power Plant, P.o. Box m/b 10/11, Slavutich, 07100 Kievsky region, Ukraine Fax: 0380447926359 Email: frd@chnpp.atom.gov.ua
Blohm-Hieber, U.	European Commission, DG TREN/H - Nuclear Energy, Euroforum building, 10, rue Robert Stumper, 2557 Luxembourg, Luxembourg Fax: 00352430130139 Email: ute.blohm-hieber@cec.eu.int
Boe, T.E	Institute for Energy Technology, Institutveien 18, P.O. Box 40, 2027 Kjeller, Norway Fax: +47 63812562 Email: trond.boe@ife.no
Bolla, G.	Decommissioning and Operation, SOGIN S.p.A., Via Torino, 6, 00184 Rome, Italy Fax: +390683060482
Bordin, G.	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Robert-Schumann-Platz 3, 53175 Bonn, Germany Fax: 00492283052810 Email: gisela.bordin@bmu.bund.de

Bredell, P.	South African Nuclear Energy Corp., Church Street West, Pelindaba, Building G (P-East), P.O. Box 582, 0001 Pretoria, South Africa Fax: 0027123053222 Email: pbredell@necsa.co.za
Brewitz, E.	Swedish Radiation Protection Authority, 17116 Stockholm, Sweden Fax: 04687297108 Email: erica.brewitz@ssi.se
Bujoreanu, C.D.	Institute for Nuclear Research Pitesti, Street Campului Nr. 1, P.O. Box 78, Mioveni, Arges, Romania Fax: 040248262449 Email: buji@nuclear.ro
Burrows, P.	Nuclear Safety Directorate, 4 N. 1 Redgrave Ct., Merton Rd., Bootle LZ0 7HS United Kingdom Fax: 00441519514821 Email: peter.burrows@hse.gsi.uk
Byrne, J.J.	Byrne & Assoc. LLC, 2 Durham Drive, Dillsburg PA 17019, USA Email: jbyrne4424@comcast.net
Camarinopoulos, L.	Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attikis, Greece Fax: 00302106506762 Email: thzorbak@eeae.gr

Carlsson, J.S.	Swedish Nuclear Fuel and Waste Management Co., Box 5864, 102 40 Stockholm, Sweden Fax: 004686625381 Email: jan.carlsson@skb.se
Cato, A.	Swedish Nuclear Power Inspectorate, Klarabergsviadukten 90, 10658, Stockholm, Sweden Fax: +46872 97 108 Email: anna.cato@ski.se
Chaloulou, C.	National Center for Scientific Research, "Demokritos", 15310 Aghia Paraskevi, Attiki, Greece Fax: 00302106503050
Changrani, R.D.	PREFRE, Bhabha Atomic Research Centre, P.O. Ghivali – 401502, Dist. Thane, Maharashtra, India Fax: 0091 2525 282158 Email: rdchangrani@rediffmail.com
Choi, K.-W.	Korea Institute of Nuclear Safety, 19 Kusong-dong, Yusong-ku, P.O. Box 114, Daejon 305-600, Republic of Korea Fax: +82 42 868 0367 Email: kwchoi@kins.re.kr

Chugha, RK.
Operating Plants Safety Division,
Atomic Energy Regulatory Board,
Niyamak Bhavan, Anushakti Nagar,
Mumbai 400 094,
India
Fax: 00912225552879
Email: rkchugha@aerb.gov.in

Chung, D.Y.
Department of Energy,
1000 Independence Avenue,
Washington, DC 20585,
USA
Fax: 01301 903 9770
Email: dae.chung@em.doe.gov

Claes, J.
Belgoprocess, J.
Gravenstraat 73,
2480 Dessel,
Belgium
Fax: +32 14 33 40 99
Email: jef.claes@belgoprocess.be

Coates, R.
Division of Radiation, Transport and Waste Safety,
International Atomic Energy Agency,
Wagamer Strasse 5,
P.O. Box 100,
1400 Vienna, Austria
Fax: 0043126007
Email: r.coates@iaea.org

Conte, D.
Nuclear Safety Authority,
Route du Panorama Robert Schuman,
B.P. 83,
92266 Fontenay-aux-Roses Cedex,
France
Fax: 0033143197166
Email: dorothee.conte@asn.minefi.gouv.fr

Covini, R.	European Commission, Joint Research Centre Ispra, Via Fermi 1, 21020 Ispra TP 800, Italy Fax: +39 0332 785077 Email: roberto.covini@ec.europa.eu
Crandall, T.	Department of Energy, (EM-3.2), 1000 Independence Ave. SW, Cloverleaf Building, Washington, DC 20585, USA Fax: +301 903 9770 Email: thomas.crandall@em.doe.gov
Culli, M.	Institute for Nuclear Physics, P.O. Box 85, Tirana, Albania Fax: 003554362596 Email: meto_culli@hotmail.com
da Costa Lauria, D.	Institute of Radiation Protection and Dosimetry, Brazilian Nuclear Energy Commission, Av. Salvador Allende s/n, Barra da Tijuca, Rio de Janeiro, Brazil Fax: 00552124422699 Email: dejanira@ird.gov.br
Dahlgren, S.	CH2M HILL, 164 Chardonnay Lane, Aiken, South Carolina 29803, USA Fax: +1 803 649 3959 Email: steve.dahlgren@ch2m.com

Dallendre, R.	Institut de radioprotection et de sûreté nucléaire, B.P. 17, 92262 Fontenay aux Roses Cedex, France Fax: 0033 1 58 35 85 09 Email: robert.dallendre@irsn.fr
Danis, D.	Vuje, QS, Okruzna 5, 91864, Trnava, Slovakia
Daniska, V.	DECONTA, a.s., Sibirska I, 917 01 Trnava, Slovakia Fax: 00421 33 5521077 Email: daniska@deconta.sk
Daryoko, M.	Centre for Development of Radioactive Waste Management, National Nuclear Energy Agency (BATAN), Kawasan Puspiptek Serpong Gedung 31, Tangerang, Serpong 15310, Indonesia Fax: 0062 21 7560927 Email: mdaryoko@yahoo.com
Decobert, G.	AREVA NC, 2, rue Paul Dautier, B.P. 4, 78141 Vélizy Villacoublay Cedex, France Fax: 0033 1 39 262801 Email: gdecobert@cogema.fr
Delcheva, T.	Department of Nuclear Fuel Cycle and RAW, Ministry of Economy and Energy, 8 Triaditza str., 1040 Sofia, Bulgaria Fax: 0035929885688 Email: tzdelcheva@doe.bg

Demireva, E.	ENPRO Consult Ltd, 16 G.M. Dimitrov Blvd, 1797 Sofia, Bulgaria Fax: +3592 971 14 16 Email: edemireva@enprococo.com
Detilleux, M.	Suez-Tractebel, 7 Avenue Ariane, 1200 Brussels, Belgium Fax: 00322 773 98 20 Email: michel.detilleux@tractebel.com
Devaux, P.	Commisariat à l'énergie atomique, Centre de la Vallée du Rhone, BP 17171 - 30207 Bagnols sur Cèze Cedex, France Fax: 0033466796432 Email: DEVAUXP@atil.cea.fr
Deydier, D.	Centre Ingénierie de Construction et Environnement, Electricite de France, 35-37 rue Louis Guérin , BP 1212, 69611 Villeurbanne Cedex, France Fax: +33 472 82 46 02 Email: denis.deydier@edf.fr
Diamond, T.V.	Australian Radiation Protection and Nuclear Safety Agency, 38-40 Urunga Parade, Miranda, NSW 2228, Australia Fax: 0061 2 95418348; 612 9541 8348 Email: vince.diamond@arpansa.gov.au

