DOE/EIS-0218-SA-2

SUPPLEMENT ANALYSIS OF ACCEPTANCE OF FOREIGN RESEARCH REACTOR SPENT NUCLEAR FUEL UNDER SCENARIOS NOT SPECIFICALLY MENTIONED IN THE EIS

Introduction

The Department of Energy is proposing to transport spent nuclear fuel by ship from forty-one (41) eligible countries that host research reactors using, or that have used, United States-enriched uranium as fuel for the reactors. The decision to transport by ship and accept foreign research reactor spent nuclear fuel (FRR SNF) from foreign research reactors was based on an analysis of potential environmental impacts in the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (EIS), DOE/EIS-0218F, issued in February, 1996 (DOE, 1996). The EIS considered the environmental consequences associated with shipment of foreign research reactor spent nuclear fuel on the oceans and along representative rail and highway transportation routes between United States ports of entry and the interim spent fuel management sites at the Savannah River Site (SRS) and the Idaho National Engineering and Environmental Laboratory (INEEL). This Supplement Analysis examines the potential impacts of accepting foreign research reactor spent nuclear fuel under three scenarios not specifically examined in the EIS. These three scenarios are: (1) accepting FRR SNF that would have been eligible for receipt under criteria set forth in the EIS, but which was not included in the estimated spent fuel inventories for purposes of analysis; (2) accepting quantities of spent fuel from specific countries in quantities greater than those identified for that country in the EIS, but within the overall numbers specified in the EIS and Record of Decision (ROD) issued on May 13, 1996 (published in the Federal Register on May 17, 1996 (61 Fed. Reg. 25092)) and revised July 25, 1996 (61 Fed. Reg. 38720); and (3) transporting more than eight casks of spent fuel on a single ocean-going vessel.

Background
1 - NEPA

The *Record of Decision on a Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel*, concludes that "management of all of the aluminum-based and TRIGA foreign research reactor spent nuclear fuel currently in storage or projected to be discharged during the policy period ... will provide the best support for United States' nuclear weapons nonproliferation policy." (ROD at 61 Fed. Reg. 25101-25102) The ROD lists 41 countries eligible for the spent fuel acceptance program and describes the types of spent nuclear fuel and target material containing United States-enriched uranium that would be accepted under the new policy. The ROD does not list the eligible research reactors, only the host countries, and describes the acceptance program as involving "approximately 19.2 MTHM (metric tonnes of heavy metal) of foreign research reactor spent fuel in up to 22,700 separate spent fuel elements...." (ROD at 61 Fed. Reg. 25099) However, a list of research reactors is provided in Appendix B to the EIS.

The list of eligible countries and the estimated quantity of spent fuel published in the EIS resulted from a survey of research reactors thought to be in possession of United States-enriched uranium at the time DOE was preparing the EIS and from data collected by the International Atomic Energy Agency (IAEA) and Reduced Enrichment for Research and Test Reactors (RERTR) Program. DOE knew the countries in which such material was located, but was less certain of the precise quantity of material, particularly the number of separate fuel elements that would be generated by May 2006, the end of the policy period. Consequently, DOE described the quantity of material to be analyzed for purposes of potential environmental impacts as "estimated" or "approximate." (See the EIS, Section 2.2.1.3, "Amount of Foreign Research Reactor Spent Nuclear Fuel," and Appendix B, Section B.1.1, "Estimated Amount of Spent Nuclear Fuel.")

The EIS clearly states that the "number of elements and number of shipments presented for each country in Tables 2-1 and 2-2 are estimates based on projections of the numbers of elements to be generated over a ten-year period into the future." (EIS at 2-9.) While the estimates were intended to conservatively bound the impacts of the projected total number of spent fuel elements and shipments associated with the proposed policy, the EIS recognized that "the actual distribution of elements and shipments among the listed countries might change, within the limits of the total number of elements and shipments listed, based on actual experience gained during the lifetime of any policy that may be established." (EIS at 2-9.) Indeed, a principal reason for "estimating" the amount of material was that many of the eligible reactors were still operational. Thus, the precise quantity of material operational reactors would generate was uncertain and, as a result, assumptions had to be made to estimate the amount of material that would be discharged from the reactors before May 13, 2006. The names of research reactors thought to possess eligible material were listed in Appendix B in Tables B-3, B-4, and B-5.

