SAFETY ANALYSIS
LONG-TERM HAZARD OF MILLSTONE UNIT 1'S MISSING SPENT FUEL RODS POTENTIALLY DISPOSED OF AT THE BARNWELL COMMERCIAL LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY

BACKGROUND

In November 2000, Northeast Nuclear Energy Company (NNECO), the licensee, at that time, for Millstone Unit 1, informed the U.S. Nuclear Regulatory Commission (NRC) that the location of two spent fuel rods could not be determined. NNECO formed an investigative team, which completed its investigation in October 2001.[1] A follow-up NRC inspection reviewed the findings of the investigation and agreed with the results.[2] These results indicated there is a chance that the rods may have been unintentionally disposed of at either the Hanford, Washington, or Barnwell, South Carolina, commercial low-level radioactive waste (LLW) disposal facility. The most likely explanation was that the rods were inadvertently shipped to Barnwell in 1988, as part of a shipment of Class C LLW. For the purposes of this safety analysis, the staff is assuming that the fuel rods were disposed at the Barnwell facility, to assess the potential for health and safety risks. This safety analysis does not address the jurisdictional issues raised by the potential disposal of spent fuel at a shallow LLW disposal facility.

The regulatory requirements of disposing of low-level waste at commercial shallow LLW disposal facilities are provided in 10 CFR Part 61. Intentional disposal of spent fuel rods, or high-level waste, is specifically listed as outside the scope of the requirements. The primary concept behind the regulations is that the site must meet four performance objectives: (1) protection of the general population from releases of radioactivity; (2) protection of individuals from inadvertent intrusion; (3) protection of individuals during operations; and (4) stability of the site after closure. Any analysis of the risks at a low-level waste facility should address the four performance objectives. To assist waste shippers and disposal facilities, one of the primary pillars of the regulations is the waste classification system. This generalized system classifies LLW into four categories of increasing hazard: (1) Class A, (2) Class B, (3) Class C, and (4) Greater than Class C (GTCC). Stability and disposal requirements differ for the different classes of waste and, generally, GTCC is not allowed to be disposed of at LLW facilities, without prior regulatory approval, because of the high hazard to the inadvertent intruder. For example, averaging the concentration over the volume of the waste is allowed for classification, which allows the disposal of discrete sealed sources. A licensee may request a site-specific analysis to receive discrete disposals of GTCC.

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[1] "Millstone Unit 1 - Issuance of Final Report Pertaining to Unaccounted for Spent Fuel Rods," October 5, 2001, ML012850396.

[2] "Special Inspection 05000245/20011013, Dominion Nuclear Connecticut, Inc., Millstone Power Station Unit 1, Waterford, Connecticut," February 27, 2002, ML020580132.

PURPOSE

The purpose of this analysis is to evaluate the potential of health and safety risks if the Millstone spent fuel was disposed at the Barnwell facility, and whether those risks are great enough to warrant locating and, if found, removing the spent fuel rods from the facility. This analysis does not analyze the general policy of forbidding disposal of spent fuel in shallow land disposal nor is it an analysis to support an exemption, from Part 61, to allow intentional disposal of spent fuel in a LLW facility. It does not address or excuse the mistakes that occurred in the illegal transfer of spent fuel from Millstone Unit 1 to the LLW facility. It is limited to investigate whether further actions are necessary to locate and retrieve the fuel rods, to protect the public and environment.

Although the requirements of Part 61 do not apply to disposal of spent fuel specifically, we will use the performance objectives as measures to evaluate the level of the risk. Although it is not known which Class C shipment carried the spent fuel rods, each of the shipments were accepted for disposal and, therefore, met the stability requirements for Class C waste, which has the most rigorous requirements for waste stability. Therefore, this safety analysis will not explore the impacts on site stability. This safety analysis evaluates the effect of the waste on the other three performance objectives.

There are both short- and long-term considerations for reviewing the health and safety impacts of the rods potentially being at Barnwell. These include the type and amount of radioactivity present, the current risks to workers and public, potential future ground-water release, and risk to potential inadvertent intruders. In addition, risks to current and future workers for location and retrieval activities need to be considered. Dominion Nuclear Connecticut, Inc., the current licensee, provided NNECO's safety analysis[3] of the risks from the missing fuel on October 5, 2001. A safety analysis[4] was provided on May 15, 2002, which responded to a NRC request for additional information.[5] After assessing the short- and long-term considerations, in consideration of the Part 61 performance objectives, it has been determined that the presence of the two fuel rods at Barnwell does not constitute a present nor future risk to the public health and safety nor to the environment.

