RETRIEVABILITY AS PROPOSED IN THE US REPOSITORY CONCEPT

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Abstract

The Nuclear Waste Policy Act states that any repository shall be designed and constructed to permit retrieval. Reasons for retrieval include public health and safety, environmental concerns, and recovery of economically valuable contents of spent nuclear fuel. The Nuclear Regulatory Commission requires that waste must be retrievable at any time up to 50 years after start of emplacement. The US Department of Energy intends to maintain a retrieval capability throughout the preclosure period. Possible preclosure periods range from a minimum of 50 years to as much as 300 years. Repository closure includes sealing all accessible portions of the repository, including ventilation shafts, access ramps and boreholes. Drip shields will be installed over the waste packages. Access to the repository after closure is not intended. The proposed repository includes horizontal emplacement drifts located in the unsaturated zone. The emplacement drift centerline spacing is 81 meters to provide a subboiling region between drifts for water drainage. A drip shield covers the waste packages. All emplacement drifts remain open until closure of the repository, providing performance benefits such as removing heat and moisture during the preclosure period and lowering postclosure temperatures. This does not impede retrieval, permitting a reversal of the emplacement process to accomplish retrieval under normal conditions. The preclosure period is therefore not to enhance retrievability, but does improve performance, and the resultant extension of the retrievability capability is a secondary effect. Information must be provided from the performance confirmation program to support a regulatory decision to close. Closure would isolate the repository from the accessible environment, preclude preferential flowpaths for water into the mountain, and minimize the possibility of inadvertent intrusion.

1. BASIS FOR US CONSIDERATION OF RETRIEVABILITY

1.1. Legislative requirements

The Nuclear Waste Policy Act, as amended in 1987, defines the requirement for retrievability and provides the reasons for which retrievability may be required. Section 122 of the Act states that any repository to be approved as a result of the Act shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository. It also states that such retrieval should take place during an appropriate period of operation of the facility. This latter requirement defines retrievability as a preclosure activity. Reasons for which retrievability is justified under the Act include public health and safety, environmental concerns, and recovery of economically valuable contents of spent nuclear fuel. The period of retrievability will be as specified by the Secretary of Energy at the time of design, and it will be subject to approval or disapproval by the Nuclear Regulatory Commission (NRC).

1.2. Regulatory requirements

The Nuclear Regulatory Commission requirements are given in Title 10 of the Code of Federal Regulations (CFR), Part 60 and draft Part 63. These regulations establish a minimum period during which retrieval must be possible. Waste must be retrievable on a reasonable schedule, starting at any time up to 50 years after start of emplacement, unless a different time period is approved by the NRC. A reasonable period is defined as the period that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

2. DURATION OF CAPABILITY FOR RETRIEVAL

2.1. Preclosure period

The US approach to retrievability envisions that waste be retrievable at any time during the preclosure period. The regulatory minimum for retrievability is 50 years from start of emplacement, but the DOE intends to maintain a retrieval capability throughout the preclosure period. The actual duration of the preclosure period for a repository has not been determined, but is subject to several inputs.

Recent project activity has addressed the issue of uncertainties in both natural and engineered system performance. It has been determined that cooler temperatures during both the preclosure and postclosure periods reduce uncertainties in modeling the system behaviors, and are also beneficial to repository operations. A design change has recently been approved which incorporates a cooler design [1]. The previous design resulted in emplacement drift rock wall temperatures well above boiling both before and after closure. The revised design maintains the rock below boiling during the preclosure period, although closure at 50 years would result in rock temperatures above boiling. The revised design is also capable of maintaining rock temperatures below boiling throughout the postclosure period by extending the preclosure period. There are therefore several conceptual preclosure periods.

The minimum preclosure period is that necessary for compliance with the NRC regulations, and is 50 years from the beginning of waste emplacement.

The second potential preclosure period is that length of time that would result in sufficient heat removal so that the repository host rock would remain below boiling after closure. Under the current design concept, a preclosure period of approximately 125 years is required to maintain the repository rock walls below boiling after closure.