Based on the estimates of spent fuel elements to be generated by foreign research reactors by January 2006, DOE estimated of the number of spent fuel casks to be shipped by country. (See Tables 2-1 and 2-2.) The analysis of environmental impacts in the EIS used these estimated number of cask shipments to determine potential radiological impacts from the transport and management of the spent fuel. There are two modes of transport affected by the number of casks -- transport over the ocean by sea-going vessel and transport overland by truck or rail. Potential environmental impacts from overland transport in the United States are independent of the number of elements in the cask or the country or reactor of origin, because the analysis in the EIS assumes that all casks: (1) have external radiation dose rates at the regulatory maximum, (2) contain the same bounding radioactive material inventories; and (3) are transported from any of the potential ports of entry to either of the management sites.

The analysis of potential environmental impacts from marine transport of the foreign research reactor spent fuel is more complicated. The number of elements accepted under the program does not affect the incident-free or accident risks of marine transport so long as the total number of casks accepted under the program does not change. The marine transport analysis assumes that each cask has external radiation dose rates at the regulatory maximum and possesses

bounding radioactive material inventories. However, the country of origin and the number of casks on a vessel does affect the analyses of potential environmental impacts from marine transport. Estimates of incident-free and accident risks from marine transport are dependent on several factors, two of which are the sea distance the cask is transported and the number of casks on a vessel.

Whereas the overland distance in the United States is the same for each cask irrespective of its country of origin, the sea distance from the foreign country to the United States can vary considerably. (See Appendix C, Marine Transport and Associated Environmental Impacts, Table C-1.) When the EIS was being prepared, the management site destination of the foreign research reactor spent fuel was not known. Consequently, the marine transport analysis assumed that the fuel could be transported to either the East or West Coasts of the United States. The sea distance from each foreign country to representative ports on the East and West Coasts of the United States was determined. These distances were then averaged so that the ocean miles a shipment could be at risk of an accident could be estimated. Based on the average sea transit distance for each country, an estimated voyage duration was determined and the crew doses from external radiation during inspections estimated. The voyage durations for all countries were then averaged together, without regard for the number of shipments from that country, to develop a program average voyage duration. This program average voyage duration was used in the analysis of marine transport to determine potential environmental impacts.

Once the voyage duration was determined, the next key parameter for the analysis of potential environmental impacts was the number of spent fuel casks transported on a vessel. For purposes of analysis, the EIS assumed that eight casks were transported on a single vessel in a two cask per hold configuration. Each cask was assumed to have the radiological characteristics discussed earlier. Using the voyage duration to determine the number of inspections in which ship personnel could be exposed to radiation from eight casks, DOE estimated potential exposures under routine conditions.

Based on the assumptions described in the preceding paragraph, the EIS estimated the maximum individual dose per shipment on a regularly scheduled commercial vessel transporting two spent fuel casks as 66 mrem to the Chief Mate and Boatswain, a dose below the 1 mSv/y (100 mrem/y) limit. Assuming, for purposes of analyses, that the same vessel and crew were used for as many shipments as possible in one year, the maximum individual dose to a crew member would be approximately 600 mrem.

If a charter is used to obtain a vessel's services, greater control can be exercised over a vessel's schedule and route than if a regularly scheduled commercial vessel is engaged. A dedicated charter vessel also could carry more casks than generally could be accommodated on a regualarly scheduled commercial vessel. Consequently, the EIS assumed that a dedicated charter vessel would transport eight casks. Because of the number of casks on a chartered vessel and the resulting potential for exposure to radiation during daily inspections, the EIS estimated that a crew member could receive and annual dose of 1,668 mrem. This estimated annual exposure is

based on projected exposure of 238 mrem per voyage and seven voyages per year with each voyage taking an average of 18 days.

