POLICY ISSUE

December 21, 1992

(NEGATIVE CONSENT)

SECY-92-421

For: The Commissioners

From: James M. Taylor
Executive Director for Operations

Subject: REPORT REQUIRED BY THE ENERGY POLICY ACT OF 1992

Purpose: To inform the Commission that staff intends to concur on a report, on the safety of plutonium sea shipments, required under the Energy Policy Act of 1992.

Background: Section 2904 of the Energy Policy Act of 1992 requires that the President, in consultation with the Nuclear Regulatory Commission, conduct a study on the safety of shipments of plutonium by sea, and submit a report to Congress within 60 days (December 23, 1992). The act also requires the President to submit an implementation plan for the study's recommendations not later than 90 days after transmittal of the report.

The act requires that the study consider the following: (1) the safety of the casks containing the plutonium; (2) the safety risks, to States, of such shipments; (3) the adequacy of a State's emergency plans with respect to such shipments (if requested by the State); and (4) the Federal resources needed to assist the States on account of such shipments.

Discussion: The enclosed report (enclosure 1) represents a joint effort by the Departments of State (DOS), Energy (DOE), and Transportation, the Coast Guard, the Environmental Protection Agency, the Federal Emergency Management Agency

NOTE: TO BE MADE PUBLICLY AVAILABLE WHEN THE FINAL REPORT IS MADE AVAILABLE

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(FEMA) and NRC. Overall coordination for the study was provided by DOS. The Executive Branch has designated DOE to submit the report to Congress.

NRC staff provided information on the physical protection of transient shipments, assisted DOS and DOE in reviewing and coordinating the various contributions to the report and participated in meetings concerning the study. To meet the submittal deadline of December 23, 1992, DOE has requested that contributing agencies provide approval of the enclosed final draft by December 22, 1992. Please note that the report should not be released until it has been made available to the public.

The report discusses the health and safety risks of shipping plutonium by sea. It concludes that plutonium can be safely shipped, by sea, under current international and domestic requirements and practices. The report did not identify any areas where specific actions would be required to protect public health and safety. The report also discusses the emergency response roles of Federal agencies, and addresses the specific issues raised in Section 2904 of the Energy Policy Act of 1992.

The report makes the following recommendations:
(1) Executive Branch agencies and NRC should maintain awareness of future plutonium shipments and monitor the need for revising transportation standards, if present circumstances change; (2) the report should be noticed in the Federal Register and distributed to State and international organizations, such as the International Atomic Energy Agency (IAEA) and the International Maritime Organization (IMO); (3) relevant Federal agencies should continue to participate in study groups or working groups organized by the IAEA, IMO, or other international organizations; (4) FEMA should promptly review State emergency plans with respect to plutonium shipments, as already requested by certain States, and should solicit submission of emergency response plans by all coastal States; and (5) Federal agencies should take into account the need for additional resources, identified during the review of State emergency plans, when preparing agency budget submissions for FY94 and beyond. These recommendations do not affect NRC's transportation program.

Staff notes that DOS has recently received a request from Representatives George Miller and Neil Abercrombie, that the participating agencies review a report prepared by the Illinois Institute of Technology Research Institute (IITRI), Definition of Bounding Physical Tests Representative of Transport Accidents - Air and Marine, before completing the study required by the Energy Policy Act of 1992 (see enclosure 2). A DOS draft response is included in enclosure 3. A more detailed NRC staff draft response to the Miller\Abercrombie letter is included in enclosure 4.

Staff believes that the discussion of the IITRI report in Section 5.1 of the final report should be replaced with the text included in enclosure 5. The revised text provides a more complete discussion on why the transport package tests developed in the IITRI study for extremely severe marine accidents were not pursued.

Coordination: This paper has been coordinated with the Office of the General Counsel, and it has no legal objection.

Recommendation: That the Commission:

(1) Note that, because of the time provided in the law, the staff intends to notify DOE that it concurs in the report (with the proposed revision) on December 22, 1992, unless otherwise instructed by the Commission.

(2) Note that the staff intends to respond to a letter from Representatives George Miller and Neil Abercrombie once DOS has responded (enclosure 4), unless otherwise instructed by the Commission.

James M. Taylor
Executive Director
for Operations

Enclosures:
1. Safety of Shipments of Plutonium by Sea, Final Report
2. Representative Miller\Abercrombie letter to DOS
3. Draft DOS Response
4. Draft NRC Response to Representative Miller\Abercrombie letter
5. Revision to Final Report

SECY NOTE: In the absence of instructions to the contrary, SECY will notify the staff at 12 noon, Tuesday, December 22, 1992, that the Commission, by negative consent, assents to the action proposed in this paper.

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DEC 1 6 1992

10:00 AM

SAFETY OF SHIPMENTS OF PLUTONIUM BY SEA

pursuant to Section 2904 of the
Energy Policy Act of 1992

December 1992

ENCLOSURE 1

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APPENDICES

ACRONYMS

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act of 1990.

COTP - Coast Guard Captain of the Port

DOE - Department of Energy

DOT - Department of Transportation

EPA - Environmental Protection Agency

eV - Electron - Volts

FEMA - Federal Emergency Management Agency

FRERP - Federal Radiological Emergency Response Plan

FRP - Federal Response Plan

FRMAC - Federal Radiological Monitoring Assessment Center

FRPCC - Federal Radiological Preparedness Coordinating Committee

IAEA - International Atomic Energy Agency

IIT - Illinois Institute of Technology

Kgs - Kilograms

LET - Linear Energy Transfer

LLEA - Local Law Enforcement Agency

LWR - Light Water Reactor

MOU - Memorandum of Understanding

NRC - Nuclear Regulatory Commission

Pu - Plutonium

PWSA - Ports and Waterways Safety Act

RAM - Radioactive material

RBE - Relative Biological Effectiveness

RERT - Radiological Emergency Response Plan

SMCC - Shipment-Movement-Control Center

SOLAS - Safety of Life at Sea

Sv - Sieverts

EXECUTIVE SUMMARY

This report was prepared pursuant to Section 2904 of the Energy Policy Act of 1992, which requires the President, in consultation with the Nuclear Regulatory Commission (NRC), to conduct a study of the safety of shipments of plutonium by sea. The study represents the joint efforts of the Departments of Energy and Transportation, the Coast Guard, the Environmental Protection Agency, the Federal Emergency Management Agency and the NRC.

Shipments of plutonium, or any hazardous material, pose a degree of risk to public health and safety. For plutonium, direct inhalation of particles smaller than a few micrometers in diameter is the principal health hazard. Release of plutonium to the sea is a lesser hazard due to dilution and the strong discrimination against plutonium absorption by the human body. After reviewing the hazards posed by plutonium, applicable transportation safety and physical protection regulations, pertinent research and experience, and contingency plans, the agencies conclude that plutonium can be shipped safely by sea.

This conclusion is based on the review of several existing risk assessments that have been performed by the DOE and the NRC. In one study, DOE/EA-0363, the total radiological risk in a port for accidents of all types including severe collision and subsequent accidents for all type including fire was estimated to be $4.5 \times (10)^{-4}$ person-rem per port call.

For accidents on the high seas, sinking in deep wasters is the most likely type of severe accident that might befall sea shipments. The radiological consequences of this type of accident were assessed in the report. Such an accident would involve the ingestion exposure pathway to man. A package was modeled as coming to rest in water over 3600 meters deep after a postulated collision and releasing its entire contents within 1 year following the accident. Published bioaccumulation factors (see Appendix A) were applied along with the International Commission on Radiation Protection ingestion dose model. The population dose was estimated to be $6.0 \times (10)^{-5}$ person-rem and the individual dose was estimated to be $6.0 \times (10)^{-8}$ rem. Such a scenario could only occur in the open ocean since coastal wasters are much shallower, usually 200 meters or less, and cask recovery is possible.

These risk assessments are predicated on conservative estimates of containment failure, dispersal of plutonium materials into the bioshpere, and transfer to man. All of these evaluations indicate that the risks to man and the bioshpere are extremely small, even though the conservative estimates used in the assessments result in a higher calculated risk than what actually might be expected.

All analyses performed by the DOE and the NRC since 1977 have consistently shown that transport of radioactive material, including plutonium, by sea has a high degree of safety when carried out in compliance with existing international and national regulations.

These regulations cover both safety and physical protection. Because of the international scope of regulations, transient shipments meet the same requirements as for any import or export shipments of similar radioactive material. The regulations provide a framework for protecting public health and safety primarily through the design and construction of the packaging used for transport. In addition, there are operational controls on how packages may be loaded and transported in sea-going vessels and requirements for seaworthiness of vessels carrying hazardous materials, including plutonium. Physical protection is required when strategic quantities of plutonium are involved in shipments. This safeguard against diversion is provided by armed surveillance and means established to notify authorities of unusual activity immediately.

The Departments of Energy and Transportation, the Coast Guard, the Environmental Protection Agency, the Nuclear Regulatory Commission, and the Federal Emergency Management Agency have all actively addressed the development of emergency preparedness plans and training for a wide variety of accidents involving radioactive and other hazardous materials. Under emergency response procedures, sea-going vessels actively releasing radioactive material which could endanger public health and safety would not be permitted to enter U.S. waters or ports. The emergency response plans for radioactive material are applicable for plutonium sea shipments. Significant Federal assistance involving the nuclear research development and production capabilities of Federal agencies is available should the need arise.

Evaluations of the emergency response plans, which are not expected to be completed at the time this report is issued, will be provided in a separate response to each state.

Aside from Federal direction to assure that consideration of sea mode accidents are included in existing emergency reposnse plans and making states fully aware of the federal accident response capability, there are no additional Federal resources needed to assest the states in preparing to respond to accidents involving plutonium sea shipments.

SAFETY OF SHIPMENTS OF PLUTONIUM BY SEA

1.0 INTRODUCTION

Section 2904 of the Energy Policy Act of 1992 charges the President to conduct a study on the safety of shipments of plutonium by sea (see Appendix G). The study is to consider (1) the safety of the casks containing the plutonium, (2) the safety risks to the United States of such shipments, (3) upon request, the adequacy of a State's emergency plans with respect to such shipments, and (4) the Federal resources needed to assist the states on account of such shipments; and to make recommendations for federal action. This report fulfills the Congressional mandate. It was undertaken by the Department of State, the Departments of Energy and Transportation, the Coast Guard, the Environmental Protection Agency, and the Federal Emergency Management Agency, in consultation with the Nuclear Regulatory Commission (NRC).

The scope of the study was limited to transient[1] shipments of plutonium by sea. There are no known programs that would lead to transient shipments of reprocessed plutonium from power reactor fuel to U.S. ports or coastal waters. The study reviews the radiological hazards of plutonium and describes the international and national regulatory systems in place that protect the public health and safety and provide physical protection during sea shipments of plutonium. The study also addresses the Federal government's role in emergency preparedness and response.

2.0 RADIOLOGICAL HAZARDS OF PLUTONIUM

The external radiation hazard from plutonium is small. Gamma radiation associated with plutonium is low energy and is easily shielded. Alpha particle emission is the primary energetic radiation from plutonium. Although the emitted alpha particles have high energies, they are not very penetrating and can be easily shielded. The alpha particles cannot penetrate the dead layer of skin on the exterior of the human body, and pose no health threat if kept outside the body. If plutonium is inhaled or ingested, however, it can be deposited in tissues where the alpha particles can damage living cells.

For plutonium, direct inhalation is the pathway of principal concern for human health effects. Release of plutonium to the sea is a lesser human health concern due

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[1] A transient shipment is one originating in a foreign country and destined for another foreign country, which may make scheduled or unplanned (i.e. emergency) stops in the United States.

to dilution and the strong discrimination against plutonium absorption by the human body. The basic radiation safety approach for plutonium therefore is to contain the material so as to prevent dispersal into the air or water, where it might be breathed or consumed. Additional information on the radiological hazards of plutonium is contained in Appendix A.

3.0 INTERNATIONAL STANDARDS AND NATIONAL REGULATORY REQUIREMENTS

3.1 Transportation Standards

Shipment of plutonium by sea must comply with the standards of the International Atomic Energy Agency (IAEA) and national regulations of the country of origin, the country of destination, the flag country of the vessel, and countries in which ports of call (if any) are located. The regulations of IAEA member states are patterned on, and are therefore consistent with, IAEA standards. Each member state has a designated Competent Authority to carry out the provisions of the IAEA standards. The DOT is the U.S. Competent Authority. The U.S. regulations of the DOT are equivalent to and compatible with the IAEA standards.

The radiation protection standards promulgated by the IAEA (IAEA Safety Series 6) and the equivalent complementary national regulations of the United States for transportation (49 CFR Parts 171-178 and 10 CFR Parts 71-72) are based on a package-centered philosophy for overall protection. These requirements protect transportation workers and the public by focusing on the packaging as the primary barrier to radiation exposure. Operational controls are used to provide additional assurance of achieving the desired level of safety. Packaging performance standards, and procedures for demonstrating compliance with the performance standards, are contained in both international standards and national regulations. Additional requirements for packages containing fissile material such as plutonium are also included to prevent criticality. Physical protection requirements are imposed to prevent theft or loss of fissile material in quantities of strategic importance.

Competent Authorities are responsible for ensuring that all radioactive material shipments comply with the system of dose limitation for transport workers and the members of the public. These dose limitation principles are set forth in the IAEA's Basic Safety Standards for Radiation Protection (IAEA Safety Series 9). This system includes operational requirements for keeping radiation exposures as low as reasonably achievable. The system also includes segregation and stowage guidelines. Packages must be segregated from transport workers and members of the public. Segregation distances (package spacing) are determined by the package dose rate or criticality concerns. Storage requirements assure that packages are not placed in holds with other dangerous goods (such as flammable materials) and are secured for transit. Also included in the system are quality assurance programs for

the design, manufacture, testing, documentation, use, maintenance, and inspection of packages. The Competent Authorities also establish a review and inspection program to assure compliance in the design, manufacture, testing, inspection and maintenance of packagings, as well as the preparation, documentation, handling and stowage of packages.

3.2 Transportation Packagings for Plutonium

Packages and packagings[2] utilized in the international transportation of plutonium or other radioactive materials are designed, constructed, maintained, loaded and closed in accordance with the performance standards recommended by the IAEA, and as adopted and enforced by the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission. These standards are employed to ensure that the packages will retain their integrity under routine (incident-free) conditions of transport, during minor mishaps, and in accident conditions.

IAEA has also established standards for the preparation of packages for shipment. These standards include package marking and labeling, and container or vehicle placarding. Consignors must satisfy requirements for the preparation of shipping documents, and provide carriers with instructions for exclusive use shipments and emergency arrangements appropriate to the consignment. For shipments such as those considered here, the consignor must also make appropriate notifications to the competent authority of each country through which the consignment is to be transported.

3.2.1 Packaging Requirements

Three criteria must be considered in the design of any radioactive materials packaging, including plutonium packagings. First, the packaging must provide adequate shielding to ensure that external radiation dose rates meet applicable limits. Second, the packaging must provide adequate containment of the radioactive material. Finally, packagings containing fissile material such as plutonium must be packaged and shipped in such a manner that subcriticality is maintained. The regulations specify acceptance criteria for shielding, containment

[2] 49 CFR 173.403 defines a packaging as one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, devices for absorbing mechanical shock, etc. A tiedown system may be designated as part of a packaging; a package is defined as the packaging together with its radioactive contents as presented for transport.

and criticality for both normal conditions of transport and hypothetical accident environments.

In order to be certified by the U.S., or any other IAEA member state, a package must be demonstrated to meet these acceptance criteria when subjected to a sequence of tests that represent hypothetical accident conditions.

IAEA specifies these package tests and corresponding acceptance criteria in its Safety Series No. 6, 1985 edition (as amended 1990).[3] Details of the IAEA package tests and acceptance criteria are provided in Appendix B. The test sequence is briefly described below:

- Impact Test A 9-meter (30-ft) drop onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.

- Puncture Test A 1-meter (40-in) drop onto the upper end of a 15-cm (6-in)-diameter solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface in the orientation for which maximum damage in expected. The top of the bar must be horizontal and its edge rounded to a radius of not more than 6 mm (0.75 in).

- Thermal Test The package is fully engulfed in a fuel-air fire of at least 800 °C for a minimum of 30 minutes. The package is allowed to cool naturally, and any combustion of materials of the specimen is allowed to proceed.

- Immersion Test - Fissile Materials Submersion under a head of water of at least 0.9 meter (3 ft) for not less than 8 hr and in the attitude for which maximum leakage would be expected. This test is for fissile material in cases where water in-leakage has not been assumed for criticality analysis.

IAEA standards require that the following dynamic crush test be used in lieu of the impact test for low density packages (less than 1000 kgs/m^3) weighing less than 500 kgs and used to transport large quantities of radioactive materials.

- Dynamic Crush Test A 500-kilogram solid steel plate is dropped onto the package from a height of 9 meters. The package must be in the orientation for which maximum damage is expected.

In addition, a packaging must be subjected to the following immersion test. The

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[3]DOT adopted the amended 1985 edition in its 1991 edition of Title 49, Code of Federal Regulations. NRC has a rulemaking in progress to adopt the amended 1985 edition. Currently the NRC has adopted the 1973 revised edition (as ammended).

packaging tested may be a separate specimen from the one subjected to the above sequence of tests.

- Immersion Test - All Packages Submersion under a head of water of at least 15 meters (50 ft) for not less than 8 hours.

Packages that meet the above criteria, as well as other design requirements, are designed as Type B packages. The IAEA performance standards and acceptance criteria for Type B packages were developed to provide protection against very severe accidents (but not necessarily against all conceivable accidents). In fact, no Type B package has failed to maintain adequate shielding or containment, or remain subcritical in a transportation accident in 40 years of worldwide shipping experience.[4] While one can postulate accidents that fall beyond those covered by the IAEA standards, the likelihood of these accidents is so low that they do not pose a credible threat to public health and safety. It should be noted that neither the IAEA's standards or other national standards are intended to provide absolute protection against "worst case" scenarios, i.e., reduce the risk of shipping radioactive material to zero.

3.2.2 Shipment Procedure

Prior to using a packaging for transporting radioactive materials in international commerce, the user must have a certificate of competent authority from the appropriate country or countries. An application for approval includes a detailed description of the proposed radioactive contents with particular reference to their physical and chemical states and nature of the radiation emitted; a detailed statement of the packaging's design complete with engineering drawings and methods of construction; a description of the package test programs and the results; the packaging operating and maintenance instructions; justifications of any assumptions made in the safety analysis; justifications of any assumption or any special stowage provisions necessary to ensure the safe dissipation of heat from a package; a reproducible illustration showing the make-up of the package; and a description of the quality assurance program. In addition, DOT must revalidate foreign certificates for new package designs involving transient shipments.

Once an approval is granted, the user must ensure that the packaging and its contents meet the applicable requirements of the approval. To do so, the user must determine that the packaging is proper for the contents to be shipped; the packaging is in unimpaired physical condition (except for superficial defects such as marks or

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[4]There has been a single incident of the loss of a radiographic source from a small Type B package following improper preparation and tiedown to the vehicle. No accident was involved.

dents); each closure device is properly installed and secured and is free of defects; the packaging has been loaded in accordance with written procedures; and any part of the packaging that could be used for lifting during transport is rendered inoperable for that purpose.

3.3 Vessel Requirements

A foreign flag vessel transporting radioactive material entering U.S. ports must comply with the standard requirements of the International Convention for Safety of Life at Sea (SOLAS), to which the U.S. is a signatory nation. Vessels carrying fissionable material are often "purpose built" to accommodate their cargo. For example, the Japanese vessel M/V Akatsuki Maru, designed for carrying spent fuel, is double-hulled and equipped with special fire-fighting, radiation safety, navigation safety, and communications equipment.

Domestic regulations for the transportation of radioactive materials by sea are consistent with the IAEA Regulations for the Safe Transport of Radioactive Materials, Safety Series 6. In addition, 49 CFR 171.12 allows certain radioactive materials to be prepared in accordance with IAEA guidelines while being imported into or exported from the U.S., or transported through the U.S., subject to certain conditions and limitations.