Dobak, D.	Jadrova Vyradovacia, Spolocnost, a.s., 919 31 Jaslovske Bohunice, Slovakia Fax: 00421335591535 Email: dobak.dobroslav@javys.sk
Dogaru, D.M.	National Commission for Nuclear Activities Control (CNCAN), 14, Libertatii Bulevard, 050706 Bucharest Sector 5, Romania Fax: 0040 21 3173887 Email: daniela.dogaru@cncan.ro
Dragusin, M.	National Institute for Physics and Nuclear Engineering "Horia, Hulubei", Atomistilor Street 407, P.O. Box MG-6, 76900 Bucharest, Magurele, Romania Fax: +40 21 457 4440 Email: dragusin@ifin.nipne.ro
Dreimanis, A.	Radiation Safety Centre. Maskavas Str. 165. 1019 Riga. Latvia Fax: 00371 7032659 Email: A.Dreimanis@rdc.gov.lv
Economides, S.	Department of Licensing and Inspections, Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6506748 Email: sikonom@eeae.gr
Efraimsson, H.	Swedish Radiation Protection Authority, 171 16 Stockholm, Sweden Fax: 0046 08 7297108 Email: henrik.efraimsson@ssi.se

Ehlert, A.	E.ON Kernkraft, Treschkowstr. 5, 30457 Hannover, Germany Email: andreas.ehlert@eon-energie.com
Ellmark, C.	Department RadWaste, Studsvik Nuclear AB, 611 82 Nyköping, Sweden Fax: +46 155 26 31 17 Email: christoffer.ellmark@studsvik.se
España, E.	Nuclear Safety Council, C/o Justo Dorado 11, 28040 Madrid, Spain Fax: +341 5673500 Email: ees@csn.es
Fabbri, S.A.	Comisión Nactional de Energía Atómica, Av. Libertador 8250, 1429 Buenos Aires, Argentina Fax: 005411 6772 7371 Email: fabbri@cnea.gov.ar
Fabian O.R.	Nuclear Safety and Safeguards, National Commission, Dr. Barragan 779, Col. Narvarte, Deleg. Benito Juarez, 03020 Mexico, D.F., Mexico Fax: +525550953291 Email: rfabian@cnsns.gob.mx
Fauver, D.	British Nuclear Group, Magnox Electric Ltd, Berkley Centre, Gloucestershire GL13 9PB, United Kingdom Fax: +1144 1453 81 3504 Email: david.fauver@britishnucleargroup.co.uk

Ferch, R.	1267 Marygrove Circle, Ottawa, Ontario K2C 2E1, Canada Fax: 0016132243752 Email: ferchr@storm.ca
Fernandez García Bermejo, R.	División de Geneación Nuclear de IBERDROLA, Ingeniería y Construcción, Spain
Ferreira, P. R. R.	Institute of Radioprotection and Dosimetry, Av. Salvador Allende s/n, CEP: 22780-160, Rio de Janeiro, Brazil Fax: 0055 021 21 2442 2861 Email: ferreira@ird.gov.br
Ferri, M.	Savannah River Corporation, 116 Sugarbury Road, Aiken, South Carolina 29803, USA
Florou, H.	Institute of Nuclear Technology, National Center for Scientific Research, "Demokritos", P.O. Box 60228, Aghia Paraskevi, Athens 15310, Greece Fax: +30 210 650 3050 Email: eflorou@ipta.demokritos.gr
Fontana, P.	Commisariat à l'énergie atomique, Centre de la Vallée du Rhone, BP 17171, 30207 Bagnols sur Cèze Cedex, France Fax: 0033466397501 Email: philippe.fontana@cea.fr

Forsström, H.	Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, 1400 Vienna, Austria Fax: +431 26007 Email: h.forsstroem@iaea.org
Frise, L.	Swedish Nuclear Power Inspectorate (SKI), Klarabergsviadukten 90, 106 58 Stockholm, Sweden Fax: +4686619086 Email: lennart.frise@ski.se
Gan Pek Yen	Atomic Energy Licencing Board, Batu 24, Jalan Dengkil, 43800 Dengkil, Selangor Darul Ehsan, Malaysia Fax: +60389254578 Email: ganpy@aelb.gov.my
Garcia Neri, E.	ENRESA, Emilio Vargas no. 7, 28043 Madrid, Spain Fax: +3491 5668167 Email: egan@enresa.es
Garcia, J.-L.	Commisariat à l'énergie atomique, Centre de la Vallée du Rhone, BP 17171, 30207 Bagnols sur Cèze Cedex, France Fax: 0033466397501 Email: jean-louis.garcia@cea.fr

Gerhart, P.	Jadrova Vyradovacia, Spolocnost, a.s., 919 31 Jaslovske Bohunice, Slovakia Fax: 0042133 5976502 Email: gerhart.peter@javys.sk
Gevorgyan, A.	Department of Atomic Energy, Ministry of Energy Republic Square 2 375010 Yerevan Armenia Fax: 00374 1 562776 Email: atomen@freenet.am
Gilmanov, D.	Republican State Enterprise, National Nuclear Center, of the Republic of Kazakhstan, Lenin Str. 6, 071100 Kurchatov, Kazakhstan Fax: +8 32251 238 58 Email: gilmanov@ncc.kz
Girones, P.	Commisariat à l'énergie atomique, Centre de la Vallée du Rhone, BP 17171 - 30207 Bagnols sur Cèze Cedex, France Fax: 0033466796432 Email: philippe.girones@cea.fr
Gomez Rodriguez, C.	Soluziona Ingenieria, Parque Empresarial La Finca, P. Club Deportivo, 1 Edif. 5, 28223 Pozuelo de Alarcon Madrid, Spain Fax: +34 91 211 45 00 Email: cagomez@soluziona.com

González, A.J.	Autoridad Regulatoria Nuclear, Av. Del Libertador 8250, Capital Federal, Buenos Aires 1429, Argentina Fax: +54 11 6323 1751 Email: agonzale@sede.arn.gov.ar
Gorn, J.	Department of State, Bureau of International Safety and Nonproliferation, Office of Nuclear Energy, Safety and Security, 2201 C Street NW, Room 3310, Washington, DC 20520, USA Fax: 001 202 6470775 Email: gornjm@state.gov
Grabia, G.	European Bank for Reconstruction and Development, One Exchange Square, London EC2A 2JN, United Kingdom Fax: 00442073387175 Email: GrabiaG@ebrd.com
Griffiths, C.	Griffiths Consultancy Services, 18 Grassthorpe Road, Sutton on Trent, Newark, NG23 6QD, United Kingdom Email: cathygriffiths@f2s.com
Gros-Gean, P.	Comex Nucléaire, 36, Bd des Océans, BP 137, 13273 Marseille Cedex 09, France Fax: 0033491291647 Email: grosgean@comex-nucleaire.com

