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CONF-880631--4

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SUBMITTED TO 29th Annual Meeting of the Institute of Nuclear Materials Management, Las Vegas, June 26-29, 1988

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ABSTRACT

The purpose of this paper is to stimulate discussions on the subject of safeguarding large quantities of plutonium contained in spent fuels to be disposed of in geologic repositories. All the spent fuel disposal scenarios examined here pose a variety of safeguards problems, none of which are adequately addressed by the international safeguards community. The spent fuels from once-through fuel cycles in underground repositories would become an increasingly attractive target for diversion because of their plutonium content and decreasing radioactivity. Current design of the first geologic repository in the U.S. will have the capacity to accommodate wastes equivalent to 70 000 Mt of uranium from commercial and defense fuel cycles. Of this, approximately 62 000 Mt uranium equivalent will be commercial spent fuel, containing over 500 Mt of plutonium. International safeguards commitments may require us to address the safeguards issues of disposing of such large quantities of plutonium in a geologic repository, which has the potential to become a plutonium mine in the future. This paper highlights several issues that should be addressed in the near term by U.S. industries and the DOE before geologic repositories for spent fuels become a reality.

I. INTRODUCTION

The back end of the nuclear fuel cycle offers numerous challenges to long-term management of a variety of waste forms. The last two decades saw an increased awareness of the problems of nuclear fuel cycle wastes as well as systematic efforts to develop strategies for the long term storage/disposal of almost all forms of radioactive wastes. Among these strategies, the one involving the direct disposal of spent nuclear fuels poses one of the most difficult safeguards problems. Although spent fuels continue to be extremely radioactive for many years after they are discharged from reactors, the radioactivity level decreases considerably after several decades, and plutonium extraction from such aged fuel becomes relatively less hazardous. This characteristic of the spent fuels makes it a unique safeguards problem.

In the international arena a broad spectrum of possible national, multinational, and international arrangements for spent fuel management has been discussed.[1-3] The international safeguards aspects of these facilities range from benign international oversight of national facilities to arrangements for bilateral and regional cooperation, and even to the creation of entirely new international institutional mechanisms.[1,2] Because of the introduction of breeder reactors in some States and the indecision regarding reprocessing, spent fuel management was not one of the acute problems of the International Atomic Energy Agency (IAEA), and the concepts for safeguarding spent fuels placed in geologic repositories have so far only received academic attention. At the same time, reactor facilities are running out of interim storage space, and this situation has created serious problems at several facilities, including a large number of reactors in the U.S. Therefore, the focus has shifted from long-term disposal to short-term management of spent fuels and related safeguards issues.[4-12] Among various storage modes proposed and studied, wet storage in pools,[3,4,7] and dry surface storage in air cooled casks[5,7] and vaults[2] have become the most accepted methods. Also, none of the safeguards studies[8-12] associated with the spent fuel programs have so far addressed the issues of long term geologic disposal of spent fuels. At the time of the International Fuel Cycle Evaluation studies (1977-80), the concept of permanent disposal of spent fuel had not been selected by any of the member States of the IAEA.[2]

Recognizing the difficulty of arriving at an international consensus on long term spent fuel management, several States, including the U.S., have embarked on a variety of domestic programs for the long term management of high level wastes and spent nuclear fuels.[13,14] Presently, in the international arena, three scenarios for geologic disposal of spent fuels are under consideration. They are

(1) Independent geologic repositories within a State exclusively for disposing of spent fuels and wastes originating from its nuclear fuel cycles. The United States, Canada, and

Sweden are presently embarked on such a program for the disposal of spent fuel in igneous rocks or other suitable geologic formations.

(2) Geologic repository within a state for the disposal of spent fuel from a consortium of States. The Federal Republic of Germany has such a program for a salt repository for nuclear wastes, including spent fuel for possible participation by other Euratom members.

(3) Commercial venture by a State to operate a geologic repository for permanent disposal of spent fuels from other States. The Peoples Republic of China offered such a service, and some of the European nations did express an interest in such a venture.

These spent fuel disposal scenarios pose a variety of safeguards problems, none of which are adequately addressed by the international safeguards community. Recently, Buttler, et al.[15], and Stein, et al.[16] from West Germany, and R. H. Smith and D. W. Jung[17] from Canada brought forth several new ideas for the IAEA to consider in developing safeguards approaches to geologic repositories. The geologic waste repository program in the U.S. is moving forward without adequate discussion of the long-term safeguards issues relevant to such repositories. The purpose of this paper is to stimulate thinking and discussions on the subject of safeguarding large quantities of plutonium contained in spent fuels to be disposed of in geologic repositories.

