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The Regulatory Challenges of Decommissioning Nuclear Reactors

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

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The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international body made up of senior representatives from nuclear regulatory bodies. The Committee guides the NEA programme concerning the regulation, licensing and inspection of nuclear installations with respect to safety. It acts as a forum for the exchange of information and experience, and for the review of developments which could affect regulatory requirements.

In 1999, the Committee established a Task Group to reflect and advance the discussion on specific issues of regulatory policy. Over the years, the Task Group produced a series of short reports dealing with early signs of declining safety performance; regulatory response strategies for safety culture problems; the regulatory challenges arising from competition in electricity markets; and the regulatory challenge of judging safety backfits.

Continuing in the series, this report describes the broad set of safety, environmental, organisational, human factors and public policy issues that may arise during the decommissioning of nuclear reactors and that the regulatory body should be prepared to deal with in the framework of its national regulatory system.

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1. INTRODUCTION

Each nuclear power plant, fuel cycle facility and nuclear research and test facility that is operating today will eventually reach the end of its useful life and cease operation. Indeed, several such facilities have already ceased operation. At that time, the operator of the facility will undertake a series of decommissioning actions that will eventually lead to a satisfactorily safe condition of the facility and an environmentally acceptable condition of the site. It is important that the health and environmental hazards and physical protection measures of the shutdown facility be managed properly during this process to protect the health and safety of public and workers and to safeguard any nuclear materials. In this regard, the regulatory body has the responsibility for independently assuring that decommissioning activities are conducted safely, that radioactive materials and spent nuclear fuel are disposed of properly and that the site is in an acceptable end state.

Although there are several uses of the term “decommissioning”, in this report we shall use decommissioning in its broadest sense to cover all of the administrative and technical actions associated with early planning for cessation of operations through termination of all licenses and release of the site from nuclear regulatory control. These actions may include early strategic and financial planning, removal of spent or unused fuel to a reprocessing or storage site, decontamination of structures and equipment, dismantling of plant and equipment, shipping radioactive and other waste to offsite disposal sites, remediation of contaminated land and remaining structures, and other related that the site is in an acceptable end state.

The decommissioning process may take a few years or even several decades, and it may involve work being done in stages of activity separated by periods of relative inactivity. While substantial research and analysis regarding the technical aspects of decommissioning have been conducted in OECD countries in recent years, there is no preferred approach to decommissioning of nuclear facilities. Nonetheless, the techniques and institutional arrangements for decommissioning are sufficient for today’s needs and, in fact, several nuclear that the site is in an acceptable end state.

The types of safety, security, environmental and public policy issues that arise in decommissioning are very different from those during operation, and

often public interest and concern can be quite high. The population living near a nuclear facility may have become accustomed to its normal operation, but they are naturally concerned that a new activity like decommissioning be done safely, and they may be even more concerned about plans for the long term condition of the site. These new safety, environmental, organisational, human that the site is in an acceptable end state.

Just as the approach for regulation of operating nuclear facilities varies widely among OECD countries, the regulation of decommissioning activities also shows widely varying approaches.[1] Some countries have, or are developing, general regulatory guidance and expectations that are applicable to both operating and decommissioning activities, while others have prescriptive regulations and guides that apply specifically to decommissioning. All regulators, however, share the same general regulatory objectives – namely that (a) the decommissioning activities be conducted safely, (b) good waste management principles are followed, and (c) the site is left in an acceptable end that the site is in an acceptable end state.

By now there is an extensive body of literature on the technical, safety, radiological, waste management and environmental aspects of decommissioning. Some of the discussions in this report draw from that extensive literature.[2,3]

This report is not intended to specify a preferred approach to regulate the decommissioning of nuclear facilities but rather to discuss the broad set of issues that may arise during decommissioning and which the regulatory body should be prepared to deal with in the framework of its regulatory system. The discussions in this report relate primarily to nuclear power plants, but the decommissioning principles and the regulatory challenges apply to other nuclear facilities as well.

