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Nuclear Material Safeguards During Storage and Disposal of Spent Nuclear Fuel

Bruce W. Moran
International Technology Programs Division

Presented at the
Institute of Nuclear Materials Management's
Spent Fuel Management Seminar VI
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NUCLEAR MATERIAL SAFEGUARDS DURING STORAGE AND DISPOSAL OF SPENT NUCLEAR FUEL*

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1. INTRODUCTION

The systems and facilities of the U.S. federal waste management system (FWMS) — managed by the U.S. Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management — will be subject to the requirements of nuclear materials safeguards. The FWMS will handle both spent nuclear fuel (SNF) and high-level radioactive waste (HLW). For SNF, the FWMS will include acceptance at the power reactor, transportation to the FWMS facilities, conditioning for storage and disposal, monitored retrievable storage (MRS), and disposal in a mined geologic repository. The safeguards requirements that must be considered and planned for early in the design of the FWMS systems and facilities are those specified in, and under development for inclusion in, the DOE orders and U.S. Nuclear Regulatory Commission (NRC) regulations and those being developed by the International Atomic Energy Agency (IAEA). Early identification of technical and institutional issues can prevent possible delays in the licensing of the FWMS facilities and ensure more economical implementation of the required safeguards elements in the FWMS.

Nuclear materials safeguards are measures applied both domestically and internationally to ensure that nuclear materials are used only in officially authorized ways. Domestically, these measures are applied to all special nuclear materials (SNM), source materials, and other specified nuclear materials. They consist of physical security, material control, and material accounting (1) to maintain knowledge of the location of these materials, (2) to detect and to prevent, or to deter their theft or loss, (3) to facilitate recovery if theft or loss occurs, and (4) to prevent or to mitigate radiological sabotage. Internationally, safeguards measures are applied to verify declared use of the nuclear materials under the IAEA's purview. These measures consist of independent verifications of material accounting records complemented by containment and surveillance to detect and to deter diversions of nuclear material and to provide assurance that the materials remain in their stated uses. While domestic safeguards is designed to detect and to prevent theft or sabotage by a person or subnational group, international safeguards is designed to detect, after the fact, and to deter diversion of SNM by the State in collaboration with the facility. The domestic safeguards regime for the FWMS facilities will be that proposed by DOE and accepted by the NRC in accordance with its regulations. The international safeguards regime will be that applied by the IAEA in accordance with the U.S.-IAEA Safeguards Agreement and given force in the United States through NRC regulations and DOE orders.

The differences in overall purpose between international and domestic safeguards have important implications for the application of safeguards to the FWMS. While certain SNM theft scenarios might be viewed as having a very low probability in the domestic context, given the limited technical capabilities of a subnational adversary, the

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same scenarios would be credible in the international context where the adversary is a State in collaboration with the facility. One area where the additional requirements of international safeguards could be especially apparent is the role of measurements to verify independently the SNM content of SNF for accounting purposes. Because the repository and MRS facility will be eligible for IAEA safeguards, planning for safeguards must take into account the requirements of both the domestic and international safeguards systems.

2. SAFEGUARDS REQUIREMENTS

Comprehensive safeguards requirements, both domestic and international, have yet to be developed for SNF storage, conditioning, and disposal facilities. The NRC has licensed a few independent spent fuel storage installations (ISFSIs) in accordance with federal regulations (i.e., 10 CFR Pt. 72) and has extended these regulations to include the MRS facility of the FWMS. In September 1988 the IAEA held its first Advisory Group Meeting on Safeguards Related to the Final Disposal of Waste and Spent Fuel.[1]

2.1 DOMESTIC SAFEGUARDS

The NRC regulations covering ISFSIs and geologic repositories (i.e., 10 CFR Pt. 72 and 10 CFR Pt. 60) require the licensee (e.g., DOE) to provide "a description of the physical security plan for protection against radiological sabotage" and DOE to provide "... such safeguards as it requires at comparable surface DOE facilities to promote the common defense and security." The storage facilities are required to comply with the applicable physical security requirements (i.e., 10 CFR Pt. 73) and to implement a nuclear material accounting and reporting system; the geologic repository is required to have a material control and accounting plan but is not specifically required to meet the physical security requirements stated in 10 CFR Pt. 73. The DOE orders governing physical protection and nuclear material control and accountability (i.e., DOE Orders 5632.2A and 5633.3) define highly irradiated nuclear materials (e.g., SNF) to be Category IV quantities of SNM (i.e., very unattractive SNM for the construction of an explosive nuclear device). Material control and accountability and physical protection requirements specified for Category IV quantities of SNM and for irradiated material are generally equivalent to the requirements stated by the NRC.

