SAFETY SUMMARY REPORT — LP-12 TRITIUM CONTAINER

(Packaging of Radioactive and Fissile Materials)

FINAL REPORT

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Department of Transportation, Title 49, Part 173 (Pertinent sections)

Abstract

Elemental tritium is shipped at low pressure in an insulated container in compliance with regulations set forth in Department of Transportation, Title 49, parts 173-178.¹ The package is not a radiological hazard under normal or hypothetical accident conditions.

Description of Shipment

Elemental tritium is shipped from the Savannah River Plant in a stainless steel vessel (LP-12), sealed within an aluminum vessel, and surrounded by 3.9-in. thick "Celotex"² insulation in a steel drum. The packaging components are shown in figures 1 and 5.

Tritium gas may be pure or contain varying amounts of protium (¹H), deuterium (²H), or helium. The following restrictions apply to the use of this container:

Maximum tritium content	12,700 cc-STP (32,600 curies)
Maximum total pressure in primary container during shipment	17 psia (880 torrs) at 25°C

Each package contains a Type B quantity of nonfissile, Group VII material, as defined in Department of Transportation, Title 49, parts 173-178 and complies with the requirements for a Type B package.

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¹ Reproductions of pertinent sections are included in this report.

² The Celotex Corporation's trademark for structural building and insulation board, Mil-F-26862-A-Type II.

Comparison with Regulations

The packaging standards for shippers are contained in Department of Transportation, Title 49, and all pertinent sections are discussed below, in sequence. Pertinent Du Pont procedures dealing with testing and loading are: DPSOL 232-H-113, -804, -822, and -1414.

173.24 Standard requirements for all packages

- a. 1) "For normal transport, there will be no significant release to the environment."

See paragraph 173.398.

- 2) "For normal transport, the effectiveness of the packaging will not be substantially reduced."

A similar shipping package, without the drum and insulation, has been shipped several years without loss of effectiveness. Inclusion of the overpack makes the package even more effective.

- 3) "There will be no mixture of gases or vapors in the package which could, through any credible spontaneous increase of heat or pressure or through an explosion, significantly reduce the effectiveness of the packaging."

At a release rate of 7×10^{-8} atm cc/sec (see 173.398,b) for 30 days of transportation, the mol fraction of hydrogen isotopes in the secondary container will be:

$$\frac{7 \times 10^{-8} \text{ atm cc/sec} \times 30 \text{ days} \times 24 \text{ hr/day} \times 3600 \text{ sec/hr}}{6500 \text{ (chamber volume)}}$$

$$= 2.8 \times 10^{-5} \text{ or } 0.003\% \text{ T}_2$$

Even if the ratio of deuterium + protium to tritium were 10, the mixture is not ignitable because the hydrogen concentration in air is less than 4%, the lower limit. The corresponding pressure increase would also be insignificant; consequently, there is no danger of creating an explosive mixture under conditions of normal transport.

- b. "For materials not specified."

No comment is required.

- c. "Design and construction criteria."

- 1) "Marking."

Each package is marked as shown in figure 1.

- 2)-8) "Packaging requirements."

Specifications for the shipping package are also shown in figure 1. The packaging components are shown on figures 1 through 5.

173.28 Reuse of containers

No comment is required.

173.393 General packaging requirements

- a) "Unless otherwise specified, all shipments of radioactive materials must meet all requirements of this section, and must be packaged as prescribed in 173.391 through 173.396."

The package containing a Type B quantity (173.395, b) of radioactive material in normal form has a 30-gallon steel drum.

- b) "The outside of each package must incorporate a feature such as seal, which is not readily breakable and which, while intact, will be evidence that the package has not been illicitly opened."

The drum closure complies with this requirement.

- c) "The smallest outside dimension of any package must be 4 in. or greater."

The outside diameter of the package is >18 in.

- d) "Radioactive materials must be packaged in packagings which have been designated to maintain shielding efficiency and leak tightness, so that, under conditions normally incident to transportation, there will be no release of radioactive materials"

"Specification containers listed as authorized for radioactive materials shipments may be assumed to meet standards, provided the packages do not exceed the gross weight limits prescribed for those containers in PART 178 of this chapter."

This package weighs 130 lb which is considerably less than the 480 lb maximum limit for a 30-gallon drum. Assurances that the container is leak tight are given in paragraph 173.398.

- 1) "Internal bracing or cushioning where used, must be adequate to assure that, under conditions normally incident to transportation, the distance from the inner container or radioactive material to the outside wall of the package remains within the limits for which the package design was based, and the"

There is not significant change in distance from the inner container to the outside wall of the package as demonstrated by the 30-ft drop test (see figures 10 and 11).

- e) "The packaging must be so designed, constructed, and loaded that, when transporting large quantities of radioactive material"

Not applicable.

