NRC Regulatory Criteria for Transport Package Approval

The regulatory requirements applicable to spent fuel transportation packages are contained in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71. In order to be responsive to the question on safety criteria, we have summarized the primary safety requirements below. While there are additional requirements that must be met, this is intended to provide an overview of the three main safety criteria involved in package reviews. According to NRC regulations, an application for a proposed package design or amendment to an existing approved package design must contain, among other things, a package evaluation. The package evaluation must show that the package will meet the appropriate regulatory criteria when it is prepared for shipment, and that it will meet the appropriate regulatory criteria after the tests for normal conditions of transport and hypothetical accident conditions.

Criteria for a Package as Prepared For Shipment

A package must be designed and prepared for shipment, so that under conditions normally incident to transportation, the radiation levels do not exceed 2 mSv/h (200 mrem/h) at any point on the external surface of the package, and the transport index does not exceed 10. (The transport index is the dose rate measured 1 m from the surface of the package.) However, spent fuel shipments that are transported by exclusive use (sole use by a single consignor of a conveyance for which all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the consignor or consignee) are allowed higher dose rates. A package shipped by exclusive use, must not exceed the following dose rates during transportation:

- 2 mSv/h on the external surface of the package, unless the following conditions are met, in which case the limit is 10 mSv/h:
  - The shipment is made in a closed transport vehicle;
  - The package is secured within the vehicle so that its position remains fixed during transportation; and
  - There are no loading or unloading operations between the beginning and end of the transportation.

- 2 mSv/h at any point on the outer surface of the vehicle, including the top and underside of the vehicle; or in the case of a flat-bed style vehicle, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load or enclosure, if used, and on the lower external surface of the vehicle.

- 0.1 mSv/h at any point 2 meters from the outer lateral surfaces of the vehicle (excluding the top and underside of the vehicle); or in the case of a flat-bed style vehicle, at any point 2 meters from the vertical planes projected by the outer edges of the vehicle (excluding the top and underside of the vehicle).

- 0.02 mSv/h in any normally occupied space, except that this provision does not apply to private carriers, if exposed personnel under their control wear radiation dosimetry devices.

In addition to the above requirements, in the package application the applicant must evaluate the tests for both normal conditions of transport (as specified in 10 CFR 71.71) and hypothetical accident conditions (as specified in 10 CFR 71.73) and ensure that the package meets the

regulatory criteria, as appropriate, after these tests. The effects of the tests may be evaluated by physical test, analysis, or a combination of the two.

Normal conditions of transport

After evaluating the tests for normal conditions of transport, a package must prevent the loss or dispersal of the radioactive contents, maintain the radiation shielding properties, and ensure subcriticality. The tests for normal conditions of transport are designed to simulate rough handling conditions, which include: falling from a transport vehicle or handling equipment; being struck by irregularly shaped freight or other packages with sharp corners; sitting on an uncovered loading dock during inclement weather; and having heavy freight loaded on top of the package. The tests that simulate the types of damage that could result from these conditions are:

- **Water Spray Test**, which simulates the package having been left in rain at a rate of about 2 inches/hr for a period of at least 1 hour; followed by
- **Free Drop Test** of 1 to 4 feet (depending on the package mass) onto a hard surface, in the most damaging orientation - simulating falling off a vehicle or loading platform;
- **Stacking Test** equal to a force of at least five times the weight of the package for at least 24 hours - simulating the damp package being at the bottom of a stack of packages; and
- **Penetration Test** with a 13 pound, 1.25 inch diameter steel rod being dropped at least 40 inches onto the damp package - simulating a loose object hitting the package.

In addition to the rough handling tests, the applicant must evaluate the package for temperature and pressure extremes to ensure that ambient conditions will not adversely affect the package.

After these tests, the package must be demonstrated to have no substantial increase in the dose rate, no loss or dispersal of radioactive contents as demonstrated to a sensitivity of 10^{-6} A_2 per hour (see note below for definition of A_2) and no substantial reduction in the effectiveness of the package. Both a single package and array of packages must be shown to be subcritical.

Hypothetical Accident Conditions

The performance criteria that the package designer must use to assess a Type B package design against the established hypothetical accident conditions are prescribed in 10 CFR 71.73 of the NRC regulations and include the following tests, which are to be done sequentially (except the immersion test for all packages which may be done on a separate specimen):

- **Free Drop**: A 9 m (30 ft) free fall of the test package onto an unyielding surface in a position for which maximum damage is expected;
- **Crush**: For packages with mass not greater than 500 kg (1,100 lb), overall density not greater than 1,000 kg/m^3 (62.4 lb/ft^3) and for normal form non-fissile material, contents greater than 1,000 A_2 - subjecting the test specimen to a dynamic crush test by positioning the specimen on a flat unyielding horizontal surface so as to suffer maximum damage by the drop of a 500 kg (1,100 lb) steel plate mass from 9 meters (30 ft) onto the test package;
- **Puncture**: A puncture test as a free drop of the test package from a height of 1 m (40 in) onto a 15 cm (6 in) diameter vertical steel peg which has a length as to cause maximum damage to the package and is at least 20 cm (8 in) long;
- **Thermal**: Exposure to a fully engulfing thermal environment of at least 800°C (1,475°F) for 30 minutes;

- **Immersion – fissile material:** For fissile packages where water in-leakage is not assumed in the criticality analysis, immersion of the test package under a head of water of at least 0.9 meters (3 ft) in the attitude for which maximum leakage is expected; and
- **Immersion – all packages**: Water immersion of the test package under at least 15 meters (50 ft) depth.

In addition, packages containing more than 10^5 A_2 must be designed to withstand an external water pressure of 2 MPa (290 psi) for a period of not less than 1 hour without collapse, buckling, or in-leakage of water (see 10 CFR § 71.61).

After the tests for hypothetical accident conditions, the package must be subcritical; must not have an escape of krypton-85 exceeding 10 A_2 in one week and no escape of other radioactive material exceeding a total amount A_2 in one week; and no external radiation dose rate exceeding 10 mSv/h at 1 m from the external surface of the package.

Note that an A_2 is the maximum activity of radioactive material, other than special form material, low specific activity, and surface contaminated objects, permitted in a Type A package. Material in excess of the A_2 value must be shipped in a Type B package that meets the criteria described above. This A_2 value is either listed in Appendix A, Table A-1, of 10 CFR Part 71, or may be derived in accordance with the procedures prescribed in Appendix A. For a package containing spent fuel, the A_2 value is determined by the formula in Appendix A, which sums the fractions of the activity of a radionuclide divided by its A_2 value.