Foreign Research Reactor Spent-Fuel Environmental Assessment*

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INTRODUCTION

In this paper a discussion of the port-of-entry selection process developed for a U.S. Department of Energy (USDOE) proposal to receive European spent-fuel is presented. Transportation risks for ports that meet and for ports that do not meet the criteria of the process are presented. The results indicate that port-election criteria can be unnecessarily restrictive with regard to the safety of spent-fuel shipments.

The transportation of foreign spent nuclear fuel into the United States is a highly controversial issue. Proposals by the Government of the United States to receive and store foreign spent nuclear fuel have been challenged in the courts and restricted under congressional legislation. Section 3151 of Public Law 103-160, the National Defense Authorization Act for Fiscal Year 1994 (the Act), imposes criteria on the USDOE for selecting a port for the receipt of spent nuclear fuel. A major concern for many stakeholders is the selection of a port of entry into the United States for the spent-fuel.

BACKGROUND

In 1978, the United States began a program to eventually eliminate the use of nuclear weapons-grade highly enriched uranium (HEU) in civilian reactor programs worldwide. The program addresses nuclear weapons proliferation issues by encouraging the use of non-weapons-grade low enriched uranium (LEU) fuel instead of HEU. In 1988 the practice of receiving foreign research reactor spent-fuel was suspended.

The USDOE has proposed to resume the acceptance of foreign HEU research reactor spent-fuel. The USDOE proposes to accept over 15,000 spent-fuel elements from

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foreign research reactor facilities over approximately 15 years. However, availability of storage space at several foreign research facilities has become a crucial issue. The USDOE has determined that an urgent need existed to relieve several reactor operators of part of their HEU spent-fuel inventory. Hence, the USDOE proposed to receive and store at its Savannah River Site (SRS) 409 HEU spent-fuel elements from eight European research facilities. It was proposed to ship the fuel to a U.S. port of entry by commercial ocean vessels in cargo containers and then to transport the fuel by truck to the SRS. In accordance with requirements of the National Environmental Protection Act (NEPA), the USDOE issued the "Environmental Assessment of Urgent Relief Acceptance of Foreign Research Reactor Spent Nuclear Fuel" (USDOE 1994) in April 1994. The analyses presented here are from that document.

FEDERAL CRITERIA ON PORTS OF ENTRY FOR SPENT-FUEL

Public Law 103-160, Section 3151, states:

> *The Secretary of Energy shall, if economically feasible and to the maximum extent practicable, provide for the receipt of spent nuclear fuel under this section at a port of entry in the United States which, as determined by the Secretary and compared to each other port of entry in the United States that is capable of receiving the spent nuclear fuel-*
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> 1. *has the lowest human population in the area surrounding the port of entry;*
> 2. *is closest in proximity to the facility which will store the spent nuclear fuel; and*
> 3. *has the most appropriate facilities for, and experience in, receiving spent nuclear fuel.*

Taken at face value, the criteria presented the USDOE with several problems. First, there exists in the criteria the potential for a contradiction within each pairwise grouping. The port with the lowest population may not be the port closest to the storage facility, nor have the most appropriate facilities for and experience in receiving spent-fuel. Likewise, the port closest to the storage facility might not have the most appropriate facilities or experience with respect to receiving spent-fuel. Second, the Act gives no guidance, direction, or insight as to how the criteria should be interpreted or applied. Should the criteria be weighed equally or unequally? Should threshold values be used to establish acceptable pass/fail levels for each criteria? Third, there has been controversy regarding what constitutes a "low population port" and a "high population port" (U.S.D.D.C. 1991). The first criterion of the Act does not define *the area surrounding the port of entry*. The population characteristics of the immediate vicinity of a port's facilities can be very different from the population characteristics taken over an entire metropolitan area. Additionally, the Act does not address the population that resides along the overland transportation route between the port of entry and the storage facility, which is also an important aspect of the population at risk.

REFINEMENT AND EXPANSION OF THE ACT's CRITERIA

The USDOE sponsored a workshop at the U.S. Merchant Marine Academy (USMMA) to facilitate the interpretation of the Act. The workshop yielded extensive insight for the application of the Act's criteria and the development of additional criteria (Massey 1995). Participants included experts on marine transportation, intermodal systems, marine insurance, admiralty law, U.S Coast Guard operations, U.S. Navy cargo operations, Military Sealift Command operations, national cargo bureaus, vessel pilotage, and ships cargo operations.

