THE UNDERGROUND RETRIEVABLE STORAGE (URS) HIGH-LEVEL WASTE MANAGEMENT CONCEPT*

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ABSTRACT

This paper presents the concept of long-term underground retrievable storage (URS) of spent reactor fuel in unsaturated rock. Emplacement would be incremental and the system is planned to be experimental and flexible. The rationale for retrievability is examined, and a technical basis for 300-year retrievability is presented. Maximum isolation is the rationale for underground as opposed to surface storage. Although the potential repository site at Yucca Mountain Nevada would be suitable for a URS, alternate sites are discussed. The technical issues involved in licensing a URS for 300 years are simpler than licensing a 10,000 year repository.

BACKGROUND

The currently planned high-level waste management approach in the United States consists of an underground repository at a potential site at Yucca Mountain, Nevada to begin operation about 2010, combined with a surface monitored retrievable storage (MRS) facility at a location and date yet to be determined. Debate continues as to whether there should be an MRS facility at all; and if there is one, whether it should serve merely as surge storage capacity between the reactors and repository, or should be capable of accepting and holding a major portion of the waste, thus allowing the repository program to proceed at a more deliberate pace. Without the siting of an MRS, spent fuel will continue to be stored at reactors until it is sent directly to a repository. Assuming that the potential site at Yucca Mountain, Nevada continues through the formal selection process, a license application will be submitted to the Nuclear Regulatory Commission (NRC) for construction authorization for a 70,000 metric ton repository. Under existing law and regulations, waste emplaced in the repository is required to be retrievable for 50 years after the first package is emplaced.

The recent position statement of the Board on Radioactive Waste Management (BRWM) of the National Research Council (1) noted that "*the U.S. waste disposal program is characterized by a high degree of inflexibility with respect to both schedule and technical specifications.*" It then called for an alternative approach that "*emphasizes flexibility: time to assess performance and a willingness to respond to problems as they are found, remediation if things do not turn out as planned, and a revision of the design and regulations if they are found to impede progress toward the health goal already defined as safe disposal.*"

The potential role of intermediate storage in reducing technical uncertainty and increasing flexibility to address the issues noted by the BRWM has been pointed out in another paper (2). Several authors have suggested as much as 100 years of surface storage to allow a more research-oriented approach to disposal (3,4). However, because of retrievability, intermediate storage can be achieved in a repository or a URS while observational experience is gained on the interaction of the waste and surrounding rock.

Various intermediate storage concepts have been developed in the past in United States and their titles are descriptive of their underlying philosophies. AFR (away from reactor) storage focused on removing spent fuel from reactor sites. RSSF (retrievable surface storage facility) emphasized storage at the land surface, as distinct from geologic (underground) disposal, and ready retrievability in contrast to the permanence of disposal. MRS (monitored retrievable storage) continued to focus on retrievability and storage while emphasizing monitoring to address concerns about security and safeguards. Likewise, URS (underground retrievable storage) continues to emphasize retrievability and storage as distinct from disposal, and focuses on emplacement underground to address issues of safety, security, and safeguards.

THE UNDERGROUND RETRIEVABLE STORAGE CONCEPT

The essential elements of the URS concept are retrievable storage of high-level waste underground at a suitable unsaturated site for 300 years, coupled with a design that facilitates incorporating new technology prior to final disposal at the same site. Heat from the waste would be used constructively (2,5) to dry the already unsaturated rock, and the disposition of both heat and water would be predicted and monitored. Assuming favorable conditions continue, the URS facility would be converted to a repository and closed in 300 years. At that time, it is likely that the predic-

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tion of long-term performance could be done with a significantly greater degree of certainty than at present.

The URS takes full advantage of the qualities of an unsaturated site in order to be reversible, incremental, experimental, and flexible.

Reversible emplacement: Unlike the 50-year retrievability period currently required for a repository, the URS concept has a period of retrievability of 300 years, equivalent to the "containment" period specified in the NRC regulation 10 CFR 60. In addition to the time difference, the proposed retrievability is conceptually different. In the URS concept, it would be anticipated in the design that the waste might be placed inside the final disposal container several hundred years in the future and only through fortunate seredipity would the 300-year container become the final container. Current repository plans call for the initially emplaced container to be the final disposal container.