It follows, therefore, that the audience for this report is primarily nuclear regulators, although the information and ideas may also be of interest to government authorities, environmental regulators, nuclear operating organisations, technical expert organisations and the general public.

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1. NEA (2000), *Regulatory Practices for Decommissioning of Nuclear Facilities with Special Regard of Regulatory Inspection Practices*, NEA/CNRA/R(99)4, February 2000, OECD/NEA, Paris.

2. IAEA (1999), IAEA Safety Guide WS-G-2.1 *Decommissioning of Nuclear Power Plants and Research Reactors*, Vienna.

3. NEA (2002), *The Decommissioning and Dismantling of Nuclear Facilities*, OECD/NEA, Paris.

2. CHANGES FROM OPERATION TO DECOMMISSIONING

Experience has shown that decommissioning is not simply an extension of operations, like a new operating mode. While the early stages after shutdown may resemble the activities during a normal outage, the operator will soon begin taking actions that will render the facility permanently inoperable.

It is important that the management and staff of the facility understand the fundamental nature of the changes taking place during this phase. Actions will be taken that are effectively irreversible, and the operator's staff must cope with the emotional effects that come with the realisation that the facility will never operate again. New organisational and human factors issues are presented, such as the need to maintain key staff personnel and staff expertise and the need to maintain a safety focus during these changing times.

One of the biggest changes will be the change in mindset among the workers. Operational staff tend to view a complex nuclear facility in terms of **systems** that run throughout the plant, whereas decommissioning staff, especially during the dismantlement phase, tend to view the facility in terms of **areas** that must be taken down. The management of decommissioning has more of a project focus rather than a focus on teams supporting the operations staff. Also, since many of the structures and components are radioactive, this presents an added complication for the dismantlement procedures relative to those used during initial construction.

It is clear that the facility operator should not have to improvise with new plans in the weeks and months immediately after a facility ceases operation. There should be a strategic plan for decommissioning prepared while the plant is still operating. This plan should describe the overall decommissioning strategy chosen, such as moving directly to complete dismantlement and site restoration for unrestricted use, or placing the facility in a safe and secure condition to await final decommissioning at a later time. The strategic plan should be accompanied by more specific plans and safety analyses for the tasks immediately after shutdown. In some countries a specific decommissioning safety analysis report is required that analyzes all significant risks expected during the entire decommissioning process.

The decommissioning plans should include financial information, including a cost estimate to complete decommissioning according to the strategy and schedule chosen by the operator and a clearly defined and reliable source of funding for these activities. This financial information is especially important for facilities operating in competitive electrical markets[4] where the facility likely will be generating little or no revenue after it has ceased operation.

There are some important policy issues that should be considered well before the facility is shut down and decommissioning begins. For example, planning for radioactive waste and other waste management and disposal should be done well in advance of shutdown. Some countries have a legal requirement that an Environmental Impact Assessment, which considers alternative strategies, be conducted before decommissioning can begin. Insofar as practical, these matters should be included in the decommissioning plans.

The need for having decommissioning plans prepared during operation is especially important in cases where a facility is unexpectedly shut down before the end of its useful life, perhaps because of economic reasons or political decisions or even an abnormal event that has resulted in serious plant damage. Having plans in place could avoid a long (and costly) hiatus while senior management decides what to do next. The plans will give the staff a new work focus that will help them overcome any emotional effects associated with the early cessation of operation of the facility. This will be true even if the plans have to be modified due to the circumstances of the shutdown.

Among the first actions after shutdown will be to transfer hazardous material, such as reactor fuel and other removable core components, to a safe interim storage location. The decommissioning plans should include an analysis of which systems, procedures and programmes are needed to maintain the facility in a safe condition and which other systems and structures can begin the process of dismantlement. The plans may include new systems and procedures – for example, some shutdown facilities have constructed new, simpler spent fuel cooling systems, and even new control rooms with dedicated power supplies, in order to isolate the existing systems in preparation for dismantlement.