Guskov, A.
Moscow City Radon Scientific Production Association,
7 -oy Rostovsky pereulok 2/14,
119121 Moscow,
Russian Federation
Fax: 007 495 2481941
Email: avguskov@mtu-net.ru

Hagihara, H.
Japan Nuclear Energy Safety Organization,
TOKYO REIT Toranomon Bldg 8F,
3-17-1 Toranomon Minato-ku,
Tokyo 105-0001,
Japan
Fax: +813 4511 1998
Email: hagihara-hirofumi@jnes.go.jp

Hanousis, A.
National Center of Scientific Research “Demokritos”,
Institute of Nuclear Technology and Radiation Protection,
P.O. Box 60228,
153 10 Aghia Paraskevi, Attiki,
Greece
Fax: 0030 210 6533431
Email: thanos@ipta.demokritos.gr

Hansson, B.
Barseback Kraft AS,
Barseback 1,
P.O. Box 524,
246 25 Löddeköpinge,
Sweden
Fax: 004646724693
Email: bertil.hansson@barsebackkraft.se

Hansson, T.
Vattenfall Ringhals NPP,
Vattenfall Ringhals AB,
430 22 Väröbacka,
Sweden
Fax: +46 340 665 102
Email: tommy1.hansson@vattenfall.com

Hanusik, V.	VUJE a.s., Okruzna, 5, 918 64 Trnava, Slovakia Fax: 00421 33 5991169 Email: hanusik@vuje.sk
Haque, Md. M.	Bangladesh Atomic Energy Commission, 4 Kazi Nazrul Islam Avenue, P.O. Box No. 158, Ramna Dhaka 1000, Bangladesh Fax: 08802 8613051 Email: romu@dhaka.net
Harriague, S.	Comision Nacional de Energia Atomica, Av. del Libertador 8250, 1429 Buenos Aires, Argentina Fax: 05411 4704 1193 Email: harriag@cnea.gov.ar
Harrison, P.C.	Central Project Management Agency, S. Konarskio 13, 03109 Vilnius, Lithuania Fax: 0037052514400
Higashi, T.	Codes and Standard Department, Japan Nuclear Technology Institute, 4-2-3 Shiba Minato-ku, Tokyo 108 0014, Japan Fax: +813 5440 3606 Email: hiagashi.toshihiko@gengikyo.jp
Hilden, W.	European Commission, Directorate General for Transport and Energy, EUROFORUM Building, 10, rue Robert Stumper, 2557 Luxembourg, Luxembourg Fax: +352430130139 Email: wolfgang.hilden@ec.europa.eu

Hinis, E.	Nuclear Engineering Department, National Technical University of Athens, 9 Iroon Polytechne 10Y, Zografos Campus, 15780 Athens, Greece Fax: +302107722914 Email: ephinis@mail.ntua.gr
Hiswara, E.	Permanent Mission of Indonesia to the IAEA, Gustav-Tschermak-Gasse 5-7, 1180 Vienna, Austria Fax: 004314790557 Email: e.hiswara@kbriwina.at
Hu, C.	China Institute of Atomic Energy, Xinzhen, Fangshan District, P.O. Box 275-24, Beijing 102413, China Fax: 0086 10 69357008 Email: cwhu@iris.ciae.ac.cn
Huda, K.	Nuclear Energy Regulatory Agency (BAPETEN), Jl. Gajah Mada No. 8, Jakarta 10120, Indonesia Fax: 0062 21 63855583 Email: k.huda@bapeten.go.id
Hutta, J.	Jadrova Vyradovacia, Spolocnost, a.s., 919 31 Jaslovske Bohunice, Slovakia Fax: 00421335591535 Email: hutta.jozef@javys.sk

Ishikura, T.	Nuclear Power Engineering Corp. (NUPEC), 4-1-8 Toranomon, Minato-ku, Tokyo 105-00001, Japan Fax: 0081345122600 Email: ishikura@nupec.or.jp
Janzekovic, H.	Slovenian Nuclear Safety Administration, Zelezna cesta 16, P.O. Box 5759, 1001 Ljubljana, Slovenia Fax: 00386 1 4721199 Email: helena.janzekovic@gov.si
Joubert, A.	National Nuclear Regulator, P.O. Box 7106, ZA-0046 Centurion, South Africa Email: ajoubert@nnr.co.za
Juenger-Graf, B.	German Cancer Research Center Heidelberg, im Neuenheimer Feld 280, 69120 Heidelberg, Germany Fax: 0049 6221 422556 Email: b.juenger@dkfz.de
Juhasz, L.	National Research Institute for Radiobiology and Radiohygiene, Anna Utca 5, P.O.Box 101, 1221 Budapest, Hungary Fax: +361 482 2008 Email: juhasz@hp.osski.hu

Kalathaki, M.
Department of Licensing and Inspections,
Greek Atomic Energy Commission,
P.O. Box 60092,
153 10 Aghia Paraskevi, Attiki,
Greece
Fax: 0030 210 6506748
Email: mkala@eeae.gr

Kalyvas, N.
Greek Atomic Energy Commission,
P.O. Box 60092,
153 10 Aghia Paraskevi, Attiki,
Greece
Fax: +30 210 650 6748
Email: nkalybas@eeae.gr

Kamenopoulou, V.
Greek Atomic Energy Commission,
Patriarxou Grigoriou and Neapoleos,
P.O. Box 60092,
15310 Aghia Paraskevi, Attiki,
Greece
Fax: 0030210 650 6748
Email: vkamenop@gaec.gr

Kardaras, S.
Euroforum (4/254),
10, rue Robert Stumper,
2557 Luxembourg,
Luxembourg
Fax: +352 4301 30219
Email: stefanos.kardaras@ec.europa.eu

Karigome, S.
Decommissioning Project Department,
Japan Atomic Power Company,
1-1 Kanda-Mitoshiro-cho,
Chiyoda-ku, Tokyo 101-0053,
Japan
Fax: 0081344156290
Email: satoshi-karigome@japc.co.jp

Kaulard, J.	Gesellschaft für Anglagen- und Reaktorsicherheit (GRS) mbH, Schwertnergasse 1, 50667 Cologne, Germany Fax: 0049 221 2068 10716 Email: joerg.kaulard@grs.de
Kazennov, A.	Division of Nuclear Power, International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, 1400 Vienna, Austria Fax: 0431 26007 Email: a.kazennov@iaea.org
Kehagia, K.	Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +3302106506748 Email: kkehagia@eeae.gr
Keinmeesuke, S.	Office of Atoms for Peace, Bureau of Nuclear Safety Regulation, 16 Vibhavadi Rangsit Road, Chatuchak, Bangkok 10900, Thailand Fax: 0066 2 5613013 Email: sirichai@oaep.go.th
Kerekes, A.	National Research Institute for Radiobiology and Radiohygiene, Anna Utca, 5 P.O.Box 101, 1221 Budapest, Hungary Fax: 0036 1 2291931 Email: kerekes@okk.antsz.hu

