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Planning, managing and organizing the decommissioning of nuclear facilities: lessons learned

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FOREWORD

Decommissioning of nuclear facilities is a process involving activities such as radiological characterization, decontamination, dismantling of plant, equipment and facilities and the handling of waste and other materials. Many organizational and management needs arise during the course of decommissioning projects. Factors such as schedules, work progress and the outcome of regulatory and other interfaces may influence project planning and implementation.

Published information and guidance on management and organizational aspects of decommissioning are scarce in comparison with those on technical subjects. Guidance on organizational aspects may lead to better decision making, reductions in time and resources, lower doses to the workers and reduced impact on public health, safety and the environment. An IAEA publication (Technical Reports Series No. 351) deals with planning and management aspects of research reactors and other small facilities. A more recent publication (Technical Reports Series No. 399) deals with large nuclear facilities. With growing experience in the decommissioning of some large scale nuclear installations, including the completion of some large scale decommissioning projects over several years, it is timely to gather and consolidate practical experience, issues and lessons learned in the management of a wide range of nuclear facilities. Good and bad experience is reported. It is intended that this report should be a source of information for those involved in the planning and execution of decommissioning projects.

A technical meeting on the present subject was held in Vienna from 24 to 28 March 2003. The meeting was attended by thirteen experts from eight Member States and one international organization. The participants discussed and revised a preliminary draft document written by a group of consultants from Belgium, Canada, Germany, Spain and the United Kingdom, and the IAEA. Through these consultations, information and experience from a wide range of sources were identified and incorporated in the publication. After the technical meeting, the text was revised by the IAEA Secretariat with the assistance of A. Brown (United Kingdom) who had been involved in the preparation of this publication from its beginning.

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CONTENTS

1. INTRODUCTION

1.1. Background

For nuclear facilities, decommissioning is the final phase in their lifecycle after siting, design, construction, commissioning and operation. It is a complex process involving operations such as detailed surveys, decontamination and dismantling of plant, equipment and facilities, demolition of buildings and structures, site remediation, and the management of resulting waste and other materials. All activities take place under a regulatory framework that takes into account the importance of the health and safety of the operating staff, the general public and protection of the environment.

Careful planning and management is essential in ensuring that decommissioning is accomplished in a safe and cost-effective manner. Until the mid 1980s decommissioning experience was scarce, but much has been learned in the intervening period in all aspects of the discipline. Sometimes the magnitude of the projects was over estimated and projected costs were believed to be very high. This often gave rise to a slow down, or even failure to start the decommissioning process while on other projects the tasks were underestimated, resulting in some mistakes being made. With experience, confidence has been gained and there has often been an incentive to publish and make much information available, particularly in the form of lessons learned. Numerous guidance documents have been published, particularly by the IAEA on subjects such as technologies, strategy, safety, waste management, regulation and by other organizations such as the US NRC and DOE, OECD-NEA, and the European Commission.

There is a growing volume of information being published annually and mainly presented at international conferences by specialists in various fields related to decommissioning. These present mainly good experiences; however, sometimes mistakes and lessons learned are included. There appears to be an increasing recognition that lessons learned should be reported. However, it should be noted that published information on organizational and management aspects of decommissioning is scarce in comparison with that on technical aspects. It is important for the collected body of international experience in decommissioning planning and management to be assembled and published for use and interpretation by those engaging in these activities. This document tries to meet this need.

1.2. Objective

The objective of this document is to encourage the development and improvement of decommissioning planning and management techniques. The focus is on organizational aspects, to reduce the duplication of effort by various parties through the transfer of experience and know-how and to provide useful information for those Member States planning or implementing decommissioning projects.

The document summarizes the reported experience in the planning and management of decommissioning. It is particularly aimed at decision makers, plant operators, contractors, and regulators involved in the planning and management of decommissioning activities. This is particularly applicable to nuclear installations, which are approaching the end of their operating lives.

1.3. Scope

The scope of the document is to report experience in planning and management of decommissioning of all types of nuclear installations from experimental and research reactors through to large commercial facilities and including fuel cycle facilities. The reporting of experience and lessons learned on technical issues is not within the scope of this document. Technical description and information is only included where it is needed to support or clarify management issues. Data and information published and freely available is the main source material.

Publications from international conferences on decommissioning are a particularly valuable source of reported experience and these have been extensively used in this report. The information is presented without undue comment or interpretation but its relevance to the subject matter of this document is highlighted as appropriate.

The document is not intended as a guide even though some guidance may be implied. Other documents have been published which give guidance, in particular Safety Guides and technical reports by the IAEA [1, 2]. In particular, the technical report [1] gives guidance on organizational aspects of decommissioning and describes factors relevant to planning and management. The material that follows in this document focuses on documented experience and lessons learned.

1.4. Structure

The document consists of four sections and two appendices. As an overview, a commentary is given in Section 2 on general experience reported over the last 10 years or so. The subject matter is then presented in more detail in Section 3, based on selected experience, and grouped into particular aspects of planning and management such as organization, project and cost management, personnel management, stakeholder issues and data and records management. Conclusions reached are given in Section 4. Appendix 1 gives lessons learned that are presented in the form of cases offered by contributors from Member States. Appendix 2 lists important radiological factors to consider in decommissioning planning. A list of contributors to the drafting and review is also included.

2. GENERAL EXPERIENCE IN PLANNING AND MANAGEMENT

2.1. General

With many nuclear installations approaching the end of operating life or already shutdown, many countries are faced with defining strategies and establishing the planning and management activities necessary to conduct decommissioning in a safe, timely and economic manner. However, the approach to decommissioning varies from country to country. This is due to the range of expertise available and the differing political and economic situations. This section of the report identifies planning and management experience that is more generic to a broad range of decommissioning projects.

In general, it can be stated that technology exists to ensure that decommissioning projects can be completed within a regulatory framework without any significant effect on the safety of the workforce and the public or any significant radiological impact on the environment. However, timeliness and cost-effectiveness are not always optimal. It has been noted on several occasions that the major weakness in decommissioning projects is poor or inadequate planning and management, including unclear identification of roles and responsibilities. This is unfortunately true in both developing and industrialized countries.

This document is intended to stimulate an awareness of the need for early and effective planning for those starting decommissioning projects and to foster developments in management and organization in association with planned or ongoing decommissioning projects. The reporting of good and bad experiences is equally effective in this respect.

2.2. Planning, management and operational issues

General experience has shown that there are a number of central issues facing management which ideally require attention some years before a plant is finally shut down. Several of these, as listed below, were selected based on this experience.

Stakeholder[1] issues including staff and public relations

Regulatory and licensing issues including Environmental Impact Assessment

Organizational restructuring

Decommissioning plans and technology

Training and retraining

Defuelling and fuel management

Waste management and disposal

Funding and finance

Project strategy, planning and contracting

Records and documentation.

The following paragraphs discuss various aspects and key issues but do not follow the above list rigorously. This is because many issues overlap and are discussed in relation to each other. Several lessons learned relating to key issues can be found in Appendix 1.

There are a number of key stakeholder issues to be considered, including staff at the affected installation, the local community, government bodies and pressure groups (see Section 3.4 and Appendix A1.1).

A common cause of problems early in the planning of decommissioning, even before shut down occurs, is the uncertainty experienced by operators about their future employment. Often the first persons to become involved in the planning for decommissioning are the operators whose primary objective has, until then, been to achieve effective operation and maintenance. This often presents a problem because of reluctance to accept and engage in the final shutdown of their plant while maintaining focus on production objectives. There is also the unpalatable situation of having final shut down decisions made elsewhere (not at the plant) for political, safety, environmental or economic reasons.

The general lack of experience in decommissioning activities, particularly in planning and management, is also a problem. The failure to recognize these situations may result in low morale, unnecessary delays and inevitably increased costs. Many decommissioning projects are delayed for many years on account of lack of adequate planning and management infrastructure. In such situations funds that could be deployed usefully for decommissioning are spent on maintaining a mothballed state[2], which depletes financial resources. (see Section 3.2)

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[1] A stakeholder is person, group or organisation who can affect or is affected by an activity.

[2] An enclosed state with some measures to minimise deterioration.

The relative importance and priority of the listed issues will vary at different times and stages of the process, but experience has shown that the most immediate issues are probably those of staff and public relations, especially if the shutdown was sudden and unexpected. The regulator will want to know what arrangements are being made to sustain safety and that plans are in place to allay public and stakeholder concerns. These are often directed through the regulatory body. Management must be prepared to expend an inordinate amount of effort in dealing with staff morale and downsizing issues and in facing a barrage of perceived and real public concerns. Evidence of this is reported extensively in Section 3.4

Personnel management and staff morale is a serious factor when the final shut down of a facility is announced. In cases when decommissioning started some years after plant shutdown, a different problem could arise due to lack of expertise, reducing plant knowledge and diminishing ability to manage plant dismantling. The early loss of the best and most effective staff is also common, especially if there are other career opportunities available. At remote or isolated sites where there are minimal alternative job opportunities, a prevailing situation of frustration and fear can occur. If the economic situation in a country is also precarious, then opportunities for reemployment of surplus staff becomes an additional burden.

Licensing is a vital function when decommissioning is planned and implemented. This will usually be provided by a regulatory body. The particular role and function of the regulator is sometimes initially unclear. In situations where the shutdown of the plant for decommissioning is the first in a country, the regulator may be unprepared for regulating decommissioning and waste management and there may also not be a regulatory framework. It has often been found that the regulator lacked appropriately trained staff and knowledge of decommissioning processes. Much closer collaboration between operator and regulator can be beneficial (particularly in case of a first-of-a-kind project in a given country) although this may raise concerns about the independence of the regulator's role and duties.

A safety case that needs assessment to demonstrate safe decommissioning practices and techniques is a definitive requirement. The safety case addresses risks and hazards and needs assessment by or on behalf of the regulator before approval for active decommissioning can take place. The level and extent of safety assessment is appropriate for the risks involved and a graded approach to safety management can save time and avoid unnecessary complication. Quality assurance procedures are also then drawn up and put into effect. If necessary, an environmental impact assessment [3] or statement is produced to satisfy interested bodies and public authorities (stakeholders). Regulatory/licensing issues and project scheduling are also associated with the application of environmental assessment legislation. More detail is presented in Appendix A1.2.

At shutdown and for short interim periods thereafter, instituting completely new nuclear safety procedures is not usually necessary because the safety procedures and culture will initially remain valid from operations. If spent fuel management is undertaken promptly, which is a normal post operational function, then immediate risks should not increase. However, when dismantling, decontamination and waste management activities for decommissioning are entered into, then new and unforeseen hazards may arise.

It is extremely important to appoint a decommissioning manager and preferably to do this before the plant is shut down. This manager would have the responsibility for undertaking the development of an adequate decommissioning plan. The manager need not necessarily have direct experience in the operation and maintenance of the plant. Sometimes formulating this plan can be the responsibility of a central company headquarters department, if this exists, or undertaken by engaging specialist consultants or contractors.

An appropriate organizational structure is needed for the decommissioning task force in order to identify lines of responsibility and to allow individual responsibilities to be defined. A particular case is presented in Appendix A1.3. At an appropriate time, the decommissioning organization must be merged or replace the existing operational structure which will eventually cease to exist. At a site where there is plant that is to be shutdown while some others remain in operation, it is vital to clarify the demarcation between operational and decommissioning responsibilities.

Restructuring the organization for decommissioning is often very problematic. The change from an operating regime with clear production goals to one aimed at demolition, dismantling and disposal, is difficult in a project and regulatory environment. A number of examples of initiatives to achieve this are given in Section 3. A fundamental change in the organization is beset by problems associated with staff morale, a persistent hope that the plant will restart and the lack of suitable training for both management and workers. Lack of equipment and financial resources to undertake even simple tasks often occurs. More seriously, confusion can arise if there is no decommissioning plan or any clear strategy or objectives. This condition can be exacerbated if, for example, key issues such as spent fuel management are not being resolved in a timely manner. Specific aspects of decommissioning planning are given in Section 3.2 and Appendix A1.4.

In changing an organization from an operating regime to decommissioning, there is a need for cultural change. This can be achieved by retraining in-house staff, extensive use of experienced contractors or, even more drastically, by changing the ownership/licensee of the facility to one specifically created for decommissioning.

Retraining initiatives can also be hampered by lack of planning and clear objectives because the relevance of training programmes may not be focussed. Instances have occurred where training in aspects of decommissioning was provided by outside organizations but subsequent reorganization rendered this ineffective or wasted. A particular case where training and retraining is focussed on new techniques and a changing situation is given in Appendix A1.5.

The process of defuelling is not likely to be problematic since spent fuel management has usually been an on going routine process during the years of operation. Longer term management of spent fuel however often becomes a problem in terms of storage capacity, long term at reactor storage or shipping away from the reactor site for storage or processing. At some facilities, spent fuel storage becomes the dominant problem because lack of forward planning has resulted in shortage of capacity and sometimes potentially unsafe storage conditions. In many cases, the start of decommissioning has been delayed because of spent fuel management problems. In some research reactors, refuelling is not a routine activity, and this situation can be a serious issue at the time of permanent shutdown. A case where a spent fuel management strategy impacts on decommissioning strategy is given in Appendix A1.6.

Waste management is an essential part of planning and will severely curtail dismantling and decontamination activities if adequate provisions are not made or are not available at the appropriate time. In some Member States, disposal routes for decommissioning waste are not yet available and arrangements are then made on site to store waste in a safe manner. Conditioning and stabilising waste to reduce risks of degradation, dispersion, and unauthorized removal is often a requirement of the regulator or environmental protection agency. Lessons learned relating to waste management are given in Appendix A1.7.

Financial provisions to cover all immediate and future decommissioning costs need to be established to ensure that decommissioning is a continuous process carried out in a safe manner. Techniques for estimating decommissioning costs have been proposed [4] and experience is available from published material. Many regulators now require the accumulation of sufficient funds from revenues during operation for eventual use in decommissioning. Arrangements for the securing of these funds are often a legal requirement. A project risk assessment should be undertaken to identify factors that could have a serious adverse effect on the decommissioning project in terms of cost and programme.

Insufficient provision of financial resources for decommissioning is often a reason for delayed start. This is due to lack of the early and timely provision of funds from revenues during operation. This situation has been addressed in a number of countries. However the existence of these funds needs to be assured because there are instances where adverse economic conditions in countries have curtailed the use or provision of funds. It is curious that substantial funding for maintaining the status quo at a shut down facility is often readily provided but there is no allocation for decommissioning. See Appendix A1.8.

An important aspect of decommissioning planning by organizations with limited or insufficiently trained in-house resources, is to decide on the need and extent to which specialist outside contractors are engaged. This will depend on many factors such as the identified need for specialist expertise, the availability of suitable alternative internal resources and the provision of the necessary funding. All these decisions are part of the primary management and planning function to formulate an appropriate strategy. Some examples of experience in the use of contractors versus in-house resources are given in Appendix A1.9.

If there is insufficient in-house knowledge or expertise to manage contracts effectively, then problems such as delays or serious cost overruns can arise. Regulators can also express concern about safety issues and risks where licensees tend to transfer some licensing and safety responsibility to contractors without ensuring adequate control. Several examples of problems associated with use of contractors are presented in Section 3.3.

A problem that frequently occurs is the lack of timely attention given to the management of facility operational records relevant to decommissioning. There are often statutory or other incentives to retain records for legal, technical or commercial reasons such as ownership title deeds, operating licence documentation, technical records to support continued operation, maintenance and safety cases, staff health and dosimetry records and financial accounts. Documentation specifically important for decommissioning (e.g. for site decontamination, dismantling and care and maintenance) is however more difficult to identify and needs to be done in the context of decommissioning plans. The practice is usually to retain everything in the hope it will be suitable for decommissioning. This results in an inordinate quantity of documentation which is often unmanageable and can result in loss of valuable information. Guidance in the management, criteria and experience in record keeping for decommissioning purposes has been addressed in [5]. Appendix A1.10 provides a few case histories relevant to lack of records.

2.3. Decommissioning experiences

Over the last decade a wealth of decommissioning experience has been accumulated and has revealed some best practices, mistakes and associated lessons learned. It can be said that hardly any of the problems were of a serious technical nature. Many problems were associated with management and staff relations during the transition to decommissioning. In some cases shortage of funds has been the main factor for delays in the start of decommissioning. Although there often seem to have been funds available from the operating period, at least to assure continuing surveillance and maintenance, such funds were often insufficient for the implementation of an active decommissioning strategy. In addition, the recurrent challenge is to conserve that funding by adapting the staff resources to the new tasks of shutdown and decommissioning. Not all experiences have been published, but some general experiences that are available are given below. These will be complemented in Section 3.3 with more detailed and specific feedback extracted from various publications.

The United Kingdom, with a large but ageing nuclear programme, encountered a number of problems and learned lessons associated with decommissioning planning, studies and the early management of decommissioning. Important lessons and experience from that programme in the early 1990s were noted but not published. There is an opportunity to highlight these as follows:

- Generic studies of decommissioning were started more than 15 years before the first plant was shut down but were mainly for outline costing purposes and to highlight any potential technical problems. In a study on cost estimates it was found that earlier initial estimates tend to be over estimated especially as large contingencies were added for uncertainties. As cost estimating became more refined and accurate, costs estimates were reduced since smaller contingencies could be applied.
- Very detailed studies were started on two plants just before the final shut down of the first plant. They were not completed before shutdown in spite of the regulators request to complete and submit plans at least two years before shutdown. The other plant that was studied in detail continued to operate for another 10 years. Two additional plants, that had not been studied in detail, shut down subsequently and there were therefore three plants needing attention. The lack of practical decommissioning experience was very apparent.
- The actual shutdown date of a plant was never established in advance and came as a surprise because the decision not to restart was made after a maintenance and upgrading outage, which proved in the end to be too costly for continued economic operation for the remaining plant life. It was accepted that precise shutdown dates cannot be predicted, although in subsequent years this was changed and a planned closure programme was declared.
- A detailed and comprehensive strategy study was undertaken covering all plants. This established a strategy of deferred dismantling (deferral for many decades to take account of beneficial radioactive decay, to reduce immediate decommissioning costs and due to the lack of a suitable waste disposal route).
- Detailed plant specific plans were subsequently made in a short period of about 2 years for all power plants within the country. This was the responsibility of a central headquarters specialist group. The work proceeded with minimal and only reluctant involvement by operating plant staff whose main objective was to continue operation. The control and planning of decommissioning from a headquarters department caused conflict with the plants in terms of responsibility and proposals. In retrospect, more operating staff involvement should have been orchestrated for the decommissioning planning.
- The regulator was not inclined to approve the decommissioning plans as a whole due to the extended time scales of the decommissioning programme. They preferred to give approval for day-to-day activities, which was their normal regulating practice. This gave the opportunity to make amendments to the plans at later dates but also made plans susceptible to regulatory changes since they were never officially approved.
- Public relations issues occurred almost immediately after shutdown was announced and a great deal of effort was expended in satisfying interested parties and the public

(stakeholders). During the operating period, interest in the plant was not nearly so intense.

- Staff morale problems were significant at all three plants but especially at two of the plants that were more remote with fewer opportunities for re employment. Staff relationship problems occupied considerable management time.
- A particular problem was that the site licence, (a single licence which covers operating and decommissioning responsibilities), was held by the operating organization and they proceeded to undertake defuelling and spent fuel management under the licence. This caused conflict with early decommissioning activities. Only when the licence responsibility was transferred to the decommissioning team was the conflict allayed. In addition, the regulator was not initially prepared for decommissioning and regulated the site as though it was still an operating organization. This caused delays.
- The situation concerning lifetime records for decommissioning was worse than expected and left too late i.e. after most of the experienced staff had left. The lessons from this adverse experience should contribute to better records management for the future.
- The on site management and conditioning of long stored operational waste was deferred too long. This should have been attended to during operation and not left until the end of operating life. This led to significant problems during decommissioning.

In the USA, experience and perspectives in the regulation of decommissioning has been reported [6]. These findings are summarized below.

The US relies on multiple regulatory agencies to control nuclear waste. In particular, an Environmental Protection Agency (EPA) develops standards for radiation in the environment and the U. S. Nuclear Regulatory Commission (USNRC) regulates licensing and decommissioning. The US Department of Energy (USDOE) manages cleanup of USDOE facilities. Some responsibilities for special nuclear materials, sources, by-products etc. are carried by individual States. The USNRC operates a risk informed, performance based strategy. It does not however endorse a probabilistic risk analysis approach.

The USNRC established decommissioning rules in 1988 with the promulgation of standards particularly to set aside sufficient funds for decommissioning. This requirement was modified between 1993 and 1997 to set up a financial assurance mechanism. Decommissioning procedures were formally issued in 1996 and criteria for licence termination finalized in 1997. An allowance was made to allow sites to be released for restricted use where it could be demonstrated that it was not ALARA to clean them up to meet unrestricted release levels.

The delays in the start of decommissioning by utilities was identified as a concern to the USNRC and a rule on the timing was introduced to allow only 2 years for a facility to remain idle, before submission of a decommissioning plan.

Another modification of the rules was setting up a system for ensuring retention of the records necessary for decommissioning. This was considered to be a safety related issue.

Attention also had to be given to the multi-faceted aspects of radioactive waste management particularly regarding the issues of toxic, non-radioactive materials and mixed wastes.

Decommissioning also raised other aspects involved in licensing:

- Impact of the National Environmental Policy Act of 1969
- Quality Assurance

- Recycle and reuse of contaminated materials
- Cost optimisation
- Overlapping responsibilities of the USNRC and the EPA.

In 1990 a Site Decommissioning Management Plan was established to focus on a series of difficult situations involving contaminated soils, water and other materials associated with site remediation. Experience with Fort St. Vrain and Shoreham revealed that final surveys to demonstrate compliance for site release were very costly. A new final survey guidance manual "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) was published in 1997 as part of a new site licence termination rule. This new survey protocol uses statistical analysis to demonstrate compliance with decommissioning standards and is expected to reduce final survey costs [6, 7].

The USNRC have adopted a generic approach to the assessment of dose and risk and use the concept of an average member critical group which is defined in terms of residual activity, source location and potential exposure scenarios.

The common problem of naturally occurring radionuclides in the context of site clean up was approached by the use of a simple conservative screening approach, rather than sophisticated and complex models which may not be sufficiently robust to use under diverse site and environmental condition.

It was recognized that there are a number of issues that are especially relevant and significant to decommissioning and site clean up. These are:

- Uniformity and consistency in site clean up criteria
- Validation of dose models and their uncertainties
- Resolution of key technical shortcomings in determining compliance with criteria
- Sharing of lessons learned from past experiences.
- Bringing about pragmatic strategies for dealing with site clean up.
- Public involvement in the decision making process.

Issues associated with organization and management of decommissioning from a US viewpoint was presented at a workshop held in Bratislava on the subject of planning and management [8]. The key points were:

- During operation there should be a small group to study and plan for decommissioning
- Factors to be considered are strategy, staffing, extent of work
- The periods of decommissioning depending on the strategy
- The decision on who will do the decommissioning (in house staff or contractors)
- The extent of guidance given by the regulator
- The national spent fuel policy and the available storage facilities
- The waste disposition policy and the availability of disposal or storage sites.
- The type and size of organization will depend on the above.

In 1999 a combined NEA /IAEA/EC workshop was held in Rome, focussing on the regulatory aspects of decommissioning. In this workshop there was a section on Human Factors and Organizational Issues, which is of particular interest to this report [9].

Particular aspects of human relations regarding safety culture and staff morale were emphasized and the threat that these can have to the project due to change and uncertainty. A number of approaches had been developed by utilities including guaranteeing employment for a certain period and emphasising the new and important technical challenges. Presenting decommissioning as an opportunity rather than a threat was an important message and good and timely communication was seen as a major tool. The sharing of international experience both successful and less successful was also recommended.

The following eight key issues were identified:

- impact of delays in decommissioning
- use and control of contractors
- sustaining safety culture and morale
- identifying key organizational functions and management skills
- reconciling regulatory demands and government policy with decommissioning
- sustaining organizational memory and staff competence
- decommissioning at sites where other facilities keep operating
- developing an experience feedback system

Key findings from the workshop are given below:

- There is a significant variation in the reasons for final shutdown which have a significant impact on organization and human factors
- The risk profile of the plant changes during the transition from operation to shutdown and eventually to the decommissioning state. This is generally from high risk, low probability to low risk, high probability and the perception of workers and management of this situation may be under estimated.
- The retention of staff competence for decommissioning work is crucial. Strategies for retention of skills need to be developed and implemented early in the decommissioning planning process.
- Emphasis on the sharing of experience on organization and human factors is needed since many decommissioning activities are performed only once or at most a few times.
- Regulator and Government oversight of decommissioning needs a clear and consistent strategy, especially if a number of licensing agencies are involved.
- The extensive use of contractors creates a number of issues. The responsibility of the licensee is paramount and there is a need to demonstrate an intelligent customer capability and to maintain sufficient control and supervision of the contractor’s work.
- There is a need to avoid degrading of the perception of risk and to guard against a tendency toward lax management and low staff morale especially during periods of increased uncertainty.
- No optimum organizational structure emerges except the need to have a dedicated decommissioning team with sufficient resources.
- A summary of the outcome of the above workshop [9] also exists in an OECD publication on the transition from operation to decommissioning that considers human factors and organisational considerations [10].

The problems of approaching decommissioning of nuclear installations in Italy arises from the following:

- The significant amount and different types of installations to be dismantled, (power plants, reprocessing plants and experimental facilities);
- The absence of any plant still in operation, and of any new plant to be commissioned.