II. INTERNATIONAL SAFEGUARDS

In the international safeguards arena, sovereign States are considered potential diverters of nuclear materials. According to present guidelines for international safeguards, systems designed for safeguarding special nuclear materials (SNM) should be able to account for the presence of such materials, and such accounting must be independently verifiable by an agent of the IAEA. Several important issues of long-term safeguards assurance for spent fuel disposal are not addressed in the IAEA's guidelines for international safeguards.[18,19] However, improved desirability of spent fuels as a source of plutonium is well known, and the fate of spent fuels should be examined in the context of (i) a long-term extension of the non-proliferation treaty (NPT) beyond 1995 and (ii) the possible termination of the NPT some time in the future.

IAEA safeguards are applied to U.S. facilities in response to an offer made by President Johnson in 1967 as an inducement to countries, especially West Germany and Japan, to sign the NPT.[20] The U.S./IAEA Safeguards Agreement[21] was endorsed by the U.S. Senate and entered into force on December 9, 1980. Accordingly, there are nearly 200 nuclear facilities in the U.S. that have the potential to be under IAEA safeguards. These include all commercial reactors and fuel fabrication facilities, and almost all research reactors, critical assemblies, and test reactors in the U.S. However, because of the limited resources of the IAEA, presently only a few facilities in the U.S. are chosen for IAEA safeguards at any one time, and this list of facilities is changed periodically by the IAEA in consultation with the U.S. In applying safeguards at U.S. nuclear facilities, the IAEA employs the same scheme as if the facilities were located in non-nuclear weapons States.

III. SAFEGUARDS AND U.S. SPENT FUEL DISPOSAL PROGRAM

Frequently the term "safeguards" is used synonymously with "security of nuclear materials." However, nuclear material safeguards is an integrated system of physical security and carefully designed administrative measures. The administrative measures should necessarily include systems for detection, accountability, and materials control designed to deter, detect, and respond to unaccountable losses as well as unauthorized possession or misuse of nuclear materials.

Current design of the first geologic repository in the U.S. (designed exclusively for the disposal of nuclear wastes from U.S. fuel cycles) will have the capacity to accommodate wastes equivalent to 70 000 Mt of uranium from commercial and defense fuel cycles.[22] Of this, nearly 62 000 Mt uranium equivalent will be commercial spent fuel, containing approximately 500 Mt of plutonium. International safeguards commitments require the U.S. to address safeguards issues of disposing of such large quantities of plutonium in geologic repositories, which have the potential to become plutonium mines in the future.

The Nuclear Waste Policy Act of 1982,[23] and the Nuclear Waste Policy Act Amendments of 1987[24] are the Congressional mandates for all programs in the U.S. for the disposal of spent nuclear fuels and high-level wastes. Neither of these legislations have addressed the issues of long-term international safeguards for spent fuels in geologic repositories. However, prior commitments by the U.S.[20,21] to open all nuclear facilities, excluding only those with direct national security significance, for IAEA safeguards would require the geologic spent fuel repository in the U.S. to be offered for IAEA safeguards.

IV. SAFEGUARDS REQUIREMENTS OF SPENT FUEL DISPOSAL PROGRAM

The major elements of the U.S. program for the geologic disposal of radioactive wastes that are of relevance to long-term safeguards are shown in Fig.1. Two major waste forms, high level wastes from reprocessing and spent nuclear fuels from commercial reactors, and various activities involved in the transfer of these waste forms to the same geologic repository are also identified in Fig. 1. Present plans for the spent fuels

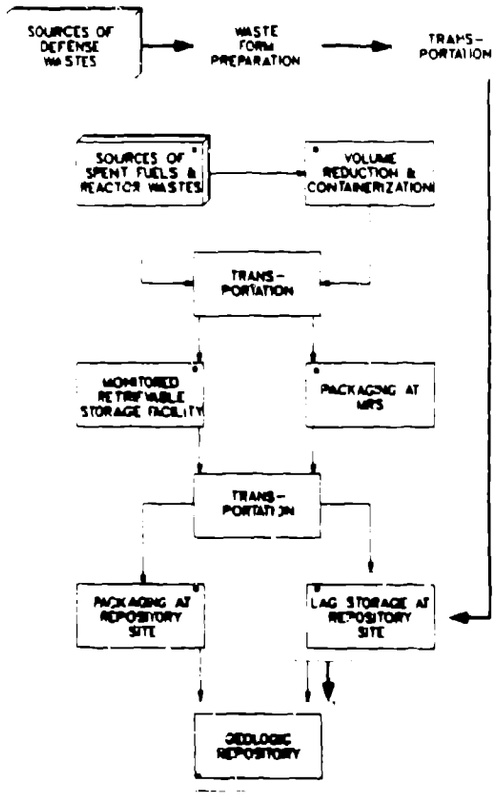

Fig. 1. Major elements of the U.S. program for the geologic disposal of radioactive wastes.

