Department of Energy
Washington, DC 20585

SAFETY EVALUATION REPORT

Addendum to the
Consolidated Safety Analysis Report
for the
T-3 Spent Fuel Shipping Cask

Docket 94-7-9132

1. GENERAL

1.1 Areas of Review

Revision 0 of the Addendum (Ref. 1) to the Consolidated Safety Analysis Report for Packaging (SARP) for the T-3 Spent Fuel Shipping Cask (Ref. 2) seeks approval for additional payloads to be transported in the T-3 Cask (USA/9132/B(M)F (DOE)) that were not previously authorized in the Certificate of Compliance. These additional payloads include combinations of Thermionic Fuel Elements (TFEs), uranium carbide (UC2) fuel test assemblies, SP-100 capsules, and non-fueled sheath insulators when configured inside the Ident 1578 liner. The specific payload shipping combinations are listed in Table 1. All of the additional payloads were irradiated in the General Atomics TRIGA reactor as part of the SP-100 space reactor research and development program. The 1H1 TFE has been disassembled and the SP-100 capsules will be individually placed in stainless steel pipes and then closed by welding. Other TFE assemblies and the UC2 assembly will be cut to appropriate lengths to fit into the Ident 1578 liner. All of the sheath insulators will be placed on a single machined brass fixture and subsequently inserted into a stainless steel pipe and then closed by welding. Containment does not rely on the stainless steel pipes or TFE assemblies but rather on the previously approved T-3 cask that was designed to assure no radioactive material release under conditions of normal transport or hypothetical accidents.

Table 1: Proposed Payload Shipping Configurations

Shipment	Combination
A	1H2 + SP-100-3
B	1H1 + 1H3
C	3H1 + SP-100-1
D	3H5 + SP-100-2
E	UC2 + Sheath Insulators
F	6H1

The maximum amount of uranium oxide fuel and UC2 fuel, in any one of the six shipping configurations, is limited to 780 g and 11 g, respectively. The total fissile material in any shipping configuration is limited to less than 100 g. The maximum net weight of any of the proposed additional payloads is 150 lbs, the empty weight of the Ident 1578 liner is 245 lbs, and the maximum total weight of any proposed additional payload with its liner is 395 lbs. The maximum decay heat loading is 120 W. All payloads are to be transported in the T-3 cask, which is currently authorized for Fissile Class III shipments under conditions applicable for exclusive use.

1.2 Findings and Conclusions

The staff has reviewed the subject T-3 Addendum and concludes that the general information contained is in compliance with the requirements of 10 CFR Part 71 (Ref. 3) and DOE Order 5480.3 (Ref. 4). The basis for this conclusion is by comparison with the previously approved T-3 SARP and its acceptance for certification for all areas except shielding. In the area of shielding, compliance was determined by examining calculations presented in the subject T-3 Addendum and by performing independent confirmatory calculations.

2. STRUCTURAL EVALUATION

2.1 Areas of Review

The structural analysis included in the subject T-3 Addendum was reviewed in order to determine the effects of the proposed additional payloads. Both the proposed maximum payload weight of 150 lbs and the maximum total weight of 395 lbs, which includes an Ident 1578 liner, were compared to previously approved maximums. The proposed holding fixture precludes the application of point loads at either end of the Ident 1578 liner. Hence, only distributed loads need to be considered when reviewing the stresses resulting from the proposed additional payloads.

2.2 Findings and Conclusions

The previously authorized maximum payload weight within an Ident 69 liner is 160 lbs. The Ident 1578 liner possesses more structural integrity than the Ident 69 liner, and the maximum proposed payload weight is 10 lbs less than the previously approved value of 160 lbs. Comparison shows that the resulting stresses are less than those already authorized and that the proposed payloads can be safely retained within the Ident 1578 liner. Further, the maximum payload weight including the Ident 1578 liner is 395 lbs which is less than the previously authorized value of 700 lbs, again resulting in stresses that are less than those previously authorized. The staff concludes that because these weights and resulting stresses are less than previously authorized, the proposed additional payloads are in compliance with the structural requirements of 10 CFR Part 71.

3. THERMAL EVALUATION

3.1 Areas of Review

The thermal evaluation included in the subject T-3 Addendum was reviewed in order to determine the effects of the proposed additional payloads. The T-3 cask is designed with a totally passive thermal system. There are no cooling fins. One principal component of this thermal system is the external thermal fire shield. The fire shield is made of 10-gauge stainless steel sheet metal that is separated from the outer surface of the cask by a 0.08-inch diameter stainless steel wire wrap. A sun shield is also present during transport that eliminates direct solar insolation on the cask and which provides a physical barrier such that the radius of the accessible external surface is larger than that of the fire shield. The thermal system is the same as that previously approved. The only change that affects the thermal evaluation is the amount of internal heat generation in the proposed additional payloads. The maximum thermal load is 120 W, which occurs mainly because of gamma decay from structural materials that were activated during the in-core irradiation. This thermal load is distributed nearly uniformly over the 22-inch length of the test articles irradiated in-core.

