Taking into account dismantling and decommissioning waste management in conception and operation phases

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ABSTRACT

Managing waste during the Dismantling and Decommissioning (D&D) phase is quite specific and different from what it was during the operation phase. Indeed, waste generated during dismantling could present some analogy especially with regards to the radionuclides spectrum and contents. However waste from dismantling and cleanup could actually presents a lower level of radiologic activity but produced in much larger quantities, which requires new solutions. Moreover the characteristics and quantities of waste to be managed during D&D are highly depending on the way the facility was designed and also how it was actually operated during its life time. Taking future D&D into consideration in the early design as well as during the operation of new facilities is becoming more and more mandatory. It is now an explicit requirement set by safety authorities, to provide - in the license application for news plants - a description of design provisions and future plans for D&D as well as anticipated technical and financial impacts,. Two major aspects are driving the cost and complexity of future D&D operations: waste volumes by categories and occupational exposure while performing the work. To reduce such impacts, key approaches are to maintain areas clean, segregate the waste types and provide appropriate provisions in the design. The paper's first part describes the related design and operation concepts derived from lessons learned, and illustrations by examples are presented in a second part.

INTRODUCTION

Design and operation principles for a new facility should fulfil the following objectives in order to facilitate later decommissioning operations:

- Reduce the quantity and volume of nuclear waste remaining in the facility when it is time to D&D, which leads to:
    - Provide solutions to maintain the facility as clean as possible with respect to nuclear contamination
    - Segment the facility into Waste Area Zones during its operating phase, to ensure segregation of the waste close to its production origin, to limit volumes, and to avoid cross-contamination and propagation of the contamination outside of the Zones

  - Design equipment and civil structures in such a way as to minimize retention and spread of contamination

- Limit occupational exposure with ALARA concept, when anticipating future D&D works, through the following measures:
  - Limit accumulation of deposits or retentions leading to high radiation sources
  - Optimize general layout with appropriate shielding
  - Design equipment in order to facilitate their removal from the facilities for post-processing in specialized waste treatment areas
  - Pre-installation of means and dispositions to facilitate D&D
  - Minimize material activation, as relevant
- Implement specific organization and procedures during operation life, to reduce facility contamination and facilitate future cleanup.
  - Including ensuring up to date as-build documentation, and full traceability of changes and incidents during the life of the plant

Facility Waste Areas "Zoning"

Preliminary note: the organization of "waste area zoning" is a requirement in the French BNI's regulation; these principles are applicable worldwide.

"Waste areas zoning" in a facility consists in identifying and segregating parts of the facility that are the source of nuclear waste, from parts of the facility that are source of only "conventional" waste, leading to the two following two categories definition:

- The Nuclear Waste Areas (NWA) in which the waste produced is likely to be contaminated or activated. Waste from these areas is named "Nuclear Waste" and is processed and disposed of with specific methods.
- The Conventional Waste Areas (CWA) in which the waste produced is not likely to be contaminated or activated. Waste from these areas is named "Conventional Waste" and is processed and disposed of using "conventional" methods.

The fundamental interest of thoroughly maintaining waste zoning integrity during operational life of the plant is that the volume and nature of waste to process - when it is time to decommission - are significantly controlled and limited, as compared to a case where all the waste generated would have to be considered as "nuclear" in the absence of clear zoning history.

Such zoning is established using an analytical approach in which the facility's design and operating rules - as well operating history - are considered to determine the presence or absence of added radioactivity. It is supported by radiological mapping to confirm the appropriateness of classification and validate the operational nature of the lines of defense adopted to ensure materials containment.

Waste area zoning evolves as a function of modifications of - or work performed into - the facility, or following an incident. It is separate from radiation protection zoning, but is consistent with that zoning. Its traceability over time is to be ensured.

Appropriate Area Zoning is established with the following approaches:

