INTERNATIONAL INITIATIVE IN TRANSPORTATION SABOTAGE INVESTIGATIONS

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ABSTRACT
An international working group has been formed to study the consequences of terrorist attacks and the behavior of systems used to store and transport radioactive materials. The group includes representatives from France, Germany, the United Kingdom, and the United States. To deal with the sensitive information common in this area of study, a formal agreement is being developed by the group. While an appropriate agreement is being established, the group has identified and begun work on a project that is mutually beneficial, and not encumbered by the need for access to sensitive information.

INTRODUCTION
Requirements, both legal and customary, pertaining to protecting certain radioactive materials and control of related information is common throughout the world. The two major concerns that motivate such requirements are the possible diversion of materials that could be used to build nuclear weapons, and the potential for a terrorist attack intended to create disturbances, harm people, or damage the environment. For some materials, the potentials for diversion and terrorism are of concern. For others, such as spent nuclear fuel (SNF), terrorism is the only concern. The study of terrorism can be divided into two primary areas of interest: the assessment of threats, and the evaluation of the potential effects of threats.

Threat assessment, which is not the subject of this paper, involves the gathering and analysis of intelligence information. These assessments seek to identify terrorists and terrorist groups, their targets, modes of operation, and the devices available and used by them. Although this area is not the subject of this paper, knowledge of terrorist

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capabilities is essential for addressing the effects of potential radiological sabotage events. Furthermore, the interdependence of these two areas of study requires coordination between experts in each area.

Studying the effects and consequences of terrorist attacks involves the application of a variety of complex engineering and scientific disciplines. The following list of disciplines, although not exhaustive, provides some insight into that complexity:

1. The interactions between explosive devices and storage or transport systems, including evaluation of the mechanical damage to the cask and fuel rods;
2. Aerosol formation and behavior prior to release to the environment;
3. Aerosol dispersion under various environmental conditions;
4. Ingestion and inhalation of radiotoxic substances by humans;
5. Potential for radiation exposure situations; and
6. Health effects of ingestion, inhalation, and radiation exposure to individuals and populations.

Within this framework, items 1 and 2 are the most difficult, challenging and expensive to fully explore, and are most amenable to international cooperation. Their study will involve development and use of detailed theoretically and empirically based quantitative models. Developing, validating, and verifying such models often requires the use of tests and experiments. These activities may be difficult and costly to perform, but in science and engineering, information and data from analyses and experiments are commonly shared within the communities through personal contact, symposia presentations and publication in technical journals. However, in most cases, because of the sensitivity of data associated with terrorist attacks on storage and transport systems, sharing is impossible without some special arrangements.

A group of experts from France, Germany, the United Kingdom, and the United States, recognized the difficulties of developing data in this area and the problems associated with sharing such information. The group recognized the commonality of needed information, and that many of the common needs might be addressed by resources available among the group, but not shared due to security restrictions. The group determined that the resolution of this set of problems might reside in the formation of a formal international study group. The initial meeting of this group in 1999, set the stage for an international working group for cooperation concerning impacts from sabotage of nuclear material during storage and transport. The need for an agreement was determined at the outset, and an initial technical study that would be mutually beneficial to the participants, but void of sensitive or restricted data, was identified.

The group has held three additional meetings since the first meeting in Albuquerque, NM in July 1999. Those meetings were held in March 2000, November 2000, and May 2001 in Paris, Berlin, and London, respectively. The meetings were held to discuss formation of an agreement, the mutually beneficial technical project, and current activities related to sabotage studies of the participant's organizations. Development of the agreement and the progress of the technical project are discussed in the subsequent sections of this paper.

AN INTERNATIONAL AGREEMENT

Formal agreements are normally used for international endeavors conducted between governments or their ministries, departments, and agencies. The study of sabotage, which involves sensitive and restricted information, makes the use of formal agreements an absolute necessity. The importance of such an agreement is evident when the group attempts to share the information they each hold about sabotage. These discussions are limited and may encounter large gaps where sensitive and restricted data cannot be shared. The experience for participants is similar to reading a book with many of the most important pages missing.

The institutions represented in the group are Institut de Protection et de Sûreté Nucléaire (IPSN) of France, Bundesministerium für Umwelt Naturschutz und Reactorsicherheit (BMU) of Germany, Department of Trade and Industry of the United Kingdom of Great Britain and Northern Ireland, Department of Energy of the United States of America, and Nuclear Regulatory Commission of the United States of America. Although the agreement is still in the informal discussion phase, some points are deemed necessary or appropriate by all the participants. The points of agreement are described along with some of the items that remain to be resolved.

