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Entombment: It Is Time To Reconsider This Technology[1]

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Abstract

It is time to reconsider entombment of nuclear reactors and other facilities. Decommissioning worker exposure and safety, transportation, cost, potential loss of LLW disposal capacity, and need for strong technical basis are shared drivers for the renewed interest in developing the entombment D&D option. Entombment relies on retarding the release of radionuclides for a very long period, a number of factors must be considered prior to selection and implementation of entombment. A technical basis for addressing and evaluating these factors with associated stakeholder acceptance of the technology is needed before entombment becomes an accepted D&D option.

Introduction

U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) licensed facilities will be decommissioned. The existing situation for decommissioning and decontamination (D&D) of these facilities is described below. Entombment is being considered as a D&D option for many of these facilities. The entombment experience at three small power reactors is also summarized. NRC regulatory development process for entombment is described. DOE's investigations are summarized for entombment at canyon and reactor facilities. The key issues influencing entombment reconsideration are identified. The advantages and disadvantages of entombment relative to the other D&D options are discussed as well. A number of factors to be considered prior to selection and implementation of entombment are also identified. The technical basis and stakeholder acceptance of entombment technology is needed. One of the keys for stakeholder acceptance of entombment will be to demonstrate the containment of radioactivity within the entombed structure. It is time to reconsider entombment as a viable D&D option for nuclear reactors and other facilities. The rationale for this conclusion is based upon cost, risk, and rulemaking issues. This paper is organized into the following sections—present situation, previous entombment experience, both NRC and DOE activities, key issues, entombment considerations, and conclusions.

Present Situation

U.S. Department of Energy's Environmental Management Program (DOE-EM) has over 65 million square feet of facilities requiring D&D. DOE-EM has identified entombment as a D&D option for large buildings such as reactors and processing facilities at the Idaho National Engineering and Environmental Laboratory (INEEL), Savannah River Site (SRS), Hanford, and Oak Ridge. INEEL is in the early planning stages for

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decommissioning three reactors with entombment being an option for each reactor. DOE-EM continues to desire safer and less costly D&D options, thus entombment is being considered as an alternative. In a recent report by the DOE Chief Financial Officer, the D&D mortgage for DOE-Defense Programs (DP), Nuclear Energy (NE), and Energy Resources (ER) is estimated to be $20 billion, cumulatively. EM will gradually accept responsibility from DP/NE/ER for the D&D of these buildings. The estimated total D&D mortgage for DOE is at least $33 billion[1]. Given the high costs and uncertainties associated with the D&D of major facilities, entombment may provide an option for some of these facilities. For entombment to be become an accepted D&D option, there must be a sound basis for the technology and it should provide additional benefits to existing D&D alternatives.

The U.S. commercial nuclear utility industry has 103 reactors that will ultimately require decommissioning. Several facility owners/operators are submitting applications for life extension while others are beginning to plan for D&D. Some utilities are putting facilities in SAFSTOR mode while others are proceeding with conventional decontamination and removal of the facility from the site. A complication to the conventional D&D scenario is the uncertainty and potential unavailability of low-level waste disposal for utilities located in most states. Currently accepted decontamination and decommissioning options are costly and result in risk for the workers and environment. Some utilities, faced with these challenges of decommissioning and decontaminating reactors are considering entombing their reactors and placing their low-level radioactive waste within the entombed structure.

To entomb a commercial nuclear reactor, the nuclear fuel is removed and typically, higher activity internal components are also removed. Low-level waste may be inserted in the vessel or elsewhere in the structure to be entombed. A concrete entombment structure is then constructed to immobilize the system of waste.

Previous Entombment Experience

Three small power reactors have been entombed in the United States: Hallam Nuclear Power Facility in Nebraska, Piqua Nuclear Power Facility in Ohio, and Boiling Nuclear Superheating Power Station (BONUS) in Puerto Rico. These facilities were entombed in 1969-1970. A brief discussion of each entombed facility follows.