- Facility design: to ensure containment of the waste as close as possible to its origin (the contamination sources). The objective is to limit the extent of nuclear waste areas (NWA) to what is strictly necessary.
- Isolation / confinement of the waste:
  - Equipment and hardware may be protected with a removable envelope, in which case the inside of the envelope could be classified as a conventional area (ex: computer hardware temporarily brought into a NWA for special handling operations).
  - Envelope protection may also be used to prevent the dispersion of radionuclides into an area that must remain contamination free (e.g. when storage of contaminated parts is considered into a CWA-classified room). In this case the zoning category of the – well packaged - object must be clearly indicated (nuclear-classified).
- Operating procedures: specifications for zoning and modes of operation to ensure consistency and compliance with them. Great care must be taken at the highest level to carry out monitoring in order to confirm the absence of contamination transfers between areas.
- Maintenance of historical information:
  - Maintain systematic and accurate traceability and record-keeping of modifications made to the process and/or the facility. Including changes in operating procedures and practices related to methods for managing containment.
  - Maintain records of radiological surveillance and monitoring carried out in the different facilities as well as incidents occurring during operation. This helps identifying and understanding the origin of potential contamination.
- Extension of the Zoning in the dismantling phase
  - The starting point is the zoning defined and used during the operational phase. It is critical to allow justification and confirmation of the conventional CWA areas. So that waste from these zones can be cost-effectively processed using conventional means.
  - Original zoning could be expanded as necessary to support the dismantling operations. Operational zoning during dismantling is established whenever waste-producing operations to perform may generate radioactive waste within areas initially classified as CWA. A change in classification is made at the conclusion of the operations and after radiological monitoring has been carried out confirming the absence of contamination in the area in question.

Specific measures and dispositions to facilitate D&D are further described hereafter.

Equipment and structures dispositions

Equipment and structures located in rooms that receive - or are likely to receive - radioactive material should be made of materials whose physical characteristics limit radionuclide migration. If necessary, surfaces are to be covered with a coating to protect them from contamination migration. The material and/or surface coating used should be compatible with the decontamination products used in the facility.

When the contamination risk is significant (ex: liquid effluent transfer stations, containers unloading areas, nuclear waste areas...), close attention is to be paid to the long-term integrity, physical properties and geometric characteristics of the materials and equipment including: tightness, absence of retention, ease of decontamination, and ease of radiological monitoring.

Provisional space should be included in the design to ensure decontamination of equipment prior to their removal from the rooms. Operations should be carried-out without significantly impacting work schedule.

Civil engineering dispositions

Metal liner protection provided for concrete structures (usually stainless steel) should be widely used in areas including pools, for the inner walls of reactors building, and in rooms containing effluent tanks and liquid processing where leakage risk is considered to be significant. This is particularly the case when the surface protective coatings ordinarily used (ex: decontaminable paint, peelable coatings, etc.) are not consistent with the activities to be carried out in the area. For example, the walls and floor of a size reduction room in waste processing facilities should be covered with a high-integrity protection such as a steel liner. The additional cost of these measures should be compared with the costs saved by not having to cleanup and dispose of the concrete civil structures, efficiently protected by such liners.

Special attention should be also paid to the placement of anchor inserts in areas with a high risk of contamination. They should be placed in areas of the rooms that are less prone to contamination and exposed to accidental spills. It would be preferable, for example, to place them in the upper part of the rooms (or at least on the vertical parts).

Structural expansion joints in buildings are to be located - whenever possible - in rooms that are not exposed to high risk of contamination. When a contamination risk is identified, the joints should include a liner / seal to limit transfer of the contamination into the structures. These liners should be periodically inspected for integrity.

The cleanup of embedded or buried piping or cabling networks poses considerable difficulties. Solutions for dealing with the consequences of an event in which containment is breached must be considered early in the design. Piping in embedded or buried networks used to carry Toxic, Radioactive, Inflammable, Corrosive, Explosive (TRICE) fluids should be avoided or double-walled or designed to provide guarantees of containment integrity for the life of the plant and have a system for monitoring leak-tightness (periodically or continuously) to prevent accidental spills.

Piping for which dose rate requires shielding to minimize the impact of radiation (personnel exposure / materials activation) should be covered rather than embedded.

Containment dispositions

The design of negative pressure HVAC cascades - based on ventilation zoning – should be based upon the levels of contamination that may be encountered in normal as well as incidental situations (excluding accidents). Focus should include the following points:

When the rooms are equipped with a ventilation system not classified for nuclear operations under normal conditions, it may be appropriate to establish "block-outs" through placement of special filtration banks to be used during the dismantling phases.

To the extent possible, the design of the filtration networks should include the following characteristics:

- containment as close to the source term as possible (filtration components kept close to the source term)
- limit ducts carrying listed effluents through rooms not classified for them

- sizing of ducts to be adapted in the event of contamination incidents in conventional networks

Material activation dispositions

The objective of minimization of the production of activated waste material is achieved by: placing shielding in place to reduce neutron radiation likely to activate materials, choice of the base materials (alloys with a low cobalt content), architecture of the facility to limit exposure to the most highly radiations.

Organization dispositions

Operating procedures should promote the maintenance of radiological cleanliness as far as possible, so as to reduce contaminated surfaces and minimize the generation of nuclear waste, both in the operating phase and in the dismantling phase.

Facility modifications and changes during the operating phases should include a study of their impact on future facility cleanup and dismantling.