As far as physical security is concerned, no new problems are expected at the FWMS facilities that have not been encountered already at other U.S. facilities except possibly those problems related to the extended and indefinite entombment period associated with the geologic repository. This entombment period raises the question of the longevity of security arrangements — a question that will be both an institutional and a technical issue. The effectiveness of the existing DOE orders and NRC regulations regarding nuclear material control and accountability (NMC&A) for SNF needs to be examined because these orders and regulations were developed prior to the advent of programs for the reconstitution of fuel, consolidation of SNF, long-term dry storage of SNF, and disposal of SNF and HLW in a geologic repository. This examination needs to be performed not only in regard to the FWMS facilities but also in the context of the relationship of these facilities to the entire U.S. commercial fuel cycle, which is an open fuel cycle (i.e., there is no reprocessing and recycle of recovered uranium and plutonium). In this open fuel cycle the last direct measurement of SNM content is routinely made on the fuel elements at a fuel fabrication facility. The existing DOE orders and NRC regulations do not specifically require accountability or confirmatory measurements (by destructive or nondestructive techniques) of the SNM content when SNF or HLW is shipped or received. Therefore, the result could be that the only determination of SNM content made before emplacement of the SNF in the geologic repository would be that based on fuel fabrication records and reactor operator fuel burnup calculations. Because fuel rod consolidation and/or repackaging prior to emplacement will occur, general safeguards assumptions concerning the accessibility of the SNM and the potential effectiveness of the safeguards procedures need to be examined, and appropriate regulatory requirements need to be developed.

2.2 INTERNATIONAL SAFEGUARDS

In addition to, and separate from, the safeguards system implemented for purely domestic purposes, the United States (as a principal architect of the international nonproliferation regime) and the IAEA entered into a safeguards agreement for the application of IAEA safeguards at U.S. nuclear facilities. The IAEA selects from the list of eligible U.S. facilities (facilities having direct national security significance are exempt from IAEA safeguards) those at which it will apply safeguards (i.e., inspections and verification activities) and those from which it wants only nuclear material accounting reports. Only a small number of U.S. facilities undergo active IAEA safeguards at any time. Because the repository and the MRS facility could be among the first of their types to operate in the world, the likelihood that the IAEA would designate these facilities for the application of IAEA safeguards must be assumed.

In early 1988 the IAEA published a draft Secretariat Working Paper on "Safeguards Related to the Final Disposal of Nuclear Material in Waste and Spent Fuel," and during September 1988 an IAEA advisory group meeting was held to discuss the subject and to make recommendations to the IAEA.[1,2] This process initiated the development of the IAEA safeguards approach for the final disposal of SNF. The recommendations of the advisory group included the following: (1) SNF does not qualify for termination of safeguards; and (2) safeguards approaches need to be developed and/or evaluated for (a) at-reactor and away-from-reactor storage, (b) preparation of the SNF for disposal, (c) positioning of the SNF in the final repository, and (d) closure of the repository (each of these stages will have different characteristics and safeguards problems). The development of safeguards approaches for SNF in storage has been under way for more than a decade, primarily on the application of safeguards to reactor storage pools.

For SNF located in reactor storage pools, the IAEA currently conducts the following safeguards procedures: (1) verification of receipts, nuclear material inventory, and shipments; (2) camera surveillance of the reactor bay and storage pool; (3) SNF verification measurements (primarily Cerenkov-glow measurements but includes gamma and neutron emission measurements on assemblies); (4) verification of assembly identification and location; and (5) attachment and verification of tamper-indicating devices (TIDs). All general procedures applicable to the storage pools are potentially applicable to a storage facility or a permanent repository (although different methods may be required). Because the repository represents the last location for SNM verification, the safeguards procedures required within the FWMS may need to contain more stringent verification activities than those implemented at a storage pool.