The entire nuclear programme was abandoned after the negative result of a referendum held in 1987. This vote was formally limited to specific aspects of siting under the nuclear legislation in force at that time, but the results represented the negative attitude of the public for nuclear technology. As a consequence, the operation of all NPPs was stopped in the years 1987–1990.

At the same time the National Electric Company ENEL was instructed by the Governmental Body to start actions for decommissioning. The "Safe Storage" option was adopted as a general strategy, in order to benefit from reduction in radioactive levels and allow time to define a strategy for waste and repository management.

However the following difficulties impacted negatively on the start of an effective decommissioning program:

- The lack of specific acts defining the national policy of decommissioning and allocating specific financial resources for the relevant operations;
- The lack of a national site for the disposal of low and intermediate level waste; and a centralized interim storage facility for spent fuel and high level waste;
- The uncertainty, at national level, of the policy for management of very low level waste (clearance levels);
- The necessity of an independent Environmental Impact Assessment for the Decommissioning of Nuclear Installations by the Ministry of Environment;
- Some gaps in the nuclear legislation, where commissioning of plants is given more emphasis than decommissioning. However, new legislation in force from 1996 (Legislative Decree N. 230), further amended in 2000 (Decree N. 241), introduced new regulations in the field of radiation protection, providing for stricter dose limits for workers and public. The legislation also provided new specific rules on the decommissioning of nuclear plants.

Subsequently "safe enclosure" of the plants was adopted as a general strategy but did not progress smoothly and underwent significant delays.

An additional difficulty resulted from the Decree 230 application. Previous decommissioning operations, previously subjected only to authorization of the Ministry for Productive Activities (MPA), were subjected to further authorization of the same MPA, but acting in consultation with Ministries of Environment, Interior, Labour and Health, and the Region concerned.

In practice, the regulatory body (APAT) responsible for the technical safety analysis on behalf of the Ministry of Industry, has to receive and take into account observations, conditions and specifications given by the other authorities involved in the licensing process (see Figure 1).

Having several bodies, playing a role in similar matters, was intended to guarantee the public interest from different points of view, but, on the other hand, this did result in delay in the start of decommissioning, mainly because all the involved authorities had to be involved twice; both at the beginning and at the end of the licensing process.

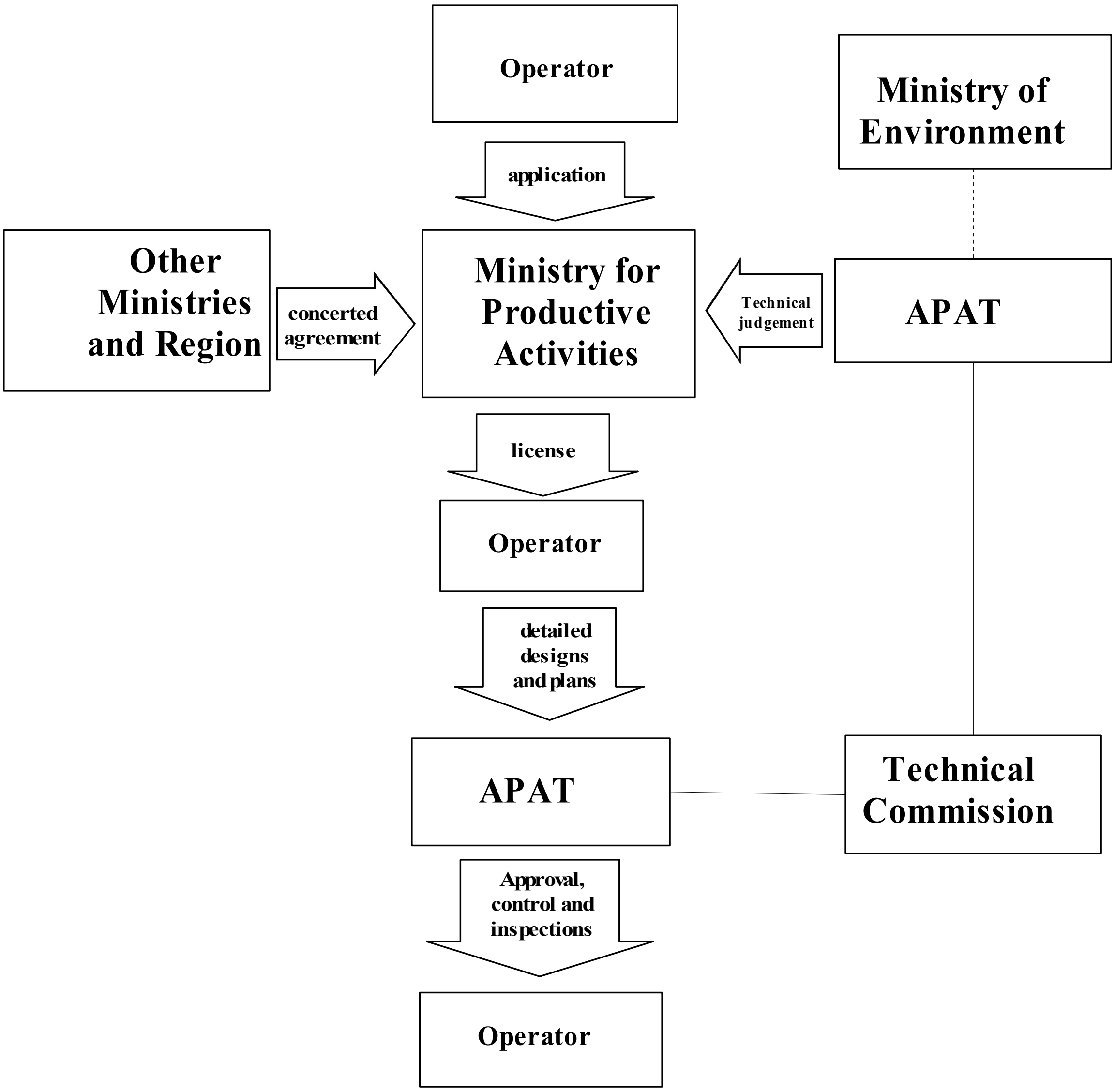


FIG. 1. Licensing process for the decommissioning of nuclear facilities in Italy.

By the end of 1999, the Ministry for Productive Activities (MPA), issued a document providing strategic guidelines for the management of liabilities resulting from past national nuclear activities.

Highlights of this new policy were:

- Treatment and conditioning of all radioactive waste stored on the sites.
- Initiation of a concerted procedure, facilitated by means of a specific agreement between the Government and the Regions, for the selection of a near surface national site for the final disposal of low and intermediate level waste and for the interim storage of the spent fuel and the high level waste.
- The adoption of the strategy for a prompt decommissioning (“DECON”) of all shut down nuclear installations, thus abandoning the previous “SAFE STORAGE” option.

- The establishing of a new national company, SOGIN, responsible for all shut-down nuclear power plants, with a mandate to perform prompt decommissioning.
- The creation of a National Agency for the Management and Disposal of Radioactive Waste, with the mandate to realize and operate the national radwaste disposal site.
- The allocation of special funds for all these activities by means of a specific drawing from the electric energy bills.

According to these directives all the nuclear installations should be completely decommissioned by the year 2020.

The new policy was followed by a Ministerial Decree in January 2001, establishing plans and procedures for funding the decommissioning of the nuclear facilities, NPPs and fuel cycle facilities, from dismantling to waste conditioning and disposal.

The strategy identified in this Decree was further detailed by a Ministerial Decree in May 2001, which provided operative directives to SOGIN to implement prompt decommissioning of the four national power stations up to an unconditional release of the respective sites within twenty years. The Decree also provided directives to SOGIN for the safe management of radioactive waste and spent fuel associated with the power stations together with funding provision with an additional fee on the consumed KWh. Comprehensive decommissioning project proposals for Italian NPP's were submitted by SOGIN in 2002.

A preliminary safety analysis had already been performed by the regulatory body at the end of 2002, but requests by other national and local authorities involved in the licensing process have been not yet received, thus delaying the conclusion of this first phase of the analysis.

A further significant change in the decommissioning approach is presently maturing. In fact international instability has emphasized the risk connected with spent fuel and waste remaining at some nuclear installations and the consequent potential for terrorist activities.

Consequently a specific Decree of the President of the Italian Government was adopted in February 2003 declaring an emergency status until the end of 2003. Consequently the entire responsibility for spent fuel interim storage and for reconsideration of the overall decommissioning strategy, including waste management and a repository, was given to a "Delegate Commissioner". As a result, involvement of all the different parties previously engaged in the decommissioning process is expected to be substantially reduced, introducing a more timely and effective start up of the decommissioning programme.

2.4. The project manager's perspective

Personal experiences have been reported from a project manager's perspective in [11]. The essence of these experiences from the United Kingdom and international projects are given as follows.

Regulatory bodies generally recognize that even with best endeavours on all sides, there will sometimes be safety documentation or technical actions that have not yet been completed. One practical solution that allows the project programme to continue in the meantime is the use of a formal "action plan". This plan identifies work still to be done, commits the operator to specific actions and target dates, and is agreed and periodically reviewed with the regulatory body site inspector, to ensure satisfactory progress.

To expedite timely clearance of safety proposals in the United Kingdom, the concept of "independent peer review" is a vital part of the safety documentation approval process. A suitable and well recognized expert (the “peer reviewer”) is selected, to produce an independent nuclear safety assessment of the acceptability of the documentation.

It is desirable that a dedicated project team, adequate resources and suitable training are arranged before any significant planning work is commenced. This helps to ensure that the plan is produced efficiently and effectively and also that key issues are fully understood by the members of the project team.

With regard to selecting appropriate resources for implementing the decommissioning plan, key staff should include members of the team that operated the facility that is to be decommissioned. This helps to ensure that the selected staff are suitably qualified and experienced. It also minimizes the chances of a surprise incident due to work being performed on an “unknown” hazard.

When assessing decommissioning options, a very practical and motivating way forward is to hold workshop sessions (sometimes called brainstorming sessions or decision conferences). In such sessions a panel of experts (including experienced operators) agree on a list of influencing factors and then assess the impact of these factors on each of the decommissioning options, using decision aiding techniques.

It is of course important to clearly understand the needs of the customer for whom the decommissioning project is being undertaken. It is helpful to bear in mind some general principles (that can be applied to any project) as follows:

- Understand customer needs (not necessarily what you think is needed)
- Respond as required (promptly, flexibly, effectively)
- Be there when you are needed (partnership style)
- Protect customer interests (think ahead, consult, advise/assist)
- Deliver what you said you would deliver
- Communicate (regular interface discussions and effective feedback)

It is also important to ensure that all interested parties, particularly the stakeholders, are kept informed of what is happening and why. In this respect it is helpful to develop and maintain a partnership style (as noted above) in which the project team help the customer to explain and manage the project while at the same time maintaining the customer’s image and reputation in the presence of major constraints and risks.

It is fundamental to achieving safe and effective decommissioning that all waste streams and routes for storing, disposing and transport of these wastes are fully identified and agreed before decommissioning work commences, including any necessary waste transport containers, vehicles and associated infrastructure (e.g. facilities for scrap/material release, waste treatment and conditioning, waste characterization, interim storage buildings and final disposal). This involves agreement of stakeholders.

Specific additional comments from various projects are summarized below:

- When considering possible decommissioning strategies, note that waste management costs, regulatory constraints, discharge constraints and dose constraints are all likely to be greater in the future
- The cost of decommissioning is strongly related to waste levels and volumes
- Volume reduction of Low Level Waste can often be more economic than attempting to decontaminate to free release levels

- Use of readily available techniques and equipment or adaptation of such techniques and equipment can often provide the quickest, most reliable and least costly solution for decommissioning tasks
- Samples can show large variations in trace element concentrations, leading to a wide range of resultant material activation and radiation fields. Such variations have to be taken into account in order to estimate a realistic radiological inventory and to ensure that dismantling techniques are appropriate with the estimated range of radiation fields.

2.5. Pending issues and trends

Global decommissioning experience identifies several issues relating to decommissioning projects which are strategic in nature, and are of current concern in many Member States. The following have been highlighted as particularly significant issues of concern:

- Estimation of decommissioning costs
- Impact of the regulatory requirements from the operating period to and throughout the decommissioning period, particularly with regard to release criteria
- Lack of adequate waste disposal facilities
- Funding issues in the short term and long term

Each of these issues is summarized briefly below and supported by specific lessons learned in Appendix 1.

2.5.1. Estimation of decommissioning costs

Experience indicates that a detailed comparison of costs associated with the two main approaches [12], immediate and deferred dismantling, should be undertaken early in the planning process. Lessons learned in some member countries indicate that the reduced short term expenditure associated with deferred strategies may give rise to higher costs for decommissioning in the future e.g. due to escalating disposal costs (See Appendix A.1.7, Case 1) The indication is that overall decommissioning costs could be significantly higher with a deferred strategy. A lesson learned relative to increased costs in returning plant and systems to service after a period of only 10 years in safe enclosure is given in Appendix A1.4, Case 2.

2.5.2. Impact of regulatory requirements

Generally decommissioning experience shows that there is potentially a tightening of regulatory requirements applied to decommissioning activities commencing at the planning stage and continuing throughout the decommissioning period. The impacts can be significant after initiating a project, as exemplified in a lesson learned by a member state in the application of environmental assessment policy as part of the regulatory process (see Appendix A1.2, Case 3). Another significant impact is the additional conservatism applied to free release and clearance criteria. A documented lesson learned details the impact of a 10 fold reduction in release criteria compared with the more relaxed criteria in place throughout the operating period (see Appendix A1.2, Case 2).

2.5.3. Unavailability of waste disposal

Decommissioning implementation to a defined end state is usually determined by the availability of waste disposal for virtually all Member States. Ideally, to achieve a final end state for a facility, all wastes would be transferred to final disposal. The expediency practiced by Member States, where disposal not readily available, is the provision of interim storage. This leaves a continuing legacy, namely the future decommissioning of the interim waste storage facility. Experience indicates that most decommissioning strategies are significantly impacted by waste management issues. When considering an overall strategy, waste handling can significantly affect decommissioning costs through the need for interim storage facilities and the re handling of waste to place it in final disposal. In addition, double handling can result in significantly higher doses to workers to complete the project. Absence of clearly defined disposal criteria make the requirements for waste conditioning unclear also leading potentially to increased future costs and worker dose commitment.

2.5.4. Funding issues in the short term and long term

Decommissioning projects for various types of nuclear facilities have demonstrated that decommissioning costs can be managed. However, comparison of individual cost estimates for specific facilities may show relatively large variations, and several studies have attempted to identify the reasons for these variations. Standardized cost items have been proposed [4]. To date, significant uncertainties still exist on decommissioning cost estimates, particularly in Member States not having enough experience/expertise in decommissioning. These uncertainties are reflected in large contingencies and possibly less than accurate financial forecasts. While several Member States have adopted mechanisms to assume collection and segregation of decommissioning-oriented funds, the validity of their funding assumptions remains to be proved in many cases. The long term financial assurance of segregated funds remains a pending issue particularly in deferred dismantling scenarios (see Appendix A1.8).

3. SELECTED DECOMMISSIONING EXPERIENCE

3.1. Introduction

This section includes material extracted from published papers, articles and proceedings of conferences and workshops over the last decade, although most publications date from the last few years. Many of the publications cover a wide range of decommissioning activities such as technical aspects, waste management and very specific local issues. The material presented has been extracted selectively from the publications to meet the objectives for this document viz. to report experience and lessons learned in the planning, management and organization of decommissioning and not to expand on technical issues.

In order to give more structure to the presentation, the material has been divided into a number of categories. This presented some editorial difficulties since many topics overlap, such as management and planning, organization and personnel management and the fact that most subjects involve some degree of management. There are also some specific subjects such as the management of large dismantling projects, public relations and record keeping.

The emphasis is on feed back of experience and lessons learned both beneficial and adverse, although many authors did not regard feedback or lessons learned as the main subject of their presentation. Nevertheless experience and lessons learned can be extracted from the subject material and this has been done. Care was taken to do this as faithfully as possible and not to add to or subtract from the material. In many cases wording and phrases were extracted almost verbatim as this portrays the essence of the meaning most accurately. If a subject or publication is particularly relevant to the reader, then it is recommended that the original text be consulted. It was not considered appropriate to include lengthy transcriptions of text from source material. All the published documents are referenced.

3.2. Planning

Planning is an essential part of all decommissioning activities and the following extracts give appropriate emphasis and report the benefits of good planning. A list of considerations to factor into planning for the radiological aspects of decommissioning is presented in Appendix 2.

3.2.1. Planning structure for normal decommissioning procedures

The utilities in Germany, as operators of nuclear plants, tackled planning at a very early stage and proved the fundamental feasibility of decommissioning by means of appropriate studies and sometimes large scale tests. For decommissioning, advance planning will be in accordance with the procedures determined by the studies [13].

Basic planning will initially have to concentrate on measures which require licensing. Two alternatives will have to be considered:

- alternative 1 Safe enclosure and deferred dismantling after about 30 years
- alternative 2 Immediate dismantling

Variations can occur within these alternatives.

There then follows scheduling or programming which can be broken down into:

- post operational phase
- phases for alternative 1 or alternative 2

The post operational phase will depend largely on the management of spent fuel and its shipment away from the reactor.

The planning structure will need attention. This should be detailed and accurate, in which the entire procedure is broken down into small manageable steps. When this is done it will be possible to attain the following:

- All work necessary will be identified
- There will be no duplication of steps
- Individual elements will be interchangeable
- A planned structure to enable costs to be determined for reserve funds
- An established model will ensure costs are commensurate with funds

The structure is also broken into hierarchical levels as follows:

Level 1 — Decommissioning Phases

For alternative 1 strategy, three distinct sections are considered, viz. preparation for safe enclosure, enclosure period and dismantling. For alternative 2 only dismantling is considered.

Level 2 — Work packages

Each phase is divided into complete work packages. This results in a maximum of 14 packages (for a PWR). The content of each package may vary within the different phases given above (for example: preparation of the site, dismantling of activated components).

Level 3 — Work groups

Allowing for spatial and chronological aspects within each work packages leads to work groups (for example: dismantling of RPV internals).

Level 4 — Work steps

The work groups are in turn divided into work steps. This sub division is to quantify and evaluate tasks according to the same criteria. Personnel, facilities and equipment are defined at this level. The time required for an activity and quantities of material are established (for example: dismantling of upper core structure).

Note in Section 3.5.1 that a more detailed breakdown of programmes and work steps is given but more specifically for the Greifswald decommissioning project.

It is concluded that planning for decommissioning must be at least as thorough as for construction. The structure of planning described in this paper is with particular emphasis to planning that must be commenced at an early stage so that the operating licence can be replaced by the decommissioning licence in a timely fashion. This is the only way of ensuring that the necessary financial resources will be commensurate with the reserve fund that has been set up.

The planning may be carried out according to the model defined in the studies on the assumption that the Government also continues to regard decommissioning of nuclear plants as a normal procedure not needing exceptional measures.

3.2.2. Designing for the past, planning for the future — decommissioning at AWE

The Atomic Weapons Establishment (AWE) in the United Kingdom has a wide range of nuclear facilities to carry out research, design, development and manufacture of components and processes [14]. It has been at the heart of the United Kingdom's nuclear defence programme for over 40 years. Many of the facilities are now reaching the end of their operating life.

Since 1993 the management of the site has been undertaken by Government owned/contractor-operated arrangements. The organisation covers the whole life cycle of its strategic nuclear business from initial concept and design, through component manufacture to in-service support and finally to decommissioning and disposal.

The programme is flexible to take account of changing priorities. Over a period of 15 years AWE has established a core of expertise using in-house and contractor services. Since 1980 many decommissioning projects have been successfully carried out.

Prior to 1997 the AWE was exempt from many of the National regulations because it was internally regulated. It is now subject to the United Kingdom Nuclear Installations Act (1965) and a number of other National acts and regulations.

Since 1997, a 10 year decommissioning plan has been issued covering all installations undergoing decommissioning. These have been approved by the United Kingdom Nuclear Installations Inspectorate (NII) in compliance with licence condition 35 — decommissioning. This allows the NII to impose hold points in the work, to stop decommissioning or to require that certain decommissioning be undertaken in the interests of safety.

The AWE decommissioning strategy is strongly influenced by the government statements on the United Kingdom national waste management policy.

This requires that:

- Regulatory approval is on a case by case basis
- Decommissioning must be done as soon as reasonably practicable
- Strategies must be drawn up and justified

- Decommissioning must ensure safety at all times

The contractual environment is such that any management or other contractors must comply with all safety standards and good practice. AWE remain responsible overall as the licence holder.

The AWE has formulated its decommissioning policy, namely:

- To decommission facilities where practical for reuse or refurbishment
- To proceed with decommissioning and disposal where no future reuse is foreseen
- To place facilities awaiting decommissioning on a defined care and maintenance basis.

The application of the Safestore (safe enclosure) strategy is not adopted because no benefit can be gained from radioactive decay. In fact, most materials are contaminated with long lived alpha activity and the spread of this activity in the long term is an unacceptable risk.

AWE consider decommissioning in 5 stages:

- Post operative clean out
- Post operative care and surveillance
- Disassembly and decontamination
- Building care and maintenance
- Building demolition.

An annual decommissioning management plan is produced. Multi-attribute analysis is used to assign priorities. Particular key factors for this are health and safety, penalties resulting from extending decommissioning programmes and the company policy of AWE.

In order to meet priorities, the use of specialist subcontractors is often resorted to. A very rigorous selection process is used in appointing appropriate contractors.

Planning for the future is an important activity. It has been accepted that lack of planning in the past has been bad practice i.e. designing for the past has essentially been making the best out of a bad job. The policy is now to plan adequately for the future and due regard is being adopted to decommissioning requirements at all stages of a facility's life cycle.

3.2.3. Organizational aspects of planning and management of the decommissioning of the nuclear facility of Paldiski

The Paldiski site in Estonia was a Russian training centre and included two full sized land based Russian nuclear submarines and associated nuclear facilities dating from the 1960s [15]. After closure of the base, the Russians defuelled both reactors and the spent fuel was sent back to Russia. The submarine reactor compartments, including the core, were prepared for safe storage by enclosing them in concrete sarcophagi. The facility was then turned over to the Republic of Estonia in September 1995 for decommissioning. The nuclear experience within Estonia was minimal and a Paldiski International Expert Reference Group (PIERG) was established to assist the participating parties in decommissioning work on technical, legal, organizational, financial, waste management and radiation protection matters.

The first task of PIERG was to assist in planning for decommissioning and a conceptual decommissioning plan was produced. This took into account the special conditions associated with the facility. Due to the pre establishment of the safe enclosure of the reactor cores, a strategy of dismantling and free release of the site was not available. In order to minimize the extent of surveillance, the extent of external active areas was to be minimized. The highest priority was to minimize the risk of spread of contamination and also the treatment of accumulated radioactive wastes.

A legal framework for regulating radiation protection and nuclear safety in Estonia did not exist and it was decided to extend the use of Russian regulations while the National legislation was being formulated. Some regulatory acts were in place by April 1997.

Organizations that became involved in decommissioning were:

- The Estonian Radiation Protection Centre (1996)
- Occupational Security Inspection
- Estonian Radioactive Waste Management Establishment (ALARA Ltd) (1995).

The Decommissioning Plan considered decommissioning in three phases:

- short term (0–2 years)
- medium term (3–6 years)
- long term (leading to site clearance when a repository is available).

The State owned company ALARA Ltd was formed to be responsible for decommissioning. It has a number of difficult problems to resolve being mainly lack of experience and trained resources and lack of technical information on the Russian designed and operated facilities and also lack of funds for decommissioning.

The lack of funding, in particular, causes problems in provision of items required for work and in timing. Planning, management, quality assurance and the setting up of systems, training of operators and managers etc. all take time, money and personnel resources, all of which are in short supply to ALARA Ltd.

Progress on Paldiski decommissioning has been reported and indicates that elements of the plan are being implemented. Some additional studies have also been undertaken. For example, European Commission PHARE financed project has been completed on a feasibility study for dismantling the Liquid Waste Treatment Facility. The study recommends:

- immediate dismantling (not deferred)
- manual dismantling (rather than remote)
- use of in-house ALARA Ltd. personnel as far as possible.

3.2.4. Department of Energy experience in planning decommissioning projects

The US Department of Energy has an Environmental Management Programme which has completed or has currently underway a large number of decommissioning projects [16]. Many lessons have been learned, the main one being the significance of careful up-front planning. The Programme has developed a uniform, systematic approach to planning in two phases: Phase 1 — planning and Phase 2 — operations. A readiness review is held before Phase 2 is commended.

The size and complexity determines the extent of planning detail. Particular planning activities are:

- Characterization, including a chemical, physical and radiological assessment.
- Engineering, including selection of alternatives, design criteria, contract bid documents and project base line and associated work packages.

- Environmental compliance which demonstrates adherence to applicable federal and state laws protecting the site, workers, the surrounding area and the public.
- Reporting system development which are established early in Phase 1. This includes technical, cost and schedule baselines with appropriate work breakdown structure.
- Procurement, which includes all those activities associated with the awarding of contracts.
- Certification and verification process to ensure all the radiological and chemical conditions comply with established criteria, standards and guidelines.

The above planning process results in a series of products which are:

- environmental compliance documents
- baseline cost and schedules
- reporting systems
- project planning documents.

