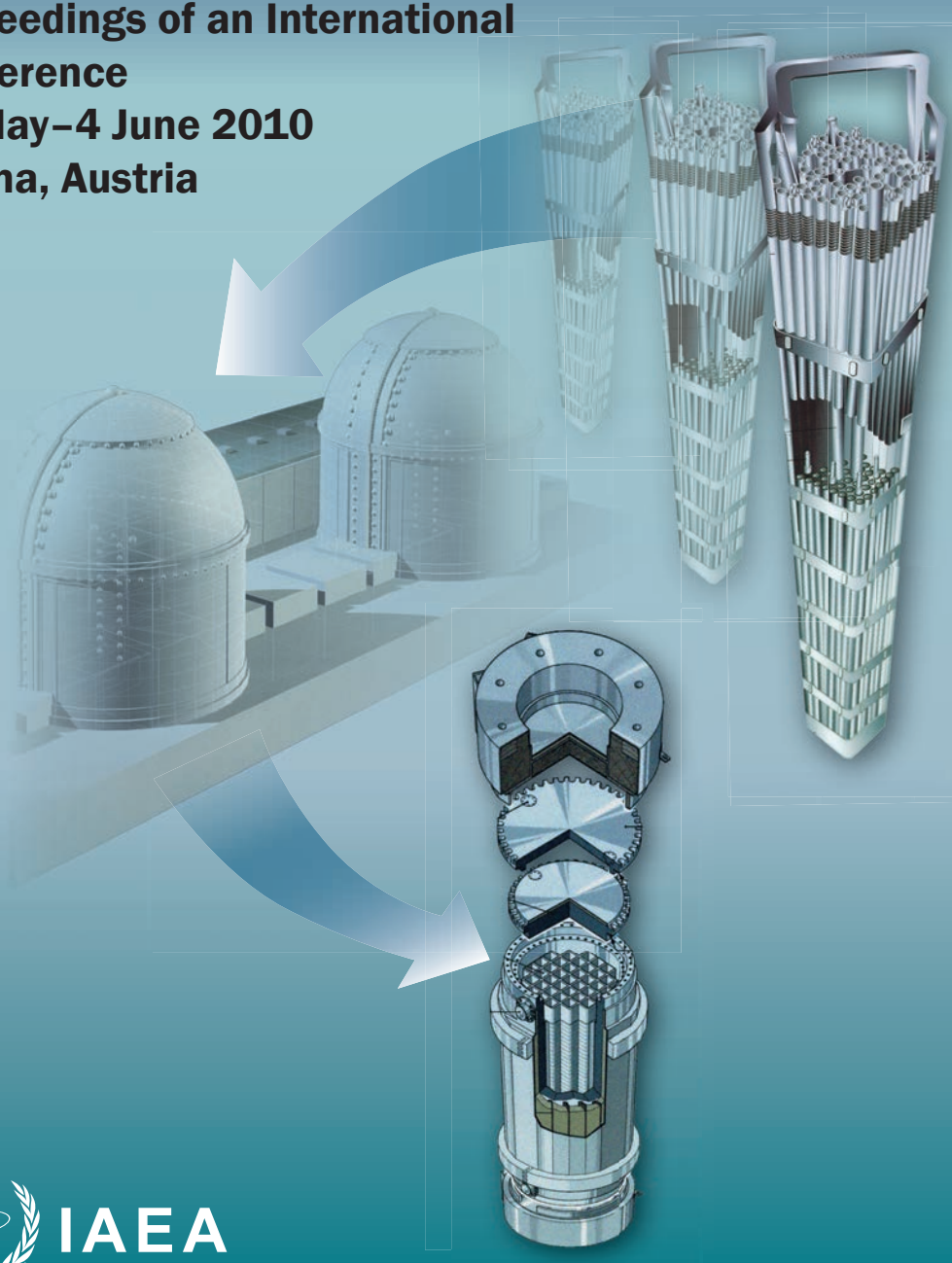
Management of Spent Fuel from Nuclear Power Reactors

Proceedings of an International Conference
31 May–4 June 2010
Vienna, Austria



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MANAGEMENT OF SPENT FUEL FROM NUCLEAR POWER REACTORS

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PROCEEDINGS SERIES

MANAGEMENT OF SPENT FUEL FROM NUCLEAR POWER REACTORS

PROCEEDINGS OF AN INTERNATIONAL CONFERENCE
ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
IN COOPERATION WITH THE
OECD NUCLEAR ENERGY AGENCY
AND HELD IN
VIENNA, AUSTRIA, 31 MAY–4 JUNE 2010

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2015

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Printed by the IAEA in Austria
April 2015
STI/PUB/1661

IAEA Library Cataloguing in Publication Data

Management of spent fuel from nuclear power reactors : proceedings of an International Conference held in Vienna, Austria, 31 May–4 June 2010. — Vienna : International Atomic Energy Agency, 2015.
p. ; 24 cm. — (Proceedings series, ISSN 0074–1884)
STI/PUB/1661
ISBN 978–92–0–103714–5
Includes bibliographical references.

1. Spent reactor fuels — Management — Congresses. 2. Spent reactor fuels — Storage — Congresses. 3. Reactor fuel reprocessing — Waste disposal — Congresses. I. International Atomic Energy Agency. II. Series.

IAEAL 15–00962

FOREWORD

Conferences on the management of spent fuel from nuclear power plants have been organized periodically by the International Atomic Energy Agency (IAEA), in coordination with the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). The last such conference prior to this one in 2010 took place in June 2006. That conference recognized that some countries considered spent fuel a resource to be recycled and reused, while other countries considered it to be something to be disposed of, but that the rate of implementing national strategies was slow, and that in general, the majority of spent fuel was destined for storage for a certain period of time. Also at that time, signs were evident that the nuclear power industry could undergo a revival because of emerging climate change concerns and concerns over supply and costs of fossil fuels.

The revival of the nuclear industry was becoming a reality and developments were taking place with respect to advanced fuel cycles and fast breeder reactors when the accident at the Fukushima Daiichi Nuclear Power Plant occurred in March 2011. Those developments are continuing, although at a slower pace. This conference does not address the incidents at the spent fuel dry and wet storage facilities at Fukushima Daiichi; however, many papers and posters are relevant to them.

Disposal facilities for spent fuel or for high level waste from reprocessing are areas where there has been progress in some countries and setbacks in others. Nevertheless, the majority of spent fuel remains in storage and it is accepted that storage periods in some countries could extend to over one hundred years.

With the substantial number of countries newly contemplating the introduction of nuclear energy, the IAEA is receiving an increasing number of requests for advice on the implications of introducing nuclear energy. The management of spent fuel is clearly an issue that is of importance for newcomer Member States.

The 2010 conference was organized and structured to cover a broad range of topics from national strategies to safety and regulatory aspects, transport, technical innovation, fuel and material behaviour, operational experience with storage, new fuel and reprocessing developments and long term storage and disposal. The conference also featured three round table discussion sessions covering regulatory aspects, stakeholder involvement and future perspectives.

This publication presents the opening and concluding presentations at the conference, the discussions and summaries of the sessions and the President's summary of the overall conference. An attached CD-ROM contains all the papers from the conference that were made available for publication.

The IAEA officers responsible for this publication were G. Dyck of the Division of Nuclear Fuel Cycle and Waste Technology and P. Metcalf of the Division of Radiation, Transport and Waste Safety.

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SUMMARY

The Conference on the Management of Spent Fuel from Nuclear Power Plants was organized by the International Atomic Energy Agency (IAEA) in coordination with the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). These conferences have been organized periodically, with the last one prior to this taking place in June 2006.

One of the conclusions of the 2006 conference was recognition that the implementation of national strategies for spent fuel (SF) management was slow. SF was seen differently in various countries, considered either as waste to be disposed of or as a resource to be recycled. As SF and high level waste disposal projects are making progress only in a few countries, and are seriously stalled in others, SF is remaining in storage for extended periods of time, and these storage periods could possibly extend even beyond one hundred years.

In the period after the 2006 conference, a substantial number of countries were newly contemplating the introduction of nuclear energy and the IAEA was receiving an increased number of requests for advice on implications of its introduction. SF management was clearly recognized as an issue of high importance for potential newcomer countries or countries planning to expand their small nuclear programmes.