A consensus of the participants was that any port with the capabilities to receive cargo from oceangoing vessels (containerized or not) could adequately receive spent nuclear fuel. The participants focused on three issues: (1) quality of port facilities (e.g., berthing availability, intermodal transfer facilities, emergency response), (2) geographic features (channel depth, channel currents, distance from the open ocean to the docks), and (3) safety of maritime transportation. The participants believed that operational issues were more crucial for safety than the density of population related to ports. Panel discussions and expert elicitation were used to establish a set of port criteria independent of the Act's criteria. These were defined as:

1. Distance of the port from the open ocean;
2. Emergency preparedness and capabilities; and
3. Access to intermodal transfer facilities.

SELECTION OF PORTS OF ENTRY FOR URGENT RELIEF SHIPMENTS

Insights from the USMMA workshop were used as guidance in interpreting and prioritizing the Act's criteria. The criteria of the Act were prioritized, with *"most appropriate facilities"* the highest priority, *"lowest human population"* next, and *"closest in proximity"* the lowest priority. In this way the mandates of Congress and the insights of maritime shipping experts were incorporated into the port-selection process. A two-phased process was developed. In the first phase, ports were screened against the criteria of the Act. Any port that failed to meet a criterion was excluded from consideration of lower priority criteria. In the second phase, all ports that met the Act's criteria were evaluated with respect to the USMMA workshop criteria. The USMMA criteria were used to determine the most qualified of the ports that met the criteria from phase one. In this manner many factors were considered in the selection of the ports most *"capable of receiving spent nuclear fuel."*

Criterion 1: Most Appropriate Facilities for Receipt of Spent-Fuel

A total of 151 commercial seaports were identified by the U.S. Maritime Administration (MARAD). The USMMA workshop participants had concluded that the Act's third criterion, *"most appropriate facilities,"* would best be met by ports that were served by regularly scheduled commercial cargo lines. It was felt that such ports would have adequate infrastructure and services required to safely transport spent nuclear fuel. The original list of 151 ports was reduced to 20 ports based on those parameters (see Table 1).

Table 1. Seaports with Appropriate Facilities Evaluated for Lowest Population

Port	Human Population Data			
	Port Area ($person/km^2$)	Metropolitan Area ($person/km^2$)	Total Truck Route Population	Average Score
1. Jacksonville, Fla.	395	310	60,036	1.0
2. Wilmington, N.C.	1765	693	117,078	3.0
3. Newport News, Va.	816	958	193,119	2.9
4. Charleston, S.C.	2251	753	139,403	3.6
5. Norfolk, Va.	648	2001	175,760	3.7
6. Portsmouth, Va.	1818	1433	122,029	3.8
7. Houston, Tex.	437	1142	364,926	3.8
8. Savannah, Ga.	2788	998	54,856	3.8
9. Richmond, Va.	2401	1370	122,308	4.2
10. New Orleans, La.	2251	1052	264,280	4.6
11. Port Everglades, Fla.	2175	1938	251,000	5.4
12. Elizabeth, N.J.	3652	3442	340,806	8.6
13. Baltimore, Md.	3263	3546	334,944	8.6
14. Miami, Fla.	2979	4208	353,000	9.0
15. Portland, Maine	2967	1022	963,550	9.5
16. Oakland, Calif.	2558	2505	1,120,470	11.7
17. Philadelphia, Pa.	4666	4569	492,946	11.8
18. Long Beach, Calif.	3478	3009	1,049,686	12.5
19. Los Angeles, Calif.	3505	2646	1,099,020	12.5
20. Boston, Mass.	3407	4597	975,615	13.7

Criterion 2: Lowest Population Density

The Act did not define *"lowest human population in the area surrounding the port of entry."* As stated earlier, a city's total population density may not be characteristic of the population density in the vicinity of its port. Wilmington, North Carolina is frequently identified as a "low population" port by certain stakeholders. Jacksonville, Florida and Norfolk, Virginia are typically considered "high population" ports. Yet the population data in Table 1 illustrate how the population characteristics in the vicinity of a port can be very different than the total population density of the port metropolitan area. It was determined that three different population characteristics should be considered for each port option: (1) port area population density, (2) metropolitan area population density, and, (3) the total population living along the intended truck route between each port and the SRS (see Table 1).