The U.S. has specific vessel manning requirements for U.S. flag commercial vessels established by law and regulation. However, the manning of foreign vessels is determined by the vessel's flag state, which if signatory to the SOLAS Convention, is required to meet minimum safe manning levels established under that Convention. Foreign flag vessels complying with SOLAS manning standards will carry SOLAS documentation certifying that the vessel meets SOLAS manning requirements. In addition to SOLAS, the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers are accepted international guidelines used by many flag states for establishing crew knowledge/competency. Though SOLAS establishes internationally recognized guidelines for vessel manning, vessel manning is also dependent on the type of ship (tanker, freight vessel, roll-on/roll-off, etc.) and the minimum number of crew necessary to safely navigate the ship, handle its cargo, operate machinery, and maintain its equipment. Captain of the Port (COTP) personnel routinely board both U.S. and foreign flag vessels to determine their compliance with international Conventions like SOLAS and numerous other ship safety and environmental protection standards. If the Coast Guard COTP determines that a vessel is inadequately manned to safely navigate/operate in U.S. waters, he or she may deny the vessel entry into a U.S. port or detain the vessel in port until the vessel manning or other safety/environmental standards are raised to accepted international standards.

The U.S. Coast Guard, operating under the authority of the U.S. Department of

Transportation, is responsible for shipboard inspections of vessels entering U.S. territorial waters. Such inspections may include radiation monitoring of radioactive cargo and determination of adherence to provisions of safety regulations and the radiation protection program.

3.4 Operational Controls during Transport

IAEA has established operational controls for the segregation and stowage of radioactive material shipments. The segregation controls require that packages be segregated from places occupied by workers and members of the public, and from other hazardous materials and undeveloped photographic film. For ships in general commerce, the stowage controls require that packages be securely stowed, and that any package with a transport index greater than 10 be shipped under exclusive use. Stowage controls for vessels also limit the sum of transport indexes[5] in an individual group of fissile packages to 100, and limit the sum of transport indexes for the vessel to 200. However, the transport of consignments by special use vessel, dedicated to carrying radioactive material, is excepted from the sum of transport index requirements.

3.5 Operational Controls for Vessels

The U.S. Coast Guard is responsible for ensuring the safety of vessels and waterfront facilities, and the protection of the navigable waters and the resources therein. Operational controls include port entry approval, denial of entry and control over vessel movements. Coast Guard enabling authorities include the following statutes:

- Ports and Waterways Safety Act of 1972
- Port and Tanker Safety Act of 1978
- Magnuson Act
- Federal Water Pollution Control Act Amendments of 1972 (as amended).
- Hazardous Materials Transportation Act of 1974 (as amended).

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[5]The transport index for a package is a dimensionless number used to limit the number of packages based on external radiation or criticality concerns.

3.5.1 Scheduled Stops - Routine Port Entry Procedures

In ordinary circumstances, the Captain of the Port has sole authority to approve or deny requests for port entry. Vessels of free-flag nations must provide advance notice of arrival in accordance with 33 CFR 160. Vessels entering United States ports carrying dangerous cargo, as defined in 33 CFR 160 (includes radioactive material), are required to notify the Coast Guard Captain of the Port (COTP) of the port or place of destination at least 24 hours before entering that port or place of destination. When notifying the COTP, the owner, master, agent or person in charge of a vessel shall provide the following information:

- The name, country of registry, call sign or numbers;
- Location of vessel at time of report;
- The name of each dangerous cargo;
- The amount of each dangerous cargo;
- The stowage location of each dangerous cargo;
- The operational condition of navigation and propulsion equipment;
- The name of the port or place of destination; and
- The estimated time of arrival at the port or place of destination.

3.5.2 Unplanned Stops

Emergency port entry or "Force Majeure"[6] is based on the historical premise in international law that if a vessel is compelled to move into the waters of a foreign state by some uncontrollable external force, then the vessel should be excused from compliance with domestic law which prohibit such entry under the authority of the Ports and Waterways Safety Act (PWSA) (33U.S.C. 1221, et seq.). Vessels entering a United States port under a claim of <u>force majeure</u> may still be denied entry if a vessel exhibits a hazard to life or property or poses an imminent threat to the safety of the port.

Under international law, vessels carrying plutonium are entitled to all normal

[6] "Force majeure" is defined as an overwhelming force or condition of such severity that it threatens loss of the vessel, cargo, or crew unless immediate corrective action is taken.

rights of innocent passage, which includes force majeure. The United States has the right to first verify a claim of force majeure, and then turn away a vessel that is a hazard to life or property, even if a valid claim exists. In the event of a force majeure request by a plutonium transport vessel, the Coast Guard District Commander and his or her delegated representative, the COTP, exercise this authority, and have discretion to deny a request if the condition of the ship or its cargo poses an imminent threat to the safety of the port or public.

The burden of proof that a vessel has a valid claim of force majeure rests with the vessel, its master, and owner. As a coastal state, the United States has every right to deny a claim of force majeure until it can be verified. Even if a vessel exhibits a valid force majeure claim, the United States may nevertheless take action to remove a hazard to life or property under the Ports and Waterways Safety Act. For example, this would authorize the Coast Guard to verify that no radiological hazard exists before allowing a vessel into port.

It is important to note that a vessel carrying a cargo of plutonium may exhibit a valid claim of force majeure that has nothing to do with the stability of its radioactive material cargo. Such a claim could include mechanical casualty, force of weather, lack of food or potable water or low fuel. To foreclose a vessel from the ability to make such a claim and receive assistance to rectify the situation would violate accepted principles of international law and possibly invite further disaster (e.g. grounding, collision, sinking). A solvable problem, left unresolved aboard a vessel carrying plutonium, could actually lead to the development of unnecessary complications. Once a force majeure claim has been validated the Coast Guard is the sole Federal agency responsible for granting or denying vessel entry.

In the event that a transport vessel transits U.S. waters or is granted port entry, the Coast Guard has authority to establish Safety Zones or Security Zones as appropriate to ensure protection of the vessel and the public.

3.6 Physical Protection Requirements

The Federal government regulates safety and physical security of the transportation of radioactive materials primarily through the DOT and the NRC. The regulatory responsibilities of the two agencies in the area of safety are delineated in a Memorandum of Understanding (MOU) (44FR 38690). For international shipments, DOT is the U.S. Competent Authority and is responsible for implementing IAEA safety standards. The NRC advises the DOT on transportation safety matters.

The "Convention on the Physical Protection of Nuclear Material" (published as IAEA INFCIRC/274/Rev.1), is a treaty among over 40 nations that are most active in the international commerce of nuclear materials. States party to the Convention, including Japan, France, the United Kingdom, and the United States, have agreed to

adhere to specific standards (listed in Annex I of the Convention). In addition, most states, including those named above, adhere to IAEA guidelines and recommendations for the physical protection of nuclear material while in transit. These guidelines are published in the IAEA's INFCIRC/225/Rev.2, "The Physical Protection of Nuclear Materials."

A general license is provided in 10 CFR 70.20b to carriers to possess transient shipments of special nuclear material and irradiated reactor fuel. General licenses are effective without the filing of applications with the NRC or the issuance of licensing documents to particular persons. The general license provisions of 10 CFR 70.20b requires carriers, i.e., general licensees, to have a physical protection plan that is in accordance with, or equivalent to, U.S. domestic requirements, including the armed personnel requirement.

For scheduled transient shipments of formula quantities of Strategic Special Nuclear Material (e.g. greater than 2 kgs of plutonium), the carrier must notify the NRC in writing, with telephone confirmation, 10 days prior to shipment. The notification must include: the schedule and the itinerary of the shipment; the type of transport vehicle; a physical description of the shipment (elements, isotopes, and enrichments); the numbers and types of packages; and the name and telephone number of the carrier's representative at each stopover in U.S. territory.

The carrier must provide physical protection as required by 10 CFR 73.25 and 73.26. These requirements include: the use of cargo ships only; shipment in exclusive use cargo containers; escort inspection of accessible locks and seals; continuous cargo area surveillance by two armed and trained persons; prohibition of ship-to-ship cargo transfer; and communication from ship to shore every 6 hours.

In addition, when a transient shipment is in a U.S. port, the carrier must establish a continuously manned shipment-movement-control center (SMCC); establish an access control area; provide protection by a force of at least seven armed persons, deployed to assure the capability to protect the shipment and communicate with the local law enforcement agency (LLEA); provide cargo area surveillance by three of the seven armed persons; notify the LLEA of any threat to the shipment and take immediate measures to neutralize it; and notify the SMCC of shipment departure.

For unscheduled transient shipments (e.g. an emergency situation), the carrier is a general licensee and must provide immediate notification to the NRC, as soon as the decision is made to make an unscheduled stopover. The carrier must also make arrangements with the LLEA to provide physical protection of the cargo commensurate with that provided for scheduled shipments. If necessary, the carriers protective measures will be supplemented by Federal, state, and local protection measures until acceptable physical protection is provided by the carrier.

4.0 EMERGENCY RESPONSE

4.1 IAEA Standards Regarding Emergency Response

Paragraph 207 of Safety Series 6 requires that, in the event of an accident, emergency provisions established by relevant national and/or international organizations shall be observed. Appropriate guidelines for such provisions are described in Safety Series 37 and in Emergency Response Planning for Transport Accidents Involving Radioactive Materials, IAEA-TECDOC-262, 1982. The U.S. Environmental Protection Agency (EPA) and the Federal Emergency Management Agency (FEMA) have established national emergency provisions that would be followed in the event of an accident in or near the United States involving a transient shipment. The responsibilities of these Federal agencies is described in Section 4.2.

4.2 Federal Emergency Response

4.2.1 EPA Role in Emergency Response

In the event of an accident involving a transient shipment, however unlikely, the Environmental Protection Agency (EPA) would have primary responsibility for any emergency response that might be required. The EPA has three fundamental roles in radiological emergency response:

- Federal protective guidance;
- Radiological monitoring; and
- Leading the Federal response to foreign source incidents.

The Federal guidance role is mandated by the Atomic Energy Act of 1954 as amended. The primary document providing protective guidance for the public is the Manual of Protective Action Guides (PAGs) and Protective Actions for Nuclear Incidents. The guidance responsibility is restated in the FEMA rule, 44 CFR Part 351 Radiological Emergency Planning and Preparedness, along with a charge to assist FEMA in providing technical training for state and local officials regarding PAGs and protective actions, radiation dose assessment and decision-making. This training charge is fulfilled in part by the availability of a PAG course at the FEMA's National Emergency Training Center in Emmitsburg, Maryland.

Under the FEMA rule, 44 CFR Part 351, EPA is also charged, in cooperation with FEMA and other Federal agencies, to review and evaluate preparedness plans of state and local governments. Under Section 2904 of the Energy Policy Act of 1992, this charge is fulfilled in a manner mutually agreeable to the potentially affected states.

The radiological monitoring and dose assessment role is mandated by the Public Health Service Act, Safe Drinking Water Act, Clean Air Act, and Comprehensive Environmental Response, Compensation, and Liability Act of 1990 (CERCLA or Superfund). The EPA maintains a Radiological Emergency Response Team (RERT) to fulfill this role. The team includes personnel, monitoring equipment, and mobile laboratories, all of which can be air transported to the scene of an accident. The RERT can respond alone or with the Federal Radiological Monitoring Assessment Center (FRMAC) organized by the Department of Energy.

The lead Federal agency role is stated in the November 8, 1985, Federal Radiological Emergency Response Plan (FRERP). This lead role is for accidents involving radioactive material not owned or licensed by a Federal agency or licensed by an NRC Agreement State, as well as for radioactive fallout from foreign sources. The EPA would conduct an emergency response using the FRERP if the response of several Federal agencies is required. If a presidential disaster declaration is made in accordance with the Robert T. Stafford Disaster Relief and Emergency Relief Act, then the EPA is also the lead Federal agency in accordance with the Federal Response Plan (FRP). Federal financial assistance to state and local governments in response to a radiological emergency could be provided under the Stafford Act if the consequences of an accident impacted the U.S. or its territories and where Federal resources are required to supplement the affected states or territory. In addition, the EPA has presidential authority under CERCLA to conduct environmental cleanups and seek compensation from responsible parties for incidents not subject to the Price-Anderson amendments to the Atomic Energy Act. The Price-Anderson Amendments are not applicable to accidents involving international shipments of plutonium.

4.2.2 FEMA Role in Emergency Response

The Federal Emergency Management Agency (FEMA) coordinates emergency management activities of 15 Federal agencies under 44 CFR Part 351. Under this rule, FEMA's coordination effort is effected through two formal mechanisms:

- Federal Radiological Preparedness Coordinating Committee (FRPCC) for coordinating activities at the national level; and

- Ten Regional Assistance Committees.

Under the authority of this rule, FEMA assigns Federal agency responsibilities for assisting state and local governments and U.S. territories in radiological emergency planning and preparedness as well as planning and preparedness for the Federal response. These assignments are made on the basis of both common and unique responsibilities inherent in each organization's authorities, mission, and expertise.

FEMA provides leadership for Federal emergency management for a variety of activities including:

- Fostering cooperation and exchanges of information with nuclear industry organizations, technical organizations, and other constituents;
- Implementing a public education and information program including technical and financial support of the nation's Emergency Broadcast System;
- Developing, testing, and issuing radiological instruments and related guidance for radiation detection and measurement;
- Offering extensive radiologically-oriented training courses through the Agency's National Emergency Training Center in Emmitsburg, Maryland.

FEMA, in conjunction with other Federal agencies, coordinates the provision of Federal assistance to state and local governments for the following functions:

- Development of planning and preparedness guidance;
- Review and evaluation of state and local government emergency response plans;
- Evaluation of emergency preparedness exercises;
- Provision of technical assistance;
- Conduct of training courses.

As part of its responsibilities as the lead Federal agency for assisting state and local governments in developing and enhancing their planning and preparedness for all types of peacetime radiological emergencies, including transportation accidents involving radioactive materials, FEMA has published Guidance for Developing State, Tribal and Local Radiological Emergency Response Planning and Preparedness for Transportation Accidents (FEMA-REP-5) Revision 1 (June 1992). This document provides guidance for Federal, state, tribal, and local governments to use in developing and enhancing their emergency capabilities for responding to transportation accidents involving radioactive materials. The guidance contained in this document does not represent a Federal regulatory requirement, and its use by state, tribal, and local governments is voluntary.

FEMA also coordinates with the EPA and other Federal agencies for the provision of specialized functions such as establishment of PAGs, development of measures to

protect the public from food contaminated with radioactive material, and development of risk assessments for various types of radiological emergencies.

4.2.3 Federal Radiological Emergency Response Plan

In the case of an accident involving an international plutonium shipment, state and local governments have the primary responsibility for protecting the public and for taking emergency actions. If a situation arises which might lead to a release of radioactivity in waters within U.S. jurisdiction, the National Response Center at Coast Guard Headquarters in Washington, D.C., would be notified and would follow procedures as set forth in the Federal Radiological Emergency Response Plan (44 CFR 351). Federal assistance provided would be in response to a state or states' official request to augment state and local resources. FEMA coordinates the provision of Federal assistance to states, tribes, and local governments. However, if the response of several Federal agencies is required, then the EPA would become the lead Federal agency in accordance with the Federal Radiological Emergency Response Plan (FRERP) (November 8, 1985). The EPA is able to provide assistance to states under the presidential authorities of CERCLA. As lead agency, the EPA would assist the affected state(s) with protective action guidance, monitoring and dose assessment assistance, and coordination of available Federal resources. Described below are the specifics of the EPA's role as delineated in the FRERP:

(1) Notification. Upon notification of an emergency [the EPA will] (a) determine the appropriate response, (b) notify other Federal agencies of the emergency, inform them of the lead agency's actions, and provide a general assessment of the emergency, (c) activate the FRERP when multiple Federal agency response is warranted to ensure coordinated response; notify other Federal agencies of that action, (d) notify the Department of State of any radiological release with international implications.

(2) Response. (a) Deploy EPA personnel to the site, when appropriate; (b) designate a lead agency official at the site of the emergency to manage the onsite Federal response to the emergency, and to coordinate with the Senior FEMA Official and the Federal Radiological Monitoring and Assessment Center (FRMAC) Director regarding any onsite actions that may have offsite impacts; (c) establish an onscene base of operations to oversee the onsite and offsite response, monitor and support owner or operator, if requested, and serve as the principal Federal source of information about accident conditions for the Federal government as well as notifying other Federal agencies of the location of the onscene operations; (d) keep other agencies informed of conditions and Federal actions and provide an assessment of any of these conditions that might have significant offsite impact and of any means for mitigating the offsite consequences; (e) provide available radiological monitoring data to the state(s) and the FRMAC Director; and (f) deploy liaison

personnel to the onscene facilities such as the FRMAC.

(3) Protective Action Recommendations (PAR). The EPA will assist state and local authorities, if requested, by advising them on protective action recommendations for the public. In providing such advice, the EPA will use advice from other Federal agencies with technical expertise in those matters whenever possible and will coordinate with FEMA concerning the communication of PARs to state and local governments.

The EPA's responsibilities for development or evaluation, and presentation of protective action recommendations are to:

(a) Respond to requests from state and local governments for technical information and technical assistance,

(b) Provide staff liaison representatives to state authorities and the Senior FEMA Official, to help interpret the technical aspects of the accident and potential or actual offsite radiological consequences,

(c) Review all recommendations made by other Federal agencies carrying out statutory authorities to ensure that they are consistent with other Federal recommendations,

(d) Approve the general release of official offsite monitoring data and assessments to the public,

(e) Approve the release of offsite Protective Action Recommendations based on monitoring data and assessments to state and Federal authorities,

(f) Prepare a coordinated Federal position on protective action recommendations whenever time permits,

(g) Immediately provide or evaluate protective action recommendations, in cases of imminent peril and inform FEMA and other Federal agencies of any protective action recommendation information presented to state or local authorities,

(h) Present the Federal assessment of protective action recommendations, in conjunction with FEMA and other Federal agencies, whenever possible, to state or other offsite authorities,

(i) Support FEMA and other Federal agencies in assisting state and

local government agencies in implementing protective actions, if requested by these agencies.

(4) EPA's Responsibilities for the Control and Coordination of Information are to:

(a) Provide information to other Federal agencies and affected state and local governments about radiological conditions onsite, the status of the facility or radioactive material, and the potential or actual offsite radiological effects.

(b) Provide information to the media and other agency public information officers about the Federal response until a joint information center is established.

(c) Establish and manage Federal public information operations at a joint information center.

(d) Classify information concerning an accident in accordance with appropriate national security classification directives.

(e) Review and concur in the release of all federally generated information related to the onscene conditions and remain informed of all information not generated by Federal agencies.

(f) Approve the release of Federally developed radiological monitoring data through the lead agency's liaison officer located in the FRMAC.

(g) Assist the state(s) public information officer(s) in developing coordinated public information releases.

(h) In coordination with FEMA, provide information and respond to inquiries from Congress and the White House.

4.2.4 Immediate Protective Action

One rem is the radiation dose protective action guide established by the EPA for protective action. Protecting the public in the early phases of an accident so severe that plutonium release might occur would be focused on preventing inhalation of respirable particulates. The most effective protective action would probably be for the State(s) to order an evacuation of citizens away from the airborne plume. In the case of a maritime hazard, this concept may also involve the withdrawal of the involved ship away from populations potentially at risk. Sheltering in place is an

alternative which could be used if it can be demonstrated to be more effective than evacuation. An analysis of the relative effectiveness of sheltering and evacuation would have to consider variables such as notification time prior to a release, wind direction, shelter air-tightness, and evacuation time.

4.2.5 Long-Term Protective Action from Environmental Hazard

The EPA has not developed specific protective action guidelines for states to protect the public from the long-term effects of a plutonium release. However, in the event of an accident involving a potential release, the EPA would exercise its Federal guidance role to work with Federal, State, tribal, and local authorities to develop protective measures appropriate to the specifics of the situation.

5.0 INTERNATIONAL AND U.S. EXPERIENCE/ANALYSIS

There has been considerable international experience with shipping radioactive materials by sea. Shipments of high activity radioactive materials in Type B packages such as spent fuel are commonly transported by sea from one country to another, including the shipments of spent fuel to France from Japan for reprocessing and plutonium removal. Some countries such as Sweden depend on the sea mode for transporting their spent fuel. Spent fuel is transported in specially designed casks and usually, but not always, in exclusive-use vessels. The NRC has no record of any transient shipment of plutonium.