The number and size of areas with a known risk of contamination, classified as nuclear waste areas, should be reduced as much as is reasonably possible. Operating procedures based on operational zoning (radiation protection and waste) should therefore be widely used. The rooms and facilities areas involved are primarily those for which the risks are present during clearly identified and completely controlled transitional phases, maintenance or operations.

Organizational means must be provided to prevent drift resulting from the unforeseen accumulation of products.

“Band-aid” type of actions consisting of implementing quick work-around solutions that hide the source should be avoided (e.g. lead protections).

Simple, robust methods and techniques, sometimes commonly used in conventional industry, are to be preferred to optimize operations and minimize maintenance times. For example: quick disconnect couplings, bypasses for maintenance preparations, and siphon vacuum-breakers.

ILLUSTRATION by EXAMPLES

Structural activation mitigation in the AREVA / EPR™ reactor design

The activation of metallic and concrete structures located in areas exposed to high neutron radiation must be limited with the use of shielding. In some cases, the thickness of the equipment may be sufficient to limit neutron flux and avoid the need for additional shielding.

- The EPR™ reactor design includes a heavy reflector inside the Reactor Pressure Vessel to limit the activation of the RPV leading to increase life duration. Moreover it also reduces the exposure of the surrounding reactor pit concrete, which brings also the advantage to reduce decommissioning waste cost. The thickness of the reactor pit concrete prevents activation of components outside of the primary shielding.
- The "heavy reflector" consists of circular components that are assembled and attached to the bottom support of the core by anchor bolts. Such neutron shield, which will be highly activated, will be removed before performing dismantling operations.

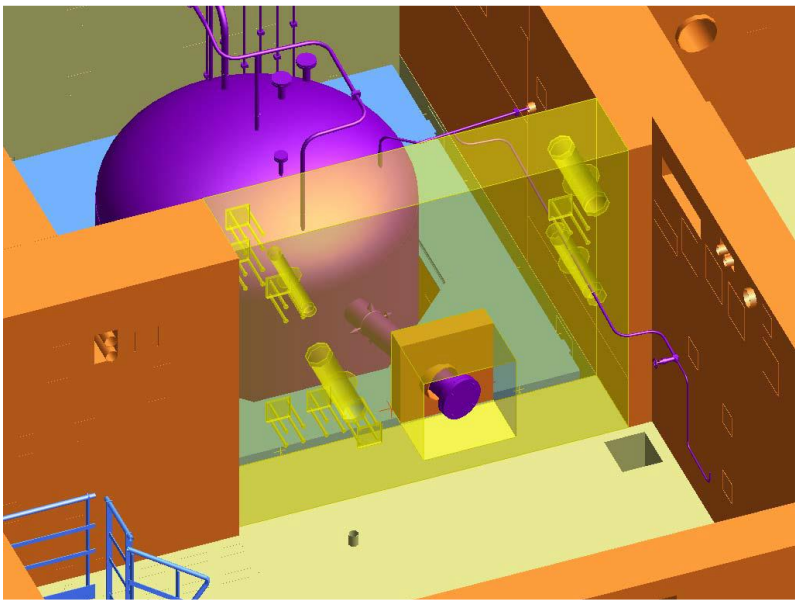
Other dispositions to limit material activation are the following:

- Equipment design is adapted to eliminate material with high cobalt content to the extent possible. "Stellite" alloy used in the event of high friction, could be replaced with other Cobalt-free alloys. Related equipment could also be positioned in area with low activation risk.
- Use of Inconel alloy 690TT (low residual cobalt content of less than 0.018% in average) is preferred to alloy 600 (previous cobalt content of less than 0.05%) for steam generator tubing to improve corrosion behavior and to minimize the proportion of cobalt in corrosion products circulating in the reactor cooling system.
- Limitation of the residual cobalt content in steels to 0.06% for other equipment subject to irradiation.
- Limitation of the silver content in steels and alloys and of the use of silver-coated seals, which may be replaced with graphite seals.

Architectural and specific dispositions in the AREVA / EPR™ reactor

A few examples:

- Non-radioactive and radioactive components are separated by shielding walls
- Heavy components can be removed in one piece necessitating neither lengthy dismantling work nor removal of other components first.
- Decontamination systems are provided with accessible nozzles on components as illustrated below



Decontamination nozzle on the Volume Control Tank

Waste zoning at AREVA / Georges BESSE 2 plant

During operations the low risk of contamination dispersion is ensured and demonstrated by the presence of a ventilation network maintained at negative pressure. During maintenance operations the work is performed under "operational zoning": the organization set up limits to the contamination risks and monitors the radiological impacts of the work performed (containment as close as possible to the source). Following maintenance operations, the absence of dispersion (or the quality of cleanup) is confirmed through radiological and contamination monitoring, thus enabling to return to the reference zoning (CWA).