The annual exposures estimated in the EIS using cask external dose rates at the regulatory limits exceeded the limits that have been established by DOE and the Nuclear Regulatory Commission for radiation protection of the general public. Even though the results of the analyses in the EIS indicated that only in special circumstances could some individual crew members receive doses that exceeded regulatory limits, these potential exposures were a concern. In response, the ROD stated that "DOE will prepare a Mitigation Action Plan under the provisions of DOE's NEPA implementation procedures." (ROD at 61 Fed. Reg. 25100) In August, 1996, DOE issued the "Mitigation Action Plan for the Implementation of a Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel" to ensure that no individual crew member would receive more that the maximum allowed under the regulatory limits established for the general public. The Mitigation Action Plan presents the steps DOE will take through the contract clauses with the shippers of record and the reactor operators' contract clauses with their shipping contractors to ensure radiation exposures are kept below the regulatory limits.

The analysis in the EIS also looked at spent fuel transport assuming that the spent fuel transported had radiation characteristics similar to historic dose rates. For this analysis, all other assumptions regarding voyage length, crew activity (time and distance from the spent nuclear fuel cask), number of shipments, and the assumptions made to estimate annual doses remained the same as in the analysis performed using the external dose rates derived from the exclusive-use regulatory limit of 10 mrem (0.1 mSv) per hour at 2 m (6.6 ft) from the surface of the shipping container. However, an estimate of two casks was used for a regularly scheduled commercial vessel, as opposed to the eight casks for a chartered vessel. Using historic dose rates, the maximum dose to an individual per regularly scheduled commercial vessel shipment would be 6.6 mrem (0.066 mSv), and the annual maximum individual dose would be 60 mrem (0.6 mSv). This dose could be received if the same crew member were involved in nine separate voyages each transporting two spent nuclear fuel casks during a single year. These doses are an order of magnitude lower than the corresponding doses calculated using the exclusive-use regulatory external dose rates. The calculated maximum individual dose under this scenario is well below the maximum allowable annual dose to a member of the public of 100 mrem (1 mSv).

The EIS discusses the possibility of shipping between one and eight casks per vessel on either regularly scheduled commercial or chartered vessels. The accident and incident-free analyses in the EIS do not examine more than two casks per hold with four holds per vessel. In reality, all shipments to date have been made on chartered vessels that have a single hold containing between two and eight casks. The ROD states at 61 Fed. Reg. 25099 that "DOE will reduce the number of shipments necessary by coordinating shipments from several reactors at a time (i.e., by placing multiple casks [up to eight] on a ship)." The EIS also contains language indicating that there is no absolute limit. For example, Appendix C, C-13, states that the "use of a chartered

vessel ... could result in the shipment of more than two casks per voyage. For this analysis it has been assumed that eight transportation casks would be shipped on a chartered vessel."

2 - New Information or Circumstances Relevant to the Implementation of the Acceptance Program

The foreign research reactor spent fuel acceptance program was established in 1996, upon issuance of the ROD. Since the implementation of the program, new and more accurate information has been received indicating that the EIS forecasts of the amount of spent fuel at research reactors, both over- and under-estimates the actual amount within a number of countries. In addition, material eligible under the program has been discovered in countries listed in the EIS, but at research reactors not mentioned in the EIS. For example, spent fuel containing United States supplied HEU was discovered in late 1997 at the shutdown ESSOR research reactor in Ispra, Italy. About 100 SNF assemblies from this reactor were shipped to the Savannah River Site (SRS) in the 1980's. The shutdown reactor was operated by the European Commission which operates the PETTEN research reactor that is eligible under the program and listed in the EIS. ESSOR still possesses 12 HEU SNF assemblies and would like to have those accepted under the program. Even though ESSOR is not listed as a research reactor possessing eligible fuel, the spent fuel contains United States supplied enriched uranium that is otherwise eligible for acceptance under the program.