The objective of the conference was to address a broad range of topics related to SF management in order to enable Member States to better understand issues related to further application of nuclear industry. The conference covered topics from national strategies, through safety, regulatory aspects, transport, technical innovation, fuel and material behaviour and long term storage and disposal. The following were the ten specific topics of the conference sessions:

— Strategic issues and challenges in SF management;
— SF management for smaller programmes and newcomer States;
— Safety and licensing of SF storage and transportation;
— Technological innovations for SF storage;
— Fuel and material behaviour;
— Managing past and damaged SF;
— Operating experience in wet and dry storage;
— Discrete issues in managing high burnup mixed oxide (MOX) and fast neutron reactor SF;
— Fuel reprocessing: status and challenges;
— Managing very long term storage and the disposal of SF.

There were also three round table discussions related to the regulatory framework for SF management, stakeholder issues and further strategies. There were an additional 12 papers presented during the parallel poster session.

In the opening session, there were two opening addresses. One, given by Mr. U. Yoshimura, was on the Changing Landscape for Management of Spent Nuclear Fuel, International Perspectives from the OECD/NEA and the other, given by Mr. A. Kakodkar, was a general opening address. Mr. Yoshimura concluded that SF is being safely managed today, but that at the same time scientific advances and technological innovations hold the potential to further improve safety for longer term storage time frames. International cooperation is an extremely valuable help in finding the way and developing strategies in SF management. Policy statements, safety standards, information sharing, international peer reviews and technical guidelines all support safe and consistent SF management worldwide. Mr. Kakodkar posed several questions on SF management issues that are essential to the nuclear community, hoping that some of them would be answered during the conference.

Mr. Kakodkar, the president of the conference, also provided the concluding remarks of the conference. Here are some key thoughts from those conclusions:

At present, most of spent nuclear fuel in the world is stored in reactor pools and other interim storage facilities. Although it is safe and secure, as the evidence from the conference confirms, it has to be recognized that such storage is only an interim stage in any SF management strategy. While some countries (such as France, India, Japan and the Russian Federation) are following programmes to recycle SF, there are few advanced disposal projects (Finland, Sweden), with the majority of disposal projects following at a slower rate of development. It may be several decades before repositories are available in all of the major nuclear countries. It is becoming clear that SF will have to be stored for longer periods than originally intended, possibly even a hundred years or more. Questions therefore arise about the safety, security and sustainability of storage over such long periods. In order to demonstrate safety over these time periods, a good understanding of the processes that may cause deterioration of storage systems is needed. The conference showed that these new priorities are well understood, and some studies presented at the conference were aimed at investigating various phenomena that might cause failure of storage systems over long periods of time. This is also being recognized by regulators as an issue for licensing the storage facilities over such long periods of time.

More than 60 ‘newcomer’ countries have indicated that they are interested in developing nuclear power, and many of them have turned to the IAEA to obtain information on the implications of such a step and infrastructure that would be required. Information about reactor systems and fuel supplies is readily available from vendors, but it has proved to be more difficult for newcomers

to obtain reliable information about the solutions that are required for the back end of the fuel cycle. The role of the IAEA in providing newcomer countries with necessary information related to SF management was recognized.

Multilateral solutions for storage, reprocessing and disposal in which there are sharing mechanisms between countries could be of interest to countries with small amounts of SF and waste, limited resources and small land areas. These approaches have frequently been discussed, but never attained real acceptance due to political and social opposition.

The link between SF storage and transport and the benefits of multipurpose (dual purpose in particular) casks has been recognized.

One focus of the conference was understanding the degradation phenomena that might affect the storage of SF over long time periods. Important potential material degradation mechanisms are: air oxidation, stress corrosion cracking, thermal creep, hydride reorientation and delayed hydride cracking. Several papers have described experimental studies for investigation of these mechanisms. To date, evidence is positive and suggests that storage systems will continue to provide safety for extended time periods. These conclusions are supplemented by comprehensive programmes for testing of metal and concrete casks involving tests to evaluate safety in scenarios involving normal operation, ageing, seismic events and accidents (including an aircraft crash). The results showed that the casks performed very well with little evidence of failures that would lead to significant safety issues.

During the conference, there was also recognition of the value of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The exchange of information by countries promotes confidence and belief in one another with respect to radioactive waste management. International organizations were encouraged to continue and, if possible, to increase peer reviews and regulatory reviews. These reviews provide evidence that countries are meeting their international safety obligations.

Public acceptance of radioactive waste and its disposal remains an issue and political will is required to move the process forward in tune with the expected growth in nuclear power programmes worldwide. It must be recognized that the eventual disposal of high level radioactive waste will be necessary regardless of whether one opts for a closed or open fuel cycle.

Climate change concerns, the availability of uranium and its price, and the philosophy held with respect to sustainable disposal of SF will determine the approach towards either reprocessing or direct disposal.

Experience in France has shown that reprocessing is cost competitive and leads to more energy with less waste. A global consensus, which does not exist at the moment, should lead to a more sustainable solution to the energy and climate crises that face the world today.

Advances are taking place with respect to higher burnup fuels, the development of fast reactors and advanced fuel cycles. Some of these have been demonstrated on an industrial scale. While this does introduce additional considerations with respect to the management of SF storage, it seems that they can be accommodated within the available solutions.

In closing his remarks, Mr. Kakodkar underscored the role of the IAEA in developing activities in the field of SF management, shaped by the needs of Member States.

OPENING SESSION

OPENING ADDRESS

Y. Sokolov
IAEA

Good morning ladies and gentlemen,

It is my pleasure to welcome you on behalf of the International Atomic Energy Agency to this International Conference on Management of Spent Fuel from Nuclear Power Reactors organized by the IAEA in cooperation with the OECD Nuclear Energy Agency.

In particular, I welcome you on behalf of the Director General, who is very interested in the outcome of this conference and would like me to convey the following message:

"We see in front of us an expected increase in the use of nuclear power. The safe, secure and effective management of spent nuclear fuel is an important challenge for the nuclear community. Spent fuel has to be managed with due regard to the applicable safety standards and in such a way that the uranium energy resource is well utilized. The experience of long term storage of spent fuel is good but strategies need to be developed and implemented for the next step, be it recycling or disposal. For effective use of uranium, the development of fast reactors holds promises, but also challenges. The discussions at this conference will be important to guide our future work."

At the time of the last conference in 2006, expectations had started rising for the future of nuclear power, and they have kept rising, year by year, since then. Moreover, specific plans for new nuclear power plants have increased. The existing plants are expected to operate longer and new plants are planned in a number of countries, including both countries that already have nuclear power, such as China, India and the United Kingdom, and countries planning to build their first plant, such as Jordan, Turkey, the United Arab Emirates and some others.

In addition, a large number of countries have turned to the IAEA to better understand what it would mean to have nuclear power and what infrastructure it would require. Most of the focus is on what is needed for a new country to build and start operating nuclear power plants to produce electricity — that is, the legal, regulatory, educational, operational and industrial infrastructure.

Much attention has also been given to the security of the fuel supply. Are uranium resources adequate? Will the fuel supply be assured? Are there political risks that fuel supplies could be cut off, and so on?

Less attention has been given so far to strategies for spent fuel management, but it must be recognized that within months of starting a new reactor, spent fuel will be discharged. Adequate capacity for storage needs to be built. Considerations need to be given to the final disposition of the fuel. Will it be seen as a resource and recycled, or will it be seen as a waste and disposed of after some 30–40 years of storage? This is a difficult issue and only a few of the present nuclear power countries have made that choice definitively. Any country embarking on nuclear power must therefore be prepared for long term storage of spent fuel and, depending on developments in the rest of the world, possibly also for ultimate disposal.

These issues are addressed by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The contracting parties to this convention have now held three review meetings, providing country reports to each other and identifying progress and continuing challenges. In addition to the generally satisfactory reports on the safety of spent fuel management, recognition by countries of the need for national spent fuel management policies and their development by many countries are seen as positive developments. However, the implementation of national policies remains elusive in many countries and the contracting parties have been urged to report on these developments at future review meetings. The Member States of the IAEA have also recently agreed new safety standards on the storage of spent nuclear fuel and on the disposal of radioactive waste.

So what has happened on spent fuel management since the last conference? Quite a lot that is good, and some that is not so good. Many initiatives are underway. Storage of spent fuel in both wet and dry conditions has become routine with no major incidents reported. Reprocessing and recycling of the plutonium in mixed oxide fuel is performed on a commercial scale in France, but few other countries have renewed their reprocessing contracts. There have been operational and teething problems with the reprocessing plants and mixed oxide facilities in the UK and Japan, but the policy for recycling is clear. Additional leverage has come from political initiatives to dispose of surplus weapons plutonium. The United States of America and the Russian Federation have agreed to burn 34 tonnes of weapons grade plutonium each as mixed oxide fuel for light water reactors in the USA and for fast reactors in the Russian Federation.