3.2 Findings and Conclusions

The maximum authorized heat load in the T-3, when using the Ident 1578 liner, is 1400 W distributed over a length of 36 inches. The maximum heat load for the additional proposed payloads is 120 W distributed over 22 inches. The total heat load is less than 18% and the heat load per unit length is less than 29% of the previously authorized values. On the basis of this comparison, the staff concludes that the thermal design features described in the subject T-3 Addendum, along with the proposed additional payloads, are in compliance with the requirements of 10 CFR Part 71.

4. CONTAINMENT EVALUATION

4.1 Areas of Review

The containment evaluation included in the subject T-3 Addendum was reviewed in order to determine the effects of the proposed additional payloads. The approved T-3 cask containment consists of a primary and a secondary containment. Both containments are composed of cylindrical shaped stainless steel pipes with double o-ring seals for closure. The seals are protected from a hypothetical fire environment by a fire shield and overpacks (impact limiters). These containment features remain unchanged. The previously approved T-3 cask containment was designed to assure no radioactive material release under any conditions of normal transport or hypothetical accidents. This containment was independent of the amount of dispersible radioactive material as long as the maximum structural and thermal loads did not exceed those authorized.

4.2 Findings and Conclusions

The maximum authorized payload weight contained in the Ident 1578 liner is 160 lbs, which is 10 lbs more than the maximum weight of the proposed additional payloads. Further, the proposed holding fixture precludes the application of point loads. Hence the structural loading on the containment boundary is reduced. The maximum authorized Ident 1578 thermal loading is 1400 W, which is more than the maximum value of 120 W for the proposed additional payloads. On the basis of the above structural and thermal loading comparisons, the staff concludes that the containment described in the subject T-3 Addendum for the proposed additional payloads is in compliance with the requirements of 10 CFR Part 71.

5. SHIELDING EVALUATION

5.1 Areas of Review

The design of the T-3 cask must have sufficient shielding for neutron and gamma radiation to assure compliance with the dose rate limits specified in 10 CFR Part 71. Because shipments are to be made in an open transport vehicle under conditions applicable to exclusive use, 10 CFR 71.47 requires that the dose be less than 200 mrem/h on any accessible external surface of the package. For the T-3 cask, the accessible external surface of the package is the sun shield that has a radius of 17.8 inches. The 13.22-inch outer radius of the T-3 cask, where confirmatory calculations of dose rates were determined by the staff, is smaller than that of the sun shield.

The dose must also be less than 10 mrem/h at a distance 2 m from the vertical projection of the outer edges of the vehicle and less than 2 mrem/h in any occupied positions in the vehicle. The width of the vehicle is considered to be 8 feet. Under hypothetical accident conditions, the external radiation dose must not exceed 1000 mrem/h at a distance one meter from the external surface of the package.

5.2 Review Procedures

This review was divided into three parts: 1) source specification, 2) model specification, and 3) shielding evaluation.

5.2.1 Source Specification

Both the gamma source strengths and the neutron source strengths associated with the proposed additional payloads were examined and compared to previously approved values. The applicant performed ORIGEN-S calculations to determine the source terms for the 1H1, 1H2, 1H3, 3H1, 3H5, 6H1, SP-100-1, SP-100-2, and SP-100-3 assemblies. ORIGEN-S calculations were not made for the UC2 fuel test assembly or the SP-100 sheath insulators because their respective source terms are bounded by other cases. An appraisal of the combinations showed that Shipment B (the 1H1 + 1H3 combination) was the largest source term for the subject T-3 Addendum. All of the shipments have assemblies that will have

been out of the reactor for over 650 days. Hence, the gamma and neutron source terms used to calculate doses were based on a 650-day decay time.

5.2.1.1 Gamma Source

Gamma-ray photon emission rates of Shipment B were determined for a 16-group structure of mean gamma energies ranging from 3.0 to 0.15 MeV. Each group was compared to previously approved T-3 payload values. Total photons/s from the 16 groups was calculated to be 6.80 E+13 for Shipment B compared to 2.21 E+15 for the previously approved T-3. Essentially all of the photon emission (95%+) comes from the structural materials that were activated during in-core irradiation. The effective length of these structural materials is 22 inches and the gamma source is nearly uniformly distributed along this length. The effective length of the gamma source in the previously approved T-3 is 36 inches that is also nearly uniformly distributed. The resulting gamma emission per unit length is 3.1 E+12 photons/s-inch for Shipment B, which is 20 times less than the 6.1 E+13 photons/s-inch for the previously approved T-3 SARP.