The United States has long maintained that facilities subject to IAEA safeguards should be designed, as far as is practicable, to facilitate the effective application of international safeguards. This position reflects the U.S. conviction that careful, early planning for international safeguards can minimize potential problems at the interface of safeguards and operations while enhancing the effectiveness of safeguards. This position is also expressed within the international safeguards community.

3. SAFEGUARDS PROCEDURES

For domestic and international safeguards, the safeguards procedure that is of principal concern is the independent verification of the SNM content of the SNF. Because the domestic safeguards authorities, DOE and the NRC, have judged that theft of highly irradiated SNM is not a credible threat, verification measurements of received SNF are not required. In international safeguards the recommendation has been made that shipments of SNF for disposal be eligible for verification by the IAEA before final disposal in a repository. Continuity of knowledge of the SNM contained in the SNF preceding and following verification (if performed) would be maintained through containment and surveillance and other monitoring systems. It is not expected that the safeguards requirements for the FWMS facilities will affect power reactor operations.

Development of the other applicable NMC&A and physical security safeguards procedures for storage and disposal facilities is expected to be consistent with procedures already in effect at power reactors and within the nuclear industry.

3.1 STORAGE FACILITIES

While NRC regulations for ISFSIs require that NMC&A procedures sufficient to enable the licensee to account for the SNF in storage be followed, they are silent as to whether accountability or confirmatory measurements need to be made when SNF is shipped or received at facilities not selected for IAEA safeguards. However, each licensee is required to conduct a physical inventory at least annually and must file material status reports concerning the SNM contained in the SNF. The NRC has not prepared detailed regulatory guidance on the acceptable approaches for satisfying these requirements at a storage facility that is not associated with a power reactor.

Transfer of ownership of SNF that is not designated for reprocessing or research programs is not routinely performed in the United States. When the SNF is shipped for reprocessing, receipt verification measurements of the fuel elements are not required because adequate verification can be provided by accountability measurements from the dissolver tanks. When the SNF is transferred to the FWMS for storage and disposal, the decision not to require measurements becomes more difficult. The following considerations favor taking measurements for domestic safeguards purposes on at least some portion of the SNF received for disposal:

1. A measurement would enhance the ability of domestic authorities to verify that no significant loss of SNM had occurred including at those stages prior to irradiation where nuclear material would have been more accessible.
2. Plutonium remains a valuable strategic material; measurements would enhance the confidence in the knowledge of the amount being emplaced in the repository.
3. The FWMS storage facilities would be the last location at which a verification or confirmation measurement could be accomplished before burial of the fuel assemblies.
4. Measurements would provide a check against operator errors and inaccuracies in the calculational methods for the determination of SNM content.
5. The DOE would hold a stronger position in responding to potential allegations of theft, diversion, discrepancies in records, etc., if it took measurements rather than relying solely on values calculated by operators of the U.S. commercial power plants.

The value of measurements for domestic safeguards purposes must be weighed against whatever additional operating costs are involved; an operational need for nondestructive assay (NDA) measurements is not evident. For the establishment of accountability values, the accuracy of current or future NDA technology must be compared with the expected accuracy of the reactor operator calculations. However, because the measurements can provide verification of calculated SNM and other nuclear material content, serious consideration should be given to the domestic utility of a measurement program.

For international safeguards the assumption must be made that the IAEA will require the right to verify SNF receipts before final disposal occurs. Verification measurements probably will be performed on a statistical basis and on a measurement level consistent with the IAEA's Safeguards Implementation Report Criteria. Assuming a low level of measurement verification by the IAEA, the greatest impact from the IAEA safeguards procedures might be from the application of containment and surveillance and other monitoring systems at the facility. These systems may include surveillance cameras, TIDs on casks or other containment systems, heat and radiation monitors, and the continuous presence of IAEA inspectors.

