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European Clearinghouse: Nuclear Power Plants Decommissioning Related Events

Summary Report of an European Clearinghouse Topical Study

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1. INTRODUCTION

Decommissioning is a major issue today: around 83 commercial power reactors, 44 experimental or prototype reactors, and over 250 research reactors have ceased operation worldwide. Besides, more than 300 power reactors were built 25 or more years ago, so even if a part of them will have their lives extended, a fraction of them will have to shut down in the next decades. Besides that, this technological challenge is not limited to each single facility, but it also affects other parties involved, such as licensees, regulatory authorities, national authorities, radioactive waste management structures, etc. The decommissioning projects that are on-going, and those that will start in the future, can benefit from the experience and lessons learned in all the work that has been carried out in the past.

However, while the exchange of operational experience has its established national and international mechanisms, the exchange of experience during decommissioning is developed to a lesser extent. Moreover, the existing exchange of decommissioning experience is not so focused in safety-related issues but rather on the technical and economical optimization of the projects.

With this goal in mind, this document summarizes the Clearinghouse Topical Operating Experience Report, drafted by the European Clearinghouse, on events related to decommissioning [5], with the purpose of presenting relevant and useful lesson learned that can be extracted from international experience. It is focused on the decommissioning of nuclear power plants (NPP), (including experimental and prototype reactors when appropriate). Research reactors, used fuel or radioactive waste management and storage facilities are excluded from the scope of this study.

2. MAIN TYPES OF EVENTS

The decommissioning events have been analyzed and classified in the following categories:

- Leakage of radiological effluents

- Violation of Technical Specifications

- Contamination and radiological protection issues

- Inadvertent actuation of equipment

- Control of nuclear and radiological material

- Other

The following paragraphs summary the causes of the events and the corrective actions taken to mitigate the consequences, and impede their repetition, highlighting as well the main findings.

Leakage of radiological effluents. Leakages and spillages of radiological effluents were caused by design errors, human errors, and malfunction of instrumentation. The corrective actions in this case consisted in arresting the leakage, cleaning and decontamination of the affected areas, and repair of the involved systems.

Violation of Technical Specifications. This category comprises events related to the violation of technical specifications, operation outside of the design basis, or similar. These events were mainly caused directly by human errors, due to overlooking or misinterpretation of the procedures (although sometimes the procedures themselves were not fully adequate). However, a number of these events are attributable to the specific configuration of a facility undergoing decommissioning. In these cases, the violations were caused because the technical specifications were not updated along with the modifications implemented in the plant as a consequence of decommissioning activities (for example, the technical specifications could request tests and maintenance interventions in some equipment which is no longer used). This was due, in some cases, to a breach in the maintenance of license documents, and in some others, to misunderstandings on when a specific document would enter into force.

A number of events were related to violations regarding the movement of heavy loads: movement outside allowed ranges, inadequate rigging and securing of the loads, insufficient checks, etc. The reason is that heavy loads are moved more frequently and on different, less routine routes during decommissioning.

The corrective actions to avoid violation of technical specifications and other limits were the review or the reinforcement of the training and of the involved personnel, drafting, review and update of the necessary procedures and documents and the review or update of the organisation for the decommissioning.

Contamination and Radiological Protection issues. This category comprises inadequate handling of contaminated materials, and the discovery of radioactivity outside of the controlled area.

The main causes were the inadequate planning of the works, inadequate packaging of contaminated equipment, dose calculation errors, and breach of the radiation protection programme (as radioactivity was found outside the fence). The corrective actions consisted in amending the found errors, by improving the procedures and the training, and updating the radiation protection programme. The radioactive material found outside the controlled area was removed, and the area cleaned or secured.

Inadvertent actuation of systems or equipment. The events in this category have in common the inadvertent actuation of plant systems, or, on the contrary, the failure to actuate of plant systems.

The main causes were failures of components or false initiating signals, caused either by material degradation, operational errors, or electrical disturbances. The corrective actions taken were to check if the actuation was justified, the replacement of the equipment, and the reparation of the system. Improvement of the procedures and reinforcement of the training were also frequent corrective actions, as well as small modifications to secure switches, etc.