There may be special situations (for example, in Spain) where responsibility for decommissioning a nuclear facility is transferred from the

4. NEA (2001), *Nuclear Regulatory Challenges Arising from Competition in Electricity Markets*, OECD/NEA, Paris.

operating organisation to a separate decommissioning organisation. In such situations the regulator is faced with the special challenge to assure that the new decommissioning organisation maintains operating records, facility design information and facility knowledge and experience during the decommissioning period. It will be especially important for the regulatory body to emphasise to the decommissioning organisation its responsibility for conducting all activities safely and to maintain careful oversight of contractors' qualifications and activities.

The change from operation to decommissioning will obviously present new challenges to the regulator as well. The regulator will want to have some early assurance that the decommissioning strategy will result in an acceptable final end state and that there are adequate resources to accomplish it safely. Regarding its own organisation and procedures, the regulatory body will naturally have to review and revise its oversight plans for the facility to focus more on the new organisational, human factors and dismantlement issues, and it may augment staff expertise in those areas. These regulatory oversight matters are discussed more fully in Chapter 4 of this report.

3. REGULATORY CHALLENGES

The decommissioning of a nuclear facility generally proceeds through the stages below. In some cases the work proceeds uninterrupted to the final end state, while in other cases there may be long periods of relative inactivity between stages. For instance, many nuclear power plants are located on multi-unit sites, and the other units continue to operate. In such cases the decommissioning activities may be limited to the first phase and portions of the second phase, whereafter the facility may rest in a safe storage state until all of the units are shut down and ready for full site decommissioning. The pace of activities may be dictated by the availability of funds or other strategic interests of the operator.

Immediate post shutdown activities:

- placing the facility in a safe and secure condition;
- removal of fuel and other materials to a safe interim storage location;
- preparation of new procedures for shutdown activities, such as new radiation protection procedures;
- measurement and documentation of the radioactive inventory and its distribution.

Preparation for dismantlement:

- environmental impact assessment;
- new contractual arrangements with specialised contractors;
- clearly distinguishing systems and components that may be de-powered from those that are needed for ongoing functions, such as spent fuel cooling;
- separation of salvageable components and materials for asset recovery;

- construction of special facilities such as a new control room, dedicated fuel pool cooling, new rail line, or sodium coolant treatment facility;
- removal of hazardous materials such as asbestos;
- decontamination of systems.

Dismantlement:

- dismantlement of systems, structures, components and buildings;
- shipping materials to a waste disposal site or a waste storage facility.

Site remediation:

- removal of all residual radioactivity above acceptable levels for the chosen end state;
- final site survey.

Acceptable end state:

- The end state does not necessarily have to be a "greenfield" condition. Some buildings or facilities like water supplies, roads, rail lines or electrical equipment may remain if the site is to be used for industrial or other purposes. There are many variations of an acceptable end state for a decommissioned facility site.

Most regulatory bodies have at least a minimum set of regulatory requirements or expectations regarding nuclear facility decommissioning:

a) Strategic decommissioning plan – that is, the operator should describe his planned decommissioning activities and the regulator should review the plans and agree that the strategy will result in safe activities and an acceptable end state.

b) Regulatory consent to begin decommissioning – that is, a judgment by the regulator that decommissioning activities can safely be started and that there are sufficient resources to carry out the plan.

c) Conditions for terminating all facility licenses – the criteria for an acceptable end state.

Thus, the regulator will have an important decision making role at the onset of decommissioning and at the termination of all licenses. Once a nuclear

facility ceases operation and regulatory approval for decommissioning is granted, the timing of site activities is largely controlled by the operator. During this period of actual decommissioning, which may be only a few years of heavy site activity or may be several decades of intermittent activity, the regulator will have continuing safety oversight activities. Many issues like those discussed in this report will require the regulator's attention and may require regulatory decisions.

The sections below describe a number of issues associated with decommissioning where the regulatory body needs to consider whether regulatory guidance may be necessary. Depending upon the regulatory approach in each country, the regulatory body may have specific requirements or only general expectations for the operator in dealing with these issues. Several specific examples of possible regulatory responses are discussed. These examples are merely illustrative and are not meant to imply that they are the preferred regulatory approaches nor do they imply that any specific regulatory guidance is necessary.