For the future, more effective use of plutonium will be needed. India and the Russian Federation are taking important steps towards their first and second large scale fast reactors. Japan and China are operating fast test reactors and France has decided to build a prototype fast reactor by about 2020. The recognition that fast reactors will be important for sustainable nuclear systems is rising again.

Important steps have been taken towards the first geological disposal facilities in Finland and Sweden for spent fuel and in France for high level

waste from reprocessing. Sites or areas have been chosen and the first licence applications are expected shortly. In most other countries, however, plans for geological disposal are only developing slowly. In most cases the possible retrievability of the waste also needs to be considered.

The developments in the USA have been more erratic. Important work was initiated to improve spent fuel processing methods and to develop recycling and burning capacity in fast reactors. In parallel, the work on the disposal facility for spent fuel and high level waste at Yucca Mountain was speeded up, and a licence application was submitted by the Department of Energy to the Nuclear Regulatory Commission in the summer of 2009. In 2010, however, President Obama declared that Yucca Mountain is not suitable for disposal and the Department of Energy has applied for a withdrawal of the licence application. A Blue Ribbon Commission on America's Nuclear Future has been appointed to study alternatives and provide recommendations for developing a safe, long term solution to managing the USA's used nuclear fuel. The commission is expected to provide draft recommendations within 18 months.

At the same time, March 26, 2010 marked 11 years of safe operation of the Waste Isolation Pilot Plant in the USA, and, moreover, in April, trucks transporting transuranic waste to the WIPP had logged 10 million safe, loaded miles, with 8400 shipments. So the experience in disposing and transporting of transuranic waste of military origin is quite good.

On the international scene, we have seen the discussion on multilateral approaches for assurance of supply has intensified. So far, mainly assurance of enriched uranium has been discussed and a fuel bank of enriched uranium has been established by the Russian Federation at Angarsk. There is a need for similar discussions on the back end of the fuel cycle including, first, the possibility of fuel take-back, as has been exercised for some research reactor fuel and fuel for Russian built reactors, and, second, considerations of fuel leasing. There are, however, quite strong political barriers, especially when it comes to disposal of spent fuel or high level waste. The advent of new reactor projects in several countries with similar interests could be a good basis for further discussions at a regional level.

We will certainly hear more about these and other developments during this week.

Irrespective of what will be the final destination of the fuel, there will be an increasing need for long term storage of the fuel. Storage periods of 100 years or even longer are being considered, and the amount of fuel that will be stored is constantly increasing. In 2010, 225 000 tonnes of fuel were stored around the world, and there is a need to ensure the efficiency, reliability, safety and security of storage. Improving storage efficiency through burnup credits is increasingly being considered. The experience with both wet storage in pools and dry storage

in casks and vaults is very good. Casks are commercially available, including in some cases combined storage and transport casks. Also the combination of storage, transport and disposal casks has been considered.

A key issue for storage is that the fuel (and facilities) must not deteriorate and that one must be sure of being able to remove the fuel (or sometimes the full cask) at the end of the storage period. Although the experience so far is very good, new challenges are connected to the trend of increasing burnup. The IAEA SPAR [Spent Fuel Performance Assessment and Research] projects are designed to collect information on fuel and facility behaviour. Further, it is important that the combined storage and transport casks can be relicensed for transport after perhaps 50 years when the transport will be needed. These and other issues have important reliability and safety consequences and will, I am sure, be discussed during the safety sessions tomorrow.

The ability to demonstrate the long term reliability, efficiency and safety of spent fuel management requires an understanding of the phenomena that will influence all these aspects in the fuel's handling, transport and storage prior to disposal or reprocessing. Progress is being made internationally to harmonize approaches to safety demonstration, which should contribute to building confidence amongst all stakeholders and facilitate licensing processes associated with national and multinational programmes. Of importance in this regard would be the development of cases for long term storage of dual use casks, with good prospects for meeting transport regulations when necessary in the future.

The assurance of safety and security in the long term is the main safety concern associated with spent fuel management. Taking into account that uncertainties increase the further we look into the future, long term assurance can only be provided by disposal. Additionally, clear strategies to implement national waste management policies are needed to optimize safety and to avoid unnecessary handling and transport of spent fuel, with their attendant radiological impact and potential for accidents or unlawful diversion.

Reprocessing is a key component in a sustainable nuclear energy system, in particular for closed cycle systems with fast reactors that will be able to utilize uranium at least 50 times more effectively than today's reactors. But there are concerns about proliferation issues in connection with reprocessing and recycling, and new, more proliferation resistant processing schemes are being developed that do not separate plutonium from uranium, or that keep some of the other actinides together with plutonium to increase the proliferation barrier. Also, dry processing methods are being developed — so-called pyroprocessing — that are considered to be more proliferation resistant and might also be more effective when reprocessing fast reactor fuels.

We should not forget that spent fuel management and, in particular, long term storage and disposal of spent fuel and/or high level waste have a public

acceptance dimension. Good progress on public acceptance has been made in a few countries, but in many countries there is still a strong public concern about waste disposal. One possible way to alleviate these concerns could be to recycle not only the plutonium and uranium but also some of the long lived actinides and fission products. Work in this direction has started, but the challenges are still great. However, it is important to think early about all possible strategies and I hope that the round table on Friday on future strategies will be able to cover both short term strategies for the fuel from the present reactors and some more visionary approaches.

Finally, like in most areas of the nuclear industry, we are witnessing a handover from one generation of experts to the next. Many of us are nearing an age where we begin to consider retirement and there is concern over not only finding qualified, trained staff to replace us, but also over our ability to manage effectively accumulated knowledge and to pass down the lessons and experience gained in the past to this new generation of experts.

In closing, I wish you a successful and profitable experience at this conference. I encourage you to engage in open and frank discussion and thank you for your contribution to the future of spent fuel management around the world.

Thank you for your attention.

OPENING ADDRESS

THE CHANGING LANDSCAPE FOR MANAGEMENT OF SPENT NUCLEAR FUEL: INTERNATIONAL PERSPECTIVES FROM THE OECD/NEA

U. Yoshimura
OECD Nuclear Energy Agency

Since the last international conference on management of spent nuclear fuel, in 2006, there have been important evolutions in the nuclear energy and waste management arenas. As we prepare to explore these topics in the coming days, it is useful to remind ourselves of the fundamental issues we face, and to consider the conclusions in 2006 and the major changes in context and perspectives since that time.

Why are we concerned about spent nuclear fuel?

The importance of safe and sustainable management of spent nuclear fuel is evident. While it comprises only a small amount by volume of the waste from nuclear power plants, it contains most of the radioactivity in national waste inventories. Its properties mean that special management is needed both in the near term as well as far into the future. The challenges are growing as greater volumes of spent nuclear fuel are foreseen to be stored for longer periods of time.

Furthermore, SF is at the heart of debates over nuclear power. At the last conference, nuclear power appeared poised to make a resurgence worldwide in response to, among other factors, desires for greater energy security and concerns over global warming. These factors have become even more prominent over the intervening years. Nuclear power is being expanded and extended in countries where it already exists. In addition, 'newcomer' States seeking sustainable and secure energy solutions are pursuing nuclear power.

The proper management of radioactive waste — and especially of spent nuclear fuel — features prominently in debates on expansions of nuclear power. Thus, the topic is crucial in itself and also related to the further expansion of nuclear power.

We are facing a period of change

The fundamental issues for spent fuel management have not changed. However, there have been important evolutions. Today, we have a broader range of options where, not so long ago, a clear choice could be made between only

a few options. We see this from the highest levels: the choice of energy options — even renewable sources — is ever widening; there are advanced fuel cycles of several designs that have the potential for commercialization. It is not only the number of factors that is increasing; so is their complexity.

This complexity extends to the management of spent nuclear fuel. Take, for example, the question of whether spent nuclear fuel is considered a waste or a resource. The answer to this question dictates whether or not the fuel is reprocessed to recover its unused energy potential. Twenty years ago, there was quite a clear divide between those countries that reprocessed fuel and those that did not. Today, however, the divide may be closing — or at least becoming less pronounced. The option of reprocessing is being considered by more and more programmes. This is true even of the USA, for example, which has had a long-standing policy not to reprocess used fuel. International strategies are being considered to improve access to the necessary technologies by smaller nuclear programmes and newcomer States, while maintaining the security of the nuclear fuel cycle. Advanced fuel cycles hold the potential to facilitate reprocessing while improving proliferation resistance.

Another example is the blurring line between storage and disposal for SF. Until recently, we could outline a clear progression for waste management — there was SF, then there was storage, and then either reprocessing or direct disposal. The choices depended largely on technological capabilities and security. They were implemented in a linear fashion, based on a plan decided at the beginning of the programme.