- f) "Pyrophoric materials"

Not applicable.

- g) "Liquid radioactive material"

Not applicable.

- h) "There must be no significant removable radioactive surface contamination on the package." (see 173.397, a.1).

Beta-gamma activity on the package exterior is less than 750 d/m per 100 sq cm which is significantly less than the 2200 d/m limit. Tritium, a beta emitter, does not present a problem from penetrating radiation.

- i) through 0) Radiation dose rate.

See paragraph 173.398.

173.394 Radioactive material in special form

Not applicable.

173.395 Radioactive material in normal form

No comment is required.

173.396 Fissile radioactive material

Not applicable.

173.397 Contamination control

Refer to item 173.393, h.

173.398 Special tests

- a) Special form material.

Not applicable.

- b) Standards for Type A packaging (also applicable to Type B packaging):

No release of radioactive material is allowed under normal conditions, yet this is an unattainable goal for gaseous tritium which permeates, at varying rates, through normal materials of

(contd)

construction. Realistically, "no release" has been interpreted to mean: no release which would expose any persons to a dose above that received by continuous exposure to the maximum permissible concentration allowed for the public. For transportation in a closed vehicle (the worst case), the maximum allowable release rate per package would be about 7×10^{-8} atm cc/sec of tritium. This value is derived by assuming that air in a closed vehicle is replaced about once a day, that a vehicle contains about 300 cu ft of air for every package, and that a workman opening and unloading the vehicle would be exposed to the maximum concentration for no more than an average of one minute (based on one exposure per week). The maximum concentration in the vehicle is computed from the maximum permissible concentration in air above natural background for uncontrolled areas set by AECM 0524. The actual exposure would be much lower than calculated because actual tritium release rates will be greatly below the proposed upper limit. (It is interesting to note that the 7×10^{-8} atm cc/sec limit compares very well the proposed IAEA¹ regulations limit of 1×10^{-7} atm cc/sec for tritium.)

(2) Environmental Conditions

(i) Heat (Ambient temperature 130°F; direct sunlight and still air)

A. General Basis

The LP container consists of a 12-liter stainless steel vessel encased in a flanged aluminum outer vessel. The assembly is packed in a steel drum, 18.25" ID $\times$ 26.99" inside height insulated with "Celotex." The package arrangement and principal dimensions are shown in exhibit 1.

¹ International Atomic Energy Agency.

EXHIBIT 1

An estimate of the maximum temperatures attained in the package in normal transport is made below. Basic assumptions for the estimate are:

- (1) The package is in thermal equilibrium at the most severe environmental condition (130°F and sunlight).
- (2) Solar heating is applied to the top and one side of the drum over a projected area equal to diagonal height $\times$ diameter.
- (3) There is no circumferential heat flow in the thin wall of the drum or in the "Celotex" insulation.
- (4) Heat escape through the bottom of the package is neglected.
- (5) The wall temperature of the aluminum vessel is uniform (high conductivity, low heat flux).
- (6) Heat passage from the sunny surfaces of the drum to the aluminum vessel, thence to the shaded surface of the drum is calculated on the basis of a weighted average insulation thickness.

B. Definitions and Constants

- (1) Q_s = Solar heat input = solar flux $\times$ projected area.

Solar flux = 241 Btu/(hr)(ft²) based on solar constant of 1.92 cal/(cm²)(min), atmospheric transmittance factor of 0.60, and absorptivity factor of 0.94[1] for a painted drum.

$$\begin{aligned}\text{Projected area} &= \text{diagonal height} \times \text{diameter} \\ &= \frac{\sqrt{(26.99)^2 + (18.25)^2} \times 18.25}{144} = 4.15 \text{ ft}^2\end{aligned}$$

$$Q_s = 241 \times 4.15 = 1000 \text{ Btu/hr}$$

- (2) Q_r = Radioactive decay heat = 1.11 watts = 3.78 Btu/hr

- (3) A_d = Surface area of drum (sun side) = top surface
+ 1/2 cylindrical surface = 7.17 ft²

- (4) A'_d = Surface area of drum (shade side)
= 1/2 cylindrical surface = 5.36 ft²

- (5) U_o = Heat transfer coefficient through insulation
(sun side) = $\frac{K}{L} = \frac{0.038}{0.363} = 0.104 \frac{\text{Btu}}{(\text{hr})(\text{ft}^2)(^\circ\text{F})}$

K = Thermal conductivity of "Celotex" in range of 180-190°F, estimated from room temperature conductivity of 0.030 Btu/(hr)(ft²)(°F/ft)

L = Average insulation thickness of cylindrical sides and top — weighed on basis of area and is 4.03" plus 0.32" "Celotex" equivalent of air gaps = 0.363 ft

