NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

December 2003

NWMO BACKGROUND PAPERS
1. GUIDING CONCEPTS

1-8 NONPROLIFERATION ASPECTS OF SPENT FUEL STORAGE AND DISPOSITION

Thomas Graham, Jr. & James A. Glasgow, Morgan Lewis

NWMO Background Papers

NWMO has commissioned a series of background papers which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these background papers is to provide input to defining possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers currently available are posted on NWMO's web site. Additional papers may be commissioned.

The topics of the background papers can be classified under the following broad headings:

1. **Guiding Concepts –** describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.
2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.
3. **Health and Safety –** provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.
4. **Science and Environment –** provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into our understanding of the biosphere and geosphere.
5. **Economic Factors** - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.
6. **Technical Methods** - provide general descriptions of the three methods for the long-term management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.
7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

MEMORANDUM

Morgan Lewis
COUNSELORS AT LAW

Table of Contents

MEMORANDUM

Morgan Lewis
COUNSELORS AT LAW

I. INTRODUCTION AND SUMMARY

This report for the Nuclear Waste Management Organization (NWMO) addresses nuclear nonproliferation aspects of spent fuel storage and disposition at nuclear power plant sites, in central storage facilities and in geologic repositories. Consistent with NWMO's statements concerning the purpose of this and other background papers, we have provided a summary of relevant policy developments over the past several decades as well as our commentary concerning international agreements that have significant implications from the perspective of nuclear nonproliferation. Because U.S. laws and regulations may be relevant to the options for spent fuel storage and disposition that NWMO is addressing, our report includes a review of the principal provisions of such laws and regulations.

Our report for NWMO first reviews the applicability, to spent fuel storage and disposition, of the following international treaties and conventions that deal with nuclear nonproliferation matters that are relevant to spent fuel: Treaty on the Nonproliferation of Nuclear Weapons (NPT) and safeguards of the International Atomic Energy Agency (IAEA) pursuant to safeguards agreements that are required by the NPT; the Convention on Physical Protection of Nuclear Material and the IAEA's Guidelines on Physical Protection of Nuclear

Material (INFCIRC 225 Rev. 4); and the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management.

While the foregoing conventions and treaties articulate broadly applicable requirements for the safe and secure storage, transportation and disposition of spent fuel, they do not set forth precise guidelines that are directly pertinent to spent fuel. Nor do they set forth "nonproliferation" considerations that are uniquely applicable to the storage, transport and disposition of spent fuel.

Of direct applicability to spent fuel is the NPT's requirement that the non-nuclear weapons states (NNWS), such as Canada, enter into agreements with the IAEA, providing for the IAEA's application of safeguards to all nuclear material within the state, including spent fuel. The IAEA's safeguards agreement with the U.S. is applicable to spent fuel stored at U.S. nuclear power plants and storage/disposal facilities licensed by the U.S. Nuclear Regulatory Commission (NRC). Similarly, the Canada-IAEA Safeguards Agreement is applicable to spent fuel at such facilities in Canada. IAEA safeguards clearly apply to spent fuel placed in geologic repositories. However, questions have been raised about whether the IAEA should terminate its safeguards following placement of spent fuel in a repository, sealing of the repository chambers, or upon final closure of the repository itself.

A substantial part of this report for NWMO is devoted to our summary of physical protection requirements in the United States for spent fuel located at each of the three types of facilities that NWMO asked us to study. These summaries illustrate the key physical protection issues that have been raised with respect to actual U.S. facilities and the manner in which the U.S. Department of Energy (DOE) and the NRC have addressed those issues.

We also review the IAEA's Guidelines on Physical Protection of Nuclear Material (INFCIRC 225, Rev. 4) and the Convention on the Physical Protection of Nuclear Material. However, the Physical Protection Convention and INFCIRC 225 do not specify specific physical protection measures for spent fuel, except to place spent fuel within the scope of "Category II" material. Also, while INFCIRC 225 Rev. 4 added a section on "sabotage," that addition does not deal specifically with spent fuel.

NWMO's analysis of the advantages and disadvantages of each of the three types of facilities specified by NWMO should take account of whether international law is evolving to favor or disfavor particular modalities for storage and disposal of spent fuel. Of importance in this respect are the revisions of the Physical Protection Convention that are being discussed. A major revision of that Convention could have implications for spent fuel storage and disposal in the U.S. and Canada if it imposes new requirements that are difficult to meet at certain facilities. The discussion of proposed amendments to that Convention is proceeding slowly, however. If ultimately implemented, these revisions may not deal specifically with spent fuel storage or disposal.

Our research yielded relatively little discussion, in the published literature, regarding the "nonproliferation" issues associated with storage, transport and disposition of spent fuel in the United States and Canada. For example, in its environmental assessments and safety analysis of existing and proposed facilities for the storage and disposition of spent fuel, the U.S. government has not discussed whether spent fuel storage and disposal options or alternatives would promote U.S. nonproliferation objectives.

To the extent that the U.S. government has considered the "nonproliferation" consequences of its decisionmaking concerning such facilities, the analysis has been cast in terms of "physical protection" of such facilities against sabotage or diversion of the spent fuel. Therefore, we have discussed the physical protection measures that will be required with respect to spent fuel at DOE's proposed Yucca Mountain spent fuel repository in Nevada, independent spent fuel storage installations (ISFSIs) at individual nuclear plants and central storage facilities.

The U.S. government's views on the "nonproliferation" aspects of storage and disposal of spent fuel in the United States are found mostly in facility-by-facility discussion of physical protection requirements. In the early 1980's, the Department of Energy's (DOE's) Environmental Impact Statement (EIS) on the Waste Isolation Pilot Plant (WIPP) devoted only a few pages to a discussion of physical protection of the radioactive material to be placed in WIPP. Twenty years later, in the context of the Yucca Mountain EIS, DOE devoted more attention to physical protection, primarily in connection with its review of the threat of "sabotage."

We were not asked by NWMO to address the nonproliferation aspects of exporting spent fuel for disposition in another country (such as Russia), accepting spent fuel from other countries, using new treatment technologies such as partitioning and transmutation or reprocessing spent fuel. We note that the U.S. Department of Energy (DOE) has supported studies and programs regarding transmutation and partitioning, carried out by its national laboratories and other companies. However, these programs are at an early stage, and it is premature to predict whether they will become a part of the U.S. system for disposing of spent fuel. Currently, there are few signs that the U.S. government is moving toward adoption of transmutation, partitioning or reprocessing as methods for reducing the amount of high level waste that must be placed in a geologic repository.

The literature on the policy and nonproliferation implications of reprocessing spent fuel is vast. However, reprocessing has only a tangential relevance to this report for NWMO, since the

U.S. and Canadian governments have not chosen reprocessing as a method of dealing with the disposal of spent fuel. Nevertheless, in Section VII, we provide a concise overview of major developments concerning U.S. policy with respect to reprocessing of spent fuel. The current U.S. approach to storage and disposition of spent fuel is largely based on a U.S. policy to forego reprocessing.

This report for NWMO touches only briefly on the contributions that "alternative" or "nonproliferative" fuels conceivably could make to spent fuel storage and disposal in Canada and the United States. In recent years, Congress has appropriated funds to support the development and testing of alternative fuels, including thorium fuel, that may have nonproliferation and other advantages, compared to conventional uranium oxide fuel. For example, in their report accompanying the FY 2004 Energy and Water appropriations bill, the congressional conferees instructed DOE to spend $4 million to continue the ongoing thorium fuel work at the Kurchatov Institute in Russia. Proponents of thorium fuel argue that spent thorium fuel is easier to store and place in a repository than conventional uranium fuel.

Because of the fundamental importance of the "spent fuel standard," our report for NWMO provides an analysis and commentary on this standard. The "spent fuel standard" refers to the intense gamma radiation emitted by spent fuel for a very long period following its discharge from a reactor. The high-level radiation effectively prevents unauthorized access to surplus weapons plutonium after it is irradiated in reactors to meet the "spent fuel standard." Despite the importance of this "standard," we were unable to find a numerical expression of the standard or recommendations regarding appropriate quantitative requirements for its implementation.

In our report, we review statements by the U.S. government, the IAEA and other commentators concerning the declining gamma radiation emitted by spent fuel as it ages. Apparently, little attention has been given to a numerical expression of the spent fuel standard because spent fuel discharged from power reactors, after being fully irradiated, will remain highly radioactive for approximately 500-1000 years. U.S. government reports point out, however, that some research reactor fuel (and possibly some other spent fuel that was irradiated for only a brief period) may have far different characteristics with respect to gamma activity as it ages. For some such fuel, the spent fuel standard may not be met after the fuel has been out of the reactor for 30 or more years. A numerical expression of the spent fuel standard appears desirable in order to ensure that appropriate additional physical security measures are established with respect to spent fuel with low gamma activity to compensate for the absence of a "radiation barrier" that is sufficient to cause the fuel to be "self protecting."

Additional consideration should be given to the manner in which IAEA safeguards will be applied to spent fuel stored in geologic repositories. While there is general agreement that safeguards will continue after the spent fuel is placed in the repository, important uncertainties remain regarding the point at which IAEA safeguards should be terminated.

An effort, such as this, to summarize the nuclear nonproliferation principles that are applicable to the storage and disposition of spent fuel in Canada, the United States and other countries must draw upon a diverse array of documents and decisions spanning several decades. To date, nuclear nonproliferation implications of spent fuel disposition have been addressed most comprehensively in the context of national policies regarding reprocessing of spent fuel. In contrast, decisions regarding storage and disposal, in the United States, of spent fuel from U.S. reactors have not been framed in terms of the nonproliferation implications of such actions.

While instances may be found where the United States and other countries addressed spent fuel storage and disposal through the lens of nonproliferation policy, most of these efforts occurred several decades ago. Prompted by recent actions in the IAEA and elsewhere, multinational storage and disposal of spent fuel is gaining renewed attention, as is discussed below.

II. INTERNATIONAL AGREEMENTS THAT ARE RELEVANT TO NONPROLIFERATION ASPECTS OF SPENT FUEL STORAGE AND DISPOSITION

A. Applicability of IAEA Safeguards to Spent Fuel, Pursuant to the Nuclear Nonproliferation Treaty

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) requires non-nuclear weapons states (NNWS) (including Canada) to accept and maintain IAEA safeguards with respect to all source and special nuclear material, including spent fuel.[1/] The nuclear weapons states (NWS) (U.S., France, U.K., Russia and China) have entered into voluntary safeguards agreements with the IAEA. Spent fuel arising from the civil nuclear power programs in these countries is covered by these voluntary safeguards agreements.

Spent fuel in Canada is within the scope of Canada's Safeguards Agreement with the IAEA. Under the Canada-IAEA Safeguards Agreement, IAEA safeguards on spent fuel continue until a "determination by the Agency that the material has been consumed or has been diluted in such a way that it is no longer usable for any nuclear activity relevant from the point of view of safeguards, or has become practically irrecoverable."[2/]

IAEA safeguards apply to spent fuel in the spent fuel pools and independent spent fuel storage installations (ISFSIs) at U.S. power and research reactors licensed by the NRC and Canadian reactors licensed by the Canadian Nuclear Safety Commission (CNSC). IAEA safeguards will also apply to spent fuel from power reactors stored at any regional ISFSIs that are constructed in Canada and the United States. Furthermore, the IAEA applies its safeguards

---

1/ Treaty on the Non-Proliferation of Nuclear Weapons, opened for signature July 1, 1968, 21 U.S.T. 483, T.I.A.S. No. 6839, 729 U.N.T.S. 161 (entered into force March 5, 1970).

2/ Article 11, Canada-IAEA Safeguards Agreement. The foregoing provision is identical to Article 11 of the U.S.-IAEA Voluntary Safeguards Agreement (both are taken verbatim from Article 11 of the Model Safeguards Agreement, pursuant to the NPT (INFCIRC 153).

to spent fuel placed in geologic spent fuel repositories, both during storage at the repository site and later, after emplacement in the repository.