5.1 U.S. ENVIRONMENTAL ANALYSES/SHIPPING EXPERIENCE

The U.S. Department of Energy (DOE) has over a decade of experience with transporting research reactor spent fuel to the U.S. from foreign countries; since 1978, over 339 casks containing such fuel have been shipped without incident to the United States. Most have come by sea from research reactors outside North America. The DOE has conducted a number of studies that address the sea shipment of plutonium and spent fuel. These studies include Consequences of Postulated Losses of LWR Spent Fuel and Plutonium Shipping Packages at Sea, PNL-2093, 1977; The Final Environment Impact Statement on the Storage of U.S. Spent Power Reactor Fuel,DOE/EIS-0015 (1979); The Environmental Assessment on Shipment of Taiwanese Research Reactor Spent Nuclear Fuel (Phase I), DOE/EA-0321 (1986); and The Environmental Assessment on Shipment of Taiwanese Research Reactor Spent Nuclear Fuel (Phase II), DOE/EA-0363 (1988). The sea mode was also considered by the NRC in The Environmental Statement on the Shipment of Radioactive Material by Air and Other Modes, NUREG-0170, 1977. All of these studies, including PNL-2093 which examined shipments of plutonium

in 6M packages[7] as well as spent fuel casks, have concluded that the radiological risks are small, especially in comparison to the nonradiological risks of injury and death from mechanical and thermal accident forces.

In DOE/EA-0363 the total radiological risk in a port for accidents of all types including severe collision and subsequent severe fire was estimated to be 4.50E-04 person-rem[8] per port call (less than one latent cancer fatality per port call).

The radiological impact of the sea transport of plutonium as an alternative to air transport was evaluated in the Environmental Assessment for the Proposed New Agreement for Peaceful Nuclear Cooperation Between the United States and Japan and an Associated Subsequent Arrangement for the Return of Recovered Plutonium from Euratom to Japan, DOE/EA-0336 (1988). A severe collision and fire in port was examined and the risk was estimated to be about 1.0E-05 person-rem per port call.

The analyses mentioned above are reviewed and summarized in Environmental Analysis of Sea Shipment of Plutonium from Europe to Japan, ANL/IEP-88-50 (1988), the full text of which is included in Appendix C. Since sinking in deep waters is the most likely type of severe accident that might befall sea shipments, the radiological consequences of this type of accident were evaluated. Such an accident would involve the ingestion exposure pathway to man. A package was modeled as coming to rest in water over 3600 meters deep after a postulated collision and releasing its entire contents within 1 year following the accident. Published bioaccumulation factors (see Appendix A) were applied along with the International Commission on Radiation Protection ingestion dose model. The population dose was estimated to be 6.0E-05 person-rem and the individual dose was estimated to be 6.0E-08 rem. Such a scenario could only occur in the open ocean since coastal waters are much shallower, usually 200 meters or less.

In 1983, the NRC sponsored a study, Definition of Bounding Physical Tests Representative of Transport Accidents - Air and Marine conducted by the Illinois Institute of Technology (IIT). This study reviewed marine and air accident data for the period 1970-1979. The study considered transport vehicles, accident severity, and the likelihood of various accidents from which a set of physical tests were developed that would be representative of an environment from an extremely severe air or marine transport accident. For an extremely severe marine accident, a crush test, penetration test, slash test and immersion test were developed as well as a separate

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[7] The 6M is a DOT Specification packaging formerly used to transport plutonium.

[8] This is exponential notation. The number 4.50E-04 means 4.5 multiplied by 1/10,000; 4.5E+04 means 4.5 multiplied by 10,000.

sequence of a fire test, hose stream test, and an immersion test. A separate deep submersion test was also specified. The tests specified in the study appear to be more severe than the traditional tests recommended and adopted by IAEA member states.

The overall intent of the IIT study was to combine the tests with appropriate post-test acceptance criteria. The safety provided by the tests and development of appropriate acceptance standards was not pursued. Some accidents considered in the IIT study were also addressed in DOE assessments and the ECO Engineering Inc. report (See Section 5.2.2). For example, the Sea Witch accident was used as the basis for determining the thermal conditions of a fire environment in a marine accident. The IIT study concluded that the most severe fire environment likely to be encountered by a RAM package during maritime transport is a hydrocarbon fuel fire initiated by a collision with a tanker vessel. The highest thermal loads on a RAM package would be for those stowed on the weather deck. The upper bound should range from 26,300 to 35,700 Btu/hr-ft^2. The heat flux represented 35,700 Btu/hr-ft^2 can be represented by a blackbody radiation source at a temperature of 1675 °F. For a container below deck, the Sea Witch accident showed that the thermal environment during an extremely severe fire is relatively mild compared to the weather deck. The IIT study further concluded that the current packaging requirement in the IAEA standards to withstand a 1475 °F fire would be more than adequate for below-deck fires.

In 1985, the Office of Technical Assessment (OTA) published a report, The Transportation of Hazardous Materials, in which it examines the adequacy of current NRC transportation packaging regulations. The OTA study concluded that, "technical evidence and cask performance in service indicate that NRC Performance Standards yield spent fuel shipping cask design specifications that provide for a very high level of public protection - much greater than afforded in any other current hazardous materials shipping activity." It should be noted that these are the same standards that would be used for plutonium packages.

In summary, all analyses performed by the DOE and the NRC since 1977 have consistently shown that transport of radioactive materials, including plutonium, by sea has a high degree of safety when carried out in compliance with existing international and national regulations.

5.2 Current Shipments of Plutonium to Japan

Some of the public concern about plutonium shipments by sea has been focused as a result of the France-to-Japan shipment of plutonium which is currently underway (December 1992). Because of its high current profile, some of the details of this shipment are provided here together with information relating to a safety analysis of public interest groups.

5.2.1 France-Japan Shipment

The current shipment is being undertaken in a "purpose built" ship, the M/V Akatsuki Maru, designed for carrying spent fuel and modified for carrying Pu between France and Japan. It is double-hulled and equipped with special fire-fighting, radiation safety, navigation safety, and communications equipment. An armed escort ship of the Japanese Maritime Safety Agency is similarly equipped with communication and emergency response equipment.

The plutonium being shipped by sea to Japan is contained in specially designed multi-layered stainless steel Type B packagings that meet the IAEA mechanical, thermal, and pressure-resistance requirements. The package is designated FS-47 by the French design agencies and received a Certificate of Compliance from the French, Japanese, and several European Competent Authorities. These packagings are sufficiently massive that they were not subjected to the dynamic crush test. The French have indicated that the package will retain its integrity to depths of 30,000 meters. A schematic diagram of the package is contained in Appendix E. Ten FS-47's are contained in a transportainer for ease in handling and ten transportainers make up the entire cargo of the ship.

The transport plan of the current plutonium shipments was developed by Japan to be consistent with applicable shipping regulations and consistent with IAEA recommendations for physical protection of strategic materials. In the event of an accident such as a collision, flooding, fire, engine failure, etc., the crew of the transport ship and the officers of the Maritime Safety Agency serving as escorts on board the transport ship will promptly respond to the situation. The escort vessel will carry out rescue operations for the transport ship if necessary.

5.2.2 Analysis by ECO Engineering, Inc.

Recently, a paper was prepared under the auspices of Greenpeace International that is relevant to the subject of this study. Greenpeace International and the Nuclear Control Institute contracted with ECO Engineering, Inc. of Annapolis, Maryland, to prepare a paper entitled "A Review of the Proposed Marine Transportation of Reprocessed Plutonium from Europe to Japan," which was completed in March 1992. The paper reviews documentation on the subject of marine transportation of radioactive materials and maritime accident conditions. The paper contains some erroneous calculations, regulations are misstated and appear to be misunderstood. More importantly, however, the paper raises concerns over severe accidents, but does not balance those concerns with the likelihood or overall risk from such accidents. It should be noted that the report does not say that current transportation regulations, including those for packagings, are inadequate. The ECO Engineering, Inc. report is included as Appendix A. A review of the ECO Engineering report by Sandia National Laboratories (under contract to DOE) is included as Appendix E.

6.0 CONCLUSIONS

As noted in the introduction, Section 2904 of the Energy Policy Act of 1992 charges the President, in consultation with the Nuclear Regulatory Commission, with conducting a study on the safety of shipments of plutonium by sea. The study is to consider (1) the safety of the casks containing the plutonium, (2) the safety risks to the United States of such shipments, (3) upon request, the adequacy of a state's emergency plans with respect to such shipments, and (4) the Federal resources needed to assist the states on account of such shipments.

6.1 Safety of the Plutonium Packagings

Packagings used for shipping plutonium must be certified under the regulations of the country of origin of the shipment and accepted by the country of destination. In order to be certified by the U.S., France, Japan, or any other IAEA member state, a packaging must be shown to provide adequate shielding and containment, and remain subcritical when subjected to a sequence of impact, puncture, fire and immersion tests that represent severe accident conditions. Meeting these requirements means that packages containing plutonium will perform their safety function even when subjected to the forces and environments of severe shipboard accidents.

Type B packagings for shipments of radioactive materials (RAM) are the only hazardous materials packagings that must demonstrate the capability to contain materials in tests that represent severe accident environments. These performance standards are a key factor in the record of no RAM release from Type B packages in transportation over the last 40 years (see footnote 4). Meeting the IAEA requirements for operational and stowage controls assures that the packages are not subjected to most of the extraordinary accident environments recorded for sea events. The package will not be in proximity to large amounts of combustible materials or stowed in a manner that enhances the likelihood of loss overboard or package containment failure. As a result, the sequence of events that one must assume to occur in order to produce an environment leading to a release makes such an event extremely rare.

In summary, Type B packagings provide the primary protection for the public in the event of an accident. The packaging design must demonstrate significant accident resistance. That resistance has assured containment in all maritime accidents that have occurred and that are likely to occur.

6.2 The Risks to the States

There are a number of reliable risk assessments relating to sea shipments of plutonium and spent fuel (both shipped in Type B packagings). An environmental analysis prepared in 1988 of known planned transient shipments of plutonium, which had no scheduled stops in the U.S., indicated that environmental impacts would be small assuming that release of plutonium occurred either as a result of deep-water submergence or an accident on the continental shelf. These risk assessments are discussed in Section 5.1; they are predicated on conservative estimates of containment failure, dispersal of plutonium materials into the biosphere, and transfer to man. All of these evaluations indicate that the risks to man and the biosphere are extremely small, even though the conservative estimates used in the assessments are such as to make the risk larger than might otherwise be expected.

Two cases are generally distinguished in the analyses: accidents that occur on the high seas and those that occur on the coastal shelf or shallow water areas. On the high seas, ship/ship collisions are extremely rare. As a result, the principal contributors to accidents are on-board events such as fires or explosions that are associated with propulsion/fuel systems and damage as a result of severe weather. Such events are unlikely, but should such an event occur, the likelihood of sinking increases and the principal radiological risk to the population at large is from dispersal of plutonium in the sea. For dispersal of plutonium in the sea to occur the packages must fail either from pressures in deep water or from direct breech caused by the triggering event(s). In either case, a release to the deep ocean is estimated to have little radiological impact on man.

For accidents that might occur on the continental shelf where a ship is moving toward port and where, typically, there are greater numbers of other ships for potential participation in accidents, the risk assessment process becomes more complex. But even in this case, the risk assessments yield very low estimates of risk to the shorebound populations. This is primarily because of the capability of the package to withstand all but the most severe accident environments and because of the unlikely sequence of events to produce an extremely severe accident for this particular type of shipment. Moreover, it is possible to retrieve packages at depths up to 200 meters routinely and thus prevent any long-term release to near-shore environments. The same conditions that raise the frequency of occurrence of accidents (proximity to port, etc.) also mitigate results of accidents because of the speed of response of emergency management measures.

6.3 Adequacy of the States' Emergency Plans

The Federal Emergency Management Agency (FEMA) is coordinating the review of

all requests received under section 2904(a)(3) of the Energy Policy Act of 1992, for the review of State emergency response plans. To date, governmental jurisdictions (Hawaii, the Virgin Islands, and the Northern Mariana Islands) have requested that their emergency response plans be evaluated. Evaluations of the emergency response plans, which are not expected to be completed at the time this report is issued, will be provided in a separate response to each state.

6.4 Federal Resources Needed to Assist the States Resulting from Such Shipments

The U.S. Departments of Transportation and Energy, Coast Guard, U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency, and the Federal Emergency Management Agency all have actively addressed the development of emergency preparedness plans and training for a wide variety of accidents involving hazardous materials including radioactive. These agencies under the FRERP can respond to any radiological accident, including those in transportation, if requested by the authorities in charge of the situation.

In a maritime accident in which plutonium was potentially released in airborne particulate form, the immediate hazard to the public would be from the inhalation of plutonium particles. Direct external exposure is not a significant hazard. The majority of plutonium released to an aqueous environment collects in bottom sediments. Risk to humans would occur from ingestion of plutonium that has been bioconcentrated in plants or animals. Guidance for public protection from this hazard would need to be developed on a case by case basis.

For states that have coastlines potentially affected by, and ports that might be host to, such a shipment in event of an emergency situation, consideration must be given to preparations and actions that would be needed. Such preparations and actions may be the same as those that would be taken for any other hazardous cargo.

Aside from Federal direction to assure that consideration of sea mode accidents is included in existing emergency response plans and making states fully aware of the federal accident response capability, there are no additional Federal resources needed to assist the states in preparing to respond to accidents involving plutonium sea shipment.

7.0 RECOMMENDATIONS

1. Executive Branch departments and agencies and the Nuclear Regulatory Commission should ensure that they remain informed about potential shipments beyond those currently planned, and should remain alert to the possible need for revisions to existing transportation standards should changes in the circumstances relating to such shipments indicate that revised transportation standards are

necessary.

2. The Secretary of Energy should (a) arrange for the availability of this Study by publishing a notice in the Federal Register, (b) make available the Study to the appropriate emergency preparedness authorities of each coastal state, commonwealth, territory and possession of the United States and of the District of Columbia, (c) provide the Study to the International Atomic Energy Agency with a request that it be distributed to all member states of the Agency, and (d) make the Study available to the International Maritime Organization with a request that it be widely distributed to IMO member states.

3. Relevant Federal agencies should continue to participate fully in study groups or working groups that may be instituted by the IAEA, the IMO, or other international bodies on possible revisions to standards relevant to international transportation. In addition, relevant Federal agencies should seek to expand the involvement of industry and the general public in the regulation process by publicizing the meetings of such groups in advance, by requesting their review of proposed regulations, and make available minutes of the meetings.

4. The Federal Emergency Management Agency should promptly complete a review of the adequacy of State emergency plans with respect to plutonium shipments as already requested by certain States pursuant to Section 2904 (a)(3) of the Energy Policy Act of 1992; and should solicit submission of emergency plans by all other coastal states for review pursuant to the provisions of the Act.

5. Federal agencies should, as appropriate, take into account the need for any federal resources identified in FEMA's evaluation of State emergency response plans in preparing agency budget submissions for FY94 and subsequent fiscal years.

8.0 REFERENCES

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4. 10 CFR Part 73, Physical Protection of Plants and Materials.

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6. IAEA Safety Series 9, Basis Safety Standards for Radiation Protection, 1982 Edition.

7. IAEA Safety Series 7, Explanatory Material for the IAEA Regulation for the Safe Transport of Radioactive Material (1985 Edition), Second Edition (As Amended 1990).

8. Ports and Waterways Safety Act of 1972, Public Law 92-340, (86 Stat. 424).

9. Port and Tanker Safety Act of 1978, Public Law 95-474, (92 Stat. 1471).

10. Magnuson Act.

11. Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, (86 Stat. 816).

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14. International Convention on Standards of Training, Certification, and Watchkeeping for Seafares.

15. Transportation of Radioactive Materials; Memorandum of Understanding (between the Nuclear Regulatory Commission and the Department of Transportation), 44 Fed.Reg. 38690, July 2, 1979.

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17. IAEA Safety Series 37, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition), Third Edition (As Amended 1990).

18. IAEA - TECDOC-262, 1982; "Emergency Response Planning for Transport Accidents Involving Radioactive Materials."

19. Manual of Protective Action Guides (PAGs) and Protective Actions for Nuclear Incidents

20. 44 CFR Part 351, Radiological Emergency Planning and Preparedness, (March 11, 1982)

21. Public Health Service Act, as amended, (1970).

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27. Price-Anderson Amendments Act of 1988, Public Law 100-408, (102 Stat. 1066).

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29. Consequences of Postulated Losses of LWR Spent Fuel and Plutonium shipping Packages at Sea, PNL-2093, 1977

30. The Final Environment Impact Statement of the Storage of U.S. Spent Power Reactor Fuel, DOE/EIS-0015, 1979

31. The Environmental Assessment of Shipment of Taiwanese Research Reactor Spent Nuclear Fuel (Phase I), DOE/EA-0321, 1986

32. The Environmental Assessment on Shipment of Taiwanese Research Reactor Spent Nuclear Fuel (Phase II), DOE/EA-0363, 1988

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35. Environmental Analysis of Sea Shipment of Plutonium from Europe to Japan, ANL/IEP-88-50, 1988

36. Napadensky, H.; et al., "Definition of Bounding Physical Tests Representative of Transport Accidents - Air and Marine;" Final Report, Contract No. NRC-04-81-203, IITRI Project K06019, November 1983.

37. Transportation of Hazardous Materials, Office of Technology Assessment, OTA-SET-304, Library of Congress Catalog Number 86-600542, July 1986.

38. "A Review of the Proposed Marine Transportation of Reprocesses Plutonium from Europe to Japan," ECO Engineering Inc., J.D. Porricelli March 1992

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APPENDIX A
Radiological Hazards of Plutonium

Plutonium (Pu) is a radioactive member of the actinide series of elements with a high atomic number (94). All isotopes of plutonium, including Pu-239, the predominant isotope in the Japanese transient shipments, emit alpha particles as their primary decay mode. Pu-239 has a half-life of 24,065 years.

Although emitted alpha particles have high energies, they have extremely low penetration. A sheet of paper or even the dead layer of skin on the exterior of the human body is an effective shield against direct radiation effects. Because alpha radiation has such extremely low penetration, standing beside a container of plutonium does not pose a health threat.

Plutonium poses a potential human or ecological threat only when it is in a form that can be inhaled or ingested by a living organism, which can thereby result in close contact of the plutonium with living tissue. If unprotected living tissue, such as the lungs or other body organs, comes into direct contact with plutonium, then the localized radiation hazard is high.[9] The radiation hazard from plutonium is evaluated in terms of dispersal mechanisms that might achieve the necessary direct contact with living tissue. Thus, mechanisms that result in inhalation, and to a lesser extent, ingestion of plutonium directly or from the food chain are the primary focus in any evaluation of risk from plutonium shipments.

- Uptake in the Human Body

Inhalation is generally the pathway of greatest concern to man. Plutonium must be in the form of particulates, whether released directly into the air or resuspended from previously deposited materials, to be available for inhalation. Ingestion is a less significant hazard, in part because of the cumulative dilution in transfer from soils or water to food and in part because ingested plutonium is poorly absorbed from the gastrointestinal tract. Alternate modes of entry, such as wound contamination, are unlikely occurrences for the general population not involved directly in any severe

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[9] Unlike exposures to x-rays and gamma rays, where the resultant charged particle flux results in a linear energy transfer (LET) or energy deposition of the order of 0.2 to 2 KeV per micron of tissue thickness, 5 MeV alpha particles result in energy deposition at a track average rate of more than 100 KeV per micron of tissue thickness. Thus, x- and gamma radiations are referred to as low linear-energy-transfer (low LET) radiations and alpha particles are referred to as high linear-energy-transfer (high LET) radiation. Most alpha particles emitted by Pu-239 have energies of about 5 MeV. High LET radiations have a greater biological effect per unit exposure (rad) than low LET radiations. For cell killing and other readily observed effects, the relative biological effectiveness (RBE) of high LET radiations may be ten or more times greater than that of low LET radiations.

occurrence affecting a sea shipment of plutonium.

Depending on their size, inhaled particles are deposited in various regions of the respiratory tract, where they remain until translocated to other body organs or removed. Larger particles deposited in the larger air passages of the lung are removed by normal body mechanisms within a few days, but some of the smaller particles, which can be carried into the deeper pulmonary regions of the lung, are removed much more slowly and have a biological half-residence-time of a year or more. This is postulated to lead to an increase in the risk of lung cancer in exposed individuals. Inhaled plutonium may also dissolve and be transferred to and be retained in other body organs, and lead to an increased risk of cancers of the bone and liver. For less soluble plutonium compounds, such as the plutonium oxide being shipped by the Japanese, transfer to other organs would contribute only marginally to the total risk that results from the inhalation pathway.