- (6) U'_o = Heat transfer coefficient through insulation
(shade side)

$$\begin{aligned}U'_o &= \frac{K'}{L'} \text{ where } K' = 0.038 \text{ as above for } K \\ &\quad L' = 0.37 \text{ ft} \\ &= \frac{0.038}{0.37} = 0.103 \text{ Btu/(hr)(ft}^2\text{)(}^\circ\text{F)}\end{aligned}$$

- (7) A_m = Mean heat transfer area (sun side)
 = Mean area of drum top + 1/2 mean area of cylindrical side
 = $1.10 \text{ ft}^2 + 2.95 \text{ ft}^2 = 4.05 \text{ ft}^2$
- (8) A'_m = Mean heat transfer area (shade side)
 = 1/2 Mean area of cylinder side = 2.95 ft^2
- (9) T_d = Drum surface temperature -- sun side, °F
- (10) T'_d = Drum surface temperature -- shade side, °F
- (11) T_c = Wall temperature of aluminum vessel, °F
- (12) T_a = Ambient temperature = 130°F

C. Calculations

1. Heat Balances

For determination of temperatures of T_d , T'_d and T_c , heat balances are made on the entire package, the aluminum vessel and the separate sides of the steel drum.

$$\text{Entire package} \quad \frac{Q_{\text{in}}}{Q_s + Q_r} = \frac{Q_{\text{out}}}{Q_1 + Q'_1}$$

$$1000 + 3.78 = (h_c + h_r) A_d (T_d - T_a) + (h'_c + h'_r) A'_d (T'_d - T_a)$$

$$\text{where } h_c = 0.19 (\Delta T)^{1/3}$$

$$h_r = \frac{0.173 \times 10^{-8} F_a F_e}{\left[\frac{(T_d + 460)^4 - (T_a + 460)^4}{(T_d - T_a)} \right]}$$

$$F_a = \text{Angle factor} = 1.0$$

$$F_e = \text{Emissivity factor} = 0.94$$

$$\text{Aluminum container} = \frac{Q_{\text{in}}}{Q_r + Q_2} = \frac{Q_{\text{out}}}{Q'_2}$$

$$Q_r + U_o A_m (T_d - T_c) = U'_o A'_m (T_c - T'_d)$$

$$\text{Steel drum (sun side)} \quad Q_s = Q_1 + Q_2$$

$$\text{Steel drum (shade side)} \quad Q'_2 = Q'_1$$

By successive substitution of trial values in the preceding equations, the following set of temperatures is required for equilibrium.

$$\text{Drum - sun side } (T_d) = 186^\circ\text{F}$$

$$\text{Drum - shade side } (T'_d) = 140^\circ\text{F}$$

$$\text{Aluminum vessel } (T_c) = 171.5^\circ\text{F}$$

(2) Temperature gradient between inner and outer vessel.

To determine the temperature of the product container (and product), it is necessary to estimate the temperature gradient between the outer vessel and the product container. Heat transfer is by conduction across the air gap between the two vessels.

$$T_c = \text{Temperature of outer aluminum vessel} = 171.5^\circ\text{F}$$

$$T_p = \text{Temperature of the product container, } ^\circ\text{F}$$

$$A_{co} = \text{Conduction heat transfer area}$$

$$= 9\text{-}1/2'' \text{ OD} \times 9\text{-}9/16'' \text{ high (conservative)}$$

$$= 1.96 \text{ sq ft}$$

L = Clearance between cylindrical surfaces.
 $= .0625" = .0052 \text{ ft}$

Heat balance

$$Q_r = h_{co} A_{co} (T_p - T_c) = h_{co} A_{co} \Delta T$$

where Q_r = Radioactive decay heat = 3.78 Btu/hr

h_{co} = Heat transfer coefficient by conduction

$$= \frac{K_{air}(170^\circ F)}{L} = \frac{0.0175 \text{ Btu/(hr)(ft}^2\text{)(F/ft)}}{0.0052 \text{ ft}} = \frac{3.36 \text{ Btu}}{(\text{hr})(\text{ft}^2)(F)}$$

$$\therefore \Delta T = 0.5^\circ F$$

$$T_p = T_c + \Delta T = 171.5 + 0.5 = 172^\circ F$$

There will be no significant difference in temperature between the product and the container wall; therefore, the temperature of the product will not exceed $172^\circ F$.

D. Pressure in Containment Vessel During Normal Transport

The pressure in both the product and outer containers is proportional to temperature. The maximum pressures that can be produced in normal transport are estimated below.