B. Convention on Physical Protection of Nuclear Material

The Convention on Physical Protection of Nuclear Material[3/] recognized that the responsibility for establishing and operating a physical protection system rests primarily with each state. The Convention's definition of "nuclear material" includes spent nuclear fuel. A table ("categorization of nuclear material"), appended to the Convention at Annex II, places "irradiated fuel" in "Category II."

Notably, the Physical Protection Convention deals exclusively with international transportation of nuclear material and temporary storage that is incidental to such transport. Consequently, as currently constituted, that Convention is not directly relevant to the storage and disposal of spent fuel in the United States, Canada and other countries.

An effort to amend the Physical Protection Convention to include the domestic use, storage and transportation of fissile material against sabotage is being considered by the parties to that Convention. The most recent review meeting to consider the proposals to amend the Physical Protection Convention was held in Vienna, Austria in March 2003, under the auspices of the IAEA.[4/] These proposed changes have the potential greatly to strengthen the regulatory and legal infrastructure for the protection of nuclear material. If its scope is expanded in the

---

3/ Convention on the Physical Protection of Nuclear Materials, with Annex, Done at Vienna, October 25, 1979, T.I.A.S. 11080 (entered into force February 8, 1987).

4/ *See*, Patricia A. Comella, *REVISING THE CONVENTION ON THE PHYSICAL PROTECTION OF NUCLEAR MATERIAL* – Chapter IV, and Denis Flory, *REVISING THE CPPNM: CHALLENGES AND CONSTRAINTS*, both in PROCEEDINGS OF THE 44TH ANNUAL MEETING OF THE INSTITUTES FOR NUCLEAR MATERIALS MANAGEMENT, Phoenix, Arizona, July 13-17, 2003.

manner contemplated in the proposed amendments, the Physical Protection Convention will truly become a cornerstone of the international nonproliferation regime.

At the March 2003 review meeting, some countries objected to a U.S. government proposal to exclude certain actions by the military and armed services from the scope of a proposed amendment to subject certain criminal offenses regarding nuclear material to the jurisdiction of an international tribunal. The participants thus failed to reach a consensus on the proposed amendments to the Convention. The prospects for adoption of these far-reaching amendments to the Convention are linked to the ongoing efforts to resolve the impasse that arose at the March 2003 review meeting.

C. Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management

The Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management ("Joint Convention")[5/] entered into force on June 18, 2001. The United States, Canada and 31 other countries are currently parties to the Convention.

In November 2003, the first Review Meeting of the Joint Convention was held in Vienna, Austria. According to the IAEA's summary of the First Review Meeting, this step "signaled that the Joint Convention, the only internationally binding legislation in this field, is now fully operational."[6/] The IAEA's summary of that meeting states that, in accordance with the Joint Convention, "National Reports" were presented by many member states. These reports explain how a country is complying with the 25 technical articles of the Joint Convention, whose objective is "to achieve and maintain a high level of safety worldwide in spent fuel and

---

5/ Treaty Doc. 106-48, 1997 U.S.T. LEXIS 123.

6/ IAEA website, NUCLEAR SAFETY AND SECURITY, article on FIRST REVIEW MEETING OF THE JOINT CONVENTION. (website visited on December 9, 2003).

radioactive waste management." During the meeting, an "issue of great concern" was said to arise from the fact that only 33 countries (including Canada and the United States) are presently Contracting Parties to the Convention.

As is evident from its title, the Joint Convention focuses on the safe storage and disposal of spent fuel and radioactive waste. It does not deal with the physical security of such material or other "nonproliferation" issues associated with the storage, transportation and disposal of spent fuel and radioactive waste.

Studies published by the IAEA have noted that geologic disposal of spent fuel has both "security and safety implications."[7/] As the OECD Nuclear Energy Agency has pointed out, "disposal represents the radioactive waste management end-point providing security and safety in a manner that does not require monitoring, maintenance, and institutional controls."[8/]

A session of the recent International Conference on Geologic Repositories: Political and Technical Progress[9/] was devoted to the "long-term safety and security of geological disposal."[10/] Papers at this session address the question of whether "security, besides safety," is an "important concern." Several papers considered whether "the current international definition of 'disposal' should be amended to indicate that it is a management solution that is also meant to provide security."

In a recent presentation concerning the Joint Convention, an NRC official explained the importance of the Joint Convention and noted that it complements other international

---

7/ OECD/NUCLEAR ENERGY AGENCY, GEOLOGIC DISPOSAL OF RADIOACTIVE WASTE – REVIEW OF DEVELOPMENTS IN THE LAST DECADE (1999), citing IAEA studies.

8/ *Id.* at 33.

9/ The Conference was held in Stockholm, from December 7-10, 2003.

10/ Session 1, December 9, 2003.

conventions.[11/] As required by the Joint Convention, the United States has reported its inventories of spent fuel and radioactive waste that are "managed and disposed," as stipulated in the scope of the Joint Convention.

According to an NRC presentation concerning U.S. actions pursuant to the Joint Convention, U.S. "national policy is safe permanent geologic disposal of spent fuel and high-level radioactive waste and surface or subsurface disposal of low-level radioactive waste to ensure long-term containment and isolation from the environment."[12/]

The Joint Convention does not deal specifically with the physical protection of spent fuel. Physical security measures with respect to nuclear material, including spent fuel, are set forth in the Convention on the Physical Protection of Nuclear Material and the IAEA's Guidelines on the Physical Protection of Nuclear Material (INFCIRC 225 Rev. 4).

11/ Presentation by Margaret Federline, Deputy Director Office of Nuclear Material Safety and Safeguards, USNRC, November 4, 2003 (available through the NRC's web site at www.nrc.gov, under the ADAMS database).

12/ *Id.*

III. U.S. GOVERNMENT AND OTHER STATEMENTS AND ACTIONS CONCERNING NONPROLIFERATION ISSUES ASSOCIATED WITH FACILITIES FOR THE STORAGE AND PERMANENT DISPOSITION OF SPENT FUEL

A. Waste Isolation Pilot Plant (WIPP)

WIPP was designed in the late 1970's to accept spent fuel from commercial nuclear power plants as well as transuranic waste (TRU) from the U.S. nuclear weapons program.[13/] Now in operation, WIPP is located in southeastern New Mexico, near the town of Carlsbad.

The Safety Analysis Report (SAR) for WIPP discusses the physical security measures that are applicable to WIPP.[14/] DOE's SAR points out that "all buildings and equipment are designed with safety and security as primary concerns," with "physical barriers" to "impede or control the access of persons and vehicles to the plant."[15/]

The Chapter of the SAR that deals with "physical security" at WIPP reviews "access control" measures, "facilities and equipment" to be employed at WIPP for physical security purposes, "procedures and emergency plan" and "training and drills."[16/]

DOE's Final Environmental Impact Statement (EIS) for WIPP includes discussion of "physical security and safeguards"[17/] and "intentional destructive acts."[18/] DOE's EIS states that "the security program to be developed will comply with the requirements of the DOE…to protect

---

13/ Although WIPP was designed to accept spent fuel as well as TRU and other radioactive wastes from DOE's defense program, DOE later specified that WIPP's sole mission is the disposal of defense wastes.

14/ U.S. DOE, WASTE ISOLATION PILOT PLANT SAFETY ANALYSIS REPORT § 9.5.

15/ *Id.* at 9.5-1.

16/ *Id.*, at 9.5-1, 9.5-3.

17/ U.S. Department of Energy, FINAL ENVIRONMENTAL IMPACT STATEMENT – WASTE ISOLATION PILOT PLANT, October 1980)(DOE/EIS-0026, UC-70), Vol. 1 at § 8.12.2.

18/ *Id.* at § 6.10.

the WIPP against deliberate acts of vandalism, arson, and sabotage and the unauthorized removal of radioactive materials or plant equipment."[19/] Detailed discussion of specific physical security measures is not provided since such information is classified or constitutes confidential safeguards information.

Chapter 6.10 of DOE's EIS discusses the possibility of "intentional destructive acts" at WIPP and during transportation of nuclear material to WIPP. DOE notes that "radioactive materials to be shipped to the WIPP, including contact – handled and remotely handled TRU waste, do not pose as serious a hazard as spent fuel and do not present as attractive a target for terrorist activities."[20/] According to DOE, "because of its higher radioactivity content per shipment, the most potentially harmful target," for a "sabotage attack, is the high level waste to be used for experiments."[21/] However, DOE concluded that "since the number of shipments of high-level waste would probably be no more than six or seven during the lifetime of the WIPP, high-level waste presents minimal exposure to the possibility of attack."[22/] DOE acknowledged that "assuming that an attack is successful, the expected impacts would be serious."[23/]

B. DOE's Evaluation Of Physical Protection Issues In Connection With Its EIS Regarding the Yucca Mountain Spent Fuel Repository

1. Nuclear Waste Policy Act

The legislative process leading to selection of Yucca Mountain, Nevada, as the site of a proposed geological repository for nuclear waste, began with Congress's enactment of the

---

19/ *Id.* at 8-57.

20/ *Id.* at 6-39.

21/ *Id.* at 6-40.

22/ *Id.*

23/ *Id.*

Nuclear Waste Policy Act of 1982[24/] ("NWPA"). This Act established the Federal Government's responsibility to provide permanent disposal of the Nation's spent nuclear fuel and high-level radioactive waste, through the means of geologic disposal.[25/]

In response to the NWPA, DOE performed environmental assessments of five sites that held the potential to become geologic repositories, finally limiting its choices to three sites: Deaf Smith County in Texas, the Hanford Site in Washington, and Yucca Mountain in Nevada.

In 1987, Congress amended the NWPA to direct DOE to focus its efforts solely on Yucca Mountain. As a result of this legislation, DOE issued its draft Environmental Impact Statement on Yucca Mountain in 1999, and its Final Environmental Impact Statement ("EIS") in 2002.

In February 2002, the Secretary of Energy recommended the Yucca Mountain site to the President. After the State of Nevada exercised its right, as provided by the NWPA, to disapprove the site, the U.S. Congress passed a joint resolution overriding that disapproval. On July 23, 2003, the President signed legislation approving the Yucca Mountain site, thus completing the scientific site characterization phase and allowing DOE's program to proceed toward licensing.

2. DOE EIS for Yucca Mountain

The EIS evaluates both the near- and long-term impacts on the environment associated with constructing, operating, and closing the Yucca Mountain repository. It also considers

---

24/ Nuclear Waste Policy Act of 1982, 42 U.S.C. 10101 et seq.; Pub. L. 97-425 (96 Stat. 2201), enacted on January 7, 1983, and amended in Pub. L. 100-202 (101 Stat. 1329-121 and Pub. L. 100-203) (101 Stat. 1330-243) on December 22, 1987.

25/ Record of Decision announcing DOE's determination to pursue mined geologic disposal for spent nuclear fuel and high-level radioactive waste (1981).

factors associated with transporting the various materials to the site. The EIS for Yucca Mountain, issued in February, 2002,[26/] consists of several volumes, totaling thousands of pages.

The Yucca Mountain EIS states that DOE, in the aftermath of the terrorist attacks on September 11, 2001, is "continuing to assess measures that it could take to minimize the risk or potential consequences of radiologic sabotage or terrorist attacks against the Nation's proposed monitored geologic repository." Physical protection measures to prevent the sabotage of spent nuclear fuel and other high-level nuclear wastes are discussed primarily in two sections of the Yucca Mountain EIS.

3. EIS Discussion of "Sabotage."

Section S.5.1.15 discusses various safeguard mechanisms for use in geologic repositories. It states that in the long term, geologic disposal of spent nuclear fuel and high-level radioactive waste "would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities." In this section, DOE further notes that the "robust metal waste packages," which would be buried more than 200 meters below the surface, would deter attempts to retrieve or disturb them." According to DOE, before its closure, the repository at Yucca Mountain would offer "certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force."