3.2 DISPOSAL FACILITIES

Conditioning (primarily consolidation) of the SNF will create a number of difficult problems for safeguards. These problems are primarily caused by the inaccessibility or destruction of the unit of accountability (i.e., the fuel assembly). In stages following conditioning, measurement verification of the nuclear material content may not be technically or functionally possible. Fuel elements in storage casks technically can be removed and measured; once these fuel elements have been consolidated, potentially with fuel of different burnup and cooling times, the capability to verify the SNM content based on gross gamma and neutron signals is lost. Additionally, the larger the number of fuel elements to be measured as a single item, the more difficult the verification of the SNM content becomes. When the spent fuel canister is emplaced in the repository, the capability to verify the contents of the container will end. In these situations increased reliance to total reliance on containment and surveillance and other monitoring techniques will be required. These techniques must obtain a level of performance and reliability not currently available.

4. SAFEGUARDS IMPLEMENTATION ACTIVITIES

A conceptual action plan for undertaking specific technical and institutional safeguards tasks for the implementation of safeguards in the FWMS was developed. Tasks were ranked according to the priority for accomplishing the tasks. Priorities were established through the identification of groups of tasks (comprising general activities) that depend on information developed during preceding tasks and that provide information to subsequent tasks. The defined activities are generally applicable to the development and implementation of most safeguards systems. The prioritized activities are as follows:

Activity 1. Establish the implementation plan for the FWMS safeguards program

The tasks comprising this activity will identify (1) the key participants in the safeguards project; (2) the organizational structure of the project; (3) those participants responsible for evaluating the generated information, approving task actions, and setting the safeguards development and implementation schedules; and (4) the program schedule and key milestones.

Activity 2. Determine the safeguards needs

The tasks comprising this activity will assess the defined safeguards concerns with respect to the potential adversaries (both domestic and international); determine credible strategies for the diversion, theft, or sabotage of the identified targets; and recommend general safeguards strategies to defeat the adversary.

Activity 3. Determine the safeguards tools available, or potentially available, for safeguarding radioactive waste and spent fuel

The tasks comprising this activity will assess the designs of the FWMS components to determine safeguards tools (e.g., accountability, material control, measurement, containment, surveillance, and monitoring techniques) that could be implemented should the defined safeguards approach require them.

Activity 4. Develop appropriate DOE, NRC, and IAEA safeguards requirements and guidance

The tasks comprising this activity will assess the safeguards needs and the safeguards tools available to address these needs and will establish the safeguards requirements and guidance that facilities should meet if the nuclear material in their possession is to be effectively safeguarded.

Activity 5. Develop specific safeguards criteria that must be implemented within the components of the FWMS

The tasks comprising this activity will determine the specific safeguards concepts that must be incorporated into each component of the FWMS for that component to meet all of the safeguards requirements.

Activity 6. Develop effective safeguards approaches

The tasks comprising this activity will define safeguards approaches that meet the established criteria for each specific component of the FWMS.

Activity 7. Develop and test prototype safeguards systems

The tasks comprising this activity will develop and evaluate safeguards systems necessary to implement the developed safeguards approaches.

Activity 8. Define cost-effective safeguards approaches

The tasks comprising this activity will assess the developed safeguards approaches and prototype safeguards systems to determine those approaches and systems that are (1) consistent with U.S. regulations and nonproliferation policy, (2) effective, (3) feasible, and (4) economic, and that do not interfere with, or preclude, the function of the waste management facility.

Activity 9. Develop safeguards instrumentation and systems required to implement the defined safeguards approaches

The tasks comprising this activity will develop the selected safeguards systems into fully engineered and tested systems that are ready for deployment.

Activity 10. Implement the developed safeguards instrumentation and systems

The tasks comprising this activity will integrate the defined safeguards approaches and systems into the FWMS components and ensure that the components meet all defined safeguards requirements.

Activity 11. Maintain and enhance the safeguards systems

After integration of the safeguards systems into the FWMS components, the safeguards systems will require maintenance, updating, and replacement as the level of technology rises and will require enhancements as the safeguards requirements imposed on the component change.

Activity 12. Initiate low-priority activities

Potential safeguards concerns that do not need to be addressed until the next century will be addressed with a very low priority because the technology available to address those concerns will grow with time and because the safeguards concerns may change also.

The above activities outline a plan for the development, implementation, and maintenance of a safeguards system for the FWMS. Until the initial safeguards technical assessments are performed, the total impacts of nuclear material safeguards on SNF storage, SNF disposal, and the commercial reactors cannot be known.

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[2] Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel: Secretariat Working Paper, STR-243, International Atomic Energy Agency, Vienna, July 1988.