The planning documents, in particular, are needed to provide for the execution of the project within the approved technical, cost and schedule baselines. The baseline activities are developed as early in the planning process as possible.

The cost and schedule baselines incorporate an earned value approach to allow monitoring of project performance.

Configuration management is used to determine and control the baseline and ensure all components are documented and integrated. Changes are limited to those that offer significant benefits and are introduced mainly to correct deficiencies.

A successful Readiness Review will result in the conclusion that each item in the project plan has been completed to the extent required for the start of the physical work on the project. The review may however conclude that there are a number of items yet to be completed but some activities may proceed while uncompleted items are being attended to.

If the planning activities have been properly carried out and the readiness review is successfully completed, then there is confidence that as many potential obstacles to completing the project to time and cost will have been avoided.

The experience of the Environmental Management Programme is that the following items need special attention early in the project:

- Decontamination and release criteria
- Waste types, volumes and disposal
- Permits and approvals
- Cost and schedule control systems.

3.2.5. Decontamination and decommissioning of a 60” Cyclotron facility at Argonne National Laboratory — East

Characterization, planning, and documentation for the 60” Cyclotron was carried out between June 1997 and December 1998. Decommissioning work started in January 2000 and took 13 months to complete [17].

The problems experienced, lessons learned and noteworthy practices reported were:

- The characterization report provided inaccurate and insufficient information resulted in unforeseen radiological problems.
- Accurate and detailed entries on Radiation Work Permit sign-in sheets provided valuable information for dose assessment and analysis.
- Question assumptions and interpretations of radiological characterization reports.
- The advance planning of lifting and rigging operations was essential.
- Disposable personal protective equipment and paper waste was used as a filler in waste packaging.
- The use of existing equipment provided engineering and material cost savings.

3.2.6. Decontamination and decommissioning of 61 plutonium glove boxes in D-wing, Argonne National Laboratory — East

The 61 glove boxes in 9 laboratories had been used from the 1960s to 1989. The work started in 1992 and was completed in 1996 after 39 months. The total cost was USD 6.9 million [18].

Lessons learned were reported:

- Mockup training was important for safety and dose minimization.
- Hold points on Radiation Work Permits (RWPs) were used to trigger reviews of safety and led to timely improvements in procedures and controls.
- Conduct work strictly according to RWPs containing planned safety precautions.

The report also includes numerous lessons learned and feedback of experience on technical issues that are not summarized here.

3.2.7. Planning in decommissioning

Planning for decommissioning is best carried out while a plant is still in operation [19]. Planning in advance reduces the likelihood of losing vital records or information on long forgotten events. Initial planning should encompass a variety of areas including licensing and regulatory compliance, funding, proposed future use, and decontamination and material release criteria. There is also the opportunity of using operational staff in the preliminary planning efforts.

A structured approach is necessary to ensure that work and schedule goals are monitored and achieved. Numerous tasks must and can be carried out during the pre implementation phase. The following tasks may be combined or accomplished separately either in house or with the assistance of a consultant:

(1) Development of a site wide radiological characterization plan

This plan serves to provide advance guidance and direction to required decontamination efforts and to establish a baseline for areas which meet unrestricted release criteria.

(2) Development of a Waste Management Plan

This is to ensure that low level radioactive waste produced is consistent with waste minimization and disposal criteria. The plan should also include such aspects as the minimization of secondary waste. Several waste streams may be expected during decommissioning and these may need to be considered on a case by case basis in the development of waste minimization techniques.

(3) Development of Hazardous Materials Characterization Plan

Many facilities will have radioactive, hazardous or mixed wastes. The characterization plan will give an important insight into the handling of these wastes and the actions that will need to be considered to ensure efficient and timely disposal.

(4) Development of an ALARA programme

Given change in mission from operation to one of decontamination and ultimate decommissioning, the current ALARA programme will likely require modification. Potential areas for modification may include use of radiation work permits and a technical assessment of decontamination techniques.

(5) Development of a Health Physics Plan

The development of health physics (HP) related procedures will be needed to support the diverse range of decontamination activities during decommissioning. The change from manufacturing to decontamination will likely require some modification of existing HP protocols and practices.

The implementation of the Decommissioning Plan will reflect the pre-planning done for decommissioning. However the details of decommissioning implementation protocols may best be maintained in Decommissioning Plan Implementation Procedures (DPIPs). These procedures can be the main drivers for the conduct of decommissioning activities. In order to be effective they should be clear, precise and easily understood. Each DPIP should be related to a specific action or task. The Decommissioning Plan should also identify a means and framework for ensuring that DPIPs are prepared, maintained current and distributed to those expected to implement them. The plan should also describe the DPIP review process.

3.2.8. A review of project planning work for decommissioning at Whiteshell Laboratories

Atomic Energy of Canada's Whiteshell Laboratories (WL) site was established in the 1960's for scientific research and development related to the CANDU reactor system. Atomic Energy of Canada (AECL) had made the decision to downsize its nuclear research activities by December 2001 and to safely decommission the site nuclear facilities [20].

Information is provided on the structure needed to prepare documentation covering a large, unwieldy shutdown project. Such a project is easier to plan when it is broken down into simple project components.

High level planning

A high level working assurance model (Figure 2) provides a method for understanding the stepwise planning sequence leading to stakeholders that are satisfied with the decommissioning project.

The project stakeholders identify any significant issues and targets. The main stakeholders include the public, the regulator and the project proponents.

Working level planning and project development

The five main areas that are part of working-level decommissioning planning are:

- Developing the project description
- Developing engineering feasibility designs
- Determining dose definition

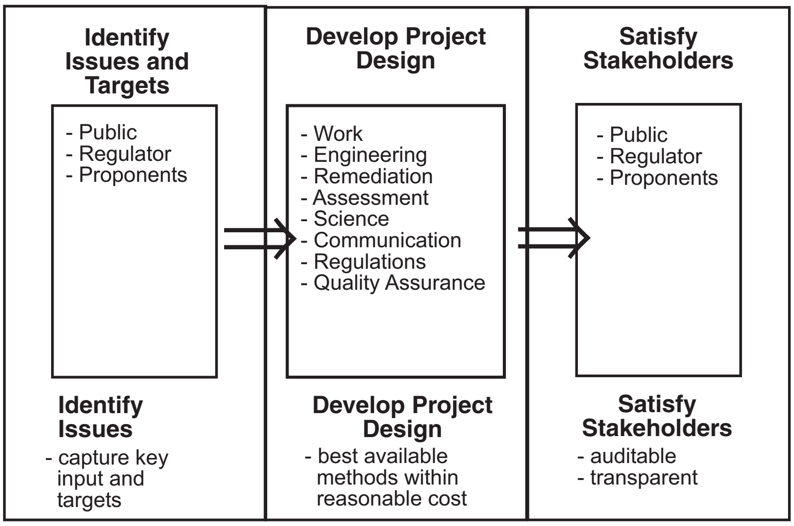


FIG. 2. Whiteshell Laboratories Decommissioning Project Assurance Model.

- Estimating the inventory of stored and decommissioning wastes, and
- Identifying decommissioning waste streams, interim handling and disposal pathways.

Some planning and project description information was required as input to the environmental assessment process, but is also needed for the purpose of short- and long-term project definition.

Lessons learned
In the four years since inception of the decommissioning project, a wide variety of project planning issues have been identified. Lessons from the planning experience are summarized as follows:

(1) Traditional and non-traditional design elements must be considered when developing the design of a decommissioning project.

(2) Documenting a stepwise sequence of engineering and other activity, in conjunction with the project schedule, is probably the most useful decommissioning planning tool.

(3) Project description is integrated with scheduling and planning activities.

(4) The production of the Whiteshell Environmental Assessment was stalled because the description available was not adequate for assessment.

(5) Dose estimation is dependent on the accuracy of the project description.

(6) Waste inventory and waste stream analysis are important inputs to decommissioning planning.

(7) Flow charting is a simple tool for identification and explanation of the waste streams and disposal pathways.

(8) Proper field data and analysis can simplify preparation of a remediation plan or help provide justification for in-situ management of waste.

Practical application
Practical applications of the lessons learned from planning the decommissioning of Whiteshell Laboratories are summarized into five statements.

(1) A team of experienced individuals should be gathered to contribute to the decommissioning planning process.

(2) A significant level of resources and effort needs to be focused toward the regulator.

(3) A good working relationship needs to be developed with other project stakeholders at an early stage in the decommissioning process.

(4) The important working level planning tasks should be identified and their work initiated at an early stage.

(5) The significant decommissioning planning documents should be identified and work contributing to these documents initiated.

3.2.9. Planning the complete decommissioning of a small research reactor

The JASON research reactor was a 10 kW Argonaut reactor that was shut down in 1996 and decommissioned between 1997 and 1999. The operating safety case did not include a rigorous plan for decommissioning and therefore a process for the production of all documentation has to be created in collaboration with the contractors. The first stage of this process was the production of a Framework Document [21] that set out the policy and safety management arrangements of the licensee. In addition, the principles and criteria for JASON decommissioning, derived from the regulators generic safety principles and criteria, were produced by the licensee [22] and the contractors had to demonstrate to an independent nuclear safety assessor compliance with 89 principles and 8 criteria.

Three main contractors were employed for overall project management, fuel removal and reactor dismantling and waste management. The production of the necessary documentation was therefore quite complex and a road map of some of the key documentation produced is shown in Figure. 3. Some documentation, such as the Quality Plan is not shown on this road map. The solid lines show the flow of documentation through the decommissioning project with the Decommissioning Plan (DP) and the Health and Safety Plan (H&S Plan) being updated throughout the process. The dashed lines indicate the linkages between the various documents.

This example demonstrates a situation where planning for decommissioning of a small facility had to be developed for a one-off project with little guidance from within the operating safety case. The decommissioning expertise of the contractors was invaluable in helping to devise a coherent linkage between the various documents that were produced by four different organisations, the three contractors and the licensee.

3.3. Management

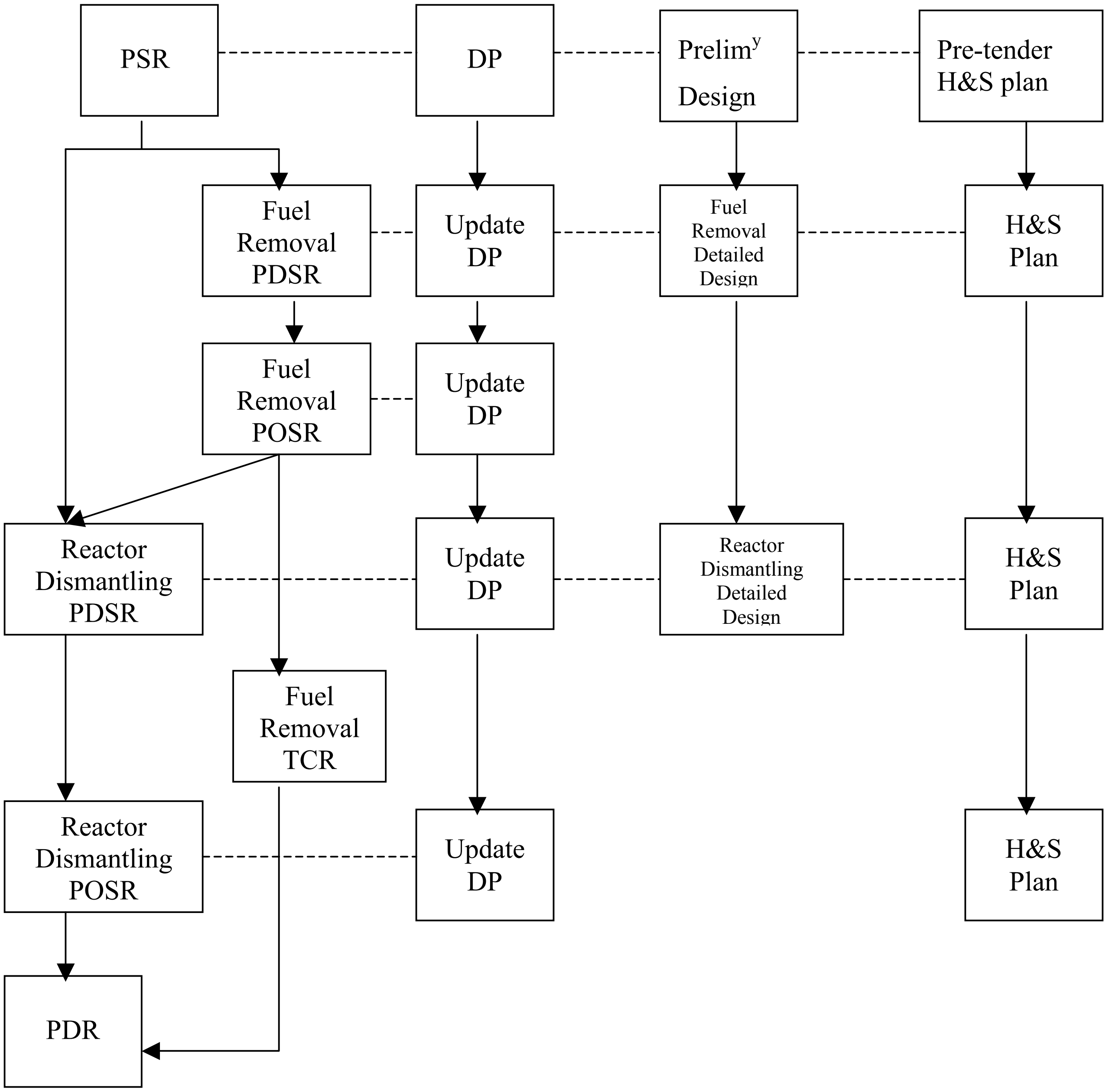
This sub section covers management of decommissioning under the headings of general management, project and cost management and special aspects. Some special aspects of management such as safety and the relationship to regulations are included.

3.3.1. General management

Under this sub section is included experience which is generic to broad management issues.

3.3.1.1. UKAEA's approach to the management of nuclear liabilities

The United Kingdom nuclear programme started in 1946 and became the responsibility of the United Kingdom Atomic Energy Authority (UKAEA) in 1954. Today the UKAEA is responsible for operating and redundant nuclear facilities and the sites at Winfrith, Harwell,



(PSR: Preliminary Safety Report; DP: Decommissioning Plan; H&S: Health and Safety; PDSR: Pre-Decommissioning Safety Report; POSR: Pre-Operational Safety Report; TCR: Task Completion Report; PDR: Post Decommissioning Report).

FIG. 3. JASON decommissioning documentation road map.

Culham, Windscale and Dounreay [23]. The main funding is from the Government. All the sites, except Culham, are licensed under the Nuclear Installations Act and comply with all relevant United Kingdom nuclear legislation including waste management.

Particular account of the following is taken in planning decisions:

- safety of the workforce
- effects on the public and environment
- specific legislation and government policy

- views of the regulators
- views of stakeholders
- reuse of sites
- availability of waste disposal routes
- skills and knowledge within UKAEA
- cost effective use of public funds.

Project risk management is of particular concern because of major uncertainties brought on mainly by the age of facilities, poor records from the past and the varied nature of the tasks.

For all projects a risk assessment is carried out at an early stage to identify major problems and to point to possible management and contract strategies. The assessment is reviewed periodically.

Studies are done in problem areas to reduce uncertainties and risks. Examples of these are:

- intrusive and non-intrusive studies of the fire damaged core of the Windscale pile
- monitoring radioactive and chemical contamination on a storage site at Harwell
- monitoring neutron activation during experiments at the JET facility at Culham
- experiments for removal of metal residues in the Dounreay Fast Reactor (DFR)
- alternative techniques for removal of stuck fuel elements at DFR
- detailed inventory of wastes in the Dounreay waste disposal shaft
- concentration and movement of fuel particles in the offshore environment at Dounreay.

UKAEA has a high level formal policy for the use and control of contract staff. It requires and supplies business systems to control:

- safety and hazards
- planning
- finance
- procurement.

It provides key support functions however, such as policing of the site, security and management of the site infrastructure and of course long term operation, maintenance and surveillance and nuclear safeguards. It also takes responsibility for long term waste stores, certain waste processing facilities, e.g. vitrification and processes such as post operational clean out. Contractors will be responsible for their own facilities and any plant being decommissioned under contract.

Contractors called ‘implementation contractors’ are often engaged for new projects (construction of buildings, supply of plant and refurbishment), for decommissioning and demolition, land remediation and associated waste management and for office based activities such as design and safety assessment.

For control and management of this work, in-house staff teams or management support contractors are used. Arrangements range from use of small project based managing agencies to large site management support contracts which provide a wide range of staff. Where mixed skills are needed these are obtained from external sources.

UKAEA engenders the site culture to ensure it meets all its nuclear safety, financial and stakeholder obligations. A clear distinction is made between buildings, plant and equipment owned by the UKAEA and that owned by contractors and brought onto site.

As the licence holders, UKAEA alone determines the programmes of work on all sites. There is an integrated site programme, but work is divided into discreet projects. Projects are subjected to a strict approval process — 'sanctioning' — which is the responsibility of the UKAEA.

The UKAEA had to undergo a profound change in management approach from controlling a research and development site to that of a decommissioning and waste management function. New skills had to be acquired and this was achieved by considerable outside specialist management support, often seconded into the organization. This has been very successful but the UKAEA had continually to ensure a sufficient backbone of staff to meet its nuclear safety and licensing obligations. This was not easy at remote sites like Dounreay in northern Scotland (see also Section 3.4.3.2).

Care was always taken to ensure that, for on-site implementation, contractors always supplied suitably qualified, trained and experienced staff.

All activities and the working environment were controlled under a "safe-system-of-work" which required at least:

- permits-to-work
- method statements
- approved operating and maintenance instructions
- continual inspection and checking of work activities.

The UKAEA also seeks to share performance risk with contractors, particularly commercial risks. The use of turnkey contracts is not adopted. The use of design and build and also design, build and operate contracts are approved. However, where there are large uncertainties in a project, commercial risks can be limited by separating design from implementation. In some longer term service contracts a partnering style of contract is used to advantage.

The UKAEA believes that it demonstrated the viability of using contractors in a wide range of diverse activities including substantial elements of decommissioning with a wide range of benefits.

3.3.1.2. Environmental remediations: The Hanford Site

A special report has been issued on the management of environmental remediation at Hanford [24]. In part, the remediation consists of over 1000 non-operational historic hazardous waste disposal sites as well as 177 large volume metal tanks containing about 410 000 tonnes of waste.

The initial approach was 'doing first things first'.

The steps were:

- defining the technical requirements
- building the technical baseline
- determining the schedule
- estimating costs
- building the integrated baseline.

The tank waste remediation system required a reinvention of the approach to project management.

The project faced significant problems:

- serious technical problems in handling highly hazardous and toxic waste in a high caustic solution to minimize corrosion
- emphasis on safety of employees, the public and environment
- waste disposal
- constantly changing project management roles.

The Hanford site operation has developed over 50 years and is unique in management complexity. Balancing the strategies and methods for addressing complex documentation requirements, government funding cycles, oversight groups, government requirements and legally binding schedule commitments while ensuring progress is a mammoth task. The solution was finding opportunity in a constant state of change. A particular problem was choosing the correct project management style for balancing risk versus productivity.

Tips for managing change are offered and were derived from the challenges:

- stick to clear objectives
- keep the team lean
- avoid redundant/wasteful practices
- consider consolidation of resources and the breakdown of old working barriers to encourage co operation
- avoid change for changes sake
- don’t forget about your people.

Special attention was given to occupational health care. The initial service called the Hanford Environmental Health Foundation (HEHF) was set up in 1966 but was largely treatment based whereas occupational endeavours are more prevention based. In a clean-up site workers may be continually faced with new health hazards which may change from facility to facility.

Figure 4 shows operators in double layer suits at a plutonium facility at Hanford.

FIG. 4. Operators in double layer suits at a plutonium facility at Hanford.

The former HEHF organization was replaced with one in which attention was given to Health Care Centres, Health Surveillance and Health Maintenance as separate functions. It is conclude that this is a new way of looking at the health care organization which will be adopted willingly and is long overdue.

3.3.1.3. Application of the graded management approach to Battelle's nuclear project

The Battelle Columbus Laboratories Decommissioning Project involves the decontamination and free release of 15 buildings at two separate sites which are radioactively contaminated. The facilities are privately owned. Decommissioning is controlled through a Battelle Decommissioning Plan and a Nuclear Regulatory Commission licence. The project has to comply with a number of Department of Energy (DOE) Orders such reporting, records control, cost control, QA and waste management [25].

The graded management approach is defined by the DOE as follows:

The process by which the level of analysis, documentation, and actions necessary to comply with requirements are commensurate with:

- the relative importance to safety, safeguards and security
- the magnitude of any hazard involved
- the life cycle of the facility
- the programmatic mission of the facility
- the particular characteristics of the facility
- any other relevant factor.

The DOE encourages the management of decommissioning programmes commensurate with their size, complexity and level of effort.

In decommissioning, conditions change with time. Even the decontamination process involves a change in the working environment. It is suggested that the graded systems engineering approach is more effective than the traditional engineering design/build approach.

The Battelle management step by step approach is as follows:

- assessment
- radiological control
- stabilization
- separation of contaminants
- monitoring
- waste minimization
- isolation of contaminate
- volume reduction
- disposal
- restoration
- closure.

The technical D&D practices are consistent with many other facility decommissioning projects. The traditional building construction approach had to be changed to accommodate lack of information and changing radiological conditions.

Implementation required a systems engineering approach for the field activities. The regulatory requirements were incorporated into the management system. A series of about nine plans were compiled and interpreted into procedures that describe how different aspects of the work are to be performed.

These procedures include:

- administrative procedures
- operational (health physics) procedures
- quality procedures
- waste management procedures
- D & D procedures.

As applied at Battelle, the systems engineering approach is an integrated procedural/work instruction enhanced by an effective change control process. Each of the segments of the system is designed to enhance the implementation of the work as well as a framework to accommodate changing conditions.

3.3.1.4. Why and when to use turnkey remediation

Turnkey remediation projects are most successful when owners and contractors understand the reasons for using a turnkey strategy and when the conditions are right [26]. They can save money and time and have the advantage of single point contact and responsibility. However turnkey projects can go wrong under some conditions and lead to unexpected delays, changes and claims.

Turnkey remediation projects use a single contractor for planning, design, procurement, implementation, acceptance testing and/or operations. They are a fast track approach to save time and money particularly overheads and achieve a shorter programme. Time can be saved also in less detailed planning and design and avoiding multiple bidding phases.

The use of a single point of contact between client and contractor is advantageous. If changes arise then cascade effects can have serious schedule and cost implications where multiple contractors and sub-contractors are used. A turnkey contractor is more able to find ‘ad hoc solutions’ which can absorb the changes and keep the overall project on track.

If the client does not have all the necessary expertise for specialist tasks and uses many interfaces with contractors, then delays are inevitable. A turnkey contract would be the most likely to avoid many problems.

Turnkey contracting does not however require fixed pricing. The level of definition and risks and competitive market forces should guide the form of a contract and the commercial terms.

Many US federal agencies prefer turnkey contracting as a way of saving money and avoiding the need for highly specialized in house skills and expertise and also avoiding complex interfaces.

The necessary conditions for a successful turnkey contract are:

- well defined functional and performance criteria
- well defined owner interfaces, regulatory oversight and approval requirements
- a well defined site and location

- use of well developed technology
- normal implementation and operational practices.

Factors that may however preclude the use of turnkey contracts are:

- funding and authorization is only available incrementally
- there may be Public Sector requirements to support small disadvantaged businesses who do not have the expertise for turnkey contracting.

The key to competitive and realistic proposals for turnkey remediation will be the preliminary planning and front-end design and the availability of a complete project cost estimate developed by the bidders for competitive proposal bidding. The project scope and the functional and performance criteria must be clear and complete for accurate planning and cost estimating. Well defined end point conditions for the project are needed.

One of the advantages of a turnkey remediation with a single point of contact and responsibility should translate into minimized direct involvement by the owner. In addition, advance definition of the regulatory oversight and permits and approvals will avoid unexpected delays and potential changes. The contractor will be obliged to determine the permits and approvals needed for construction and implementation.

The necessary project site surveys and investigations should be complete and accurate and interfacing utilities and locations should be defined. Good quality pre-project data will reduce risks and unexpected conditions.

The use of developed technology is one of the important factors for successful turnkey projects. New technologies do not have the necessary industry track record for assessing and managing project risks. Scale up factors from pilot tests cannot be properly predicted. The use of unknown high risk technology will most likely give unsatisfactory results for the owner and contractor. In addition, the need for innovative, unusual or unique implementation and operation practices may not give the best results. Competitive turnkey contracts rely heavily on the contractor's experience to assess requirements. The use of innovative approaches will only add to project risks.

In addition:

- turnkey projects based mainly on price should only require minimum technical proposal data.
- where qualifications and experience are important, a two step approach may be considered to initially evaluate a short list of potential bidders.
- where completion schedules are important, positive incentives are useful.
- contract terms and conditions should avoid onerous liabilities which could drive prices up. Also a very competitive best and final offer tactic can also drive prices up.

Finally turnkey contracts work best when:

- the owner and contractor recognize and share the risks
- all parties agree to avoid disruption of the initial project planning both parties deal effectively with constructive changes.

3.3.1.5. Technical aspects of premature shutdown

The Yankee Rowe plant was shut down prematurely in 1992 [27]. The aim was to proceed to a possession only licence (POL) as soon as possible. A period of 3 months from shutdown was the intention. POL essentially removes the authority to operate.