DOE notes that current NRC regulations require performance objectives that provide "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute

---

26/ FINAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGICAL REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA (continued).

an unreasonable risk to public health and safety."[27/] These regulations require that "spent nuclear fuel and high-level radioactive waste be stored in an area protected by: 1) two physical barriers, where the outer barrier must have isolation zones on each side to allow observation and threat assessment, and which must be continually monitored and protected by an active alarm system"; 2) illumination adequate to provide for "observation and assessment; 3) surveillance by random patrol; and, 4) a controlled access system."[28/] A "trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat."[29/]

Additional physical protection measures that DOE states that it could adopt, if necessary, include the following: 1) build facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects; 2) construct underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes; 3) provide additional doors, airlocks, and other features to delay unauthorized intrusion; 4) add more site perimeter barriers to provide enhanced physical protection of site facilities; and 5) activate denial systems to disable any adversaries, thereby preventing access to the facility.

In Section S.6.2.3, "Sabotage," DOE's EIS discusses two scenarios that assess the risk for sabotage of alternate types of spent nuclear fuel and high-level nuclear waste.

MOUNTAIN, NYE COUNTY, NEVADA, U. S. Department of Energy, DOE/EIS-0250 (February 2002).

[27]/ 10 CFR 63.21; 10 CFR 73.51.

[28]/ EIS, S.5.1.15.

[29]/ *Id.*

C. Nonproliferation Aspects of the Ongoing NRC Licensing Proceeding Concerning the Away-From Reactor ISFSI Proposed by Private Fuel Storage L.L.C.

In June 1977, Private Fuel L.L.C., an entity formed by several U.S. electric utilities, applied with the NRC for authorization, pursuant to 10 CFR Part 72, to construct and operate an independent spent fuel storage installation (ISFSI) in Skull Valley, Utah.

"Physical protection" of spent fuel and contentions regarding the risk of "sabotage" or attacks on the spent fuel storage facility by terrorists are the contexts in which "nuclear nonproliferation" has been addressed in the NRC's licensing proceeding concerning PFS's proposed ISFSI for spent fuel, in Skull Valley, Utah.

As part of its overall effort to prevent construction of PFS's ISFSI within the State, the State of Utah filed various contentions with the NRC in opposition to that facility. Among them was a contention that PFS's physical security plan did not meet the requirements of 10 CFR Parts 72 and 73 regarding the involvement of a local law enforcement agency (LLEA).

PFS's physical security plan for its proposed ISFSI was filed with the NRC in June 1997, as part of its license application. Citing a cooperative law enforcement agreement (CLEA) between Tooele County, Utah, in which the proposed ISFSI is sited, and the U.S. Department of the Interior's Bureau of Indian Affairs, PFS stated that the Tooele County sheriff's office had the authority and responsibility to provide law enforcement services on the Skull Valley Band reservation. Therefore, the physical security plan prepared by PFS indicated that the Tooele County sheriff's office was the designated local law enforcement agency that would respond in the event of a threat of sabotage or an attack on the facility.

To bolster the State's opposition to licensing and construction of PFS's ISFSI in Utah, the Utah legislature passed a bill (Senate Bill 81) in March 2001 that was signed into law by the

Governor. The bill established various obstacles to licensing of the PFS facility, including provisions prohibiting Utah's counties from entering into agreements with nuclear waste disposal sites to provide "municipal services." As defined in Senate Bill 81, "municipal services" include law enforcement services.

In April, 2001, the State of Utah asked the NRC's Atomic Safety and Licensing Board (ASLB) to admit an additional contention regarding the consistency of PFS's physical security plan with the NRC's Part 73 requirements regarding a local law enforcement authority's role in responding to requests for assistance at PFS's ISFSI. Subsequently, the U.S. District Court for the District of Utah granted PFS's Motion for Summary Judgment, in its lawsuit against the State, asserting that the State statute was an unconstitutional preemption of authority that Congress had entrusted to the NRC.[30/]

In an October 15, 2002 Memorandum and Order, the ASLB granted PFS's motion for summary disposition in its favor with respect to the State's late-filed contention regarding PFS's Physical Security Plan. Relying on the U.S. District Court's decision holding that the State statute was preempted by federal law, the ASLB concluded that the State's contention regarding an alleged inadequacy with the Physical Security Plan was not admissible because that contention was grounded on a State statute that the U.S. District Court had struck down.

Early in the PFS licensing proceeding, the ASLB admitted numerous issues for hearing. However, the Board rejected the State of Utah's contentions relating to the risks of terrorism or sabotage at the proposed facility. After the terrorist attacks on September 11, 2001, the State renewed and supplemented its contentions regarding the risk of terrorism and sabotage, contending that, after the attacks on September 11, the NRC should recognize that the risk of a

---

30/ *Skull Valley Band of Goshute Indians v. Leavitt*, 215 F. Supp. 2d 1232 (D. Utah, 2002).

terrorist attack on nuclear facilities was both more likely and potentially more dangerous than had previously been recognized. In its new claim, Utah argued that the NRC staff's EIS was inadequate because, among other alleged inadequacies, it failed to consider the environmental consequences of terrorists flying a fully loaded large commercial aircraft into the PFS facility.

In assessing PFS's contention regarding the risk of terrorism, the Board first reviewed cases in which the Commission had refused to require that acts of war be addressed in the safety analysis required by the Atomic Energy Act of 1954, as amended (AEA). The Board held that U.S. responses to acts of war are the responsibility of the national defense establishment, and the AEA did not require the NRC to assess the risk that such acts may damage a nuclear facility that is the subject of an NRC licensing determination. This same rationale, according to the Board, applies to its consideration of whether the National Environmental Policy Act (NEPA) requires it to assess the risk of acts of sabotage and other acts of terrorism. Because of the importance of this issue, the Board referred its terrorism ruling to the Commission for immediate review.

In its December 18, 2002 Memorandum and Order, the Commission affirmed the ASLB's rejection of Utah's contentions concerning the risk of an attack by terrorists on the PFS facility.[31/] The Commission initially observed that "the horrors of September 11 notwithstanding, it remains true that the likelihood of a terrorist attack being directed at a particular nuclear facility is not quantifiable."[32/] The Commission referred to its "guess" that the probability of a hijacked jumbo jet hitting the PFS facility and causing "catastrophic effects" is "actually minuscule."

31/ *In the Matter of Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation),* Docket No. 72-22-ISFSI; CLI-02-25 (December 18, 2002).

32/ 56 NRC 340, 349.

D. U.S. Government Analysis of Nonproliferation Aspects of Spent Fuel Storage at Independent Spent Fuel Storage Installations and Other Facilities

1. NRC Physical Protection Requirements for Spent Fuel During Storage and Transportation

NRC's rules governing receipt, storage and possession of power reactor spent fuel in an independent spent fuel storage installation (ISFSI) are codified at 10 CFR Part 72. After the terrorist attacks in the United States on September 11, 2001, the NRC issued a series of orders to various licensees, including an October 2002 order to "all power reactor licensees, research and test reactor licensees, and special nuclear material licensees who possess and ship spent nuclear fuel" requiring the implementation of certain compensatory measures. These measures must be implemented by licensees as "prudent, interim measures, to address the current threat environment." The precise measures are classified as safeguards information. In October 2002 the NRC also issued orders to the operators of ISFSIs requiring them to implement enhanced security measures. The NRC later issued orders to other ISFSIs that had not began to load spent fuel when the NRC issued its October 2002 Order.

The NRC's rules in 10 CFR Part 72 are applicable to the "receipt, transfer, packaging and possession" of "power reactor spent fuel to be stored in a complex that is designed and constructed specifically for storage of power reactor spent fuel aged for at least one year, other radioactive materials associated with spent fuel storage, and power reactor-related [greater than Class C] GTCC waste in a solid form in an ISFSI." 10 CFR § 72.2(a). As defined in Part 72, "spent nuclear fuel" or "spent fuel" means "fuel that has been withdrawn from a nuclear reactor following irradiation, has undergone at least one year's decay since being used as a source of energy in a power reactor, and has not been chemically separated into its constituent elements by reprocessing." 10 CFR § 72.3.

Among other requirements, an applicant for a specific license for an ISFSI must provide the NRC "a description of the detailed security measures for physical protection, including design features and the plans required by Subpart H."[33/]

Subpart H of Part 72, dealing with "physical protection," is the portion of the NRC's rules for ISFSIs that is most directly related to "nonproliferation" requirements. It requires the licensee to "establish, maintain and follow a detailed plan for physical protection as described in § 73.51 of this chapter."[34/] The plan "must describe how the applicant will meet the requirements of § 73.51 of this chapter and provide physical protection during on-site transportation to and from the proposed ISFSI…and include within the plan the design for physical protection, the licensee's safeguards contingency plan and the security organization personnel training and qualification plan."[35/] Among other requirements, the license applicant's "design for physical protection must show the site layout and the design features provided to protect the ISFSI…from sabotage."

NRC's "requirements for the physical protection [at fixed sites] of stored spent nuclear fuel and high-level radioactive waste" are set forth in 10 CFR § 73.51. The requirements of this subsection are applicable to (1) "spent nuclear fuel and high-level radioactive waste stored under a specific license issued pursuant to Part 72 of this chapter;" and (2) "at an independent spent fuel storage installation (ISFSI)." Those requirements are also applicable to "spent nuclear fuel and high-level radioactive waste at a geologic repository operations area (GROA) licensed pursuant to Part 60 or 63 of this chapter." 10 CFR § 73.51.

33/ 10 CFR § 72.24(o).

34/ 10 CFR § 72.180.

35/ 10 CFR § 72.180.

Section 73.51 requires that a licensee "meet the following performance capabilities:"[36/]

(i) Store spent nuclear fuel and high level radioactive waste only within a protected area;

(ii) Grant access to the protected area only to individuals who are authorized to enter the protected area;

(iii) Detect and assess unauthorized penetration of, or activities within, the protected area;

(iv) Provide timely communication to a designated response force whenever necessary; and

(v) Manage the physical protection organization in a manner that maintains its effectiveness.

In general, the licensee must "establish and maintain a physical protection system with the objective of providing high assurance that activities involving spent nuclear fuel and high-level radioactive waste do not constitute an unreasonable risk to public health and safety."[37/] Additionally, the NRC's rules specify that "the physical protection system must be designed to protect against loss of control of the facility that could be sufficient to cause a radiation exposure exceeding the dose described in § 72.106 of this chapter."[38/]

Notably, a "licensee that operates a GROA [geologic repository operational area] is exempt from the requirements of this section for that GROA after permanent closure of the GROA."[39/]

The NRC's "requirements for physical protection of irradiated reactor fuel in transit" are set forth at 10 CFR § 73.37. This section recognizes the significance of the "self-protecting"

36/ 10 CFR § 73.51(b)(2).

37/ *Id.* at (b)(1).

38/ *Id.* at (b)(3).

39/ *Id.* at (e).

aspect of spent fuel due to its inherent radiation barrier to handling without the massive casks in which the spent fuel is transported and stored. Consequently, this section is applicable only to spent fuel which has "a total external radiation dose rate in excess of 100 rems per hour at a distance of 3 feet from any accessible surface without intervening shielding…."[40/]

Spent fuel that has aged to the point where it no longer meets the 100 rem requirement specified in 10 CFR § 73.51 would instead be subject to the more comprehensive physical protection requirements specified in Section 73.26, which deals with "transportation physical protection systems, subsystems components and procedures." If the spent fuel in a single shipment is no longer "self protecting" because it does not meet the "100 rem at 3 feet" standard and contains sufficient plutonium to fall within the NRC's category of "strategic special nuclear material for domestic shipments," the NRC's physical requirements set forth in 10 CFR § 73.26 would be applicable. They include a provision that "all transfers shall be protected by at least seven armed escorts or other armed personnel – one of whom shall serve as commander."[41/] Under Section 73.26, armed escorts and other "armed response personnel" are required to "prevent or impede acts of radiological sabotage or theft of strategic material by using sufficient force to counter the force directed at [them] including the use of deadly force when armed escorts or armed response personnel have a reasonable belief that it is necessary in self defense or in the defense of others."[42/]

In summary, whether spent fuel is sufficiently radioactive to be "self protecting" (100 rem or more at a distance of 3 feet) is a critical regulatory determination. In practice, however,

40/ 10 CFR § 73.37(a)(1).