Kharlampiev, S.	Concern Rosenergoatom, Bolshaya Ordynka Str. 24/26, Moscow 119017, Russian Federation, Fax: 0074952392553 Email: kharlampiev@rosenergoatom.ru
Kilochytska, T.	State Nuclear Regulatory Committee, Ulitsa Arsenalnaya 9/11, 01011 Kiev, Ukraine Fax: 00380 44 2543311 Email: tanya@hq.snrc.gov.ua
Kim, G.	Republican State Enterprise, National Nuclear Center of the Republic of Kazakhstan, Lenin Str. 6, 071100 Kurchatov, Kazakhstan
Kim, H.T.	Korea Institute of Nuclear Safety, PO Box 114, Yuseong, Daejeon 305-600, Republic of Korea Fax: +82 42 868 0531 Email: k093kht@kins.re.kr
Kipouros, P.	Department of Licensing and Inspections, Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +30 210 650 6748 Email: pkipou@gaec.gr

Kirchner, T.	European Commission (EC), DG TREN H.2, EUFO 4387, 1 rue Henry Schnadt, 2530 Luxembourg, Luxembourg Fax: 00352430130139 Email: Thomas.Kirchner@ec.europa.eu
Klepikov, A.	Nuclear Technology Safety Center (NTSC), Liza Chaikina 4, Almaty, Kazakhstan 050020 Fax: +7 327 2646803
Kölschbach, K.-H.	Division of Decommissioning of Nuclear Facilities, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, P.O. Box 12 06 09, 53048 Bonn, Germany Fax: 004918883052849 Email: karl-heinz.koelschbach@bmu.bund.de
Konecny, L.	Nuclear Regulatory Authority of the Slovak Republic, Okruzna 5, 918 64 Trnava, Slovakia Fax: 00421 33 5991190 Email: Ladislav.Konecny@ujd.gov.sk
Koroll, G.	Whiteshell Laboratories, Pinawa, Manitoba ROE 1L0, Canada Email: korollg@aecl.ca
Kostor, M.	Atomic Energy Licensing Board, Batu 24, Jalan Dengkil, 43800 Dengkil, Selangor Darul Ehsan, Malaysia Fax: 0060389223685 Email: monalija@aelb.gov.my

Koukouliou, V.	Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6506748 Email: vkoukoul@eeae.gr
Koumartzis, G.	Environmental Protection Engineering S.A., 24 Dervenakion Str., 185 45 Piraeus, Greece Email: gkoumartzis@epe.gr
Koutsoyannopoulos, C.	Directorate I — Nuclear Safeguards, Directorate General for Energy and Transport, European Commission, Complex EUROFORUM, 1 rue Henry M. Schnadt, Zone d'Activite Cloche d'Or, 2530 Luxembourg Fax: 00352 4301 36059 Email: christos.koutsoyannopoulos@ec.europa.eu
Krasny, D.	Jadrova Vyradovacia, Spolocnost, a.s., 919 31 Jaslovske Bohunice, Slovakia Fax: +42133 559 1564 Email: krasny.dusan@javys.sk
Kurylchyk, M.	Department of Technical Cooperation, International Atomic Energy Agency, P.O. Box 100, Wagramer Strasse 5, 1400 Vienna, Austria Fax: 0043126007 Email: m.kurylchyk@iaea.org

LaGuardia, T.	LaGuardia Associates LLC, 303 Periwinkle Way, Unit 112, Sanibel Island, FL 33957, USA Fax: +0012037487942 Email: tsl8@aol.com
Langer, H.	Vattenfall Europe Nuclear Energy GmbH, Überseering 12, 22297 Hamburg, Germany Fax: +4940 6396 5823 Email: Hermann.Langer@vattenfall.de
Laraia, M.	Department of Nuclear Energy, International Atomic Energy Agency, P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna Austria Fax: (+43) 1 26007 Email: M.Laraia@iaea.org
Lareynie, O.	Autorité de sûreté nucléaire, 10, Route du Panorama Robert Schuman, B.P. 83, 92266 Fontenay aux Roses Cedex, France Fax: 0033 1 43 197166 Email: olivier.lareynie@asn.minefi.gouv.fr
Lauridsen, K.	Danish Decommissioning, Frederiksborgvej 399, Building 214, P.O. Box 320, 4000 Roskilde, Denmark Fax: 004546774302 Email: kurt.lauridsen@dekom.dk

Lavrinovich, A.	Federal Service for Environmental, Industrial and Nuclear Supervision (Rostechnadzor), Ulitsa Taganskaya 34, 109147 Moscow, Russian Federation Fax: 007 4959121223 Email: laa@gan.ru
Le Goaller, C.	Commisariat à l'énergie atomique, Centre de la Vallée du Rhone, BP 17171 - 30207 Bagnols sur Cèze Cedex, France Fax: 0033 4 66796422 Email: christophe.legoaller@cea.fr
Lebedev, L.	GNTC EPT, Ordynka 24-26, Moscow, Russian Federation Email: rybalchenko@givnipiet.spb.ru
Lee, J.-S.	Korea Institute of Nuclear Safety, 19 Kusong-dong, Yusong-ku, P.O. Box 114, Daejon 305-600, Republic of Korea, Fax: 0082 42 8619945 Email: jslee@kins.re.kr
Lehew, J.	CH2M Hill, c/o Ms. Lindsay Foubister/UKAEA, D1200, Dounreay, Thurso, Caithness KW14 7TZ, United Kingdom Fax: 00441847802250 Email: john.lehew@ch2m.com

Liebard, F.	IRSN, BP 17, 92262 Fontenay aux Roses Cedex, France Fax: +158358829 Email: florence.liebard@irsn.fr
Lindberg, M.	Studsvik Nuclear AB, Department of RadWaste, 611 82 Nyköping, Sweden Fax: 0046155263117 Email: maria.lindberg@studsvik.se
Lindskog, S.	Swedish Nuclear Power Inspectorate (SKI), Klarabergsviadukten 90, 10568 Stockholm, Sweden Fax: +468 6619086 Email: statten.lindskog@ski.se
Lindvall, C.G.	Barsebäck Kraft AB, Box 524, 24625 Löddeköpinge, Sweden Fax: 004646724580 Email: carl-goran.lindvall@barsebackkraft.se
Linsley, G.	Division of Radiation, Transport and Waste Safety, International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria
Liu, H.	State Environment Protection Administration, National Nuclear Safety Administration, 115 Nan Xiao Jie, Xi Zhi, Men Nei, 100035 Beijing, China Fax: +8610 66126 715 Email: nscliuh@public3.bta.net.cn

Ljubenov, V.	Vinča Institute of Nuclear Sciences, Mike Petrovica Alasa 12-14, P.O. Box 522, 11001 Belgrade, Serbia Fax: 00381112447457 Email: vladan@vin.bg.ac.yu
Lockhart, F.	Rocky Flats Project Office, US Department of Energy, Denver Federal Center Bldg. 55, P.O. Box 25547, Denver, CO 80225-0547, USA Fax: 0013032363651 Email: frazer.lockhart@rf.doe.gov
Lopez Fernandez, P.	Soluziona Ingenieria, Parque Empresarial La Finca, P. Club Deportivo, 1 Edif. 5, 28223 Pozuelo de Alarcon Madrid, Spain Fax: +34 91 211 45 00 Email: plopezf@soluziona.com
Lorentz, H.	Barsebäck Kraft AB, P.O. Box 524, 24625 Löddeköpinge, Sweden Fax: 0046 46 724693 Email: hakan.lorentz@barsebackkraft.se
Louvat, D.	Division of Radiation, Transport and Waste Safety, International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, 1400 Vienna, Austria Fax: 0043126007 Email: d.louvat@iaea.org