The immediate issues were:

- achieve a personnel and plant programme commensurate with the reduced risk of a permanently defuelled reactor.
- implement a spent fuel storage programme which would be safe until 2018
- develop and submit a decommissioning plan by February 1994.

Among the activities to achieve these goals were re analysis of the final safety analysis report, review technical specifications for reclassification of systems, consolidation of licence requirements, evaluation of spent fuel storage requirements and modification to ensure efficient use of energy.

Yankee Rowe relied on the well developed relationship between plant operating staff and corporate engineering staff. The corporate engineering staff organizational structure was changed to support closure activities. Three new groups were added viz. POL Group, Decommissioning Plan Group and a Spent Fuel Storage Group. Each Group was a multidisciplinary team incorporating appropriate expertise.

The POL group attended to accident analysis to reflect changes in the shutdown state and included spent fuel handling issues. The evaluation identified systems needed for defuelling operations and decommissioning.

The decommissioning plan group analysed the options of DECON (immediate dismantling) and SAFSTOR (safe enclosure) and adopted SAFSTOR which became the basis of the funding schedule.

The spent fuel group established the options and strategy for spent fuel storage looking at wet, or dry and on or off site storage.

The Board of Directors adopted a fair and responsible treatment of staffing requirements and employees affected after shutdown. In particular:

- continued employment to a given date
- assistance with outplacement
- a special severance plan for those not successfully placed
- a 60 day notice plan
- early retirement for those eligible.

The majority of individuals not needed were placed within the nuclear industry showing that the nuclear industry was in need of skilled staff.

In conclusion it was reported that an aggressive licensing, plant maintenance and corporate support effort resulted in achievement of the goal of securing a possession only licence.

3.3.1.6. Implementation effective radiological work at decommissioning reactors: breaking technical and cultural barriers

It is becoming apparent from experience at Connecticut Yankee [28] that large scale reactor decommissioning is more complex than originally thought and requires a different focus from constructing or operating a nuclear plant.

It was perceived that dismantling an old de-fuelled commercial nuclear reactor would be much easier than building or operating one. With the consequent reduction in technical specification requirements and the elimination of many quality requirements, the work environment at a shutdown facility appeared attractive. It was felt by some that decommissioning was “deconstruction” with a little leftover radioactivity, and thirty years of nuclear experience made it easy to deal with that.

Recent decommissioning jobs have therefore been started with aggressive schedules, limited resources, and an underestimation of the role of Health Physics. Since most quality requirements are eliminated for demolition work, the trend has been to use a lesser skilled labour force for decommissioning to reduce costs. The introduction of new and inexperienced workers to a radiological environment creates cultural issues that can impact productivity.

Perhaps the most difficult environmental challenge is the non-static nature of radiological areas during decommissioning. The proper characterization of plant areas and packages becomes a primary technical focus. The selection of appropriate packages for waste requires up-front technical assessment to prevent double handling.

The regulatory environment also changes during decommissioning. The means of obtaining an approved licence termination plan is a technically challenging process that requires a dedicated team to compile and then interface with State and Federal regulators and other stakeholders to obtain approval.

Several utilities have subcontracted all or parts of the decommissioning to other companies. In some cases, these decommissioning operations contractors (DOCs) have entered into turnkey agreements with utilities to decommission a plant for a fixed price. These agreements have proven to be economically challenging for DOC project managers due to the difficulty in identifying all of the costs and risks associated with the decommissioning process. The resources and equipment necessary to perform base work during decommissioning can be deceiving to decommissioning companies not familiar with managing a radiation protection group.

The inexperience of the labour force at a decommissioning facility can lead to front-line issues that can impact work progress. This cultural barrier puts a strain on radiation protection technicians in the field to maintain compliance with radiation protection programme requirements and guard against worker errors. Using inexperienced workers for tasks at decommissioning can also lead to rework and extra handling. This causes workers to spend more time in radiation areas and receive additional exposure. It does not take long for the added cost of radiological rework to justify using more experienced individuals to perform high-risk evolutions.

There have been several lessons learned from the commercial decommissioning projects to date that will help future projects become more successful. It is the complexities and uncertainties of the radiological aspects of decommissioning which have the most impact on schedule and cost. These are as follows:

- Decommissioning managers have to set solid up-front expectations for the workforce.
- Integrated task planning is essential in decommissioning.
- All disciplines, including craft, health physics, industrial safety, and others, should be involved when developing and scheduling job evolutions.
- Taking the time to evaluate and understand the level and experience of the decommissioning workforce will pay dividends.
- It usually proves more efficient and cost effective in the long run to use highly skilled workers for the higher risk tasks to avoid the cost and liabilities associated with training or the consequences of using unskilled workers.

- It can be a mistake in decommissioning to ignore the advice of long-time plant employees who understand plant characteristics and history.
- Detailed pre-job briefings are vital to ensure hazards are avoided during job performance.
- Work-in-progress briefings should be given to work crews at critical junctures during complex high-risk tasks to ensure all job requirements are understood and implemented.
- Because the regulatory process for licence termination is continuing to develop, it is critical to understand the roles of each organization involved.
- Developing working relationships with the key individuals in each regulatory organization will foster open communication and help site-closure activities progress.
- It is important to take time to know community stakeholders and actively work to eliminate their concerns.

All of the lessons discussed will help assure future successful decommissioning projects, however, the most important insight gained is the need to develop appropriate contingencies against failures.

3.3.2. Project and cost management

Experience specific to managing projects and costs are included in this section.

3.3.2.1. Decommissioning contract management — lessons learned from recent contractor experience

Early decommissioning experience reported by a contractor [29], when decommissioning was more of a novel experience, reported the following positive aspects:

- a realistic approach to risk sharing
- clear contract responsibility
- strong project management by the contractor with integrated client support
- contractor responsibility for authorizations, safety and security minimized interfaces
- the site was exempt from regulatory control
- a practical approach incorporating experience from elsewhere
- significant effort to understand the facility status and conditions.

Some decommissioning principles learnt were:

- Do not foreclose on techniques at the tendering stage
- encourage multiple options to replace non optimum plans
- seek opportunities to use experience from elsewhere
- ensure individual cost rates are relevant to total cost reduction.

Lessons learned from recent decommissioning projects were reported:

- There should be an understanding of the waste management process. This includes costs and waste routes.
- Possibilities to improve the planning process. The use of contractors experience in the client planning process was not always done.

Key parameters to address in improving decommissioning contracts are:

- a good understanding of the work as a contribution to risk management
- safety culture development including day-to-day safety, operator behaviour and safety planning
- client contribution
- staff competence and training.

Important project management lessons were:

- encourage best use of client/contractor skills
- establish performance monitors
- regular management audits
- full documentation of records.

More attention should be given to the tendering process particularly in the time made available, the extent of negotiations and the incumbent tendering costs to contractors.

3.3.2.2. Nuclear decommissioning — a contractors perspective

This example refers to both the client and the contractor. It points out that the contractor may also be a client if work is sub contracted. Salient points extracted from [30] are given below:

- Many contractors spend much time seeking opportunities and the issue of periodic bulletins by clients is useful. In Europe, all significant tasks must be advertised in the Official Journal of the European Communities.
- A question that is usually asked for long term decommissioning projects is how well the commercial risk is defined.
- The insistence on a compliant bid with no allowance for alternatives may not be the best approach.
- Inviting expressions of interest and pre-qualifying bids can help both client and bidders.
- Inquiry documents should be well prepared and include everything that is needed for a good tender.
- Following the issue of an enquiry, there should be enough time to prepare the bid and resolve any queries or clarification.
- The degree of involvement by the client in the project must be clarified and agreed.

Risk management is important for a successful contract. Factors that will influence risk are:

- Environmental
- Safety
- Regulatory
- Technical
- Programme
- Resources
- Finance.

Types of contracts depend on the contract strategy and are:

- Fixed price
- Phased fixed price (work by stages)
- Target cost with cost sharing formula
- Reimbursable rated with fixed rates, budget costs and limited liability
- Cost plus with reimbursable cost plus agreed mark up.

It is concluded that a contractor experienced in all aspects of the work and willing to work closely with the client and the regulator will deliver a successful project.

3.3.2.3. Mining surveillance and maintenance dollars

Reference [31] discusses a requirements based surveillance and maintenance (RBSM) process and how costs can be saved. It is a systematic approach to identify costs and drivers for surveillance and maintenance.

Some observations are made:

- Lack of reliability based engineering practices create over conservative surveillance frequencies e.g. lower usage during shutdown conditions.
- Unclear roles and responsibilities impact on surveillance costs and oversight e.g. duplication of work by engineering and licensing staff.
- Lack of facility integration drives up costs e.g. different organizations doing similar work and not combining or sharing work.
- Lack of worker and management acceptance of the waste in collecting duplicated surveillance data e.g. collection of computerized and manual data.
- Overly frequent surveillance inflates costs e.g. collecting data at twice the frequency to avoid the risk of missing a collection.

Lessons learned in applying the RBSM approach have been identified:

- The process requires committed management and facility personnel support
- The process requires dedicated well trained evaluators
- Best results are achieved by independent experienced are unbiased individuals
- Implementation planning is essential
- Facility staff must be well informed and trained
- Pre evaluation review and analysis is critical
- The team needs knowledge of management and DOE/industry practices
- A facilitated review process is the most effective rather than a self directed questionnaire process
- Identifying savings, first requires a review of the organization
- Administrative activities also need reviewing.

It was reported that, within the USDOE, about 160 000 man hours have been saved by this approach.

3.3.2.4. An analysis of decommissioning costs

A task force of several international experts was commissioned by the NEA/OECD in Paris to identify the reasons for large variations in decommissioning cost estimates [32]. Cost estimates from 12 projects (reactors and fuel cycle facilities) formed the basis of the study. The projects were divided into groups with similar characteristics and progressively refined by dialogue with project managers. A comparative analysis was then performed and project specific differences were identified. These were presented at a seminar in 1991.

Over two thirds of the refined percentage costs were found to be comparable and could be utilized. In the remaining third there were only marginal differences. Four cost models were developed covering different types of facility groups and stage of decommissioning. It was concluded that simulated costs in the models were more or less applicable and valid for the raw data from projects. It was emphasized that the models were for comparison only and are not absolute cost calculation models.

The lessons learned were that there is potential for making errors and also difficulty in performing quick international cost comparisons. Numbers taken at face value without regard to context are likely to lead to misinterpretation.

At the same NEA seminar in 1991, a supplementary paper was presented which tried to resolve the reasons in more detail for the discrepancies in international decommissioning costs [33]. Factors given were:

- exchange rates may bias comparisons
- decommissioning plans are different
- facilities are different
- differing estimated waste quantities correlate with cost differences
- waste disposal criteria are still to be fixed
- unit cost assumptions are important

It was concluded, however, that there is still a considerable degree of consistency in cost comparisons.

A further paper at the seminar [34] addressed the problem of achieving credibility in decommissioning estimates. The various factors contributing to uncertainty and loss of confidence were evaluated. It concluded that:

- Planning was wholly in the hands of the utility.
- International initiatives could greatly assist comparability of costs
- Independent review is desirable to enhance integrity of estimates
- Disclosure and form of presentation is essential for public confidence.

The last two items above will take time and this means additional cost to the industry.

It was noted in 1992 that there was no standardized listing of cost items or estimating methodology. This situation has been addressed in a 1999 publication by the NEA/OECD of a proposed standardized list of items for costing purposes [4]. A recent study [12] by the European Commission aimed at developing a simple, reliable and transparent methodology for cost assessment and financial planning of the decommissioning of nuclear power plants (see also Section 2.5.1). The methodology mainly contains:

a) Calculation methods and algorithms for the elaboration of cost items making up the whole decommissioning cost

b) Estimated or standard values for the parameters and for the cost factors to be used in a)

c) Financial mechanism to be applied as to establish a financial planning.

In particular, task 3 of this study provides an overview of the financial implications of different decommissioning strategies, calculations of costs, funding schemes and financial assumptions. The situation in several countries with nuclear facilities is analysed.

3.3.2.5. RMI decommissioning project strategies employed for major equipment remediation

The project involved the removal of a 3850 ton extrusion press, 7 furnaces and miscellaneous equipment totalling about 550 tons of Uranium contaminated material [35].

The project was undertaken in-house by RMI Environmental Services using subcontracted assistance from a separate organization and a series of limited scope service oriented sub contracts for improving efficiency. Bidders were allowed to propose the most effective strategy for completion of the project based on their own experience, expertise and equipment availability. Sub contractors were allowed to develop their own technical specifications which were then agreed.

The bid evaluation was technically based. Evaluations were performed using 70% technical and 30% cost criteria. Technical evaluation awarded points for each of 15 submittals defining the sub contractors approach which specified the technical aspects, experience and references, innovativeness and techniques for safety and quality assurance. Extensive and detailed evaluation was performed to determine the bidders familiarity with the specification, their ability to perform the work and their preparedness to interface with existing company systems, procedures and personnel.

Careful planning and technical specification development paved the way for efficient, on time and on budget completion of the project. There were effective approaches to waste minimization and cost control. The project was completed in 7 months.

It was concluded that decommissioning projects can be completed successfully though use of selective service sub-contracts.

3.3.3. Other specific management aspects

Although safety for decommissioning is a special subject in its own right, there have been reports on particular aspects and experience in the management of safety and the effects on the project. There is a strong relationship between safety and regulation. The experience of regulators in meeting the new challenges of decommissioning has been reported as well as the experience of decommissioning operators and planners in working within the regulatory framework. Some of the findings are reported below.

3.3.3.1. Industrial hygiene and construction safety issues and encountered during decommissioning

This experience is based on the Yankee Rowe decommissioning project [36].

In the transition from operation to decommissioning a number of human resource problems are likely to be encountered. Early resolution of the problem of staffing levels will reduce the negative impact of uncertainty among personnel. Construction crews, often accustomed to intervals of being out of work, require significant management of work on the site to maintain safety. As the previous operating procedures decrease, construction safety and decommissioning procedures become increasingly necessary. Any disparities between the facility and contractors safety programmes need to be resolved.

The components of an effective multi-employer work site management system need to be addressed. Important points are:

- contractors must submit information on their safety programmes with their bids
- the safety department staff will most likely increase with decommissioning needs
- need for safety training may increase with more exposure to radiation hazards
- engineering controls may become a first line of defence for safety
- construction safety hazards change daily
- each contractor should have a strong injury management programme
- for team work and cohesiveness, high safety expectations must be constantly applied.

Some issues for health, safety and industrial hygiene are:

- familiar hazard controls need to be tested daily and exercised often on a larger scale
- exposure to metallic lead should receive adequate monitoring and control
- training for work in confined space must receive adequate attention
- heat stress issues must be addressed especially when important plant is dismantled
- fume controls must be adequate especially where there is extensive cutting/welding
- standards must be applied to scaffolding especially due to variety of usage
- respirators needed for protection from dust from cutting and decontamination
- respirators needed for non radiological airborne hazards must also be provided
- provision of low volume personal air monitoring pumps to be considered
- good record keeping avoids encountering hazards as decommissioning work level increases
- Significant planning and preparation are warranted and a teamwork concept is vital to success of the project, which must be communicated in terms of safety, cost and schedule parameters.

3.3.3.2. A commercial approach to integrated safety management: decommissioning a Savannah River site tritium facility

The Tritium facility building 232-F was constructed in 1953. It is a one storey building of 17 000 sq ft, external facilities of 2260 sq ft and a stack 200 ft tall. The plant was shut down in 1958 and closed for about 35 years. In 1994 decommissioning initiatives were taken. A private company contract was allowed and the approach to safety was ‘as commercial as reasonably achievable’. This was a key feature of the procurement specification.

A description is given of the safety management programme [37] used by the contractor working under a fixed price contract. Utilising the safety management philosophy, accidents were minimal and cost savings of 77% over the initial estimate were made. Governed by company policies and requirements, the contractor is reported to have performed the work safely and economically.

An assessment is made of the key tenets of the contractors safety programme with the 7 principles for an Integrated Safety Management System (ISMS) prescribed by the DOE Policy.

The DOE policy is that safety systems be integrated into management and work practices at all work planning and work execution levels.

The system consists of six components:

- objective
- guiding principles
- core functions
- mechanisms
- responsibilities
- implementation

The seven guiding principles are:

- line management responsibility for safety
- clear roles and responsibilities
- competence commensurate with responsibilities
- balanced priorities
- identification of safety standards and requirements
- hazard controls tailored to the work
- operations authorization.

The five safety management functions are:

- define scope of work
- analyse hazards
- develop and implement hazard controls
- perform work within the controls
- provide feedback and improvements.

A key goal of the contractors safety policy is to prevent any type of loss caused by accidents or incidents and is intended to tie business performance to safety performance. The policy is claimed to have achieved 825 continuous day of work without lost time accidents. Justification and explanation of how the contractor complied with all the ISMS guidelines is given in detail.

An independent US DOE Oversight Organization conducted an evaluation of safety management and concluded in a final report in 1996 that: ‘the essential elements of an effective safety programme are in place for the 232-F project’ and ’ technical work documents contain sufficient detail to facilitate effective programme implementation’ and ’managers and workers are competent, technically qualified and knowledgeable of their safety responsibilities and authorities’.

3.3.3.3. A regulatory perspective of decommissioning in the United Kingdom

Decommissioning of power plants and nuclear chemical plants in the UK presents unique technical and organizational challenges to the licensed sites. It takes place in a situation where options for radioactive waste management and disposal are limited and the future is uncertain. This situation also presents the regulator with challenges [38].

Regulatory framework

The main legislation is the Health and Safety at Work Act (1974) and the Nuclear Installations Act (1965). All operators of a nuclear installation require a nuclear site licence which covers all operation, waste management on site and decommissioning. This remains in force until there is no danger from ionising radiation on the site. The sites are regulated by the Nuclear Installations Inspectorate (NII) which falls under the Government Health and Safety Executive (HSE)

Waste management including discharges from the site (liquid and gaseous) and waste disposal are regulated under the Radioactive Substances Act (1993) and administered by Environment Agencies. The HSE (NII) and Environmental Agencies work closely together.

Process of regulation

Licence conditions are attached to the Licence which cover many safety matters including the handling, treatment and disposal of nuclear matter. The conditions are generally non prescriptive and the licensee must make and demonstrate adequate arrangements to meet the safety issues. The conditions apply equally to operation and decommissioning. The NII can give consents, approvals and directions. The NII also administers the Health and Safety at Work Act that covers Industry as a whole.

One of the central requirements for the licensee is to issue safety cases for all operations which may affect safety. This includes work and plant needed for decommissioning. These safety cases must be periodically reviewed on a regular basis and reassessed in a long term review.

A requirement under conditions is the need to produce and implement decommissioning programmes and schedules. The NII has the option to approve programmes and to regulate the progression from one stage to another.

The NII has a high degree of regulatory control and can examine the adequacy of all arrangements for decommissioning and to challenge the arguments given in the safety cases. For the operation of a power plant or other nuclear facility, the NII can impose shut down or cessation instructions with punitive commercial implications but for decommissioning this is not the case. In the case of decommissioning, the NII has to ensure that the licensee pays adequate attention to planning so there are commitments to a reasonable programme of work. Regulatory pressure can be imposed to ensure that approved programmes are met.

Policy of the regulator

In 1995 the United Kingdom Government issued a White Paper on radioactive waste management [39] in which a fundamental theme is that decommissioning of plants should be undertaken as soon as it is reasonably practicable to do so, taking into account all relevant factors.

A requirement was placed on all licensees to draw up decommissioning strategies including proposed timetables and demonstration of adequate funding. HSE had responsibility to review these and to ensure there was adequate safety for protection against hazards for workers on site and that hazards are reduced in a systematic and progressive way. Priority would be given to high potential hazards. The availability of nuclear waste disposal routes was an important consideration.

Decommissioning strategies
Licensees are expected to keep their decommissioning strategies under review. The HSE would review strategies in conjunction with the Environment Agencies on a 5 year basis. The strategies should be feasible and within the constraints of Government policy, technical knowledge, safety, environmental requirements and site security. They will need to be costed and adequate financial provisions demonstrated. Where periods of surveillance are included, consideration must be given to monitoring, maintenance, and surveillance staffing and technical support.

Storage and disposal of wastes
The Government Paper of 1995**,** referred to above**,** states the intention to dispose of intermediate level wastes in a deep repository. No such facility exists in the United Kingdom and is unlikely to be provided until well into the 21st century hence safe storage on site is the only option. The waste must be characterized, conditioned and stored safely and passively in a form ready for disposal. The issues raised in terms of waste management do not stop with decommissioning. Consideration must be given to the eventual clearance of the site. Continued containment and storage of waste is an integral part of the site-wide strategy for decommissioning.

Decommissioning policy
It is HSE policy to decommission as soon as it is practicable to do so. For radiochemical plants there is little benefit to be gained by delay for radioactive decay and early action is encouraged. For large power plants, activation of certain internal components can yield benefits from delay for radioactive decay. There is a balance however between dose to workers and to the public in introducing delays.

Where consideration is given to deferring decommissioning, the licensee must not underestimate the regulatory requirements.

Human and organizational matters
The managing of change from an operational facility to one under decommissioning is seen by the regulator as important. Particular concerns are:

- loss of valuable staff
- reduction in morale and commitment to safety culture
- the effects of large corporate organizational changes
- the use of large numbers of outside contractors
- the loss of valuable documents and records and know how.

It is Government policy to encourage openness in all aspects of health and safety and this extends to nuclear decommissioning where many stakeholders can be identified. In reviewing licensee's decommissioning strategies, separate public explanation will be provided on the views of the regulators.

3.3.3.4. Strategic management of a large decommissioning project
On the Greifswald site, 8 units of the Russian-designed reactor WWER 440 are located, including several facilities to handle and store fuel and radwaste. Shortly after the reunification of Germany in 1989, the operating units 1–5 were shut down and the construction work at the nearly completely installed units 6–8 was stopped. After extensive investigations to restart some of the units, a decision was finally taken to decommission the site. Due to this decision, massive personnel reductions were unavoidable.

Technically the work was primarily focused on the removal of fuel and treatment of operational waste to provide the preconditions for decommissioning and dismantling. To solve this task of management of the spent fuel, operational waste and the large amounts of dismantled material, a large interim storage facility was built at the Greifswald site. This facility was built in order to guarantee that continuous dismantling could be achieved throughout the lifetime of the project. As can be understood from the initial conditions mentioned, this decommissioning project is multi-facetted and it was necessary to develop a strategy covering the following key areas [40]:

- personnel
- decommissioning/dismantling
- licensing
- waste/material management.

All these issues are interrelated and had to be solved in an integrated and iterative manner. In one respect the new managers of the plant Energie Werke Nord (EWN) are in a favourable position, since it is solely owned by the German State and thus a certain financial basis is secured.

Since no preparatory decommissioning planning had been performed before the decision to shut down, it was absolutely necessary to prepare a basis for the project and also the company.

First of all, a strategic analysis of the company was performed in order to:

- establish and evaluate all possible alternative company developments, considering all prevailing boundary conditions (technical, political, legal, economical and social).
- evaluate personnel needs and qualifications.
- transfer the company from an operational structure to a decommissioning project structure.

As a result of this analysis the following parameters were fixed:

- complete prompt dismantling (i.e. no safe enclosure period).
- construction of an interim storage for waste and fuel onsite (to achieve independence from disposal).
- transfer of the operating licence into a decommissioning licence.
- removal of nuclear fuel from the reactor units into the wet fuel storage on site and later dry storage in the interim storage.
- conditioning and removal of all operational waste.
- establishing an overall technical concept.
- perform as many activities with existing personnel as possible.
- reuse of the site.

After agreement on this company analysis, it was possible to introduce a project structure and begin the planning of decommissioning in a well defined manner.

Personnel

First of all measures had to be taken to reduce the number of employees, since this was much too high. To solve this problem, the following measures and principles were introduced:

- No major contractors
- A retirement scheme
- Privatisation/outsourcing where possible
- Education and training for decommissioning or re-employment in the labour market
- Dismissal with economic and financial support
- Re-industrialization of the site.

In this way it was possible to reduce the personnel from about 5000 to only 1100, which is still high, but justifiable. This value will be slowly reduced due natural wastage over the project lifetime. In this way the remaining personnel have clear perspectives and thus the basis for a motivated workforce has been laid.

Decommissioning

The second major decision was to decide on the decommissioning strategy, i.e. direct or deferred dismantling after a safe enclosure phase. Taking the overall boundary conditions on site, this was clearly a primary issue with major implications. In order to resolve this issue on a technoeconomic basis, it was necessary to perform complete project planning and cost calculation for both alternatives. As a result, it was shown that the direct dismantling is about 20 % cheaper, produces less radioactive waste and results in less total dose commitment. In order to understand this it must be remembered that the earlier Russian plants have a limited design lifetime (especially the buildings), have no containment (i.e. are not air tight) and have inadequate storage for operational waste. Obviously the direct dismantling option also had a positive influence on the job situation on site.

The timely planning on the basis of a thorough technical and radiological characterization of the plant and the organisation of the overall waste management, are absolutely necessary preconditions for a successful project. Due to the lack of disposal facilities in Germany in the near future, the Interim Storage North (ISN) was erected on site as an independent, integrated treatment and storage centre for radioactive waste and dismantled material, as well as a storage for spent fuel in CASTOR casks.