41/ 10 CFR § 73. 26(f)(2).

42/ *Id.* at (e)(3).

this standard will be far surpassed by nearly all spent fuel discharged from U.S. power reactors, which has a high level of gamma radiation for about 500-1000 years.

If the spent fuel has an activity of 100 rem or more (unshielded) at a distance of 3 feet, the physical protection requirements during transportation are as specified in 10 CFR § 73.37. These physical protection measures include two armed guards within "a heavily populated area." In contrast, spent fuel that has aged to the point where it is less radioactive than the 100 rem at 3 feet threshold established by the NRC is subject to the substantially more restrictive transportation requirements of § 73.26, including a mandatory provision that "two separate escort vehicles shall accompany the cargo vehicle" and "there shall be a total of seven armed escorts" accompanying a "specially designed cargo vehicle truck or tractor that reduces the vulnerability to theft, with at least two in the cargo vehicle."[43/] Alternatively, Section 73.26(h)(3)(i) provides that for shipments using an "armored car cargo vehicle," there must be "three separate escort vehicles," accompanied by a "total of seven armed escorts, with at least two in the cargo vehicles."

Notably, the NRC's physical protection rules in Part 73 do not distinguish between self-protecting and non-self protecting spent fuel [44/] for the purpose of physical protection requirements at fixed sites. The applicable requirements for both self-protecting and non-self protecting spent fuel are specified in 10 CFR § 73.51. Additional physical protection requirements are not mandated by § 73.51 when spent fuel has been stored for a substantial period of time and the radiation barrier has decayed to the point (below 100 rem at 3 feet,

43/ *Id.* at (h)(3)(i).

44/ For the purposes of this discussion, "self-protecting" spent fuel refers to spent fuel having a level of radioactivity greater than 100 rems at three feet (unshielded), as specified in 10 CFR § 73.37.

unshielded) where substantial additional protective measure would be required during transportation of spent fuel. Presumably, this distinction between the physical protection measures required for aged fuel at nuclear power plant sites, as opposed to transportation of aged fuel that does not meet the 100 rem at 3 feet standard, reflects the NRC's determination that the physical protection barriers at a nuclear power plant site include fences, exclusion zones and other measures, that cannot be duplicated during transportation. Consequently, the NRC determined that the additional physical protection measures specified in § 73.26 are needed for aged spent fuel that does not meet the 100 rem at 3 feet requirement.

2. History of 10 CFR § 73.37

In its 1980 Interim Final Rule regarding "Protection of Irradiated Reactor Fuel in Transit," the NRC observed as follows with respect to the "intrinsic protection against theft" afforded by spent fuel that has an external dose rate in excess of 100 rems per hour at a distance of 3 feet:

> The Commission considered a number of sets of measures for the protection of spent fuel shipments. One of these sets of measures would have provided that spent fuel shipments would be protected equivalently to shipments of formula quantities of strategic special nuclear material (SSNM), which must also be protected against theft. However, 10 CFR 73.6 of the Commission's physical protection rules for SSNM specifically exempts spent fuel which is not readily separable and which has a total external dose rate in excess of 100 rems per hour at a distance of 3 feet from any accessible surface without intervening shielding. Such materials possess intrinsic protection against theft and are not readily usable to fabricate nuclear explosives. Nevertheless, the Commission considers it prudent to require some additional measures to protect spent fuel against radiological sabotage.[45/]

45/ 45 Fed. Reg. 37403 (June 3, 1980).

In its "Statements of Consideration" accompanying its Final Rule regarding "Physical Protection for Spent Nuclear Fuel and High-Level Radioactive Waste," the NRC responded as follows to commentators who thought the rule was not sufficiently strict and others who found it unnecessarily burdensome:

> The Commission believes that the appropriate level of physical protection for spent fuel and high-level radioactive waste lies somewhere between industrial-grade security and the level that is required at operating power reactors. The Commission also notes that the nature of spent fuel and of its storage mechanisms offers unique advantages in protecting the material. This factor, along with revised consequence considerations, leads the Commission to conclude that physical protection at sites where spent fuel and high-level radioactive waste are stored under a 10 CFR Part 60 or 72 license can be more flexibly applied than previously proposed. Accordingly, the final rule has been revised to minimize redundancy and add flexibility.[46/]

The history of Section 73.37 does not disclose the basis for the NRC's selection of 100 rem at 3 feet as the threshold for treatment of spent fuel transport under that section. According to a manual prepared by the IAEA regarding the medical treatment of persons exposed to radiation, an exposure totaling 100 rems is generally not considered to be fatal, and a person suffering such an exposure probably would not be promptly disabled.[47/] As is indicated in the IAEA manual, the "reversibility of the injury is virtually certain" at doses between 1 and 2.5 Gy (100 and 250 rad).[48/] According to the IAEA, with an exposure of about 2 Gy (200 rad), survival is "probable," although "there is rarely a lack of clinical symptomatology: the onset of nausea and vomiting is relatively early (2-6 hours, but it rarely lasts longer than until the second

---

46/ 63 Fed. Reg. 26955, May 15, 1998.

47/ IAEA, MANUAL ON EARLY MEDICAL TREATMENT OF POSSIBLE RADIATION INJURY (Safety Series No. 47), at 3 (1978).

48/ *Id.* at 2.

day….”[49/] Based on the IAEA's description of these medical symptoms and the rapidity of their onset, it is unclear whether terrorists who received a total dose of 200 rad, for example, would be incapacitated rapidly enough to prevent them from removing spent fuel having a relatively low gamma dose rate of 200 rem per hour[50/] from storage casks at an ISFSI. An opportunity for such terrorists to attempt to remove fuel elements from storage containers seems remote, however, in view of the physical protection measures that are applicable at such facilities.

E. NRC's Review of "Nonproliferation" issues in the Context of Licensing ISFSIs at the Site of NRC-Licensed Nuclear Power Stations

1. Diablo Canyon ISFSI

The NRC recently reviewed an application by Pacific Gas and Electric Company to construct and operate the "Diablo Canyon Independent Spent Fuel Storage Installation." In accordance with 10 CFR Part 72, the applicant submitted its Safety Analysis Report (SAR).[51/] The "physical security plan" is addressed in Chapter 9.6, of Volume 2.

The NRC staff considers the security of spent fuel as part of its safety review of each application for an ISFSI license. In addition to reviewing an ISFSI application against the requirements of 10 CFR Part 72, the NRC staff evaluates the proposed security plans and facility design features to determine whether the requirements of 10 CFR Part 73, "Physical Protection of Plants and Materials," are met. The details of specific security measures for each facility are safeguards information, and as such, cannot be released to the public.

49/ *Id.* at 3.

50/ Since the gamma activity of power reactor fuel remains very high for centuries following its discharge from a power reactor, spent fuel having a gamma level of 100-200 rems during transport presumably would be research reactor fuel that had aged to approximately 30 years or more following discharge from a reactor.

51/ SAFETY ANALYSIS REPORT BY PACIFIC GAS AND ELECTRIC COMPANY FOR DIABLO CANYON INDEPENDENT SPENT FUEL STORAGE INSTALLATION, NRC Docket No. 72-26.

As required by Parts 72 and 51 of its Rules, the NRC issued an "Environmental Assessment Related to the Construction and Operation of the Diablo Canyon Independent Spent Fuel Storage Installation."[52/] The Environmental Assessment (EA) does not contain a discussion of "nonproliferation" or "physical protection" issues in connection with ISFSIs. The absence of such a discussion was the basis for a comment by the California Energy Commission (CEC) that "there is no discussion in the EA of the potential destruction of the casks or blockage of air inlet ducts as the result of sabotage or a terrorist attack."[53/] In response, the NRC indicated that "an NRC environmental review is not the appropriate forum for the consideration of terrorist acts:"

> Response: In several recent cases, including an appeal of a decision in the Diablo Canyon ISFSI hearing, the Commission has determined that an NRC environmental review is not the appropriate forum for the consideration of terrorist acts. The NRC staff considers the security of spent fuel as part of its safety review of each application for an ISFSI license. In addition to reviewing an ISFSI application against the requirements of 10 CFR Part 72, the NRC staff evaluates the proposed security plans and facility design features to determine whether the requirements in 10 CFR Part 73, "Physical Protection of Plants and Materials," are met. The details of specific security measures for each facility are Safeguards Information, and as such, cannot be released to the public.[54/]

In responding to the CEC's comment, the NRC also observed that "additional security measures have been put in place at nuclear facilities, including ISFSIs currently storing spent fuel."[55/] These measures "include security patrols, augmented security forces and weapons, additional security posts, heightened coordination with law enforcement and military authorities,

---

52/ Docket No. 72-26, Pacific Gas and Electric Company, October 2003.

53/ EA at 22.

54/ *Id.* at 23.

55/ *Id.* at 23.

and additional limitations on vehicular access."[56/] Furthermore, the NRC noted that it "is conducting several technical studies to assess potential vulnerability of spent fuel storage facilities to a spectrum of terrorist acts." The NRC indicated that "the results of these studies will be used to determine if revisions to the current NRC requirements are warranted."[57/]

F. National Academy of Sciences Study of "Management and Disposition of Excess Weapons Plutonium: Reactor Options" (1995)

This study by the National Academy of Sciences (NAS) produced two options for disposition of surplus weapons plutonium that it characterized "as the most promising": (1) "the use of LWRs or CANDU reactors, employing MOX fuel in a once-through mode, to embed the WPu in spent fuel that would be emplaced eventually in a geologic repository (together with the larger quantity of such spent fuel that will exist in any case from ordinary nuclear-electricity generation);" and (2) "vitrifying the WPu, together with defense high-level radioactive wastes, in borosilicate glass logs of the type planned for use in the immobilization of defense HLW in any case, again for eventual emplacement in a geologic repository."

Both of these options identified by NAS were based on what NAS referred to as the "spent fuel standard." NAS said that the "spent fuel standard" means "making the excess WPu roughly as inaccessible for weapons use as the much larger and growing quantity of plutonium in spent fuel from commercial nuclear power reactors."[58/] NAS further explained that the "reactor grade plutonium found in commercial spent fuel, while it could be used to make nuclear bombs…poses much smaller risks than separated plutonium in this regard because of the mass, bulk, and intense radiation field of the spent fuel assemblies and because of the additional

---

56/ *Id.*

57/ *Id.*

58/ NAS Study at 3.

technical sophistication and resources required for chemical separation of the spent fuel from the accompanying fission products and uranium."[59/] While noting that "under current U.S. policy, the ultimate fate of either of these waste forms is expected to be a geologic repository," NAS said that "our conclusion that these two options are the most attractive ones in our purview does not depend, however, on emplacement of the waste forms in a particular repository or by a particular time, or even on emplacement in a repository at all: the key point is that once the plutonium is embedded in spent fuel or waste-bearing glass logs of suitable specifications, it will be approximately as resistant to theft or diversion as the larger quantities of plutonium in commercial spent fuel and will represent neither a unique security hazard nor a large addition to the radioactive waste management burdens that the spent fuel and immobilized defense wastes would pose in any case."[60/] Discussing "security" considerations, the NAS study observes as follows: "with respect to the security of the final plutonium forms that disposition options produce, we have concluded that meeting the spent fuel standard is both necessary and, for the decades immediately ahead; sufficient."[61/]

G. Rand National Defense Institute Study

The Rand National Defense Institute Study: Limiting the Spread of Weapons – Usable Fissile Materials,[62/] notes that it was prepared in response to a request by the Office of the Deputy for Non-Proliferation Policy, Office of the Under Secretary of Defense for Policy. It is a broadly focused review of the use of plutonium and highly enriched uranium in civilian nuclear

---

59/ *Id*.