In such a progressive plan, storage was clearly differentiated from disposal. Storage was a temporary measure that was inherently retrievable. That is, waste is intended, eventually, to be removed from storage for another purpose, such as reprocessing or disposal. In itself, it is not a valid and sustainable endpoint in a waste management strategy (according to, for example, the Joint Convention on Radioactive Waste Management). However, the timeframes considered for storage have been growing. This is due to several factors, including the extension of nuclear power plant operating lifetimes and the unavailability of disposal facilities for spent nuclear fuel.

In contrast, disposal is intended to be a permanent solution. Material is not *disposed of* unless it is viewed as a waste material and is not intended to be recovered or removed in the future. However, a growing number of deep disposal designs provide a significant degree of waste retrievability for longer periods into the future. Phased development of disposal with pilot or test programmes, for example, may in practice provide nearly the same degree of retrievability as underground storage for periods of time on the order of a century or more. In such cases, it becomes increasingly difficult to distinguish between very long term storage and disposal.

To navigate a coherent waste management programme under such complex circumstances is a challenge. To face this challenge, programmes today adopt a stepwise approach that recognizes the long duration of the project. It is acknowledged that not everything can be known or decided at the start. Decision making must be based on the best available information, but should also encourage further learning and should allow flexibility to adapt as technology advances and conditions evolve. Some of our systems may need to be examined and updated to match this approach; we must ask, for example, whether current licensing procedures are well adapted to such a stepwise process. Fortunately, we have already some valuable tools available that provide a solid foundation for decision making and implementation.

National strategic plans

The first important tool is the development of comprehensive national strategies — not only for waste management, but also in terms of energy policy. This provides the foundation and ensures coherence of subsequent decision making. The strategy for waste management should address the technical aspects of the approach. Importantly, it also must provide a framework and roadmap for decision making, using a process that allows the time and means to understand and evaluate the basis for management options. It must take into account social and political, even economic, factors. The opening and closing sessions of this conference underline the strategic considerations that drive national plans and provide examples of such plans from newcomer States as well as more established nuclear programmes.

Stakeholder engagement

Stakeholder agreement is both a contributing factor and a solution to the increasing complexity in spent fuel management. It has sometimes been seen as an obstacle to be overcome. However, there is increasing awareness that robust societal discussion and agreement can be a powerful force in *supporting* implementation and providing programme stability through, for example, changes in political leadership. Furthermore, building durable links with host communities may contribute to safety by maintaining institutional care and knowledge of a facility. The NEA has invested significant work in such issues, through its Forum on Stakeholder Confidence. We find that the perception of stakeholder engagement by the waste management community has changed considerably over the last decade. We also find examples of effective approaches and success stories. These will be discussed in a round table discussion tomorrow, led by Mr Pescatore of the NEA.

International cooperation

International cooperation is extremely valuable to help navigate the current landscape of spent fuel management. Activities by organizations such as the NEA and the IAEA contribute at all levels of decision making in national programmes, from strategic choices on the fuel cycle to technical details of implementation. Policy statements, safety standards, information sharing, international peer reviews, technical guidelines and assistance: all these activities support safe and consistent management worldwide, provide a benchmark for assessing progress and help build public confidence. This conference is an example of the value that can be gained from such activities.

Conclusions

In closing, let me reaffirm that SF is being safely managed today. Scientific advances and technological innovations hold the potential to further improve safety for longer storage time frames. However, waste management programmes are in a period of change in which we are challenged by a wider range of considerations than ever before. This conference provides us the means to examine and understand these issues. Perhaps even more importantly, the conference also gives us the direction and tools to navigate this complex landscape, and to continue and expand safe and effective management of spent nuclear fuel. I look forward to a productive and interesting meeting.

Relevant publications of the OECD Nuclear Energy Agency

For further information, please consult the following publications of the OECD Nuclear Energy Agency. These and other documents can be found on the NEA web site at www.nea.fr:

— NUCLEAR ENERGY AGENCY, Regulation and Guidance for the Geological Disposal of Radioactive Waste: Review of Literature and Initiatives of the Past Decade, OECD/NEA, Paris (2010).
— NUCLEAR ENERGY AGENCY, International Experiences in Safety Cases for Geological Repositories (INTESC) + CD-ROM — Outcomes of the INTESC Project, NEA, Paris (2009). Available online at: http://www.nea.fr/html/rwm/reports/2009/nea6251-INTESC-eng.pdf (in PDF) — free download.
— NUCLEAR ENERGY AGENCY, Strategic and Policy Issues Raised by the Transition from Thermal to Fast Nuclear Systems, OECD/NEA, Paris (2009).

— NUCLEAR ENERGY AGENCY, Moving Forward with Geological Disposal of Waste: A Collective Statement of the NEA Radioactive Waste Management Committee, NEA, Paris (2008). Available online at: http://www.nea.fr/html/rwm/reports/2008/nea6433-statement.pdf (in PDF).
— NUCLEAR ENERGY AGENCY, Timing of High-Level Waste Disposal, OECD/NEA, Paris (2008).
— NUCLEAR ENERGY AGENCY, Management of Recyclable Fissile and Fertile Materials, OECD/NEA, Paris (2007).
— NUCLEAR ENERGY AGENCY, Regulating the Long-term Safety of Geological Disposal: Towards a Common Understanding of the Main Objectives and Bases of Safety Criteria, NEA, Paris (2007). Available online at: http://www.nea.fr/html/rwm/reports/2007/nea6182-regulating.pdf (in PDF).
— NUCLEAR ENERGY AGENCY, Advanced Fuel Cycles and Radioactive Waste Management, OECD/NEA, Paris (2006).
— NUCLEAR ENERGY AGENCY, The Roles of Storage in the Management of Long-lived Radioactive Waste – Practices and Potentialities in OECD Countries, NEA, Paris (2006). Available online at: http://www.nea.fr/html/rwm/reports/2006/nea6043-storage.pdf (in PDF).
— NUCLEAR ENERGY AGENCY, Workshop proceedings and summaries. A series of national workshops explore the context, process and challenges of policy-making and implementation of waste management in different countries. See http://www.nea.fr/rwm/fsc/.

OPENING ADDRESS

A. Kakodkar
President of the Conference
India

Let me begin by thanking the IAEA for the invitation to preside over this Conference. Management of SF from nuclear power reactors is an issue that has been engaging international attention for a long time. There are differing dimensions to management of SF depending on the national policy with respect to fuel cycle, methods adopted for storage and disposal and emerging understanding. This conference is an excellent opportunity for us to exchange our experiences, scientific knowledge and ideas on the large number of issues that are involved, develop common understanding and derive appropriate conclusions. The organizers have worked out a comprehensive and well structured programme for us. With such wide participation in the conference we should be in a position to enrich ourselves with broader perspective and reach some useful conclusions arising out of our discussion.

There have been debates on whether SF from nuclear power reactors is a waste or a resource. Now there is widespread talk on a renaissance in nuclear power. Will it really take place? If it does, how far can we go on the basis of an open nuclear fuel cycle? What are the implications in terms of spent fuel management issues? There are also issues related to permanent disposal of SF and indeed of long lived radioactive waste. Considerations of energy security, size of national programme, national policies etc. have led to differing choices in terms of open or closed fuel cycles. Considerations of security and proliferation add further complexity. Questions are being raised about sustainability of nuclear power in a once through fuel cycle mode. The national policies with respect to open or closed fuel cycles could well be influenced by the shape of things to come in respect of international consensus on nuclear fuel cycle and waste management issues. Our deliberations at this conference are therefore very important.

Perhaps the most important aspect of this conference would be the exchange of opinion on scientific understanding of issues involved in long term storage of SF and their safety implications. What are the relative considerations? We need to also understand if there are additional issues involved with high burnup fuel. Are there limits in terms of time for retrievable disposal? Safety management practices with respect to storage, transport and disposal of SF have evolved over a period. Are the current codes and standards adequate? Do we have adequate actions in place to address legacy issues? Are we happy with the current level of international cooperation in safety of spent fuel management?

Can it be intensified further? How are the international information system and incident reporting system working? With emerging multilateral arrangements for management of spent fuel, are there specific safety management issues? Do we need greater harmonization of practices of spent fuel management in case multilateral arrangements become a reality?

Transportation of spent fuel, especially on a large scale and over long distances, needs our careful attention. We need to discuss all issues involved, including those involved in international transport. Should a global mechanism be established in transport regulation to facilitate certification for long periods? Relative aspects of transportation with respect to centralized or decentralized spent nuclear fuel management may also merit some deliberation. There is perhaps a need to develop clarity on relative disposition of reprocessing facilities vis-à-vis nuclear power plants in case of closed fuel cycle.