These operations are undertaken under a specific organization which allows to classify most of the facility as CWA (conventional waste area). This leads to a significant optimization of the areas and nuclear waste produced, these progress are boosted by an adapted design of the factory,

Following review of a "Decommissioning Specialist Team", the initial design was adapted with the following dispositions:

- Rearrangement of the UF6 management area (limitation of the risk of contamination) and consequently, reduction of the extent of the Nuclear Area.
- Locating of most of the electric rooms in a non-nuclear area, leading to further reduction of the extent of the NWA.

Covering of the nuclear waste storage at Malvesi (ECRIN)

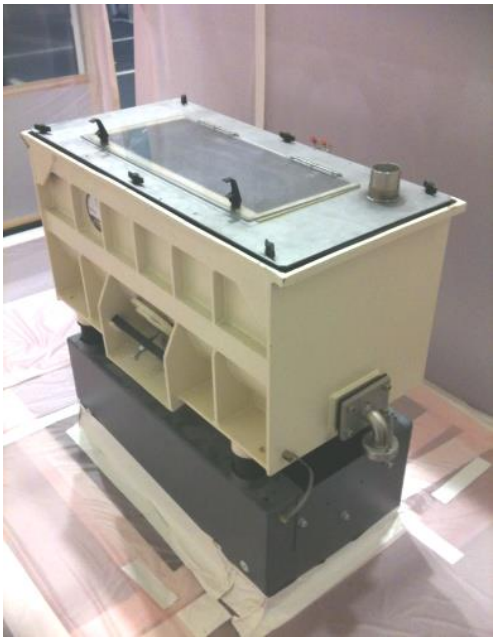
The historical nuclear waste storage of Malvesi (ECRIN) will be transformed into a long term interim storage for 3 or 4 decades. The floor of this storage area will be reinforced with a specific bituminous protection against infiltration of rain water.

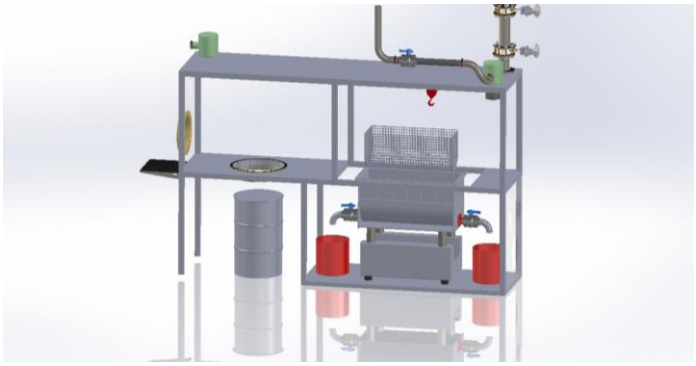
Such specific disposition will avoid the indirect generation of secondary nuclear waste (bituminous protection) which will contain chemical and nuclear material (mixed waste). This disposition will help AREVA to optimize the future management of nuclear waste and reduce the environment impact.

Waste classification and category management at AREVA / MELOX plant

Main process equipment at the MELOX plant (Mixed Oxide Fuel Fabrication Facility) is enclosed in glove-boxes for control and confinement of radioactive contamination. The radionuclides operated by MELOX are mainly uranium and plutonium. Consequently the glove-boxes and waste coming out of the glove-boxes are alpha contaminated, which places them in the most expensive category for disposal (deep geological disposal) for the most active items.

To reduce such burden, MELOX has developed new technologies to maintain these glove-boxes as clean as possible including a specific vacuum cleaner (bicyclonic), ultra-sonic decontamination and “advanced cleaning” processes with innovative approaches to cleaning. Such technologies will also be very useful to limit the volume of high cost alpha waste during the decommissioning phase.





Decontamination tank and glove-box at MELOX

CONCLUSION

Preparation and anticipation for future D&D is a growing concern in the design and engineering and operation of new facilities. It is also becoming an explicit requirement from safety authorities, to include design provisions for D&D in the license application for news plants. To support this demand, AREVA setup a dedicated team of D&D specialists from concerned disciplines (design, operations, licensing, dismantling…) to support projects. This team provides review, benchmarking and recommendations for the design, with the aim to optimize nuclear waste management, for the full life of the plant.

This team puts a special emphasis on radiologic cleanliness, waste area management, and segregation of waste by types (zoning of the plant) to avoid spreading of contaminants and mixing of different waste categories and thus reducing the volume and future disposal costs of D&D waste, as far as possible.