Incremental approach: The URS concept is incremental, starting with experimental emplacement of a small amount of waste (on the order of 10 metric tons), staging up to ~ 100 MT, followed by 1000 MT. Only after proceeding through these steps would full loading take place. This is a clear departure from the current "all or nothing" approach to a 70,000 metric ton repository license. An incremental approach is not necessarily slower than a single-step approach, particularly when one is licensing a first-of-a-kind facility. A small increment of waste might be emplaced very early as part of site characterization for either the URS concept or a repository. Because of the incremental approach, the technical aspects of licensing a URS should be significantly easier than licensing a repository based on the credibility of 300 versus 10,000 year projections.

Because of the incremental approach, the URS may not eliminate the near-term need for continued surface intermediate storage. It is vital to the success of either a URS or a repository that the reality as well as perception be that safety is more important than schedule. Therefore, the URS should no more be rushed to meet an arbitrary schedule than a repository.

An experimental and flexible system: Because of the reversible and incremental attributes, the URS concept is experimental and flexible. It would be designed to take full advantage of scientific advances of the next few centuries in fields such as material sciences and predictive geology. It would also provide a large amount of information ranging from initial insights based on pre-emplacement testing and incremental emplacements of waste to the results of long-term monitoring after full loading. This information would be used to manage the facility by means of a process such as the monitored-decision methodology described by D'Appolonia (6).

RATIONALE FOR UNDERGROUND RETRIEVABLE STORAGE

The important aspects of the URS concept are not physical differences from previously proposed facilities, but rather the differences in strategic goals and the rationale of the concept. URS is the cornerstone of a philosophically different type of nuclear waste management system than currently pursued in the US. At a fundamental level, it is an attempt to reconcile two conflicting goals of nuclear waste management: early isolation for immediate safety versus assurance of future safety over 10,000 years or more. The URS provides both early isolation and a long-enough period of retrievability to significantly reduce uncertainty about future safety.

The goal of early isolation is based on the technical fact that high level nuclear waste is most hazardous at the moment it is withdrawn from the reactor core and rapidly declines in radioactive intensity thereafter. Therefore, storing it at the surface for 10 or 50 or even 100 years does not seem sensible from a viewpoint of true safety.

The technical reason high-level nuclear waste continues to be stored for extended times at the surface follows from the goal of assuring safety for unprecedented timeframes. As a society we have decided that potential hazard levels from a permanent repository shall be very low. But we have not yet determined how to deal with the uncertainties in predicting hazard levels during the long times of projection: 10,000 years by regulation in the US, and up to one million years in some countries. Therefore we have stored waste while debating how to assure meeting our disposal goals. Although minimizing present risk calls for rapid disposal, dealing with uncertainty has introduced delay.

The rationale and purpose of the URS is to balance these conflicting goals. The URS concept would begin underground storage as expeditiously as possible in order to reduce present risk. The underground storage mode would resemble a repository, perhaps having an identical configuration to current conceptual designs. It should function safely in a passive mode, so that if surface control were lost due to societal breakdown there would be fail-safe conversion to a disposal facility.

To reduce uncertainty, initial operations would follow an incremental approach. Because perturbed natural systems are the greatest source of uncertainty, early emplacement of a small amount of waste would allow data acquisition and analysis aimed at resolving key technical uncertainties. This incremental approach would assure both that the URS could meet the goal of underground storage for 300 years and that there was a high probability of being suitable for conversion to a repository at the end of that time.