A. Organisation and human factors

The decision to permanently cease operation of a nuclear facility can have a profound impact on the operating organisation, especially if the shutdown is because of an accident, economic reasons or political decisions and if the facility is shut down before its expected end of life. Immediately upon shutdown the operator will be faced with many decisions of how to proceed with decommissioning. Having an approved decommissioning plan in place will provide a road map for management to navigate through the changing circumstances and will give the operating staff a new work focus that will help them overcome the emotional effects associated with the shutdown.

Whether the shutdown is relatively sudden and unexpected, or the culmination of several years of planning, the immediate aftermath will almost certainly be a period of high uncertainty for workers accustomed to the routines of an operating facility. Some will recognise that their skills are no longer needed, and all will realise that long-term employment at the facility is not a realistic prospect. In these circumstances the facility management must have plans for retaining adequate staff competency, for maintaining the safety focus of the staff and for sustaining the overall safety culture of the site.[5,6]

5. NEA (1999), *The Role of the Nuclear Regulator in Promoting and Evaluating Safety Culture*, OECD/NEA, Paris.

As the operator develops specific plans for hiring specialised contractors, the operator will have to consider hiring new workers and managers in his own organisation with the necessary skills for decommissioning and for overseeing contractors. It will be important that the operator retains an appropriate mixture of experienced workers with organisational and operational memory and new workers with decommissioning experience. It will be especially important to have procedures in place for maintaining facility records and for controlling changes to the facility. For instance, at a multi-unit site, the shutdown facility may share systems with operating facilities, and these systems cannot be altered without a careful analysis for unreviewed safety questions.

In view of these new challenges, which are quite different from those of normal operation, the regulator will have to consider new approaches for oversight of the operator's activities. For example, while the regulator will have reviewed the general strategic plans and the decommissioning safety analysis report, he will need to have frequent discussions with site management in the months after shutdown as more detailed decommissioning plans are prepared. The regulator will certainly want to know of the operator's plans for maintaining the safety focus of the staff and for management of contractors, and will also want to review the specific procedures for facility change control and for maintaining site records. In addition to frequent meetings with site management, the regulator will want to conduct regular inspections in the months after shutdown to look for possible adverse trends in the overall safety culture at the site.

B. Shutdown and preparation for dismantlement

Final shutdown of a nuclear facility will normally be followed by a formal notification to the regulatory body and a public announcement of the shutdown. The operator may have authority under the previous operating license to remove fuel, removable core components and other radioactive materials to a safe interim storage location, such as a spent fuel pool. Before substantive decommissioning activities can begin the operator will need regulatory approval, and the operator must confirm that the broad strategic plans are still valid and that adequate financial resources are available for the immediate work ahead. The regulator will also want some reassurances regarding the operator's plans for dealing with the organisational and human factors issues discussed above.

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6. NEA (2000), *Regulatory Response Strategies for Safety Culture Problems*, OECD/NEA, Paris.

Experience has shown that public interest and concern over decommissioning issues can be quite high. Typically the public concerns are centred on safety and radioactive releases during decommissioning and the residual risks of the site after all licenses have been terminated. The public is also naturally concerned if there are long-term plans for a spent fuel storage facility or an interim radioactive waste storage facility on the site. All of these issues should be addressed by the operator before decommissioning work begins. Some operators have found it of great benefit in communicating with the public to establish a committee of local political and civic leaders to have regular public discussions of decommissioning issues. Representatives of the regulatory body should plan on attending the public meetings to present the regulatory perspective on the issues, to describe the regulatory oversight activities, and listen to public concerns.

The early months of decommissioning will be devoted to preparation for the dismantlement of plant systems and structures. Many new procedures will have to be written, and the regulator may want to review these procedures. An early activity will be to conduct a comprehensive site survey for radioactive and hazardous material contamination in buildings, in the ground and in groundwater. The operator will no doubt begin to separate salvageable components and materials for asset recovery, and procedures must be in place for surveying and release of such materials.