As noted above, ingestion of plutonium generally represents a smaller environmental risk to humans than inhalation. A relatively small fraction of any ingested plutonium may be transferred to the bloodstream from the digestive tract and be deposited in bone, liver, gonadal tissue, and other organs. In most cases, less than one part in ten thousand (1.0E-04)of the ingested material is absorbed by the body, with the remainder excreted. The potential consequences as a result of ingestion are mainly bone and liver cancers.

A potential risk of genetic damage to the progeny of exposed individuals exists because of possible accumulation of plutonium in gonadal tissue. However, compared to other plutonium hazards, this risk is smaller by factors of 1000 to 10,000.

- Ecological Hazard in Aqueous Environments

Since plutonium is a radiation hazard only when it comes into direct contact with a living organism, any assessment of the ecological hazards of plutonium dispersal must focus on potential mechanisms in the environment that could bring plutonium into direct contact with living organisms.

<u>Lake Michigan Fallout Study</u>

A study of the plutonium that entered Lake Michigan as a result of atmospheric fallout from weapons testing has shown that 95% is rapidly removed from the water column to the sediments. Further studies of Lake Michigan have demonstrated that plutonium is strongly associated with the sediments and is not easily solubilized under aerobic conditions. The chemical behavior of plutonium in fresh water is not fully understood, but many studies have consistently demonstrated that plutonium will quickly associate with the solid phase, and, under the oxidation-reduction conditions normally encountered in the environment, solubilization will be minimal. As with

the freshwater studies, marine studies have shown that over 90% of the plutonium entering either as fallout or in the form of liquid effluent was found trapped in the sediments.

Irish Sea Study

A study of the fate of relatively soluble plutonium released into the Irish Sea over a period of twenty years has noted that over 95% of the plutonium released was removed to the sediments in a relatively short time period. The mechanism responsible for carrying the plutonium to the sediment bed appears to be neither biological nor a simple diffusion mechanism. Sorption to particles in the water column and subsequent deposition in the sediment bed seems to be the primary mechanism for removing plutonium from the water.

- Summary of Plutonium Behavior in Water Bodies

Even though plutonium is strongly bound to the sediment in most water bodies, it can still move with water currents and other physical actions. The effects of biota on plutonium are mostly seen in the sediments. Both microorganisms and more complex species can alter the depth profiles. Primary amines released deep in the sediment by anaerobic microbes can solubilize the plutonium in a lower region and carry it toward the surface. However, microbes in the interface region, along with chemical reactions, bind the plutonium to the sediment again. Larger biota can physically alter deposition profiles by burrowing, tunneling, and otherwise reworking a sediment bed and allowing overlying waters to penetrate.

The form of remaining soluble plutonium in water environments is determined by the oxidizing or reducing capability of the water environment. The availability of plutonium for uptake by plants and other biological systems varies depending on the valence state of the plutonium. The predominant chemical form of soluble plutonium is not consistent in all studies. The Lake Michigan study, for example, indicates that most of the soluble fraction is in a negatively charged form with a particle diameter of less than 30 Angstroms, which may indicate sorption of the plutonium to colloidal silica and other negatively charged colloidal minerals. There has also been speculation that the VI valence state can be an important environmental species of the element.

The most significant role of certain biota is the bioconcentration of plutonium. Marine algae (i.e., seaweed), with concentration factors of up to 1000, are by far the most notable. Shellfish, even though they have lower concentration factors, are important because they are a direct human food source.

• Health Effects Overview

Direct inhalation is the principal pathway of concern. With respect to the ingestion pathway, the concentration effect in some elementary food chains is offset by strong discrimination against plutonium absorption by the human body. These facts, coupled with the significant dilution of any releases to the sea, mean that releases to the sea are of considerably lower human health concern than airborne releases where humans might be in the path of the aerosol cloud.

APPENDIX B
IAEA Regulations Governing the Safe Transport of RAM

This appendix contains excerpts from the IAEA documents which describe the Type B performance test requirements and the reasoning behind the regulations. U.S. regulations are similar to those for the IAEA. NRC and DOT regulations are modified from time to time to be consistent with the principal content of IAEA's Regulations for the Safe Transport of Radioactive Material (1985 Edition), Safety Series No. 6.

SAFETY SERIES No. 6

REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL

1985 Edition
(As Amended 1990)

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1990

626. The specimen shall be subjected to the cumulative effects of the tests specified in para. 627 and para. 628, in that order. Following these tests, either this specimen or a separate specimen shall be subjected to the effect(s) of the water immersion test(s) as specified in para. 629 and, if applicable, para. 630.

627. *Mechanical test:* The mechanical test consists of three different drop tests. Each specimen shall be subjected to the applicable drops as specified in para. 548. The order in which the specimen is subjected to the drops shall be such that, on completion of the mechanical test, the specimen shall have suffered such damage as will lead to the maximum damage in the thermal test which follows.

(a) For drop I, the specimen shall be dropped onto the target so as to suffer the maximum damage, and the height of the drop measured from the lowest point of the specimen to the upper surface of the target shall be 9 m. The target shall be as defined in para. 618.

(b) For drop II, the specimen shall be dropped so as to suffer the maximum damage onto a bar rigidly mounted perpendicularly on the target. The height of the drop measured from the intended point of impact of the specimen to the upper surface of the bar shall be 1 m. The bar shall be of solid mild steel of circular section, (15.0 ± 0.5) cm in diameter, and 20 cm long unless a longer bar would cause greater damage, in which case a bar of sufficient length to cause maximum damage shall be used. The upper end of the bar shall be flat and horizontal with its edges rounded off to a radius of not more than 6 mm. The target on which the bar is mounted shall be as described in para. 618.

(c) For drop III, the specimen shall be subjected to a dynamic crush test by positioning the specimen on the target so as to suffer maximum damage by the drop of a 500 kg mass from 9 m onto the specimen. The mass shall consist of a solid mild steel plate 1 m by 1 m and shall fall in a horizontal attitude. The height of the drop shall be measured from the underside of the plate to the highest point of the specimen. The target on which the specimen rests shall be as defined in para. 618.

628. *Thermal test:* The thermal test shall consist of the exposure of a specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent and in sufficiently quiescent ambient conditions to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800°C for a period of 30 minutes, or shall be any other thermal test which provides the equivalent total heat input to the **package**. The fuel source shall extend horizontally at least 1 m, and shall not extend more than 3 m, beyond any external surface of the specimen, and the specimen shall be positioned 1 m above the surface of the fuel source. After the cessation of external heat input, the specimen shall not be

cooled artificially and any combustion of materials of the specimen shall be allowed to proceed naturally. For demonstration purposes, the surface absorptivity coefficient shall be either 0.8 or that value which the **package** may be demonstrated to possess if exposed to the fire specified; and the convective coefficient shall be that value which the designer can justify if the **package** were exposed to the fire specified. With respect to the initial conditions for the thermal test, the demonstration of compliance shall be based upon the assumption that the **package** is in equilibrium at an ambient temperature of 38°C. The effects of solar radiation may be neglected prior to and during the tests, but must be taken into account in the subsequent evaluation of the **package** response.

629. *Water immersion test:* The specimen shall be immersed under a head of water of at least 15 m for a period of not less than eight hours in the attitude which will lead to maximum damage. For demonstration purposes, an external gauge pressure of at least 150 kPa (1.5 kgf/cm^2) shall be considered to meet these conditions.

Water immersion test for packages containing irradiated nuclear fuel

630. The specimen shall be immersed under a head of water of at least 200 m for a period of not less than one hour. For demonstration purposes, an external gauge pressure of at least 2 MPa (20 kgf/cm^2) shall be considered to meet these conditions.

Water leakage test for packages containing fissile material

631. **Packages** for which water in-leakage or out-leakage to the extent which results in greatest reactivity has been assumed for purposes of assessment under paras 564–567 shall be excepted from the test.

632. Before the specimen is subjected to the water leakage test specified below, it shall be subjected to the tests in para. 627(b), and either para. 627(a) or (c) as required by para. 548, and the test specified in para. 628.

633. The specimen shall be immersed under a head of water of at least 0.9 m for a period of not less than eight hours and in the attitude for which maximum leakage is expected.

SAFETY SERIES No. 7

EXPLANATORY MATERIAL FOR THE IAEA REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIAL (1985 EDITION)

Second Edition
(As Amended 1990)

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1990

Tests for demonstrating ability to withstand accident conditions in transport

E-626.1. The accident tests specified in the Regulations were originally developed to satisfy two purposes. First, they were conceived as producing damage to the package equivalent to that which would be produced by a very severe accident (but not necessarily all conceivable accidents). Second, the tests were stated in terms which provided the engineering bases for the design. Since analysis is an acceptable method of qualifying designs, the tests were prescribed in engineering terms which could serve as unambiguous, quantifiable input to these calculations. Thus, in the development of the test requirements attention was given to how well these tests could be duplicated under field conditions (see, for example, para. E-618).

E-626.2. The 1961 Edition of the Regulations was based on the principle of protection of the package contents, and hence the public health, from the consequences of a 'maximum credible accident'. This phrase was later dropped because it did not give a unique level or standard with which to work and which was necessary to ensure the international acceptability of unilaterally approved designs (see para. 114). Recognition of the statistical nature of accidents is now implicit in the requirements. A major aim of the package tests is international acceptability, uniformity and repeatability; tests are designed so that the conditions can be readily reproduced in any country. The test conditions are intended to simulate very severe accidents in terms of the damaging effects on the package. They will therefore produce damage exceeding that arising in the vast majority of incidents recorded, whether or not a package of radioactive material was involved.

E-626.3. The purpose of the mechanical tests (para. 627) and the thermal test (para. 628) that follow is to impose on the package damage equivalent to that which would be observed if the package were involved in severe accidents. The order and type of tests are considered to correspond to the order of environmental threat to the packaging in a real transport accident, i.e. impact and puncture followed by thermal exposure. The test sequence also ensures mechanical damage to the package prior to the imposition of the thermal test; thus the package is most liable to sustain maximum thermal damage. The mechanical and thermal tests are applied to the same specimen sequentially. The immersion test (para. 629) may be conducted on a separate specimen because the probability of its occurrence in conjunction with a thermal/mechanical accident is extremely low.

E-627.1. Mechanical test requirements for Type B packages were introduced first in the 1964 Edition of the Regulations, replacing the requirement of withstanding a 'maximum credible accident', which was not specified by test requirements. On the assumption that Type B packages are likely to be used in all modes of transport, the Type B test requirements are intended to take into account a large range of accidents for land, sea and air transport which can expose packages to severe

dynamic forces. The mechanical effects of accidents can be grouped into three categories: impact (crash), crush and puncture loads. Though the figures for the test requirements (9 m drop for impact and crush and 1 m drop for puncture) were not derived directly from accident analyses at the time when first introduced into the Regulations, subsequent risk and accident analyses have demonstrated that they represent very severe transport accidents [26–31].

E-627.2. In drop I, the combination of the 9 m drop height, unyielding target and most damaging attitude produce a condition in which the majority of the drop energy is absorbed in the structure of the packaging. To create the same damage in a transport accident, with the yielding surfaces that actually exist, it would be necessary to increase the impacting velocity by a factor of 2 or more relative to that required by the test prescribed in the Regulations [29–31].

E-627.3. Thin walled packaging designs or designs with sandwich walls are sensitive to puncture loads with respect to both loss of containment integrity and loss of thermal insulation. Even thick walled designs may have weak points such as closures of drain holes, valves, etc. Puncture loads can be expected in accidents as impact surfaces are frequently not flat. In order to provide safety against these loads, the 1 m drop test onto a rigid bar has been required (drop II). The drop height and punch geometry parameters are more the result of an engineering judgement than deductions from accident analyses.

E-627.4. The degree of safety provided by the drop I test is smaller for light, low density packages than for heavy, high density packages, owing to the reduced impact energy and to the increased probability of impacting a relatively unyielding 'target' [29, 32–35]. Such packages may also be sensitive to crush loads [32–35]. Accident analyses show that the probability of dynamic crush loads in land transport accidents is higher than that of impact loads because lightweight packages are transported in larger numbers or together with other packages [26–28]. Also, handling and stowage mishaps can lead to undue static or dynamic crush loads.

E-627.5. In order to provide safety against dynamic crush loads (the static ones are covered to some extent by the compression test requirement) the crush test (drop III) was included in the regulatory requirements in the 1985 Edition of the Regulations. The introduction of this test requirement was justified also by the fact that light, low density packages, which may not be inherently stiff as a result of thick shielding materials, are often used for the transport of large amounts of alpha emitters, e.g. plutonium oxide powders and plutonium nitrate solutions, which are radioactive materials with high potential hazards.

E-628.1. Work in the United States of America [26–28, 36–39] suggests that the thermal test specified in para. 628 provides an envelope of environments which encompasses most transport related accidents involving fires. The Regulations

specify a test condition based on a liquid hydrocarbon-air fire with a duration of 30 minutes. Other parameters relating to fire geometry and heat transfer characteristics are specified in order to define the heat input to the package.

E-628.2. The thermal test specifies a liquid hydrocarbon pool fire which is intended to encompass the damaging effects of fires involving liquid, solid o. gaseous combustible materials. Liquids such as LPG, LNG and liquid hydrogen are covered by the test because pool fires with such fuels generally will not last for 30 minutes. Liquid petroleum products are frequently transported by road, rail and sea and would be expected to give rise to a fire following an accident. Liquids that can flow around the package and create the stipulated conditions are restricted to a narrow range of calorific values, so the severe fire is quite well defined.

E-628.3. The flame temperature and emissivity (800°C and 0.9) define time and space averaged conditions found in pool fires. Locally, within fires, temperatures and heat fluxes can exceed this description. However, non-ideal positioning of a package within a fire, the movement with time of the fire source relative to the package, shielding by other non-combustible packages or conveyances involved in the accident, wind effects and the massive structure of many Type B packages will all combine to average the conditions to conform to, or be less severe than, the test description [38, 39]. The presence of a package and remoteness from the oxygen supply (air passing through about 1 m of flame) may both tend to depress the flame temperature adjacent to the package. Natural winds can supply extra oxygen but tend to remove flame cover from parts of the package, hence the requirement of quiescent ambient conditions. The flame emissivity is difficult to assess, as direct measurements are not generally available, but indications from practical tests suggest that the 0.9 value specified is an overestimate. The combination of parameters in the test results in a severe flame description unlikely to be exceeded by accident conditions.

E-628.4. The duration of a large petroleum fire depends on the quantity of fuel involved and the availability of fire fighting resources. Liquid fuel is carried in large quantities but, in order to form a pool, any leakage must flow into a well defined area around the package with consequent losses by drainage. In general, not all the contents of a single tank will be involved in this way as much will be consumed either in the tank itself or during transfer to the vicinity of the package. The contents of other tanks will most likely be burnt at a more remote location as the fire moves from tank to tank. Recognition must also be given to the fact that, when lives are not directly at risk, fires are often allowed to continue to natural extinction. Consequently, historical records of fire durations should be viewed critically. The 30 minute duration is therefore chosen from consideration of these factors and encompasses the low probability of a package being involved in a fire with a large volume of fuel and the 'worst case' geometry specified. The low probability, long duration fire is most likely to occur in combination with a geometry which effectively reduces

the thermal input, with the package resting on the ground and/or protected by the vehicle structure. The heat input from the thermal test is thus consistent with realistic, severe accident situations.

E-628.5. The fire geometry is designed to provide the highest heat input to the package. The 1 m elevation of the package ensures that the flames are well developed at the package location, with adequate space for the lateral in-flow of air. The extension of the fuel source beyond the package boundary ensures a minimum flame thickness of about 1 m, providing a reasonably high flame emissivity. Thicknesses beyond 3 m can lead to oxygen starvation at the centre and relatively low temperatures close to the package. This description minimizes the effects of radiation losses and maximizes heat input to the packages, providing a very severe model of a fire.

E-628.6. Previous editions of the Regulations have required that no artificial cooling should be used before three hours have expired following cessation of the fire. The 1985 Edition deletes reference to the three hour period, implying that the assessment of temperatures and pressures should continue until all temperatures, internal and external, are falling and that natural combustion of package components will continue without interference. Only natural convection and radiation contribute to heat loss from the package surface after the end of the fire.

E-628.7. The Regulations allow other values of surface absorptivity to be used as an alternative to the standard value of 0.8 if they can be justified. In practice, a pool fire is so smoky that it is probable that soot will be deposited on cool surfaces, modifying conditions there. This is likely to increase the absorptivity but interpose a conduction barrier. The value of 0.8 is consistent with thermal absorptivities of paints and can be considered as approximating the effects of surface sooting. As a surface is heated, the soot may not be retained and lower values of surface absorptivity could result.

E-628.8. The 1985 Edition of the Regulations removes the previous ambiguity of "convection heat input in still ambient air at 800°C" but does not specify a value for the coefficient, requiring the designer to justify the assumptions. A significant proportion of the heat input may derive from convection, particularly when the outer surface is finned and early in the test when the surfaces are relatively cool.

E-628.9. The effects of the thermal test are, of course, dominated by increased package temperatures and consequent effects such as high internal pressures. The peak temperature depends to some extent on the initial temperature, which should therefore be determined using the highest appropriate initial conditions of internal heat generation, solar heating and ambient temperature. For a practical test, not all of these initial conditions will be achievable, so appropriate measurements (e.g. ambient temperature) should be made, and package temperatures corrected after the test.

E-628.10. The fire conditions defined in the Regulations and the requirement for full engulfment for the duration of the test represent a very severe test of a package. It is not intended to define the worst conceivable fire. In practice, some parameters may be more onerous than specified in the Regulations but others would be less demanding. For example, it is difficult to conceive of a practical situation where all surfaces of a package could experience the full effects of the fire, since it would be expected that a significant fraction of the surface area would be shielded, either by the ground or wreckage and debris arising from the accident. Emphasis has been placed on the overall fire prescription rather than on the individual parameters chosen, and in this respect the conditions specified represent a very severe test for any package [39]. It should also be emphasized that the thermal test is only one of a cumulative series of tests which must be applied to yield the maximum damage in a package. This damage must remain demonstrably small in terms of stringent criteria of containment integrity, external radiation level and nuclear criticality safety.

E-629.1. As a result of transport accidents near or on a river, lake or sea, a package could be subjected to an external pressure from submersion under water. To simulate the equivalent damage from this low probability event, transport regulations require that a packaging be able to withstand external pressures resulting from submersion at reasonable depths. Engineering estimates indicated that water depths near most bridges, roadways or harbours would be less than 15 m. Consequently, 15 m was selected as the immersion depth for packages (it should be noted that packages containing large quantities of irradiated nuclear fuel must be able to withstand a greater depth (see para. 630)). While immersion at depths greater than 15 m is possible, this value was selected to envelop the equivalent damage from most transportation accidents. In addition, the potential consequences of a significant release would be greatest near a coast or in a shallow body of water. The eight hour time period is sufficiently long to allow the package to come to a steady state from rate dependent effects of immersion (e.g. flooding of exterior compartments).

E-629.2. Since the primary purpose of the immersion test is to demonstrate that a package can maintain its structural integrity when subjected to an external pressure, a pressure test or calculation can be substituted for actual immersion.

Water immersion test for packages containing irradiated nuclear fuel

E-630. See paras E-550.1 to E-550.3 and E-629.1 and E-629.2.

Water leakage test for packages containing fissile material

E-632. This test is required because water in-leakage may have a large effect on the allowable fissile material content of a package. The sequence of tests is selected to

provide conditions which will allow the free ingress of water into the package, together with damage which could rearrange the fissile contents.

E-633. The submersion test is intended to ensure that the criticality assessment is conservative. The sequence of tests prior to the submersion subject the package to accident simulating conditions similar to those which it could encounter during a severe accident near or on water in transport.

APPENDIX C
Environmental Analysis of Sea Shipment of Plutonium From Europe to Japan

Several earlier Federal analyses are reviewed and summarized in Environmental Analysis of Sea Shipment of Plutonium from Europe to Japan, ANL/IEP-88-50 (1988), the full text of which is included in this appendix.