60/ *Id.* at 3-4.

61/ *Id.* at 375.

62/ B. Chow and K. Solomon, LIMITING THE SPREAD OF WEAPON-USABLE FISSILE MATERIALS (Rand National Defense Institute Study, 1993).

power programs as well as an assessment of options for disposing of fissile material produced for use in nuclear weapons.

Only a few pages of the Rand study are directly relevant to the nonproliferation topics addressed in our report for NWMO. The Rand study observes that "there is a second source of plutonium in addition to dismantled nuclear weapons."[63/] According to the Rand study, "at the end of 1990, there were 532 tonnes of plutonium in spent fuel worldwide." As the study points out, "the intense radiation in the spent fuel, however, would make it difficult for any terrorist group to extract plutonium from it."[64/]

The Rand study refers to the spent fuel standard and endorses that standard as a suitable barrier to terrorists' extraction of plutonium. However, it does not discuss the technical basis for this standard.

While the Rand study advocates removal of weapons grade materials from the Former Soviet Republics (FSUs), it supports a "second" option of fabricating weapons grade plutonium in the FSUs into MOX fuel and "burning" it in power reactors. Because the plutonium in the resulting spent fuel is "inaccessible," the Rand study prefers this option over storage of plutonium in the FSUs under IAEA safeguards.

H. DOE's Record Of Decision On A Nuclear Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel

In 1995, the U.S. Department of Energy (DOE) and the Department of State jointly formulated a policy to manage and protect spent nuclear fuel of U.S. origin that was irradiated in foreign research reactors. In accordance with the requirements of the National Environmental

---

63/ Rand study at 14.

64/ Rand study at 14.

Policy Act of 1969 (NEPA), DOE published a Draft Environmental Impact Statement (EIS) on a "Proposed Nuclear Weapon Nonproliferation Policy Concerning Foreign Research Reactor Spent Fuel." After receiving public comments on this draft EIS, DOE published its Final EIS in February, 1996.[65/]

In its record of decision (ROD), DOE selected alternative number 1, involving U.S. acceptance of U.S.-origin spent fuel irradiated in foreign research reactors, containing up to approximately 19.2 metric tons of heavy metal (MTHM).

DOE's EIS addressed the risk that spent fuel containing highly enriched uranium may be diverted by terrorists or subnational groups who may attempt to separate the HEU from the spent fuel and use it to produce nuclear weapons. While much of the EIS is not relevant to the storage and disposal of spent power reactor fuel, DOE's EIS and ROD are noteworthy for the purposes of this report for NWMO because they deal with the "spent fuel standard" and acknowledge that aged spent research reactor fuel that is no longer "self-protecting" may be vulnerable to diversion by terrorists.

In its discussion of the "characteristics and types of foreign research reactor spent nuclear fuel," DOE addresses the "self protecting" aspect of spent fuel, as follows:

> Spent nuclear fuel is radioactive because of the presence of the radioisotopes, which are products of the fission process. The radiation of most concern from spent nuclear fuel is gamma rays.[66/]

In its EIS, DOE considered the consequences, from a nonproliferation perspective, of not accepting the return of such spent fuel to the United States. DOE determined that this alternative would have significant disadvantages, from a nonproliferation perspective:

65/ DOE/EIS-02180, March, 1995.

66/ Vol. 1, EIS at § 2.6.1.

> The accumulation overseas of even larger amounts of spent nuclear fuel containing HEU poses a risk that such weapons-usable material might be illicitly diverted to a weapons program; although U.S. assistance in maintaining adequate physical security for foreign research reactor spent nuclear fuel repositories may lessen the potential for diversion, the proliferation risk would still be greater than under the basic implementation of Management Alternative 1. As the foreign research reactor spent fuel ages, it would become less radioactive and thus a more attractive target for illicit diversion.[67/]

In Appendix B, "Foreign Research Reactor Spent Nuclear Fuel and Transportation Costs," DOE briefly discussed the declining radioactivity and associated handling requirements for spent fuel after it is discharged from a reactor:

> The quantity of radioactive materials in spent nuclear fuel, and the resulting heat generation, decreases over time because of decay of fission products in the spent nuclear fuel. Radioactive decay refers to a process whereby the radioactive elements undergo nuclear transformations that ultimately convert them to stable (nonradioactive) elements. Many fission products formed during reactor operation have short half-lives (the time required for a quantity of radioactive material to decrease to one-half of its original amount) and others remain radioactive for tens to thousands of years. The high initial quantities of fission products in the spent nuclear fuel put the greatest requirements on providing shielding and cooling during the first few months after the spent nuclear fuel is discharged from the reactor. The rapid decay of short half-lived radioactive material leads to reduction of the amount of radioactive material in the spent nuclear fuel over time. This, in turn, reduces the need for continued storage of the spent nuclear fuel in a wet pool. After about 1 year, the heat generation rate in a spent nuclear fuel element decreases to about one percent of the level present at the time of its discharge from the reactor, and this heat generation rate would not damage the spent nuclear fuel if it is stored in a "dry" cask in preparation for transportation and dry storage.

67/ EIS § 4.6.1 at 44, emphasis added.

Because of differences in size, weight and gamma radiation, physical protection and safety-related requirements for the transportation, storage and disposal of spent research reactor fuel assemblies may differ from those requirements with respect to power reactor spent fuel.

I. U.S. Acceptance of Foreign Spent Power Reactor Fuel

In October, 1977, President Jimmy Carter announced a presidential policy on the interim management of spent fuel.[68/] President Carter's statement noted that "limited quantities of foreign spent fuel would be accepted on the same terms as domestic spent fuel when it would contribute to nonproliferation goals."[69/]

As part of the Carter Administration's effort to implement the President's policy regarding acceptance of spent fuel from certain foreign power reactors, DOE issued a draft environmental impact statement (EIS) in December 1978.[70/] The EIS "proposed that the decision to accept spent fuel from a given country [would] be made on a case-by-case basis, measured against one or both of the following criteria:

- The country is located in sensitive regions in which the storage of spent fuel would contribute to international tension.
- The acceptance of spent fuel would lead to significant gains in nonproliferation (*e.g.,* by encouraging alternatives to developing a national capacity to meet spent fuel disposal needs, by stimulating implementation of desirable regional or international fuel cycle approaches consistent with overall U.S. policy, or by inducing adherence to the Treaty on the Nonproliferation of Nuclear Weapons, or other similar steps)."[71/]

68/ DOE NOTICE CONCERNING AVAILABILITY OF DRAFT ENVIRONMENTAL IMPACT STATEMENTS AND SUPPLEMENT, CONCERNING STORAGE OF SPENT POWER REACTOR FUEL, December 7, 1978.

69/ *Id.*

70/ U.S. DOE, DRAFT ENVIRONMENTAL IMPACT STATEMENT: STORAGE OF FOREIGN SPENT POWER REACTOR FUEL (DOE/EIS-0040-D).

71/ *Id.* at ii-iii.

DOE's EIS evaluates a "full range of options associated with implementing the policy" and concludes that "not implementing the policy in regard to foreign spent fuel will be least acceptable in the context of U.S. nonproliferation objectives."[72/] Summarizing the various anticipated impacts, DOE explained that "basically, the U.S. offer to store foreign spent fuel involves a tradeoff between the gains for the non-proliferation policy and the additional risks to the environment posed by the transportation and storage of foreign fuel within the U.S."[73/]

In the Nuclear Nonproliferation Act of 1978 (NNPA),[74/] and the Department of Energy Act of 1978 – Civilian Applications,[75/] Congress established limitations on the return of foreign spent fuel to the United States. First the "subsequent arrangement" procedures[76/] established by the NNPA, are expressly made applicable to "arrangements for the storage or disposition of irradiated fuel elements." Furthermore, foreign spent power reactor fuel cannot be shipped to the United States unless the President has submitted either a specific or generic plan and the Congress does not disapprove that plan.[77/] Finally, Section 107 of the Department of Energy Act – Civilian Applications,[78/] prevents DOE from using any funds for the repurchase, transportation or disposition, interim or permanent, of any such foreign spent nuclear fuel in the United States unless such funds have been expressly approved by Congress.[79/]

72/ *Id.* at I-2 and I-3.

73/ *Id* at I-3.

74/ Pub. L. No. 95-242, 92 Stat. 120 (1978), codified at 22 U.S.C. §§ 3201-3282 and 42 U.S.C. §§ 2011-2160a.

75/ Pub. L. No. 95-238, § 107, 92 Stat. 55 (1978), 22 U.S.C. § 3224a.

76/ 42 U.S.C. § 2160.

77/ 42 U.S.C. § 2160(f)(1). Subsection (f)(2) provides an exception for limited quantities of spent fuel if the President determines that an emergency exists and the national interest so requires.

78/ Pub L. 95-238.

79/ *Id.*

Partly because of the above-mentioned limitations established by Congress, the Carter administration was unable to implement President Carter's proposal to accept limited quantities of foreign spent power reactor fuel for permanent disposition in the United States. Subsequent administrations have not sought to bring foreign power reactor spent fuel to the United States.

IV. APPLICABILITY OF THE "SELF-PROTECTING" CHARACTERISTIC OF SPENT FUEL AS THE FUEL AGES FOLLOWING DISCHARGE FROM A REACTOR

A. Commentary in INFCE Reports

On April 7, 1977, President Jimmy Carter announced the decision of the United States to pursue the establishment of an International Nuclear Fuel Cycle Evaluation Program (INFCE), with the objective of developing alternative fuel cycles and assuring access, by nations sharing common nonproliferation objectives, to supplies of nuclear fuel and facilities for the storage of spent fuel.[80/] After consultations and an organizing conference, INFCE was formally convened in Washington, D.C. in October 1977. The participants totaled 41 countries and 4 international organizations.

INFCE was a unique exercise that produced several reports that are important sources of information concerning nonproliferation issues in connection with spent fuel storage and disposal. Therefore, our report for NWMO includes a review of pertinent portions of several INFCE reports.

The Final Report of the International Nuclear Fuel Cycle Evaluation states as follows in its summary of the nonproliferation characteristics of spent fuel storage:

> The high radiation level inherent in spent fuel is an important factor against proliferation. As such levels decrease, the safeguards techniques applied may require adjustment or replacement by other existing techniques. No significant changes would be expected in the inherent proliferation resistance of the spent fuel during the interim storage time, [10 years] envisaged by Working Group 6. The Working Group determined that the existing legal and institutional framework for spent fuel management is adequate to minimize the risk of proliferation.[81/]

80/ Remarks by President Carter on Nuclear Power Policy, 13 Weekly Comp. of Pres. Doc. 502 (Apr. 12, 1977).

81/ INFCE Summary Volume, INFCE/PC/2/9, at 28.

However, the INFCE Report also concluded that spent fuel will become an "increasingly attractive target for diversion" as it ages:

> Consequently, only spent fuel from once-through cycles will be an item to be considered as regards the possibility of diversion as its underground repositories would become an increasingly attractive target for diversion owing to their large content of fissile material and their decreasing radioactivity."[82/]

To deal with risks associated with storage and disposition of spent fuel, the INFCE Report stressed the importance of physical and "technical" barriers to diversion by terrorists and other unauthorized persons. In the Summary Volume, the INFCE Report points out that "safeguards for spent fuel storage and transport are implemented according to national or multinational requirements and bilateral and IAEA agreements."[83/] According to that Report, "current safeguards measures for different types of spent fuel storage (at reactor and away from reactor) are in general similar and well established."[84/] Furthermore, the INFCE Report observed that such safeguards "are independent of location and consist of materials accountancy complemented by containment and surveillance."[85/]

Addressing the possibility of new methods for storing spent fuels, the INFCE Report commented that "the impact on safeguards requirements of new storage techniques is not yet known, but present safeguards arrangements appear to be adequate for future large storage facilities based on present technology."[86/] The Report cautioned, however, that "when future

---

82/ *Id.* at 30.