A difficult policy issue for the regulator is that of defining acceptable clearance criteria for the release of waste material from nuclear regulatory control. Large volumes of waste will be handled, and much of the waste, like structural concrete debris with no detectable radioactivity above background levels, can be shipped offsite to normal landfills or used on the premises for filling the large ground cavities that dismantling may produce. Other material, such as concrete from the reactor pressure vessel cavity, will have surface contamination and must be surveyed and sent to a low level waste disposal site. Other material like steel piping and steam generator shells may have salvage value if surface contamination can be reduced to meet the material release criteria. There is currently no consensus within OECD countries on clearance criteria for the unrestricted release of waste material. For example, in some countries the release of radioactive material is not permitted at all, while in other countries nuclide-specific clearance levels are included in the legal framework.

Before undertaking substantive work on radioactive systems and components, it is a good practice, from a worker protection viewpoint, to remove other hazardous materials from the plant, such as asbestos and chemicals. In this regard the operator must coordinate its activities with the

nuclear regulator as well as with the regulatory bodies having primary responsibility for regulating the hazardous materials being removed.

After the non-radioactive hazardous materials have been removed the operator can undertake the decontamination of systems, components and buildings in preparation for dismantlement. Before decontamination is started, however, the operator must carefully distinguish systems and components that may be depowered and drained from those which are still needed for ongoing functions such as spent fuel cooling. The choice of the method for decontamination should consider the production of secondary waste arising from the decontamination activity itself, which may pose its own disposal challenges. All of these activities should be reviewed by the regulatory staff.

Before major dismantlement can begin it is likely that new, temporary facilities may need to be constructed. Some examples are a new control room, a new dedicated offsite electrical power supply, a new heat sink for the spent fuel pool, a new spent fuel pool cooling system, a new rail line, and facilities for waste treatment and material clearance measurements. Each of these new facilities will require new operating and maintenance procedures. Because these new facilities may present unreviewed safety questions, the regulator should review the new designs and procedures.

Since this initial period of decommissioning will be a very active time at the site, with many diverse activities happening in parallel, the regulator may find that its inspection and oversight are more intense than when the facility was operating. The planning and staffing implications for the regulator are discussed in Chapter 4 of this report.

C. Regulatory guidance on radiological and environmental controls

Nuclear safety regulators will typically have some shared responsibilities with the environmental regulators during decommissioning, but the basic radiological and environmental standards, especially effluent discharge and material release criteria, should be the same for decommissioning activities as for operations. Since each country's laws and practices are different, it is not practical in this report to discuss the division of responsibilities between the nuclear and the environmental regulatory authorities. Therefore, when the term "regulator" is used, it is understood that it may mean either the nuclear or the environmental regulator, depending upon national laws and practices.

Specific regulatory guidance will be needed on radiological and environmental controls for decommissioning. The form and content of the

guidance will depend on the individual country's regulatory approach, but the following topics will need to be addressed:

- Acceptable duration of decommissioning period – some regulatory bodies place a limit on the length of time that a facility is allowed to complete decommissioning. There can be several reasons for such a time limit, but one important consideration is that the local public may find an indefinite delay to be unacceptable.
- Acceptable strategic options – many countries permit a choice of (a) immediate dismantlement, (b) temporary safe storage for a period of years, with eventual dismantlement, or (c) structures encased in concrete and maintained until radioactivity decays to a level permitting removal of regulatory controls, or some combination of these options.
- Scope of radiation surveillances – the regulator will want to ensure that the early site radiation survey covers all important buildings, ground locations, potential groundwater contamination and all effluent discharge pathways. Even if all effluent discharges have been within acceptable levels during the operating life of the facility, the cumulative effect over the years could be great enough that remediation of effluent discharge pathways may be necessary. All offsite shipments of waste must be monitored and documented. It will be especially important for the operator to have controls for any gaseous and liquid wastes that may be different from those during normal operation.
- Interim storage facilities for radioactive waste, if needed.
- Requirements for the scope and duration of maintaining operational and decommissioning records, especially if there is contemplated a long period of safe storage of the facility.
- Acceptance criteria for termination of all licenses.