ANL/IEP-88-50

ENVIRONMENTAL ANALYSIS OF SEA SHIPMENT OF PLUTONIUM FROM EUROPE TO JAPAN

September 1988

Argonne National Laboratory

Office of International Energy Development Programs

SUMMARY

This environmental analysis evaluates the environmental impacts of sea transportation of plutonium from Europe to Japan for normal and accidental conditions. A credible accidental event leading to potential environmental release of radioactivity is postulated. This event is the submergence of the cask to sufficient depth to compromise the integrity of the cask due to extreme hydrostatic pressure resulting in the subsequent release of radioactivity. The environmental impact of this release was found to be small even assuming in the analyses the unlikely event of the entire contents of the container being released in one year. It was concluded from a comparison of the risks for sea and air transportation modes for plutonium from Europe to Japan that they are all small and comparable. A Department of Defense analysis concluded that the physical protection measures for the sea transport of plutonium proposed in Annex 5, taken in conjunction with the side letters of November 4, 1987, and the side letter to be exchanged in conjunction with the modification, provide a satisfactory basis for establishing adequate physical security for future sea shipments of plutonium from Europe to Japan.

Environmental Analysis of Sea Shipment of Plutonium from Europe to Japan

1.0 INTRODUCTION

On July 17, 1988, a new Agreement for Cooperation between the United States and Japan concerning the peaceful uses of nuclear energy pursuant to Section 123 of the Atomic Energy Act (AEA), as amended, entered into force. On July 18, 1988, an associated "subsequent arrangement" with EURATOM pursuant to Section 131 of the AEA entered into force. Together, these actions provide the framework for the return from EURATOM to Japan of plutonium recovered from spent fuel reprocessed for Japan in France or the United Kingdom. Article 11 of the Agreement for Cooperation requires the parties to make separate arrangements, consistent with non-proliferation and national security interests, to facilitate certain aspects of the Japanese nuclear program. The separate arrangements are set forth in an Implementing Agreement and constitute an integral part of the Agreement for Cooperation under the Atomic Energy Act. In Article 1(1)(a)(iii) of the Implementing Agreement, the parties agreed to the transfer of spent reactor fuel from Japan to facilities in France and the United Kingdom for reprocessing (i.e., the removal of residual plutonium and residual uranium). In Article 1(3)(a)(iii) of the Implementing Agreement, the U.S. is required to give its consent to EURATOM under the U.S.-EURATOM Agreement for Cooperation for return of the recovered material to Japan. However, one of the conditions for this approval, as set forth in Annex 5 of the Implementing Agreement is that the recovered plutonium must be shipped by air.

In view of the difficulties encountered in development of a suitable cask for air shipment of plutonium, the government of Japan recently requested that the U.S. agree to sea shipment of plutonium from EURATOM to Japan under the U.S.-Japan Agreement for Cooperation. In addition, the Japanese advised that they have not excluded the possibility that they may request, at some future date, addition to Annex 1 of the Implementing Agreement, a facility for the fabrication of mixed oxide (UO_2-PuO_2) fuel which would also be transported by sea. On May 26, 1988, the administration notified Congress that it would, "consider programmatic shipment by sea under adequate physical security pursuant to the Implementing Agreement. Such an arrangement would be treated by the administration as a 'subsequent arrangement' in accordance with Section 131 of the Atomic Energy Act." Japanese and U.S. representatives have now worked out a possible modification of Annex 5 of the Implementing Agreement which would specify the physical protection measures applicable to sea transportation of plutonium.

1.1 Previous Environmental Assessment

In support of the Agreement of Cooperation and, in particular, the "subsequent agreement" involving air shipments of plutonium, the DOE prepared an environmental assessment, DOE/EA-0336 (see references), of the potential environmental impacts of air shipments of plutonium oxide over U.S. territories and the global commons. The finding of no significant impact based on the EA concluded that there would be no potential significant environmental impacts to the U.S. or global commons resulting from the air shipments of plutonium. Also considered in the EA as an alternative mode of transportation was the sea shipment of plutonium. The EA concluded that under normal

circumstances, a sea transfer should have no adverse effect on the global commons. However, "from a physical security standpoint and especially if one assumed that a civilian carrier rather than a military vessel is employed to carry the plutonium, shipment by sea appears to offer a lesser degree of protection of the human environment against risks associated with the seizure of plutonium than would be provided by shipment of the material by air." It should be noted that the latter conclusion did not take into account specific physical protection measures and safeguards as provided for in the proposed addition to Annex 5 of the Implementing Agreement.

2.0 ENVIRONMENTAL CONSEQUENCES OF SEA SHIPMENT OF PLUTONIUM OXIDE AND MIXED OXIDE (MOX) FUEL ELEMENTS

2.1 Introduction

There has been considerable international experience in shipping radioactive material by sea. Large shipments of radioactive materials such as spent fuel are commonly transported by sea from one country to another, and some countries depend on the sea mode for transporting their spent fuel. These shipments are transported in specially designed shipping casks. No maritime accident has ever occurred that resulted in release of radionuclides from shipping casks. A number of studies including (DOE/EIS-0015, DOE/EA-0321) on the sea shipment of spent fuel, which contains a high concentration of highly radioactive fission products, have concluded that the radiological risks are small compared to the non-radiological risk of injury and death caused by collision of the ship or shipboard fire or explosion.

The radiological impacts for the sea transport of plutonium, as an alternative to air transport, was evaluated in DOE/EA-0336. The population risk for normal sea transport per Kg of PuO_2 powder was found to be 3×10^{-7} rem/km.

The risk involving a port accident and subsequent fire was estimated to be 1×10^{-5} person-rem per port call. The modification to Annex 5 does not permit scheduled stops at ports. An accident involving a collision with subsequent dispersal of plutonium in the sea was not evaluated. This environmental analysis considers an accident scenario involving the dispersal of plutonium in the high seas and also the same scenario involving transportation of mixed oxide fuel elements containing 3-11% plutonium in the mixed oxide.

2.2 Radiological Impacts under Routine Conditions

The radiological impacts which pertain to the exposure to radioactivity to the crew and guards as a result of handling the plutonium oxide is discussed below.

Prior to transport across the ocean, the plutonium oxide is contained in a vessel which, in turn, would be placed in a large cask. Mixed oxide fuel elements would be placed directly in the cask. The casks are transferred aboard ship and stowed below deck in a hold. The hold would be strategically selected so that it would sustain relatively minimal damage in the event of a collision. The ship would be dedicated to radioactivity shipment and will contain no other cargo.

The shipping casks, would conform with the IAEA transport guidelines for the safe transport of radioactive materials, provisions of the International Dangerous Goods Code, and other relevant safety agreements. The U.S. regulations are compatible with the guidelines of the IAEA. These regulations and guidelines include a requirement as to the quantity of plutonium or mixed oxide fuel elements in the packages and vessel that can be shipped safely and a requirement for demonstration that the cask can survive with minimum loss of shielding and radioactive material from tests simulating a severe transportation accident.

In DOE/EA-0336, the radiological impacts under normal conditions were estimated for the case of transport of plutonium oxide in the PAT-1 container, which has been certified by NRC for air transport. These impacts are applicable to the Type B cask currently considered for sea shipment. If mixed oxide fuel elements containing 3-11% Pu or plutonium oxide are shipped in a Type B spent fuel cask, the dose estimates for both would be expected to be comparable to the dose estimates given for PuO_2 in DOE/EA-0336, and would be small, namely, 5 person-rem per year.

2.3 Radiological Impacts under Accident Conditions

During the transoceanic portion of the plutonium shipments, accidents or incidents involving the ship might include collision, immersion, and/or fire. The potentially affected population would be quite small, limited to the ship's personnel. A scenario involving a port accident followed by a fire was analyzed in DOE/EA-0336. The risk was found to be 1×10^{-5} person-rem per port call. It should be noted that Annex 5 does not permit any scheduled port calls between Europe and Japan. However, the risks of a fire at sea should be considerably less. There is, however, the possibility of ocean contamination, if the transport container and its plutonium contents were to be compromised during an accident. Immersion of the cask, per se, will not cause a release of radioactive materials. Casks damaged or undamaged can be recovered in water shallower than 200 meters, which is typical of near shore and port depths. No long-term environmental consequences are expected in such a case.

Submersion deeper than 200 meters (off the continental shelf) can let water into a cask through the seal areas of the container, but the release is not expected to be substantial unless the sea depth is about 3,600 meters (a typical depth off the continental shelf) or greater, where the container may collapse. This was analyzed in BNWL-2093. It is at this depth that the potential exposure of significant population groups was examined. The scenario includes the release of plutonium oxide powder into the ocean environment following a postulated collision with subsequent loss of a cask to the ocean floor.

Following the approach used in BNWL-2093, it was assumed that the cask on the ocean floor would release its entire content within the first year of the accident, a highly unlikely event. Although plutonium oxide is exceedingly insoluble in water, it was assumed that 1% of the released material would become soluble in the sea water, resulting in an estimated plutonium concentration of 2×10^{-13} Ci/M^3. Based on the published bioaccumulation factors for fish and shellfish in seawater and on an estimated consumption rate of 7×10^3 kg/yr of the contaminated seafood, and using the ICRP ingestion dose model, the population dose was estimated to be 6×10^{-5} person-rem and the individual dose of 6×10^{-8} rem.

In DOE/EA-0363, it was assessed that accidents leading to submersion in the open seas occur with a frequency of about 3×10^{-4} to 6×10^{-4} accidents per trip. Based on the latter value and one 600 Kg shipment per year the annual risk of sea shipment of plutonium on the global commons was estimated to be: 2×10^{-8} person-rem for the individual risk, and 2×10^{-5} person-rem for the population risk per trip per 600 Kg of plutonium shipped.

For the case of a shipment of mixed oxide fuel elements in a cask, the consequences and risk of cask failure in the ocean would be considerably less. This arises from the fact that even if the fuel cladding* failed and the fuel pins were exposed to sea water, the corrosion and subsequent release of the plutonium from ceramic pellets would be very much slower than that assumed for the plutonium oxide shipment (release of the entire contents in 1 year).

2.4 Comparison of Risks for Sea and Air Shipment

The radiological risks assessed in Section 2.3 for sea transport are compared in Table 1 with risks by air shipment. The risk values are annual risks and are based on the assumption that a total annual quantity of plutonium shipped is 600 Kg for both air and sea. For sea shipment, a distance of 20,000 Km was assumed, whereas, for air shipments (12 trips), a total of 60,000 Km was assumed.

Table 1

Comparison of Annual Risks for Shipment of Plutonium by Sea and Air From Europe to Japan

	Sea Shipment		Air Shipment[a]	
	Routine	Accident	Routine	Accident
Individual Risk (rem)	0.2	2×10^{-8}	6×10^{-2}	1×10^{-7}
Population Risk (person-rem)	5	2×10^{-5}	0.6	1×10^{-6}

[a] Estimated from DOE/EA-0336, where the risks were assessed for flights over the continental U.S. and scaled to the same population exposed for sea shipment.

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* Fuel cladding would not be expected to fail unless water depths of greater than 3.6 Km were reached.

APPENDIX D
ECO Engineering, Inc. Report

ECO Engineering, Inc.

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A REVIEW OF THE PROPOSED MARINE TRANSPORTATION OF REPROCESSED PLUTONIUM FROM EUROPE TO JAPAN

MARCH 30, 1992

This paper was prepared by ECO Engineering, Inc. of Annapolis, Maryland, USA, for the Nuclear Control Institute and Greenpeace International.

ECO Engineering, Inc., is a company of interdisciplinary marine system professionals who have conducted numerous assessments and risk analyses for the marine transportation of petroleum and its products, liquefied flammable gases, bulk chemicals, and dangerous goods including radioactive wastes. Such projects have been performed for both governmental and commercial clients within the United States and other countries.

The corporation was originally founded in 1973 and has been in continuous existence since then.

I. INTRODUCTION

This paper represents the results of a review of technical and general documentation concerning the transportation of reprocessed plutonium from Europe to Japan by ship. The documents include the "Environmental Assessment" and the "Environmental Analysis" prepared by the U.S. Department of Energy in connection with the U.S. - Japan Nuclear Cooperation Agreement of 1987 and with the associated Subsequent Arrangement for Sea Shipment of Plutonium, along with relevant government documents cited in these reports. (See Appendix A for a detailed listing of these citations as well as Appendix B which lists all other documents furnished by the Nuclear Control Institute and Greenpeace International.)

The results of that review are organized as follows:

- a statement of the general understanding of the marine transportation system that will transport the plutonium;
- a discussion of the exposure of the cask in a marine accident and the ability of the cask to maintain its integrity given that exposure;
- the effect of the intended manner of transport on accidents; and,
- a summary of concerns.

II. THE MARINE TRANSPORTATION SYSTEM

The marine transportation system is defined as the casks containing the reprocessed plutonium;[1] the ship carrying those casks; the location and manner of stowage of the casks aboard the ship; the armed escort vessel; the intended manner in which the loaded ship is to be operated within congested waters (e.g., harbors and other areas of traffic confluence) and along the open ocean route from Europe to Japan; and any other security measures which are intended to protect the reprocessed plutonium cask from damage either due to the ordinary risks associated with marine transportation or to armed attack or acts of sabotage.

In general, little detail has been afforded with respect to much of the foregoing except for the understanding that the reprocessed plutonium casks will be

[1] The casks, also referred to as a flask, will contain plutonium either in the form of plutonium-oxide concentrate or of plutonium-uranium mixed oxide (MOX) fuel elements.

transported within a special or so-called "purpose built" vessel for the transport of spent nuclear fuel. The vessel, PACIFIC CRANE, recently modified for the transport of reprocessed plutonium,[2] displaces approximately 7,000 long tons. Upon departure from the European port, the transport vessel is expected to make a non-stop voyage to Japan via one of three points: Cape Horn in South America, or the Cape of Good Hope in Africa, or the Panama Canal. (A fourth possible route via the Suez Canal is presumably ruled out for security reasons.) The longest route (via Cape Horn) is a distance of approximately 17,000 nautical miles. Throughout the voyage the nuclear transport vessel is to be escorted by an armed escort vessel of approximately 6,600 long tons displacement and which is provided with helicopters to assist in surveillance and protection operations.[3] Because of the stated intention to make an entire voyage of up to 17,000 nautical miles without the need to enter any port, both the nuclear transport and the escort vessels would have to be capable of carrying a 60-day supply of fuel oil for propulsive and electric power generation purposes based on an average speed of 12 knots for th[illegible]ay voyage.[4] Based upon a round trip time of 120 days, any one nuclear tra[illegible]up could conceivably make three such round trips per year. Thus, there woul[illegible]ar to be the need for at least two nuclear transport and two escort vessels to support the stated transport requirement of four to five shipments per year.[5] Yet, the present plan appears to call for only one nuclear transport vessel and one escort vessel suggesting highly intensive vessel utilization.

Little detail is provided within the furnished documentation with regard to the marine transportation system except for that summarized herein. Conceptually, the documentation suggests the establishment of procedures and conditions of carriage which support safety and the minimization of risk. However, in the absence of any further detail, no judgment can be made as to the level of that risk and, therefore, as to its acceptability from the societal point of view. Given the high toxicity of plutonium and the potential consequences of its release into the environment in

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[2] "Spent Fuel Transport Ship to be Refitted for Plutonium Transport," Nuclear Fuel, September 20, 1991.

[3] "Japan's MSA Places Order for Vessel to Escort Pu Shipments from Europe," Nuclear Fuel, April 16, 1990.

[4] The total, one-way, transit time could be as high as 75 days. See "Transportation Alternatives for the Secure Transfer of Plutonium from Europe to Japan," Sea Transportation Alternatives, U.S. Department of Defense, March 7, 1988.

[5] Alan J. Kuperman, "The Revised 1988 U.S. - Japan Nuclear Cooperation Agreement and Japan's Commercial Plutonium Program (Draft)", Prepared for Greenpeace USA, November 9, 1989.

populated areas near heavily trafficked waterways and in ports, the question of involuntary public risk must be carefully assessed.

III. FATE OF THE CASK IN A MARINE ACCIDENT

A. General. Much of the furnished documentation concentrates on the reprocessed plutonium cask's ability to withstand the consequences of a marine accident.

This is not surprising given the International Atomic Energy Agency's (IAEA) stated position that "no new evidence has been submitted that the accident environment on board a ship would be beyond the level of safety covered by the test requirements described in the IAEA - Regulations for the Safe Transport of Radioactive Material" and "the current level of safety is fully adequate and is provided by the accident resistance of the flasks not by the conveyance."[4] The Director General of the IAEA also states in a letter dated May 6, 1991, to the Secretary General of IMO that "if safety assessments demonstrate that accident environments on board ships at sea were more rigorous than those for the land mode, then it is the accident resistance of the transport package that should be upgraded rather than making the transport dependent on the availability of special ships." (Emphasis added.)

An opposing viewpoint, as expressed by the International Confederation of Free Trade Unions (ICFTU) in the same Working Group Report just previously referenced, states, "the maritime handling and carriage of these containers introduces a number of additional and significant factors which could lead to cask failure. The actual dynamics of cargo handling accidents, ship collisions, explosions and fire, and the loss of cargo at sea, could all lead to circumstances beyond the original design parameters of INF (irradiated nuclear fuel) casks."

The overall issue straddled by these two opposing viewpoints is whether the cask by itself or the cask within a total marine transportation system is to provide the necessary protection from the nuclear material and in either case, whether that protection is sufficient from the public risk point of view. Based upon the

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[4] Position of the representative of the IAEA as stated in the report of the Working Group on Requirements for the Carriage of Irradiated Nuclear Fuel in Purpose-Built and Non-Purpose-Built Ships to the 42nd session of the Subcommittee on the Carriage of Dangerous Goods of the Maritime Safety Committee of the International Maritime Organization (IMO), October 11, 1990.

documentation furnished, there is no substantive evidence to support any claim relative to the integrity of a cask exposed to the consequences of a maximum credible marine accident.[7] Without such supporting evidence, one cannot accept the premise that any cask or container is impervious to the kinetic energy of ship collisions, to the time-temperature domains of shipboard fires, or to the hydrostatic pressures associated with immersion in deep water.

Marine accidents involve significant forces and outcomes that appear to exceed the limits of the standards to which the casks are designed.[8] The kinetic energy associated with a ship collision can exceed that of a 747 aircraft landing at 200 knots or a locomotive traveling at 60 miles per hour. Shipboard fires routinely exceed 2,000 degrees Fahrenheit (F) or nearly 1,100 degrees Centigrade (C), have average durations of nearly one day, but often extend over a period of days and sometimes, weeks. The capsizing or sinking of vessels is hardly an unknown event especially with smaller vessels. Such events can result in immersions to ocean depths of thousands of meters.

Some of the documentation reviewed, notably the Battelle Pacific Northwest Laboratories' study[9] and the Large and Associates' study[10], conclude that the casks would not survive a major marine accident. Some of the failure mechanisms for the casks that are described are the sinking of the casks in deep water and the resulting collapse of the cask due to hydrostatic pressure; the exposure of the casks to a sustained fire of sufficient intensity and the resulting rupture of the cask due to internal pressures; and, the crushing of the cask due to the cask being directly or indirectly subjected to the kinetic energy of a collision.

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7 The term "maximum credible accident" was originated by the U.S. Atomic Energy Commission. It is not necessarily the "worst case" accident but rather, is the maximum accident that can be potentially developed based on what the physical situation will allow without regard to statistics or probability of occurrence.

8 Current IAEA standards require the casks to be tested to demonstrate their ability to withstand normal conditions of transport by being subjected to specified water spray, free drop, stacking and penetration tests. They are further required to be tested to demonstrate their ability to withstand accident conditions in transport by: (a) being subjected to a mechanical test consisting of three different drop tests; (b) being subjected to a thermal test consisting of a 30 minute exposure to a 1,472 degree Fahrenheit (800 degrees Centigrade) fire; and, (c) being subjected to a one hour immersion test at a depth of 200 meters.

9 "Consequences of Postulated Losses of LWR Fuel and Plutonium Shipping Packages At Sea", Battelle Pacific Northwest Laboratories, Richland, Washington, October 1977.

10 "Import/Export of Irradiated Fuel and Irradiated Waste To and From the United Kingdom", Large and Associates, London, August 1990.

Actual marine accidents do result in the casks being exposed to environments which can create such failure mechanisms. Some examples include:

- the collision in the Bay of Tokyo in 1974, between the freighter PACIFIC ARES and the LPG/naptha carrier YUYO MARU NO. 10 and the subsequent fire[11] with repeated deflagrations and burning aboard YUYO MARU NO. 10. Intense fires lasted until the vessel was intentionally sunk nearly three weeks after the initial incident.

- the collision in New York Harbor in 1973, between the container ship SEA WITCH and the oil tanker ESSO BRUSSELS and the subsequent fire aboard SEA WITCH which lasted for a period of days.[12]

- the collision in the Caribbean Sea in 1979, between the oil tankers AEGEAN CAPTAIN and ATLANTIC EXPRESS and the subsequent fire aboard ATLANTIC EXPRESS which lasted for approximately two weeks until the ship sunk.