83/ *Id.* at 43.

84/ *Id.*

85/ *Id.*

86/ *Id.*

[spent fuel storage] facilities are at the design stage the requirements for improved containment, surveillance and materials accountancy techniques should be taken into account."[87/]

During the INFCE study, Working Group 7 concluded as follows with respect to the application of IAEA safeguards to spent fuel and radioactive waste:

> [B]ecause of their relative unattractiveness for the production of nuclear weapons, most categories of nuclear waste are likely to meet the IAEA criteria for termination of safeguards prior to their disposal. An exception is spent fuel from once-through fuel cycles, which, though initially unattractive because of the radiation barrier, becomes more accessible with time. Safeguarding of spent fuel, which is contained in canisters and thus amenable to item accountability and inventory verification, would be relatively straightforward during transport and emplacement in the geologic repository. Following that, successive backfilling of emplacement holes, storage rooms and galleries would provide increasing containment. After closure of the facility, on the assumption that the repository is designed for irretrievability, even very cursory surveillance would ensure the timely detection of diversion operations since these would require massive mining equipment, a large work force and surface disposal of mined rock and earth. However, the surveillance effort will extend over an indefinite period. Facilities are currently also being contemplated for interim storage of canistered spent fuel over an indefinite period of time, pending a decision on whether the fuel will be reprocessed or disposed of. In that event, the encapsulation could well be preceded by pool storage of the fuel assemblies for a period much longer than the 10 years assumed in the Working Group 7 report. It will be clear that, as the radioactivity of the spent fuel decreases with time, the diversion risks, and thus the required safeguarding effort, of such extended storage, would both increase.[88/]

The Report of INFCE Working Group 4 noted that "the advantages of the once-through cycle from the point of view of diversion are therefore that the spent fuel must first be reprocessed in order to extract the plutonium; and that the intense radiation from a discharged

---

87/ *Id.*

88/ *Id.* at 43.

fuel assembly adds to its diversion resistance."[89/] However, the Report points out that "this resistance gets weaker with time as the radioactivity decays over several decades."[90/] In its discussion of the "relative diversion resistance of the different fuel cycle," INFCE Working Group 4 further explored the "technical barrier" to proliferation or theft that is afforded by the radioactive properties of spent fuel.[91/] In its Report, Working Group 4 stated that "most of the existing spent fuel elements have cooled [as of 1980] for only a short time and thus require considerable technical effort to reprocess."[92/]

In the Working Group's view, "this creates a technical barrier to the separation of plutonium that is difficult for individuals or sub-national groups to overcome."[93/] Relevant commentary is also found in the Working Group's comparison of the nonproliferation characteristics of a "once-through" cycle with a "closed" nuclear fuel cycle, in which plutonium is separated from spent fuel:

> The concern for the future is thus that, if reprocessing develops, the best technical, safeguards and institutional measures should be adopted to increase the protection of such material against diversion. If the once-through cycle were adopted, the barriers would still be effective against theft, but additional technical, safeguards and institutional measures would be needed to protect long-term and indefinite stores of spent fuel against diversion by national governments. Therefore, taking into account the qualitative nature of the evaluation, different stages of development of the different fuel cycles, the extent to which complete fuel cycles are present within individual countries and institutional improvements that may be implemented, no simple

---

89/ Working Group 4 Report at 135.

90/ *Id.*

91/ Report of Working Group 4 at 140-142.

92/ *Id.* at 140.

93/ *Id.*

> judgment about the diversion resistance of the different fuel cycles can be made that is valid both now and for the future.[94/]

INFCE Working Group 4 stated that a "balanced" conclusion regarding the nonproliferation risks of "closed and "once-through" fuel cycles must be based on an assessment of all of the applicable "technical" and institutional aspects of each fuel cycle. It concluded that "technical reasons," such as the radiation barrier associated with spent fuel, "should neither be discarded nor exaggerated in a proliferation assessment."[95/] While "plutonium in a spent fuel element has a higher diversion resistance than plutonium in a fresh MOX fuel element," the Working Group cautioned that "it is not valid to rely strongly upon that to decrease the risks of proliferation."[96/]

B. Other Reports and Studies

Other U.S. government studies and academic reports also discuss the aging of spent fuel from the perspectives of physical protection, safety and handling. A 1980 report by the U.S. Comptroller General to the Subcommittee on Energy and Power of the House Committee on Interstate and Foreign Commerce[97/] addressed the use of existing nuclear power plant sites for new power plants and nuclear waste storage. The Comptroller General's report observes that 95% of the radioactivity in spent fuel decays in 10 years and the level of radioactivity drops by 80% in only three years:

> On-site spent fuel storage for up to about 10 years does provide an opportunity for about 95 percent of the radioactivity in spent fuel to decay. In fact, about 80 percent of the radioactivity in spent fuel

94/ *Id.*

95/ *Id.* at 141.

96/ *Id*.

97/ The Comptroller General, REPORT TO THE SUBCOMMITTEE ON ENERGY AND POWER, HOUSE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE, *Existing Nuclear Sites Can Be Used for New Power Plants and Nuclear Waste Storage,* EMD-80-67 (1980).

> decays within 3 years. Most of the radioactivity remaining after 10 years of storage will take thousands of years to decay. Thus, from the stand point of shipping and handling spent fuel, on-site storage for from 3 to 10 years does have advantages. After that time, the only advantage of continued on-site interim storage over interim storage at DOE facilities would be savings in the additional handling and transportation required to transport spent fuel first to the DOE storage facility and then to either a reprocessing plant or a DOE long-term storage/permanent storage facility.[98/]

The 1995 Report by the National Academy of Sciences, regarding Management and Disposition of Excess Weapons Plutonium, also discusses the radiation barrier associated with spent fuel, as follows:

> [A] MOX fuel assembly from a Westinghouse PWR would have a mass of about 660 kg, would contain about 18 kg of plutonium after irradiation to 40 megawatt-days per kilogram of heavy metal (assuming initial WPu content of 4.0 percent of heavy metal), and would produce a gamma-ray dose of 7,900 rem per hour at the surface of the assembly 30 years after discharge from the reactor.[99/]

The authors of a "Handbook" on spent nuclear fuel disposal and plutonium recycle, referred to the "difficult accessibility" of spent fuel "for the first 50 years;" during this period, "spent fuel is highly radioactive, must be handled remotely for reprocessing or any other purposes, and is a danger to anyone exposed to it."[100/] Other sources indicate that the gamma radiation associated with spent power reactor fuel remains substantial for about 500-1000 years. As this Handbook notes, the "highly radioactive" nature of spent fuel is "the principal

---

98/ *Id.* at 20.

99/ NAS Study at 10.

100/ A. Blumenthal and E. Lindeman, HANDBOOK: THE INTERNATIONAL NUCLEAR FUEL CYCLE BACKGROUND AND ISSUES: THE DEBATE OVER SPENT NUCLEAR FUEL DISPOSAL AND CIVILIAN PLUTONIUM RECYCLE, at 23 (New York Nuclear Corporation, 1995).

component of the so-called spent fuel standard recommended by the U.S. National Academy of Sciences, the other being isotopic composition…."[101/]

Commentary concerning the spent fuel standard is provided in the reports of the DOE, Department of State, Department of Defense (DOD), Arms Control and Disarmament Agency (ACDA) and the Nuclear Regulatory Commission (NRC) in their "Reports to Congress Pursuant to Section 604 of the Omnibus Diplomatic Security and Anti-Terrorism Act of 1986."[102/] On August 12, 1986, Congress passed the Omnibus Diplomatic Security and International Terrorism Act of 1986. In part, that legislation required the above-mentioned Executive Branch entities to review the adequacy of physical protection measures applied by other countries to the shipment and storage of nuclear material that is subject to U.S. prior consent rights.[103/] While this 1986 law required that the Executive Branch reports focus on the physical protection standards applicable to plutonium and highly enriched uranium (HEU) outside the United States, a few portions of these reports deal with nonproliferation and physical protection issues with respect to storing and transporting spent fuel.

The DOD Report to Congress concludes that while "unreprocessed spent fuel is widely recognized to be of little interest to terrorists" as a source of plutonium for nuclear weapons, "terrorists could target spent fuel in storage or transport with a view to extortion or the creation of a radiological hazard."[104/]

101/ *Id.* at 23.

102/ These reports are collected in a "Committee Print" of the Committee on Foreign Affairs of the U.S. House of Representatives (100th Cong. 2d Sess. 1988); *International Physical Security Standards for Nuclear Materials Outside the United States*.

103/ U.S. prior consent rights refers to the obligations of other countries, under U.S. agreements for cooperation, to obtain U.S. consent before re-transferring, reprocessing or altering the physical or chemical form of nuclear material, including spent fuel.

104/ *Id*. at 59.

In its report to Congress, the Arms Control and Disarmament Agency (ACDA), devoted a subsection to "plutonium in irradiated fuel"[105/] produced in peaceful nuclear power programs. ACDA noted that "during the 15 years between 1985 and the year 2000, there will be a significant growth in the amount of plutonium produced and stored in irradiated nuclear fuel."[106/] According to ACDA, "a conservative estimate is that there will be approximately 1,000,000 kg of plutonium stored in irradiated fuel by the year 2000."

In its report to Congress, the NRC compared its physical protection standards (10 CFR Part 73) against the IAEA's Guidelines concerning Physical Protection of Nuclear Material (INFCIRC 225) and concluded as follows with respect to the physical protection of spent fuel:

> Standards for the protection of irradiated fuel against sabotage are not included since this was not a primary consideration in INFCIRC/225/Rev. 1. Furthermore, irradiated fuel is generally viewed as self-protecting due to the associated high levels of radiation and is not readily useable in nuclear explosive devices until reprocessed.[107/]

The self-protecting nature of spent fuel discharged from power reactors has also been acknowledged by proponents of substantially strengthened efforts to protect HEU and plutonium against the threat of diversion by terrorists:

> [U]nlike spent fuel from power reactors (which is massive and so intensely radioactive that potential thieves would likely be incapacitated by radiation effects as they tried to steal it and drive away), even the "spent fuel" from HEU-fueled research reactors poses a danger – because the fuel elements are typically small and easy to carry away, and have radioactivity levels too low to deter suicidal terrorists (enough to increase their long-term risk of

---

105/ *Id* at 126-127.

106/ *Id*. at 126.

107/ Report at 155.

> cancer, but not to incapacitate them before they could steal the material and build a bomb).[108/]

C. Absence of a Quantitative Expression of the Spent Fuel Standard

Any attempt by terrorists to gain access to spent fuel stored in an ISFSI, whether at the site of a nuclear power station or at a central or regional site that is not associated with a nuclear power station, would initially be met by the armed guards, fences and other physical protection measures established by the licensee in accordance with the applicable rules regarding physical protection of nuclear material at such facilities.[109/] The armed response of the licensee's on-site guards would be bolstered by local law enforcement agencies. If the attackers nevertheless gained access to the spent fuel storage vaults or containers, the massive size and weight of these containers would be a formidable barrier to the attacker's removal of the containers from the site. Ultimately, however, the high-level radiation emitted by the spent fuel (the so-called "spent fuel standard") is a fundamental barrier that should prevent terrorists or other attackers from opening the storage containers and removing the spent fuel assemblies. Even after spent fuel has aged for 30 years following discharge from a reactor, the gamma radiation near the surface of the assembly would likely be in the range of 8,000 rem per hour.[110/]

108/ Matthew Bunn, PREVENTING NUCLEAR TERRORISM: A PROGRESS UPDATE at 5, fn. 11 (Cambridge, MA: Project on Managing the Atom, Harvard University, and the Nuclear Threat Initiative, October 22, 2003).