With oncoming of fast breeder reactors likely, we will be dealing with SF that has gone through a much high level of irradiation in the reactor. The heat management with these fuels is also a matter that needs greater attention. Spent fuel management with fast reactors and reprocessing are likely to be closely linked. I am glad that some of the aspects related to reprocessing will be deliberated upon. Reprocessing of fast reactor fuel elements could also follow a non-aqueous route in future. The management of spent fuel in a closed fuel cycle has several alternate routes which we need to understand both in absolute and relative terms.

It seems to me that the world is heading towards an energy crisis and also a crisis in terms of climate stability. International consensus that facilitates spent fuel management in a safe manner, particularly through a closed fuel cycle, would go a long way in resolving both these crises. We are well aware that this is a complex issue, in which technical and political aspects are thoroughly intermixed. I think it is up to us in the scientific community to bring in greater clarity and guide the political process rather than the other way around. We need global approaches and mechanisms that lead to safe and secure nuclear energy worldwide. Can we think of a dual track where there is growth of nuclear energy potential through a plutonium–uranium cycle in fast reactors in a secure way and there is spread of nuclear energy throughout the world through proliferation resistant systems?

Long term disposal of long lived waste has always been a matter of concern in the public mind. Convincing the public about the safety of repositories over a time frame that is orders of magnitude larger than the human lifespan or even the institutional lifespan is an issue that is difficult to resolve. We must share our experiences and insights into this problem. There is also talk about reducing the radiotoxicity of high level waste to a level comparable with what exists naturally say in a uranium mine, in a reasonable time span of, say, around 300 years. What

is our current collective scientific thinking and technological readiness in this regard? What road map needs to be followed to realize such an objective? Are there opportunities for international cooperation in this area? We need to reach an international understanding on the way forward.

There are international instruments with respect to spent fuel management. What is the experience so far? What is the status of international cooperation in respect of science and technology related to spent fuel management? Are there further opportunities?

Security and proliferation concerns with respect to SF storage, management and disposal are an important area for national and international action. The levels of proliferation concerns differ depending on whether an open or closed fuel cycle is being adopted. Even in the case of an open fuel cycle there may be long term security issues arising out of the ease with which plutonium can be recovered by future generations after a good part of the radioactivity in the SF is decayed. What about development of proliferation resistant technologies — what is the current status? Do they offer comfort in terms of proliferation and security risks? Do they lead to greater technological complexities making nuclear energy unviable? Does thorium offer advantages in terms of proliferation resistance?

Dear participants, we have a very broad range of issues to discuss in this conference. The conference organizers have identified a number of issues where we expect we need to reach conclusions for further action. The presentations of Mr. Sokolov of the IAEA, Mr. Yoshimura of OECD and Mr. Graf of GNS [Gesellschaft für Nuklear-Service], Germany, which we just heard, have also put forward some additional points. Let us use our time at this conference to discuss these and several other related issues and aim at deriving appropriate conclusions both with regard to our collective understanding of strategies as well as with respect to the needs and priorities for international cooperation in this important area. I look forward to carefully listening to our deliberations and the summary and conclusions from each session.

SESSION SUMMARIES

SESSION 2: STRATEGIC ISSUES AND CHALLENGES IN SPENT FUEL MANAGEMENT (SFM)

The papers in this session provided an overview of the strategies, infrastructures and regulations in major nuclear power countries related to spent fuel management. The presentations suggested that India, France, Japan and the Russian Federation plan to reprocess their spent fuel and to recycle the products in light water or fast breeder reactors while Canada, Germany, Spain and the United Kingdom (in relation to its planned new reactors) plan to dispose of spent fuel directly without reprocessing. It is evident that, regardless of the plans of some countries, at the present time there is limited reprocessing capacity in the world.

In most countries, the majority of the spent fuel is being stored at the nuclear power plants where it was generated. National plans often involve the establishment of centralized interim facilities for dry spent fuel storage or vitrified high level waste storage until geological repositories become available. The expected times at which geological repositories will be available are often quite far into the future, and interim storage periods in excess of 100 years are being planned.

As part of the design approval process for new reactors in the UK, proponents are being required by the regulators to describe plans for decommissioning and radioactive waste management at the outset. As part of this 'Generic Design Assessment Process' they are required, among other things, to explain how spent fuel can be recovered, transported and stored for periods in excess of 100 years, and how such facility lifetimes can be substantiated.

The issue of whether spent fuel can be regarded as a resource or a waste product is a regular topic in the context of conferences such as this one. However, it was pointed out that in the longer term perspective, it is more a question of when spent fuel will come to be regarded as a resource.

It was noted that, at a time when nuclear energy is undergoing a renaissance, spent fuel management can be seen as an Achilles heel, because in the minds of many people it is an unresolved issue. Furthermore, a Eurobarometer survey recently indicated that public opinions about nuclear energy would be boosted favourably it the waste question was seen to be solved.

SESSION 3: SFM FOR SMALLER PROGRAMMES AND NEWCOMER STATES

More than 60 newcomer countries have indicated that they are interested in developing nuclear power. While information about reactor systems and fuel supplies is readily available from vendors, it has proven more difficult for newcomers to obtain reliable information about the back end of the fuel cycle. The IAEA has assisted by giving advice to newcomers, but it needs to continue to ensure that its guidance is at an appropriate level for all countries.

It has to be made clear to newcomers that the basic conditions they need to have are safe and secure facilities, security of front and back end services and access to geological disposal.

The options that they have for spent fuel management are: national storage and disposal, reprocessing abroad, recycling and disposal nationally, reprocessing, recycling and waste disposal abroad, national storage, disposal in shared repositories, fuel leasing, or retention of spent fuel as a valuable commodity. The choice between these is not easy, and some are not available or feasible for smaller countries.

It is clear that multilateral solutions for storage, reprocessing and disposal with sharing mechanisms between countries would greatly help newcomer countries, especially smaller newcomer countries. However, while these are actively being discussed (some under the auspices of the IAEA), none has yet materialized. Off the shelf solutions are not likely to be realistic in this context. It would be difficult for the vendor to provide a guarantee that all back end aspects would be provided, e.g. spent fuel reprocessing, storage and disposal. A problem for many countries is the size of the nuclear units on offer; they are too big (greater than 1000 MW) for the needs of smaller countries.

SESSION 4: ROUND TABLE — REGULATORY FRAMEWORK FOR SPENT FUEL MANAGEMENT

The round table addressed four questions. The first was: Is there enough emphasis on safety standards for spent fuel management? The general view of the participants was that, taking into account the evidence from around the world that spent fuel is being managed safely, they did not see an immediate need for new safety standards in the area of spent fuel management. It was recognized, however, that standards will ideally be continuously updated to reflect new knowledge acquired and experience gained and that the standards in this area had been in existence for quite some time. Some areas were identified where more guidance could usefully be developed, for example, in relation to extended long term storage. There was also a suggestion that there could be greater

harmonization in certain areas, such as international requirements for dry cask design. It was noted that it is too early for detailed standards in this area and the emphasis still needs to be on principles rather than on quantitative technical criteria.

The second question was: Is there sufficient international consensus on the approaches to demonstrate the safety of geological disposal? There was thought to be a general consensus among experts in the field that geological disposal is likely to be a viable and safe technology and that, at least qualitatively, safety can be demonstrated. A number of issues were raised, however. One concerned the elements that need to be considered in a geological disposal facility safety case, and how long term integrity issues are to be addressed. It was also noted that although the introduction of the concept of retrievability in some disposal strategies might imply that there is not a full consensus on long term repository safety, many stakeholders take comfort from the promise of retrievability. There was a call for a greater clarification of terminology, for example, of terms such as 'retrievable', 'final closure' and 'management after closure'. The IAEA and NEA are addressing many of the issues raised here in standards and guidance. It was pointed out that these organizations have an important role to play in ensuring close collaboration between countries engaged in licensing geological repositories.

The third question was: Is it possible to achieve international consensus on the future strategy for spent fuel management? At the present time, participants thought that it was not possible to build an international consensus on a strategy for spent fuel management, as countries have different positions on how to regard spent fuel. However, it is possible to find a consensus on different elements of a strategy and on the basic principles underlying it. It is recognized that uranium is a limited resource in the world and ought not to be wasted; recycling needs to be encouraged where feasible. At this time, it might be useful to have a global overview of uranium, including estimates of available resources compared to likely demand and options for its further use. This is a topic that might be considered by international organizations.