INVENTORY

The two fuel rods contain an estimated 16.9 terabecquerel (TBq) [457 curies (Ci)], with the predominate, by activity, radionuclides, shown in Table 1. Most of this activity is in fission products with half-lives of equal to or less than 30 years (see Table 1). At the time of potential disposal in 1988, the activities were higher and the total activity was approximately double the present activity. If these rods were not spent fuel, they would be classified as GTCC waste. If

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[3] "Safety Analysis of Millstone Fuel Rods Potentially Disposed in Either the Barnwell, South Carolina or Hanford, Washington Commercial LLRW Disposal Sites," Dr. Michael T. Ryan, C.H.P., October 5, 2001, ML020320392.

[4] "Response to a Request for Additional Information Regarding Safety Analysis of Millstone Unit No. 1 Missing Fuel Rods," May 15, 2002, ML021500428.

[5] "Safety Analysis of Millstone Unit 1 Missing Fuel Rods," February 14, 2002, ML020450361.

the rods were inadvertently exhumed today, the external exposure rates of the fuel rods might result in grave danger [approximately 10 gray per hour (1000 rad/h)] to the intruder. Most of this threat is caused by the fission products, which are important for analyzing short-term hazards. Radiological decay will reduce the activities significantly before the long-term hazards, such as releases to ground-water or inadvertent intrusion, would likely occur (e.g., more than 100 years of decay). As shown in the table, the total activity will drop from 16.9 TBq (457 Ci) to about 0.24 TBq (6.4 Ci) in approximately 500 years.

TABLE 1. ACTIVITY PRESENT BY PREDOMINATE RADIONUCLIDES AND TOTAL ACTIVITY IN TWO FUEL RODS

Year 2000 Inventory		Year 2472 Inventory	
Radionuclide (Half-life)	Activity [TBq (Ci)]	Radionuclide (Half-Life)	Activity [TBq (Ci)]
Cesium-137 (30 yrs)	4.0 (109)	Americium-241 (430 yrs)	0.13 (3.5)
Barium-137M (2.6 min)	3.8 (103)	Plutonium-239 (24,000 yrs)	0.06 (1.7)
Strontium-90 (29 yrs)	3.1 (85)	Plutonium-240 (6500 yrs)	0.04 (1.1)
Yttrium-90 (2.7 days)	3.1 (85)		
Plutonium-241 (14 yrs)	2.1 (57)		
Americium-241 (430 yrs)	0.3 (7.4)		
Total Fission Products	14.4 (389)	Total Fission Products	0.004 (0.1)
Total Actinides	2.5 (68)	Total Actinides	0.23 (6.3)
Total Activity	16.9 (457)	Total Activity	0.24 (6.4)

CURRENT RISKS

The current risk to human health from the missing fuel rods, given the controls at the site, if they were disposed of at Barnwell, is negligible. The potential shipments that may have contained the rods have been disposed of in Class C trenches that have engineered barriers. Any retrieval option would need to evaluate the potential risks to workers, which could be significant, and possible damage to the final covers currently in place. With the rods presenting no current risk to workers nor the public, and very little risk to future generations, locating and retrieving them would likely result in more actual dose being delivered to workers, than the potential dose future generations could receive if the rods were not retrieved.

GROUND-WATER RELEASE

Another potential hazard is the long-term release of radionuclides from the fuel rods to the groundwater. The disposal site currently has a total inventory in excess of 104,000 TBq (2.8 million Ci). The ceramic and activated steel waste forms of the spent fuel rods would limit the release rate, as compared with the release rate expected from the larger volume and activity present in all the Class A wastes at the site. In addition, the fuel rods do not introduce any new radionuclides to the site, although, for some specific radionuclides, the fuel rods may be a significant fraction of the total activity disposed of at Barnwell. These radionuclides - isotopes of plutonium, americium, and curium - however, are not major contributors to long-term release through the ground-water pathway, as these elements are not very mobile. Overall, the incremental releases that could result from the fuel rods would be insignificant compared to potential releases to groundwater from the rest of the site, and therefore, would not constitute any significant increase in the risk to the future generations nor the environment.

INADVERTENT INTRUDER SCENARIOS

The inadvertent intruder scenarios assume that at some point after closure of the facility, the site is forgotten and is accidentally used by others for a residence. In the development of Part 61, NRC assumed that the intrusion would occur either 100 or 500 years after closure of the facility. The scenarios analyze the various opportunities that could occur to contact the buried waste. These include drilling a well, building a home, or growing a garden in exposed waste. NNECO's May 15, 2002, safety analysis provides adequate summaries of each of the scenarios, along with references to the original sources of the scenarios. Since risk is a function of both the probability and the consequence, each will be evaluated.