In some cases, the affected system was not needed for the decommissioning of the plant, which showed that not sufficient attention was paid to taking out of order some equipment or systems which, although necessary during the operational phase of the plant, were not needed during the decommissioning. The corrective action in this case consisted in putting out of order the affected system or equipment while removing all non-necessary surveillance or maintenance requests.

In some other cases, systems that were needed were inadvertently or mistakenly disconnected while deactivating systems no longer needed for the decommissioning of the plant, normally because of human errors. The corrective actions consisted in re-establishing the operation of the incorrectly deactivated equipment or systems, as well as improving the management, training and preparation of non-routine operations. These events did not present risks, nor adverse consequences, but highlighted weaknesses in the organisation, management and monitoring of the decommissioning project.

Control of nuclear or radioactive material. Missing of nuclear or radiological material during decommissioning is another category of events. It is usually detected in inspections, in which the written records are examined and confronted to the physical identification of the material they refer to, or when the decommissioning activities aim at the management of such material. In some cases, the cause is operational (equipment that becomes contaminated and which is not controlled), and in some other cases, the causes are historical, and involve old nuclear or radiological material. The requirements to control nuclear and radiological material have been developed over the years, and nowadays are a lot stricter than in the past. Additionally, the available tools to keep record of the nuclear or radiological material have significantly improved over the years. The combination of these two factors limits the re-occurrence of such events. Corrective actions normally involved a search for the missing material, the assessment of the consequences of a potentially inadvertent shipment of this material elsewhere, and the reinforcement of the control and surveillance mechanisms (both in the licensee and regulatory authorities) to ensure that these events do not recur.

Other. Several other events could not be classified in any of the categories described above. Although the nature of these events is different (design errors, operational errors, loss of offsite power, fires, dis-coordination of decommissioning teams, etc) the causes were quite similar, and always related to the need to adapt the structure and practices of the plant organisation to the new configuration for decommissioning.

More specifically, the causes of events were related to inappropriate or incomplete previous evaluation of risks, inadequate work preparation and execution, inadequate surveillance, unclear distribution of responsibilities, etc. Corrective actions included the suspension of the works until the situation was normalized, reinforcement of the training and co-ordination, and especially the reinforcement of the surveillance of the works by the decommissioning organisation.

3. MAIN FINDINGS

This section summarizes the most important findings from the event analysis.

Many decommissioning events reported were caused by human or design errors, inadequate manuals or procedures, and other well-known causes which are present in operational events of currently operating installations. But apart from these, the study has identified a number of contributing issues which are typical of the decommissioning of a nuclear facility.

In effect, a number of events were caused by the inadequacy of the organisation put in place to carry out the decommissioning. The new organisation missed to rigorously and systematically transfer the responsibilities on safety from the operational organisation to the decommissioning organisation.

The miss-coordination of different teams to carry out decommissioning activities in parallel, inadequate planning of decommissioning activities, inadequate control of the continuous update of guidelines, decommissioning technical specifications, and other license documents have shown that the plans for deactivation of system and components were not systematically and appropriately designed, executed and monitored.

The nature of the decommissioning activities, in which a large number of interventions and works are carried out by many workers in many locations of the facility, can trigger the actuation of systems due to human errors, electrical disturbances, and other causes. Reduction of the maintenance work also causes malfunctions of equipment and systems that could be needed during the decommissioning.

Similarly, the management of large quantities of diverse radioactive material, which is quite different to the management of radioactive material during normal operation, can be more prone to mistakes and gaps in the control measures. Another contributing cause is the evolution of the requirements for the control of nuclear and radiological material over time, which may imply that some legacy material is considered insufficiently controlled.

These facts demonstrate the importance of paying sufficient attention to organisational and managerial issues during the transition period from operation to decommissioning. In particular, the importance of maintaining a strong, yet flexible organisation that ensures the continuity of important tasks that have to be carried out with the highest standards up to the very end of the decommissioning project.

4. RECOMMENDATIONS

A number of recommendations have been extracted from the analysis of the reported events and also from the analysis of additional sources (see list in section 7) and are presented in the categories specified below.

The more specific lessons learned from the events and other sources are listed in annex.

