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REGULATORY AND EXTRA-REGULATORY TESTING TO DEMONSTRATE RADIOACTIVE MATERIAL PACKAGING SAFETY

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ABSTRACT

Packages for the transportation of radioactive material must meet performance criteria to assure safety and environmental protection. The stringency of the performance criteria is based on the degree of hazard of the material being transported. Type B packages are used for transporting large quantities of radioisotopes (in terms of A_2 quantities). These packages have the most stringent performance criteria. Material with less than an A_2 quantity are transported in Type A packages. These packages have less stringent performance criteria. Transportation of LSA and SCO materials must be in "strong-tight" packages. The performance requirements for the latter packages are even less stringent. All of these package types provide a high level of safety for the material being transported. In this paper, regulatory tests that are used to demonstrate this safety will be described. The responses of various packages to these tests will be shown. In addition, the response of packages to extra-regulatory tests will be discussed. The results of these tests will be used to demonstrate the high level of safety provided to workers, the public, and the environment by packages used for the transportation of radioactive material.

INTRODUCTION

The transportation of radioactive material is a safe undertaking. This safety is derived from compliance with the stringent requirements that radioactive material transportation packages must meet. Testing is the most commonly used method to show that packages meet these criteria. Subjecting a package to a series of tests is an excellent method to show how it will respond to the environments to which it may be subjected during use. In this paper the performance criteria that each package must meet are given, along with the source of each criterion, and the facilities used to carry out the performance tests are described. The responses of packages to these test environments are given as well as the response of packages to extra-regulatory test conditions.

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REGULATIONS

The requirements for packages for the transportation of large quantities (greater than A_2) of radioactive materials are given in Part 71 of Title 10 of the Code of Federal Regulations (10CFR71)[1]. These are Type B packages, and they are required to be accident resistant. The hypothetical accident sequence, which they must withstand, is given in the regulations. Following the accident sequence the package must meet a very stringent release-rate criterion. The accident sequence consists of: 1) a free drop from a height of nine meters onto an essentially unyielding target, 2) a free drop from a height of one meter onto a 15 cm diameter bar, and 3) a 30 minute exposure to a totally engulfing hydrocarbon-fuel pool-fire, all to be performed in the sequence given on a single. A separate package must withstand immersion in water at a pressure equivalent to a depth of 15 meters. In addition, packages that have a mass less than 500 kg and a density less than water must withstand, as part of the hypothetical accident sequence, a dynamic crush test that consists of dropping a 1-meter-square steel plate having a mass of 500 kg from a height of 9 meters onto the package. The tests must be performed with the package in an orientation to cause maximum damage.

Type B packages must also survive the normal conditions of transportation and meet an even more stringent release-rate criterion. The tests for normal condition of transportation are: 1) High temperature of 38°C with solar insolation, 2) Low temperature of -40°C in shade, 3) Reduced external pressure of 25 kPa (3.63 psi), 4) Increased external pressure of 140 kPa (20.3 psi), 5) Vibration normally associated with the transport mode, 6) Water spray simulating rainfall of 5 cm/hr for at least one hour, 7) Free drop from a height of 0.3 to 1.2 meters, depending on package weight, 8) Corner drop of 0.3 m onto each corner (lightweight fiberboard or wood packages only), 9) Compression of a weight equal to five times the package weight or 13 kPa (1.89 psi) times the package cross section, whichever is greater, and 10) Penetration of a 6 kg rod of 3.2 cm diameter with a hemispherical end dropped from 1 meter.

The requirements for packages that are used to transport less than an A_2 quantity of radioactive material are less stringent, because of the lower hazard associated with this type of shipment. The requirements for these packages are given in Part 173 of Title 49 of the Code of Federal Regulations (49CFR173)[2]. These are Type A packages: they are not specifically designed for accident resistance, but they still must survive the normal conditions of transportation listed above without loss or dispersal of the radioactive contents and with no significant increase in external radiation levels.

Material with low specific activity (LSA) may be transported in strong, tight packages so that there will be no leakage of radioactive material under conditions normally incident to transportation. In order for these materials to be shipped this way, they must be shipped in exclusive-use conveyances, and may not be shipped by air. For other conveyances, these materials must be shipped in Type A or Type B containers, depending on the amount of radioactivity being transported.