The population characteristics for each port were scored by taking the ratio of each datum to the lowest valued datum for each characteristic. Based on this method, Jacksonville received the best score of 1.0 for both port area and metropolitan area population density. Savannah, Georgia scored 1.0 with respect to persons residing along the truck route. The worst port area score was for Philadelphia (11.8), the worst metropolitan area score was for Boston (14.8), and the worst truck route score was for Oakland, California (20.4). The three scores for each port were averaged to yield a final weight. The results are shown in the last column of Table 1. A value of 5.4 was used as the score to eliminate ports from further consideration, reducing the list of candidate ports from 20 to 11 ports.

Criterion 3: Closest in Proximity to the Storage Facility

The distance between a port and the SRS was based on the guidelines of the U.S. Department of Transportation's (USDOT) routing regulations for spent nuclear fuel, HM-164. Under these guidelines interstate highways are the preferred choice for routing. The U.S. Nuclear Regulatory Commission (USNRC) can approve alternate routes, and States can designate specific route alternatives. Nevertheless, the HM-164 guidelines provided a consistent framework to evaluate the ports. Ratios of the distance of each port to the distance of the port closest to SRS were calculated to score each candidate port. The results are shown in Table 2. Ports that were more than twice as far as the closest port (Charleston, South Carolina) were eliminated from further consideration. Four ports remained as candidate port options: Charleston, South Carolina, Jacksonville, Florida, Savannah, Georgia, and Wilmington, North Carolina.

Application of USMMA Workshop Criteria

The four ports that most favorably met the criteria of the Act were evaluated with respect to the criteria established at the USMMA workshop: distance from the open ocean to the port facilities, emergency preparedness and capabilities, and access to intermodal transportation. Distances between the ocean and the ports ranged from 18.5 km for Jacksonville up to 48 km for Savannah and Wilmington. A cargo vessel would require approximately 2 to 4 hours for such a transit. For ports with greater distances between the ocean and the port facilities, transit times as high as 12 or more hours are required. Thus, the range of distances from open ocean to port was not considered sufficient to disqualify any of the remaining ports.

All four ports compared similarly to each other with respect to emergency preparedness. Each port has a full-time risk management staff and maintains a hazardous materials incident response team. None of the ports routinely handle spent nuclear fuel nor do they maintain special procedures for dealing with spent-fuel versus

Table 2. Closest in Proximity to the Savannah River Site

Port	Highway Distance from Savannah River Site	Distance Ratios
1. Charleston	221	1.0
2. Savannah	267	1.3
3. Jacksonville	388	1.9
4. Wilmington	399	2.0
5. Richmond	471	2.3
6. Portsmouth	485	2.4
7. Norfolk	499	2.5
8. Newport News	540	2.7
9. Everglades	574	2.8
10. New Orleans	643	3.2
11. Houston	956	4.7

other hazardous cargoes. Thus, even though there have been a few spent-fuel shipments that have passed through the ports of Savannah and Wilmington, no distinction could be made between the ports with respect to emergency preparedness.

All four ports compared similarly to each other with respect to intermodal transportation access. Good access to major interstate and U.S. highways and rail lines exist at all four ports. Access to rail was considered desirable by the USDOE to ensure flexibility in the overland transportation campaign.

Selection of a Military Port of Entry

Military ports and bases were also considered as potential ports of entry by using the same process applied to the original set of 151 commercial ports. Based on this process the Military Ocean Terminal at Sunny Point (MOTSU) in Sunny Point, North Carolina, was added to the set of four commercial ports as a potential port of entry. MOTSU, commonly referred to as Sunny Point, is located on the Cape Fear River, 22 km from the ocean and 26 km downstream from the port of Wilmington, North Carolina. Sunny Point's primary mission for the U.S. Army is the intermodal transfer of military ordnance between both rail and truck modes and oceangoing cargo vessels.

TRANSPORTATION IMPACTS AND RISKS FOR PORT OPTIONS

Incident-free impact and accident risk assessments were performed for two sets of ports: *"preferred ports"* - the four commercial ports and one military port that most fully met the criteria of the Act and of the USMMA workshop, and *"alternative ports"* - six commercial and two military bases that did not meet the Act's criteria. The results of the transportation impact and risk assessment are summarized in Table 3.