Hallam Nuclear Power Facility[2]: The Hallam reactor was 240 MW sodium cooled graphite-moderated reactor. D&D activities at the facility concluded in 1969. The irradiated fuel and all bulk sodium were removed from the reactor and residual sodium was rendered inert. Some radioactive components were dismantled and removed. The remaining radioactive components and materials were sealed in vaults in the plant and the vaults were filled with expanding concrete. All penetrations were seal-welded and the reactor was sealed beneath two plates of 0.5-in. steel, which were welded in place. The entire entombed structure was sealed with sand, a waterproof polyvinyl membrane, and a covering of earth. Drainage was designed to move water away from the entombed structure. The above-grade structure was weatherproofed and secured by the addition of sand, earth, and water-impermeable membrane. The reactor vessel with surrounding guard vessel with associated double-walled piping, and most of the reactor vessel internals, are contained within the entombment structure.

An estimated 300,000 Ci of activity were contained within the enclosure at the time of entombment. The design life of several components of the entombed structure is 100 years. Only low-level waste was included in the entombment structure. Therefore, as radioactive decay continues to occur, the facility will be approaching safe and acceptable release levels at the end of this period.

DOE is conducting semi-annual surveillance and monitoring as part of an agreement with the Nebraska Department of Health to monitor the potential release of radioactivity and ground water. To date, no contamination migration has been observed and the structure integrity is unchanged. The entombment technology utilized was simple and was coupled with a continuing monitoring program to verify containment of radioactive constituents. Currently, there is no known contamination at the Hallum Nuclear Power Facility.

Piqua Nuclear Power Facility[2]: The Piqua Nuclear Power Facility consisted of an organically cooled and moderated 45.5 Mwt reactor. The facility was constructed as a demonstration project by the U.S. Atomic Energy Commission (AEC) and was operated by the City of Piqua under contract to the AEC. Between 1967 and 1969, the Piqua Nuclear Power Facility was dismantled and decommissioned. The fuel, selected reactor core components and other radioactive materials were moved off-site. The organic coolant was removed and burned. The reactor vessel, thermal shield, grid plates, and support barrels remained in place. Vessel penetrations were seal-welded, the vessel and spaces between the vessel and cavity liner were filled with dry quartz sand, and enclosure penetrations were plugged. The enclosure was sealed with a waterproof barrier and a concrete cover. About 260,000 Ci were sealed within the enclosure. Therefore, as radioactive decay continues to occur, the facility will be approaching safe and acceptable release levels after approximately 120 years.

Surveys of the entombed structure and auxiliary buildings have been performed since closure. The survey results verify that there have been no detectable releases to the environment from the entombed facility. The Piqua reactor was entombed using very simple technology and was expected to be below unrestricted release levels in about 120 year.

Boiling Nuclear Superheater Power Station[2]: BONUS was a 50MW boiling water research reactor. The facility was decommissioned by 1970, and the reactor vessel and other components were entombed in place. Fuel, selected radioactive materials, and unirradated fuel were removed from the site. Penetrations through the lower portion of the reactor building were plugged and sealed. A concrete slab seals off the upper surface of the engineered barrier enclosure. An estimated 50,000 Ci were sealed within the engineered barrier structure at the time of closure. Routine environmental radiological surveys of the site since entombment have shown no significant changes inside the containment and the entombment structure shows no indication of deterioration. The BONUS reactor entombment design is simple and has a relatively short design life.

Three small reactors with varying amounts of radioactive contamination were entombed by 1970. Since 1970, entombment has successfully contained the radioactive contamination at these three reactors.

Nuclear Regulatory Commission Activities[3]

The NRC is developing regulations to allow entombment as an option for decommissioning power reactors. NRC prepares a Generic Environmental Impact Statement (EIS) to support its rulemaking and usually various data needs exist for the EIS. As NRC moves forward with these activities, NRC has identified a path forward that includes:

- Acceptable entombment designs and intruder scenarios need to first be defined and agreed upon. An isolation assessment needs to be conducted that specifically incorporates the residual source term and site characteristics relevant to nuclear power reactors.
- When the NRC determines that entombment of nuclear power reactors is an acceptable alternative to DECON and SAFSTOR, a supplement to the Generic EIS on Decommissioning of Nuclear Facilities will need to be prepared.
- NRC should establish the bases and methodologies acceptable for the performance assessments needed to determine whether a given reactor/site is suitable for decommissioning via the entombment alternative, similar to the information contained in NUREG-1573. Appropriate regulatory guides must be developed and issued, including appropriate databases containing the families of parameters and required level of conservativeness to be used in the isolation assessment analyses.
- Eliminating the need for full-time onsite security and surveillance staff will greatly reduce the ongoing costs associated with an extended safe storage period. An appropriate regulatory guide should be developed that defines the minimum acceptable monitoring and surveillance system and methods for a shutdown entombed reactor.
- If entombment is determined to be an acceptable decommissioning alternative, NRC will have to decide whether to permit entombment of Greater-than-Class C (GTCC) material, or to explicitly exclude GTCC material from entombment enclosures.

In July 2000, the NRC announced that direction was issued to the NRC staff to proceed with rulemaking for Entombment. This direction instructed the staff that entombment is to be added to the GEIS and include provision for inclusion of GTCC waste in the entombment plan for commercial reactors. A rulemaking plan will be in place by February 2001.

Department of Energy Activities

The DOE is investigating the option of using entombment to D&D canyons and reactors. The D&D Focus Area initiated the Canyon Disposition Initiative at Hanford in March 1998. This CERCLA RI/FS process utilizes the U-Plant (a chemical reprocessing canyon) and is working toward establishing a Record of Decision by the end of FY2000. One potential option is to remove all TRU contaminants, to fill the structure with low level waste, and to entomb the canyon as a permanent LLW disposal facility. This potential option could reduce the canyons D&D mortgage at Hanford by more than $1 billion, and is applicable to similar chemical reprocessing facilities at SRS, Oak Ridge and INEEL. At INEEL, entombment alternatives are being considered for several nuclear reactor facilities.

Long-term stewardship has been identified as an emerging critical element to the Environmental Management Program. The goal of long-term stewardship is to ensure sustainable protection of human health and the environment after cleanup, disposal or stabilization is completed. Developing and deploying new science and technology are clearly vital to the success of the long-term stewardship program for two reasons. First, development and deployment of effective technologies at a lower cost will result in fewer sites that will require long-term stewardship. Second, the current methods of providing long-term stewardship are not sustainable and significant improvements are needed.

The Office of Long-Term Stewardship is responding to the need for improved science and technology and will encourage the development and use of improved technologies for more sustainable long-term stewardship. The immediate science and technology needs for the long-term stewardship program include:

- Information about the durability of materials and more durable materials
- Knowledge of fate and transport mechanisms and predictive capabilities
- Cost-effective monitoring and surveillance methods
- Information management
- Systems engineering and design

Key Issues

The key issues influencing entombment reconsideration are as follows. Decommissioning worker exposure and safety, transportation, cost, potential loss of LLW disposal capacity, and the need for strong technical basis are shared drivers for interest in developing the entombment D&D option. Ongoing decommissioning of reactors is a complex and difficult process. Worker exposure is increasing because of the longer than expected time it is taking to dismantle reactor components. The costs are higher than estimated due to additional time needed to complete the work. Due to the recent legislative changes in South Carolina, the Barnwell facility will not be as accessible for disposal of LLW as in the past. The NRC has sponsored a viability study of entombment as a D&D option for commercial nuclear power reactors[3]. The study concluded that entombment appears to be a viable D&D option and the entombment concept would reduce D&D cost and significantly reduces worker and public exposure.

Entombment Considerations

The D&D options for nuclear reactors include three alternatives—SAFSTOR, DECON, and ENTOMB. NRC conducted a workshop on entombment in November 1999. At this workshop about 30% of the U.S. commercial reactor facilities were represented and indicated significant interest in entombment as a D&D option. Entombment is another option for nuclear reactor D&D, it is not the answer for every reactor, but it may be the solution for many reactors based upon appropriate analysis of many different complex factors.

The advantages and disadvantages of entombment D&D relative to the other options (SAFSTOR and DECON) which involve removal and disposal at off-site locations are briefly summarized in Table I.