(1) Basis & Assumptions

- (a) The inner vessel is loaded to 1.22 atmospheres (880 torrs) and $77^\circ F$.
- (b) The outer vessel is sealed at atmospheric pressure and $77^\circ F$.
- (c) The maximum transport temperature for the product container and contents is $172^\circ F$.
- (d) The maximum transport temperature for the air space between the two vessels is midway between the wall temperatures of the two vessels.

$$\left[\frac{172 + 171.5}{2} \right] = 171.75^\circ F$$

2. Pressure in outer vessel

$$P = 14.7 \text{ psi} \times \left[\frac{171.75 + 460^\circ R}{77 + 460^\circ R} \right] = 17.3 \text{ psia (2.6 psig)}$$

The ability of the vessel to withstand this pressure is shown in 173.398,b,2,iii.

(contd)

3. Pressure in inner vessel

$$P = \frac{880 \text{ torrs}}{760 \text{ torrs/atm}} \times 14.7 \text{ psi/atm} \times \left[\frac{172 + 460^\circ\text{R}}{77 + 460^\circ\text{R}} \right] = 20.2 \text{ psia (5.5 psig)}$$

The pressure differential across the wall of the inner vessel is

$$20.2 - 17.3 = 2.9 \text{ psi}$$

E. Tritium Lost

Equilibrium hydrogen permeation through type 347 stainless steel at 78°C (172°F) is $1.2 \times 10^{-5} \frac{\text{cc (STP) mm}}{(\text{sq cm})(\text{hr})}$ at 760 torrs[2]. Corrected for pressure, surface area, and wall thickness, the permeation rate becomes

$$\frac{1.2 \times 10^{-5} \text{ cc (STP) mm} \times 3040 \text{ cm}^2}{3.6 \times 10^3 (\text{sec/hr})(\text{cm}^2)(\text{hr}) \times 1.57 \text{ mm}} \sqrt{\frac{1.38 \text{ atm}}{1 \text{ atm}}} = 0.76 \times 10^{-5} \text{ cc (STP)/sec}$$

A very long time, however, is required to reach the equilibrium rate. The time to reach $7 \times 10^{-8} \text{ atm cc/sec}$ is obtained from a graphical plot of $\frac{P_t}{P_\infty}$, where P_t = permeation rate at time t or $7 \times 10^{-8} \text{ atm cc T}_2/\text{sec}$. (The permeation equations and plots are derived and their use illustrated in DPWD-1057, DPWD-1132, DPSTWD-69-131.)

$$\text{For } \frac{P_t}{P_\infty} \text{ of } \frac{7 \times 10^{-8} \text{ atm cc T}_2/\text{sec}}{7.6 \times 10^{-6} \text{ atm cc T}_2/\text{sec}} = 0.009, \frac{Dt}{L^2} = 0.038$$

where: D = Diffusivity = $2.65 \times 10^{-2} e^{-14,000/RT}$ (assumed 347 SS is like 304 SS)

$$= 2.65 \times 10^{-2} e^{-14,000/(1.987)(351)} = 5 \times 10^{-11} \text{ cm}^2/\text{sec}$$

$$R = 1.987 \text{ g-cal}/(\text{g-mole})(^\circ\text{K})$$

$$T = 351^\circ\text{K}$$

$$L = 0.157 \text{ cm}$$

$$\therefore t = \frac{(0.038)(0.157 \text{ cm})^2}{(5 \times 10^{-11} \text{ sq cm/sec})(3.6 \times 10^3 \text{ sec/hr})(24 \text{ hr/day})} = 216 \text{ days}$$

Because it is reasonable to expect the transportation to be completed within 30 days, tritium permeation would be significantly less than the $7 \times 10^{-8} \text{ atm cc/sec}$ limit.

Tritium may be stored in these containers for several years before shipment but the permeation rate is extremely low under normal handling conditions ($<100^{\circ}\text{F}$). Calculations (not shown here) indicate that about 28 years would be required for the permeation rate to reach 0.7×10^{-8} , a factor of 10 below the derived maximum allowable limit. Therefore, permeation during normal storage is so small as to not alter the conclusions drawn above.

Before initial use, each container is leak tested ($<7 \times 10^{-8}$ atm cc/sec) at 1-1/2 times its maximum operating pressure (5.5 psia) to show that it complies with the Regulations. Loss through the container valve is also negligible ($<10^{-8}$ atm cc/sec) as shown in 173.398,c,2,iii,D. Therefore, it is concluded that the LP-12 container does not represent a hazard at the maximum normal operating temperature.

(ii) Cold (An ambient temperature of -40°F in still air and shade.)

This package contains no liquids or other materials harmfully affected by a temperature of -40°F .

(iii) Reduced Pressure (Ambient atmospheric pressure of 0.5 atmosphere [absolute] (7.3 psia).

It is shown under 173.398,b,2,i,D, that the maximum internal pressure in the secondary container (container bucket and cover) is 17.3 psia. With one-half standard atmospheric pressure on the outside of the bucket, the differential across the wall is

$$P = 17.3 - 1/2(14.7) = 9.95 \text{ psig}$$

The wall temperature is $\sim 170^{\circ}\text{F}$.