All the participants recognize that, to varying degrees, sabotage is a potential threat for all countries involved in transport and storage of nuclear and radioactive materials. We are committed to gain a better understanding of potential impacts of sabotage in order to assure protection for people and the environment and to seek to cooperate on research, development, testing, and evaluation related to sabotage and protection against its impacts. The objective of the agreement is to establish a framework for cooperation through sharing of information and development of new information where appropriate.

The agreement would form a working group, managed by a steering committee, consisting of one member from each participant organization. Decisions of the committee would be by consensus. The working group itself would include the steering committee members and researchers and experts invited to participate by the steering committee or by its individual members. The responsibilities of the steering committee include overall direction of the effort, planning to achieve the groups' objectives, and establishing task forces for specific jobs.

The agreement will establish a framework for cooperation among the participating organizations. It would include provisions for sharing and exchanging staff and equipment for projects and the treatment and sharing of sensitive material. These provisions would accommodate projects where participants jointly conduct research using international teams and share or co-fund facilities and equipment. Current thinking on funding and conduct of research and development projects seems to show a preference for a flexible approach. Such projects could be conducted under the agreement with two to all of the participants contributing to the effort, and with the level of contributions decided by the project participants. Areas of cooperation may include, but are not limited to sharing information and results of previous analytical and experimental work to assess the consequences on public health and safety and the environment of sabotage against nuclear and radioactive material transport or storage casks.

INITIAL TECHNICAL PROJECT

Significant work has been done in Germany, the USA, and France to assess potential impacts of hypothetical sabotage on spent fuel casks and to develop source terms for release of spent fuel materials from such events. Early experiments conducted in the USA on actual spent fuel to determine its behavior compared to that of surrogate materials were undertaken. These experiments and subsequent analyses of the basic relation of spent fuel release versus surrogate (depleted UO2) release in the respirable particle diameter range after a high energy density device (HEDD) attack, was predicted to be within a range of 0.5 to 12 i.e., about a factor of 10 uncertainty (Sandoval, et al.)[1] (Luna, et al.)[2] Thus, this large spread in values for a parameter that has a direct influence on the predicted consequences of an optimally successful sabotage attack could benefit from an experimental program to narrow the level of uncertainty range.

Gesellschaft für Reactorsicherheit mbH (GRS) and Sandia National Laboratories (SNL) met in July 2000 after the international working group meeting in March 2000 to discuss preparation of a common proposal to better determine the ratios of aerosol produced by spent fuel in an energy intensive attack to aerosol produced by surrogate (depleted uranium oxide) fuel for the same attack. During the working group meeting in November 2000, Institut de Protection et de Sûreté Nucléaire proposed that they prepare the spent fuel test rods as part of the collaborative effort. Thus the collaborative effort will be supported by the USA (performing tests at SNL), Germany (designing and manufacturing the aerosol chamber), and France (manufacturing of the spent fuel sample rods).

The goals of the program are designed to define important features of the interaction of a HEDD with spent fuel:

- Mechanical damage of the fuel rods;
- Mass and physical characteristics of the particles produced – aerodynamic diameters (AED) up to 100 microns with special emphasis on the respirable fraction (<10 micron aerodynamic diameter); and
- Enrichment of volatile nuclides like cesium and ruthenium in specific particle size fractions.

The information gained will be compared in paired experiments (using the same apparatus and with the same HEDD) to the particles generated from UO_2 surrogate materials in order to make an appropriate comparison to prior experiments.

These goals are based on a review of the prior experimental investigations concerning an optimally successful attack using an HEDD on a spent fuel shipping cask. The source term of released radioactive aerosol particles and, any estimate of radiological consequences based on that data would be improved by a better knowledge of the correlation of aerosol mass release data between the surrogate material (un-irradiated depleted UO_2) and actual spent UO_2 fuel. In addition, there is insufficient knowledge about degree of enrichment (fractionation) of volatile elements (termed fractionation) in the respirable aerosols. Fractionation was observed, but not well quantified, in both Battelle Columbus Laboratory (Schmidt, et al.)[3] and Idaho National Engineering and Environment Laboratory (Alvarez, et al.)[4] studies conducted in the early 1980s.

The experiments proposed are small scale to reduce the amount of radioactive materials that will need to be handled and eventually to be disposed of. However, the experiments are expected to provide useful information on the fractionation mechanisms involved. Measurements of the airborne radioactive particle release from spent fuel and from surrogate material following HEDD penetration of fuel rod segments are proposed using aerosol collection equipment developed by GRS and Fraunhofer ITA. The experiments with spent fuel need to be performed in a shielded sealed glove box or hot cell facility because of the high radiological hazard of the spent fuel samples. Analysis of samples will require similar precautions and perhaps remote manipulation. As a result, for even the most elementary experimental set-up, the sample analysis must be as simple as possible to keep costs within reasonable bounds.