Table I. Advantages and Disadvantages of Entombment[4]

ADVANTAGES		DISADVANTAGES	
Item	Comments	Item	Comments
Reduced cost	• Lower cost than dismantling • Minimal off-site transport and disposal	Need for long term maintenance and surveillance (institutional control)	• May be multiple sites to monitor
Reduced worker dose	• Less dismantling • Reduced waste handling	Difficulty of licensing and gaining public acceptance	• Change of site use from operations to disposal was never planned
Minimal off-site transport of waste	• Bulk of waste disposed of on-site	Proximity of site to population centers	• May only apply to some sites • Public resistance
Reduced public interaction	• Fewer off-site activities	Long term site commitment	• Change of site use
Continued use of existing site support facilities	• Less cost, use of existing personnel and infrastructure • Less training	Increase of waste disposal sites within the country	• Public acceptance issue • More sites may increase burden on future generations
Reuse of site and facilities for nuclear applications	• Uninterrupted nuclear licensing of the site	Deferred release of site for other uses	• May remain restricted for long periods

For some nuclear programs avoids need for central repository	• Country specific and may not always apply • Yucca Mountain • Barnwell	Disposal may preclude other nuclear facilities	• Site size may be too small
Early on-site disposal may reduce monitoring costs	• Lower surveillance cost than SAFSTOR	May only be acceptable for certain nuclides	• Long lived nuclides may be precluded
Possible early release of parts of site for non-nuclear use	• Reduces boundary of licensed site	May be multiple disposal areas on the site	• More complexity for monitoring
Early disposal of nuclear facility eliminates future D&D activities	• Near-term disposal reduces future D&D obligations	Multiple sites needing monitoring and surveillance	• More sites increase monitoring and surveillance costs
On-site transfer allows good design of new disposal facilities	• More robust safety, optimum design of barriers	Additional complications if site remediation is required in the future	• Extra barriers may render dismantling of disposed structures more difficult

Since entombment relies on retarding the release of radionuclides for a very long period (the expected range may be 100 – 1,000 years), evaluation of numerous factors prior to selection and implementation of entombment is necessary. These factors include:

- Size, complexity and type of nuclear facility
- Residual radioactive inventory and associated radioactivity decay profile
- Inclusion of conditioned operational waste
- Location: geographic, topographical, demographic and local site conditions
- Retention of radioactive constituents within the entombed structure
- Integrity and durability of engineered barriers and appropriate shielding
- Geology and hydrogeology of the site
- Continued and future site use
- Retrievability and repairability of the entombed structure

A technical basis for addressing and evaluating these factors is needed. Equally important is stakeholder acceptance of entombment technology. One of the keys for stakeholder acceptance of entombment will be to demonstrate the containment of radioactivity within the entombed structure. As NRC rulemaking proceeds, a research and development program is needed to provide the technical basis for entombment. With sufficient technical basis, there will be increased certainty that entombed nuclear facilities will have a very high likelihood of successfully completing D&D of nuclear reactors.

Conclusions

It is time to reconsider entombment as a viable D&D option for nuclear reactors and other facilities for the following reasons:

- The estimated total D&D mortgage for DOE is at least $33 billion. Given the high costs and uncertainties associated with the D&D of major facilities, entombment may provide an option for D&D of some facilities. For entombment to be become an accepted D&D option, there must be a sound basis for the technology and it should provide additional benefits to existing D&D alternatives.
- Currently accepted decontamination and decommissioning options for commercial nuclear reactors are costly and result in risk for the workers and environment. Additional data and information are needed before entombment is accepted as an effective, safe, and cost conscious solution for the D&D of nuclear facilities.
- Three small power reactors have been entombed in the United States since 1970. Entombment has successfully contained the radioactive contamination at these three reactors.
- NRC announced that its staff would proceed with rulemaking for entombment. This direction instructed that entombment is to be added to the GEIS and include provision for inclusion of GTCC waste in the entombment plan for commercial reactors. A rulemaking plan will be in place by February 2001.
- Decommissioning worker exposure and safety, transportation, cost, potential loss of LLW disposal capacity, and the need for strong technical basis are shared drivers for interest in developing the entombment D&D option.
- Since entombment relies on retarding the release of radionuclides for a very long period, a number of factors must be considered prior to selection and implementation of entombment.
- A technical basis for addressing and evaluating these factors is needed.
- Stakeholder acceptance of the entombment technology basis is needed.

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