Allowable stresses are not listed in the ASME Code for 356-T51 aluminum.

SB-26-SG70A-T71 is similar and will be used.

$$\text{Allowable stress at } 170^{\circ}\text{F} = 6000 - \frac{170-150}{200-150} (250) = 5900 \text{ psi}$$

Bucket stresses: $P = 9.95 \text{ psig}$

$$\text{Shell: } S = \frac{P(R + 0.6t)}{Et} = \frac{9.95 [4.81 + 0.6(0.1875)]}{(1)(0.1875)} = 269 \text{ psi} < 5900 \text{ OK}$$

$$t_r = \frac{PR}{SE-0.6P} = \frac{9.95(4.81)}{5920-6} = 0.00808''$$

Bottom head: $C = 0.5m \geq 0.3$ [figure UG-34 (b-2)]

$$C = 0.5 \left(\frac{t_r}{t_s} \right) = 0.5 \left(\frac{0.00808}{0.1875} \right) = 0.022, \text{ use } C = 0.3$$

$$S = CP \left(\frac{d}{t} \right)^2 = 0.3 (9.95) \left(\frac{9.625}{0.3125} \right)^2 = 2840 \text{ psi} < 5900 \quad \text{OK}$$

Top head: $C = 0.20$ [figure UG-34(d)]

$$S = CP \left(\frac{d}{t} \right)^2 = 0.2 (9.95) \left(\frac{9.5}{0.25} \right)^2 = 2870 \text{ psi} < 5900 \quad \text{OK}$$

Flange & Bolting Operating Condition

$$H_D = 0.785 B^2 P = 0.785 (9.5)^2 (9.95) = 706; 706 \times 0.625 = 441$$

$$H_G = 2b\pi GmP = 2(0.06) \pi (10.12)(1.0)(9.95) = 38; 38 \times 0.44 = 17$$

$$H_T = \pi(9.81)(.31)(9.95) = 95; 95 \times 0.595 = 57$$

$$W_{m1} = 839 \text{ lb} \quad M_O = 515 \text{ in. lb}$$

$$W_{m2} = \pi b G y = \pi(0.06)(10.12)(200) = 380 \text{ lb} < W_{m1}$$

$$A_{m1} = \frac{W_{m1}}{S} = \frac{839}{20,000} = 0.0419 \text{ sq in.}$$

$$A_b = 4(0.0269) = 0.1075 \text{ sq in.} > 0.0428$$

$$W = 1/2(A_m + A_b) S_a = 1/2(0.0419 + 0.1075)(20,000) = 1494 \text{ lb}$$

$$M_O = W h_g = 1494(0.44) = 660 \text{ in. lb (gasket seating)}$$

Gasket Seating Governs

$$\text{Bolt stress} = \frac{1500}{0.1075} = 14,000 \text{ psi} \quad \text{OK}$$

Flange stresses: See item II,B,2, for flange constants

Gasket seating: ASME allowable stress = 6250 psi

$$S_H = \frac{fM_O}{Lg_1^2 B} = \frac{1.0(660)}{0.639(0.25)^2(9.5)} = 1750 \text{ psi} < 1.5(6250) \quad \text{OK}$$

$$S_R = \frac{(1.33 t_e + 1) M_O}{L t^2 B} = \frac{[1.33(0.25)(0.59) + 1](660)}{0.639(0.25)^2(9.5)} = 2080 \text{ psi} < 6250 \quad \text{OK}$$

$$S_T = \frac{YM_O}{t^2 B} - ZS_R = \frac{9.15(660)}{(0.25)^2(9.5)} - 4.72(2080) = 305 \text{ psi} < 6250 \quad \text{OK}$$

Operating condition: ASME allowable stress = 5900 psi

$$S_H = \frac{fM_O}{Lg_1^2 B} = \frac{(1.0)(515)}{0.639(925)^2(9.5)} = 1360 \text{ psi} < 1.5(5900) \quad \text{OK}$$

$$S_R = \frac{(1.33te + 1)M_O}{Lt^2 B} = \frac{[1.33(0.25)(0.59) + 1](515)}{0.639(0.25)^2(9.5)} \\ = 1630 \text{ psi} < 5900 \quad \text{OK}$$

$$S_T = \frac{YM_O}{t^2 B} - ZS_R = \frac{9.15(515)}{(0.25)^2(9.5)} - 4.72(1630) = 237 \text{ psi} < 5900 \quad \text{OK}$$

NOTE: Container bucket and cover are tested with 20-psig internal air pressure which proves the ability of the flange and bolts to make and maintain the seal.

(iv) Vibration.

The stainless steel and aluminum container have been shipped for many years without vibration damage. The addition of the insulation and a steel drum provides additional protection. These facts indicate that vibration will not damage the package.