Organization and management

- Safe and efficient decommissioning of nuclear power plants is enhanced with early planning, sufficient funding, and with a national policy for decommissioning, waste management, and spent fuel management with a long term perspective.
- A strong and flexible management is needed to face the continuous changes and evolution of the facility configuration, including the transition from operation to decommissioning. The management must ensure that there is always a clear responsibility defined in every task. This is also applicable in the case of outsourcing certain activities (i.e. to subcontractors).
- The decommissioning team could significantly improve by incorporating both personnel with a deep knowledge of the facility to be decommissioned and external personnel with wide knowledge in decommissioning techniques and practices, although their specific knowledge on the particular plant to be decommissioned is limited.
- During decommissioning projects, especially in the long term, it is very difficult to retain and obtain the best professionals in terms of knowledge, skills, and experience. This is due to both the difficulty of maintaining in the long term the knowledge and experience of one particular facility, and the scarce personnel skilled and experienced in decommissioning. The life extension of the nuclear facilities is an additional factor that could worsen this issue. Mechanisms to enhance record keeping and knowledge transfer need to be put in place.

Decommissioning Works

- Simple and proven decontamination and decommissioning technologies are available, and have some advantages in comparison to new and innovative technologies. Where new and innovative technologies are foreseen, extensive testing and demonstration are required to ensure that the new technology will be capable of performing safely and efficiently the requested task.
- During decommissioning, equipment and systems are operated in ways that are quite different than during routine normal operation. This fact yields to the need of defining these new ways of operations, as well as a potential for operational circumstances that might lead to unforeseen consequences (i.e. radioactive effluents directly discharged to the environment, inadequate heavy load handling). Retaining expertise and knowledge of plant systems, (especially with regards to non-routine operations during normal operation), is fundamental in order to devise both the operations specific of decommissioning, and the recovery actions (in case they are needed).
- The decommissioning tasks are usually carried out in parallel by different work teams. These teams must have a very clear definition of their work, specifically with respect to the limits of the systems or areas in which they intervene, as well as the potential risks they might encounter. Additionally, the work teams must be adequately coordinated, so their activities do not interfere.
- During decommissioning, a number of small modifications can be carried out successively, maybe by different teams. Sufficient consideration shall be paid to the cumulative effect of all the small modifications, especially when the individual changes are not significant. In these cases, work coordination shall be ensured so as the different teams respect the same plant restrictions, or plant conditions.

Stakeholders.

Early involvement of relevant stakeholders, along with close co-operation and open communication with them will help to establish a trustful relationship especially with regard to the activities to be carried out in the site and their socio-economic impact in the local communities. Transparency in the communication of the main results of the safety assessment, especially those on risks and hazards is fundamental for not breaking the trust-based interaction.

Regulatory framework

The application of the normal operational-based regulatory framework to the first decommissioning projects has highlighted the need for a graded approach of the regulation with the aim of reflecting the continuous reduction of the radiological hazard levels with the progression of the decommissioning project. At the same time, the radiological hazards shift to industrial hazards. These facts and the varying physical configuration of the plant as the decommissioning takes place require flexibility and quick adaptation of the regulatory framework.

Additionally, regulatory requirements should focus on operational management (rather than on technical issues), importance of contamination control (rather than accident analysis), the inclusion of industrial safety and non-radiological hazards, and the management of changing situations. It seems appropriate that the regulatory decision making adapts to the developing project, rather than to a fixed calendar.

6. LIST OF ACRONYMS

IRS	International Reporting System
LER	Licensee Event Report (USA)
DTS	Decommissioning Technical Specifications
HSA	Historical Site Assessment
IAEA	International Atomic Energy Agency
JRC	Joint Research Centre
NEA	Nuclear Energy Agency
OECD	Organization for the Economic Co-operation and Development
TSO	Technical Support Organizations
US NRC	United States Nuclear Regulatory Commission

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APPENDIX: SUMMARY OF LESSONS LEARNED

For Regulatory Bodies

The vast majority of the waste material produced is inactive or below clearance levels and the use of clearance has the potential for saving considerable waste disposal costs. It then would be very useful to harmonize the clearance level in the different countries to avoid misunderstandings and trans-boundary problems, so the regulatory framework shall tend to simplification and flexibility.