In addition to more accurate information on spent fuel inventories, DOE has obtained updated information on the inventory of spent fuel casks available to support the program. When the EIS was under preparation, eight casks on a vessel was assumed to be the maximum number of casks that could be made available for any one shipment. This assumption was then incorporated into the assessment of potential environmental impacts. The worldwide supply of spent fuel casks has now increased to the point where it is possible to transport more than eight casks on a single shipment.

The Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA), 40 CFR 1502.9(c), direct federal agencies to prepare a supplement to an environmental impact statement when an agency "makes substantial changes in the proposed action that are relevant to environmental concerns, or there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or impacts." When it is unclear whether a supplemental EIS is required, DOE regulations for compliance with NEPA (10 CFR 1021.314) require the preparation of a supplement analysis to assist in making that determination. This supplement analysis evaluates the acceptance of foreign research reactor spent nuclear fuel under three scenarios: (1) accepting FRR SNF fuel from policy-eligible research reactors not specifically mentioned in the EIS but within the same set of countries included in the EIS; (2) accepting spent fuel from a specific reactor in quantities greater than those estimated in the EIS, but within the overall numbers specified in the EIS and ROD; and (3) transporting more than eight casks of FRR SNF on a single vessel.

Analysis

The EIS is clear that DOE considered the likelihood that the actual distribution of elements and shipments associated with the acceptance policy might change over the lifetime of the policy. Since the issuance of the EIS and ROD, several countries have indicated that they are unlikely to participate in the program. Information has also been received indicating that several reactors have inventories smaller than those estimated in the EIS. As a result, the number of elements to be accepted and the number of cask shipments to be made are substantially smaller than those that originally formed the basis of the risk assessment. The total number of elements eligible to be accepted in the United States under the ROD is 22,700 spent fuel elements in 837 casks. The current estimate of elements to be transported to the United States is approximately 17,500 in 680 casks. Of the original estimate of 837 casks, 721 of those casks required marine transport. Current estimates indicate that less than 572 casks will require marine transport.

Because the risk assessment of overland transport in the United States is not affected by the origin of the spent fuel, provided that the total number of casks does not exceed the limit in the EIS, the potential environmental impact of accepting spent fuel from reactors not listed in the EIS would not exceed the impacts analyzed in the EIS. Similarly, if the number of elements from any one country differed somewhat from the country-specific estimates in the EIS, the environmental impacts from overland transport described in the EIS would not be exceeded as long as the total number of cask shipments were not exceeded.

The analysis of potential environmental impacts from marine transport of spent fuel is dependent upon the distance from the foreign country to the United States, the time it takes to make that voyage, and the number and characteristics of spent fuel casks on a vessel. The EIS assumed an average voyage distance and duration based on East and West Coast destinations for all spent fuel eligible for receipt. The total program risk, as well as the annual risk, from marine transport is based on these average voyage durations. However, in the ROD, DOE implicitly decided to accept all but the TRIGA shipments from Pacific-rim countries through the East Coast port of entry. Consequently, the voyage durations used in the EIS for all European-origin shipments destined for the East Coast are over-estimated by about 50%. Because the voyage duration used in the EIS was a simple arithmetic average of the durations of all foreign country-United States pairs, a recalculation of the voyage duration using only an East Coast destination for European shipments results in a reduction of the assumed voyage duration of 21 days in the EIS to 18 days. If the average voyage duration is calculated using averages weighted by the number of shipments per country of origin, the effect of shipping approximately 500 European-origin spent fuel shipments (out of the original total of 721) only to the East Coast has a further impact on the overall voyage duration average, lowering the duration to 17 days. Consequently, the analysis in the EIS overestimates voyage duration by approximately 20%.