Because the gamma emission rates in the proposed T-3 Addendum are less than those previously approved, we used the previously approved values of 12.5, 4.7, and 0.8 mrem/h at the cask side, bottom, and top, respectively, in calculating total neutron and gamma dose rates.

5.2.1.2 Neutron Source

The neutron emission rates were determined for a 15-group structure of mean neutron energies ranging from 13.5 to 0.002 MeV. Total neutrons/s from these 15 groups was 1.32 E+06 and 1.82 E+07 for Shipment B and previously approved T-3 SARP (Ref. 2), respectively. However, in contrast to the gamma source, the neutron source for Shipment B is concentrated at a location 1.83 inches long and is not distributed as was the case with the previously approved T-3 SARP. The neutron emissions per unit length for Shipment B can be as large as 7.2 E+05 neutrons/s-inch, which exceeds the value of 5.1 E+05 neutrons/s-inch of the previously approved T-3.

Because the neutron emissions per unit length exceed previously approved values, confirmatory shielding calculations were performed by the staff to assure compliance with the shielding requirements of 10 CFR Part 71.

5.2.2 Model Specification

Radial and axial shielding configurations used in analyses of the proposed additional payloads are identical with shielding configurations previously approved in the T-3 SARP. The T-3 cask was designed structurally so that no rupture or significant deformations would occur during any credible accident. Hence, no distinction is made in the shielding configurations between normal and accident conditions. Radial shielding includes a 0.3-inch-thick cylindrical inner stainless steel shell (liner) separated from a 1-inch-thick cylindrical outer stainless steel shell (plate) by lead that is 7.7 inches

thick. Axial shielding is accomplished with plugs, the details of which are shown in Section 5.3 of the previously approved T-3 SARP. Shield regional atom densities are 0.085 E+24 and 0.033 E+24 atoms/cc for the steel and lead, respectively.

5.2.3 Shielding Evaluation

Confirmatory shielding calculations were performed for Shipment B with the FCXSEC 43-group (22 neutron groups and 21 gamma groups) cross section library and the TWODANT (Ref. 5) discrete ordinate code. The neutron energy group spacing provided in Ref. 1 matched that in the FCXSEC cross section library within a fraction of one percent. The neutron flux-to-dose conversion factors from Ref. 6 were conservatively applied by selecting the largest flux-to-dose factors for each energy group.

The 1H1 contains 29.39 g of uranium at 57.49% enrichment. The 1H3 contains 30.47 g uranium at 19.59% enrichment. The confirmatory analysis for Shipment B (1H1 + 1H3 combination) was conducted using 0.6-inch diameter by 1 inch long TFE pellets. The actual size of the TFE pellets, documented after the confirmatory analysis was complete, is 0.411 inch diameter by 1.83 inches long. The smaller length of the TFE pellet used in the confirmatory analysis is conservative and provides dose rates that are upper bounds to any dose rates that would be obtained using the actual TFE element dimensions.

Components used in the TWODANT model are:

a) a single cylindrical pellet homogenized and sized to conserve the volume of two pellets, having a length of a single pellet. The homogenized pellet is 0.848 inch in radius and 1 inch long;

b) a cylindrical 0.322-inch-thick, 8-inch diameter Schedule 40 stainless steel pipe, approximately 167 inches long;

c) a cylindrical 7.7-inch lead liner, approximately 167 inches long;

d) a cylindrical 1-inch-thick stainless steel cask wall, 26.44 inches outside diameter, approximately 167 inches long;

e) the 8-inch and 11-inch top and bottom stainless steel plugs, fitting inside the Schedule 40 pipe; and

f) air filling the spaces between the Schedule 40 pipe and the homogenized fuel pellet.

The 5-inch outside diameter tubing holding the 1H1 and 1H3, the individual support tubes for the 1H1 and 1H3, and the top and bottom flanges were not modeled. The model is conservative in that it replaces the stainless steel tubing, support tubes, and flanges that would normally provide some attenuation, with air. The bottom of the homogenized fuel pellet was placed 12.1 inches above the bottom 11-inch plug.

5.3 Findings and Conclusions

Neutron dose rates calculated at the side, bottom, and top of the cask were 15.5, 14.9, and <0.1 mrem/h respectively. Using the previously approved gamma dose rates of 12.5, 4.7, and 0.8 mrem/h at the cask side, bottom, and top surfaces, respectively, the total calculated neutron plus gamma ray dose rates are:

a) side, 15.5 mrem/h neutron + 12.5 mrem/h gamma = 28.0 mrem/h

b) bottom, 14.9 mrem/h neutron + 4.7 mrem/h gamma = 19.6 mrem/h

c) top, <0.1 mrem/h neutron + 0.8 mrem/h gamma = <1.0 mrem/h

These dose rate results confirm that the proposed shipments listed in the T-3 Addendum (Ref. 1) meet the 200 mrem/h limit at any accessible surface of the cask for exclusive use shipments as documented in 10 CFR 71.47.