include various options for packaging and transporting the spent fuels from reactors to the geologic repository. Almost all the activities leading to the final disposal of spent fuels do affect the long-term safeguards goals for the spent fuels. Proper accounting of fissionable materials in various categories of spent fuel-derived waste forms, such as in-tact spent fuel assemblies, canistered spent fuel assemblies, consolidated rods, and non-fuel bearing materials, is required by the U.S. Nuclear Regulatory Commission to satisfy the needs of domestic safeguards. Present safeguards requirements by the IAEA would additionally require the States to have containment and surveillance and to allow periodic verification of the declared SNM values by direct measurements or by item accounting. The need for independent verification capability imposes additional requirements; these requirements will be considerably more detailed and intrusive if rod consolidation is practiced. Figure 1 identifies a minimum of six key measurement points where the SNM content of spent fuels or spent fuel derived waste forms have to be accounted for either through direct measurement or by item counting when prior measurements are unable. Depending on the number of volume reduction locations and monitored retrievable storage (MRS) facilities, the verification points for the entire waste management system can grow to a very large number.

One of the issues that is complicating safeguards implementation for spent fuels at commercial nuclear reactors in the U.S. is fuel pin consolidation. According to an independent study by the Electric Power Research Institute,[10] "a substantial burden will be imposed on the utility if a requirement for independent verification of container contents (after rod consolidation) is forthcoming, as might be anticipated if the facility is selected for IAEA safeguards." A detailed site-specific study (for the Yucca Mountain Site repository) of the effects of fuel pin consolidation on geologic disposal of spent fuels has demonstrated the undesirability of consolidation.[25] However, a number of nuclear power plants in the U.S. are compelled to resort to consolidation and storage because of the limitations of existing spent fuel storage facilities and the lack of alternatives. These efforts to consolidate and store spent fuels make the safeguards implementation efforts all the more complex and expensive. Therefore, it would seem prudent at this time to consider incorporating program elements in the U.S. spent fuel disposal program to address the issues of long-term safeguards for spent fuels emplaced in geologic repositories.

V. DESIRABLE NEAR-TERM ACTIONS

Since the international community is generally convinced of the value of safeguards for fissile materials, it is important that all on-going programs for the disposal of spent fuels start discussions about the need to have international safeguards for the geologic repositories containing large quantities of plutonium and other fissile elements. It is well recognized that the proliferation resistance of spent fuels decreases with storage time according to the total burnup and decay time. The IAEA should provide guidance to States as to the requirements of safeguards for underground disposal sites. While the IAEA and the rest of the international community is developing a consensus, the on-going programs for spent fuel disposal should recognize that spent fuels will become a desirable source of plutonium in the future and proceed to incorporate program elements to address long-term safeguards for nuclear materials to be placed in these geologic repositories. Considering the current elements of the U.S. waste management program, some of the measures that should be initiated to address safeguards concerns expressed here are the following.

1. Because the IAEA has yet to offer guidelines to the States on the safeguards requirements of geologic disposal facilities for spent fuels, discussions with the IAEA should be initiated to formulate long term safeguards

measures for underground disposal of spent nuclear fuels. The existing guidelines for safeguarding SNM in the rest of the fuel cycle may have to be modified recognizing the unique requirements of spent fuels placed in geologic repositories. Participation in international discussions to develop a consensus and a strategy to address issues of long-term safeguards for geologic disposal of spent fuels is a necessary near-term undertaking.

2. The Non-Proliferation Treaty (NPT) is due to expire in 1995 unless it is renewed on a timely basis. Now is the opportune time to examine possible safeguards regimes assuming (i) that the NPT will be extended for an indefinite period, and (ii) that the NPT will be terminated some time in the future.

3. Consolidation of fuel rods destroys the integrity of the assemblies as an accountable item. Therefore, it becomes necessary to verify the fissile content of the consolidated packages through nondestructive assay techniques or by other methods. If consolidation is unavoidable, the activities of volume reduction and containerization of spent fuels should be limited to a few locations to address verification issues of international safeguards. It may be possible to carry out all volume reduction and containerization of spent fuels at centralized MRS facilities and transport all spent fuel to the repository as sealed items after proper accounting at the MRS.

4. If no major changes in the present system of international safeguards occur, it would be necessary to maintain presence of international inspectors at the geologic repository during all transfers into and out of repository. Alternatives to this requirement should be examined to minimize the burden on both IAEA and the States.

5. When the time comes to close the repository permanently, it may be necessary to seal all entrances to the repository in a predetermined manner in the presence of international inspectors and establish appropriate containment/surveillance measures to ensure safeguards.

6. To prevent the need for periodic IAEA inspection, it would be desirable to develop and install a remote monitoring system to detect any mining activities or intrusion in the vicinity of the geologic repository after the repository is sealed.

7. Because it is important for the U.S. to assure safeguards to the international community, now is the time to consider alternatives that would reduce the cost of safeguards measures for geologic repositories containing large quantities of plutonium and other fissile materials.

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