The fourth question was: How would international instruments be used in the event of multilateral arrangements being adopted for spent fuel management? The most relevant international instrument in this context is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention). There was agreement on the benefits of the Joint Convention; the process of exchanging information between countries promotes confidence and belief in other countries. The Joint Convention was intended to facilitate interactions between individual countries and has no mechanism for multilateral arrangements; on the other hand, it does not exclude them and has already provided a forum for discussions on the subject.

A multilateral facility would have to be located on the territory of a particular country and it seems clear that the facility would have to operate within the regulatory requirements of that country, with consequent implications to any other countries wishing to place material within the facility. It was noted that public confidence has been enhanced by the Joint Convention but also by international peer reviews and regulatory review teams. Together, they provide evidence that countries are meeting their international safety obligations. International organizations are encouraged to continue and, if possible, to increase these types of activity.

SESSION 5: SAFETY AND LICENSING OF SPENT FUEL STORAGE AND TRANSPORTATION

In this session, participants presented their arrangements for licensing and regulating spent fuel storage facilities. On the basis of the experience gained and lessons learned, improvements in safety guidance have been made. Some research and assessment work related to the behaviour of spent fuel in storage and in transport was also presented, and the IAEA provided an update on its safety standards for the storage of spent fuel.

There is a growing awareness that the storage and transport of spent fuel are linked because each stage in spent fuel management, whether it is related to open or closed fuel cycles, involves transport. The different timescales for transport and storage licensing have to be accommodated in regulations (short transport licence validity, usually less than a decade, versus storage licences valid for several decades). To address the interface issues between storage and transport, a holistic approach to regulation is needed.

Casks were initially considered for transport only; however, the dual purpose cask is now a well-established technology for storage.

Regulators are increasingly interested in obtaining information on spent fuel ageing for safety case development related to extended storage periods and also for transportation; those responsible for spent fuel management are starting to address these issues.

The evidence required by regulators to support proposed extended storage periods (>100 years) is likely to be in the form of data from accelerated tests plus evidence from the monitoring of structures.

Globally, there is extensive experience of a variety of different types of spent fuel storage technology. However, access to operational experience is rather limited and it would be useful to be able to share the information between countries with the same storage systems.

SESSION 6: ROUND TABLE — STAKEHOLDER ISSUES

A panel of experts was assembled to address four questions related to stakeholder issues. The panel was made up of people with different backgrounds. It was asked to address four questions.

The first was: What symbolism do you associate with spent fuel — what images and what attributes does it promote? A variety of answers was given and it is clear that much depends on whether people have experience of nuclear matters. Those who have no direct nuclear experience may associate spent fuel with a 'menace' or 'endless danger' and would not consider spent fuel different from radioactive waste. Members of the public in towns where nuclear facilities exist or are planned may have different views, mainly because they have been informed about nuclear issues and see a benefit for their communities.

The second question was: How can durable relationships be built with local people living in the vicinity of a planned spent fuel storage facility? It seems to be generally agreed that this has to be done by building trust through openness, transparency and respect. The building of trust may take some time to achieve. Involvement in decision making related to the facility also helps, as do improvements in the education of local people with regard to understanding the purpose and functioning of the facility.

The third question was: Is spent fuel a national problem or one between the spent fuel owner and the local community? It was generally agreed that this will ideally be seen as a national problem, but it depends on the national situation. In one of the countries represented in the panel, it was dealt with entirely at the local level with no national government involvement. In another country, it started as a local issue but is now a national one.

The fourth question was: Timescales for spent fuel management — is it an issue with stakeholders? Generally, the timescale issue is difficult for people to grasp and they are not usually able to distinguish conceptually between 100, 10 000 and one million years. One community did not want a storage to be in the local area for more than 50 years, and has obtained the agreement of the proponents on this.

SESSION 7: TECHNOLOGICAL INNOVATIONS FOR SPENT FUEL STORAGE

In this short session, presentations described progress in the use of burnup credit to optimize spent fuel storage arrangements while taking due account of the need to avoid criticality. In addition, some examples were given of technological innovations relevant to spent fuel storage.

The use of burnup credit criticality safety analysis to allow improvement in the arrangement of stored spent fuel assemblies is well established, and a report was presented on advances in the subject which had been reported at a special workshop in Spain in 2009. It was concluded that there had been a significant improvement in the spent fuel assay data now available, leading to more reliable assessments. Measurement studies in Belgium to improve assessment reliability were described, as well as an application of the burnup credit approach for high-power channel-type reactors in Ukraine.

Proven solutions to problems are not always the best, and a paper was presented which described a formalized approach that was being used in France to encourage and structure innovative ideas within an organization. Various methods are used to generate ideas, from discussions with customers to brainstorming. The ideas are then screened and the best ones are selected for application. Examples of ideas which have come from this process are: a method for optimizing spent fuel baskets, improved containment of casks, mitigation of hydrogen risks, neutron shielding, thermal and structural management and novel dry storage systems.

SESSION 8: FUEL AND MATERIAL BEHAVIOUR

With the likelihood of interim storage times being extended, it is more important than ever to develop a comprehensive understanding of the behaviour of spent fuel and its cladding and containment materials.

In an opening paper, an overview was given on the general status of nuclear power with emphasis on spent fuel. ‘Managed storage’ was described as a temporary activity, which needs to be safe and secure, for periods in excess of 100 years, in a passive system, with public acceptance. The important element which needs to be managed is ageing (degradation phenomena). Important potential material degradation mechanisms are: air oxidation, stress corrosion cracking, thermal creep, hydride reorientation and delayed hydrogen cracking. In several papers, experimental studies were described to investigate these mechanisms. To date, the evidence is favourable and suggests that storage systems will continue to provide safety for extended time periods. Confirmation would be provided by surveillance of the systems.

A substantial and comprehensive Japanese programme for the testing of metal and concrete casks was described. The programme has been conducted on behalf of the national regulator. It has involved tests to evaluate safety in scenarios involving normal operation, ageing, seismic events and accidents (including an aircraft crash). Generally, the casks performed very well with little evidence of failures that would lead to significant safety issues.

SESSION 9: MANAGING PAST AND DAMAGED SPENT FUEL

In this short session, several case studies on the strategies adopted to render damaged spent fuel from nuclear power reactors and research reactors safe were described.

Another paper described problems caused by corrosion of stored advanced gas cooled reactor fuel by intergranular attack, and a method of avoiding the problem through the use of an inhibitor compatible with the storage facility.

SESSION 10: OPERATING EXPERIENCE IN WET AND DRY STORAGE

In this session, several papers were presented describing operating experience of spent fuel storage in both wet and dry conditions. The session was useful in providing for the exchange of information on common issues between experts from different countries who might otherwise not be aware of solutions developed for similar issues to those they are facing. A report on an IAEA project to gather lessons learned in wet and dry spent fuel storage was also presented and provided a further basis for information exchange.

Two Japanese papers were concerned with determining the status of spent fuel casks after dry storage for up to ten years, and inspection procedures were described for that purpose. The results were favourable, with no signs of leakage and only minor signs of cask seal corrosion. Comments were made to the effect that in order to provide confidence that fuel recovery from the casks would be possible after several decades, some monitoring of the state of the fuel cladding and baskets inside the casks would be necessary, and some destructive testing of the cask contents would be needed.

An analysis of possible regional strategies for the back end of the fuel cycle in Central and Eastern Europe by an independent group of experts was described. It examined the potential for regional cooperation and looks to the far future, when there may be a greater degree of harmonization than at present and existing nuclear power plants will have been replaced by GEN-4 fast breeders, and regional geological repositories will be in use.

An analysis of the thermal environment in and around a store of dry storage casks using computer modelling was described. It illustrated how the study could be used to optimize the storage geometries to prevent overheating.

SESSION 11: DISCRETE ISSUES IN MANAGING HIGH BURNUP, MOX AND FAST NEUTRON REACTOR SPENT FUEL

Papers from a group of countries that have decided to pursue the closed fuel cycle described the progress being made in fast breeder reactor research

and development. Among the advantages sought are improved long term energy security, the saving of natural resources through the recycling of uranium and a reduction in the amount of radioactive waste needing disposal. Another paper discussed the options for using MOX fuel including further recycling in light water reactors, future recycling in advanced fast breeder reactors or direct disposal.

The introduction of high burnup UOX and MOX fuels has implications for spent fuel management. Some of these implications were summarized as a need for spent fuel pool upgrading to cope with extra heat generation, provisions to address the higher criticality potential, cask upgrading to allow for heat removal and repository modification to cope with higher radiation dose rates, as well as a greater potential for release to the environment. It was pointed out that most of these implications are negative and that they may be balanced by the advantages of introducing high burnup fuels. It was suggested that it could be useful for international organizations to undertake a study that provides a more balanced and fuller picture on this.