- the grounding, break-up and subsequent sinking of the oil tanker AMOCO CADIZ in 1978 off the Normandy coast of France.

- the structural failure and subsequent sinking of the oil tanker HAWAIIAN PATRIOT in 1977 in the North Pacific Ocean.

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[11] The Japanese investigative report describes the initial fire as follows: "Flames rose up to a height about 60 metres. White glare blazed up 30 metres in height, mixing with red hot flames. Black smoke went up to a height of 300 metres."

[12] Within the "Environmental Assessment on Shipment of Taiwanese Research Reactor Spent Nuclear Fuel (Phase II)," U.S. Department of Energy, June 1988, it is stated, "As severe as the Sea Witch/Brussels accident was, the accident conditions were not severe enough to breach a spent fuel cask. The damage to the cargo containers in the below deck region on the Sea Witch indicates that a spent fuel cask would not have been subjected to threats in excess of those specified by the hypothetical conditions in the IAEA and U.S. regulations." This comment is speculative and neither accounts for the facts that SEA WITCH was a very large vessel (on the order of 3 to 4 times larger in terms of gross volume) as compared to the proposed nuclear transport vessel and that SEA WITCH was the striking (as opposed to the struck vessel), which tended to make much of the damage to SEA WITCH be "bow oriented". Nonetheless, the U.S. Coast Guard Marine Board of Investigation states, "One longitudinal and one transverse welded seam on the side shell fractured due to heat in the area of number 3 cargo hold." (Emphasis added.) It also states "The containers below deck, especially those in holds number 2 and 3, were the most damaged by the fire . . . The containers on deck and in number 2 and 3 holds continued to burn for many days after the casualty . . ." (Emphasis added.)

- the explosion and fire aboard the oil tanker MEGA BORG off the coast of Galveston, Texas, in 1990. Fire and subsequent explosions continued for nine days and extended from the engine room, to the accommodation areas, the pump room, and the cargo area. The fire was reported to be so intense that fire fighters and salvers could not approach the vessel for days.

The foregoing illustrative examples clearly show the potential for collision, fire, and sinking of ships; all of which were significantly larger vessels than the proposed nuclear transport vessel.

B. Fire. Shipboard fire temperatures "easily reach 2,000° F".[13] Depending upon the fuel for the fire (such as in the case of petroleum products) they can reach 3,000 degrees F. The standard fire test that is used for structural fire protection purposes aboard ship uses the following time/temperature relationship: 1,000 degrees F after 5 minutes; 1,300 degrees F after 10 minutes; 1,500 degrees F after 30 minutes, and 1,700 degrees F after 60 minutes.[14] The spilling of oil on the deck of the nuclear transport vessel with almost certain ignition following a collision with a tank vessel can develop fire conditions that will exceed the standard fire test in terms of both temperature and duration. In addition, the volume of onboard fuel oil required to sustain the nuclear transport vessel (approximately 1,100 long tons of fuel oil), on a non-stop voyage of approximately 17,000 nautical miles is capable of supporting equivalent fire loads whether the ignition of that onboard fuel oil occurs directly or is induced by heat from an outside source as could occur with the ignition of and subsequent heat generated from the spilled on-deck oil or as the result of the detonation and subsequent deflagrations arising from an armed attack or act of sabotage.

Therefore, the cask can be subjected to severe fire environments that exceed the IAEA standard of 1,472 degrees F for a period of 30 minutes and can potentially fail due to the build-up of internal pressure as a result of that thermal exposure. The furnished documentation does not support the contention that the casks can survive such exposure arising from maximum credible accident scenarios.

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[13] "Firefighting Manual for Tank Vessels," (CG-329), U.S. Coast Guard, Washington, D.C., January, 1974.

[14] Title 46, Code of Federal Regulations, 72.05-5(g).

C. Immersion. The Battelle study previously referenced points out that among other things, the cask will begin to fail under extreme hydrostatic pressure due to immersion in deep water.[15] That depth of water will be encountered along 75 to 90 percent of the nuclear transport vessel's ocean route.

It also appears credible that the nuclear transport vessel could sink in sufficiently deep water to externally pressurize the cask to the point of collapse with subsequent release of the plutonium into the ocean.

Seagoing vessels sink due to any number of reasons. Some of the more prevalent accident chains include sinking following a collision; sinking following fire; structural failure with subsequent sinking; and, flooding, capsizing, and sinking.

Vessel sinkings are not an incredible event; rather, in any given year, there are a number of vessels lost. Among those vessels lost, there is a distinct skew towards smaller vessels.[16] There are a number of reasons for this; they include the lesser level of survivability often required for these smaller vessels and the susceptibility of these smaller vessels to experience greater extents of damage as might be inflicted by larger vessels and their greater susceptibility to the forces of wind and waves. Both the nuclear transport vessel and the escort vessel are not large by seagoing vessel standards. Not only does this fact make them more susceptible to damage and the vagaries of the sea with the resultant increased potential of sinking as compared to their larger counterparts, but in the case of the escort vessel, also lessens its effectiveness in providing surveillance and protection to the nuclear transport vessel - an important consideration for voyages in treacherous waters such as occur around both Cape Horn and the Cape of Good Hope.

D. Impact. As previously stated, the forces and energy levels associated with ship collisions are enormous. For example, the kinetic energy associated with a vessel whose displacement is 5,000 long tons and traveling at 15 knots is approximately 250 million foot-pounds which roughly equates to dropping a cask weighing 2.5

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15 According to data contained within that study, the seal areas of the casks will begin to fail at 200 meters and total collapse of the casks will occur at 3,600 meters.

16 By "smaller vessels" is meant ships whose displacement is 10,000 long tons or less; a category that includes both the proposed nuclear transport and escort vessels.

long tons a vertical distance of 2,000 feet.[17] If that vessel displacement was increased to 50,000 long tons (a "handy size" tanker by today's standards), that kinetic energy level would be increased an entire order of magnitude or about 2.5 billion foot-pounds of energy.

Historical accident data show that when ships of relatively equal size collide, there is a 50 percent probability that the striking vessel will penetrate the struck vessel up to a distance equal to one-fifth of the struck vessel's beam before all of the kinetic energy is dissipated. Under the same circumstances (i.e., ships of relatively equal size colliding), penetrations of up to half of the struck ship's beam and the complete severing of the struck ship have occurred. Given any advantage in size between the struck ship and the striking ship in favor of the striking ship, the extent of penetration and the extent of damage to the struck ship and its cargo will be proportionately increased. Given the very credible occurrence of a large, seagoing vessel colliding with the relatively small, nuclear transport vessel, the casks can be subjected to very large crush forces. The magnitude of these forces is so large that without supporting documentation to the contrary, it appears unlikely for the casks to be able to withstand such energy levels. Thus, there is a risk of the release of plutonium in heavily trafficked waterways and ports where ship collisions are most likely to occur and where population centers tend to be located; both of which would increase the involuntary risk to the public.

E. Acts of Sabotage or Terrorism. The detonation of any implanted explosive and/or incendiary devices aboard the nuclear transport vessel or a missile or other large projectile hit upon the nuclear transport vessel will create shock and fire with resultant exposures at least as intensive as those arising from marine accidents. In the Falkland Islands War, a single EXOCET missile hit upon HMS SHEFFIELD caused fires which forced the abandonment of the ship, melted the aluminum superstructure, initiated secondary fires and explosions, buckled steel structures, and generally destroyed the ship. Even if the nuclear transport ship survived such an act of sabotage or terrorism (i.e., did not sink), it is difficult to imagine without further evidence that the casks could successfully survive the resulting shock, fire,

[17] A reprocessed plutonium cask of this weight, when dropped from a height of 2,000 feet onto a concrete apron and having attained a terminal velocity of approximately 260 feet per second was "damaged". See: P.W. Wilson and N. Carr, "Packaging for the Transport of Plutonium," 1986 IAEA International Symposium on the Packaging and Transport of Radioactive Materials, Davos, Switzerland, June 16-20, 1986.

and secondary effects of damage; circumstances that again could result in the release of plutonium.

Accordingly, the execution of such acts cannot be permitted to occur and in order to deter such acts the escort vessel is provided. However, even this security system is no guarantee to absolute deterrence; it only mitigates the risk from acts of sabotage or terrorism.[18]

IV. THE EFFECT OF THE INTENDED MANNER OF TRANSPORT ON ACCIDENTS

Information on the manner of transport for the casks containing reprocessed plutonium is very limited in the furnished documentation, which includes all U.S. government documents submitted with the U.S. - Japan Nuclear Cooperation Agreement and with the associated Subsequent Arrangement for Sea Shipment of Plutonium. There is essentially no information provided on the location of and manner in which the casks are to be carried by the nuclear transport vessel. There is essentially no information provided regarding the manner in which the nuclear transport ship is to be operated within congested waters and in the vicinity of other traffic. There is little information provided regarding the ocean route, its proximity to populated areas, and contingency plans if the vessel is forced to make an unplanned port entry.[19]

As a result, it is not possible to make any definitive judgments regarding accident occurrence. While one is totally aware of and sensitive to the necessity for some restrictions in information due to security concerns, there is so little substantive disclosure that risk must be accepted on the basis of good faith and little factual data. Considerably more information on safety specifications and accident prevention is required.

Security considerations aside, the treatment of risk within the furnished

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18 The U.S. Department of Defense has stated, " . . . even if the most careful precautions are observed, no one could guarantee the safety of the cargo from a security incident, such as an att[illegible] on the vessel by small, fast craft, especially if armed with modern anti-ship missiles." ("Transportation Alternatives for the Secure Transfer of Plutonium from Europe to Japan," Sea Transportation Alternatives, U.S. Department of Defense, March 7, 1988.

19 Under the terms of the U.S. - Japan agreement, Japan is to prepare "detailed contingency plans established in advance," including "emergency port calls". However, no information has been made available on the details of such contingency plans.

documentation is simply not complete enough to make any quantitative judgment of risk. However, some of the furnished documentation suggests that those risks are not "credible"; something on the order of once in a half million years for the loss of the ship and once in a million years for a "severe fire".[30] However, there is no data to support the claimed incredibility of the occurrence of such events. In fact, historical occurrence of the type of accident events necessary to place the casks in jeopardy do occur as previously demonstrated and nothing in the furnished documentation gives any definitive basis as to why the historical frequency will be mitigated by the intended manner of transport.

V. SUMMARY OF CONCERNS

A. The Casks. Unless there is something within the manner of operation which has not been uncovered or understood and which will significantly mitigate the occurrence of accidents, the exposure of the casks to severe fire, crush, and immersion are within the realm of maximum credible accidents.[31]

Given those exposures, there is no information provided that supports any suggestion of the casks' ability to maintain their integrity under those conditions. The duration and intensity of shipboard fires, the enormity of the energy levels associated with ship collisions, and the extent of hydrostatic pressure of the ocean depths, to say nothing of the consequences of acts of terrorism, would appear to create exposure environments beyond the limits of the casks designed in accordance with IAEA standards.

Although the casks are tested and certified to meet IAEA standards, the point at which they will fail is not known. Therefore, given their exposure to the fire, crush and immersion environments associated with maximum credible ship accidents, it is not known whether those casks can survive but it is strongly suspected that they could not survive such exposure.

It is also not known where and how the casks will be stored within the nuclear transport vessel in order to protect them from fire and crush environments as well as from any act of sabotage or terrorism. Such information is required to determine

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[30] Source: United Kingdom Atomic Energy Authority, as cited in "Transportation of Plutonium and Irradiated Fuel Products, Hazards and Risks," John H. Large, Large and Associates, London.

[31] See footnote 7, page 4.

what degree of mitigation to risk, if any, is provided by such stowage, in the overall assessment or involuntary public risk.

B. The System. The system is so generally defined that no quantitative judgment can be made on the total risk. For example, there is no information concerning the issue of cask storage and protection aboard the nuclear transport vessel. There is little information on the details of the transport vessel itself and its ability to withstand collision, fire, and flooding. The ship is a relatively small ship which gives additional concern for its survivability following an accident. The ship will also be carrying a disproportionate amount of fuel oil for a vessel of its size which gives added concern for fires should that fuel be ignited for any reason, including a ship collision or terrorist strike.

Other than the presence of the escort vessel, essentially nothing is known about the manner in which the nuclear transport vessel will be operated when in restricted waterways and in the presence of other marine traffic. Little is known about the ocean route and the manner in which the vessel will be operated when on the high seas. However, it is known that the vessel will traverse some of the more unforgiving areas (in terms of weather, wind, and wave environments) of the oceans without any planned port calls between Europe and Japan. This, coupled with the vessel's relatively small size, gives concern as to both the vessel's safety and its ability to make the entire 17,000 nautical mile voyage without any intervening port calls should it encounter any adverse weather and/or mechanical difficulties.

Another concern in this regard is the apparent lack of any details on contingency plans or emergency port calls which might prove necessary for whatever reason. This is especially critical because of the increased potential for accidents in heavily trafficked ports and waterways and increased potential in consequences due to the typical proximity of populated areas.

C. Concluding Remarks. In summary, the entire system is not defined sufficiently to make any expert judgments on risk. This operation, as with the movement of any hazardous material at sea, will always create some level of risk. The real question is whether the involuntary risk created to people and the environment is sufficiently small to be socially acceptable? That question cannot be answered at this time based on the available documentation.

APPENDIX A

U.S. GOVERNMENT DOCUMENTS PREPARED IN CONNECTION WITH U.S./JAPAN NUCLEAR COOPERATION AGREEMENT AND SUBSEQUENT ARRANGEMENT FOR SEA SHIPMENT OF PLUTONIUM

1. "Environmental Assessment of the Proposed New Agreement for Peaceful Nuclear Cooperation between the United States and Japan and an Associated Subsequent Arrangement for the Return of Recovered Plutonium from Euratom to Japan," U.S. Department of Energy, 1987.

Documents (pertaining to sea shipment) cited in Environmental Assessment:

a. "Regulations for the Safe Transport of Radioactive Materials," Safety Series No. 6, International Atomic Energy Agency, Revised 1990.
b. Title 10, Code of Federal Regulations, Part 71.

2. "Environmental Analysis of Sea Shipment of Plutonium from Europe to Japan," Argonne National Laboratory paper, prepared for the U.S. Department of Energy, September, 1988.

Documents cited in Environmental Analysis:

a. "Final Environmental Impact Statement, U.S. Spent Fuel Policy," DOE/EIS-0015, U.S. Department of Energy.
b. "Assessment of the Risks of Transporting Uranium Research Reactor Fuel from Taiwan," DOE/EA-0321, U.S. Department of Energy.
c. "Environmental Assessment for the Proposed New Agreement for Peaceful Nuclear Cooperation between the United States and Japan and an Associated Subsequent Arrangement for the Return of Recovered Plutonium from Euratom to Japan," DOE/EA-0336, U.S. Department of Energy.
d. "Consequences of Postulated Losses of LWR Spent Fuel and Plutonium Shipping Packages at Sea," Report BNWL-2093, Batelle Northwest Laboratory, Richland, WA, October, 1977.

APPENDIX B

OTHER DOCUMENTATION FURNISHED FOR REVIEW

1. "Environmental Analysis of Sea Shipment of Plutonium from Europe to Japan," Argonne National Laboratory, Office of International Energy Development Programs, September, 1988.

2. "Import/Export of Irradiated Fuel and Radioactive Waste to and from the United Kingdom," (Full Report), Large and Associates, London.

3. "A Review of Marine Transportation of Plutonium," Alan J. Kuperman, Greenpeace International, November 9, 1989.

4. "Briefing Paper on the Current Europe-Japan Plutonium Transport Issue," Andy Stirling, March, 1989.

5. "Transportation of Plutonium and Irradiated Fuel Products, Hazards and Risks," John H. Large, Large and Associates, London.

6. "Affidavit of Dr. Marvin Resnikoff in Support of Motion for Preliminary Injunction," Marvin Renikoff, United States District Court, Western District of Washington at Tacoma, March 25, 1986.

7. "Environmental Assessment of Shipment of Taiwanese Research Reactor Spent Fuel (Phase II)," U.S. Department of Energy, June, 1988.

8. "The Revised 1988 U.S.-Japan Nuclear Cooperation Agreement and Japan's Commercial Plutonium Program (Draft)," Alan J. Kuperman, Greenpeace USA, November 9, 1989.

9. "Nuclear Health and Safety," U.S. General Accounting Office, Washington, D.C., September, 1988.

10. "A Comparison of the IAEA vs. NRC Standards for Testing the Crashworthiness of Casks used for the Transport of Plutonium by Air," Memo by Alan J. Kuperman, Nuclear Control Institute, Washington, D.C., March 25, 1987.

11. "Regulations for the Safe Transport of Radioactive Material," 1985 Edition (As Amended 1990), International Atomic Energy Agency, Vienna, 1990.

12. "Air Transport of Plutonium Obtained by the Japanese from Nuclear Fuel Controlled by the United States," Paul Leventhal, Milton Hoenig and Alan Kuperman, Nuclear Control Institute, Washington, D.C., March 3, 1987.

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APPENDIX E
Review of the ECO Engineering, Inc. Report by Sandia National Laboratories

Greenpeace International and the Nuclear Control Institute contracted ECO Engineering, Inc. of Annapolis, MD, to prepare a paper entitled "A Review of the Proposed Marine Transportation of Reprocessed Plutonium from Europe to Japan." The full text of the paper is included in Appendix D. The ECO paper reviews documentation on the subject of marine transportation of radioactive materials and maritime accident conditions. The paper is flawed by an apparent misunderstanding of the regulations and by incorrect calculations.

Review of ECO Engineering Paper

The ECO paper begins with the mistaken premise that Type B casks are required by regulation to withstand maximum credible accident conditions. It states that

> "...there is no substantive evidence to support any claim relative to the integrity of a cask exposed to the consequences of a maximum credible marine accident. Without such supporting evidence, one cannot accept the premise that any cask or container is impervious to the kinetic energy of ship collisions, to the time-temperature domains of shipboard fires, or to the hydrostatic pressure associated with immersion in deep water." [Emphasis added] (ECO paper, p. 4).

Both U.S. and IAEA regulations make it clear that while the certification tests represent severe accidents conditions, they do not represent maximum credible accident conditions. The ECO paper summarizes these certification tests on p. 4 (footnote 7), but the impact and fire test conditions are misstated. The important requirement for the drop tests to be onto an unyielding surface is omitted; and the important requirement for full engulfment during the fire test is omitted (fuel pool for test must extend at least 1 m beyond edges of package and package must be suspended 1 m above pool; IAEA Safety Series 37). They correctly describe the immersion test, but also assume as a "premise" that regulations require Type B packagings to be "impervious" to "immersion in deep water" (see above quote). Every study performed by the Federal government has conservatively assumed cask failure in deep waters.

The paper does not specifically address the plutonium casks used by the Japanese. As described in Appendix F, these casks have been certified in France and have been shown to meet all IAEA regulatory test requirements. The French and Japanese Tests on the package exceed design standards.

The paper states categorically that "Marine accidents involve significant forces

and outcomes that appear to exceed the limits of the standards to which the casks are designed." The paper goes on to state that very large kinetic energies are associated with ship collisions, that "shipboard fires routinely exceed 2000 degrees Fahrenheit....[and] have average durations of nearly one day" and that "capsizing or sinking of vessels is hardly an unknown event." However, a review of the accident database shows that no marine accident has exceeded the limits of the standards," making this argument greatly overstated.

The paper correctly identifies sinking as the most likely severe accident. The potential consequences of this type of accident were analyzed in detail in Federally-sponsored environmental analyses, including the analysis in Appendix E, and found to be small (i.e. to result in a maximum individual dose of 6.0E-08 rem).

The calculations for all of the values of kinetic energy given in the paper are incorrect. A 5000 long ton (5000 tonne) vessel traveling at 15 knots has a kinetic energy of approximately 111 million foot-pounds, not approximately 250 million foot-pound. A 2.5 long ton (2.5 tonne) cask dropped vertically 2000 feet has a kinetic energy of approximately 11 million foot-pounds (neglecting losses from air friction), not 250 million foot-pounds as stated in the paper. A 50,000 long ton (50,000 tonne) vessel traveling at 15 knots has a kinetic energy of approximately 1.1 billion foot-pounds, not about 2.5 billion foot-pounds.[10] A package can only be damaged by energy absorbed by the package itself, not by the kinetic energy of a vessel, and it is the change in kinetic energy during a collision (i.e. initial kinetic energy minus final kinetic energy for both vessels) that indicates how much energy is potentially available to cause damage to the vessels and their cargo. In Subsection D, by equating the kinetic energy of a marine vessel of a 5000 long ton (5000 tonne) displacement traveling at 15 knots with that of a cask weighing 2.5 long tons (2.5 tonnes) which has been dropped vertically 2000 feet, it is implied that all the energy would be brought to bear on a single package. As noted above, the two are not equal, and the implication that a single package or even several packages would absorb the entire kinetic energy of a ship-ship collision is false.