Table 3. Transportation Radiological Impacts for Urgent Relief Shipment of 409 Foreign Research Reactor HEU Spent-Fuel Elements

Preferred Ports and Alternative Ports		
Port Of Entry	Annual Incident-Free Dose (Person-rem)	Annual Accident Dose Risk (Person-rem)
Charleston[1]	0.12	5.5×10^{-4}
Jacksonville[1]	0.14	1.6×10^{-4}
Savannah[1]	0.12	6.8×10^{-4}
Sunny Point[1] (Military)	0.16	7.6×10^{-5}
Wilmington, NC[1]	0.14	4.3×10^{-4}
Elizabeth	0.21	9.1×10^{-4}
Kings Bay, Ga. (Naval Base)	0.15	4.3×10^{-4}
Morehead City, N.C.	0.15	4.3×10^{-4}
New Orleans	0.18	5.6×10^{-4}
Newport News	0.16	3.4×10^{-4}
Norfolk	0.16	2.7×10^{-4}
Portsmouth	0.16	4.5×10^{-4}
Yorktown, Va. (Naval Base)	0.17	1.4×10^{-4}

[1] Preferred Port of Entry for Receipt of Foreign Research Reactor Spent-Fuel

Incident-Free Impacts

The incident-free impact estimates vary from 0.12 person-rem yr^{-1} for the option of Charleston to 0.21 person-rem yr^{-1} for the option of Elizabeth, New Jersey. Only small differences exist between the various port options with respect to incident-free transportation impacts. The range in dose estimates is driven by the range in distance for the truck route to SRS for each port option. Population dose estimates to truck crews and to members of the public who share the route with the shipments increase as the distance of the truck shipment increases. Maritime shipping distances and port population characteristics have very small influences on incident-free impacts. Vessel crew dose estimates, approximately 5.0×10^{-2} person-rem yr^{-1}, are two orders of magnitude less than dose estimates for dock workers, truck crews, and members of the public who share the transportation route with the overland shipments. All of the port options, both *preferred* and *alternative*, demonstrate low incident-free dose estimates.

Accident Risk Assessment

Results of the accident risk analysis vary from a dose-risk estimate of 7.6×10^{-5} person-rem yr^{-1} for Sunny Point to 9.1×10^{-4} person-rem yr^{-1} for Elizabeth. The dominant contributor of accident risk is the transit of a vessel through the port. Accident dose risk associated with the overland truck shipments to SRS is less than 1×10^{-5} person-rem yr^{-1} for all of the port options. The variation of risk estimates between port options is a function of the population density in the immediate area surrounding the port facilities. However, the variation of risk estimates between port options is insignificant with respect to an absolute perspective on risk.

CONCLUSIONS

Only minor variations of incident-free impacts and accident risk from the USDOE's analysis for the urgent relief shipments (USDOE 1994) can be attributed to two issues addressed by the criteria of the Act: *human population in the area surrounding the port* and *proximity to the storage facility*. Yet these criteria resulted in the elimination of 16 ports that, on the basis of expert maritime experience and insight, satisfy the Act's requirement that a port of entry have *the most appropriate facilities for . . . receiving spent nuclear fuel*. The results show that the port-of-entry selection criteria mandated by the U.S. Congress are unnecessarily restrictive. Several of the most qualified ports in the United States, when evaluated in the context of expert insight from both maritime operations and risk assessment, have been eliminated as potential ports of entry because of Congress's overemphasis on population characteristics and route distance.

The results are important because there continues to be movement among certain stakeholder groups to further restrain the movement of spent-fuel through U.S. ports of entry and to require port selection on the basis of criteria formulated without the benefit of expert maritime advice and risk assessment insight.

REFERENCES

Massey, C.D., *Report on the Workshop on Port Selection Criteria for Shipments of Foreign Research Reactor Spent Nuclear Fuel*, SAND94-2061, Sandia National Laboratories, Albuquerque, New Mexico (1995).

U.S. Department of Energy, *Environmental Assessment of Urgent-Relief Acceptance of Foreign Research Reactor Spent Nuclear Fuel*, DOE/EA-0912, Washington, D.C. (1994).

U.S. District Court for the District of Columbia, *Sierra Club v. Watkins, 808F Supp 852*, Washington, D.C. (1991).