SESSION 12: FUEL REPROCESSING: STATUS AND CHALLENGES

Speakers from several countries committed to the closed fuel cycle described their countries' plans for recycling uranium, in both the immediate and the far future, and elaborated on the benefits of these strategies.

A paper presented by a participant from the United States of America, a country which has not committed itself to the closed fuel cycle but recognizes that there may be a need to do so in future, outlined the changes that would be necessary in the regulatory framework to accommodate recycling. For the time being, the United States Nuclear Regulatory Commission will look only at mature recycling technologies, e.g. PUREX based.

The presentations provoked a discussion on the merits of recycling. Questions as to the economic justification of recycling were raised, as were questions on its comparative safety aspects. It was noted that for countries committed to the closed cycle, the advantages of recycling and FBR technology mean that the justification is clear, but for other countries that, for various reasons including the disproportionate costs and scale required, have not committed themselves to the closed fuel cycle, the arguments are not so compelling. For these countries, the policy for the immediate future has to be 'wait and see'. It remains to be seen how these countries can share and cooperate in developments.

SESSION 13: MANAGING VERY LONG TERM STORAGE AND THE DISPOSAL OF SPENT FUEL

The progress being made towards the licensing of deep geological repositories in Finland and Sweden was described, with emphasis on the success achieved in obtaining acceptance of the projects by the local communities in which they will be sited. It is expected that the repositories will open for operation between 2020 and 2025.

Recognizing that small countries will have difficulty in developing a geological repository, and that each country needs access to a means of disposing of spent fuel or high level waste, discussions have been held to investigate the concept of a multinational repository. In particular, a European initiative called the European Repository Development Organisation has been started. The project has links with the European Commission. The participants emphasized the role of the IAEA in encouraging global multilateral initiatives.

In recognition of forthcoming studies in the USA to investigate the safety of the long term storage of spent fuel, a database is being established by the Electric Power Research Institute on behalf of the United States Nuclear Regulatory Commission. The database will contain information relevant to all of the areas identified as needing study related to welds and seals and their behaviour in salt atmospheres, fuel cladding and baskets, conditions warranting repackaging, ageing management, climate change effects, the influence of storage on transportability, record keeping and security. The Electric Power Research Institute welcomes external organizations interested in participating in their study.

CLOSING SESSION

SUMMARY AND CONCLUSIONS OF THE CONFERENCE[1]

A. Kakodkar
President of the Conference

Dear friends, I think we have had a productive conference this week on a very important subject, the management of spent fuel from nuclear power reactors — a subject that is linked with the role of nuclear power in meeting global energy needs in a sustainable and climate friendly way. I have carefully listened to most of the presentations and the discussion that followed, and I have also had the benefit of inputs from the session chairpersons and colleagues from the IAEA. It is always a challenge to condense a week of deliberations into a short conclusion. This is what I am attempting for you.

At the present time most of spent nuclear fuel in the world is stored in reactor pools and in interim storage. Although it is safe and secure, as the evidence from this conference confirms, it has to be recognized that such storage represents only an interim stage in any SFM strategy. While in countries like France, the Russian Federation, Japan, India and others there are ongoing programmes to recycle spent fuel, there is an urgent need to move on towards final disposal options. The delay has been caused, for the most part, by the slow rate of development of geological repositories for final disposal of spent fuel. Fortunately, as we heard in presentations, there is good news on this front — the geological repository projects in Finland, Sweden and France are moving towards the licensing stage.

It will still be several decades before repositories are available in all of the major nuclear countries. For these reasons, it is becoming clear that spent fuel will have to be stored for longer periods than initially intended. Storage times may have to be extended up to 100 years and beyond. Questions then arise about the safety, security and sustainability of storage over such long time periods. In order to demonstrate safety over these time periods a good understanding of the processes that might cause deterioration of the systems is needed. This conference has shown that these new priorities are reasonably well understood, and studies have been presented here aimed at investigating the various phenomena that might cause the failure of storage systems over long time periods. The issue is also being increasingly recognized by regulators, and we have heard about the sorts of proofs that they would be looking for in licensing storage facilities over extended periods of time.

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[1] The opinions expressed in this summary — and any recommendations made — are those of the participants and do not necessarily represent the views of the IAEA, its Member States or the other cooperating organizations.

More than 60 ‘newcomer’ countries have indicated that they are interested in developing nuclear power in their countries. Many of them have turned to the IAEA to obtain information on the implications and the infrastructure that would be required. While their initial attention tends to be on the legal, regulatory, educational and industrial infrastructure needed to start nuclear programmes, they also need to develop strategies for SFM. Information about reactor systems and fuel supplies is readily available from vendors, but it has proved to be more difficult for newcomers to obtain reliable information about the solutions that are required to be put into place in respect of the back end of the fuel cycle. It would be unrealistic to expect the vendors to provide a guarantee that all back end aspects would be provided, e.g. spent fuel reprocessing, storage and disposal. The IAEA should thus provide newcomer countries with all necessary information related to SFM aspects including the long term issues so that they become intelligent buyers and no loose ends are left in terms of SFM over the entire life cycle of the spent fuel.

In this context it is interesting to note that countries in which there are well established nuclear programmes seem to be learning lessons from the past. As part of the design approval process for planned new reactors in the UK, proponents are being required by the regulators to describe plans for decommissioning and radioactive waste management at the outset and, amongst other things, they are being required to explain how spent fuel can be stored, recovered and transported for periods in excess of 100 years, and how such facility lifetimes can be sustained.

Multilateral solutions for storage, reprocessing and disposal in which there are sharing mechanisms between countries would greatly help smaller countries with small amounts of spent fuel and waste, limited resources, and, sometimes, small land areas. However, while these are being actively discussed in various forums (some under the auspices of the IAEA) none have yet materialized.

Taking into account the evidence from around the world, it appears that spent fuel is being managed safely. It was recognized, however, that standards should be continuously reviewed to reflect new knowledge and experience gained. Some areas were identified where more guidance could usefully be developed, for example in relation to extended long term storage, and there was a suggestion that there could be greater harmonization in certain areas, such as international requirements for dry cask design.

There is a growing awareness that the storage and transport of spent fuel are linked because each stage in SFM, whether it is related to open or closed fuel cycles, involves transport. Casks were initially considered for transport only. The ‘dual purpose’ cask is now a well established technology for storage. To address the interface issues between storage and transport, a holistic approach

to regulation is needed in which the different timescales for transport and storage licensing are accommodated.

One focus of the conference was on understanding the degradation phenomena that might affect the storage of spent fuel over long time periods. Important potential material degradation mechanisms are: air oxidation, stress corrosion cracking, thermal creep, hydride reorientation and delayed hydrogen cracking. In several papers experimental studies were described to investigate these mechanisms. To date, the evidence is positive and suggests that the storage systems will continue to provide safety for extended time periods. These conclusions are supplemented by comprehensive programmes for the testing of metal and concrete casks involving tests to evaluate safety in scenarios involving normal operation, ageing, seismic events and accidents (including an aircraft crash). Generally, the casks performed very well with little evidence of failures that would lead to significant safety issues.

There was recognition about the benefits of the Joint Convention; the process of exchange of information between countries promotes confidence and belief in other countries with respect to radioactive waste management. The international organizations are encouraged to continue and, if possible, to increase peer reviews and regulatory reviews. Together they provide evidence that countries are meeting their international safety obligations.

We need to emphasize that credible engineering solutions for disposal of long lived radioactive waste are feasible and can be implemented in a manner that assures safety of people and the environment. Public acceptance about radioactive waste and its disposal, however, remains an issue and would require political will for forward progress in tune with the expected growth in nuclear power programmes worldwide. It must be recognized that a repository is necessary regardless of whether one opts for a closed or open fuel cycle. The issue of repository thus must be effectively addressed if nuclear energy is to be more generally accepted. While the experiences in countries vary, it seems to be generally accepted that public support for nuclear projects has to be obtained by building trust through openness and transparency, and more importantly by gaining respect through sustained credible performance. The trust building process may take some time to achieve. Maybe there is scope here for a well informed international technical view in respect of repositories. The involvement of local people in decisions related to the facility also helps. Similarly, if local people can be educated to understand the purpose and functioning of the facility, this will alleviate many of their concerns.

Climate change concerns, the availability of uranium and its price and the philosophy held with respect to sustainable disposal of spent fuel will determine the approach towards either the nuclear recycle route or the direct disposal route. It seems that while adoption of the nuclear recycle option in some countries will

lead to the enhancement of the nuclear energy potential from uranium, in some other countries there will be growth in nuclear power capacity on the basis of the once through use of uranium. In either case, it is important that the road map with respect to management of spent fuel over its entire life cycle is clearly defined and is being acted upon.