One of the strongest arguments for the URS concept is that it does not foreclose any options for our descendants. At the present time, one cannot say with certainty whether in 300 years the risk from ionizing radiation will have been found to be about what we think it to be today, much less, or much greater. Further, we cannot say whether the fissionable material in spent reactor fuel will be regarded as a valuable resource or a nuisance left over from a primitive energy system of a bygone generation. It is argued that this generation should dispose of this generations waste. However, by so doing, this generation should not leave the legacy of an unwise decision. With a URS, our descendants can decide whether to accept our plan for disposal or take some alternative action. If we have planned wisely, they can seal the facility. If not, remediation will be considerably less costly and hazardous than for a "permanent" repository.

RETRIEVABILITY

In the current US repository program, retrievability is a secondary rather than a primary goal. And in the overall waste disposal system, intermediate storage is an operational convenience in the movement of spent fuel between reactors and the repository. The URS concept makes retrievability and reversibility major goals and elevates intermediate storage to a significant long-term role in the nuclear waste management system.

One can address uncertainty with either surface intermediate storage or retrievability in a repository. The main historical reason favoring surface intermediate storage has been the ease of siting a surface facility. However, studies that established the period of retrievability considered repositories in salt and saturated hard-rock (7). As pointed out by the USGS, fully retrievable disposal is a possibility in the unsaturated zone (8). To determine whether uncertainty is best reduced through retrievability in an intermediate storage facility, a repository, or a URS, it is necessary to examine the reasons for delaying permanent disposal.

There are two technical reasons for maintaining retrievability: safety and conservation. If the facility design or the site is discovered to have some significant safety flaw during the period of retrievability, then the waste can be withdrawn and stored or disposed elsewhere. The waste can also be retrieved to apply a future superior immobilization technology. With respect to the conservation motive, the energy value in the spent fuel cannot be ignored. Retrievability will ensure economical recovery of the fissionable material if desired at a future date. The retrievability provision of the Waste Management Policy Act of 1982 was driven by the conservation motive; so only spent fuel and not high level waste is required to be retrievable.

Given the motivations of safety and conservation for retrievability, can we establish a desired period of retrievability? From a conservation viewpoint this is difficult, because it would require a prediction of the time when reprocessing and recycling of fissionable material will become economically viable in the United States. From a safety viewpoint, things are more straightforward. Compared with fuel ten years out of the reactor core (the shortest time interval before direct disposal currently considered), a significant reduction in radioactive intensity appears by 300 years out-of-core. This was recognized by the NRC in the rationale for the containment time requirement in 10 CFR 60, the regulation for repositories (9, pp 449-468, 518-519). However, the NRC chose to address this issue with a containment requirement rather than extending the period of retrievability to 300 years.

Three hundred years is 10 half-lives or more of the abundant radionuclides Sr-90, Cs-137, and Pu-241. It is significantly more than 10 half-lives for a large number of fission and activation products including tritium, Kr-85, and Eu-154. During that time-frame, significant reduction in inventory will occur for Ni-63, Sm-151, Pu-238, Am-242, Cm-242, -243, and -244. By the time 300 years has elapsed, the radiation level of the spent fuel is down by a factor of 1000 compared with year-old fuel. Because the radionuclides that decay to insignificant levels within 300 years are generally more mobile, more soluble, and more hazardous than those remaining in the fuel, the fuel after 300 years is significantly less hazardous compared with younger fuel. This means that it is desirable to maintain control for up to 300 years in order to reverse any mistakes or inadvertent breakdowns.

Another factor to consider in setting a period of retrievability is when the effects of heat will have stabilized. For expected conditions at Yucca Mountain, the rock temperature near the waste package peaks within 20 to 40 years and drops within 200 years to a level that then slowly declines over centuries (10). In order to confirm predictions of long-term temperatures, 200 years monitoring of the temperature would be desirable.

ISOLATION

Ideally, spent fuel should be isolated from the biosphere as fast as possible because it is most hazardous in the period immediately following removal from the reactor core. If the only consideration were short-term safety, spent fuel should be disposed in a repository as soon as feasible. In such a case, the purpose of retrievability would be to reverse a mistake in how the fuel was disposed. The URS concept meets the need for early isolation of spent fuel.