Licensing

The licensing strategy is an intricate issue, since, although it is easier to execute the project with one licence for a large plant, this represents an enormous effort from the applicant and also from the licensing authority and its authorized experts. If an unplanned plant shut down takes place, it is necessary, within a short time, to prepare the licensing documents, and therefore the initial number of documents must be limited in order not to seriously delay the project start date. Furthermore, it is normally necessary to proceed in an iterative manner with the licensing authority in order to agree on the number and detail of licensing documents necessary and finally on a licensing time schedule. Since the provisional license ended 30 June 1995, as a result of the transition agreement on laws between both German States in 1989, attempts were made to obtain as comprehensive a licence as possible and then to complement this with dismantling licence applications divided into parts. In this way, the efficient use of personnel, a continuous work plan and continuity in the licensing procedures and in-process control could be guaranteed.

After lengthy discussions with the authority and authorized experts, it was agreed that no public hearing was required, since there is no real public concern. However, the importance of informing the public of progress and developments on the project is well recognized and this is achieved through a liaison committee with representatives from the Government, NGO's and members of the public who meet regularly.

Waste and material management

The waste management concept is mainly based on the following boundary conditions and principles:

- Provision of sufficient buffer and intermediate storage capacities to achieve a high flexibility in logistics and waste management, including the construction of the Interim Storage North (ISN).
- Removal of the spent fuel from the reactors and cooling ponds to the wet interim storage (to obtain easier boundary conditions for dismantling activities) and later transport in dry CASTOR casks to the ISN.
- Installation of equipment for the treatment of dismantled material using modern technologies for the reduction of dose exposure and increase of efficiency.
- Further use of the existing waste facilities, upgrading or extension, as far as it is economically justified.

Concluding remarks

After initial difficulties caused by a massive reduction in personnel, combined with the introduction of a market economy and West German laws and procedures, EWN has succeeded in restructuring the company to arrive at a size suited to the task of decommissioning. A positive atmosphere has now been created to enable work to proceed effectively and to prepare part of the personnel and the site for the new tasks.

The decommissioning and dismantling of the Russian WWER type reactors does not pose specific problems when compared with the Western PWRs. However, the size of the project and the resulting material flow is exceptional. It can be concluded that dismantling of nuclear facilities is basically not a technical problem but a challenge to project management and logistics, once the legal and economical boundary conditions have been clarified. In order to achieve a safe and cost effective project, it is necessary that all stakeholders (i.e. EWN, the regulators, authorities, authorized experts and the public) achieve positive co-operation.

The project has proceeded very well. Major licenses have been obtained, agreement on licensing strategy with the authority has been achieved, fuel elements have been transferred, and interim storage facilities for radioactive waste, dismantled material and spent fuel are operational. For the future, the two gas fired power plants will keep the site as an energy producing site and thus, there will be a nucleus for further industrial enterprise.

To sum up, the lessons learned are:

- The development of a comprehensive inventory (radiological, material) is a necessary prerequisite for all planning especially waste management.
- Social aspects and psychological effects must be taken into account.
- Clear licensing structure - one licence is better if the project is not too large. Clear and realistic requirements from the licensing authority (related to real safety risks).
- The overall project must be planned from shut down, through decommissioning to disposal.
- Establishment of a project structure and the integration of all site activities.
- The dissemination of open public information as a key activity.
- Recognising that decommissioning is basically not a technical problem, but rather a management and waste management issue.
- ALARA principles must be strictly applied in the planning phase.

3.3.3.5. Regulatory requirements for the use of contractors on nuclear licensed sites

The legal position of licensees using contractors has been the subject of regulatory interest for some time and the current views are given in [41].

The principle regulatory difficulty is the need to preserve the special responsibilities of the nuclear site licensees that arise from the fundamental differences between the duties of the licence holder and those organizations running other types of installations.

The United Kingdom Nuclear Installations Act 1956 has three main aims:

- to implement the Paris and Brussels Conventions on third party liability.
- to provide a legal basis for licensing and inspection.
- to establish special controls for certain nuclear processes and security thereof.

At the first of these lies the heart of the difference between the roles and duties of operators and contractors.

The use of contractors is not ruled out by the regulator but licensees must oversee and take responsibility for contractors activities. The licensees employees must also have expertise, knowledge and control. The regulator would wish to see management prospectuses, organizational structures and safety management arrangements.

Considerations when using contractors are:

- only senior management would be of regulatory interest if items or services are of safety significance.
- routine services by contractors rarely have direct nuclear safety implications.
- short term contractors can be controlled through direct site operator supervision.
- long term contractors can present difficulties especially if they substitute the licensee's in-house staff.
- contracted management services may present difficulties if they dominate the site culture.

Particular items of regulatory interest include:

- exercise of sufficient control
- robustness of contract arrangements
- dealing with unsuitable or insolvent contractors
- industrial action or emergencies
- control of subcontractors
- maintenance of intellectual property at the end of the contract
- what arrangements are there if the contractor owns the assets
- arrangements for managing change
- arrangements at the end of the contract
- cover for emergencies and contingencies
- proper evaluation of contractors work
- availability of licensees supervisory resources

Questions that may arise:

- Can the licensee remain an intelligent customer?
- Is the work appropriate for a contractor?
- Is the licensee's safety management system adequate?
- Is the process planned and compatible with the duties of the licensee?
- Have long term considerations been considered?

A further consideration is whether the safety culture is acceptable and whether the licensee is proactive in this respect and able to transfer it to the contractor.

The long term considerations of decommissioning sites are of concern especially the care, maintenance and surveillance of a passive site. The expectation is that sites will continue to be managed in a professional and competent manner. The powers of the regulator can only be imposed on the licensee in this respect and have no effect on contractors. It would be quite unacceptable for incremental changes to drift towards absentee licensees or those without in house knowledge, expertise and control. For this reason 5 yearly reviews of decommissioned site will be done.

In conclusion the NII accepts that contractors can and do play a valuable role on nuclear sites but sole liability remains with the licensee and transfer of responsibility to contractors is limited.

3.3.3.6. The Trojan Large Component Removal Project

This project involved the shipping of large components (steam generators and the pressurizer) from the shutdown Trojan Plant owned by Portland General Electric (PGE) in Oregon by land and water to the Hanford Reservation low-level waste facility at Richland, Washington State [42].

Even greater regulatory oversight than normal was needed because:

- the work was performed before approval of the Decommissioning Plan
- existing regulations did not apply to shipments
- land and water transport was involved.

Court actions to prevent shipment by opponents of the project had to be dealt with first.

The regulatory process took two years of public processing to gain acceptance.

Two options for managing the project were considered:

- management by PGE personnel
- a turnkey contractor.

Bids form a turnkey contractor and individual bids to be managed by PGE showed that the PGE managed option would save about USD1.5m. A risk analysis between the options still confirmed the decision to manage smaller contractors by PGE.

The performance measures were:

- schedule
- cost
- dose.

The project was reported to have been accomplished safely, on schedule, under budget and at less than half the estimated radiation dose.

3.4. Stakeholders issues

The period covering the end of operation including shut down period and start of decommissioning brings significant changes not only in organization and personnel management but also in public relations and hearings. Clear concept of future changes understood by all stakeholders is one of the essential conditions for good and successful preparation of decommissioning process. This section covers specific experience in the development of the organization including suggestions for its improving, as well as experience in personnel management, which is recognized as one of the most sensitive, important and crucial issues after shut down.

3.4.1. Organizational issues

A sound organization allows an optimal use of available human and financial resources for the whole decommissioning optimisation process. This section covers specific experience in the development of the organization for decommissioning and lessons learned. Suggestions for improving the organization are given in specific projects.

3.4.1.1. Decommissioning at Nuclear Research Center SCK·CEN

The nuclear research center SCK·CEN at Mol in Belgium comprises of the following facilities that need decommissioning:

- BR1, a graphite research reactor
- BR2, a MTR reactor
- BR3, a PWR reactor
- Research laboratories
- An underground laboratory for research into geological waste disposal.

It was found by experience [43] that the sound management of a decommissioning programme implied the following:

- clear definition of the roles and responsibilities of all the parties involved
- close co-operation between the services concerned
- good description of the work to be done including the preparation work (e.g. provision of electricity, instrumentation and circuits)
- records of the progress made (e.g. update of the inventory, traceability of the decommissioning work streams)
- debriefing of the work done to improve the decommissioning studies in terms of management, safety and performances.

3.4.1.2. Decommissioning and decontamination lessons learned from US experience

From the US experience based upon several major decommissioning projects [44] including Three Mile Island unit 2, Fort St Vrain and the Purex facility at Hanford we could learn lessons which were particularly applicable to decommissioning and decontamination.

Organizational lessons

a) *Establish clearly stated, verifiable end states*

This is probably the most important single factor. The end states must be derived from the goals and objectives of the organization responsible for the tasks and also be acceptable to the organization taking over the facility at the end of decommissioning and any remaining stakeholders.

The end state must also be readily verifiable and independently measured and reported. If iteration is needed to achieve goals, then this must be taken into account.

b) *Use a dedicated organization*

Many sites have an operating team style of organization to begin with and it is recognized that their expertise and knowledge is vital. Experience however has shown that it is not effective to use an operating style organization because a new and different organization is needed which is specifically oriented to the new tasks. This is particularly so because decommissioning is more like construction than operation. It is important however to incorporate some of the experienced site personnel within the new team so their expertise can be fully utilized.

c) *Utilize flexible, short term planning horizons*

Decommissioning and decontamination is full of surprises and often techniques are being tried for the first time on a large scale. Experience has shown that a high level overall schedule backed up by a detailed planning process for relatively near term activities works the best. This type of planning coupled with an effective data gathering and analysis programme can allow for effective, flexible use of resources.

Technical lessons

- *Obtain and use hard site specific data*

In the absence of actual site specific data, it is premature to develop plans that expend a lot of resources for conditions that may not exist. Existing conditions, when revealed, may dictate an entirely different direction.

- *Minimize the volume of waste to be stored or shipped off site.*

Many factors influence the quantity of waste. These are highlighted and are an integral part of good decontamination and waste management practices.

- *Recognize and deal with special safety hazards*

Decommissioning can encounter many unusual configurations and non standard working conditions. Special concern with safety must fully consider safety hazards both internal and external to the facility.

3.4.1.3. Rocky Flats transitioning from nuclear operations to deconstruction

Rocky Flats is a very large site which provided fabrication of nuclear assemblies and chemical reprocessing, refining and alloying of plutonium and uranium. There were 792 facilities covering over 3.6 million sq ft (0.33 million m^2) of which 1.2 million sq ft (0.11 million m^2) were contaminated. Initially 9000 employees were used reducing to 4000 in 1997. The project cost is estimated to be USD 6 to 8 billion over 8 to 12 years.

Organizational lessons

a) Understanding and modelling of the facility cost drivers [45] was key to starts a new approach that cut billions of dollars off the estimated costs and decades off the schedule. Overheads have been cut by USD 100m per year which is available for funding more work.

b) The transition from operations to deconstruction highlighted many key elements:

- rebaseline of time frame and cost to suit employees and stakeholders
- restructure of site economic model
- focus on improved safety and safety infrastructure

- select early example projects to demonstrate achievement
- convert to a project construction-like attitude
- work with stakeholders towards a rapid demolition schedule
- competitive subcontracted production work
- renegotiate labour agreements
- renegotiate regulatory agreement

Objectives achieved

The site safety record has been significantly improved over the first year.

The pace of activity is increasing rapidly to meet production targets. It was noted that there were similarities with the project to decommission Fort St Vrain.

It was established that balancing on going operations costs with deconstruction costs is the consideration most impacting on the total project. Cutting the cost of operations by rapid closures, re-engineering and refined licensing was most beneficial.

Some important differences between deconstruction and operations were identified:

- temporary versus permanent design life
- activity versus facility based safety management
- as-verified versus as-built configuration
- off normal versus routine safety risk
- environmental and nuclear regulatory closure versus continuing operations
- management of change versus steady state
- reduced administrative support
- new employee training expectation
- employee tenure reduced and goals re focused.

Some of the challenges that were faced were:

- inadequate nuclear safety mindset
- nuclear and environmental regulation focused on operation
- inadequate and inappropriate safety infrastructure
- stakeholder expectations.
- workforce culture.

In conclusion it is stated that the transition of culture at Rocky Flats has nearly been accomplished.

3.4.2. Public relations and stakeholders issues

General public, workers and stakeholders are frequently concerned about issues like safety, local employment and the environmental impact of decommissioning. Experience has shown that to ignore the public relations aspects of decommissioning can lead to many adverse situations and delays. The following material gives some experience gained in public relations, which is supplemented with lessons learned as reported in Appendix A.1.1.

3.4.2.1. Stakeholders can help: improving D&D policy decisions at Rocky Flats

The Rocky Flats closure project involves deactivation and decommissioning some 700 buildings and other structures ranging from highly contaminated plutonium production facilities to uncontaminated office trailers [46]. This 10 year project which involves:

- Removal of all plutonium and special materials
- Deactivation and decommissioning of all buildings
- Environmental remediation.

There is a legal document called the Rocky Flats Cleanup Agreement signed by various authorities (Stakeholders e.g. DOE, Environmental Protection Agency and the State of Colorado)

A deactivation and decommissioning group composed of stakeholders formulated the decommissioning plan.

A public meeting was held to discuss building cleanup standards. Feedback was very negative because:

- pre-meeting communication was poor
- the subject was too technical
- there was no clear purpose
- limited advance notice was given
- senior managers were not involved.

It was decided to restart the consultation dialogue and a three tiered programme was initiated including the following:

- scoping session
- pizza meetings
- stakeholder participation in working groups.

The scoping sessions were public meetings advertised in newspapers, mail etc. Attendance was poor with little comment.

Two weekly pizza meetings were held over 6 months for persons with higher level of understanding (there was a wide variety of attendees). Dialogue was encouraged. Records kept of each meeting were distributed to attendees.

There was an open invitation to participate in internal working group meetings. There were only few participants due to other commitments. The result however was believed to be an increase in trust between stakeholders and decision makers.

In addition, copies of the Decommissioning Operations Plan (DOP) was distributed and yielded more understanding and dialogue.

The Rocky Flats Citizens Advisory board was invited to participate. They formed an ad hoc D&D committee and which effective in distributing information and creating dialogue. There were also periodic public tours of buildings. A particular success was the tours of building 779, the first major plutonium building to undergo deactivation and decommissioning in the US. There was also a tour of building 771 once considered 'the most dangerous building in the US'. Stakeholders made useful comments on the DOP. Figure 5 shows stakeholders being shown inside building 779 at Rocky Flats.

FIG. 5. Stakeholders reviewing room inside building 779 — Rocky Flats.

The pizza meetings were the most successful and dialogue and concerns were raised on:

- Worker health and safety and the environment
- Disposition of building debris and relative costs of disposal
- Deactivation and decommissioning technologies and use of experience from elsewhere
- Impacts on ground water especially during foundation removal
- Impacts on air quality due to releases of dust
- Use of building 779 as a pilot to improve future performance.

Particular benefit from the consultations has been the sustained involvement at senior level of Kaiser-Hill (contractor) and DOE decision makers rather than middle managers. This gave effective leadership and confidence at stakeholder dialogue meetings. This contributed to the success of the Rocky Flats project particularly in having dialogue before implementation. The project has been referred to as a successful case study in the making.

Two beneficial outcomes were identified:

- Deactivation and decommissioning planning benefited from stakeholder involvement and expectations
- Confidence was high that stakeholder interests were identified and addressed.

3.4.2.2. Addressing decommissioning and associated radiological issues: a community outreach programme

The Connecticut Yankee Power Plant was commissioned in 1968 and shut down in 1996 after an economic feasibility study. Decommissioning planning was proceeding when a number of radiological issues received attention from the local media [47].

A community outreach programme which addressed decommissioning was developed by Northeast Utilities (NU), who own Connecticut Yankee, together with the Oak Ridge Institute for Science and Education (ORISE) in order to attract the attention of various community stakeholders including employees, residents, political and business leaders, activist groups and the media.

The actions outlined address the needs of stakeholders using a variety of approaches and tools. Plant events and adverse non factual media coverage prompted the need for more educational efforts by the Citizens Decommissioning Advisory Committee (CDAC) and the Nuclear Energy Advisory Council (NEAC). There was mistrust about site characterization, discovery of unexpected radioactive sources and unauthorized transport of material off site.

NU and ORISE developed a comprehensive public education programme to help stakeholders make informed judgements on events. There was also a desire to enhance relations with stakeholders.

The initial step was to identify the key stakeholders and target audience. These were:

- general public/community
- educational institutions
- the media
- advisory groups
- local, state and national political leaders
- business leaders
- employees.

There was then the need to determine what problems were associated with the D&D programme and to decide what communication channels to use.

Actions

Public opinion poll survey

A telephone interview was conducted with a very high and encouraging response rate of 76%. Most respondents were over 60 with about 80% over 35. It was found that the older and more educated respondents were better informed. Many were interested in receiving more information.

Six key issues of concern were revealed:

- safety
- who pays
- environmental
- cost of cleanup
- rate (tax) increase
- soil contamination.

More poll surveys are intended.

Key message development

A short coming identified was telling the public what the organization thinks or assumes it wants to know rather than what the public actually wants to know.

Three salient points in the ‘message’ were:

- what happened?
- the impact

- what are we doing.

Types of messages could be categorized into:

- safety
- environment
- economics
- credibility.

Communication initiatives

The following initiatives have been instituted:

- open house to allow key stakeholders to visit for question and answer sessions
- a downloading home page giving information, using video etc.
- a community newsletter
- fact sheets
- a toll free information line
- a media relations programme
- political and business leader involvement including notifications before media coverage, a speakers bureau and political leaders days.
- a public education campaign to augment CDAC and NEAC information briefings.

There have also been internal communications efforts for employees so they can become informal but informed communicators with family, friends and neighbours.

It was concluded in 1998 that the public outreach programme had been successful and promised to continue.

3.4.2.3. Understanding why stakeholders matter

The importance of stakeholders and behavioural psychology is explained in the context of hazardous waste treatment. It is suggested that all stakeholders must feel that the benefits of the project must outweigh the perceived risks [48].

The factors to be considered in obtaining permits involved perceived risks and acceptability of risks. It was noted that earlier work on risks versus benefit had proposed that risk is proportional to approximately the third power of benefit i.e. doubling the benefits raises the level of acceptable risk by 8. This made involvement of stakeholders essential. An example of the trade off between technical and political questions was given in selecting between two different waste processing technologies. Case studies at the Hanford and Savannah River sites and the related choice of disposal sites were presented to illustrate stakeholder involvement.

The lessons learned from the case studies and another study were presented to illustrate the needs and rewards of stakeholder involvement:

- do not make decisions before involving the public
- if there is uncertainty about public involvement ask them
- organized opposition should be allowed for but not surrendered to
- trust accumulates through a process of better information and understanding
- stakeholders should be helped to focus on clean up issues and goals

- stakeholders should be involved in developing the plans and not presented with the plan
- the use of trained facilitators for building consensus can improve results
- NIMBY (not in my backyard) can be overcome if the process is carried out properly.

It is concluded that stakeholder involvement is a necessary but not sufficient condition for reaching acceptable solutions in difficult situations.

3.4.2.4. Decommissioning of a United Kingdom nuclear power station in a natural park — an owners perspective

Trawsfynydd is a large twin reactor gas cooled power station, which operated from 1965 to 1993 [49]. Defuelling took 2 years and decommissioning has been on going since then in preparation for safe enclosure (Safestore).

Being in a national park particular attention has been taken of environmental and countryside issues. Public consultation resulted in a general preference for deferred dismantling of the reactor structures.

Lessons learned show that the following aspects had a positive impact on public opinion:

- There was a clear and declared vision and strategy
- Safety objectives were zero lost work due to accidents, no significant events and a clean and tidy site
- Decommissioning objectives were doing the right things at the right time, making use of available waste disposal routes, knowing the end points and achieving milestone dates and lifetime costs within provisions
- An integrated project approach
- An integrated and committed staff/contractor workforce putting safety first
- Investment in the decommissioning infrastructure e.g. refurbishment and good house keeping
- Adoption of a total risk approach by considering all significant risks and their relationship with each other.

3.4.2.5. Socio-economic impact of commercial nuclear power plant decommissioning projects

Experience in decommissioning Vandellos 1 NPP in the period 1990 and 2001 reported that the socio-economic impact was significant [50]. It was suggested that dismantling could not be separated from the overall decommissioning process. The impact of dismantling should be analysed in three phases:

- Permanent shutdown
- Decommissioning
- Post closure.

Permanent shutdown

Permanent shutdown can be scheduled, which will allow pre-planning, or non scheduled which is more complex in terms of impact.

Loss of direct employment at the plant is inevitable but the impact may not be too high on individuals if there are options of early retirement or employment elsewhere.

If shutdown causes a demographic slump in the area, then the impact is more serious; there will adverse effects on local services and an overall economic impact. It will also affect local taxes and local amenities by reducing revenues.

The effect on local indirect employment can be serious. At Vandellos, the direct job loss was 300 in a local community of 4000.

During the dismantling period, the site is effectively blocked for any other beneficial activity.

It was recommended that the dismantling period is kept as short as possible to minimize the uncertainty and disruption on the local community.

Decommissioning period
Costs and hence activities are lower than for construction, but the start of dismantling work has been shown to produce a new impulse in the area. The society was shown to change and there was much more involvement and a desire for information. Public relations were particularly important. Figure 6 shows the "visiting point" into Vandellos 1 NPP reactor building, illustrating operator's efforts in public relations. A group of visitors to Vandellos watching a waste container being filled is shown in Figure 7.

An Information Commission was set up to track the progress of dismantling in terms of the following:

- Compliance with regulations and licence conditions
- Progress of the work
- Waste management
- Safety and the environment
- Events
- Training
- The training policy was particularly active.

FIG. 6. Vandellos reactor building, "Visiting Point".

FIG. 7. Visitors viewing waste container at Vandellos.

Dismantling work has reactivated the local community. As much local workforce as possible has been used. Vandellos dismantling work used up to 65% of locals. The work force has peaked at about 400 workers on site at the same time.

The economic impact was good. Revenues were obtained from permits and licences. There have been fees for waste storage and there has been promotion of local amenities for the community.

Post closure

The training initiatives in special skills were undertaken and can now be used by individuals to seek employment elsewhere.

There have been benefits in administration and management for the local authorities and companies which allows better job profile for employment in other sectors of the economy.

Institutions like a local university can benefit in creating specialisation for teachers and students in areas of high technology.

Companies can increase their skill and experience in gathering groups of specialists which can be used in contracting for work elsewhere.

The eventual release of the site for new enterprises can boost the local economy.

As a consequence of the local employment, training and communication policies described above, the project has won the credibility of the public opinion and it is being developed without any significant controversy.

3.4.2.6. Fostering community participation in decommissioning

Maine Yankee Plant has a Community Advisory Panel (CAP) which first met in August 1997 [51]. This was the first time in 25 years that a dialogue with the community was held. The reason was that the plant was placed on a public/media ‘watch list’. There were allegations of falsifying safety codes. A NRC review also revealed numerous safety deficiencies and there was a $30m upgrade programme. The plant was held off line.

A new management team had been engaged (Entergy Nuclear Inc.) to bring in required management services. In May 1997 however the Board of Directors withdrew funding and sought a new owner. The CAP continued to function to avoid adverse public intervention particularly if decommissioning was to be the next step. In August 1997 the plant was permanently shut down.

The CAP was established to enhance open communication, public involvement and education. Within three weeks of shut down the CAP was able to review the decommissioning plan and was alerted of decisions needed for spent fuel management.

The CAP was seen as vital to cost effective decommissioning. Its meetings were attended by a diverse group of 30–60 people and the local media. At almost every meeting a major decommissioning issue was presented such as post shut down activities report, the winning bid for site characterization, an updated decommissioning cost estimate and the defuelled emergency plan.

At one stage the question of re powering the plant with gas was discussed. There were great incentives to reemploy local people. CAP was involved in assessing of the bids. This project was not taken forward.

Another problem appeared when it was alleged that there was a potential for off-site contamination from the local landfill site which had been used by the plant. Involvement in an investigation followed on whether contaminated material had been taken from the plant to the local land disposal site about 10 years ago. This proved to be negative.

There were numerous other discussions and involvement in the decommissioning plans and activities. It was concluded that open communications gave benefits such as:

- rebuilding trust
- fostering understanding
- deterring delays.

Reasons to encourage citizen involvement were:

- people are entitled to be involved in issues that directly involve them
- involvement leads to better understanding
- input from those who live with the risks every day can lead to better policy decisions and solutions
- cooperation between the plant and citizens can increase credibility
- citizen outrage is reduced.

3.4.2.7. Decommissioning dialogue with stakeholders

As part of the decommissioning process for Magnox reactors in the United Kingdom, BNFL established a dialogue with a wide ranging group of stakeholders (industry groups, other government departments, regulators, institutes/societies, national/local pressure groups etc). A Timescales Working Group, Main Group and Steering Group were established to consider all issues from strategy to technical, ethics and morals. The dialogue process is facilitated by the United Kingdom Environment Council. Work has been ongoing through 2001 and 2002 and the lessons learned from this work were described in a Main Group meeting in March 2003 [52]. The revised aim of the dialogue was:

- To bring together the range of stakeholder interests to identify and explore the various decommissioning options for Magnox power stations and their sites and the implications of those options.
- In doing so, to generate common understanding of issues, problems and solutions and mutual understanding of all stakeholder perspectives.
- To identify where consensus exists and, if not, why it does not exists: in order to inform the development of strategic decision making.