There are some unique challenges of decommissioning that the operator and regulator must recognise early. The radiological protection and physical safety of workers will be challenged by the decontamination, disassembly and removal of large radioactive components such as reactor pressure vessel, steam generators and pressuriser, large pipes, pumps and valves. Some workers will be sent into areas of the facility that have not been entered for a very long time and whose condition is uncertain. These activities will require careful planning and adherence to sound ALARA principles. Another unique challenge of decommissioning is the large quantity of waste containing only small

concentrations of radioactivity, which must nevertheless be surveyed and monitored throughout its movement on the site and offsite to its ultimate disposal location.

Of course there is much other regulatory guidance on radiological and environmental controls during decommissioning activities, such as routine worker monitoring and effluent controls, but this guidance remains largely the same as it was during normal operation.

D. Safety and security challenges

Once a nuclear reactor has ceased operation and the fuel has been removed from the reactor vessel to a safe storage location, the radiological risks to the offsite public are greatly reduced. Nonetheless, the regulator will expect the operator to update the safety analysis report or prepare a specific decommissioning safety report to ensure that all decommissioning risks have been considered and analysed. There have been several generic studies of the risks of shutdown nuclear facilities, but the facility-specific risks must be carefully considered and analysed.

Perhaps the most immediate and pervasive safety challenge facing the operator upon shutdown will be the organisation and human factors issues discussed earlier, particularly the need to maintain the safety focus of the staff. The operator will have to develop plans for retention of essential workers, for retraining workers in new skills, hiring new workers and contractors and plans for oversight of contractors. The regulator will want to have discussions with operator management to assure these plans are satisfactory.

A key safety question concerns the plans for the spent fuel. The fuel may be transported offsite after a cooling period to a storage site or a reprocessing facility. Alternatively, the fuel may be stored in the spent fuel pool for a few years or even several decades under the temporary safe storage option. Yet another possibility is for the fuel to be stored in special storage casks at a separate facility on the site. In any case the regulator will have to assure that the safety systems for spent fuel storage are maintained during the decommissioning period as long as spent fuel is on site.

A major challenge for both the operator and regulator will be to decide which regulatory requirements that were in place for the operating facility can be modified for the decommissioning phase. Of course there will be new regulatory requirements and expectations for decommissioning, but just as

clearly there are many requirements for an operating facility that can be modified, such as:

- control room staffing;
- worker training;
- maintenance and surveillance testing of systems and components removed from service;
- emergency planning;
- insurance;
- programmes such as fire protection and steam erosion protection;
- quality assurance and oversight – the operator may decide to eliminate some operational oversight functions and replace them with a new oversight body that deals with special decommissioning issues.

The regulator can expect that each of these modifications to operational regulatory requirements will require review and discussion with operator management.

The security plans for the site will have to be revised to protect against diversion of nuclear materials to unauthorised uses and to protect against sabotage during decommissioning. If a special fuel storage facility is constructed there will be security requirements associated with it as well.

There may be situations where the facility owner may request that parts of the site be removed from the nuclear license before decommissioning is complete. The regulator will want assurances that such portions of the site have been thoroughly surveyed, that they meet the site release criteria, and that any new activities do not adversely affect decommissioning. A special case would be where the owner or other organisation desires to use a portion of the site for a new, non-nuclear electrical generating facility (sometimes called repowering the site). In this case, the regulator will want assurances that any new construction will not interfere with decommissioning and that any stored materials such as chemicals or fossil fuel storage tanks will not present a hazard to the safe storage of nuclear fuel and materials on the site.

E. Waste management

A major factor affecting the successful completion of decommissioning a nuclear facility is the availability of a repository for disposing of low-level and intermediate-level radioactive waste. When no repository is available, the radioactive waste from decommissioning must be stored until a repository becomes available. The availability of disposal facilities greatly affects the degree of decontamination and dismantlement and thereby influences the operator's decommissioning strategy. If necessary, new interim waste storage capacity will have to be constructed. In some cases, *in situ* disposal may be considered, although this option must be discussed thoroughly with local officials since the local public may object strongly to the site becoming a waste disposal site. The question of waste treatment, waste storage and waste disposal is an important challenge of nuclear facility decommissioning and it requires regulatory guidance. It is important that requirements and responsibilities be defined clearly, particularly in the cases where intermediate storage is built to store waste until a final disposal site is available.