PERFORMANCE TESTS

The ability of a package to meet the test conditions described in the preceding section may be determined by analysis, test, or comparison to other approved packages. For Type A packages the method generally employed to determine whether the package is acceptable is physical testing. For Type B packages a combination of physical testing and analysis is generally employed. Most testing of Type A packages is performed at Hanford, and a list of all approved Type A packages is maintained there[3]. In general, these packages are relatively inexpensive, and using several packages for the test sequence does not impose a severe financial burden on the organization attempting to obtain package approval. Type B packages are generally more expensive than Type A packages, and often only a single prototype is available for testing. In such cases analyses are generally performed to assure that the tests are conducted in the most damaging configuration for the package and that configurations not being tested will also meet the performance requirements.

The requirement that the package survive an impact onto an essentially unyielding target has a profound effect. This requirement forces all of the impact energy to be absorbed by the package, and none by the target. During impacts with real targets the impact energy is absorbed by both the target and the package. The degree of energy absorbed by each is determined by the relative strength and stiffness of the target and the package.[4] Most Type B packages are very strong and stiff, therefore a great deal of the impact energy is absorbed by real targets rather than the packages. At Sandia, the essentially unyielding target that is used for these tests consists of a

2,000,000 pound block of concrete approximately 25 feet thick surfaced with an armor plate that is 8 inches thick.[5] With regard to the fire test, a 60 foot by 30 foot pool is used at Sandia, and can accommodate even the largest packages to the totally engulfing fire environment. Smaller pool sizes are used for smaller packages. When a package is being tested, it is suspended above the pool surface. It is also possible to simulate the conditions of a pool fire by use of either an oven, such as those used in the heat treatment of metals, or an array of high-intensity quartz lamps. In real fires, it is unlikely that the package would be suspended above the fuel surface and be totally surrounded by fire. This is one of the reasons why real fires of longer duration provide lower heat input to the package than that from the regulatory fire.

TEST RESULTS

Packages are required to have very low release rates at the conclusion of the performance tests, both for normal conditions of transport and hypothetical accident conditions. To meet this requirement the containment boundary of the package must be essentially undamaged by the tests. For normal-conditions-of-transport tests the post-test release rate cannot exceed 10^{-6} A_2/hour. For most packages, this release rate requires the packages to be leak-tight following the test, and package designers generally design the packages to remain leak-tight following these tests. Additionally, no significant increase in radiation dose at the surface of the package is permitted.

For accident-resistant (Type B) containers the release rate following the hypothetical accident sequence may not exceed A_2/week. Generally, this requirement is interpreted as no change in the pre-test leak rate, and many packages are in fact leak-tight. The external radiation dose rate is allowed to increase from a pre-test level of 200 mrem/hour at the surface of the package to a post-test level of 1 rem/hour at a distance of 1 meter from the package. In other words, there can be essentially no change in the ability of the package to provide containment of the radioactive material and only limited decrease in the amount of shielding provided for the radioactive material. Typical Type B packages have sacrificial impact limiters that absorb the energy of the drop tests such that there is no damage to the containment boundary. The impact limiters often also serve as thermal insulation to protect the package from the pool-fire environment. Most packages use some type of elastomeric material as an O-ring or gasket to achieve the required leak rate. In the fire test, the temperature of this gasket material must remain sufficiently low that the material does not thermally degrade. The hypothetical accident tests may result in significant damage to the impact limiter and some of the shielding material, but this is not important as long as the package still performs its intended functions of containment of radioactive material and limitation of external radiation dose rates.