However, the voyage duration in the EIS was based on an average ship's speed of 15 knots. The small chartered vessels being used to transport the spent fuel are actually making approximately 12 knot transits. The reduced speed results in approximately 20% longer transits than a transit

using the speed estimated in the EIS. The slower speed essentially balances out the reduction in voyage duration because of the decision to accept most fuel through the East Coast.

As a result of the combination of slower vessel speed, lower number of shipments, and shorter transit, the overall effect of changes in the country of origin or number of casks from that country is to essentially have no impact on the overall program risk. The analysis in the EIS has enough conservatism built into the assumptions, given the real decrease in number of shipments, to provide a bounding analyses of potential impacts from accepting spent fuel casks in greater numbers from countries listed in the EIS, so long as the total number of casks for the overall program is not exceeded.

As shown in Table 1, the package dose rates for the spent fuel received to date have been well below the regulatory limit of 200mrem/hr (2mSv/hr) at surface of the package. All spent fuel has been received on skids or in containers that mate with the standardized 20-foot container handling equipment available at ports. The time spent in cask inspection and unloading is proving to be less than the estimates used in the EIS. The EIS assumed cask unloading times of 65 minutes per cask. Operational experience has shown that cask unloading activities (radiation surveys, removal of firefighting headers, removal of lashing, and rigging of container for offloading) take an average of 20 minutes per container. At sea inspection times of 4 to 15 minutes per cask are being reported and involve one to two individuals on a daily basis. In some cases, company assigned radiation protection personnel have accompanied the shipment and taken responsibility for cargo inspections. These personnel have worn dosimetry devices and have reported no measurable doses.

Assuming that only two casks are carried per hold, the EIS concludes that only one cask would be ruptured in the event that a ship carrying FRR is in a collision. In reality, the probability of a collision having an impact on a cask is independent of the number of holds. Whether the casks are stowed in one or more holds is not of importance in the EIS analysis because no credit was taken for the increased structural strength provided by multiple holds.

In the EIS, the overall probability of a collision and cask release (per shipment risk) depends upon the number of voyages and transversely stowed casks. The EIS estimated that one cask would be damaged in a collision. More recent analysis has shown that the cask damage scenarios used in the EIS were too conservative. In reality, a spent fuel cask is much stronger than the hull of a vessel. If there were to be a collision involving penetration of the hull of the spent fuel carrying vessel, a spent fuel cask would be pushed out the other side of the vessel before enough force could be brought to bear on the cask to breach it. (Ammerman, 1998) Thus, DOE now concludes that, at most, only one cask could be breached during a severe accident, regardless of the number of casks stowed transversely in a hold. Consequently, the transport of more than eight casks on a single vessel would not increase the risk of an accidental release.

The potential inventory of material present in a spent fuel cask in the event of a vessel sinking with complete loss of cargo is addressed on p. 2-34 of the EIS: "The International Maritime

Organization currently limits the typical commercial cargo ship (Class INF-2) to a maximum of 200 petrabecquerels of radioactivity (IMO, 1993), which equates to approximately 5.4 million Ci. A typical cask of foreign research reactor spent nuclear fuel is predicted to contain 1 million Ci (see Appendix C). Therefore, a shipment in a commercial cargo ship could contain several casks." Experience has shown that curie inventory per cask is in the 50 to 200,000 curie range, with the median around 50,000 curies. (See Table 1) This would allow shipment of up to 20 casks per vessel even at the higher activity loads. The IMO regulations are also discussed in Section 5, p. 5-10, of the EIS, Applicable Laws, Regulations, and Other Requirements.

As long as IMO requirements for INF Class II shipments are met and the requirements of the MAP satisfied for worker exposure, the environmental impacts presented in the EIS would bound shipments of more than eight casks per vessel.

