PROGRESS ON THE FULL-SCALE TESTING PROGRAM

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One of the several nontechnical problems that plague the nuclear-electric power industry is the suspicion by some members of the public that an accident in the transportation phase of the nuclear fuel cycle is equivalent to a nuclear disaster. This suspicion is based in part on an intuition that shipping casks, like other containers for hazardous materials used in routine commerce, are likely to be broken open in any moderately severe accident. For some of those concerned, this intuition is supported by the belief that (a) the regulations defining accident survival criteria are nonrepresentative of accident conditions and (b) that the regulations allow the cask to be evaluated by mathematical analysis rather than requiring full-scale testing.

To address these concerns, Sandia Laboratories has, for the past two years, been embarked upon a program designed to accomplish two major objectives. Through the combined use of calculational analyses, $\frac{1}{8}$-scale model testing, and full-scale testing, the program is structured to evaluate the capabilities of modern technology to predict the survivability of spent fuel shipping casks exposed to severe transportation accidents. Furthermore, the program is intended to collect data on the system behavior of transportation vehicles and their cargo during severe accidents. The program has been open to the public to allow individuals harboring concerns with such shipping systems to view these tests, have access to the reported results, and to come to their own conclusions concerning the adequacy of spent fuel shipping containers.

Since analyses revealed that the vast majority of transportation accidents offered only trivial assaults upon spent fuel shipping casks, the program was structured to cover three scenarios chosen to represent extra severe transportation accidents. Chosen as the situations to be investigated were the impact of a tractor-trailer rig carrying a spent fuel shipping cask into a massive concrete wall, the impact of a diesel locomotive into a spent fuel shipping cask mounted on a tractor-trailer rig stalled across the tracks (a grade-crossing-type accident), and the impact of a rail-mounted shipping cask and its special carrier into a massive concrete abutment followed by a pool-type hydrocarbon fire. Two tests have been conducted (during January and March of 1977) covering the first of these three scenarios.

The first of these tests was to involve a tractor-trailer rig traveling at 97 kph carrying a 20-MT spent fuel shipping cask into a 626-MT concrete barrier backed by 1600 MT of compacted earth. The cask used in these two tests is an older unit that does not meet current licensing requirements. For the purpose of this program, the use of such equipment represents no significant technical difficulty, since the analytical and scale modeling techniques differ only in minor details between the design of modern casks and the one used in these tests. Calculational results and $\frac{1}{8}$-scale model tests had predicted that the cask would survive with damage limited to fin displacement and possible rupture of some external piping. In the full-scale test, the 32-MT tractor-trailer rig and the associated shipping cask were accelerated by a complement of five surplus Hawk rockets. The system was guided by a pair of standard-gauge railroad rails already available as part of Sandia's inventory of test facilities. After an acceleration phase covering ~700 ft, the test vehicle coasted another 250 ft where it impacted the target at 98 kph. As had been predicted by the scale model tests and the calculational analyses performed prior to the test, the cask was essentially undamaged, failing even to completely crush the balsa wood impact limiter mounted on the forward end of the cask. (All modern casks now in service utilize some form of impact limiter on each end.) There was some fin damage and external piping was broken. (Modern casks do not utilize external piping connected to the cask cavity.) Furthermore, as had also been predicted, the crushup of the tractor and deformation of the trailer had reduced the velocity of the shipping cask to <48 kph at the time it impacted into the concrete barrier. The value of 48 kph is significant, since it is the impact velocity required by the U.S. Nuclear Regulatory Commission regulatory standards. An NS Savannah fuel element (unirradiated) was carried inside the cask and was removed following this test and inspected for possible damage. This fuel element had been modified by adding an extension to the lower fitting to boost the mass of the system to approximately that of commercial fuel elements in use today. Upon removal, no damage could be detected in this fuel element. Maximum rigid body accelerations experienced by the cask were <20 g's. An accident of this severity is, on the most conservative basis, expected in service about once every 4.5×10^8 miles traveled. Assuming 3500 shipment/yr (year 1990 estimate), each shipment being 2000 miles (one way), this test would represent a condition occurring on the average only once every 65 yr. Even so, an accident of this severity would not breach the container or expose irradiated fuel elements to the public.

For the second test in this series, the same spent fuel shipping cask, with its external piping capped off and a new NS Savannah fuel element installed in its inner cavity, was mounted on another tractor-trailer rig for an impact at a projected 129 kph. Analytical predictions and scale model tests had indicated that this impact would impose sufficient loads upon the system to completely demolish the impact limiter and to plastically deform the head end of the cask. While this plastic deformation would produce a slight mushroom shape to one end of the cask, the damage was not predicted to be sufficient to cause failure of the outer skin nor was it considered sufficient to cause significant leakage through the cask seal.

In the full-scale test, a combination of five Hawk and three Zuni rockets accelerated the tractor-trailer and cask to a velocity of 135 kph at impact (see Fig. 1). As predicted, the impact limiter was demolished, plastic deformation occurred in the head end of the cask, and zero leakage was detected immediately following the impact. (A dark blue dye had been used to represent the coolant in the cask.) During subsequent handling of the cask, ~100 cm^3 of liquid leaked from the cask at a rate of about one drop every 30 s, continuing until the crane placed the cask on another truck and released the tension in the lifting sling. Once this handling operation was completed, there was no additional leakage. A release of this quality of coolant does not represent a risk to the public. The plastic deformation at the head end of the cask has caused considerable difficulty in removal of the cask closure; therefore, the effect of this impact upon the NS Savannah fuel element is as yet unknown. As before, the cask velocity was reduced as a result of crushup of the tractor and deformation of the trailer structure such that the cask impacted the barrier at ~100 kph and sustained peak accelerations somewhat <180 g's. Again, on a very conservative basis and using 1990 projected shipment rates, an accident of this severity can be expected no more often than once every 7×10^9 miles or about once every 1000 yr. More realistic figures place the probability as low as once in 10 000 yr. Again, the cask remained integral and contained the fuel element.

Fig. 1. Parts of tractor-trailer rig and impact limiter fly as a truck-mounted spent fuel shipping cask hits an immovable concrete barrier at 135 kph. Integrity of the cask was not compromised by this extra severe crash.

Results of this test program to date have shown that modern engineering analysis techniques and scale model testing are valid tools for the prediction of damage to spent fuel shipping systems involved in severe transportation accidents. Therefore, full-scale testing of every cask is not necessary. Furthermore, it is evident that spent fuel shipping containers are among the most rugged structures ever used for the protection of hazardous materials.

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