'In process' inspections, consisting in frequent interaction with the licensee during the decommissioning phase, are more efficient than 'one time' confirmatory surveys.

The regulator can propose measures to prevent future legacy sites, by promoting changes in the financial assurance (to avoid shortfalls in decommissioning funding) or imposing conditions to the operating license (imposing conditions to limit the possibility of causing environmental contamination).

For Licensee

Cornerstone	Lessons Learned
Planning	Planning for the decommissioning must start as early as possible, being considered during the design phase if possible, and be complete, from shutdown to disposal. Discussions between regulators and licensees are encouraged before the decommissioning phase. Besides, the licensee shall coordinate early with all regulatory agencies regarding waste disposal options. Raising funds should also be addressed in an early stage, so a premature close can be successfully faced. Physical and radiological inventory is a prerequisite for adequate planning, especially regarding to waste management.
Strategy	The preferred strategy for decommissioning is immediate dismantling, which allows using the existing strengths of the facility. On the other hand, deferred dismantling can be a reasonable option in situations of lack of funding or waste management routes, or by external reasons. It should be taken into consideration the future use of the site
Cost/Funding	Funding for many facilities is the main reason for lack of progress in decommissioning. Waste management and labor cost of decommissioning activities are the two major contributors to the cost of decommissioning. The estimation of the decommissioning costs should be done in a prudent way based on appropriate risk management and external supervision. Project cost control should be integrated from the beginning into project planning and must be continually reinforced, and those who work in it must understand cost estimating well enough to anticipate potential cost problems. If the plant is shutdown before its planned operating lifetime, the decommissioning funds raised might not be enough, and adequate provisions, with the help of the authorities, must be put in place.

Management	The management should be constituted by a small group with all disciplines involved. It is important to keep all departments involved. It is important to retain expertise and experience in construction in addition to keeping managers with operational experience. It is also important to obtain personnel with expertise in construction and/or demolition experience. Management should assure a key early transition activity for moving the site mentality toward decommissioning rather than operations.
Radiological Characterization / Final Survey	Modeling Issues - Assumptions and justification for parameters used in developing site-specific calculations must be shared with the regulatory authority, and agreed upon. The models shall be realistic. Historical Site Assessment (HAS) has major impact on the planning and scheduling of all subsequent survey activities. Licensee shall dedicate enough time and resources to perform and effective HSA. Personnel questionnaires and interviews are a valuable source of information. Old records should not be used as the sole source of information, and must not substitute the radiological characterization. Additional environmental monitoring data for groundwater may be needed. Note that under leaking conditions, Tritium is by far the most mobile and pervasive radionuclide within the groundwater flow domain (other primary radionuclides of concern ring are Sr-90, Co-60, and Cs-137). Groundwater investigations are best undertaken with an iterative approach that can be expected to require a minimum to three years to complete, in even relatively simple situations. In developing the final survey design, the licensee needs to identify all appropriate data quality objectives (DQOs) in planning and designing the final status survey plan. The process of identifying the applicable DQOs ensures that the survey plan requirements, survey results, and data evaluation are of sufficient quality, quantity, and robustness to support the decision on whether cleanup criteria have been met using statistical tests.

Decontamination	Decontamination should be performed immediately after the final plant shutdown while all the plant systems are still well maintained and operational and while knowledgeable plant operations personnel are still available. High flow rates yield better results. Operation of the reactor coolant pumps (RCPs) is recommended. Secondary pumps, such as residual heat removal pumps, should be used if the RCPs are not available. Vendor-supplied pumps are the least preferable option since they will have smaller flow capacity than pumps at the site. The reactor pressure vessel (RPV) should be bypassed during chemical decontamination. For PWRs, inclusion of the steam generators (SGs) in the flow path should be seriously considered. To achieve flow to all the tubes would require operation of the RCPs. The major downside of including the SGs in the flow path is the additional waste. Flexibility is preferred to quick termination of the decontamination. To this end, extra chemicals should be stored on site in case the foreseen decontamination factor is not achieved and further cycles have to be implemented. The decontamination and the disposal of concrete must be faced and evaluated by a cost benefit analysis to understand if the savings of radioactive waste space compensate the additional costs of characterization and successive decontamination.
Safety	Safety in decommissioning comprises radiological safety, conventional safety, environmental protection, and public safety. The importance of each of them shifts from radiological safety towards conventional safety. Health physicists who understand the work should allocate radiation dose allowances to each project and monitor its use at least weekly.