The paper's discussion of shipboard fires omits emissivity, absorptivity, and engulfment requirements for the fire test; the engulfment (location and extent) requirement is as important as temperature and duration, because unless a fire of such magnitude and duration occurs at the same location as the package rather than in an engine compartment or on deck, for example, then the engulfment requirement is not met and the fire would have no direct impact on the plutonium packages. Shipboard fires do not "routinely" threaten cargo holds. Furthermore, the French have stated publically that France- and Japan-certified plutonium casks will withstand hotter fires for a longer period of time than required by the regulations (1832 F engulfing fire for 90

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10 ECO did not show their calculations. All calculations performed by Sandia National Laboratories are deposited in a quality assurance file, and copies are on file with the NRC. They are available on request.

minutes rather than 1475 F engulfing fire for 30 minutes), and all cargo holds on the Japanese ships carrying plutonium are equipped with sophisticated fire-suppression systems.

The paper objects to a DOE analysis of a severe historical accident involving a ship named the Sea Witch, which was described in DOE/EA-0363 (p. 5 of ECO paper) and dismisses the conclusion of the analysis that "a spent fuel cask [had it been in the Sea Witch accident] would not have been subjected to threats in excess of those specified by the hypothetical accident conditions in the IAEA and U.S. regulations." This conclusion was based on a detailed post-accident analysis of the Sea Witch, conducted by the U.S. Coast Guard (USCG) Marine Board of Investigation and summarized in DOE/EA-1363, which gave information about the fire (maximum temperatures achieved, durations in various locations aboard the ship, etc.). The ECO paper cites a statement in the USCG report, "The containers on deck and in number 2 and 3 holds continued to burn for many days after the casualty," as opposition to the conclusion in the DOE EA. However, the fact that some containers burned for several days (i.e. that flammable components and contents were ignited and continued to burn and smolder) does not mean that the fire to which the containers were originally exposed burned for several days nor does it mean that the fire was severe enough to damage a Type B package. The fact that the containers still had enough unburned material in them to smolder and burn for a few more days is evidence that the initiating fire was relatively moderate.

ECO attempts to show that both temperature and duration would be greater than those specified for the regulatory fire test for a fire involving the "spilling of oil on the deck of the nuclear transport vessel ... following a collision with a tank vessel." The conditions might be exceeded at the location of the fire, but the requirement of full engulfment of the package is equally important, as noted previously. A package that is stowed below deck is unlikely to be fully or even partially engulfed by a fire on the deck. This is well illustrated by the Sea Witch accident, which involved a collision with a petroleum tanker ship and in which oil was spilled and ignited. Most containers stowed below deck suffered little damage. The below-deck containers that were counted as "total losses" from a monetary point of view had flammable contents that burned or were damaged by smoke but were not themselves exposed to a hot external fire for "days" as the ECO paper asserts.

In summary, although the ECO paper cites some of the most severe shipboard accidents in maritime history, they are unable to demonstrate that these accidents would represent credible threats to a Type B package of the type used to transport plutonium.

APPENDIX F
Container for Transport of Plutonium to Japan

This appendix includes figures and information that describe the packaging used to make the current shipment of plutonium to Japan. Figures 1-3 show the IAEA source document cover and the listing for the FS-74, which is being used as the containment package for the current France-to-Japan shipments. The listing indicates that the package is Type B and certified by France with Certificate No. F/290/B(U)F. The certificate expires August 1 of 1994. Total package mass is 1500 kilograms.

Figure 4 shows a drawing of the FS-47 as described in the official certification documents.

IAEA-TECDOC-662

Figure 1.

Directory of national competent authorities' approval certificates for package design, special form material and shipment of radioactive material

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Figure 2.

CERTIFICATE NUMBER	REV NO	MASS (Kg)	CONTENTS	SHAPE	L(CM)	WIDTH	DIAM	HGHT	SHIELDING MATERIAL	OUTER CASING	DESCRIPTION LINE 2
F/261/B(U)	00	10	U233, Np237, Pu238,Pu239,Pu241,Pu242, Am241, Am243, Cm242+, Cm244	CYL.			280	375		STEEL	
F/262/F	00	987	Hexafluorure d'Uranium (UF6)	CYL.	2873	850	702	850		STEEL	Composé d'une coque et d'une bouteille
F/264/B(U)F	00	3400	Aiguilles à base d'UO2-PuO2. 250g d'U235, 150g de Pu, 232g de U-Pu	CYL.	7300		493			STEEL	
F/265/B(U)	00	75	Ir192 sous forme solide en métal (840 Ci)	PARAL.	610	410		320	DEPL. URANIUM	PLASTIC	Comporte 4 alvéoles
F/266/B(U)	00	2530	Co60 sous forme solide en métal. Cs137 sous forme de poudre	CYL.	1050	846		1180		STEEL	Comporte 2 alvéoles
F/267/B(U)F	00	23100	Crayons REP UO2 sous forme quelconque. U - Pu, UO2 - PuO2	CYL.	6480	1285		1312	COMPOUND	STEEL	
F/269/F	00	4325	Assemblages combustibles non irradiés du type CAP 1800	CYL.	5710		1130	1295		STEEL	
F/271/B(U)F	00	106090	Assemblages irradiés REP et REB	CYL.	6150		2500		STEEL	STEEL	
F/272/B(U)F	00	106000	Assemblages CI type Biblis	CYL.	4370		2500		STEEL	STEEL	
F/273/B(U)	00	4180	Capsules contenant éprouvettes sous forme solide en métal (840 Ci)	CYL.	2809		700		LEAD	STEEL	
F/274/B(U)F	02	112000	Assemblages CI. U-Pu. UO2	CYL.	6670		2500		STEEL	STEEL	
F/275/B(U)F	01	94000	Crayons constitués par des pastilles frittées. Assemblages CI	CYL.	5900		2500		STEEL	STEEL	
F/276/B(U)	00	125	Mo99 (1000 Ci) - Iodure de sodium (300 Ci) - Ir192 (6000 Ci)	CYL.			350	403	DEPL. URANIUM	STEEL	
F/278/F	00	910	Perche Phebus ou tout assemblage formé de crayons d'oxyde d'U	PARAL.	6350	600		600		WOOD	Constitué d'un caisson muni d'un banc de stockage pivotant
F/280/B(U)F	00	252	U sous forme solide. Solution nitrique ou chlorhydrique de Pu	CYL.	600	600		1140		STEEL	
F/283/B(U)	00	1400	Co60 sous forme solide en métal (6670 Ci)	PARAL.	1030	770		970	LEAD, URANIUM	WOOD	Composé d'une coque de protection et d'une tête renfermant la tour
F/285/F	00	3265	Assemblages combustibles non irradiés pour réacteurs à eau légère	CYL.	4945	1102	1064	1196		STEEL	Constitué de 2 demi-coquilles
F/286/B(U)	00	335	Co60 (300 Ci),Ir192 (25000 Ci),Cs137 (25000 Ci) sous forme solide	CYL.			424	525	DEPL. URANIUM	STEEL	
F/287/B(U)F	00	15310	Déchets divers. Déchets métalliques	CYL.		1872	1477	1580	LEAD	STEEL	Constitué de 4 alvéoles
F/289/B(U)	00	247	Ir192 sous forme solide en métal (20000 Ci)	CYL.			440	500	DEPL. URANIUM	STEEL	
F/290/B(U)F	00	1500	Oxyde de Pu en poudre	CYL.			742	2055	COMPOUND	STEEL	
F/291/F	00	4328	Assemblages combustibles non irradiés pour REP ou crayons	CYL.	5740	1130	1059	1293		STEEL	Constitué de 2 demi coquilles
F/292/B(U)	00	12000	Co60 sous forme solide en métal (150000 Ci)	PARAL.	2300	2700		1020	LEAD	WOOD	Muni d'un barillet comportant 12 logements
F/294/F	00	415	Perche Phebus ou autre assemblage. Crayons d'UO2 soit 600g d'U235	PARAL.	2980	560		489		WOOD	Constitué d'un caisson protégeant un banc de stockage
F/295/B(U)	00	2700	Cs137, Co60 (@Ci137 10Ci137 15Ci137 1Ci6000 1Ci40000 1Ci2000 1(5A))	CYL.			1640	1960		STEEL	Constitué d'une coque chargée d'un irradiateur
F/300/B(U)F	00	58140	Assemblage ou DIMEP irradié dans le réacteur SPX 1	CYL.	7630		3068		COMPOUND	STEEL	
F/301/B(U)F	00	37520	Assemblage CI ou non et/ou grappe	CYL.	6645		1500		COMPOUND		
F/302/B(U)	00	3450	Cs137 sous forme solide (5100 Ci - 900 Ci - 6000 Ci)	PARAL.	1520	1520		1930	LEAD, URANIUM	WOOD	Constitué d'une coque protégeant un irradiateur
F/303/B(U)F	00	3410	Assemblages combustibles non irradiés (la matière fissile est UO2)	PARAL.	1102	1107		2739		STEEL	Constitué de 4 alvéoles
F/304/B(U)F	00	102000	17 assemblages CI dans SEP la matière fissile est de l'UO2	CYL.	6800		2500		COMPOUND	STEEL	
F/306/B(U)F	00	20	PuO2 en poudre (300 g de PuO2 maximum autorisés)	CYL.			298	352		STEEL	
F/307/AF	00	4325	Assemblages combustibles non irradiés (pastille d'UO2 CI 1+3)	CYL.	5710		1130	1295	STEEL	STEEL	Composé de 2 demi coquilles
F/308/B(U)F	00	36700	Aiguilles fissiles - Tronçons de crayon		4540		2340				
F/309/B(U)F	00	22100	Solutions : Pu238 - Pu239 - Pu240 - Pu241 - Pu242	CYL.	3700		2150		LEAD	STEEL	
F/310/B(U)F	00	4950	1 ou 2 assemblages combustibles à oxyde mixte U et Pu non irradié	PARAL.	5024	1040		825		STEEL	Constitué coque extérieure, berceau et banc muni d'ailettes
F/311/B(U)	00	2255	Co60 sous forme solide en métal (7700 Ci)	CYL.	1430	760		1160	LEAD	STEEL	Constitué de 2 alvéoles
F/312/B(U)	00	6000	Co60 sous forme solide en métal (20000 Ci) sous forme spécial	CYL.			930	1282	LEAD	STEEL	
F/313/B(U)F(I)	1		ZEBRA PLATES	PARAL.	600	600		1821	STEEL	STEEL	

FIGURE 2.

CERTIFICATE NUMBER	REV NO	MASS (kg)	CONTENTS	SHAPE	LGTH	WIDTH	DIAM	HGHT	SHIELDING MATERIAL	OUTER CASING	DESCRIPTION LINE 2
F/261/B(U)	00	16	U233, Np237, Pu238,Pu239,Pu241,Pu242, Am241, Am243, Cm242, Cm244	CYL			200	375		STEEL	
F/263/F	00	687	Hexafluorure d'Uranium (UF6)	CYL	2073	850	782	850		STEEL	Composé d'une coque et d'une bouteille
F/264/B(U)F	00	3400	Aiguilles à base d'UO2-PuO2, 250g d'U235, 150g de Pu, 250g de U-Pu	CYL	7200		493			STEEL	
F/265/B(U)	00	75	Ir192 sous forme solide en métal (848 Ci)	PARAL.	610	410		320	DEPL. URANIUM	PLASTIC	Comporte 6 alvéoles
F/266/B(U)	00	2530	Co60 sous forme solide en métal, Cs137 sous forme de poudre	CYL.	1050	846		1100		STEEL	Comporte 2 alvéoles
F/267/B(U)F	00	23100	Crayons REP UO2 sous forme quelconque. U - Pu, UO2 - PuO2	CYL.	6480	1285		1312	COMPOUND	STEEL	
F/269/F	00	4325	Assemblages combustibles non irradiés du type CAP 1800	CYL.	5710		1130	1295		STEEL	
F/271/B(U)F	00	108000	Assemblages irradiés REP et REB	CYL.	6150		2500		STEEL	STEEL	
F/272/B(U)F	00	200000	Assemblages Ct type Biblis	CYL.	6370		2500		STEEL	STEEL	
F/273/B(U)	00	4180	Capsules contenant éprouvettes sous forme solide en métal ([illegible] Ci)	CYL.	2005		700		LEAD	STEEL	
F/274/B(U)F	02	112050	Assemblages Ct. U-Pu. UO2	CYL.	6670		2500		STEEL	STEEL	
F/275/B(U)F	01	99000	Crayons constitués par des pastilles frittées. Assemblages Ct	CYL.	5900		2500		STEEL	STEEL	
F/276/B(U)	00	125	Mo99 (1000 Ci) - Iodure de sodium (300 Ci) - Ir192 (6000 Ci)	CYL.			250	403	DEPL. URANIUM	STEEL	
F/278/F	00	940	Perche Phébus ou tout assemblage formé de crayons d'oxyde d'U.	PARAL.	6350	600		600		WOOD	Constitué d'un caisson muni d'un banc de stockage pivotant
F/280/B(U)F	00	252	U sous forme solide. Solution nitrique ou chlorhydrique de Pu	CYL.	600	600		1140		STEEL	
F/283/B(U)	00	1400	Co60 sous forme solide en métal (6670 Ci)	PARAL.	1130	770		970	LEAD, URANIUM	WOOD	Composé d'une coque de protection et d'une tête renfermant la tour
F/285/F	00	3265	Assemblages combustibles non irradiés pour réacteurs à eau légère	CYL.	4975	1102	1064	1156		STEEL	Constitué de 2 demi-coquilles
F/286/B(U)	00	335	Co60 (300 Ci),Ir192 (25000 Ci),Cs137 (25000 Ci) sous forme solide	CYL.			474	525	DEPL. URANIUM	STEEL	
F/287/B(U)F	00	15310	Déchets divers. Déchets métalliques	CYL.		1072	1877	1500	LEAD	STEEL	Constitué de 4 alvéoles
F/289/B(U)	00	247	Ir192 sous forme solide en métal (200000 Ci)	CYL.			440	500	DEPL. URANIUM	STEEL	
F/290/B(U)F	00	1500	Oxyde de Pu en poudre	CYL.			742	2055	COMPOUND	STEEL	
F/291/F	00	4320	Assemblages combustibles non irradiés pour REP ou crayons	CYL.	5740	1130	1050	1293		STEEL	Constitué de 2 demi coquilles
F/292/B(U)	00	12000	Co60 sous forme solide en métal (150000 Ci)	PARAL.	2300	2700		1020	LEAD	WOOD	Muni d'un barillet comportant 12 logements
F/294/F	00	415	Perche Phébus ou autre assemblage. Crayons d'UO2 soit 600g d'U235	PARAL.	2080	560		489		WOOD	Constitué d'un caisson protégeant un banc de stockage
F/295/B(U)	00	2700	Cs137, Co60 [illegible]	CYL.			1646	1960		STEEL	Constitué d'une coque chargée d'un irradiateur
F/300/B(U)F	00	58160	Assemblage ou BIMEP irradié dans le réacteur [illegible]	CYL.	7630		2068		COMPOUND	STEEL	
F/301/B(U)F	00	37530	Assemblage Ct ou non et/ou grappe	CYL.	6645		1500		COMPOUND		
F/302/B(U)	00	3450	Cs137 sous forme solide (5100 Ci - 500 Ci - 8000 Ci)	PARAL.	1520	1520		1930	LEAD, URANIUM	WOOD	Constitué d'une coque protégeant un irradiateur
F/303/B(U)F	00	3410	Assemblages combustibles non irradiés (la matière fissile est UO2	PARAL.	1182	1182		2734		STEEL	Constitué de 4 alvéoles
F/304/B(U)F	00	102000	12 assemblages Ct dans REP la matière fissile est de l'UO2	CYL.	6800		2500		COMPOUND	STEEL	
F/306/B(U)F	00	20	PuO2 en poudre (300 g de PuO2 maximum autorisés)	CYL.			298	252		STEEL	
F/307/AF	00	4335	Assemblages combustibles non irradiés (pastille d'UO2 [illegible])	CYL.	5710		1130	1295	STEEL	STEEL	[illegible]ée de 2 demi coquilles
F/308/B(U)F	00	36700	Aiguilles fissiles - Tronçons de crayon		4540		2340				
F/309/B(U)F	00	23100	Solutions - Pu238 - Pu239 - Pu240 - Pu241 - Pu242	CYL.	3700		2150		LEAD	STEEL	
F/310/B(U)F	00	4950	1 ou 2 assemblages combustibles à oxyde mixte U et Pu non irradié	PARAL.	5024	1840		825		STEEL	Constitué coque extérieure, berceau et banc muni d'ailettes
F/311/B(U)	00	2255	Co60 sous forme solide en métal (7700 Ci)	CYL.	1430	760		1160	LEAD	STEEL	Constitué de 2 alvéoles
F/312/B(U)	00	6000	Co60 sous forme solide en métal (20000 Ci) sous forme spécial	CYL.			830	1262	LEAD	STEEL	
F/313/B(U)F(1)	1	22884	PLATES	PARAL.	[illegible]	600		1021	STEEL	STEEL	

Figure 3.