109/ 10 CFR Part 73, for facilities in the United States, and applicable NRC Orders.

110/ NATIONAL ACADEMY OF SCIENCES, MANAGEMENT AND DISPOSITION OF EXCESS WEAPONS PLUTONIUM: REACTOR-RELATED OPTIONS, at 10, fn 4 (National Academy Press, 1995): "A MOX fuel assembly from a Westinghouse PWR…would produce a gamma ray dose rate of 7,900 rems per hour at the surface of the assembly 30 years after discharge from the reactor." The gamma ray dose rate from a uranium oxide PWR fuel assembly presumably would also be quite substantial after 30 years. *See* Report of Working Group 4, INFCE, at 67, fig. 19, "Comparison of gamma activity of spent PWR fuel assembly and a new PWR fuel assembly with Pu and *fission* products."

According to an IAEA publication, data from animal studies indicates that about 90% of individuals exposed to doses of 5 Gy (500 rad) will die "assuming that there is no treatment and no other complication."[111] A key question, of course, is whether the gamma dose rate from spent fuel that is the subject of such an attempted removal by attackers is sufficiently high to convey a lethal dose that would quickly incapacitate the attackers and prevent them from removing spent fuel assemblies from the site of the ISFSI. Akin to suicide bombers, some terrorists or other attackers may be willing to incur a lethal gamma ray dose in an effort to remove spent fuel from an ISFSI. Except possibly for spent fuel that was irradiated for only a short time or has aged for more than 500 years, the gamma ray dose rate of spent power reactor fuel is likely to be sufficiently high to incapacitate attackers before they could successfully remove spent fuel from a storage container and remove it from the site of an ISFSI.[112]

This report for NWMO is not intended to provide definitive information regarding the gamma dose rate of spent fuel. Instead, the objective of the discussion in this section is to point out that published government reports that discuss the spent fuel standard do not establish or recommend quantitative guidelines for the applicability of that standard as the fuel ages. The reports cited in this section uniformly mention that this radiation barrier declines substantially over time, to the point where the spent fuel standard may no longer be met after prolonged storage.

111/ IAEA, MANUAL ON EARLY MEDICAL TREATMENT OF POSSIBLE RADIATION INJURY, Safety Series No. 47, at 2 (1978).

112/ *See* REPORT OF WORKING GROUP 4, INFCE, at 67, fig. 19, indicating that approximately 30 years following discharge from a reactor, the gamma activity of spent PWR fuel is approximately 10,000 MeV Ci.

The published sources that we reviewed in connection with preparation of this report for NWMO do not discuss the "spent fuel standard" in terms of the gamma ray dose rate that must be generated by the spent fuel in order for it to meet this "standard." As spent fuel continues to age, questions may be expected as to whether the spent fuel standard continues to be applicable. Without clearly articulated gamma ray dose rates, the spent fuel "standard" actually appears to be a concept that lacks a precise applicability to spent fuel that has aged for a substantial period.

The apparent absence of an accepted numerical implementation of the spent fuel standard, in terms of gamma ray dose rate, may become increasingly important as the volume and age of spent fuel stored in ISFSIs in the United States and other countries continues to increase.

V. NONPROLIFERATION AND SECURITY ASPECTS OF REGIONAL OR CENTRAL SPENT FUEL STORAGE AND MULTINATIONAL SPENT FUEL REPOSITORIES

A. Recent Statements by the IAEA Director General

Recently, the IAEA Director General, Dr. Mohamed El Baradei, proposed, among other measures, that "we should consider multinational approaches to the management and disposal of spent fuel and radioactive waste."[113/] According to Director General El Baradei, "considerable advantages – in cost, safety, security and nonproliferation – would be gained from international cooperation" with respect to management and disposal of spent fuel and radioactive waste, as well as other stages of the nuclear fuel cycle.[114/] He repeated this theme in a statement to a conference in Stockholm, Sweden.[115/] Dr. El Baradei stated that "a relevant initiative that the IAEA has begun to study recently is the feasibility and merit of greater cooperation on proliferation-sensitive portions of the nuclear fuel cycle – including consideration of multinational approaches to the management and disposal of spent fuel and radioactive waste."

B. Factors Favoring Multinational Spent Fuel Repositories

It has been noted that most nuclear waste disposal programs have experienced significant delays from the schedule that was initially proposed for disposing of spent nuclear fuel and high level radioactive waste in a repository. As commentators have pointed out, the early operational dates initially proposed for a geologic repository in the U.S. are explained, in part, by the U.S.

113/ Mohamed El Baradei, *TOWARDS A SAFER WORLD*, Article, by invitation, in THE ECONOMIST, October 18, 2003 at 47-48.

114/ *Id.* at 48.

115/ Dr. Mohamed El Baradei, "Geologic Repositories: The Last Nuclear Frontier," statement at the International Conference on Geological Repositories: Political and Technical Progress" (December 8-10, 2003).

intention to dispose of relatively young spent fuel, as opposed to many other countries which plan for a cooling period of 30-50 years.[116/]

Security aspects of repositories have received heightened attention in the wake of the terrorist attacks of September 11, 2001. A proponent of multinational repositories has observed that "the pressure for any nation to get spent fuel as soon as possible into an inaccessible underground facility has increased."[117/] Regional or international facilities may offer "additional, specific features relative to the inherent safeguard advantages of a national deep repository; for example:

> Many countries with spent fuel may not have repositories soon, or ever.
>
> Host countries can be identified that have especially good safeguards credentials.
>
> Control may become even more international than through the current IAEA regime.
>
> Repository sites can be selected in regions that are extremely remote and more amenable to surveillance."[118/]

C. The IAEA's Study on "Regional Nuclear Fuel Cycle Centres."

In 1977, the International Atomic Energy Agency (IAEA) issued a report on "Regional Nuclear Fuel Cycle Centres." This project was undertaken by the IAEA "to determine if multinational fuel cycle centres" would have significant advantages for the activities related to

116/ Charles McCombie, Paper Presented at 2000 Nuclear Energy Institute Fuel Cycle Conference in Chicago.

117/ *Id.*

118/ *Id.*

the back-end of the nuclear fuel cycle, in addition to making substantial contributions toward the goal of nonproliferation.[119/]

This IAEA study contemplated that reprocessing facilities would be co-located with MOX fuel fabrication facilities, at regional fuel cycle centers (RFCC), under multinational control. Among other advantages, the study found that "the RFCC option would have advantages as far as physical protection is concerned."[120/] Although this study did not focus on RFCCs that were solely intended to store spent fuel, many of the legal, institutional and economic concepts addressed in the study are relevant to proposals to store spent fuel in regional facilities, under agreements among the host state and other participating governments.

In the Nuclear Nonproliferation Act of 1978 (NNPA), the Congress directed that the "President shall institute prompt discussions with other nations and groups of nations…to develop international approaches for meeting future worldwide nuclear fuel needs…[including] (4) the establishment of repositories for the storage of spent nuclear reactor fuel under effective international auspices. Limited consultations between the United States and other countries for this purpose took place, including discussions during the International Nuclear Fuel Cycle Evaluation (INFCE)."[121/]

119/ INTERNATIONAL ATOMIC ENERGY AGENCY, REGIONAL NUCLEAR FUEL CYCLE CENTRES, VOL. 1, SUMMARY: 1977 Report of the IAEA Study Project, at 3 (1977).

120/ *Id.* at 67.

121/ James A. Glasgow, *Nuclear Fuel Leasing: An Exploration of New Legal Mechanisms*, Paper delivered to NEI International Uranium Fuel Seminar (2002).

D. Discussion of Spent Fuel In The MIT Report: The Future Of Nuclear Power

The nonproliferation characteristics of "once through" and "closed" nuclear cycles were discussed in a recent study by the Massachusetts Institute of Technology (MIT), entitled, "The Future of Nuclear Power." Among the Report's key conclusions is the following:

> Nuclear power entails potential security risks, notably the possible misuse of commercial or associated nuclear facilities and operations to acquire technology or materials as a precursor to the acquisition of a nuclear weapons capability. Fuel cycles that involve the chemical reprocessing of spent fuel to separate weapons- usable plutonium and uranium enrichment technologies are a special concern, especially as nuclear power spreads around the world."[122]

The authors of the MIT Report conclude that "the once through cycle has advantages in cost, proliferation, and fuel cycle safety, and is disadvantageous only in respect to long-term waste disposal; the two closed cycles have clear advantages only in long-term aspects of waste disposal, and disadvantages in cost, short-term waste issues, proliferation, risk and fuel cycle safety."[123]

Turning to spent fuel and high level waste management programs in the United States, the MIT Report concludes as follows:

> For fifteen years, the U.S. high-level waste management program has focused almost exclusively on the proposed repository site at Yucca Mountain in Nevada. Although the successful commissioning of Yucca Mountain would be a significant step towards the secure disposal of nuclear waste, we believe that a broader, strategically balanced nuclear waste program is needed to prepare the way for a possible major expansion of the nuclear power sector in the U.S. and overseas."[124]

122/ *Id*. at Chapter 1, at 2.

123/ *Id*. at Chapter 1, at 4-5.

124/ *Id*. at 10.

While calling for a broader “strategically balanced” program, the MIT Report rejects certain emerging technologies proclaimed by proponents as solutions to the spent fuel disposal program: “We do not believe that a convincing case can be made on the basis of waste management considerations alone that the benefits of partitioning and transmutation will outweigh the attendant safety, environmental and security risks and economic costs.”[125/]

The authors also conclude that “waste management strategies in the once-through fuel cycle are potentially available that could yield long-term risk reductions at least as great as those claimed for waste partitioning and transmutation, with fewer short-term risks and lower development and deployment costs.” [126/] In place of what the MIT Report refers to as an “an hoc approach to spent fuel storage at reactor sites,” the Report recommends that “a network of centralized facilities for storing spent fuel for several decades should be established in the U.S. and internationally.”[127/]

Security concerns are among the reasons for the MIT Report’s above-mentioned recommendations regarding establishment of central spent fuel storage installations in the United States. In its discussion of “nonproliferation,” the Report focuses primarily on “existing stocks of separated plutonium around the world that are directly usable for weapons,” and technologies, and facilities (*e.g.,* reprocessing and enrichment) that are associated with acquisition of weapons grade fissile material. Notably the MIT Report concludes that “international spent fuel storage has significant nonproliferation benefits for the growth scenario and should be negotiated promptly and implemented over the next decade.”[128/]

125/ *Id*. at 10.

126/ *Id*. at 11.

127/ *Id*. at 11.

128/ MIT Report, Chapter 1, at 13.

VI. RECOMMENDATIONS AND ACTIONS CONCERNING ENHANCEMENT OF THE SECURITY OF SPENT FUEL

A. U.S. General Accounting Office (GAO) Report

In July 2003, the U.S. General Accounting Office (GAO) issued a report concerning options to "enhance the security of spent fuel stored at nuclear power plant sites in the United States.[129/] GAO's report acknowledged that DOE and NRC have concluded, on the basis of studies that they conducted, that "the likelihood of widespread harm from a terrorist attack or severe accident involving commercial spent fuel is low."[130/] However, GAO concluded that "DOE could potentially enhance the security of this fuel through options such as minimizing the number of shipments and picking up fuel in an order that would reduce risk, such as moving older less dangerous fuel first."[131/]

In support of its recommendation that DOE ship the oldest fuel first, GAO observed that "one of the more radioactive elements in spent fuel – cobalt^{60} accounts for about 90 percent of the gamma radiation emitted by spent fuel when it is first removed from the reactor."[132/] GAO also pointed out, however, that "after about 25 years, cobalt^{60} emits about 3 percent of the gamma radiation it did when first removed from the reactor." Similarly, the radioactivity of cesium^{137}, a comparatively volatile element that would be a major component of any accidental or deliberate release, declines by half after 30 years."[133/] GAO relied on these observations to

---

129/ U.S. General Accounting Office Report No. GAO-03-426, Report to the Chairman, Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives, SPENT NUCLEAR FUEL: OPTIONS EXIST TO FURTHER ENHANCE SECURITY (July 2003).