3. Test conditions

(i) Water spray.

The closed steel drum, with vent holes sealed with metallic tape, is impervious to water spray and is not significantly affected.

(ii) Free drop.

The package was dropped 30 ft without significant damage as discussed in 173.398,C,2,(i), and would obviously pass the 4-ft drop.

(iii) Corner drop.

Not applicable.

(iv) Penetration.

A 13-lb 1-1/4-inch-diameter rod was dropped on end four feet on the weakest area of the drum. Maximum deflection of container in test was less than 1/8-in. (see figure 9) with no damage to the "Celotex" insulation.

(v) Compression.

An empty drum was uniformly loaded to 700 lb (more than 5 times normal package weight) in the manner required in 173.398,(a),(3),(v), without visible damage or deformation.

c) Standards for hypothetical accident conditions of transportation for Type B packagings:

Under accident conditions, no more than 10 curies of tritium may be released as stated in 173.398,3,c,(1),(ii).

(i, ii, iii) Free drop, Puncture, and Thermal

A complete package was dropped on a flat surface and on a piston, then heated in a furnace, in the manner prescribed in 173.398,3,c,2. The package was not significantly damaged from the drops in either test (figure 6). Before the tests, the primary container was pressurized to 930 torrs. Following the tests, no pressure had been lost and there was no apparent damage to the container valve.

Figures 7 through 13 show the package during the thermal test and the good condition of the insulation. Maximum temperature at various points in the package were determined from the condition of pellets of known melting points. The temperature rise in the furnace test was low enough that tritium permeation and leakage would have been less than the 10-curie limit.

(iii) Furnace Test

A large annealing furnace was used for a thermal test on a full scale package. After the furnace was raised to 1475°F, the package was inserted for 30 minutes, then removed for cooling. Furnace and package temperatures are shown in figures 14 and 15. The package thermocouple measured the temperature of the aluminum vessel just inside the insulation. The package tested contained no radioactive material. During the 60 minutes following removal of the package from the furnace, the thermocouple indicated lower than it should have. After replacing the thermocouple, the observed maximum temperature was 212°F.

(contd)

Thermopellets (accuracy — $\pm 3^{\circ}\text{F}$) on the inner wall of the second container showed that the temperature just reached 200°F ; the pellet for this temperature was only partially melted. Therefore it is concluded that the aluminum container exterior was only a few degrees over 212°F . For the purpose of estimating the maximum temperature that the primary container would attain under regulatory conditions, it is conservatively assumed that the rise in the furnace was 140°F (78°C) above an ambient of 80°F .

A. Temperature Calculations

The maximum temperature of a loaded container in a fire is less than the sum of the following:

1. Calculated temperature of the aluminum vessel before the fire [see the following discussion].
2. Measured temperature rise of the aluminum vessel during the furnace test [78°C from 178.398,C,2,(iii)].
3. Calculated temperature difference between the primary and aluminum vessels [0.3°C (0.5°F) as calculated from 173.398,b,2,(i),C].
4. Calculated temperature rise of the primary and aluminum vessels caused by adiabatic self-heating while the temperature is elevated from the fire [see the following discussion].

The temperature before the fire is calculated as follows:

$$Q_r = UA\Delta T$$

where: Q_r = radioactive decay heat = 3.78 Btu/hr or 2.10 pcu/hr

ΔT = temperature difference between aluminum container and air

U = overall heat transfer coefficient

A = heat transfer area, sq ft

$$\frac{1}{UA} = \frac{1}{U_i A_i} + \frac{1}{U_a A_a} \quad (\text{resistance of drum is negligible})$$

U_i = heat transfer coefficient for "Celotex" insulation

= 0.103 Btu/(hr)(sq ft)($^{\circ}\text{F}$)

A_i = heat transfer area for insulation = 4.05 + 2.95 = 7.00 ft²

(contd)

U_a = heat transfer coefficient for air film outside the drum
 = 1 Btu/(hr)(sq ft)(°F) [from Perry, J. H., "Chemical Engineer's Handbook," 3rd ed, figure 12, p 473, and Marks, L. S., "Mechanical Engineer's Handbook," 5th ed., table 11, p 377]

A_a = heat transfer area for drum exterior = 7.17 + 5.36
 = 12.52 ft²

$$\frac{1}{UA} = \frac{1}{(0.103)(7)} + \frac{1}{(1)(12.52)} = 1.385 + 0.0799 = 1.4649$$

$$UA = 0.683 \text{ Btu/(hr)(°F)}$$

$$\therefore \Delta T = \frac{3.78 \text{ Btu/hr}}{0.683 \text{ Btu/(hr)(°F)}} = 5.5^\circ\text{F}(3.1^\circ\text{C})$$

It is assumed with reasonable conservatism that the air temperature is 30°C; therefore, the temperature of the aluminum vessel would be 33°C before the fire.