Lux, J.	Tronox Worldwide, LLC, 123 Robert S. Kerr Avenue, Oklahoma City, OK 73102, USA Email: Jeff.Lux@tronox.com
Lyras, C.	Australian Nuclear Science and Technology Organisation, New Illawarra Road, Lucas Heights NSW 2234, Australia Fax: +612 9717 9269 Email: con.lyras@ansto.gov.au
Mabbott, P.E.	Australian Radiation Protection and Nuclear Safety Agency, P.O. Box 655, Miranda NSW 1490, Australia Fax: 0061295418348 Email: phillip.mabbott@arpansa.gov.au
Makarovska, O.	State Nuclear Regulatory Committee of Ukraine, 9/11 Arsenalna Street, 01011 Kiev, Ukraine Fax: 00380442543311 Email: Makarovska@hq.snrc.gov.ua
Malliarou, H.	Environmental Protection Engineering S.A., 24 Dervenakion Str., 184 45 Piraeus, Greece
Maltezos, A.	Department of Environmental Radioactivity, Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +302106506748 Email: antonis@eeae.gr

Manoussaridis, G. | Department of Licensing and Inspections,
Greek Atomic Energy Commission,
P.O. Box 60092,
153 10 Aghia Paraskevi, Attiki,
Greece
Fax: +30 210 650 6748
Email: gmanous@eeae.gr

Marinkovic, O. | Ministry of Science and Environmental Protection,
Nemanjina 22,
11000 Belgrade,
Serbia
Fax: 00381 112643675
Email: rasa98@ptt.yu

Mastauskas, A. | Radiation Protection Centre,
Kalvariju 153,
08221 Vilnius,
Lithuania
Fax: 00370 5 2763633
Email: a.mastauskas@rsc.lt

Mauron, O. | Hauptabteilung fuer die Sicherheit|
der Kernanlagen,
5232 Villigen HSK,
Switzerland
Fax: +41 56 3103907
Email: oliver.mauron@hsk.ch

Mawson, R. | CH2M Hill International Nuclear Services,
Avon House,
Kensington Village,
Avonmore Road,
London W14 8TS,
United Kingdom
Fax: 00442074716101
Email: Robert.Mawson@ch2m.com

Mbizo, S. | Greek Atomic Energy Commission,
P.O. Box 60092,
153 10 Aghia Paraskevi, Attiki,
Greece
Email: stanmbizo@yahoo.co.uk

McEahern, P.

CH2M -wg LLC,
P.O. Box 1625,
MS 3936,
Idaho Falls, ID 83415,
USA
Fax: 0012085266527
Email: Partrice.McEahern@icp.doe.gov

McWhirter, A.

United Kingdom Atomic Energy Authority,
B21, Forss, Dounreay,
Caithness KW14 7UZ,
United Kingdom
Fax: 00441847804755
Email: Sandy.McWhirter@ukaea.org.uk

Messier, C.H.C.

French Nuclear Safety Authority,
10 route du Panorama,
92266 Fontenay-aux-Roses Cedex,
France
Fax: +33 1 43 19 71 66
Email: cedric.messier@asn.fr

Metcalfe, D.

Natural Resources Canada,
580 Booth Street,
Ottawa, Ontario K1A 0E4,
Canada
Email: doug.metcalfe@nrcan-rncan.gc.ca

Michal, V.

VUJE, Inc.,
Okruzna 5, 91864,
Trnava,
Slovakia

Mieleszczenko, W.

Subdirectorate for Reactors,
Institute of Atomic Energy,
05-400 Otwock Swierk,
Poland
Fax: 0048 22 7799700293
Email: wladekm@cyf.gov.pl

Mikheykin, S.	State Unitarian Enterprise Moscow, Scientific and Industrial Association “Radon”, 2/14 Rostovsky line, Moscow 119121, Russian Federation Fax: 0074954918014 Email: serge128@rambler.ru
Miller, C.	Nuclear Regulatory Commission, Mailstop TWFN-8F3, Washington, DC 20555, USA Email: clm1@nrc.gov,
Miralles Ferrete, A.	ENRESA, Juan Duque 13, 1, pta 2, Madrid 28005, Spain Email: amif@enresa.es
Mirsaidov, U.	Academy of Sciences of the Republic of Tajikistan, Nuclear and Radiation Safety Agency, Rudaki Avenue 33, 734025 Dushanbe, Tajikistan Fax: 00992372215548 Email: ulmas2005@mail.ru
Moser, T.C.	Siempelkamp Nuckleartechnik GmbH, Am Taubenfeld 25/1, 69123 Heidelberg, Germany Fax: 00496221824100 Email: thomas.moser@siempelkamp.com
Murray, A.	NUKEM Limited, The Library, 8th Street, Harwell International, Business Centre, Didcot, Oxon OX11 ORA, United Kingdom Fax: 00441235514857 Email: alan.murray@nukem.co.uk

Nachmilner, L.	Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, 1400 Vienna, Austria Fax: +43 1 26007 Email: l.nachmilner@iaea.org
Nakayama, S.	Waste Disposal and Decommissioning Safety Research Group, Nuclear Safety Research Center, Japan Atomic Energy Agency, Tokai-mura Naka-gun, Ibaraki-ken 319-1195, Japan Fax: 0081292825934 Email: nakayama.shinichi@jaea.go.jp
Nattress, E.	Health and Safety Executive, Redgrave Court, Merton Road, Bootle, Merseyside L20 7HS, United Kingdom Fax: +440151 951 4163 Email: elaine.nattress.hse.gsi.gov.uk
Necas, V.	Department of Nuclear Physics and Technology, Faculty of Electrical Engineering and Technology, Slovak University of Technology in Bratislava, Ilkovicova 3, SK-812 Bratislava, Slovakia Fax: 00421265427207 Email: vladimir.necas@stuba.sk
Negin, C.A.	Project Enhancement Corp., 20300 Century Blvd Ste 175, Germantown, MD 20874, USA Fax: +1240 686 3959 Email: cnegin@pec1.net

Neretin, V.	Federal Service for Environmental, Industrial and Nuclear Supervision (Rostekhnadzor), Ulitsa Taganskaya 34, 109147 Moscow, Russian Federation Fax: 007 495 9124710 Email: neretin@gan.ru
Nettleton, J.	Health and Safety Executive, Redgrave Court, Merton Road, Bootle, Merseyside L20 7HS, United Kingdom Fax: 00441519514845; 04401519514799 Email: Joanne.Nettleton@hse.gsi.gov.uk
Nguyen Ba, T.	Institute for Technology of Radioactive and Rare Elements, 48 Lang Ha, Dong da, Hanoi, Vietnam Fax: 08448350966 Email: itrre@hn.vnn.vn
Nokhamzon, J.-G.	Commisariat à l'énergie atomique, Gif sur Yvette, Cedex 91191 Saclay, France Fax: 033169085784 Email: jean-guy.nokhamzon@cea.fr
Noynaert, L.	Assainissement des Sites, Studiecentrum voor Kernenergie (SCK/CEN), Boeretang 200, 2400 Mol, Belgium Fax: 003214333434 Email: lucnoynaert@sckcen.be