In conclusion, increasing the number of casks per vessel from eight per ship up to sixteen per ship does not affect the accident radiological risk. The potential incident-free risk would be expected to remain essentially the same for the program, but increase slightly on a per voyage basis. However, experience has shown that the EIS estimates of doses during daily spent fuel inspections aboard ship was very conservative. To date, no exposures of ship's personnel have been reported. Nevertheless, DOE will continue to implement a number of mitigative measures based upon the requirements of the Mitigation Action Plan that will prevent the exposure of ship's crew to doses greater than those allowed by regulatory limits.

Conclusions

This Supplement Analysis considers the potential environmental impacts from the acceptance of foreign research reactor spent nuclear fuel from research reactors not specifically mentioned in the EIS but within the set of countries considered in the EIS, or in quantities greater than those estimated for a specific reactor or country in the EIS. The acceptance of spent fuel from research reactors not specifically mentioned in the EIS, but otherwise meeting the parameters established in the EIS for eligibility, or in quantities greater than those estimated for a specific reactor or country, would not change the estimated total number or type of shipments from foreign countries to the United States.

The results of the supplement analysis indicate that the potential environmental impacts from acceptance of this material are bounded by the analysis performed in the EIS. On this basis, DOE has determined that the acceptance of foreign research reactor spent nuclear fuel from research reactors not specifically mentioned in the EIS or possessing quantities greater than those estimated in the EIS does not constitute significant new circumstances or information relevant to

environmental concerns, and therefore no supplement to the EIS need be prepared, provided that the total number of elements accepted and cask shipments made under the acceptance policy do not exceed the total number provided in the EIS.

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Table 1: Foreign Research Reactor Spent Fuel Shipment Cask Information

Cask Type	Surface dose rate (mSv/h)	0.3 meter dose rate (mSv/h)	Activity (TBq)	Elements	Transport Index
IU-04	ND	ND	1.6e3	26	3
IU-04	0.015	0.001	9e2	40	2
GNS-11	0.033	0.005	1.75e3	26	1.3
GNS-11	0.035	0.005	6.04e2	33	0.8
TN-7/2	0.015	0.01	1.84e3	64	8.33
TN-7/2	0.23	0.008	4.45e3	42	8.33
NAC-LWT	-	0.15	-	41	-
NAC-LWT	0.002	ND	1.67e0	21	2
NAC-LWT	0.005	ND	2.11e2	28	0.1
GNS-11	0.005	ND	2.15e3	33	0.5
GNS-11	0.002	ND	1.39e3	33	0.3
TN-7/2	ND	ND	4.79e3	39	8.3
TN-7/2	0.036	0.022	7.98e3	53	8.3
IU-04	ND	ND	5.1e2	36	0.00
IU-04	ND	ND	4.5e2	39	0.00
IU-04	ND	ND	3.7e2	39	0.4
JMTR	ND	ND	5.7e2	30	0.3
JMTR	ND	ND	5.9e2	30	0.3
TN-6/3	0.005	ND	5.1e0	1	-
TN-7/2	0.018	0.002	1.49e3	48	8.3
TN-7/2	0.005	0.003	2e3	64	8.3
GNS-11	ND	ND	6.21e3	33	3.1
GNS-11	ND	ND	7.39e2	26	0.4
NAC-LWT	0.005	0.0012	2.68e3	42	0.5
IU-04	ND	ND	2.22e1	40	1
IU-04	ND	ND	5.55e2	36	1
IU-04	0.005	0.0012	1.38e3	25	-
IU-04	0.005	0.0001	1.77e3	36	1
TN-7/2	0.005	0.0002	2.95e3	64	8.3
GNS-11	0.07	0.005	7.24e3	33	10.3
GNS-11	0.07	0.007	7.52e3	33	10.1
LHRL	ND	1.5	1310	120	50
TN-7/2	ND	50	736	60	8.3

TN-7/2	ND	10	718	60	8.3
NACLWT	0.5	ND	96	96	
NACLWT	3.5	ND	978	96	
NACLWT	2.2	ND	604	107	

ND = not detectable
Note: Table reflects shipments through July 1998.

References

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