For the maximum assurance of isolation, underground storage is necessary. Credible failure modes for storage are related to loss of control of the facility, either due to war, civil disruption, or accidents. The longer the period of storage, the more an underground location is favored, because the probability that a negative scenario might occur increases with time.

Storage 100 meters or more below the surface provides additional assurance of isolation, as recognized by the Swedes in their intermediate storage facility, CLAB. However, the water pool storage at CLAB requires active maintenance. Dry storage would be desirable for passive control. This requires an unsaturated underground environment such as Yucca Mountain that does not require a dewatering system.

LOCATION OF URS

The potential repository site at Yucca Mountain has unusual qualities that would support the type of waste management system that meets the goals laid out by the Board on Radioactive Waste Management. Because the site is unsaturated to unusually large depths, it can accommodate a facility at depths suitable for a repository, yet be expected to remain dry for centuries. The site also provides strong rock in which mined openings can be maintained for centuries. Ramp access can facilitate retrievability and workover of the openings.

Of these attributes, the unsaturated condition is key to the URS concept. Very long-term in-tunnel storage in Rainier Mesa at the Nevada Test Site.was suggested as early as 1979 (11). At Rainier Mesa, the rock is close to saturated, and dryness was guaranteed by keeping the waste storage racks within a sealed inner tube in the tunnel. The degree of dryness at Yucca Mountain is sufficient so the containers of waste can be emplaced within unsealed drifts and unsealed emplacement holes.

Although Yucca Mountain appears qualified to host a URS, alternative sites exist. The United States Geological Survey (USGS) has long advocated the unsaturated zone in the arid west as an ideal location for nuclear and toxic waste disposal (8,12,13,14). The USGS has considered the arid Great Basin as a general location for waste management sites and published reports detailing their evaluation (15). Although the large depth to the water table at Yucca Mountain may not be duplicated elsewhere, there may be numerous other suitable sites. A panel of the Committee on Radioactive Waste Management of the National Academy of Sciences in 1978 recommended serious consideration of locating a high-level repository for defense wastes in the unsaturated zone in a "tunnel or adit driven into the Rattlesnake Hills" at the Hanford, Washington site (16).

The Nuclear Waste Policy Amendments Act of 1987 established the Office of the Nuclear Waste Negotiator. The Negotiator has broad powers to negotiate an agreement with a host State and/or Indian Tribe. Within those powers lie the most likely path to implementation of the URS concept. Because it is different than any of the entities established by the WMPA of 1982, Congressional authorization will likely be necessary to construct a URS. However, the Negotiator could seek a host site for the concept prior to Congressional authorization.

RELATION OF THE URS TO A REPOSITORY

The URS would be designed so that it could be converted to a permanent disposal site after 300 years, assuming that no flaws are detected in the site or engineered components. With respect to proving the safety of a repository, the recent BRWM critique of the high level nuclear waste program in the United States noted that *"proof in the conventional sense cannot be available until we have experience with the behavior of an engineered repository system--precisely what we are trying to predict."* (1) Because a URS facility at Yucca Mountain would be virtually indistinguishable from a repository, 300 years of experience equivalent to a functioning repository could be obtained. The NRC containment requirement could be met before ever converting the facility to a repository. The 300 years experience combined with expected advances in technology would also significantly enhance the likelihood of predicting performance for 10,000 years. Although it is certainly possible to plan to use the URS facility for safe underground storage for 300 years and then dispose of the waste elsewhere, such an approach is neither cost-effective nor technically productive.

CONCLUSIONS

A URS would provide greater safety than a surface facility. Placing the URS at the proposed site of a repository would provide for orderly study of a one-of-a-kind facility. Such study would reduce the technical uncertainty in projecting repository performance for 10,000 years or longer. A period of 300 years retrievability can be established from technical considerations. Given sufficient technical confidence, a future generation could convert the URS to a repository prior to 300 years, yet the design would be sufficiently robust to meet an objective of 300-year retrievable storage. It is possible that during this 300 years, the energy value in spent reactor fuel will become a valuable resource. The URS concept could best be implemented by the Nuclear Waste Negotiator.

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