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An Assessment of the Response of Spent Fuel Transports to Malevolent Acts*

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In 1978 a study sponsored by the Nuclear Regulatory Commission (NRC) of radiological impacts from the transport of radioactive material through urban areas, the 1978 Urban Study, indicated very severe consequences from a successful malevolent act on spent fuel shipments. A subsequent version of the 1978 Urban Study,[1] the 1980 Urban Study,[2] reduced the postulated release quantity by a factor of 14 and thus showed reduced numbers of early fatalities, morbidities and latent cancer fatalities. On the basis of the 1978 Urban Study the NRC instituted stringent physical security requirements[3] for spent fuel transport which were designed to prevent sabotage events in urban areas.

Since no relevant experimental data base was available for use in the Urban Studies,[1,2] source term estimates were based upon assumed physical and chemical characteristics and estimated quantities of the released fuel.

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Consequently, there was a high degree of uncertainty in the estimated source terms and radiological consequences. A need existed to provide experimental data characterizing the quantity, physical, and chemical form of fuel released from hypothetical attacks on spent fuel shipping casks.

This paper describes the results of a program[4] conducted at Sandia National Laboratories (SNL) for the U.S. Department of Energy to provide an experimental data base for more accurately assessing the radiological consequences from a hypothetical sabotage attack on a spent fuel shipping cask. The primary objectives of the program were limited to: (1) evaluating the effectiveness of selected high explosive devices (HED) in breaching full-size spent fuel casks, (2) quantifying and characterizing relevant aerosol properties of the released fuel, and (3) using the resulting experimental data to evaluate the radiological health consequences resulting from a hypothetical sabotage attack on a spent fuel shipping cask in a densely populated area.

Subscale and full-scale experiments in conjunction with an analytical modeling study were performed to meet the programmatic objectives. The results of these experiments may be summarized as follows:

<u>HED Evaluation Experiments</u>--An extensive survey of available high explosive devices (HEDs) was performed to select those that might be capable of breaching a full-size spent fuel truck cask. Four general types of HEDs were selected for testing and further evaluation:

1. Shaped charges.
2. Contact-breaching charges.
3. Platter charges.
4. Pyrotechnic torches.

An HED was selected from the four types tested and was used as the reference attack device for the full-scale source term characterization test from which the needed source term data base was obtained.

Subscale Tests--Five subscale tests of 1/4-size casks containing full-size fuel pins made up of unirradiated UO_2 pellets were conducted. These tests provided initial experimental data characterizing the fuel material released from the 1/4-size cask as a result of the attack.

Full-Scale Test--A full-scale test subjected a 25.45 t generic dry truck cask containing a single PWR-like unirradiated depleted UO_2 fuel assembly to the reference full-scale HED. These full-scale test data were used to calculate the quantity of radioactive material that could be released as a result of an explosive attack on a three-PWR fuel assembly generic truck cask. These calculations indicated that approximately 5.0×10^{-4} percent (6 g) of the total unirradiated fuel inventory (1.4 t) could be released as a respirable radioactive aerosol as a result of an explosive attack on a 3 PWR fuel assembly truck cask.

Correlation Tests--Effects of the high energy environments created by a variety of HEDs on breakup and particulation of spent commercial nuclear reactor fuel and its surrogate, depleted uranium dioxide (d-UO_2), were evaluated in a series of single pellet tests. Tests conducted on single irradiated fuel pellets and single depleted UO_2 pellets enabled measurement of the radioactive aerosols typical of the high energy environments.

Correlation ratios were obtained from both irradiated and unirradiated fuel tests relating particle size distributions for fracture, breakup, and aerosolization of depleted UO_2 fuel to that of irradiated fuel. For conservatism in the health risk assessment the maximum correlation value of 5.6 was used. This leads to an upper limit release value of 34 g (2.4×10^{-3} percent) of respirable aerosol from a three-PWR assembly shipping cask.

Health Effects Evaluation--The "Calculation of Reactor Accident Consequences" model, CRAC,[5] used in the Urban Studies was used in this study to estimate human health consequences from an attack using the reference HED on a 3 PWR fuel assembly truck cask. The basic scenario as defined in the Urban Studies was (1) the attack occurred in the borough of Manhattan in New York City, weekday, midafternoon, (2) the spent fuel inventory was typical of PWR assemblies after 150 days cooling at the reactor, (3) all consequence estimates were made without any evacuation to avoid early exposure. Using this study's experimentally determined release fraction (2.4×10^{-3} percent) for an attack on a three PWR fuel assembly truck cask (1.4 tHM, 150 days cooled), values of health consequences were found to be 0/0 (mean/peak) early fatalities, 0/0 (mean/peak) early morbidities, 1/3 (mean/peak) early latent cancer fatalities, and 4/14 total latent cancer fatalities. These newly calculated latent cancer fatalities are smaller by a factor of 350/433 (mean/peak early latent cancer fatalities) than the original Urban Study predictions upon which the NRC interim regulations for the protection of US transport of spent fuel were based.

Overall Program Result--The data from this program indicate that the Urban Studies[1,2] greatly overestimated the impact of malevolent acts directed at spent fuel casks in urban environs. From that standpoint this work could be the basis of additional regulatory revisions of the NRC physical protection requirements. In a larger sense this work can also be the basis of more credible "worst case" analyses since it defines the actual result of an event which is well beyond any expectations of cask failures in accident environments.

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