Oh, W.Z.	Korea Atomic Energy Research Institute, 150, Deokjin-dong, Yuseong-gu, Taejon 305-600, Republic of Korea Fax: 008282428640355 Email: wonzin@kaeri.re.kr
Ondaro del Pino, M.	ENRESA Emilio Vargas, 7, 28043 Madrid, Spain Fax: 0034915668167 Email: monp@enresa.es
Oren, D.	CH2M HILL, 9191 S. Jamaica St., Englewood, Colorado 80112, USA Fax: +1 720 286 9002 Email: david.oren@ch2m.com
Orsini, A.	Agency for New Technologies, Energy and the Environment, Via Anguillarese, 301, Sta. Maria di Galeria, C.P. 2400, 00060 Rome, Italy Fax: +390630483147 Email: alberto.orsini@casacoia.enea.it
Ostergaard, M.	Danish Decommissioning, Frederiksborgvej 399, P.O. Box 320, 4000 Roskilde, Denmark Fax: +45 46 77 4302 Email: max@dekom.dk

Otake, K.	European Office, Japan Electric Power Information Centre, Inc., 422 Rue Saint Honore, 75008 Paris, France Fax: +331 42 86 90 70 Email: koji_otake@club.ntt.fr
Pafilis, C.	Department of Education, Training and Research, Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6506748 Email: chpafil@gaec.gr
Paliukhovich, V.	Department for Supervision of Industrial and Nuclear Safety, Ministry of Emergency Situations of the Republic of Belarus, Kazintsa ulitsa 86/1, 220108 Minsk, Belarus Fax: 00375 17 2786083 Email: v.paliukhovich@rambler.ru
Pan, Z.	China National Nuclear Corporation, P.O. Box 2102, Beijing, China Fax: 0086 10 68539146 Email: panzq@cnnc.com.cn
Park, H.-S.	Korea Atomic Energy Research Institute, Yu-Song, P.O. Box 105, Daejon 305-600, Republic of Korea Fax: 0082 42 861 5852 Email: nhspark@kaeri.re.kr

Paul, M.	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Robert-Schumann-Platz 3, 53175 Bonn, Germany Fax: 00492283052810 Email: michael.paul@bmu.bund.de
Pauli, H.	Paul Scherrer Institut, OBG/101, 5232 Villigen, Switzerland Fax: 0563104726 Email: heinz.pauli@psi.ch
Percival, K.	UK Atomic Energy Authority, D2003, Dounreay, Thurso, Caithness, KW14 7TZ, United Kingdom Email: ken.percival@ukaea.org.uk
Persinko, A.	US Nuclear Regulatory Commission, Mailstop TWFN-8F36A, Washington, DC 20555, USA Fax: 0013014155369 Email: axp1@nrc.gov
Pescatore, C.	OECD Nuclear Energy Agency, 2 rue André-Pascal, 75116 Paris Cedex 16, France Fax: +331 44 30 61 11 Email: john.stein@oecd.org
Petropoulos, N.	Nuclear Engineering Department, National Tehnical University of Athens, Zografos Campus, 15780 Athens, Greece Fax: +30 210 7722 9191 Email: npetro@nuclear.ntua.gr

Piani, C.	South African Nuclear Energy Corp., SAFARI-1 Reactor, P.O. Box 582, 0001 Pretoria, South Africa Fax: 0027 12 3055956 Email: csbpiani@necsa.co.za
Plecas, I.	Vinča Institute of Nuclear Sciences, P.O. Box 522, 11001 Belgrade, Serbia Fax: 00381 11 455 943 Email: iplecas@rt270.vin.bg.ac.yu
Podlaha, J.	Nuclear Research Institute Řež plc, Husinec Řež, cp 130 PSC 250 68, Czech Republic Fax: 00420220941170 Email: pod@ujv.cz
Ponjuan, G.	Nuclear Safety Council, Justo Dorado 11, 28040 Madrid, Spain Fax: 0034913460588 Email: gpr@csn.es
Poskas, P.	Lithuanian Energy Institute, Breslaujos 3, 44403 Kaunas, Lithuania Fax: 00370 37 351271 Email: poskas@mail.lei.lt
Potier, J.-M.	Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria Fax: +431 26007 Email: j.m.potier@iaea.org

Potiriadis, C. | Environmental Radioactive Department,
Greek Atomic Energy Commission,
153 10 Aghia Paraskevi, Attiki,
P.O. Box 60092,
60092 Athens,
Greece
Fax: +30 210 650 6748
Email: cpot@gaec.gr

Psomiadou, C. | Institute of Nuclear Technology,
National Center for Scientific Research
"Demokritos"
P.O. Box 60228
Aghia Paraskevi, Attiki,
15310 Athens,
Greece
Fax: +30 210 650 3050
Email: spsom@ipta.demokritos.gr

Qafmolla, L. | Institute of Nuclear Physics,
P.O. Box 85,
Tirana,
Albania
Fax: 03554 362 596
Email: l_qafmolla@hotmail.com

Quarmeau, S. | OECD Nuclear Energy Agency,
12 boulevard des Iles,
92130 Issy-les-Moulineaux,
France
Fax: 0033145241112
Email: solange.quarmeau@oecd.org

Reisenweaver, D.W. | Alion Science and Technology,
1475 Central Avenue,
Los Alamos, NM 87544,
USA
Fax: +1 505 661 2621
Email: dreisenweaver@alionscience.com

Revilla González, J.L.	Nuclear Safety Council, Pedro Justo Dorado Dellmans, 11, 28040 Madrid, Spain Fax: 0034913460497 Email: jlrg.csn.es
Rindahl, G.	Institute for Energy Technology. Os alle 13, P.O. Box 173, 1779 Halden, Norway Fax: 004769212490 Email: Grete.Rindahl@hrp.no
Riotte, H.	Radiation Protection and Waste Management Division, OECD Nuclear Energy Agency, 12, boulevard des Îles, 92130 Issy-les-Moulineaux, France Fax: 0033145241145 Email: hans.riotte@oecd.org
Rodríguez Fernández, A.	ENRESA, Emilio Vargas 7, 28043 Madrid, Spain Fax: 0034915668100 Email: arof@enresa.es
Romanenko, O.	Nuclear Technology Safety Center, Liza Chaykina Street 4, 050020 Almaty, Kazakhstan Fax: 0073272646803 Email: romanenko@ntsc.kz