The small compact nature of the fuel rods reduces the probability of the waste being inadvertently exhumed. The inadvertent intruder scenarios were developed to analyze the overall risk from many waste disposals, not a single specific shipment. Coupling the small compact nature of the fuel rods with the current size of the waste facility results in odds that if a well were to be dug anywhere on the site, with equal probabilities, there would be less than a one in a million chance of the well intercepting the location where the fuel rods might be buried. Although the odds of a basement being placed over the waste are higher because of the basement's greater footprint, the basement would not intrude on the waste because of the depth of the burials, as discussed below.

As stated previously, NRC, in developing Part 61, analyzed inadvertent intruder scenarios at 100 years and 500 years post-closure. Because of considerations on the degree of decomposition, and degree to which an intruder may not recognize the material as waste, Classes A and B waste disposal cells are analyzed at 100 years. In the case of Class C disposal cells, which is where the suspect casks would be buried, it is generally assumed that the intruder barriers would preclude any intrusion into the waste before 500 years. For an intruder scenario to be plausible, the intruder barriers (e.g., bentonite covers, reinforced concrete, other engineered cover designs, and the waste package) would need to be fairly decomposed, resemble ordinary strata, and/or not provide resistance to the drilling rig. Even after 500 years, the waste form of the fuel rods also reduces the probability of the inadvertent intruder scenarios (except for discovery). Most inadvertent intruder scenarios have, as a fundamental assumption, that the waste is sufficiently decomposed to resemble ordinary soil. Realistically, the metallic/ceramic form of the fuel rods and disposal casks will not likely decompose to resemble ordinary soil in 500 years.

Another consideration is the depth of the disposals. The waste is buried approximately

6.1-7.6 meters (m) [20-25 feet (ft)] below existing disposal-cell final grade at Barnwell. For the building construction and agricultural intruder scenarios, the assumption is that the cover material and waste within 3 m (9.8 ft) of the surface would be exhumed and spread around the final structure. The basement, which is rare in that area of South Carolina, would not intersect the buried waste because of its depth. Therefore, no further analyses of the building, discovery, nor agricultural scenarios, which require waste to be dispersed over the surface, are necessary.

The only remaining intruder scenario to consider is the well-drilling scenario, which intersects the fuel rods. In this scenario, an intruder is drilling a ground-water well for domestic use. The scenario assumes that a two-person drilling crew uses a hydraulic drilling rig, or another rig appropriate for the region. In the methodology used for development of Part 61, the crew digs to a depth of 61 m (200 ft).

The scenario assumes that the drill does not encounter resistance from the intruder barriers present over Barnwell's Class C trenches, and that some waste comes to the surface, mixed with water and clean soil, ending up in a drilling mud pit. The driller helper is assumed to be standing adjacent to the mud pit and could receive direct gamma radiation from the waste. At the end of the operation, the mud pit would be covered with soil.

The conceptual model for this exposure scenario conservatively ignores any shielding factor for any water or covering mud in the drill pit during the time the helper is exposed to external radiation. The helper is assumed to stand next to the pit for 6 hours. The total direct gamma exposure would be less than 0.002 millisieverts (mSv) (0.2 mrem). This is far below the 5 mSv/y (500 mrem/y) dose value that was used in assessing intruder doses for Part 61.

If a well were drilled through the facility and then used for drinking water or irrigation, the same conclusions for the passive ground-water release, discussed above, would apply. Although the infiltration rate would increase, the ceramic and activated steel would reduce the release rates of radionuclides. Releases to groundwater from other waste similarly affected (i.e., cap penetrated or disturbed, waste packaging damaged or destroyed, etc.), or even the Class A trenches that are not affected, would likely be greater.

Therefore, it is unlikely that an inadvertent intruder would disturb the fuel rods if activities were to take place on the site. In addition, even if the inadvertent intruder were to disturb the fuel rods, the resulting dose would be very low. The doses to inadvertent intruders would not only meet the performance objective for inadvertent intruders but also would likely be below the performance objective for general releases.

CONCLUSION

The conclusion, from these analyses, is that the overall risk from the fuel rods, if they are at Barnwell, is minimal to both the present workers and future generations of the public. The risks are so low that doses to workers are likely greater if activities to verify the waste's location, and retrieve it from its current location, were to occur. Low-probability inadvertent intruder scenario analyses resulted in potential doses not only well below the 5-mSv/y (500-mrem/y) dose value used for inadvertent intruder analyses, but also below Part 61's 0.25-mSv/y (25-mrem/y) public dose limit for releases of radioactive material. Based on the very low risk that the fuel rods pose, if they are at Barnwell, retrieval of the rods would not be justified by arguments concerning public health and safety.