A special discussion group meeting was held in June 2002 and the stakeholders were generally supportive of a strategic action planning approach to continue the dialogue. A meeting of the strategic action planning (SAP) exploration group took place in November 2002 and four meetings of the SAP group have taken place up to February 2003.

In July 2002 the United Kindgom published a White Paper on Managing the Nuclear Legacy — a strategy for action. The changes include the creation of a new national body — the Liabilities Management Authority (recently renamed the Nuclear Decommissioning Agency — NDA). The Magnox Dialogue Steering Group welcomes this initiative as being both relevant and a valuable opportunity to influence the future strategy for decommissioning in the United Kingdom [52].

During the autumn of 2002, BNFL publicised more widely plans being developed, under contract and in partnership with the Italian company SOGIN, to decommission the Magnox power station at Latina, Italy by 2020. In addition, the Trawsfynydd public inquiry has also taken its evidence. Both of these cases raised several issues that the dialogue groups will need to consider in the future.

This example gives an overview of a Member State actively engaged in stakeholder issues with respect to decommissioning.

3.4.3. Personnel management

There is recognition that the management of personnel after shutdown is one of the most important and crucial issues that face human resource or other management groups tasked with managing this aspect of decommissioning. Experience from Member States indicates that there a number of general aspects to consider in this area, including:

- Phased staff reductions, post-generation, via a revised organizational structure. This is linked to a reduced workload since there is no longer a generating plant, resulting in reduced hazards (nuclear and conventional) and a reduced maintenance burden
- Retraining key staff for the defuelling and decommissioning organization and attracting replacement staff if necessary
- Good communication to staff as experience has shown that most problems arise when staff do not know what is going on
- As appropriate, keep the trade unions aware of the organization's staff selection process
- Review the organization regularly
- Consider an enhanced focus on personnel development.

Given below are some specific reports on experience and lessons learned relating to personnel management. Relevant lessons learned are given in A.1.1.

3.4.3.1. People issues on a major nuclear decommissioning project

A large gaseous diffusion plant is to be decommissioned at Oak Ridge involving the removal of about 114 000 tonnes of material for disposal or recycle from 3 large buildings which will then be cleaned for unrestricted use.

People are educated and trained to create and not to destroy or pull down. Decommissioning is therefore seen as demotivating. Historically government sponsored projects have people believing they work for an impersonal system for which they have little ownership. To counteract these perceptions and motivate people to work safer and more effectively, a cultural change must be introduced [53].

The key aspects that will be affected are:

- safety
- quality assurance
- productivity.

Safety

A 24 hour a day behavioural safety concept will be introduced. This is to change behaviour before an accident occurs. The foundation of the system is:

- culture change workshops (CCW)
- safe and unsafe acts (SUSA) auditing.

The CCW is usually given in the first week of employment. The emphasis will be that all accidents are preventable and injuries and unsafe practices are unacceptable. The workshops will involve all managers and workers. Managers will have to develop a 'safety vision'. Workers will have a list of safety issues affecting the areas in which they work.

The SUSA procedure requires auditors to discuss safety with individuals in the workplace and provides a powerful tool for encouraging individuals to consider the possible consequences of their unsafe actions. Auditors are expected to undertake a given number of workshops per month.

Feedback is produced and published to record:

- safe and unsafe conditions observed
- safe acts observed
- unsafe acts and actions arising there from.

Enhanced work planning initiatives build on the CCW and SUSA activities and once a work task is identified, a team is set up with experts whose role is to identify hazards, mitigate the hazards and issue work safety instructions which are tested in practice. All workers are involved.

Another strategy is one minute assessments in which people are asked to simply step back from the task and ask if any unsafe conditions have arisen.

Case studies of accidents on a number of sites will also be used where persons will be asked to act as the investigating committee for an accident. This involvement will give employees better buy-in than merely telling people the answers.

Quality management system

It is suggested that many modern QA systems are large, unwieldy, often out of date, costly in money and effort and lead to non compliance.

A new approach is to involve the workforce and to make instructions as short, relevant and concise as possible. This approach takes into account that people are trained and qualified and allows them some discretion provided safety is not compromised. The emphasis is to move from a paper based system to a people based approach. Workers will be encouraged to use more intelligence in carrying out work.

Productivity

Teamwork is recognized as paramount to success and a good union and management relationship is a key factor. Discussions with appropriate unions were held early on in the project and the introduction of a good safety culture was engendered.

Flexibility in working practice was also a requirement as workers would be working in multi-disciplined teams. A labour agreement was signed with the Building Trades Union. The agreement has a no-strike clause and includes productivity bonuses. Other clauses on hiring, promotion, transfer, lay-off and discharge were agreed.

Conclusion

Involving people at an early stage in the decision making processes leads to a motivated workforce.

Good communication tools and techniques will significantly assist in gaining staff buy-in and contribute to customer and contractor success in the project

This project will demonstrate a way forward to a safer and more productive workforce.

3.4.3.2. UKAEA Doureay — restoring confidence in decommissioning of complex nuclear sites

In 1994, when the UKAEA (United Kingdom Atomic Energy Authority) was split up into government owned (incorporating the licensee) and private sectors, skilled staff retention became an issue. In privatising part of the UKAEA, many skilled staff transferred to the privatized companies leaving a shortage of skills in the UKAEA, resulting in an over dependence on contractor's skills for the delivery and management of key functions. Four years of organisational changes within the UKAEA had so weakened management and technical expertise at Dounreay that UKAEA were in a poor position to carry out the tasks of decommissioning and delegation of responsibilities was carried to far in the view of the regulator [54]. Dounreay was the UKAEA's main site for fast reactor research from 1955 to 1994.

A United Kindom Health and Safety Executive/Scottish Environment Protection Agency (HSE/SEPA) Safety Audit [55] of Dounreay in 1998 revealed concerns over safety and physical security. It was suggested that a key factor was the over enthusiasm in using private sector support to help manage the site and external contractors in carrying out the operational decommissioning work. The regulators were expecting a culture change in the management of the site. The use of contractors was accepted but the responsibility of the licensee is to supply the controlling mind, drive through the work and be satisfied that the work is being carried out properly.

Since 1998 the situation has improved and the approach of the reorganized UKAEA in managing nuclear liabilities has been reported [23]. The UKAEA responded [56] to the 142 detailed recommendations in the Audit Report through allocation of the recommendations to six logical groups in order to address them, wherever possible, by common approaches or solutions. The six groups identified were:

- Management and organisation.
- Human resources and training.

- Operational strategy.
- Safety cases.
- Safety management systems.
- Safety culture.

Interim progress reports on the Audit Report were presented in 1998 and 2000. As a follow up from the Audit Report [55], the Dounreay Site Restoration Plan was published in October 2000 [57]. The Final Report 2001 was published in January 2002 [58]. The report confirms that the UKAEA have completed work on 89 of the 143 recommendations. The remaining recommendations cover long term strategic topics and these have been addressed in the Site Restoration Plan [57].

Work by the UKAEA and audit by the HSE/SEPA will continue but this example demonstrates a commitment to continuous improvement in the six group areas given above in order to restore confidence in decommissioning of complex nuclear sites.

3.5. Data, information and records

Rigorous data management and record keeping are recognized as an essential part of decommissioning due to the long period involved. As the operating experience of a nuclear facility may be lost when it is shut down, one important element of planning it is to identify and store before shut down the appropriate design and operational records needed to support decommissioning. After decommissioning starts, important records produced during decommissioning have to be preserved for a limited time as well as records produced after the termination of the nuclear licence. The details are given in an IAEA Technical Report [5].

Some of the experience gained and measures taken are given below. The lack of records leads to decommissioning delay, under or over estimating input data and consequently increasing costs.

3.5.1. Decommissioning Management System at Greifswald NPP, Germany

This describes comprehensive computerized decommissioning management system for a very large decommissioning project. It was developed for the Greifswald NPP and Rheinsberg NPP facilities [59].

Decommissioning Management System (DeManS) consists of:

- Decommissioning Information System (DIS) (planning, execution, supervision and analysis), as described below,
- Document Management System (decommissioning related documentation),
- Service Event Tracking (SET), (registration and supervision of events),
- Environmental Information System (EIS), (measured data collection and analysis).

The basic features of DIS are the control and optimisation of the decommissioning project in terms of capacities, resources and costs.

The Greifswald DeManS is running on the basis of 4 structures which are:

- work breakdown structure
- responsibility structure
- object structure
- resource structure.

The execution of tasks under these structural elements is performed within an interrelated data system that is described in detail below.

The work on the two sites is divided into 6 projects within the company organization Energie Werke Nord (EWN). Figure 8 shows the hierarchy of the Work Breakdown structure with the three planning, calculation and control levels described below.

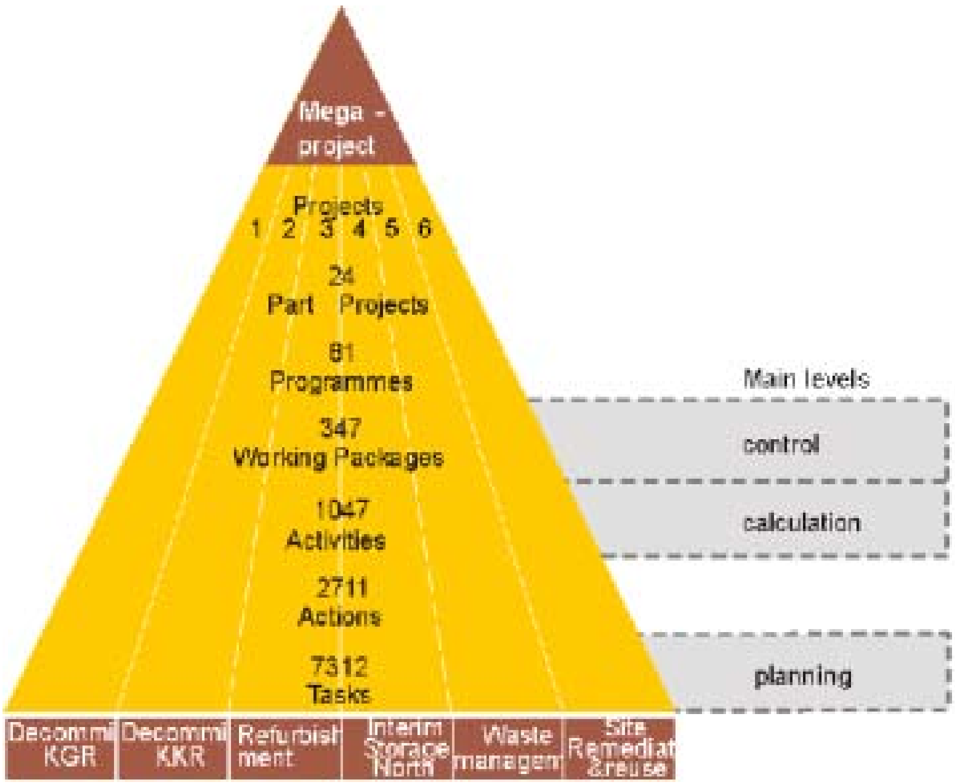


FIG. 8. Hierarchy of decommissioning information system (DIS) at Greifswald.

Individual tasks are the smallest planning unit while the Working Packages (WP) level is the main control level. Each WP has a complete specification (e.g. definition, task details, target dates, costs, capacities interfaces etc.) together with a "Project Permit" signed by the Managing Director. On the basis of the WP, the network plan, time schedule, budget plan and personnel plan will be prepared and the project execution supervised.

A database system is required for running and administering each of the projects. The DIS had to be specially developed within EWN. It takes into account:

- determination of planning data
- collection of actual data concerning dismantling (it gives a feed back to next step)
- cost calculation on the real basis
- comparison of planning and actual data
- reports/documentation.

The system also allows the critical path schedule to be determined. The system is accessed from numerous computer terminals located a various positions and connected to central processors. Main levels of system (shown in Figure 8) are used for project control, cost calculation and detailed planning.

Lessons learned during the creation of DIS:

- A specific software system has to be developed
- Development was best done using in-house resources but in a close co-operation with external sources
- A clear project structure as a main basis of a well running software system.

3.5.2. Safe shutdown of defense programme facilities at the Mound Plant Miamisburg, Ohio

The Mound Plant is a large facility consisting of over 100 buildings on a 306 acre site [60]. It was primarily an explosives component manufacturer but also handled nuclear materials such as Polonium, Plutonium and Tritium and stable isotopes. Activities have ceased on the site and the DOE became the ‘landlords’ in 1995.

The three main objectives are:

- reducing hazards
- reducing financial liability
- reuse of facilities for economic development.

The buildings are divided into:

Type A — currently in use

Type B — destined for reuse

Type C — no further use.

The materials are divided into:

- energetic materials — explosives
- inert classified components
- chemicals
- cleanup of energetic materials
- nuclear materials.

The nuclear materials are a complex issue because the wide variety and the lack of characterization. They are to be shipped to other DOE sites which causes public concerns. Packaging is also a problem.

The lessons learned are:

- It is very important to collect process knowledge about past operations before knowledgeable staff leave.
- It is almost impossible to get an accurate fix on the location of all accountable equipment and material because of the loss of historic data. A comprehensive plant inventory is now necessary.
- Contractor and DOE past practices need to be examined and challenged.
- As one of the first sites to attempt to transfer buildings to the private sector, there have been continual changes in the interpretation and implementation of acceptance criteria.

3.5.3. Data and records management in NPP A1 Jaslovske Bohunice, Slovakia

The nuclear power plant A1 was constructed and operated even before requirements for safety documentation were issued. Lack of experience and non-optimal spent fuel management during the start of NPP A1 operation led to serious corrosion of spent fuel cladding and consequently to contamination of all connected systems. Hence, much attention now has to be paid to radiation protection.

Abnormal occurrences at NPP A1 during operation were either not recorded or the data that was obtained was not classified and maintained as such. Data was therefore badly managed and partially lost. As a result contamination levels was underestimated.

The start of decommissioning was strongly hampered by significant lack of data and an ad hoc approach was adopted. For example, some parts were dismantled non-systematically for the purpose of making space for waste management. A conceptual decommissioning plan was only prepared 15 years after final shut down and great attention and effort was therefore needed to devise a suitable information system to support the systematic decommissioning of the plant.

Some material, structural and radiological data were obtained on the basis of drawings and files, checking of actual status by personnel and remote video recording and measurements. The process still continues for systems where dismantling is planned during the next phases.

The existing information system for this NPP was not suitable for decommissioning purposes and a new independent system based on ORACLE 8 was devised. Data had to be re-entered and this process is now still on-going.

This system now includes the following information:

- description of plant and equipment
- description of building construction
- electrical connections, measurement and control (including procurement construction records with types and quantities of materials used during the construction, specification of components, supplier details and weight, size and type of material).
- lists of technical and safety documentation for decommissioning preparation (e.g. safety reports, technical manuals, environmental assessments, radiological survey reports, decontamination procedures and reports, technical specifications)
- radiological characteristics including dose rates
- abnormal occurrence reports including surface and internal contamination
- documentation and procedures for work breakdown structures.

Although attention to decommissioning started very late and many documents were lost, the situation has now been largely recovered and the new data information system is operating satisfactorily and continuously. More details are given in the IAEA publication on record keeping criteria and experience for decommissioning [5].

4. CONCLUSIONS

A survey of source material and literature on general experience in decommissioning planning and management has revealed a considerable amount of information and lessons learned over the last 10 years.

There is an awareness of the importance of feedback and reporting of experiences both good and bad. Not all aspects of decommissioning were covered equally, however, and there are areas where more reporting would be useful. Some subjects that were not well reported are on safe enclosure, care and maintenance, cost outcomes at the end of projects and aspects of waste management. A good deal of information is available on management, public relations and personnel management, and on the merits of various approaches to the management of projects. Regulators have also reported some of their experiences and learning process in the area of decommissioning.

A large number of publications exist on the technical and practical aspects of decommissioning but these have not been included except where there are specific lessons to be learned on planning and management or the lack thereof. This includes some of the very large projects and sites.

From the experience reported throughout this document, the main conclusions are identified below:

- National decommissioning policies are evolving due to an accumulation of the experience at national and international levels.
- Experience has shown that to ignore public relations aspects of decommissioning can lead to many adverse situations and delays. Lack of information is often treated as lack in transparency by the public.
- Planning is an essential part of all decommissioning activities and there are numerous reports on the benefits of good planning. Planning at least a few years in advance while the facilities are still in operation is best, preferably with appointment of a dedicated project team. There are also reports of where lack of planning has lead to unnecessary and avoidable problems.
- Reviews of ongoing decommissioning processes are essential for two main reasons. Firstly, the assumptions made at the initial planning stage will inevitably need review. This especially concerns funding and planning of longer decommissioning projects. The second is that improvements in the decommissioning activities during the project need to be included.
- Roles and responsibilities of the stakeholders are best determined at an early stage in the decommissioning planning. Waste and spent fuel management issues are particularly relevant in this regard.
- Human resource needs to be focused on. Ideally, skilled operating staff would be integrated into the decommissioning team.
- The uncertainties felt by personnel when plant is finally shut down is common in all situations and should be anticipated.
- Feedback has been received from contractors on decommissioning experience. Based on this experience, it is recognized that advantages can be obtained by training of personnel in respect to radiological protection, use of new equipment and work safety. The benefits are risk minimisation and timely delivery of the plan, resulting in safe and cost effective work.
- The identification of radioactive waste streams and routes is a key issue in decommissioning planning. The absence of routes for waste disposal can result in delays in the decommissioning process.

- The importance of secure record keeping throughout the design, operation and decommissioning of a facility is widely recognized.

It is concluded that the continued feedback and reporting of lessons learned is a valuable contribution to decommissioning and should be encouraged. Forums such as workshops, seminars and international conferences are particularly effective in assembling information for the benefit of others.

APPENDIX 1
LESSONS LEARNED RELATING TO DECOMMISSIONING ISSUES

The following examples of the lessons learned from decommissioning projects also include a brief technical description of the problems encountered. They are specific lessons learned that were identified by authors or were easily derived from their published material. Some of the material is anecdotal however from those with direct experience. No commentary is made on any of the material. This appendix is supplementary to the much of the material presented in Sections 2 and 3. The situations described are typical of the issues that can arise in the planning or management of decommissioning activities. The information presented is not intended to be exhaustive and the reader is encouraged to evaluate the applicability of these cases to a specific decommissioning project.

The Appendix is divided into 10 categories of subjects to allow some systematic presentation of information although it is appreciated that some categories may overlap. The division of material into **problem**, **solution** and **lessons learned** and considered as a **case** is purely editorial for this document.

A.1.1. Stakeholder issues including staff and public relations

Case 1: Overcoming the grief of plant closure (Fort St. Vrain/USA)

Problem

Two problems associated with plant shutdown are obvious: the technical challenges of decommissioning and the cost of closure. However, little recognition is given to maintaining an effective organization and dealing with the effects on people. Technical, cost and people issues are bound together [61].

During downsizing an organization, people may potentially lose substantial control over their lives and welfare. In the nuclear industry this is accompanied by a pre-existing dominance of regulatory agencies. Lack of control of the organization impairs morale and performance.

Employees face three critical changes:

- they are working themselves out of a job (unless there is the opportunity to retrain or redeploy)
- they may deal with higher levels of radiation than in normal operation
- they are dealing with radiation in a different mode.

An example is given of Fort St Vrain which was beset with low morale during years of unsatisfactory operating performance and then again at shutdown. Psychology consultants addressed the following:

- assessing the executive management team
- providing access and consultation with the vice president
- consulting with team managers to assist in the transition
- comprehensive assessment of the organization
- review of safety and health indicators
- periodic debriefing to relieve grief due to the shutdown
- participation in the design of the new organization.

It is important to recognize the psychological and social effects of shutdown. It was contended that emotional and social needs are not just something to put up with or endure. Stress of change can impact on work groups as well as individuals. Three common impacts on teams are:

- withdrawal and decrease of useful communication
- confusion caused by decreased information flow and ambiguity
- decreased intergroup co-operation and diminished common goals.

The above can spread and cause a chronic condition in the entire organization. This is noticeable in decreased quality of decisions, deterioration of co ordination and fragmentation of the organization. Even with an apparently logical technical plan, chaos can occur often resulting in even more bureaucratic rules and routines.

When closure is announced and decommissioning proceeds from planning through defuelling to dismantling, a number of human responses occur and reoccur to individuals, groups and the organization. Some of these are:

- denial and anger
- increasing confusion, depression, anxiety and withdrawal
- sense of loss and 'death' of the organization
- increased perception of safety risks
- decreased co operation and diminished confidence in management
- conflicts over goals and with other groups, protection of one's own "turf"
- acceptance and co-operation if progress is seen to be made
- increased focus if goals are clarified.

Solution
It is suggested that seven critical actions must be taken by management for decommissioning to unfold successfully:

- be honest and respectful to employees
- increase accessibility to management and listen
- develop a comprehensive plan which includes people issues
- increase the flow of information
- provide training, consultation and support for managers to deal with their emotional reactions and enhance their skills in dealing with staff
- acknowledge staff commitment and extend rewards
- routinely monitor emotional climate.

Lessons learned
It was concluded, from the Fort St Vrain experience, that attending to the psychological aspects gave a smooth transition in changing the organization. Conflict was managed well and all senior managers grew and developed their management skills. The plant exceeded 5 million man-hours without time lost due to injuries and the decommissioning project stayed on schedule and budget.

Case 2: Maine Yankee principles (USA)

The following guiding principles were recently written as a group effort by the employees of the shut down Maine Yankee NPP. The purpose of this exercise was to provide a kind of touchstone of core values which employees could turn to when faced with uncertainty on how to proceed [62]. The initiative taken by Maine Yankee to address employee problems is indicative of a problem anticipated and avoided and is a lesson to be learned. The core values were identified as:

Act with integrity
Be open, honest, trustworthy, reliable and responsible.

Recognize employees are Maine Yankee's most important resource
Provide and seek opportunities for career and professional development; recognize employee and peer performance; provide appropriate training, facilities and resources for all employees; respect the importance of employee personal time.

Practice ownership
Promote and accept empowerment; recognize and seize opportunities for ownership of responsibility; make a committed personal investment; expect and strive for excellent results; practice personal accountability.

Practice self-critical behaviour
Self-check, Stop-Think-Act-Review (STAR), identify problems, resolve problems correctly the first time, learn from mistakes, and raise personal performance standards.

Work and operate safely and efficiently
Make well-informed decisions, avoid workaround situations, put personnel and equipment safety first and respond to plant priorities.

Adhere to technically accurate human-factor procedures
Develop procedures that are simple, easy to follow, with clear intent, that are performed as written; improve procedures promptly utilizing worker inputs.

Maintain equipment
Maintain a low corrective maintenance backlog; a high preventive maintenance/corrective maintenance ratio and low out-of-service frequency for all equipment; improve work processes; use capital and O&M resources effectively and make sure installed equipment is consistent with design basis.

Case 3: Failure to communicate start of decommissioning work effectively (Belgium)

Problem
At the end of the 1980s, the Belgian government decided to restrict the activities to nuclear R&D and to create a Flemish research institute (VITO) dealing with non nuclear research from SCK•CEN. Buildings and employees were divided between the two research institutes. Four buildings where nuclear R&D was performed in the past had to be decontaminated to unrestricted reuse levels (i.e. de-licensed).

The decommissioning of the first building was used as a test case. The radiological survey has shown that contamination can be found in very unexpected places even though the contamination levels were rather limited. No information to other employees on the site was given because it was judged that they had enough nuclear background through their past career at SCK•CEN. The decommissioning work as performed without causing any interruptions in the R&D work performed in the other parts of the building. However the decommissioning work generated strong reactions from the other employees because they were not aware of the intent. This was seen as a potential problem.

Solution
Several information sessions were organized for the personnel. The first information session presented the global project and was followed by other sessions presenting each phase of the project. When the decommissioning was completed a debriefing session was held.

Lessons learned
Information to the employees and public has to be well prepared in terms of topics, content and timing. Compared with the total cost of a decommissioning project, the cost of the information is rather marginal and can save money by avoiding problems due to lack of communication. Failure to communicate is often considered by the public and other employees to be a lack of transparency.

Case 4: Public perception associated with the decommissioning of Niederaichbach (KKN Germany)

Problem
As KKN decommissioning represented the first total dismantling project of a nuclear power plant in the Federal Republic of Germany. The licensing authority had insisted on formal participation of the public according to Article 7.3 of the Atomic Law, even though this was not necessary according to Article 4, Paragraphs 2 and 5 of the Rules of Procedure under the same Atomic Law. Under these rules, participation of the public is obligatory when there is potential for an increase in risk. During the public hearing in 1985, about 3000 objections were raised. With a few exceptions the comments were found to be identical in content.

A citizen of Niederaichbach and the city of Landshut took legal action against the licence granted. In general the citizens of the local communities and cities were concerned because they assumed that significant radioactive releases to the environment were associated with the dismantling work which was not correct. Following legal judgement, the actions were dismissed by the Administrative Court of Regensburg. For the public benefit, immediate execution of the licence for the public benefit was ordered on 30 June 1987.

Solution
The project manager established a continuous relationship with the mayors of the neighbouring communities and cities. Meetings were scheduled at the beginning of every month to inform the local council about the activities. The members of these meetings were invited to visit the site on several occasions. The frequency of the meetings was reduced consistent with an increase of confidence in the work by the public, because no relevant incidents or accidents were reported.