Rowling, J.	Australian Nuclear Science and Technology Organisation, Private Mail Bag 1, Menai, NSW 2234, Australia Fax: 0061297179269 Email: john.rowling@ansto.gov.au
Rubtsov, P.	Federal Environmental, Industrial and Nuclear Supervision Service of Russia, Malaya Krasnoselskaya, 2/8 bld 5, 107140 Moscow, Russian Federation Fax: 0074952642859 Email: rubtsov@secnrs.ru
Rybalchenko, I.L.	VNIPIET, Savushkina str. 82, 197183 St. Petersburg, Russian Federation, Fax: 7(812)430-2379 Email: rybalchenko@givnipiet.spb.ru
Saint-Pierre, S.	World Nuclear Association, Carlton House, 22a St. James' Square SW1Y 4JH London, United Kingdom Fax: 00442078391501 Email: saintpierre@world-nuclear.org
Salgado Mojena, M.	Center for Radiation Protection and Hygiene, 20 No. 4109 Miramar, Playa, P.O. Box 6195, La Habana, Cuba Fax: +5372041188 Email: mercedes@cphr.edu.cu

Santiago Albarran, J.L.	ENRESA, Emilio Vargas 7, 28043 Madrid, Spain Fax: +34 91 566 82 68 Email: jsaa@enresa.es
Sapozhnikov, A.	Federal Service for Environmental, Industrial and Nuclear Supervision (Rostechnadzor), Ulitsa Taganskaya 34, 109147 Moscow, Russian Federation Fax: 007 095 9124041 Email: sai@gan.ru
Savidou, A.	National Center for Scientific Research "Demokritos" Aghia Paraskevi, Attiki, P.O. Box 60228, 15310 Athens, Greece Fax: +30 210 653 4710 Email: savidou@ipta.demokritos.gr
Seferlis, S.	Department of Environmental Radioactivity Monitoring, Greek Atomic Energy Commission, P.O. Box 60092, 15310 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6506748 Email: stsefer@gaec.gr
Semenov, S.	Russian Research Center, "Kurchatov Institute" Trardovsky Str. 21-2-361, 123458 Moscow Russian Federation Fax: +7495 196 2774 Email: sgs@kiae.ru

Seyda, V.	Chernobyl Nuclear Power Plant, Ulitsa Voennyh Stroiteley 1, P.O. Box 21/2, 10/11, 07100 Slavutich, Ukraine Email: seyda@chnpp.gov.ua
Shang, Z.	State Environmental Protection Administration, Nuclear Safety Center, 54 Hong Lian Nan Cun, Beijing, Hadian 100088, China Fax: +86 10 62257804 Email: zhaorongshang@tom.com
Shao, D.	Tanzania Atomic Energy Commission, P.O. Box 743, Arusha, United Republic of Tanzania Fax: 00255272509709 Email: shaoda26@yahoo.co.uk 29-Jan-07
Shiganakov, S.	Kazakhstan Atomic Energy Committee, Ulitsa Lisy Chaikinoy 4, 480020 Almaty, Kazakhstan Fax: 007 3272 607220 Email: sh.shiganakov@atom.almaty.kz
Simantirakis, G.	Department of Licensing and Inspections. Greek Atomic Energy Commission. P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6506748 Email: gsim@gaec.gr
Simeonov, G.	Nuclear Regulatory Agency, 69, Shipchenski Prokhod Boulevard, 1574 Sofia, Bulgaria Fax: 00359 2 9406919 Email: g.simeonov@bnsa.bas.bg

Simon Cirujano, I.	Consejo de Securidad Nuclear, c/ Justo Dorado 1, 28040 Madrid, Spain Email: isc@csn.es
Slavik, O.	VUJE a.s., Okruzna, 5, 918 64 Trnava, Slovakia Fax: 00421 5991494 Email: slavik@vuje.sk
Sorokin, V.	VNIPIET, Savushkina str., 82, 197183, St. Petersburg, Russian Federation Fax: +7 (812) 430 2379 Email: rybalchenko@givnipiet.spb.ru
Spooner, K.	EHS&Q Reactor Sites, Berkeley Nuclear Research Centre, Gloucestershire GL13 9PB, United Kingdom Fax: 00441453813504 Email: keith.g.spooner@britishnucleargroup.com
Stamatelatos, I.E.	National Center of Scientific Research "Demokritos", Institute of Nuclear Technology and Radiation Protection, P.O. Box 60228, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +30 210 6533431 Email: faidra@ipta.demokritos.gr

Stamatis, V.	Department of Environmental Radioactivity Monitoring, Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +30 210 650 6748 Email: vstamat@gaec.gr
Steinkuhler, C.	DDR Consult, 39 rue de la Station, 1325 Longueville, Belgium Fax: +3210881475 Email: claude.steinkuhler@skynet.be
Strufe, N.	Danish Decommissioning, Frederiksborvej 399, P.O. Box 320, 4000 Roskilde, Denmark Fax: +4546 77 43 02 Email: nst@dekom.dk
Sun, Q.	China Institute for Radiation Protection, 270 Xuefujie, P.O. Box 120, Taiyuan, Shanxi 030006, China Fax: 0086 351 7020407 Email: sunqhcirp@tom.com
Syed Hakimi Sakuma Syed Ahmad	Malaysian Institute for Nuclear Technology Research, Bangi 43000 Kajang, Selangor, Malaysia Email: hakimi@mint.gov.my
Szilagyi, A.	US Department of Energy, 1000 Independence Ave. SW, Washington, DC 20585, USA Fax: 301 903 4307 Email: Andrew.szilagyi@em.doe.gov

Takats, F.	TS Enercon Kft., Csalogany U. 23-33, 1027 Budapest, Hungary Fax: 0036 1 4576761 Email: takats@tsenercon.hu
Taniguchi, T.	Department of Nuclear Safety and Security, International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria Fax: 0043126007 Email: t.taniguchi@iaea.org
Teskeviciene, B.	Ministry of Economy, Gedimino ave. 38/2, 01104 Vilnius, Lithuania Fax: 00370 5 2623947 Email: b.teskeviciene@ukmin.lt
Thierfeldt, S.	Brenk Systemplanung GmbH, Heider-Hof-Weg 23, 52080 Aachen, Germany Fax: 0049 2405 465150 Email: s.thierfeldt@brenk.com
Tikialine, A.	Nuclear Research Centre of Birine, Comena, BP 180 Ain-Oussera 17200, W. Djelfa, Algeria Fax: +213 27 87 42 80 Email: tikiadz@yahoo.fr
Tkachenko, A.V.	Moscow City Radon Scientific Production Association, 7 -oy Rostovsky pereulok 2/14, 119121 Moscow, Russian Federation Fax: 007 495 3240191 Email: radonalex@mail.ru

Tripputi, I.	SOGIN S.P.A., Via Torino 6, 00184 Rome, Italy Email: tripputi@sogin.it
Tritakis, P.	Department of Licensing and Inspections, Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: +210 650 6748 Email: ptritak@eeae.gr
Tulonen, S.	European Atomic Forum, Rue de la Loi 57, 1040 Brussels, Belgium Fax: +3225023902 Email: sami.tulonen@foratom.org
Tuunanen, J.	Teollisuuden Voima Oy, 27160 Olkiluoto, Finland Fax: 00358283813259 Email: jari.tuunanen@tvo.fi
Tzika, F.	National Center of Scientific Research "Demokritos", Institute of Nuclear Technology and Radiation Protection, Research Reactor Laboratory, P.O. Box 60028 153 10 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6533431 Email: faidra@ipta.demokritos.gr
Tzotchev, S.	Nuclear Regulatory Agency, 69, Shipchenski Prokhod Boulevard, 1574 Sofia, Bulgaria Fax: 0035929406919 Email: s.tzotchev@bnsa.bas.bg