Dose rates were also calculated at 1 meter from the cask surface. These rates for neutrons were found to be 1, 2, and <0.1 mrem/h respectively, at the side, bottom, and top of the cask. Gamma dose rates from the previously approved T-3 were 3, 1.2, and 0.3 mrem/h, respectively. Because the vehicle used for transport is considered to be 8 feet wide, the location 1 meter from the surface of the cask is just outside the side edge of the vehicle. These results confirm that the proposed shipments meet the criteria of not exceeding 200 mrem/h at any point on the outer surface of the vehicle, not exceeding 10 mrem/h at any point 2 meters from the vertical planes of the vehicle, and of not exceeding 2 mrem/h in any normally occupied position of the vehicle.

The previously approved T-3 SARP shows that there is no significant damage to the T-3 cask under hypothetical accident conditions. Therefore, no further analysis is required to confirm that the proposed shipments meet the requirement of not exceeding 1000 mrem/h at 1 meter from the external surface of the cask.

6. CRITICALITY EVALUATION

6.1 Areas of Review

The criticality evaluation included in the subject T-3 Addendum was reviewed in order to determine the effects of the proposed additional payloads. Total fissile material is limited to less than 100 g and consists mainly of U-235. This fissile material must comply with the requirements for shipment of Fissile Class III as follows:

a) One shipment of packages is to remain subcritical when it is in contact with an identical shipment and the two-shipment array is reflected on all sides by water.

b) One shipment of packages is to remain subcritical under hypothetical accident conditions with optimum moderation and close reflection by water.

6.2 Findings and Conclusions

The "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANSI/ANS-8.1-1983 (Ref. 7) lists the subcritical limit for a fissile solution containing U-235 as 0.765 kg U-235. A shipment of 100 g or less of U-235 fissile material, doubled to meet the two-cask criteria for normal conditions of transport, still gives a safety factor of more than three. On the basis of this comparison, the staff concludes that the proposed additional payloads are in compliance with the criticality safety requirements of 10 CFR Part 71.

7. OPERATING PROCEDURES

7.1 Areas of Review

Operating procedures described in the T-3 SARP are applicable to the additional payloads proposed in the subject Addendum. For each shipment, the proposed additional payload and handling fixture will be completely assembled prior to insertion into the Ident 1578 liner. This one-piece assembly allows for easy loading and unloading of the contents.

7.2 Findings and Conclusions

The staff has reviewed the subject T-3 Addendum and finds that, other than the assembly of each additional payload and handling fixture into a one-piece unit before insertion into the Ident 1578 liner, there are no changes proposed or required to the operating procedures from those previously authorized in the T-3 SARP. On the basis of this comparison, the staff concludes that the operating procedures are in compliance with the requirements of 10 CFR Part 71.

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Areas of Review

There are no changes from the approved T-3 SARP associated with the acceptance tests and maintenance program.

8.2 Findings and Conclusions

The staff has reviewed the subject T-3 Addendum and finds that no changes are proposed or required to the acceptance tests and maintenance program. The staff concludes that the proposed additional payloads are in compliance with the acceptance tests and maintenance program requirements of 10 CFR Part 71.

REFERENCES

1. Westinghouse Hanford Company, Richland, WA, "Addendum to the Consolidated Safety Analysis Report for the T-3 Spent Fuel Shipping Cask Demonstrating Compliance to the Requirements of 10 CFR 71," WHC-SD-TP-DA-002, Rev. 0, June 1994.

2. Westinghouse Hanford Company, Richland, WA, "Consolidated Safety Analysis Report for the T-3 Spent Fuel Shipping Cask," Revision 6, August 1990.

3. Office of the Federal Register, Washington, DC, "Packaging and Transportation of Radioactive Material," Title 10, Code of Federal Regulations, Part 71, latest edition (January 1, 1992).

4. U.S. Department of Energy, Washington, DC, "Safety Requirement for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes," DOE Order 5480.3, latest edition (July 9, 1985).

5. R. E. Alcouffe, F. W. Brinkley, D. R. Marr, and R. D. O'Dell, "User's Guide for TWODANT: A Code Package for Two-Dimensional, Diffusion-Accelerated, Neutral-Particle Transport," Report LA-10049-M, Los Alamos National Laboratory, April 1992.

6. American Nuclear Society, "American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors," ANSI/ANS-6.1.1-1977.

7. American National Standards Institute, "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANSI/ANS-8.1-1983.

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