RESPONSE TO EXTRA-REGULATORY TESTS

The very stringent post-test release-rate criteria result in packages that can survive events much more severe than the design tests. Many Type A packages use a standard 55-gallon drum as the containment boundary. These packages are only required to withstand a 4-foot free fall onto an essentially rigid target. However, for many impact orientations these drums can survive impacts from much higher drop heights. As an example, Sandia recently tested a series of two-drum stacks with drop heights of 30 feet. These drums were standard Type A drums that are used for the storage and transportation of low-level radioactive waste. In the test, two drums were bound together end-to-end with metal strapping, raised so the bottom of the lower drum was 30 feet above an essentially rigid target. When the drums impacted the target, the lower drum was shortened by collapse of the drum chines, but the closure remained in its initial condition and the drum remained intact. Similarly, in the qualification testing of a new waste container for shipment within the TRUPACT-II Type B package, a set of seven Type A drums within a steel cylindrical shell arranged as shown in Figure 1 was dropped from 30 feet impacting on the side of the drums.[6] All of the drums remained intact, and only the lower drums experienced significant deformations. Even the drums that were deformed retained their lids, and there were no noticeable gaps between the lid and the drum body. Similar results were obtained in an earlier study that examined the behavior of low-level-waste drums.[7]

Extra-regulatory testing of Type B packages also has shown that there is a considerable margin of safety against release of radioactive contents. Tests of plutonium shipping containers have shown only limited release when impacted onto an unyielding target at velocities up to 300 feet/second.[8] This test program also included impacts onto concrete and soil targets at even higher velocities (up to 535 feet/second for concrete targets and 760 feet/second for soil targets) with no leakage or only minor leakage of the simulated PuO_2 contents. In a more recent program aimed at determining the factor of safety for Type B casks, the Structural Evaluation Test Unit was

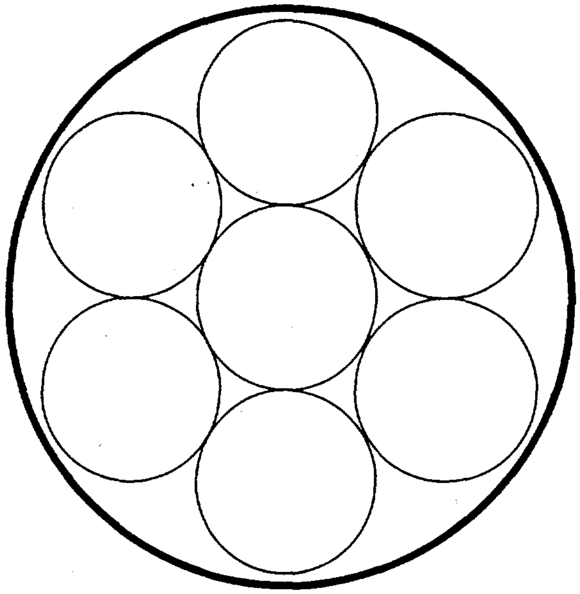

Figure 1. Arrangement of seven Type A drums within a TRUPACT-II Inner Containment Vessel to be drop tested from a height of 30 feet.

subjected to impacts up to 88 feet/second onto the unyielding target and remained essentially leak tight.[9] Other testing has been conducted that reproduces more realistic accident scenarios. In one program, trucks carrying a 22 ton Type B spent fuel cask were impacted into a large concrete target at velocities of 60 and 84 MPH (the same cask was used for both tests). Another test had a locomotive impact a 25 ton spent fuel cask on a truck stalled at a grade crossing at a velocity of 81 MPH. In still another test of this series a 68 ton rail cask on a rail-car was impacted at 80 MPH into the same concrete target. All of the casks used in these tests continued to contain their contents following the tests.[10,11] In another program, two packages were dropped from a height of 2000 feet onto hard prairie soil.[12] One of the packages incurred no measurable deformations and the other incurred only superficial damage. Both would have been able to contain any radioactive material contents that might have been present.

Extra-regulatory fire tests have also been performed on packages, but much less frequently than the extra-regulatory impact tests. In one test a rail-car and rail spent fuel cask were subjected to a totally engulfing hydrocarbon fuel pool fire for 90 minutes. This fire, with three times the duration of the regulatory fire resulted in no leakage of radioactive contents from the package.

CONCLUSIONS

The tests required by the regulations are not intended to reproduce real conditions that packages will encounter during transportation, but have been developed to assure the packages can provide adequate safety during their use. The movement of radioactive material throughout the country with no loss of life due to the radioactive hazard has shown how well this design philosophy provides safety. The conservatism built into radioactive material packages allows them to survive events that are much more severe than the regulatory conditions. Many Type A containers, which are not supposed to be accident resistant, have been involved in accidents without releasing their radioactive contents.

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