Lessons learned
Public relations and information is considered cost effective. It is important to recognize and accept the public perceptions, answer all questions and try to inform in an open manner. As a result of this approach, the local communities and the district administration promptly passed the civil licence for demolition of buildings, and also accepted the release level for concrete as filling material for road construction. During the demolition many local citizens including young mothers with children observed the work from the KKN fences. At the end of the project the mayor of Niederaichbach reflected the sadness of the local community over the demolition of the KKN stack, which was considered a landmark by the community.

Case 5: Strategic decision-making for the decommissioning of the Whiteshell Nuclear Research Laboratory (Canada)

Problem
The decision in 1998 to close AECL's Whiteshell Laboratories left a great deal of uncertainty in the termination time frames for several research program activities. The planning for

decommissioning of the site, already in progress when the formal closure decision was announced, was impacted because nuclear facilities included in the decommissioning scope were still actively being used by research programmes. Further compounding the problem was the use of supporting nuclear facilities (e.g. waste management and handling) and general site infrastructure. This led to significant issues, relating to continued need for site services in developing a closure and decommissioning plan that best met overall AECL needs.

The key impact on decommissioning planning emanated from the conflict between meeting key AECL business needs related to existing research programs while reducing significant operating costs associated with a large laboratory site operation. Although the remaining research programs used only a relatively small percentage of site facilities, those activities required an inordinately large amount of supporting infrastructure in operation. This contributed to high, continued operating costs and constrained the ability of the decommissioning project to progress efficiently to drive down the site legacy costs.

Solution
The approach to resolving the conflicts between continued use and decommissioning was to engage all affected parties in developing key planning assumptions and time frame commitments for operating areas, service requirements and cost sharing. For several operational components this involved selection of shutdown dates which best met business needs for research but limited decommissioning delays and constraints. It also required some consolidation of the continuing programs to allow shutdown/decommissioning to advance in facilities where most space was already vacated.

For one key component, the Whiteshell Waste Technology Business, the solution was to acknowledge that the business would operate indefinitely at the site. Accordingly, the operation was consolidated into a part of the largest site laboratory building which could be segregated to allow decommissioning of the balance of the facility.

Lessons learned
The main lesson learned was that the initial concept developed for the Whiteshell Site closure and decommissioning was unrealistic when detailed consideration was given to existing business needs. Some experimental facilities were too large to be moved and required lengthy time frames to terminate operations at Whiteshell and to establish replacement facilities elsewhere.

However, involving all parties in discussions with the clear objective of setting operational shutdown or alternative operation location assumptions was successful. These activities led to a workable decommissioning strategy which could accommodate the needs of interim and in some cases longer term operational requirements.

A.1.2. Regulatory issues and licensing

Case 1: Step change in licensing regulation (Belgium)

Problem
When expediting the decommissioning plan of the SCK•CEN, Belgium in the period 1995-1996, the decommissioning management team found that the management costs could be reduced without affecting the quality of the management and in compliance with the existing legislation.

In the last five years, however, the legislation concerning the management of liabilities for nuclear installations has drastically changed as follows:

- The National Agency for radioactive waste management is, by law 1997, entrusted with the centralized management of the inventory of all nuclear installations and all sites containing radioactive substances within the country. It is also responsible for approval of the decommissioning plan, cost assessment for decommissioning and site remediation and the verification of sufficient financial provisions for the future execution of the decommissioning and restoration programmes.

- By the Royal Decree of 20 July 2001, authorities must be notified of the intention to shutdown a nuclear facility. In addition, for the major nuclear facilities, a decommissioning licence is required. The decommissioning licensing documents consist of the final decommissioning plan, a safety case on the foreseen decommissioning operation and an Environmental Impact Assessment report.

- By Royal Decree of 18 November 2002, waste producers have to obtain an agreement concerning the methodologies and the measuring devices used for radiological, physical and chemical characterization of the waste.

Those changes have also led to reorganization and modification of the responsibilities of regulatory bodies and authorities, with a consequent increase in paperwork and management costs as well as delays in obtaining the required licences.

Solution

For the management of the nuclear liability funds, SCK•CEN developed, in the early 1990s, a tool called DEMATO (*DE*commissioning *MA*nagement *TO*ol). This allowed not only estimates of costs or the remaining costs to complete decommissioning, but also the traceability of the decommissioning waste and management of the nuclear liability inventory. Other management practices have been examined, e.g. duplication of work was eliminated and backup functions were implemented inside the management team.

Figure 9 shows the qualitative evolution of the management costs over a seven year period. The obvious benefit of the implementation of the decommissioning management tool (DEMATO) can be observed in the decrease of the "in house costs". Unfortunately the changes in legislation and the fees charged by stakeholders are now off setting the benefit of this management improvement.

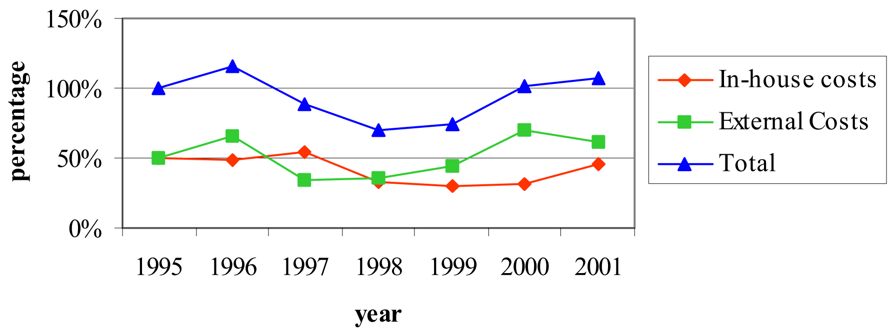


FIG. 9. Evolution of the management costs in function of time (1995=reference year).

Lessons learned

- The routine work has to be frequently scrutinized to improve the ratio of quality to expenses.

- When possible, the changes in the legislation have to be anticipated to limit the impacts on the project, by allowing the implementation of backup or alternative solutions.

Case 2: Changes in release criteria (Germany)

Problem

Due to technical problems, the Niederaichbach Power Plant (KKN) in Germany was shut down on 31 July 1974. The licence for safe enclosure, the first step of decommissioning, was granted in 1975. Implementation of safe enclosure took until 1981 costing a total amount of 18 Meur, including 1.1 Meur for regulation and technical supervision. By then, all operating fluids including the heavy water and the fuel elements had been disposed of and the controlled area had been restricted to the containment accommodating the entire radioactive inventory of about 7.4 E+13 Bq (1982).

Upon completion of these activities, the ambient dose rate was less than 0.01 mSv/h in the accessible areas. The annual cost of safe enclosure — checks by the technical control board (TÜV), radiation protection and monitoring, conservation, repairs and safeguarding — amounted to about 0.3 Meur and, in the course of time, increased to about 0.6 Meur in 1987.

During the implementation of safe enclosure, a project to demonstrate total dismantling of a power reactor to "green field status" was considered necessary from the research policy point of view. Due to its short operating time and the comparatively small radioactivity inventory, the KKN was selected as a demonstration dismantling project. The decision in favour of complete dismantling of KKN was taken in 1979. A licence application was made in accordance with Article 7.3 of the German Atomic Law. This licence was granted on 6 June 1986 and became effective with the order of immediate execution of 1 July 1987.

In 1979, a general contractor was hired to prepare planning and licensing documents based on free release levels of 3.7 Bq/cm² for ^{60}Co averaged over an area of 100 cm². The contract for complete dismantling of KKN was also awarded at a value of 35 Meur. Subsequent changes in release criteria resulted in the licence granted in 1986 specifying release levels of 0.37 Bq/cm² for ^{60}Co (10% of the original value applied for).

Following difficult negotiations with the contractor, the reduction of the release level resulted in a remarkable increase in costs by approximately 15 Meur.

Lessons learned

It is important that all relevant licence requirements and criteria exist before any tendering process is undertaken. In this case, with the tender already placed, the tenfold reduction in release levels resulted in a massive increase in work content with the consequent cost escalation demanded by the contractor.

Case 3: Environmental assessment impacts on the licensing strategy for decommissioning of the Whiteshell Site (Canada)

Problem

The Whiteshell Laboratories (WL) operating licence was administered by the Canadian Nuclear Safety Commission (the Regulator) and included provision for commencing decommissioning of redundant nuclear facilities. Therefore, AECL's initial strategy to decommission the nuclear facilities to a Monitoring and Surveillance state was proposed under the existing operating licence. The proposal included a transition to a site decommissioning licence after a first phase of work lasting about 5 years.

Ultimately, the regulator decided that this approach was not suitable for a project where the final objective was a fully decommissioned site. The ensuing licensing activity, requested by the regulator to issue a site decommissioning licence, triggered a full site environmental assessment under Canadian Environmental Assessment Agency legislation. The environmental assessment (EA) study level was established as a Comprehensive Study

Report. This level of assessment necessitated evaluation of all WL facilities, buildings and service infrastructure to a final endstate.

The study involved in-depth analysis of several significant site components and incorporated a Federal and Provincial government level review as well as a regional public consultation program. Compared to the initial proposal to commence decommissioning under the operating license, this imposed licensing and EA approach resulted in a delay of approximately two years in commencing decommissioning project work.

Solution
The only solution was to expedite the EA process as efficiently as possible to minimize schedule impacts. This required maintaining tight control over the EA preparation, review and comment process and document revisions to address issues. The EA process was completed, culminating in formal acceptance by the Minister of Environment, within a period of ~ 3 years. The resulting project delay was mitigated to the extent possible by advancing site characterization work, facility shutdown operations and preparation of supporting licensing documentation in parallel with the EA process.

Lessons learned
One important lesson learned relates to the strategic decision-making process for the WL project. Careful consideration must be given to the announcement of an official site closure date. In this case initial decommissioning activities might have been advanced for selected nuclear facilities while decisions on the termination of site research programs were being finalized. The formal announcement of a decision to close the site was a major factor in the regulator imposing the comprehensive EA study.

Another lesson is to recognize when the regulator is developing the licensing approach as the project develops. The licensing approach to administering the decommissioning of a major nuclear research laboratory to a final endstate had not previously been conducted in Canada. This tended to delay regulatory decision-making on the licensing strategy (and associated EA study level) required to implement decommissioning.

A third lesson learned was the value of establishing early and frequent interaction with the regulator. Clear definition and communication of key project messages and a relationship that fostered early discussion and resolution of issues proved to be instrumental in moving the EA forward.

Case 4: Step change in regulation (France/COGEMA)

Problem
A decommissioning project is mainly composed of two phases called the final shutdown and dismantling. The main objectives of the final shutdown phase are to place the facilities under safe condition and to reduce the activity level to as low as reasonably achievable. The application of the regulatory procedures fixed by the actual decree pointed out a certain number of technical and administrative difficulties, such as:

The necessity to get two decrees (one for final shutdown and one for dismantling). The consequences are delays in the dismantling operations. The decommissioning project is then too segmented and overall coherence can be lost.

Difficulties in application of the decrees, linked to the definition and interpretation for different installations. The definitions are well adapted for reactors, but not for installations such as laboratories or reprocessing plants. It is difficult to define a precise limit of what can be done under final shutdown and dismantling decrees.

Solution
Subsequently, the French Regulatory body wishes to integrate the feed-back of several French decommissioning projects and published new regulatory procedures early in 2003. It is planned to cover all the decommissioning operations in a unique dismantling decree, thus simplifying the regulatory framework. To get the authorization, the nuclear operator will have to submit a list of documents (defining the chosen final state, explaining the main dismantling steps, a safety report, general rules of surveillance and maintenance, internal emergency plan, an environmental assessment study and waste management study).

In order to get a certain level of flexibility during dismantling, the regulatory body recommends also that the operator to put in place his own organization to proceed through internal authorizations and inform the authority.

Lessons learned
Due to a fruitful discussion between the different nuclear operators and the Regulatory body, the lessons learned from several French decommissioning projects were integrated in the establishment of new regulatory procedures. This clarified and defined more clearly the second main step of a nuclear installation after operation, which is decommissioning, with the need of only one decree.

A.1.3. Organizational restructuring

Case 1: Forming a new organization structure for decommissioning (Vandellos I — Spain)

Before establishing the organization to be used in the project, ENRESA, the new operator of Vandellos I, established the following criteria [63]:

ENRESA must operate as a management company with a minimum of internal resources in key positions at Vandellos, obtaining maximum support from the head office and applying its own methods and management systems.

ENRESA must optimise the use of the resources and know-how of the former operator.

ENRESA will hire specialist companies for specialized activities

ENRESA has to take advantage of this first decommissioning experience and obtain a reusable model, valid for similar future projects.

Taking these guidelines into account, before the decommissioning began, ENRESA developed and successfully implemented the key aspects of the new organization:

- A new general organization chart, in which decommissioning services (engineering, work performance, waste management), and controlling services (quality assurance, radiological protection) are clearly separated and report to different managers.
- Organization guides giving job descriptions, responsibilities and training requirements.

New basic documents, classified into three main groups:

- Operation, maintenance and security procedures.
- Administrative and quality assurance procedures.
- Engineering and work performance procedures.

Management information systems, incorporating documentation, financial, human resources and waste management data. This system is based on newly developed software that allows identification and control of routing for all materials arising from decommissioning in three main areas: non-radioactive, declassifiable and radioactive waste material.

Lessons learned
For implementing decommissioning successfully, it was necessary to develop an appropriate new organizational structure and new management systems. The existing operating organization could not meet the needs of decommissioning.

Case 2: Forming a new organization structure with complementary skills. (France/COGEMA)

Problem
The change from operation with clear production objectives, to a decommissioning project extending over a very long period of time, with vague objectives, can be very problematic. Even if it is known that the end of operation will occur, this change is often sudden and the management structure not fully prepared to face such a situation. The first persons to be involved in a decommissioning project are nearly always the operators, who are essential because they are familiar with their facilities, but generally have a lack of experience in decommissioning activities and particularly project management.

Solution
An appropriate organizational structure is needed for the decommissioning task force. In changing the organization from operations to decommissioning, there is a need for culture change and the involvement of others skills such as those of the prime contractor. A dedicated decommissioning team gathering complementary cultures with sufficient resources is a key factor.

Lessons learned
With regard to selecting appropriate resources for implementing a decommissioning plan, the decommissioning project structure should include members in the team from different backgrounds the operators of the facilities, decommissioners and prime contractors.

Complementary skills are necessary to conduct this type of complex process with many interfaces.

A.1.4. Decommissioning plans and technology

Case 1: Evaluating the correct techniques for decommissioning work (Belgium)

Problem
Most of the techniques required by a decommissioning project have reached industrial maturity. Therefore it would seem unnecessary to perform non-radioactive testing. Unfortunately, this overlooks the fact that the industry always tries to improve performance by changing some components and that in some cases the decommissioning requires the simultaneous use of techniques creating an interface (e.g. a cutting technique coupled with a deployment system). The combined use of well proven techniques does not necessarily ensure that the goals will be achieved. The specific nuclear environment can indeed introduce new problems not previously experienced by the industry.

In addition, development of new techniques can be beneficial to tackle some special decommissioning problems.

Solution
In the selection of decommissioning techniques, there is still a need to collect relevant information concerning actual performance in practical use and the requirements to interface with other systems or techniques. Information can be gathered by contacting experienced users and/or by performing non-radioactive tests. When “new” techniques have to be used, it is worthwhile to recommend intensive tests on scale models before use in a nuclear environment.

Lessons learned
Selection of adequate and correct techniques is an important process in a decommissioning project. It allows optimizing the planning by reducing the uncertainties and risks. Assurance can also be obtained by tests. An advantage of the tests in a realistic situation is that they allow training of personal and improvement in performance resulting in decreased intervention time, reduced dose uptake and minimized waste production. (see Appendix A.1.5, Case 1).

Case 2: Experience with safe enclosure — re-equipping the site after 10 years (Lingen site — Germany)

Problem
The licence for safe enclosure usually imposes the removal of all operating media and the limitation of the controlled area to the containment accommodating the entire radioactive inventory. This also implies the termination of the operational license and a substantial reduction of radioactivity to the environment by air and water discharges. The reapplication of a new decommissioning licence after only 10 years of safe enclosure resulted in a significant recommissioning of equipment, e.g. crane, elevators, social infrastructure, etc. in accordance with the existing state of the art regulation as well as in new, more restrictive release limits and discharge levels. For example: Lingen, after approximately 10-12 years of safe enclosure, had to apply for a new water discharge licence invoking more then 17 legal acts by the local communities to increase the discharge amount from 100 m^3 to 1000 m^3. The project was therefore delayed, resulting in an increase of costs and general slowdown of other decommissioning activities.

Solution
When selecting a decommissioning strategy, one must be aware that some strategies are more sensitive than others to changes in boundary conditions and evolvement of legal framework.

Lesson learned
Safe enclosure is vulnerable to changes in legislation and regulatory requirements. Immediate dismantling is less sensitive to many of the above problems.

A.1.5. Training and retraining

Case 1: Enhancing the application of safety rules and procedures at SCK·CEN (Belgium)

Problem
People involved in decommissioning activities on the BR3 reactor and other facilities at Mol are faced not only with radiation hazards (direct radiation and airborne contamination) but also with industrial safety problems (fire, toxic substances, dust, noise, load handling and work with scaffolding). They often use new techniques or proven techniques but in a new environment. There is however a trend, when performing work, to minimize the implementation of the safety rules in order to make the work easier and quicker.

Solution
Information and training sessions were organized to emphasize that the decommissioning procedures that are approved by the Health Physics Department, specifically mention the safety measures to be taken before, during and after performing the dismantling work. Non-radioactive testing on mock-ups was also organized for the BR3 reactor for the dismantling of the highly activated internals and pressure vessel. Testing was also used in laboratory buildings where glove boxes and hot cells have to be dismantled or decontaminated. Figures 10a & 10b shows the training of personnel by non-radioactive tests on mock-ups of reactor internals compared with the actual dismantling.

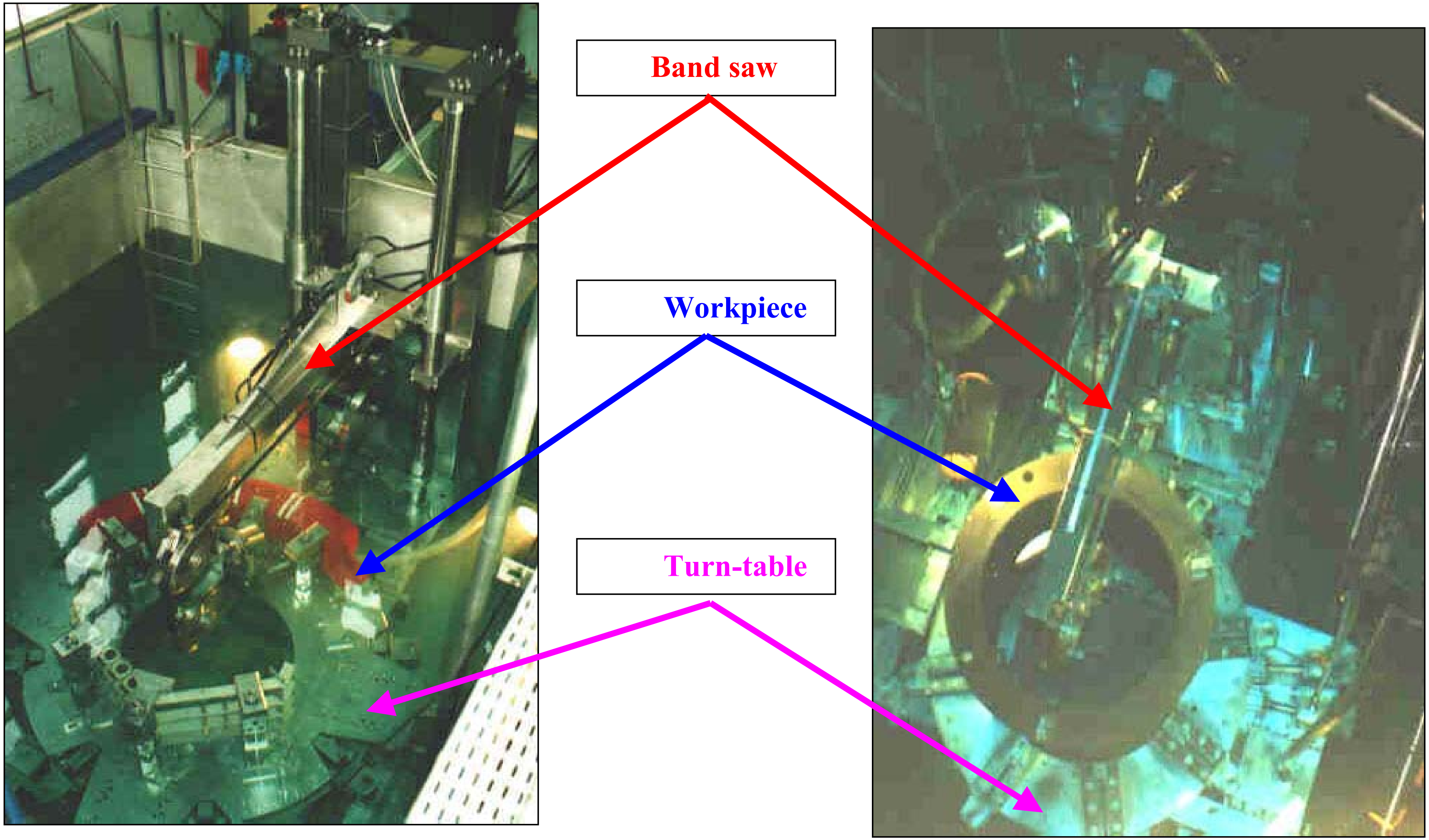


FIG. 10a. Mockup testing tank.

FIG. 10b. Actual cutting in refuelling pool.

Lesson learned
To minimize the hazards during the decommissioning activities, the personnel have to be informed about the safety measures and trained to work in this specific environment. During these mock up tests all aspects of the decommissioning with the exception of the radiation hazards are simulated. Non-radioactive tests allow reduction of the intervention time and consequently, minimizing the dose uptake. Information and training have to be repeated periodically to maintain and improve the safety culture of the personnel.

Case 2: The use of dedicated teams for surface decontamination at Vandellos I (Spain)

Problem
The decontamination and declassification of surfaces proved to be a special problem. This occurred in zones where there were suspected or known incidents and where adequate records were not kept. This situation was made more complex by the activity of other contractors undertaking dismantling work in adjacent areas. It was found that the resources available for this decontamination and declassification work were inadequate.

Solution
The solution was to train specialized teams dedicated to these activities. They would be responsible for methodology, regulatory approvals, procedures and also for the necessary equipment e.g. scaffolding, lifting equipment, protective coatings and scabbling of concrete and cleaning of equipment.

Lesson learned
The lesson learned was that the importance and complexity of surface decontamination should not be under estimated and specialist teams trained in this work would greatly facilitate decommissioning.

A.1.6. Defuelling and fuel management

Case 1: Unresolved problems in the management of spent fuel and an impact on costs (Belgium)

Problem
The management of the back-end of the fuel cycle is a major concern in decommissioning projects particularly when faced with experimental spent fuel from research reactors. Different solutions such as reprocessing dry and wet storage were evaluated. The licensee and stakeholders collectively decided to adopt dry storage and specified a detailed budget covering all the costs including the disposal costs. A few years later, the commitment between the licensee and the stakeholder had to be signed by both parties to define the decision taken in legal terms. This has led to a re-discussion of the financial considerations and responsibility for the fund to be secured to cover all the future costs, from the commencement of dry storage to the final disposal of the spent fuel. Significant increase of some costs is to be expected.

Due to the reorganization of the authorities, the transport and the dry storage licences were not issued even after a delay of several years.

Solution
Once the licences obtained, the spent fuel was put into dry storage to avoid further delay. Financial aspects (operation and maintenance, repackaging prior to disposal and final disposal) are still however under discussion.

Lesson learned
It is difficult to reach a definitive consensus for costing a 50-year storage project (50 years correspond to the retained storage period for spent fuel before the repackaging and disposal).

Delays in solving the back end of the fuel cycle have impacted the decommissioning planning.

A.1.7 Waste management and disposal

Case 1: Optimizing waste costs by using alternative routes (Belgium)

Problem

When implementing the decommissioning plan of the SCK•CEN in the period 1995-1996, the decommissioning management team noticed a yearly increase of the waste cost by about 15% (Figure 11). At that time, it was reported that the costs would soon be stabilized.

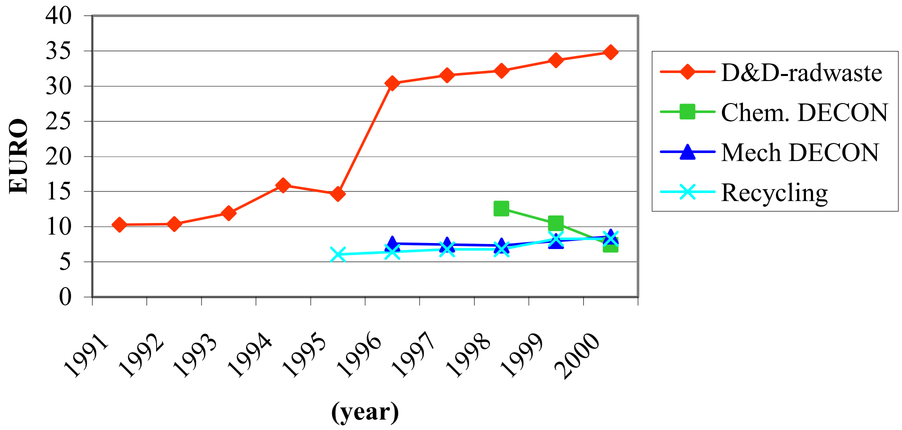


FIG. 11. Indicative evolution of the different evacuation ways for 1 kg scrap metal LLW.