The third potential preclosure period results from a repository concept that defers the closure decision to future generations. The US concept does not preclude extending the preclosure period to allow future generations to make the decision when to close, and to continue to monitor and acquire performance data to support such a closure determination. The repository is being designed to permit a preclosure period of 300 years, with reasonable maintenance. This approach is directly responsive to public input. Public concerns have been expressed that closure in relatively short periods does not provide adequate assurance of safety.

2.2. Accessibility after closure

The US concept of repository closure includes sealing all accessible portions of the repository, including ventilation shafts, access ramps and boreholes. Drip shields will be installed over the waste packages, and the emplacement drifts backfilled. Access to the repository after closure is not intended.

3. DESCRIPTION OF REPOSITORY LAYOUT

3.1. Open drifts in unsaturated zone

The concept for the proposed repository at Yucca Mountain includes horizontal emplacement drifts located in the unsaturated zone, approximately 300 meters below the mountain surface and approximately 300 meters above the saturated zone. The recent design change has focused on reducing performance assessment uncertainties through achieving a cooler design than that proposed in the Viability Assessment (VA). The spent fuel loading has been reduced from 85 to 60 MTHM per acre. The emplacement drift centerline spacing has been increased from 28 to 81 meters to provide a subboiling region between drifts for water drainage. The maximum power per waste package has been reduced from approximately 19 KW to less than 12 KW. The preclosure ventilation rate has been increased from 0.1 cubic meters per second (CMS) per drift to 2 to 10 CMS. Other features, such as a drip shield over the waste packages and backfill to protect the drip shield, have been added to provide defense in depth in reduction of the amount of water contacting the waste packages during the postclosure period.

3.2. Drifts open until closure

The emplacement drifts are to remain open until closure of the repository. This provides numerous performance benefits in this emplacement concept, primarily removing heat and moisture during the preclosure period, lowering the postclosure temperatures and slowing the increase in relative humidity upon closure. Other benefits include facilitating the measurements taken during the performance confirmation period, after loading the waste packages into the drifts. With respect to retrieval, this provides the benefit of not impeding retrieval, permitting a reversal of the emplacement process to accomplish retrieval under normal conditions. The preclosure period is therefore not to enhance retrievability, but does improve performance, and the resultant extension of the retrievability capability is a secondary effect.

4. METHODS OF RETRIEVAL

4.1. Drift conditions during retrieval

Under the cooler conditions of the revised design, the temperatures inside a drift during the preclosure period are reduced. During the preclosure period, the drift wall now is required to remain below boiling and retrieval conditions are enhanced. Because of the lower rock temperatures, stresses in the rock and the risk of premature drift failure are reduced. Further cooling will be necessary for human entry into the drift. The increased confidence in drift stability is of interest, due to the higher radiation field in the drift resulting from the use of thinner, more corrosion resistant waste packages as compared to the previous design concept.

4.2. Retrieval under normal conditions

Because the drifts are to remain intact and open during the preclosure period, retrievability would be accomplished through reversal of the emplacement process under normal conditions. The main components of the emplacement equipment include the primary and secondary transport locomotives, a shielded waste package transporter, and an emplacement gantry.

4.3. Retrieval under abnormal conditions

An abnormal retrieval condition would occur when the equipment and operating sequence stated above cannot be used, most likely due to drift wall collapse conditions that would preclude the use of the remotely operated waste package gantry. Under these circumstances several additional operations would be added to the sequence, including clean up and removal of fallen debris, stabilizing the drift, restoring the tracks, repositioning waste packages, and control and removal of breached or damaged waste packages. In these abnormal circumstances, waste package retrieval from the drift is not limited to the gantry operation. Other equipment pieces have been identified which can perform the operation successfully. Waste package skirts are fitted with holes allowing grappling in the event that lifting of the supporting bases is not possible. To perform these activities, it is anticipated that cooling would be required to lower the temperatures from near-boiling to human-accessible temperatures, and that portable radiation shielding may be required to permit access to those packages which cannot be remotely retrieved.