As decommissioning proceeds, large volumes of waste will be handled. Much of the waste, like structural concrete debris, will pose no health risks, and after monitoring it can be shipped offsite to normal landfills or remain on the site for filling operations there. Other waste that may have low levels of radioactive contamination will have to be monitored and sent to a low level waste disposal site or a temporary storage site. There will be other materials having chemical or other environmental contaminants that will have to be treated and sent to special disposal sites.

Special plans and procedures will be needed for removing the large components such as the reactor pressure vessel, steam generators, pressuriser, piping, pumps and valves. The operator will usually have these components decontaminated to remove much of the surface radioactivity before removal and sent to a low-level waste disposal site. The reactor pressure vessel internal structures present a special challenge because they are intensely radioactive and may not be permitted to be disposed of in a low-level waste site. In that case the operator will likely have the structures cut into segments that can be placed in special canisters and stored in the spent fuel pool or special storage facility on site. Ultimately the reactor vessel internal structural materials will have to be removed to a long-term disposal site. The debris that is generated during these decontamination and cutting process will also have to be packaged and sent to a low level waste disposal site or a temporary storage site.

F. License termination

The final regulatory decision associated with a nuclear facility at the end of decommissioning is the decision to terminate all licenses. Experience has shown that there can be high public interest in the conditions for terminating nuclear facility licenses and in the final end state of the site. In particular, there may be public concern that the delicensed site not be viewed as a nuclear waste site.

A particularly difficult challenge for the regulator is to establish a clear set of site release criteria for terminating the license. There is currently no consensus within OECD countries on a preferred set of site release criteria or even the form of such criteria. Whatever conditions or criteria are chosen, it is important for openness and transparency, and ultimate public acceptance of the decommissioning process, for the operator to have public discussions of the site release criteria. These public discussions should include a description of any final site surveys that will lend a degree of assurance that the site meets the release criteria. The regulatory body should also plan on meeting with the public to present the regulatory perspective and listen to public concerns.

There are many variations of an acceptable end state for a decommissioned nuclear facility site. In particular the end state does not necessarily have to be a “greenfield” condition. Some buildings or facilities may remain on the site, as long as they meet the site release criteria. A portion of the site may remain under a new type of nuclear license for storage of spent fuel in special storage casks.

Some nuclear facility sites may have become so thoroughly contaminated during operation, either through spillage, ground disposal or accidents, that it is not economically practical to clean the site for unrestricted use. In these cases, the regulator will have to work with the operator in deciding what level of decommissioning and cleanup is practical and what restrictions must be placed on use of the site in the future. The regulatory body could require that the license remains in force or require that there be legally enforceable controls placed on future use of the site, for example, restrictions placed in the deed for the site property describing what the site can and cannot be used for.

The regulator should also have requirements or expectations on what records for the site should be maintained. Such records could include a description of decommissioning activities completed, a description of any waste stored on the site, the results of the final site survey, and the overall final condition of the site. The regulator will have to specify where these records are to be maintained and for how long.

4. REGULATORY OVERSIGHT DURING DECOMMISSIONING

The broad range of safety, environmental and public policy issues that arise in decommissioning a nuclear facility are quite different from those during operation, and they produce corresponding new challenges for the regulator. In the weeks and months after a facility ceases operation, there will likely be intense regulatory activity as the operator makes decisions on how to proceed in light of his changing circumstances. Just as the operator should have prepared a strategic plan for decommissioning before shutdown, the regulator also should plan ahead for decommissioning. Many of the regulatory challenges discussed above involve substantive public policy issues and they may generate a good deal of local and even national public interest. In the interest of efficient regulation it is best to have those public policy issues, such as site release criteria, settled before decisions must be made for individual facilities in the midst of decommissioning.