Dismantling	Extensive pre-deployment planning, simulation, and testing should be done prior to any onsite segmentation work. A comprehensive testing involving a full mockup of the cutting arrangement, materials, tooling, and waste capture and processing system is beneficial. Computer simulations can help to identify and mitigate high risk factors in advance. In the planning of RPV internal segmentation, plants should commit to capture the lessons learned from preceding projects. Abrasive water jet cutting provides a reasonable cutting speed and a high degree of precision. The cutting plan should minimize the number of cuts, produce waste pieces that can be easily packaged, and minimize the final waste volume. Segmentation should begin with the least irradiated components in order to gain experience with the tooling before applying it to highly radioactive components, where tooling failure could significantly increase personnel exposure. The benefits of using robotic equipment include minimizing worker exposure, precision and repeatability of movement and overall worker safety. Projects should use multi-purpose machines if possible. Explosives are a viable alternative to mechanical demolition, but impose the need for strict control, and it should only be used on clean or decontaminated buildings.

Waste Management	The characteristics of the waste must be profoundly understood for efficient and a responsible and efficient management On site waste volume reduction should be limited to simple, efficient packaging activities. The absence of suitable repositories for intermediate level waste is not normally a reason to prevent going forward. Most waste types can be stored safely until repositories become available. Decommissioning efforts should focus on plant dismantlement and eliminating radioactive materials from the site rather than equipment decontamination. The waste conditioning infrastructures (mainly at older plants) are often obsolete, offer low levels of remote operation and are focused on the most abundant operating waste streams. The capacity of the storage facilities, for both conditioned and unconditioned waste, is a parameter to be kept under review from the design phase onwards. The capacities of storage facilities should be overestimated in design. The minimization of waste volumes during the process is of great economic and strategic importance; however, that this is an aspect that is often not dealt with as carefully as its importance demands. From the design phase to the completion of the decommissioning, the instruments required for giving assurance that waste volumes are being minimized should be in place. Consideration should be given to producing a logistical plan for the different waste packages to be moved.

Stakeholders	Decommissioning has a major impact on local communities, usually a negative one in the local economy. These negative consequences cannot be fully avoided but can be reduced through the involvement of the concerned parties. They should be involved since the beginning of the decommissioning process. It is essential to build trust with the various project regulators and stakeholders: keep them informed and updated is essential. Nevertheless, it is important to identify the different parties involved and develop an appropriate and specific strategy with each of them. Negotiation is often better than litigation. Public meetings with a community advisory panel have been successful in the past. Alternatives include updates in newsletters or advertisements in newspapers. It is a great benefit to have engineers who can discuss technical issues in a manner people can understand and can answer questions clearly.
Knowledge management	There are often problems in retaining a knowledgeable and skilled workforce to do decommissioning work. Measures to motivate and retain the most valuable professionals shall be put in place. It is important to develop an early de-staffing plan to retain needed workers and release the rest. This opens up opportunities to bring in workers with skills that are more suited to a decommissioning environment
Site remediation	Licensees should make reasonable efforts to prevent, detect, and control minor leaks of radioactive materials over prolonged periods of time. Minor leaks over long periods of time can contribute to significant contamination in soil and groundwater that result in significant costs for remediation.

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Abstract

Decommissioning is the final phase in the life cycle of an installation. The term decommissioning refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a nuclear facility. It is an integral process that involves complex and diverse operations as well as several stakeholders and regulatory organisations. Regardless of its complexity and its cost, suitable strategies and techniques for the decommissioning of nuclear power plants are available, and have been successfully applied in many sites. However, the operative experience could be better collected, and the lessons learned should be shared as their equivalents of the operational phase. This is a major issue considering the large number of NPP that are in this phase, or are close to their shutdown.

This Summary Report presents the results of a study performed by the European Clearinghouse on Operating Experience Feedback of NPP about events related to decommissioning.

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