CERTIFICATE NUMBER	REV	EXPIRY DATE	REVALIDATION OF	REV	PACKAGE IDENTIFICATION	PACKAGE SERIAL NUMBERS	MODES RAIL	MODES ROAD	MODES AIR	MODES SEA	SAFETY SERIES NUMBER
F/220/B(U)	00	1994.08.07			D 80161		X	X	X	X	6/73AA
F/221/B(U)	00	1994.11.30			RD 11		X	X	X	X	6/73AA
F/223/B(U)	00	1992.02.06			PLS 401		X	X	X	X	6/73AA
F/224/B(U)	00	1994.11.30			RD 14		X	X	X	X	6/73AA
F/225/B(U)	00	1992.04.06			RD 17		X	X	X	X	6/73AA
F/227/B(U)	00	1994.08.13			R 59		X	X	X	X	6/73AA
F/228/B(U)	00	1994.08.01			D 14265		X	X	X	X	6/73AA
F/229/B(U)F	00	1994.02.01			IL 45		X	X	X	X	6/73AA
F/230/B(U)F	00	1994.02.15			LR 44		X	X	X	X	6/73AA
F/231/B(U)F	00	1992.06.17			IL 47		X	X	X	X	6/73AA
F/232/B(U)F	00	1992.10.01			IU 17		X	X	X	X	6/73AA
F/233/B(U)F	00	1992.12.21			R 52						6/73AA
F/236/B(M)F	00	1994.06.14			IU 15		X	X	X	X	6/73AA
F/237/B(U)F	00	1994.10.07			NTL 8/1		X	X	X	X	6/73AA
F/238/B(U)F	00	1994.04.25			NTL 8/2						6/73AA
F/239/B(U)F	00	1993.03.13			TN 6/3		X	X	X	X	6/73AA
F/240/B(U)	00	1993.03.25			DV 52		X	X	X	X	6/73AA
F/241/B(U)F	00	1992.01.31			RD 10		X	X	X	X	6/73AA
F/242/B(U)	00	1993.12.14			R 61		X	X	X	X	6/73AA
F/247/B(U)	00	1994.04.10			D 14368		X	X	X	X	6/73AA
F/248/B(U)F	00	1993.02.01			IL 42		X	X	X	X	6/73AA
F/251/B(U)F	01	1993.07.15			NTL 8/3		X	X	X	X	6/73AA
F/253/B(U)	00	1994.03.10			D 80249		X	X	X	X	6/73AA
F/254/B(U)	00	1994.05.28			D 80288		X	X	X	X	6/73AA
F/255/B(U)F	00	1991.07.29			R 48		X	X	X	X	6/73AA
F/2c0/B(U)	00	1992.u3.29			IL 28		X	X	X	X	6/73AA
F/260/B(U)F	00	1994.08.01			IL 28						6/73AA
F/261/B(U)	00	1994.08.13			SV 59		X	X	X	X	6/73AA
F/262/F	00	1994.03.12			DV45 FS45		X	X	X	X	6/73AA
F/264/B(U)F	00	1993.06.30			FS 41		X	X	X	X	6/73AA
F/265/B(U)	00	1992.09.15			CONT 6LD		X	X	X	X	6/73AA
F/266/B(U)	00	1992.11.20			CTT 2 CC		X	X	X	X	6/73AA
F/267/B(U)F	00	1991.06.20			IL 46		X	X	X	X	6/73AA
F/269/F	00	1992.06.25			FBFC-RCC		X	X	X	X	6/73AA
F/271/B(U)F	00	1993.07.15			TN 12/2		X	X	X	X	6/73AA
F/272/B(U)F	00	1992.08.17			TN 10/1		X	X	X	X	6/73AA
F/273/B(U)	00	1993.05.01			D 14798		X	X	X	X	6/73AA
F/274/B(U)F	02	1993.04.18			TN 13/2		X	X	X	X	6/73AA
F/275/B(U)F	01	1992.07.10			TN 12/1		X	X	X	X	6/73AA
F/276/B(U)	00	1992.12.12			D 80367		X	X	X	X	6/73AA
F/278/F	00	1992.08.31			FS 62		X	X	X	X	6/73AA
F/280/B(U)F	00	1994.04.09			FS 55		X	X	X	X	6/73AA
F/283/B(U)	00	1994.02.04			ETI ALCYON		X	X	X	X	6/73AA
F/285/F	00	1993.07.31			RCC3		X	X	X	X	6/73AA
F/286/B(U)	00	1993.05.01			D 80433		X	X	X	X	6/73AA
F/287/B(U)F	00	1992.02.06			RD 24		X	X	X	X	6/73AA
F/289/B(U)	00	1994.10.31			D 80457		X	X	X	X	6/73AA
F/290/B(U)F	00	1994.08.01			FS 47		X	X	X	X	6/73AA
F/291/F	00	1993.12.26			RCC4		X	X	X	X	6/73AA
F/292/B(U)	00	1992.09.27			SV 61 + CC28		X	X	X	X	6/73AA
F/294/F	00	1992.C9.31			FS 63		X	X	X	X	6/73AA
F/295/B(U)	00	1993.03.01			CC 10		X	X	X	X	6/73AA
F/300/B(U)F	00	1993.02.09			IL 49		X	X	X	X	6/73AA
F/301/B(U)F	00	1992.08.21			R 62						6/73AA
F/302/B(U)	00	1994.08.15			CC 30		X	X	X	X	6/73AA
F/303/B(U)F	00	1992.02.23			FS 64		X	X	X	X	6/73AA
F/304/B(U)F	00	1992.U6.18			LK 100 R		X	X	X	X	6/73AA
F/306/B(U)F	00	1993.12.03			FS 67		X	X	X	X	6/73AA
F/307/AF	00	1992.08.25			FBFC RCC		X	X	X	X	6/73AA
F/308/B(U)F	00	1994.02.08			IU 25						6/73AA
F/309/B(U)F	00	1993.05.11			LR 56		X	X	X	X	6/73AA
F/310/B(U)F	00	1994.05.24			FS 69		X	X	X	X	6/73AA
F/311/B(U)	00	1994.03.10			SV 65		X	X	X	X	6/73AA
F/312/B(U)	00	1994.03.10			IBL 460		X	X	X	X	6/73^A
F/313/B(U)F(1)	1	1991.09.12	F/313/B(U)F	Aa			X	X	X	X	6/73AA
F/314/B(U)	00	1992.10.17			VEGA 80						6/73AA

FIGURE 4.

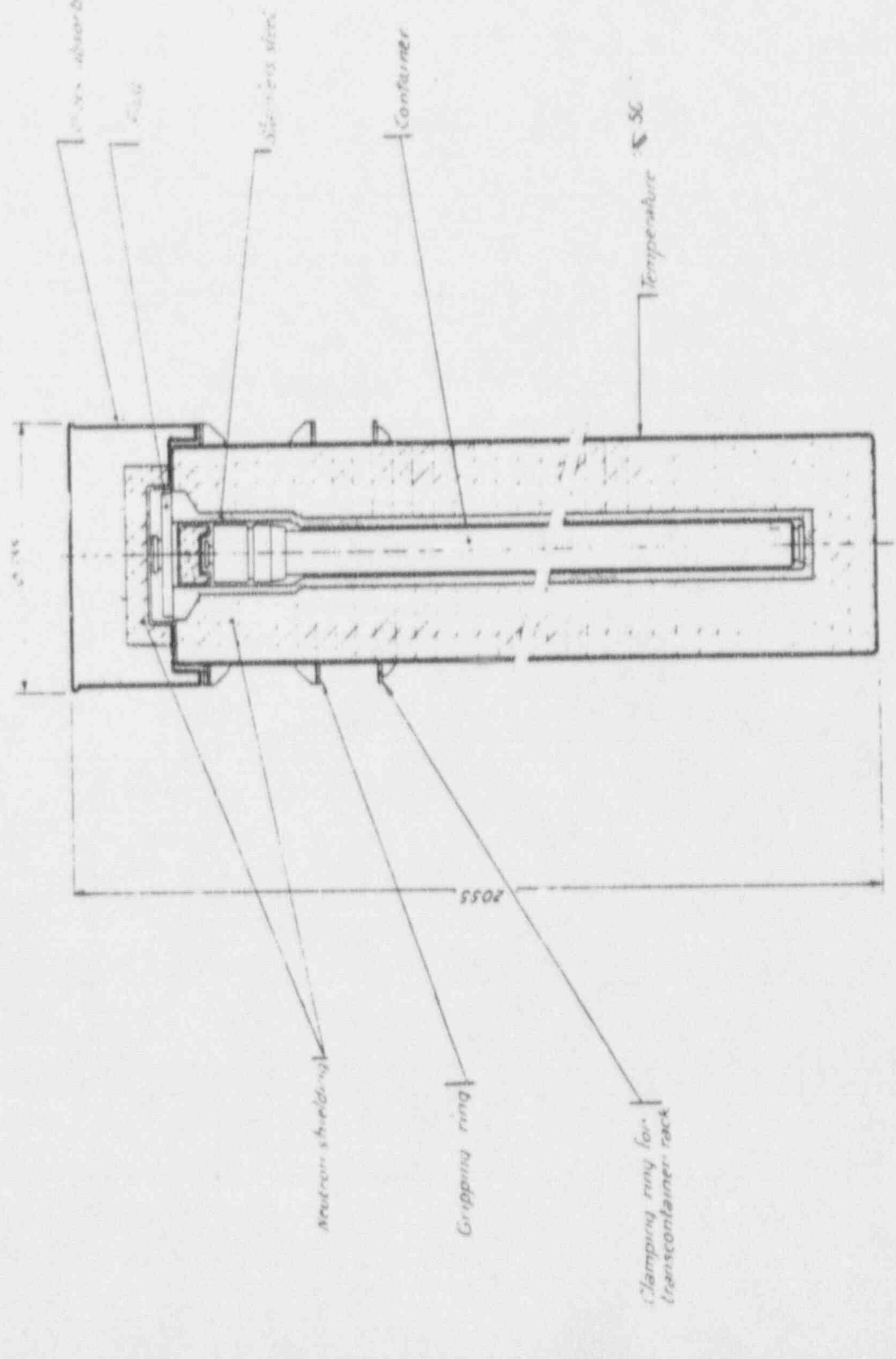
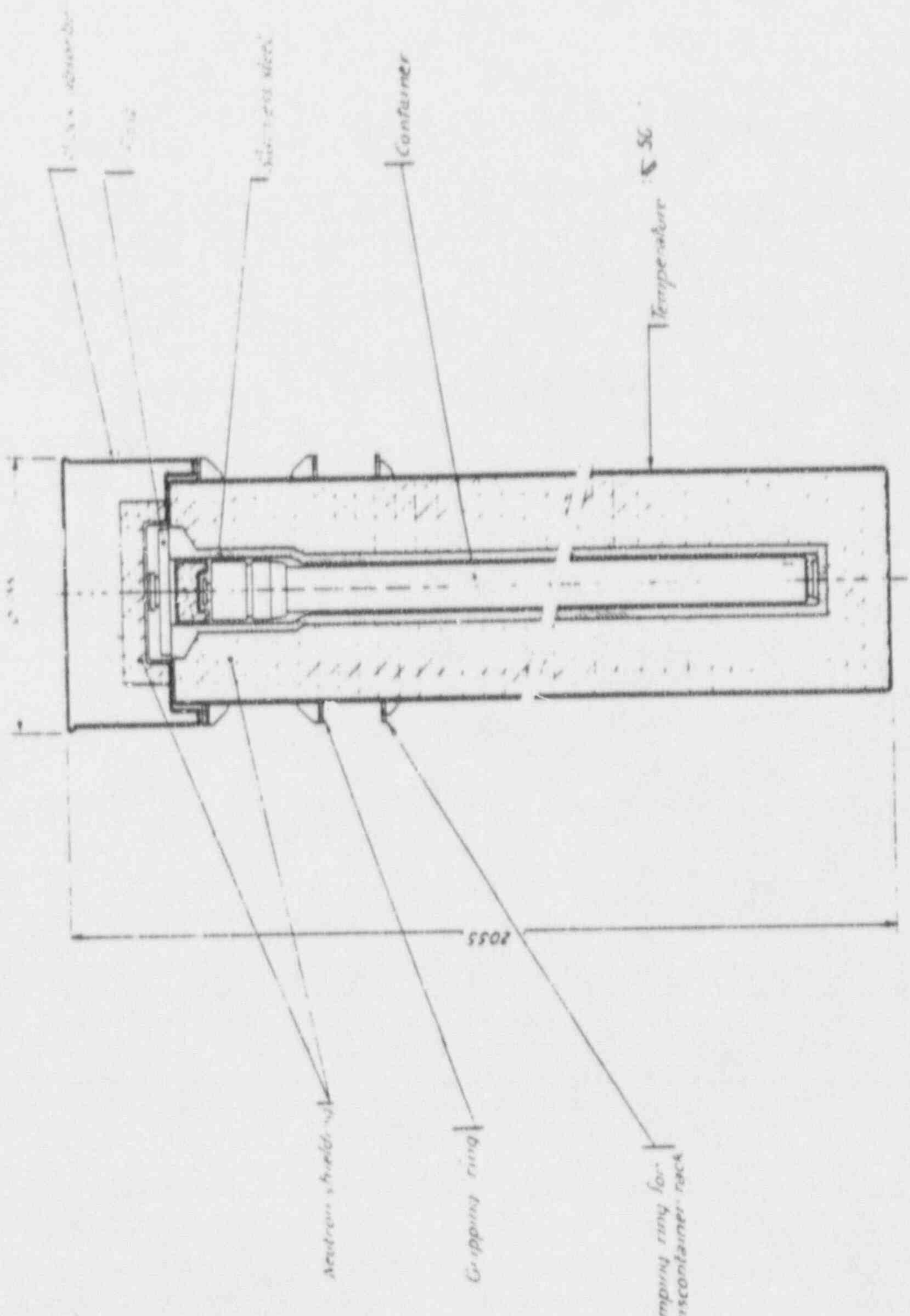

Container
Temperature
2055
Neutron shielding
Gripping ring
Clamping ring for transcontainer rack

FIGURE 4.


Container
Temperature
Neutron shielding
Gripping ring
Clamping ring for transcontainer rack
2055

APPENDIX G

SECTION 2904 OF ENERGY POLICY ACT OF 1992

STUDY AND IMPLEMENTATION PLAN ON SAFETY OF SHIPMENTS OF PLUTONIUM BY SEA

(a) STUDY - *The President, in consultation with the Nuclear Regulatory Commission, shall conduct a study on the safety of shipments of plutonium by sea. The study shall consider the following:*

(1) The safety of the casks containing the plutonium.

(2) The safety risks to the States of such shipments.

(3) Upon the request of any State, the adequacy of that State's emergency plans with respec to such shipments.

(4) The Federal resources needed to assist the States on account of such shipments.

(b) REPORT - *The President shall, not later than 60 days after the date of the enactment of this Act, transmit to the Congress a report on the study conducted under subsection (a), together with his recommendations based on the study.*

(c) IMPLEMENTATION PLAN - *The President, in consultation with the Nuclear Regulatory Commission, shall establish a plan to implement the recommendations contained in the study conducted under subsection (a) and shall, not later than 90 days after transmitting the report to the Congress under subsection (b), transmit to the Congress that implementation plan.*

(d) DEFINITION - *as used in this section, the term "State" includes the District of Columbia and any commonwealth, territory, or possession of the United states.*

Congress of the United States
Washington, DC 20515

December 14, 1992

The Honorable Fred McGoldrick
Acting Deputy Assistant Secretary
Nuclear Energy and Energy
Technology Affairs
Bureau of Oceans and International
Environmental and Scientific Affairs
United States Department of State
Washington, D.C. 20520

Dear Mr. McGoldrick:

Enclosed is a copy of a report, "Definition of Bounding Physical Tests Representative of Transport Accidents -- Air and Marine," that was recently brought to our attention. We believe the report is highly relevant to the Executive Branch study now being carried out in consultation with the Nuclear Regulatory Commission (NRC) pursuant to Public Law 102-486.

This report, prepared for the NRC in 1983, includes a detailed set of tests for determining whether casks used for transporting radioactive materials by sea could withstand extremely severe accidents. Unfortunately, although the report was completed under contract for NRC's Office of Nuclear Regulatory Research by a team at the Illinois Institute of Technology's Research Institute (IITRI), the tests proposed in the report have never been pursued. This report was part of the Modal Study, a project begun by NRC in 1978 to examine safety issues related to various modes of transportation of radioactive materials.

The IITRI team has identified both historical and hypothetical scenarios for severe air and marine transport accidents involving radioactive material containers and used this data to develop scenarios for "extremely severe credible accidents for each shipping mode." IITRI then developed tests for radioactive material casks that would simulate the stresses that actually occur in such severe accidents. It appears that the report satisfactorily defined a maximum credible accident scenario involving plutonium transport based upon a survey of maritime accidents and an assessment of the most severe conditions under which such accidents have occurred. The study further designed appropriate test procedures to replicate such conditions.

ENCLOSURE 2

Page Two
McGoldrick

The tests recommended by IITRI for collision, fire and immersion are considerably more severe than those required by the International Atomic Energy Agency (IAEA). You may recall that it was concern over the adequacy of the current standards which prompted the study you are currently conducting. Thus, we enclose this report for your review and consultation prior to completion of the study being done pursuant to Public Law 102-486.

Thank you for your attention to this important matter.

Sincerely,

George Miller
Chairman
Committee on Natural Resources

Neil Abercrombie
Member
Committee on Natural Resources

DRAFT

Dear Mr. Miller:/Dear Mr. Abercrombie:

Thank you for your letter of December 14 enclosing a copy of the report, "Definition of Bounding Physical Tests Representative of Transport Accidents - Air and Marine," prepared by the Illinois Institute of Technology's Research Institute (IITRI) for the U.S. Nuclear Regulatory Commission (NRC) in 1983.

The U.S. agencies involved in preparation of the study on the safety of shipments of plutonium by sea pursuant to section 2904 of the Energy Policy Act of 1992 (P.L. 102-486), including the NRC, are familiar with the IITRI report and have taken it into consideration in preparing the P.L. 102-486 study. I have also provided a copy of your letter to the NRC, which may wish to provide you with a more detailed response.

The U.S. Department of Energy will forward the P.L. 102-486 study to Congress in the very near future.

Sincerely,

Fred McGoldrick
Director, Office of Nuclear
Non-Proliferation and Export Policy

ENCLOSURE 3

DRAFT

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

The Honorable George Miller, Chairman
Committee on Natural Resources
United States House of
  Representatives
Washington, D.C. 20515

Dear Chairman Miller:

I am responding to your letter to Mr. Fred McGoldrick of the U.S. Department of State regarding the Executive Branch study required by Public Law 102-486. In your letter you identified a report, "Definition of Bounding Physical Tests Representative of Transport Accidents -- Air and Marine", prepared for NRC in 1983 by the Illinois Institute of Technology's Research Institute (IITRI). You requested that this report be reviewed prior to completion of the Executive Branch study.

The IITRI report has been reviewed in preparation of the Executive Branch study. In 1979, the NRC was concerned with frequent public criticism that regulatory test requirements and performance standards for packages containing large quantities of radioactive material were not realistically linked to possible severe accident conditions. For example, survival of a 30-ft drop on an unyielding surface without incurring significant leakage did not appear to be a stringent collision standard. The NRC initiated a multiphase effort (the Modal Study) to evaluate the extent to which regulatory tests and performance standards bounded high severity transportation accidents, and to evaluate the residual risk from any accidents which may not be bounded. The initial phase of this effort resulted in two studies: (1) Severe Rail and Truck Accidents: Toward a Definition of Bounding Environments for Transportation Packages, by Ridihalgh, Eggers and Associates (REA); and (2) Definition of Bounding Physical Tests Representative of Transport Accidents - Air and Marine, by the Illinois Institute of Technology Research Institute (IITRI).

IITRI submitted their final report to the NRC in 1983. The IITRI report developed a series of physical tests, based on an analysis of marine and air accident data for 1970-1979. These included a crush test, penetration test, slash test and immersion test for extremely severe marine accident conditions, as well as a separate test sequence comprised of a fire test, hose stream test, and an immersion test. A separate deep submersion test was also proposed. The tests specified by the IITRI study appear to be more severe than the traditional tests recommended and adopted by IAEA member states. However, the study did not develop post-test acceptance criteria. While the tests seem more severe, the level of safety afforded by the suggested tests was not evaluated, and could not be determined without corresponding acceptance criteria.

In one crucial area concerning shipboard fires, the IITRI study concluded that the current IAEA packaging requirement that packages withstand a 30-minute 1475° F fire would be more than adequate for below-deck fires. This conclusion is particularly germane to plutonium shipments, where the greatest risk is

DRAFT

ENCLOSURE 4

from respirable particles, such as those that may be produced in fires. The IITRI study based this conclusion on its analysis of a collision between a container ship (the Sea Witch) and a oil tanker which occurred in New York Harbor in 1973, an accident which is characterized by the Coast Guard (according to the IITRI report) as a "worst-case" accident.

About the time the IITRI report was submitted, a reconsideration of program strategy led to a redirection of the Modal Study. This redirection was based on program costs and timing, since at that time, large numbers of road and rail spent fuel shipments were being projected (e.g., shipments to a monitored retrievable storage facility), many of which were anticipated to be made in new package designs. As a result, neither the IITRI or the REA study was pursued beyond its initial effort to develop package qualification tests (e.g., no efforts were undertaken to establish post-accident acceptance criteria). Because of the redirection, neither the IITRI or REA reports were subjected to normal peer review. Instead, NRC redirected its effort towards determining the adequacy of protection provided by spent fuel packages (built to Type B standards) when subjected to historically severe highway and railway accident conditions. The resulting study (NUREG/CR-4829) showed that spent fuel packages, which are designed to the same international standards used for plutonium packages, would perform their safety functions under severe accident conditions.

In our consulting role in the Executive Branch study,the staff reviewed the IITRI report as well as DOE and NRC risk studies previously performed. The staff concluded that due to the low probability of severe marine accidents (as acknowledged in the IITRI report) and the minimal risk posed by such accidents, the current IAEA package standards provide adequate public health and safety for plutonium shipments by sea.

We hope that this addresses your concerns. We expect that the Executive Branch study will be issued shortly.

Sincerely,

James M. Taylor
Executive Director
for Operations

Revision to Final Report

Replace the last paragraph on page 18 and the first paragraph on page 19 with the following text:

In 1979, the NRC was concerned with frequent public criticism that regulatory test requirements and performance standards for packages containing large quantities of radioactive material were not realistically linked to possible severe accident conditions. For example, survival of a 30-ft drop on an unyielding surface without incurring significant leakage did not appear to be a stringent collision standard. The NRC initiated a multiphase effort (the Modal Study) to evaluate the extent to which regulatory tests and performance standards bounded high severity transportation accidents, and to evaluate the residual risk from any accidents which may not be bounded. The initial phase of this effort resulted in two studies: (1) Severe Rail and Truck Accidents: Toward a Definition of Bounding Environments for Transportation Packages, by Ridihalgh, Eggers and Associates (REA); and (2) Definition of Bounding Physical Tests Representative of Transport Accidents - Air and Marine, by the Illinois Institute of Technology Research Institute (IITRI).

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