Self-heating following a fire is calculated as follows:

[self-heating time (estimated) from figure 15] × [tritium decay heat rate]
 ÷ [mass of primary container × specific heat of stainless steel + mass of aluminum vessel × specific heat of aluminum] = temperature rise

$$\frac{(8 \text{ hr})(2.10 \text{ pcu/hr})}{[1.82 \text{ lb}][0.11 \text{ pcu/(lb)(°C)}] + [23.15 \text{ lb}][0.22 \text{ pcu/(lb)(°C)}]} = 3.1^\circ\text{C}$$

The sum of the preceding factors is the maximum primary container temperature following a fire, or about 114°C(237°F).

B. Container Pressure

The initial tritium loading pressure (assume 100% T₂) will be 17 psia (880 torrs) at 25°C. At 114°C, the temperature reached in a fire, the primary container may begin to yield at about 23 psia. This was determined as follows:

As the primary container temperature increases, the internal pressure increases, but the container yield pressure decreases (yield pressure is defined as that which produces a 0.2% permanent strain). For a cylinder, yield

(contd)

pressure is directly proportional to yield strength (yield strength of Type 347 SS as a function of temperature is shown in U. S. Steel's Low Temperature Steels, Materials Manual, February 1967, p 67). Thus:

$$\frac{P_{114^{\circ}}}{P_{25^{\circ}}} = \frac{S_{114^{\circ}}}{S_{25^{\circ}}}$$

where: P = yield pressure, psi

S = yield strength, psi

The yield strength at 25°C was determined experimentally to be 10-15 psig (to be conservative, assume 10 psig).

$$\frac{P_{114^{\circ}}}{10 \text{ psig}} = \frac{35,000 \text{ psi}}{41,500 \text{ psi}} \text{ or } P_{114^{\circ}} = 8.4 \text{ psig or } 23.1 \text{ psia}$$

Assuming a reasonable transport time of 30 days, an initial pressure of 17 psia at 25°C will be 22.1 psia at 114°C. This is a conservative loading pressure because a test container was pressurized to 85 psig at 25°C without failure. This is equivalent to about 60 psig at 114°C.

C. Tritium Lost

Equilibrium hydrogen permeation through Type 347 SS at 114°C (237°F) is $8 \times 10^{-5} \frac{\text{cc (STP) mm}}{(\text{sq cm})(\text{hr})}$ at 760 torrs^[2]. Corrected for pressure, surface area, and wall thickness, the permeation rate becomes

$$\frac{8 \times 10^{-5} \text{ cc (STP) mm} \times 3040 \text{ cm}^2}{(\text{cm}^2)(\text{hr}) 3.6 \times 10^{-3} \text{ sec/hr} \times 1.57 \text{ mm}} \sqrt{\frac{22.1 \text{ psia}}{14.7 \text{ psia}}} \\ = 5.3 \times 10^{-5} \text{ cc STP)/sec}$$

A very long time, however, is required to reach the equilibrium rate. The time to reach 7×10^{-8} atm cc/sec is calculated as shown in section 173.398,b,2,(1),E.,

$$\text{for } \frac{P_t}{P_{\infty}} = \frac{7 \times 10^{-8} \text{ atm cc } T_2/\text{sec}}{5.3 \times 10^{-5} \text{ atm cc } T_2/\text{sec}} = 0.0013 \\ \frac{Dt}{L^2} = .02$$

(contd)

$$\begin{aligned}\text{where: } D &= \text{diffusivity} = 2.65 \times 10^{-2} e^{-14,000/RT} \\ &= 2.65 \times 10^{-2} e^{-14,000/(1.987 \times 387)} = 3.2 \times 10^{-10} \text{ sq cm/sec} \\ L &= 0.157 \text{ cm}\end{aligned}$$

$$\begin{aligned}\therefore t &= \frac{(0.02)(0.157 \text{ cm})^2}{(3.2 \times 10^{-10} \text{ cm}^2/\text{sec})(3.6 \times 10^3 \text{ sec/hr})(24 \text{ hr/day})} \\ &= 18 \text{ days}\end{aligned}$$

Because the time at the elevated temperature is less than 12 hours, the tritium permeation rate would not reach the limit for even normal shipping conditions.

The Mark II valve used on the primary containers was tested for leak-tightness by cycling between 25 and 110°C with the results shown in the following table:

<u>Temperature in Sequence, °C</u>	<u>Leak Rate, atm cc/sec</u>
25	1.1×10^{-9}
110	1.1×10^{-9}
25	3.4×10^{-8}
110	2.9×10^{-8}

At 25°C, leakage was well below the 7×10^{-8} atm cc/sec limit. At 110°C, leakage was still insignificant, especially when compared with the 10 curies (3.9 cc) loss allowed under accident conditions.