Experience in France has shown that nuclear recycle is cost competitive and leads to more energy with less waste. A global consensus, which does not exist at the moment, should lead to a more sustainable solution to the energy and climate crises that the world faces today.

Advances are taking place with respect to the higher burnup of fuels, the development of fast reactors and advanced fuel cycles. These have been demonstrated on an industrial scale. While this does bring in additional considerations with respect to the management of spent fuel storage, it seems that they can be accommodated within the available solutions.

Developments in nuclear power technology have enabled solutions to the question of meeting growing energy needs and we should expect growth in nuclear power development on the basis of these solutions. Research and development may enable further advances in the future. Most important among these is the possibility of reducing the radiotoxicity of radioactive waste to acceptable levels within a reasonable time period and bringing in greater proliferation resistance. There is urgency in realizing such solutions to overcome the remaining barriers to the growth of nuclear power worldwide.

Dear friends, you will agree with me that this conference has enabled a comprehensive discussion on a wide range of issues related to the management of spent fuel from nuclear power reactors. The exchange of information and views expressed at this conference will enable different programmes around the world to benefit from the experience of others. More importantly, the discussions here should be of significant benefit to countries about to start their own nuclear programmes. The discussions have also provided a view of the current interests and directions being pursued by the Member States of the IAEA and will facilitate the shaping of IAEA activities in this area. Let us hope that as we exploit nuclear energy for our use, we do not deprive future generations of their energy needs. Even more important is the aspect that we do not burden future generations with waste management problems that we could not solve.

Let me, on your behalf and on my own behalf, once again thank the organizers for putting together this very useful conference. Thank you.

Annex

CONTENTS OF THE ATTACHED CD-ROM

The following papers and posters presented at this conference are available on the attached CD-ROM. Please note that Sessions 4 and 6 were round table sessions and therefore no papers were presented at them.

SESSION 2: STRATEGIC ISSUES AND CHALLENGES IN SPENT FUEL MANAGEMENT (SFM)

Integrated strategy for spent fuel management
M. Weber

Indian strategy for management of spent fuel from power reactors
S. Basu

Nuclear spent fuel management in Spain
P. Zuloaga

Management of spent fuel in Germany
U. Alter

The required level of design of waste plants for new build reactors in the generic design assessment
C. Fischer

Long-term management of spent fuel in Canada
K. Nash

SESSION 3: SFM FOR SMALLER PROGRAMMES AND NEWCOMER STATES

Spent fuel challenges facing small and new nuclear programmes
C. McCombie

Spent fuel in Chile
F. López Lizana

SESSION 5: SAFETY AND LICENSING OF SPENT FUEL STORAGE AND TRANSPORTATION

SESSION 7: TECHNOLOGICAL INNOVATIONS FOR SPENT FUEL STORAGE

The role of technological innovations for dry storage of used nuclear fuel
H. Issard

Advances in burnup credit criticality safety analysis methods and applications
J.C. Neuber

Experimental methods and Monte Carlo simulations for burnup assessment of spent fuel elements
A. Borella, R. Carchon, K. van der Meer

Meet the challenges of spent fuel interim storage by using intensive innovation
J. Garcia, S. Compere, O. Jung

Evaluation and selection of boundary isotopic composition for burnup credit criticality safety analysis of RBMK spent fuel management
Y. Kovbasenko

SESSION 8: FUEL AND MATERIAL BEHAVIOUR

Integrity assessment of CANDU spent fuel during interim dry storage in MACSTOR
J.W. Lian

Challenge to overcome the concern of SCC in canister during long-term storage of spent fuel
T. Saegusa, J. Tani, T. Arai, M. Wataru, H. Takeda, K. Shirai

Demonstration test program for long-term dry storage of PWR spent fuel
M. Yamamoto, T. Fujimoto, K. Shigemune, H. Matsuo, T. Matsuoka, D. Ishiko

Demonstration drop test and design enhancement of the CANDU spent fuel storage basket in MACSTOR/KN-400
W.S. Choi, J.Y. Jeon, K.S. Seo, J.E. Park

Distributions of fission products on PCI in spent PWR fuel using EPMA
Y.H. Jung, Y.B. Chun, S.B. Ahn, W.S. Ryu

Evaluation of creep during dry storage in low and high burnup fuels
F. Feria, L.E. Herranz

Materials performance and ageing considerations for power and research reactor spent nuclear fuel in storage systems
R.L. Sindelar, N.C. Iyer, T.M. Adams, G.T. Chandler

Testing of metal cask and concrete cask
K. Shirai, M. Wataru, H. Takeda, J. Tani, T. Arai, T. Saegusa

SESSION 9: MANAGING PAST AND DAMAGED SPENT FUEL

Management of damaged SNF handling operations at PAKS NPP
E.A. Zvir, V.P. Smirnov, I. Hamvas

Development of an alternative corrosion inhibitor for the storage of advanced gas-cooled reactor fuel
P.N. Standring, B.J. Hands, S. Morgan, A. Brooks

Damaged fuel storage and recovery — A case study
D.L. Fischer, N.C. Iyer, R.L. Sindelar, J.E. Thomas, T.J. Spieker

Proposals on AMB SNF management
V. Smirnov

Organization of work with accumulated damaged spent nuclear fuel
V. Smirnov

SESSION 10: OPERATING EXPERIENCE IN WET AND DRY STORAGE

Results on technical and consultant service meetings on lessons learned from operating experience in wet and dry spent fuel storage
B. White, X. Zou

Indian experience in commissioning, operation and safety of wet type spent fuel storage facilities
B. Shreekumar, K. Agarwal

SESSION 11: DISCRETE ISSUES IN MANAGING HIGH BURNUP, MOX AND FAST NEUTRON REACTOR SPENT FUEL

SESSION 12: FUEL REPROCESSING: STATUS AND CHALLENGES

Overview of spent fuel management in China
G. Deng

The Korean strategy for nuclear fuel cycle
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Complex approach to study physical features of uranium multiple recycling in light water reactors
A.A. Dudnikov, V.A. Nevinitsa, A.V. Chibinyaev, V.N. Proselkov, A.Y. Smirnov, G.A. Sulaberidze

Introduction of the large scale spent fuel reprocessing plant in China
Y. Dai

Updating the regulatory framework for spent nuclear fuel reprocessing
T.G. Hiltz, A.G. Croff, R.G. Wymer

SESSION 13: MANAGING VERY LONG TERM STORAGE AND THE DISPOSAL OF SPENT FUEL

Experience in analyzing safety of SNF management back-end in the Russian Federation
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Developing the technical data supporting licensing of very longterm dry storage of spent nuclear fuel
R. Einziger, E. Benner, C. Regan

Construction of first phase of spent fuel repository in Finland: Lessons learned and success factors
T. Varjoranta, R. Paltemaa

Multinational initiatives for longterm spent fuel management: an update on current international projects
N.A. Chapman, C. McCombie, E. Verhoef

POSTER SESSION

Managing ageing in spent nuclear fuel storage facilities
S. Fabbri, G. Vega, R.A. Versaci

Spent fuel management in Bulgaria
D. Dacheva

Differences of technical requirements between transportation and storage metal casks
R. Asano

Nuclear energy and public opinion: Chile's case
G. Gonzalez

The state of the WWER nuclear spent fuel management in Ukraine and trends on the optimal choice of spent fuel management strategy
I. Tregub, G. Raspopin, G. Luchna

Atucha I: NPP spent fuel dry storage conceptual design
G. Moliterno, O. Beuter, J.M. Frediani, S. Zanni, J.P. Oyola

Management of casks in Japan's interim storage facility
N. Shimoozaki, S. Kawamura, S. Hoshikawa, M. Yamamoto

Improvement of operational safety of dual-purpose cask for SNF in storage
T. Makarchuk, A. Glukhov, A. Semenov

Spent fuel management program in the 3 MW TRIGA Mark-II research reactor of Bangladesh
M.A. Salam, M.A. Zaman, M.M. Rahnan, A. Kalam, M.M. Haque, M.A. Zulquarnain

Safety aspects and economic impacts of spent fuel management policies in PWR nuclear fuel cycle
A.A. Gadalla

Exploring alternatives for nuclear fuel disposal in Mexico
J. Ramón Ramírez S., Javier Palacios H., Verónica Badillo A.,Gustavo Alonso

Thai strategic plan for spent fuel management
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INTERNATIONAL ATOMIC ENERGY AGENCY
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ISBN 978–92–0–103714–5
ISSN 0074–1884