130/ GAO Report at "Highlights" page.

131/ *Id.*

132/ *Id.* at 20.

133/ *Id.*

support its finding that, in the event of a deliberate or accidental release during transit, the public health and security would benefit from shipment of the oldest fuel first: "For example, a release of spent fuel that is 25 or 30 years old would be lesser – though still a significant threat to public health – than fuel that is only 5 or 10 years old."[134/]

B. Congressionally Mandated Report by the National Academy of Sciences

In the Energy and Water Appropriations Act for fiscal year (FY) 2004,[135/] Congress provided funds for the National Academy of Sciences (NAS) to determine whether spent fuel stored at commercial power plants may be vulnerable to attacks by terrorists. According to news reports,[136/] NAS will "study potential safety and security risks of spent fuel stored in cooling pools at 103 commercial reactor sites and determine whether the fuel assemblies would be safer kept in above-ground casks at the reactors."[137/]

C. NRC Response to an Article Concerning Security of Spent Fuel

A recent article by Robert Alvarez and others makes various recommendations concerning "reducing the hazards from stored spent power reactor fuel."[138/] The authors contend that societal costs and risk of attacks by terrorists on spent fuel pools at power reactors warrant remedial action. Responding on August 19, 2003, in a letter to Professor Harold Feiverson, NRC Chairman Nils Diaz stated that the article was "an overly conservative evaluation of the safety of pool storage of power-reactor fuel." Therefore, Chairman Diaz stated that the article's "proposal to relocate all older fuel into dry storage casks is not justified."

134/ *Id.*

135/ Signed into law on December 1, 2003.

136/ Las Vegas Review Journal, December 4, 2003.

137/ *Id.*

138/ Robert Alvarez et al., REDUCING THE HAZARD FROM STORED SPENT POWER REACTOR FUEL IN THE UNITED STATES, Science and Global Security, Spring 2003.

Chairman Diaz also pointed out that following the terrorist attacks on September 11, 2001, "the Commission, NRC licensees and the Federal Government have taken numerous actions" to "protect nuclear facilities, including specific enhancements for protection of spent fuel pools." The Chairman expressed the NRC's view that "these actions support our judgment that public health and safety continues to be adequately protected."

VII. OVERVIEW OF U.S. POLICY REGARDING REPROCESSING OF SPENT FUEL

During the 1970's, as the civilian nuclear power industry developed, there was substantial commercial interest in reprocessing in the United States. General Electric Company built an experimental reprocessing facility at Morris, Illinois. Another reprocessing facility, known as the West Valley facility, was constructed in the 1970's by Nuclear Fuel Services (NFS), on behalf of the New York State Atomic Energy Authority. The West Valley facility operated for a number of years and accepted spent fuel from several U.S. utilities. That facility is now being decommissioned under an agreement between DOE and New York State, which is responsible for ten percent of the decommissioning cost. DOE has assumed responsibility for the remainder of the decommissioning costs, pursuant to Congress' requirement in the West Valley Project Demonstration Act.

In August 1974, the U.S. Atomic Energy Commission (AEC) regulatory staff published a draft generic environmental statement on mixed oxide fuel (GESMO). This statement was prepared to fulfill the AEC's duties under the National Environmental Policy Act of 1969 (NEPA). GESMO essentially dealt with the appropriateness of recycling plutonium. GESMO's principal conclusion, as later characterized by the NRC, was that "utilization of plutonium resources as recycle fuel in light water reactors should be approved."

On April 7, 1977, President Jimmy Carter announced a nuclear non-proliferation policy which, among other things, called for the indefinite deferral of domestic commercial reprocessing and recycling of plutonium and the commencement of domestic and international studies of alternative fuel cycles. As a result of President Carter's decision, the NRC suspended the GESMO proceeding. President Carter's April 7, 1977 statement, together with the NRC's ensuing suspension of the GESMO proceeding, effectively ended active U.S. utility plans for recycling plutonium through the use of MOX fuel.

According to a GAO report on Federal funding of the Barnwell reprocessing plant, Barnwell was designed to reprocess 1,500 metric tons of commercial nuclear spent fuel per year and was the first large-scale commercial reprocessing venture in the United States. The plant was to consist of five major facilities: (1) a nuclear spent fuel receiving and storage facility, (2) a chemical separation facility to process the solid spent fuel into liquid uranium, plutonium, and waste products, (3) a uranium hexafluoride facility to prepare the uranium for its eventual re-use as reactor fuel, (4) a plutonium conversion facility to convert the plutonium to solid form, and (5) a waste solidification facility to solidify the liquid waste for final disposal. The partnership that was formed to construct the Barnwell facility (Allied-General Nuclear Services) obtained a construction permit for the Barnwell facility on December 18, 1970.

On December 22, 1977, the NRC issued an order terminating the GESMO proceeding and all licensing proceedings involving the use of plutonium, including the Barnwell licensing proceeding. By the time the NRC suspended its proceedings on an operating license for Barnwell, parts of the Barnwell facility were essentially complete. However, the facility could not operate, since its owners had not received the required NRC operating license.

On July 16, 1981, President Ronald Reagan issued a statement on U.S. nuclear non-proliferation policy. Along with other elements of the Reagan Administration's nonproliferation policy, the President stated that his administration would "not inhibit or set back civil reprocessing and breeder reactor development abroad in nations with advanced nuclear power programs where it does not constitute a proliferation risk." The President also emphasized the importance of the private sector taking the lead in developing commercial reprocessing services.

Ultimately, the Reagan Administration's reversal of the Carter Administration's plutonium use policy did not revive the commercial reprocessing industry in the United States or prompt U.S. nuclear utilities to take a renewed interest in MOX fuel.

In President Clinton's September 1993 speech to the United Nations and the associated White House Fact Sheet, the President noted that the U.S. "does not encourage the civil use of plutonium and does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes." Significantly, however, the President also stated that the "United States will maintain its existing commitments regarding the use of plutonium in civil nuclear programs in western Europe and Japan." In an October 20, 1993 letter to Representative Pete Stark, President Clinton stated that "the United States does not encourage the civil use of plutonium." The President further stated that "its continuing production is not justified on either economic or national security grounds and its accumulation creates serious proliferation and security dangers."[139/]

139/ Our research did not produce publicly available statements by President George W. Bush concerning reprocessing of spent fuel in the United States. Some senior Bush Administration officials have recently expressed the view that reprocessing should be reconsidered for potential use in the United States.

VIII. CONCLUSION

Nuclear nonproliferation has rarely been discussed in U.S. government decisions and documents concerning storage and disposal of spent fuel and high-level radioactive waste. More than two decades ago, the Carter Administration explored the possibility of accepting certain spent power reactor fuel from other countries, in order to achieve U.S. nonproliferation objectives. However, this program was never implemented.

Nuclear nonproliferation was also the stated rationale for the Carter Administration's abandonment of reprocessing in the United States.[140/] It remains to be seen whether reprocessing, partitioning, transmutation and "nonproliferative" fuels will be adopted in the United States as adjuncts to the proposed geologic repository at Yucca Mountain, Nevada.[141/]

Currently, physical protection of spent fuel is the context in which the U.S. government has addressed the "nonproliferation" aspects of storing spent fuel at nuclear power stations, in central ISFSIs and ultimately disposing of the spent fuel in a geologic repository. Efforts to

---

140/ A new design of thorium-based reactor fuel is being developed in Russia by Thorium Power, Inc. Among other benefits that are claimed by its proponents, the spent fuel generated by power reactors using this new fuel design is said to be "45 percent less in weight and 75 percent less in volume than current fuels," and would result in a "90 percent reduction in long-term radio-toxicity." Thomas Graham, Jr., *ENHANCED PROLIFERATION RESISTANCE AND SAFEGUARDS TECHNOLOGY FOR NUCLEAR ENERGY*, paper presented at the Nuclear Nonproliferation Treaty and Nuclear Power Workshop in Washington, D.C. (May 20, 2003).

141/ According to an account in the press, the Chairman of the Advanced Nuclear Transmutation subcommittee of DOE's Nuclear Energy Research Advisory Committee (NERAC) recently stated that "the use of a separations process and long-term above ground storage of fission products in spent fuel could significantly prolong the operation of a nuclear waste repository planned for Yucca Mountain, Nevada." Burton Richter, chairman of the NERAC subcommittee, said the extraction of roughly 99% of transuranics and long-lived actinides could result in disposal of all spent fuel produced in the U.S. for the next two centuries at Yucca Mountain. DOE reportedly has shifted the focus of its Advanced Fuel Cycle Initiative from early implementation of new fuel cycle and nonproliferation technologies to R&D that would help DOE decide the need for a second repository. Nucleonics Week, November 6, 2003.

amend the Convention on Physical Protection of Nuclear Material clearly are relevant to national regulatory regimes regarding the physical protection of spent fuel.

Although multinational repositories for spent fuel have recently been endorsed by the IAEA Director General, the U.S. government has not suggested that such facilities could be located in the United States. Nor has the U.S. government specifically addressed the role that such repositories conceivably could play in achieving U.S. nonproliferation objectives.

A comprehensive review of the implications, from a nonproliferation perspective, of storing spent fuel at nuclear plant sites and central facilities and disposing of it in geological repositories could be undertaken through a 21st century version of the INFCE exercise that concluded nearly a quarter century ago. In view of the increasing support for multinational repositories for spent fuel, it is timely to explore this concept from various viewpoints, including the potential advantages and disadvantages of such repositories, with respect to nonproliferation policy.

Appendix A

Ambassador Thomas Graham, Jr. is special counsel in the Energy Practice Group of Morgan Lewis. Ambassador Graham has served as a senior U.S. diplomat involved in the negotiation of every major international arms control and non-proliferation agreement for the past 30 years, including The Strategic Arms Limitations Talks (SALT) Treaties, The Strategic Arms Reduction Talks (START) Treaties, The Anti-Ballistic Missile (ABM) Treaty, Intermediate Nuclear Force (INF) Treaty, Nuclear Non-Proliferation Treaty (NPT), Conventional Armed Forces in Europe (CFE) Treaty, and Comprehensive Test Ban Treaty (CTBT). He has also served as the Acting Director and Acting Deputy Director of ACDA, as Legal Advisor to the U.S. SALT II, START I and START II Delegations, the Senior Arms Control Agency Representative to the U.S. Intermediate-Range Nuclear Forces and the Conventional Armed Forces in Europe Delegations, and many others. In addition, Ambassador Graham led U.S. Government efforts to indefinitely extend the Nuclear Non-Proliferation Treaty in 1994 and 1995.

James A. Glasgow is a partner in Morgan Lewis's Energy Practice Group. His law practice focuses on international trade issues and transactions involving nuclear fuel, nuclear power plants and other energy facilities. From 1970-1976, Mr. Glasgow was a trial and appellate attorney with the U.S. Department of Justice, Atomic Energy Commission and the U.S. Nuclear Regulatory Commission. From 1976 to 1981, he was a senior legal adviser and deputy assistant general counsel for International Affairs in the Office of General Counsel of the U.S. Department of Energy and its predecessor, the U.S. Energy Research and Development Administration (ERDA). He represented ERDA and DOE on U.S. delegations engaged in the negotiation of peaceful nuclear cooperation agreements. Mr. Glasgow has authored papers on nuclear fuel and international nuclear commerce topics to the American Nuclear Society, the U.S. Council for Energy Awareness, the Nuclear Energy Institute, the Uranium Institute, the World Nuclear Association and the World Nuclear Fuel Market.