Generally, preparation for retrieval under abnormal conditions would be the same as stated for the normal operation, with the exception that a unique retrieval plan would be developed as required for each case. Due to the double-ended nature of the emplacement drifts, retrieval may be accomplished from either end.

5. CLOSURE OF A REPOSITORY

5.1. Closure authority

The decision to recommend closure will be based upon completion of an appropriate preclosure performance confirmation monitoring program. To receive approval to close a repository, the DOE must submit a license amendment to the NRC. Information must be provided from the performance confirmation program to support a regulatory decision to close. The intent is to ensure that an adequate basis exists for understanding the postclosure performance of a repository prior to performing closure activities.

5.2. Closure activities

When approval is granted, closure would commence and require a number of years to accomplish. The drip shields would be emplaced over the waste packages, backfill emplaced over the drip shields, additional backfill emplaced in access ramps and potentially in perimeter and ventilation drifts, and seals installed in all penetrations to the surface of the mountain. These would include all access shafts and ramps, ventilation shafts, and boreholes. The intent of the closure activity is to isolate the repository from the accessible environment, preclude preferential flowpaths for water into the mountain, and minimize the possibility of inadvertent intrusion.

6. SUMMARY

Retrieval of spent nuclear fuel from a geologic repository is a regulatory requirement. A design is being developed for a proposed repository, which has the capability to retrieve any or all emplaced spent nuclear fuel. Reduction of uncertainties affects the duration of the preclosure period. Retrieval under normal conditions would be accomplished through the reversal of the emplacement process, but abnormal retrieval is also possible. The extended monitoring capability proposed for a repository does not degrade repository safety. Retrieval activities could be initiated at any time prior to repository closure.

REFERENCE

[1] US DEPARTMENT OF ENERGY, Civilian Radioactive Waste Management System, *License Application Design Selection Report*, Report No. B00000000–01717–4600–00123 REV 01, US–DoE, Las Vegas, Nevada, USA (1999).

QUESTIONS (Q), COMMENTS (C) & ANSWERS (A) AFTER THE PRESENTATION

Q: You said that the rock would boil?

A: That has become shorthand for the boiling of water in the rock, for us that is 96°C.

Q: In France, Belgium, Sweden and so on, one seems to regard the retrievability or the postponed closure as something which is disturbing the long term safety, and one does not seem to be very happy with this additional requirement. In the USA, you seem to be happy with this requirement of retrievability, since it gives you 50–300 years to make your final safety case and to cool a bit more than before. In Switzerland, for instance, we would not be allowed to place anything in the repository before the final safety case has been made, and we are worrying about leaving it open 50 years or 100 years or even 30 years in order not to jeopardise the long term safety. Have I understood this correctly?

A: What I said initially was that performance is driving the design and then the design supports a pre-closure ability, not the other way around! We would not expect to hold a repository open simply for retrievability. We have to make a safety case before we can even get a licence to construct. We go through two licensing evolutions, prior to construction and prior to emplacement. Once we have substantially completed construction, we go back to the NRC to get a licence to receive and handle waste. At that point, we have to show them that the construction activities were in compliance with the safety case we made initially. The closure period comes in to ensure that the safety cases that we made on the basis of modelling, on testing, on our assumptions as to what would actually happen in a loaded repository, were true. That is why that performance confirmation period is there, to allow us to collect sufficient data. So we are not allowed to postpone the safety case until we have already built, constructed, loaded and sat on a repository for fifty years or more. We have to make that safety case before we can even get a construction authorisation.

Q: You said that performance is driving the design. What is the purpose of the backfill and drip shield or so-called Richard's Barrier in the total systems performance assessment? If it does not play any role, why then bother to put them in there?