Because of the organisational and human factors issues that will inevitably arise in the wake of cessation of operation of a nuclear facility, the regulator should be prepared to conduct regular inspections to look for possible adverse trends in the overall safety culture at the site. The regulatory body will want to review its overall staffing and inspection plans for the facility to focus more on the new organisational, human factors and dismantlement issues and may augment staff expertise in these areas.

It will be important for the regulator to have regular communications with the operator's corporate and site management prior to cessation of operation and throughout the period of active decommissioning. The regulator will want to review the operator's plans for decommissioning, the adequacy of funding for the proposed strategy, the plans for dealing with the organisational and human factors issues at the site, and other licensing issues. The regulator may request regular reports on the plans and status of decommissioning as work progresses.

Just as important for the regulator will be regular communications with the public. The shutdown and imminent decommissioning of a nuclear facility will present a new situation for the local population, and they will be concerned about safety and radioactive releases during decommissioning and about plans

for the long term condition of the site. The operator should be encouraged to have regular public discussions to explain his plans and activities and especially the long term plans for the site. The regulatory body should also plan on meeting with the public to present the regulatory perspective on the issues, to describe the regulatory oversight activities, and listen to public concerns.

Since the public health risks posed by a shutdown facility are substantially reduced from those of an operating facility, the regulatory inspection programme should be tailored to address the new regulatory challenges. For example, many of the challenges involve regulatory policy questions rather than operator performance issues. Those regulatory bodies that utilise resident inspectors at operating facilities may want to replace the resident inspectors with periodic team inspections focused on special areas such as ALARA programme implementation, worker radiation protection, site security, operator's contractor oversight, and looking for signs of deteriorating safety culture. When special operations are planned, such as removing the pressure vessel, the regulator may want to review the procedures and have inspectors on site to observe the activities.

As decommissioning progresses there may be periods of only routine activity on the site, and the regulatory inspections can be scaled back accordingly. If the operator chooses to place the facility in a safe storage mode for an extended period, there will be reduced need for inspections to observe that safety and security systems are not degrading. The regulator should continue to assure that the license conditions are maintained, including adequate funding for subsequent dismantlement.

The final regulatory oversight activity at a decommissioning site will be to review the plans for the final site survey and the results of the survey. When the regulatory body is satisfied that its site release criteria have been met, it can take actions to terminate all licenses.

5. SUMMARY AND CONCLUSIONS

When a nuclear facility ceases operation and enters the decommissioning phase, both the operator and the regulator face a new set of challenges very different from those of an operating facility. The operator should have in place a strategic plan for decommissioning, prepared well in advance of shutdown and reviewed by the regulatory body, to guide the facility managers and workers through the changed circumstances. An essential part of the strategic plan should be the operator's plan for securing adequate funds to complete the decommissioning activities. In fact, the regulator should ensure that the operator sets aside funds, perhaps in a trust fund, while the facility is still operating and generating revenues.

Both the operator and the regulator should expect a heightened public interest and concern about decommissioning. The public will naturally be concerned that a new activity like decommissioning be done safely and that the site will be returned to an acceptable end state. It will be important for both the operator and the regulatory body to have regular public discussions to explain the decommissioning plans and activities and the regulatory oversight activities, and listen to public concerns. Such public discussions will greatly enhance the transparency of the decommissioning process.

The regulatory response to the challenges of decommissioning will involve frequent communications with the operator management, revised inspection programmes and regular communication with the public and local authorities. In the interest of efficient regulation it is best to have the important public policy issues, such as material release criteria, site release criteria, and the availability of waste disposal or storage sites, settled well before decommissioning commences. In this regard, regulatory bodies should continue to share decommissioning information and experiences with their international colleagues.

Most of the decommissioning experience to date has been with research and test facilities and relatively small commercial nuclear facilities. As experience is gained with decommissioning large commercial facilities like nuclear power plants and fuel cycle facilities, regulators and operators should collect the lessons learned and propose design guidelines for future nuclear facilities that will facilitate their decommissioning.

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