EXPERIMENTAL CONCEPT

In essence, it is proposed to compare the airborne release from the interaction of a HEDD projectile with a fuel rod segment of spent fuel on the one hand and a fuel rod segment with pellets of un-irradiated depleted UO_2 (or some other material) as surrogate material on the other. Cerium oxide was suggested as an appropriate surrogate by one of the French experts at the London meeting in May 2001. Realization of the concept will include the following steps:

- Selection of one or more HEDDs that can be directed with sufficient precision onto the target fuel rod segment filled with pellets.
- Preparation and characterization of the targets that are either real spent fuel rod segments or sections of fuel cladding filled with surrogate pellets.
- Selection and verification of suitable analysis procedures for measuring total released mass, different mass fractions for various particle size intervals and relevant fission product composition.
- Development and testing of the experimental set-up for aerosol collection and classification.
    - Performance of pretests with fuel rod segments of surrogate material.
    - Scaled HEDD experiments with spent fuel and surrogate material.
- Determination and comparison of the airborne releases following HEDD penetration of rod segments of spent fuel and of surrogate material by measuring the collected aerosol portions collected in a hot cell.
- Evaluation of other potential surrogate materials for future experiments (e.g., cerium oxide, as suggested by our French colleagues)

The number of experiments to be performed on spent fuel will be limited, to reduce the amount of radioactive material that will be handled. Experiments with surrogate materials will duplicate those on spent fuel, but there will be a few additional tests with surrogate material to demonstrate the functionality of the test apparatus prior to the spent fuel tests. In addition, there could be one or two tests to investigate scale effects related to jet diameter to pellet diameter (d_j / d_p). These few experiments, together with prior experience from impact experiments at the Fraunhofer Institute are expected to provide sufficient information from which to derive reliable source term estimates.

TEST PHASES

Phase 1: The first phase will include pre-experiments with the aerosol collection and classification unit that will be performed to:

- study the energy transfer between projectiles having various speeds (including a high speed projectile in form of a shaped charge jet) and surrogate specimens with and without cladding,
- verify the scaling laws for the size distribution,
- obtain information on the necessary size of the final chamber suitable for hot cell experiments,
- determine the necessary precautions to be taken for proper blast shielding of the aerosol instrumentation, and
- optimize the basic design for the sampling chamber.

Many of the experiments in phase 1 have been performed in the Fraunhofer Institute facilities. The later experiments related to HEDD aspects will be performed at SNL.

Phase 2: Several experiments with depleted UO_2 will be performed to obtain the data that portrays the dependence of the behavior of surrogate materials on HEDDs. These experiments will provide verification of the basic experimental design and be conducted in accord with the test procedure to be used for the spent fuel tests. It is expected that these tests also will be the basis for the final approval to conduct the spent fuel experiments, which is required by facility safety procedures.

Phase 3: Experiments with PWR spent fuel samples will be performed to obtain the data that portrays the dependence of the behavior of SNF on HEDDs. Before the SNF experiments begin, sufficient time between Phases 2 and 3 will be programmed in order to improve or modify the experimental procedure and/or arrangement, if necessary. In case of essential modifications, additional comparative experiments with depleted UO_2 will be performed during Phase 3. In this Phase, an adequate number of experiments using the same experimental set-up as used in Phase 2 will be performed, but with fuel rod samples containing PWR spent nuclear fuel pellets.

CONCLUSIONS

An international cooperative effort has been proposed to accommodate the sharing of information and investigative activities for the study of sabotage affects during the storage and transport of nuclear and radioactive materials. A working group consisting of five organizations from four countries has been formed to pursue this international effort. Because the information dealt with in this area is usually classified, a formal agreement between the participating countries is deemed necessary to protect such information. An agreement has been proposed and is being developed by the working group. Once consensus is reached by the working group, the agreement can be processed by the proposed participant countries through appropriate inter-governmental channels.

An initial technical project that does not involve classified information has been identified for study by the working group. The project seeks to establish a rigorous quantitative correlation between aerosol release quantities for spent fuel and surrogate materials commonly used for spent fuel in tests and experiments that study sabotage effects. Estimates of this correlation parameter have ranged from 0.5 to 12. This wide range of values suggests a high degree of uncertainty in the estimates. Although some test data is available, uncertainties remain.

The proposed technical project, which is an optimized, three phase experimental project, offers an economically sound approach to establishing a verified correlation factor to relate the behavior of spent fuel and UO_2 fuel for certain sabotage events. The correlation factor reduces the uncertainties associated with using simulated spent fuel (e.g., UO_2 fuel) in sabotage affects testing and experiments. The initial technical project will provide useful technical data and test the ability of the international working group to perform a cooperative research and development activity.

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