Solution

To keep the decommissioning costs under control, it was decided to invest in decontamination facilities and to find alternatives routes for decommissioning scrap metals. The routes used at SCK•CEN are:

1. radioactive waste conditioning and storage
2. free release after chemical or mechanical decontamination
3. melting for recycling in nuclear industry
4. melting for free release.

Figure 11 shows the evolution of the cost of the different routes for 1 kg metal in the low level waste category (activity higher than 20 Bq/g and dose rate less than 2 mSv/h). This figure shows that large savings can be made by decontamination.

Lesson learned

From the early beginning of the decommissioning programme at SCK•CEN, it was found important to establish alternatives for waste and to apply these according to actual cost. This allows minimizing the impact of inflation of the waste costs.

It was also important to create some alternative waste management routes because each of them has particular constraints e.g.:

- Free release of material by decontamination or by melting depends on public acceptance.
- Recycling and reuse in the nuclear industry depends on the demands of this industry.

Case 2: Optimizing the packaging of containers to reduce the number of waste packages (Germany)

Problem

In order to increase profits, contractors have a tendency to package the radioactive material in containers or drums as quickly as possible without regard to packing efficiency. This increases the number of waste packages which results in higher disposal costs. The general contractor of the KKN project predicted a total of 169 containers each with a volume of 4.6m^3, to load the reactor pieces. During the loading of the first containers the project manager observed inefficient loading of containers.

Solution

The solution was to assign responsibility to optimizing the packaging procedure, thereby utilizing the volume of waste containers to a maximum. This required a revision of the cutting processes. The contractor was encouraged to load the containers according to a new optimized procedure resulting in 143 containers. The reduction of 26 containers represents savings of 52 000 Eur for container costs and 325 000 Eur for disposal costs.

Lesson learned

The optimized packaging of containers and drums when closely controlled can result in a significant cost saving through reduced waste volumes. In this case a saving of EUR 377 000 was achieved through close attention to packing efficiency.

Case 3: The creation of a special waste management department to deal with large waste volumes (Vandellos I — Spain)

Problem

A particular problem was experienced during decommissioning at Vandellos I, concerning the management of dismantling waste. It became clear that the existing organization initially established to carry out materials management was not able to deal with the very large quantity of resulting material (300 000t), although only a small percentage was radioactive [64].

Solution

The solution found was to create a new department dedicated to the coordination of all materials management activities e.g. reception, storage, conditioning, characterization, declassification, dispatch and records management. This department was also partially responsible (along with the health physics department) for procedures, including those related to declassification and clearance. They also established waste transfer routes and temporary storage areas for different materials.

Lesson learned

The lesson learned was that controlled & coordinated materials management become a vital part of the decommissioning process. It is important to organize waste management activities and to approve procedures required as soon as possible in order to avoid delays in decommissioning.

A.1.8. Funding and finance

Case 1: State funding (Slovakia)

Problem

No proper funding mechanism was available in Slovakia when NPP A1 shut down after an accident in 1977 and that unit was decommissioned on an ad hoc basis. Funding was provided by an annual state budget and therefore each individual task was planned on a yearly basis. This way did not allow a systematic and successful approach.

Solution
An Act on the State Decommissioning Fund was promulgated and issued in 1994. In 1995 the Fund was established and used for NPP A1 decommissioning in accordance with a decommissioning plan issued in 1994-95.

Lesson learned
State Decommissioning Fund was created for all Slovak nuclear installations and financed on the basis of power and electricity sales. State budgets can also be another source of funding especially for NPPs shut down before the fund was created.

Case 2: Government approach to liabilities and funding (Belgium)

Problem
The Belgian government wanted to have a better review of the nuclear liabilities, to understand the situation better and to prepare future policy.

Solutions
By a Law issued on 12 December 1997, the Belgian government entrusted the radioactive waste management agency (NIRAS/ONDRAF) with the drawing up of the inventory of all nuclear facilities and sites containing radioactive substances on Belgian territory.

The site licensees have to send to the Agency all the required information concerning:

- The inventory of their sites, installations and radioactive substances
- Their costs estimates for decommissioning and cleaning up facilities and sites
- Their funding mechanisms to assure that sufficient financial means will be available for decommissioning.

Lesson learned
- 1064 sites containing radioactive materials were identified. This was more than expected.
- For some nuclear sites, the financial responsibility for covering the liabilities differs from the operator, the licensee and/or the site owner. The duties of each party have to be clarified within the next few years;
- The existence of a liability fund is not easy to control when it concerns institutions (e.g. universities, state owner companies, etc.) that are not obliged to submit a yearly financial plan for approval;
- The cost estimates are based on borderline conditions and assumptions, which are changing with time. A periodical review of the cost estimates is required (e.g. every 5 years);
- The management of the liability fund is influenced by the economic situation. Some concerns have been raised about the availability of sufficient funds to carry out the entire decommissioning programme.

A.1.9. Project strategy and contracting

Case 1: Maine Yankee explains issues in contractor's dismissal (USA)

Problem
The decommissioning is intended to make the 800 acre property suitable for other uses, including recreational and business development. The plant closed in 1997.

Maine Yankee terminated its agreement with a contractor responsible for the shut down nuclear power plant's radiological protection programme citing inconsistent management practices. The problem was a human resources issue. "Their management practices were inconsistent, and the effects of that were becoming too distracting to everyone else on site"[65].

Solution
Some key considerations in managing the contractor staff were:

About 85 contractor's employees working at Maine Yankee were allowed to reapply for their jobs.

Managers were to become Maine Yankee employees.

Lesson learned
Contractor internal management practices must be a key factor to be considered when granting a contract.

Case 2: Development of a decommissioning strategy for the large Greifswald decommissioning project (EWN — Germany)

Problem
The main issues to be taken into account for the decommissioning project strategy are:

- to establish project management
- to develop a personnel management strategy
- to establish detailed and clear project planning.

The objective is to achieve:

- a detailed technical decommissioning concept
- a well running licensing procedure
- to fix a dismantling strategy
- to establish a waste management strategy (materials flow)
- to develop the site for reuse.

Lesson learned
Project management

- Technical planning has to be established at the earliest decommissioning phase, if possible before the end of the operational phase.
- All constraints and risks must be considered.
- Definition of a clear work breakdown structure on the basis of clearly defined decommissioning objectives.
- Recognizing the importance of a clear resources structure for the personnel planning (internal and external).
- Practical project planning at the most detailed project level possible.
- Definition of the main cost and manhour calculations and control levels for the project.
- The timely installation of a decommissioning management system to keep a clear overview of the project and to ensure flexible cost and time management.

Personnel management strategy
Main decisions were:

- To resolve the personnel issue as soon as possible.
- To avoid using major contractors by:
  - using experienced operation personnel,
  - only using contractors for special small requirements.

Licensing procedure
The main decisions were:

- One major overall licence complemented by specific ones (eight part licences to cover progressive steps in dismantling which:
  - ensure work continuity (a full work load process),
  - give adequate time for preparing planning documents and continuity of authority control.
- Exemption levels included in the first licence as a basis for planning of waste management.

Waste management
The main decisions were:

- To construct a new on-site interim storage facility for fuel, waste including treatment stations for the dismantling waste.
- Decontamination of the dismantled waste so far as reasonably possible.
- Early and complete use of free release and exemption criteria (to avoid a bottleneck in the free release measurement facility).
- To create buffer storage places to ensure a continuous material flow at all times.
- Early planning and implementation of treatment facilities and material flow logistics.

Dismantling strategy
The main decisions were:

- To dismantle items as intact as possible and transfer these to the new interim storage as large items.
- To provide decay storage for large components with higher contamination.
- To dismantle with fuel in the plant where this is possible or permitted.

Site reuse
The main decisions were:

- To start the planning for reusing the site as soon as possible in order:
  - to create new working areas at an early stage.
  - to give a positive outlook to the project for personnel.

A.1.10. Records and documentation

Case 1: Spillage from fuel casks (Germany)

Problem
During control measurements of soils, pavements and roads of the HDR site discovery of contamination under bitumen sealing between road and pavement lead to comprehensive

sampling at varying depths. The gamma spectrometric analysis of the samples revealed a potential for a large contaminated area under the road. The reason for the contamination was obviously a spill from a fuel cask used in the late 1970’s for wet transportation of fuel rods. At that time the limit for contamination was 3.7 Bq/cm². The contamination resulting from the spills was probably less than the 3.7 Bq/cm², therefore the incident was not recorded. Currently the free release value is now 0.5 Bq/cm² and 0.03 Bq/g for Cs-137 and Co-60 respectively which constitutes a problem.

Solution

Excavation of the road and pavement over an area of 1000 m² was necessary with subsequent removal of soil up to 1.7 m depth. A total of 80 tons of concrete and 450 tons of soil had to be removed (see Figures 12–14) hugely escalating costs by 2 Meur and causing a delay of three months.

Lesson learned

During the characterization of soil and roads on a site special attention should be directed to areas were accumulations of contamination can occur or is suspected e.g. seals under roads and drains. In such areas an intense sampling program should be considered to prevent unforeseeable delays and costs.

FIG. 12. Segmentation of HDR road to remove contamination.

FIG. 13. View after remediation measures at HDR.

FIG. 14. Control measurements of drains at HDR.

Case 2: Removal of shielding spheres out of the reactor neutron shield (Germany)

Problem
The chambers forming the neutron shield of the KKN reactor were filled with a large quantity of steel spheres that had to be removed to allow dismantling of the neutron shield to progress. To remove the spheres the decision was taken to use a high velocity vacuum system to suck them into a transport and disposal container. The vacuum system used had an oscillating suction tube and a small inlet orifice (max. 38 mm diameter) through which individual spheres could be sucked. Development trials using mock-ups of the spheres led to the inclusion of an oscillating tandem suction tube and proved that the system should perform adequately during actual operations on the reactor.

When the system was deployed, the following problems were experienced for the following reasons:

- The spheres did not correspond to the design drawings and were in fact crude stampings, unsymmetrical in shape and having burred edges.
- The spheres had a resin-like coating which caused them to stick together to form a solid structure.

The consequence of the above was that removal rates dropped to one tenth of those achieved during mock-up trials, and a number of spheres could not be removed. These subsequently caused problems during removal of the shield girders as they tended to become trapped in moving parts [66].

Solution
For removal of the lower neutron shield the unit was modified to improve suction capacity and the performance of the vibration device and suction tubes. These improved the efficiency of the operation such that the project programme could be maintained.

Lesson learned
The lesson that can be drawn from this case is the need for visual inspection of components, especially on old plants where the drawings very often do not reflect the as-built status of the plant.

Case 3: Robust estimation of fissile material quantity in a dissolver (France/COGEMA)

Problem
The continuous dissolution process was used for the dissolution of the gas cooled reactor spent fuel in the reprocessing plant. The basic decontamination parameters were derived from values taken 15 years ago when a dissolver was replaced and dose rate measurements were taken. A first rinse using nitric acid started without any chemical analysis of the deposits at the bottom of the dissolver and unfortunately the quantity of plutonium removed was much higher than the forecast amount which presented a problem.

Solution
This discrepancy in the estimation of fissile material in the dissolver, when it was discovered, led the operator to quickly redefine a characterization programme in order to determine the physical, chemical and radiological characteristics of the deposit and the remaining quantity of plutonium. Non Destructive Assays such as active and passive neutron measurements were used as well as video and sampling analysis.

Lesson learned
The troubles encountered during the rinsing of the continuous dissolvers came from a poor knowledge of the initial state, mainly from a lack of quantitative and qualitative characterization of the deposits contained inside the dissolvers. The lesson learned was to

monitor the initial state of the dissolver and to carefully characterize the deposits. That should have permitted an accurate idea of the quantity of fissile material left and to adapt the decontamination reactants and set-up accordingly. The application of incorrect initial parameters impacted on the level of confidence of the regulatory body in charge of this project. There was also a significant repercussion on the re-planning of this operation.

Case 4: NPP A1 decommissioning, Jaslovske Bohunice, Slovakia

Problem
The waste water treatment facility was contaminated as a consequence of not properly handling spent fuel with damaged cladding. Radioactive sludge remaining in some components, on equipment insulation and in some rooms resulted in a high level of dose.

Solution
Lack of as-built drawings, material data, visual records and details of the location of decontamination required the extensive use of remote video recording and remote measurement. After obtaining all the necessary data, the decontamination work started in 2000. Sludge from the room was removed, contaminated insulation was dismantled and the dose rate was significantly reduced. Figures 15 and 16 give views of the initial condition and the final state after decontamination.

Lesson learned
Record keeping for design and from operational events are essential to support decontamination and dismantling. If they are not available, considerable delays and cost can occur as well as unnecessary dose to operators.

FIG. 15. A-1 NPP, Slovakia, waste treatment system; neutralization tank before decontamination and removal of the insulation.

FIG. 16. A-1 NPP, Slovakia, waste treatment system; neutralization tank after decontamination and removal of the insulation.

APPENDIX 2
SOME IMPORTANT RADIOLOGICAL CONSIDERATION TO FACTOR INTO PLANNING FOR DISMANTLING AND DECONTAMINATION OF A NUCLEAR FACILITY[3]

Programme Area	Consideration
Management Control	1. Preparation of a Decontamination and Dismantling (D&D) plan which would: • define project scope and objectives • describe subtasks and sequence of events • define organization and assign responsibilities for project components (e.g. Radiation Protection, Operations, Engineering, Quality Assurance, Maintenance, Instrument Calibration, Surveillance, Documentation, Environmental Monitoring and Effluent Control, Training, Waste Handling) • provide for work safety analysis, both radiological and non-radiological • define waste handling procedures • describe operational and release survey plans • define ALARA considerations • address emergency preparedness • describe the method of safety review management • define training requirements (general and specialized) • consider personnel and environmental radiation protection requirements • financial considerations • assess the environmental impact of D&D activities • identify waste streams and routes 2. Specific D&D plan implementation procedures should be prepared, reviewed, and formally approved by management. At a minimum, the Radiation Protection, Engineering, Quality Assurance, Operations and maintenance organization components should be involved in the review and approval of D&D plans and implementation procedures. 3. An assessment as to the adequacy of use of support equipment during the D&D process should be made. Examples include: • ventilation (process, room air, portable)

[3] **(DERIVED. FROM [67])**

- monitoring instrumentation
- filtration (process, room air, portable)
- ingress and egress controls of the air flow
- air sampling
- waste handling
- personnel monitoring
- respiratory protection
- industrial protection equipment (gloves etc.)

Safety Analysis

(1) Job safety analyses should be performed and documented to support implementation procedures. The analysis should contain a description of the work hazards expected to be present, and protective measures for risk reduction. An accident analysis should be performed to identify potential accidents during the D&D process and related response measures should be defined and included in the D&D plan.

(2) An evaluation should be performed and documented to identify locations, types, quantities, chemical/physical form of radioactive materials and expected associated hazards.

(3) An evaluation of airborne contamination potential during D&D activities should be performed to assess the need for respiratory protection. If respiratory protection equipment is used, a formal training and fit test programme should be established and documented.

(4) Evaluation of effectiveness of special equipment, techniques, and/or processes to minimize potential for radiation exposure and reduce potential for other hazards should be performed.

Surveillance

(1) A surveillance programme should be established to address:

- facility air flow patterns (decon room, building, portable enclosures)
- air sampling
- area postings
- dosimetry (Personnel Monitoring)
- contamination surveys
- instrumentation monitoring of personnel
- environmental and effluent pathways
- respiratory protection equipment
- ventilation system (facility and portable tent structures)

(2) A pre-decommissioning radiological survey should be performed to define the radiation source terms with respect to

isotopic composition, physical status and chemical composition, and radiation levels. A radioactive material inventory should be evaluated and used to determine disposal requirements and estimate occupational radiation exposures.

(3) Radiation protection, effluent monitoring, and environmental surveillance criteria should be determined and implemented as appropriate to maintain adequate control.

(4) Provisions should be made to ensure that effluent and environmental sampling is representative, proper sampling equipment is used, proper sampling locations are utilized, and proper sampling procedures are used.

(5) The environmental/effluent sampling programme should be adequate to determine quantities and concentrations of radionuclides.

(6) All potential effluent pathways should be monitored for radioactivity and the results recorded and retained. Effluent control equipment should be maintained functional throughout the D&D process until such time at the end of the cleanup activities when these systems could be removed.

(7) Hold up capacity should exist to permit sampling and analysis of liquid waste prior to release to unrestricted areas.

(8) Action levels and the measures to be taken should be described by procedures for external exposure control, air sampling (in-plant and out-of-plant), bioassay, contamination, and environmental discharges.

(9) Emergency support equipment and supplies should be included in a routine surveillance programme to assure adequacy of the inventory, functionality, and calibration where appropriate.

Instrumentation

(1) Measurements performed to release materials for unrestricted use and for radiation protection of personnel and the public should be traceable to the instruments used.

(2) Survey and monitoring instrumentation should be included in a documented calibration and performance testing programme to assure continuing adequate operation.

(3) Appropriate survey instrumentation and techniques should be selected to assure proper assessment of radiation hazards.

(4) A sufficient number of survey instruments should be maintained, available and operational to adequately monitor D&D activities.

(5) Maintenance, surveillance, and calibration (if applicable) of safety related facility systems should be maintained throughout the D&D process.

ALARA

(1) Limits for release of contaminated materials for unrestricted use should be established consistent with regulations in place.

(2) Active support of ALARA principle must be demonstrated and

documented at all levels of the decommissioning process to assure success in maintaining exposures as low as reasonably achievable.

(3) Authority and responsibility for application of the ALARA programme should be defined and assigned. The cost/benefit criteria used in making ALARA decisions should be defined.

(4) Radiological data should be collected, reviewed, evaluated, and trended for D&D job segments to determine if improvements in interest of ALARA can be made for future D&D tasks.

Training

(1) At a minimum, workers involved in the D&D process should be provided with documented basic radiation protection orientated training which includes:

- Safety rules, procedures, and special work permit system.
- Dosimetry, air sampling programme information
- Emergency plan and procedures
- Administrative system to report conditions adverse to safety and/or quality
- Monitoring instrumentation usage
- ALARA considerations

(2) Radiation workers should be provided documented training in D&D implementation procedures.

Quality Assurance

(1) A quality assurance programme should be established and implemented to address:

- Radiation protection and environmental measurement systems and analysis techniques to assure validity and accuracy of reported data.
- Characterization, packaging, transport and disposal of radioactive materials
- Outside contracted measurement services, if any
- Documentation associated with the D&D process
- Verification to assure that all quality assurance aspects are being addressed as defined in the D&D D/D plan

Audits and Reviews

(1) A Safety review committee should be established to review and approve the D&D plan, implementation procedures, and review and track safety audit results.

(2) Periodic safety audits of D&D activities should be performed and documented to evaluate the effectiveness of worker training, surveillance equipment operability and adequacy, management control, safety controls, ALARA results, emergency programme, documentation systems and exposure assessments.

(3) Audits should also review and evaluate the conformance of documents to established specifications and procedure requirements.

(4) An audit programme to assure continuing implementation of radiation protection policy and procedure requirements should be established and documented.

(5) Audit results, corrective actions, and follow-up verification of corrective action implementation should be documented and reviewed by management.

Emergency Preparedness

(1) An evaluation of the potential types of emergencies and consequences should be performed to develop an appropriate emergency plan and implementation procedures.

(2) The emergency plan and implementation procedures should address actions for all types of emergencies expected during D&D activities.

(3) An emergency organization should be established and revised periodically.

(4) Authorities and responsibility should be delineated for components of the emergency organization and the communication chain for notifying, alerting, and mobilizing necessary personnel should be defined.

(5) Emergency response capability should be maintained throughout the D&D process. The emergency plan and associated procedures should be kept current, consistent with the level of activities involved in the D&D process.

(6) An adequate inventory of emergency support equipment should be maintained throughout the D&D process. Periodic checks should be performed to assure continuing operability of such equipment.

(7) Adequate instrumentation should be available and operable to determine the existence and extent of an accident or emergency situation.

(8) Emergency procedures should be prepared to address:

- Authority and responsibility for specified tasks
- Coordination of on-site and off-site support activities
- Types of emergencies and corresponding responses
- Utilization of instrumentation to identify magnitude of emergency and mitigate effects of the accident.
- Action levels for implementation of various emergency response actions
- Identification and utilization of communication networks (primary and backup).
- Evacuation and personnel accountability.
- Specification and location of emergency support equipment.
- Offsite eventual dose calculations.

- Radiological monitoring of personnel and equipment prior to release from the site.
- Personnel decontamination.

(9) Agreements with offsite agencies which define the level of support, responsibilities and action levels should be maintained current.

-- Medical -- Police -- Firefighting --Ambulance

(10) Systems handling hazardous materials should be removed from service at the beginning of the D&D process or as soon as no further need is identified.

(11) Emergency communication links to on-site and off-site support groups should be established, periodically tested, and properly maintained.

(12) Periodic emergency drills should be conducted and documented.

Fire Protection

(1) A fire protection surveillance programme to include inspection and testing fire detection and suppression systems and fire fighting equipment should be maintained during the D&D process.

Documentation

(1) A master index of the D&D plan and implementation procedures, and of subsequent revisions should be maintained.

(2) Sufficient records should be maintained to provide traceability of quality assurance activities associated with the D&D process.

(3) D&D activities should be documented in such a manner to provide a correlation between the following information:

- Worker identification
- Work location
- Radiological conditions of the workplace
- Job description
- Special precautions and instructions
- Protective equipment
- Exposure incurred on the job
- Supervision and written approval of the job by radiation protection function
- Worker signature on work package to document that the worker has read and understood job conditions, precautions, and requirements
- Monitoring surveillance results and instruments used usually provides this correlation.

(4) Records relating to quality control of radiation protection and environmental monitoring measurement system and results obtained should be retained.

(5) Applicable documentation supporting the D&D process should be collected and archived to provide a detail record of the process.

- D&D plan
- D&D implementation procedures
- Job safety analysis reports
- Environmental impact assessments
- All site surveys (licensee and regulatory body)
- License termination approval
- Radiological survey results of materials being released for unrestricted use
- Training relative to D&D activities
- Quality Assurance associated records

(6) Procedures should be established to assure that adequate document control is maintained for D&D implementation procedures during use.

(7) Records of incidents and/or emergencies should be retained to document:

- Classification of emergency
- Cause of incident
- Personnel and/or equipment involved
- Extent of injury and/or damage resulting from incident
- Corrective actions taken to terminate emergency
- On-site and off-site support assistance requested and received.
- Results of special surveys and evaluations.

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ABBREVIATIONS

AECL	Atomic Energy of Canada Limited
ALARA	As Low As Reasonably Achievable
ALARA Ltd.	State owned company in Estonia
APAT	Agency for Environment Protection and for Technical Services (Italy)
AWE	Atomic Weapons Establishment (UK)
BNFL	British Nuclear fuel Limited (UK)
CAP	Community Advisory Panel
CASTOR	German storage and transport cask for fuel elements
CCW	Culture Change Workshop
CDAC	Citizens Decommissioning Advisory Committee
D&D	Decontamination and Dismantling
DECON	Deconstruction (immediate dismantling)
DeManS	Decommissioning Management System
DFR	Dounreay Fast Reactor (UK)
DIS	Decommissioning Information System
DOE	Department of Energy (also US DOE)
EA	Environmental Assessment
EC	European Commission
EIA	Environmental Impact Assessment
ENEL	National Company for Electric Energy (Italy)
ENRESA	National Company for Radioactive Waste Management (Spain)
EPA	Environmental Protection Agency (USA)
EWN	Energie Werke Nord (Germany)
HEHF	Hanford Environmental Health Foundation
HMSO	Her Majesty’s Stationary Office
HP	Health Physics

HSE	Health and Safety Executive (UK)
IAEA	International Atomic Energy Agency
ISMS	Integrated Safety Management System
ISN	Interim Storage North – Greifswald NPP (Germany)
JET	Joint European Torus
KGR	Nuclear Power Plant – Greifswald (Germany)
KKN	Nuclear Power Plant – Niederaichbach (Germany)
KKR	Nuclear Power Plant – Rheinsberg (Germany)
MPA	Ministry for Productive Activities (Italy)
NEA	Nuclear Energy Agency (Paris)
NEAC	Nuclear Energy Advisory Council (USA)
NGO	Non Government Organisation
NII	Nuclear Installations Inspectorate (UK) (also HMNII)
NIMBY	Not In My Back Yard
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission (USA) (also US NRC)
OECD	Organisation for Economic Co-operation and Development
ORISE	Oak Ridge Institute for Science and Education (USA)
PIERG	Paldiski International Expert Reference Group (Estonia)
POL	Possession Only Licence
PWR	Pressurized Water Reactor
QA	Quality Assurance
R&D	Research and Development
RPV	Reactor Pressure Vessel
RWP	Radiation Work Permit
SAFSTOR	Safe Enclosure
SEPA	Scottish Environment Protection Agency (UK)

SCK•CEN	Research Center for Nuclear Energy (Belgium)
SOGIN	Company for Nuclear Plants Management (Italy)
SUSA	Safe and Unsafe Acts Auditing
TÜV	Technical Control Board (Germany)
UKAEA	UK Atomic Energy Authority
VITO	Flemish Research Institute (Belgium)
WL	Whiteshell Laboratories (Canada)
WWER	Water-cooled Water-moderated Energy-production Reactor

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