Urbonavicius, S.	Ignalina Nuclear Power Plant, 31500 Visaginas, Lithuania Fax: 00370 386 24387 Email: us@ent.lt
Valencia, L.	Forschungszentrum Karlsruhe GmbH, HDB, P.O. Box 3640, 76021 Karlsruhe, Germany Fax: +497247824272 Email: luis.valencia@hdb.fzk.de
Valentin, P.	Commisariat à l'énergie atomique, Centre de la Vallée du Rhone, BP 17171 — 30207 Bagnols sur Cèze Cedex, France Fax: 0033466796432 Email: valentinp@atil.cea.fr
Vegvari, I.	Hungarian Atomic Energy Authority, Fenyes Adolf u. 4, 1036 Budapest 114, Hungary Fax: 0036 1 4364893 Email: vegvari@haea.gov.hu
Verhoef, E.V.	COVRA N.V., P.O. Box 202, 4380 AE Vlissingen, Netherlands Fax: 0031113616650 Email: ewoud.verhoef@covra.nl
Verstraeten, I.	NIRAS-ONDRAF, Avenue des arts 14, 1210 Brussels, Belgium Fax: +3222185165 Email: i.verstraeten@nirond.be

Visagie, A.	South African Nuclear Energy Corp., P.O. Box 582, 0001 Pretoria, South Africa Fax: 0027 12 3053484 Email: abrie@necsa.co.za
Vogiatzi, S.	Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Aghia Paraskevi, Attiki, Greece Fax: 0030 210 6506748 Email: sbogiatz@eeae.gr
Volkov, V.G.	Russian Research Centre, Kurchatov Institute (RRC KI), Kurchatov Square 1, 123182 Moscow, Russian Federation Fax: 0074951966074 Email: vvg@kiae.ru
Wada, S	Japan Nuclear Energy Safety Organization, Tokyo Reit Toranomon Bldg 8F, 3-17-1 Toranomon Minato-ku, Tokyo 105-0001 Japan Fax: +813 4511 1998 Email: wada-shigeyuki@jnes.go.jp
Waggitt, P.W.	Division of Radiation, Transport and Waste Safety, International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria Fax: +43 1 26007 Email: P.Waggitt@iaea.org
Waisley, S.	Office of Environmental Management (EM-23), US Department of Energy, 1000 Independence Ave. SW, Washington, DC 20585, USA Fax: 2025864314 Email: Sandra.waisley@em.doe.gov

Walthery, R.	Belgoprocess, Gravenstraat 73, 2480 Dessel, Belgium Fax: 003214334099 Email: robert.walthery@belgoprocess.be
Warnecke, E.	Division of Radiation, Transport and Waste Safety, International Atomic Energy Agency, Wagramer Strasse 5, 1400 Vienna, Austria Fax: +431 26007 Email: e.warnecke@iaea.org
Watts, N.	Crown Agents, St. Nicholas House, St. Nicholas Road, Sutton, Surrey SM1 EL, United Kingdom Email: norman.watts@crownagents.co.uk
Welch, R.A.	City of Richland, 505 Swift Boulevard, Richland, WA 99352, USA Fax: 0015099427379 Email: rwelch@ci.richland.wa.us
Wilson, J.	Nuclear Decommissioning Authority, Herdus House, Westlakes Science and Technology Park CA24 3HU, United Kingdom Fax: +44 1925 802 170 Email: janet.wilson@nda.gov.uk
Wingefors, S.	Swedish Nuclear Power Inspectorate, Klarabergsviadukten 90, 106 58 Stockholm, Sweden Fax: +46 8 661 9086 Email: stig.wingefors@ski.se

Wood, C.	EPRI, 3420 Hillview Ave, Palo Alto, CA 94304, USA Email: cwood@epri.com
Woollam, P.	British Nuclear Group, Berkeley Centre, Berkeley, Gloucestershire GL13 9PB, United Kingdom Fax: 0441453813816 Email: paul.woollam@magnox.co.uk
Xavier, A.M.	National Nuclear Energy Commission, Porto Alegre Office, Av. Bento Gonçalves 9500, Prédio 43322 Sala 110, Porto Alegre, RS 91501-970, Brazil Fax: 0555133222455 Email: axavier@if.ufrgs.br, cnen@ufrgs.br
Xu, Xianhong	Tsinghua University, Beijing 100084, China Fax: 0086 10 62771043; 0086 10 62771043 Email: xhxu@mail.tsinghua.edu.cn
Yadigiaroglou, G.	Greek Atomic Energy Commission, P.O. Box 60092, Patriarhou Grigoriou and Neapoleos, 153 10 Athens, Greece Fax: 0041446321105 Email: yadi@ethz.ch
Yagi, N.	Japan Atomic Energy Agency, 2-4 Shirakata-Shirane, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan Fax: +81 29 282 6983 Email: yagi.naoto@jaea.go.jp

Yaroslavtsev, G.	Concern Rosenergoatom, Bolshaya Ordynka Str. 24/26, Moscow 119017, Russian Federation Fax: 0074957106322 Email: yaroslavcev@rosenergoatom.ru
Youtsos, A.G.	Institute for Nuclear Technology and Radiation Protection, National Centre for Scientific Research "Demokritos" 153 10 Aghia Paraskevi, Attiki, Greece Fax: +302106545496 Email: youtsos@ipta.demokritos.gr
Ziakova, M.	Nuclear Regulatory Authority of the Slovak Republic, Bajkalska 27, P.O. Box 27, 820 07 Bratislava, Slovakia Fax: 00421258221166 Email: marta.ziakova@ujd.gov.sk

AUTHOR INDEX

The process for the decommissioning of facilities that use radioactive material is becoming mature, and lessons have been learned from the experience obtained to date. However, many countries are still at the beginning of that process and are very interested in taking advantage of the experience already accumulated. The creation of well established and approved procedures for decommissioning is also important because of the increased awareness of the need for protection of the public and the environment, and also because of the potential for the construction of new nuclear facilities on sites after decommissioning. The development of a holistic approach for adequate planning, performance and completion of decommissioning involving all interested parties has been widely recognized. This conference, held in Athens, was organized as a follow-up to an earlier IAEA conference on the Safety of Decommissioning for Nuclear Activities, which was held in Berlin in 2002. The aim of this conference was to identify and highlight the lessons learned and the good practices in the various areas of decommissioning, such as regulation, planning, implementation, waste management, technology and the decommissioning of small facilities, that can be used by regulators, operators, technical support organizations and decision makers to improve safety, enhance effectiveness and ensure the successful completion of decommissioning projects. These proceedings report on the ten sessions of the conference and include the invited papers, the summaries of the sessions and the summary of the Conference President. The contributed papers and presentations, as well as the complete text of these Proceedings, are provided on a CD-ROM that accompanies this publication.

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–106107–2
ISSN 0074–1884