A: They do play a role, at post-closure, not at pre-closure. For those who are not familiar with that: A Richard's Barrier is a dual layer backfill, where you have a coarser material, like a gravel, underneath a finer material, like a sand, and the intent of that is to keep the water wicked within the sand such that it will not go into the coarser gravel material underneath and you can then divert down a sloped interface between them. We decided that there would be an inordinate amount of difficulty in trying to install such a device and then demonstrate in a regulatory environment that it is really going to work as you expect it would for the period of time that you are interested in. So the Richard's Barrier as a dual layer is gone. But we do have the drip-shield and the backfill. The waste package with its outer surface of Alloy 22 is susceptible to some corrosion mechanisms at elevated temperatures, so the intent of the drip-shield is to keep the water off of the waste package during that period of elevated temperature. It is made out of Titanium, a different barrier material, another defence in depth mechanism, should we have misunderstood some of the failure mechanisms, but the drip-shield would keep the water off of the waste package during the waste package elevated temperature regime of a couple thousand years. The backfill is on top of the drip-shield to provide mechanical protection to it, from rock falls. One of the things we are doing is trying to determine just how large a rock can fall. Earlier estimates had had them as large as fifteen tons, we are now down to about seven and a half tons. Again, it is a fairly substantial rock, so the intent of the backfill is to provide a cushioning mechanism on top of the drip-shield.

Q: Could you please say something about the intermediate storage facilities and what kind there are, and why there are no national ones?

A: I do not know that there are any real intermediate storage facilities. What I said is that each of the reactors has storage capacity and some of the reactors have had to go to dry storage because they have used up there pool capacity. There is no other high level waste or spent nuclear fuel storage facility. High level waste comes to us from the other Department of Energy facilities, at Hanford, Savannah River etc. Some of them are already reprocessing some of the reprocessing waste. You have heard of the Hanford tanks, I am sure. There they have not yet started. At Savannah River they have, so they are going to create high level waste canisters, and they are building storage facilities on their sites for storage of those until a repository is ready to accept it. I say a repository because we have not yet finished site characterisation. We do not know yet that we will even recommend Yucca Mountain for a repository site. The DOE waste stream includes high level waste from reprocessing and also DOE spent nuclear fuel from the various DOE test reactors, production reactors and some commercial fuel that DOE has taken title to. The large majority, ninety percent of what would come to a repository, would come from the commercial power plants.

Q: I would like to reflect on your remark about the safety indicators and would like to mention to you that the IAEA has prepared — on the basis of consultations with international experts — a report on this. The report is available here at this meeting, so you may choose to look at the report on indicators others than dose and risk. I would also like to ask you a question regarding your third bullet statement "Normal retrieval is reverse of emplacement". It seems very simple but if you have temperatures of say 100°C you have changed the situation very much compared to the emplacement situation. Temperatures of 100°C leads to quite a complicated system because of the thermo-mechanical reactions and probably the breakdown of rock stability. What is your experience in this area with respect to the tuff?

A: We convened an expert panel on rock mechanics to address that specific question. The first meeting was in fall of 1998 and then the panel reconvened in spring 1999. As you might surmise, there is not a great deal of experience with tuff, with elevated temperatures, so the experts were highly reluctant to try and prognosticate how long we can expect tunnel integrity. One thing that they did agree upon though, was that the liner, the concrete liner, was more than would be necessary. They thought that probably you could get by with rock bolts and wire mesh for a period of up to around 100 years before having to go back and do some substantial remediation reinforcement. They did not expect that you would have significant failure, but rather it would be a general unravelling of relatively small pieces of rock coming out. So we have another panel of sub-surface construction experts, who have taken the position that steel sets or some sort of liner, if not concrete then steel with lagging, is a more appropriate solution, that is why I said earlier that we would probably end up with a combination of the two depending upon the specific rock. We are doing extended thermal tests; you may know that we had a single element heater test, we had a large block test, we are in the middle of a drift scale test, where we have heated up about eighty metres of drift with several different types of ground support to repository temperatures. These are even actually higher than the temperatures we are looking at now, just to see what would happen to water movement within the rock, to the host rock itself, and we used that data to support the safety case. One comment is that the horizon of rock, that the test is in, is representative of only about fifteen percent of the overall repository rock. There is another much larger area called the lower lithophisal, that most of the repository horizon would be in. We have not run heater tests in that yet. We have recently completed a tunnel that went over to that particular rock and one of the things for the future is to do thermal testing in there, just to balance the large scale test against what we find from that lower lith.