D. Smoldering

During a thermal test on a similar package (DPSPWD 69-124-1), smoldering continued in the insulation for several days, ultimately destroying a large amount of the insulation. Because smoldering centered on the vent holes in the side of the drum, the vent holes were relocated on an experimental LP-12 package so that there were three 5/16-in.-diameter holes equally spaced 1 in. under the rim at the top of the drum. Additionally, a noncombustible insulation ring, Johns Manville "Cera Form," was inserted near the vent holes and extended into the drum a greater distance than the maximum char depth, 1-1/2 in., observed on any test. "Cera Form" is a light weight refractory-fiber insulation having thermal and chemical stability up to 1149°C (2100°F). A furnace test of the experimental LP-12 package did not produce smoldering, and the changes were incorporated as standard features of the package.

(iv) Water Immersion

The water immersion test was not done because water obviously cannot harmfully affect the safety of the package following an accident.

173.399 Labeling of packages of radioactive materials

Packages are labeled in compliance with these requirements.

References

- [1] Perry et al, R. H., Chemical Engineers' Handbook, 4th edition, p 10.36.
- [2] Flint, P. S., The Diffusion of Hydrogen through Materials of Construction, Knolls Atomic Power Laboratory, Schenectady, New York, USAEC report KAPL-659.

OUTER SHIPPING CONTAINER LP-12 SPECIFICATION

DRUM, CARBON STEEL PER MILITARY STANDARD MS 24209-2 WITH FOLLOWING EXCEPTIONS.

1. BODY AND COVER TO BE .048 INCH THICK (18 GAGE) MATERIAL.
2. INSIDE HEIGHT TO BE 26 9/16 INCHES
3. THREE 5/8 INCH DIAMETER HOLES DRILLED ONE INCH BELOW TOP OF CURL OF BODY APPROXIMATELY 120° APART EACH HOLE TO BE COVERED ON BOTH SIDES WITH LEAD TAPE OF MINIMUM THICKNESS OF .005 INCH BONDING OF TAPE TO BE RESISTANT TO SUN AND WATER.
4. LOCKING RING TO HAVE DROP FORGED LUGS. LUGS TO BE DRILLED WITH GOOD ALIGNMENT FOR 3/8 INCH BOLT LUGS TO BE DRILLED 1/8 INCH DIAMETER, APPROXIMATELY 3/8 INCH ABOVE EDGE OF BOLT HOLES FOR SEAL WIRES. LENGTH OF LOCKING RING TO ALLOW 1/8 MINIMUM TO 3/4 MAXIMUM END SEPARATION WHEN COMPLETELY CLOSED WITHOUT GASKET.
5. LOCKING BOLT AND NUT TO BE 3/8-16 UNC HEX ZINC OR CADMIUM PLATED BOLT 4 INCHES LONG AND THREADS 2 3/4 INCHES LONG MINIMUM MATERIAL ASTM A325 OR EQUAL WITH HARDNESS 23-35 RC.
6. NO GASKET ALLOWED.
7. PAINT BODY, COVER, AND LOCKING RING AS FOLLOWS:
 - A. ALL SURFACES MUST BE CLEAN AND FREE OF RUST, OIL, AND OTHER FOREIGN MATERIAL. (SANDBLASTING MAY BE REQUIRED FOR RUSTED MATERIAL.)
 - B. PRIMER - APPLY ONE COAT SHERWIN-WILLIAMS "KROMIK" METAL PRIMER #E41N1 (MAY BE APPLIED OVER SHOP PRIMER) THICKNESS 15 MILS OR 300 SQ FT/GAL. DRY 18 HOURS.
 - C. FINISH COATS - APPLY TWO COATS SHERWIN-WILLIAMS "KEM-LUSTRAL" (KL) ENAMEL MIXED TO MATCH FEDERAL STANDARD 595 COLOR CHIP NUMBER 34087. THICKNESS 2 MILS/COAT OR 250 SQ FT/GAL/COAT. MINIMUM RECOAT DRYING TIME - 16 HOURS. MINIMUM DRYING TIME FOR HANDLING - 24 HOURS.

* APPROXIMATE MIXING PROPORTIONS ARE BELOW:

SHERWIN-WILLIAMS NUMBER	PERCENT VOLUME
F 65B2	40
F 65Y2	20
D 64T1	30
F 65W3	10

8. CONTAINERS TO BE RECEIVED FROM VENDOR ASSEMBLED.

NOTES:

- * FOUR DIGIT NUMBER TO BE PROVIDED BY AEC.
- ** SERIAL NUMBER TO BEGIN AT 7 OR AS SPECIFIED ON PURCHASE ORDER.

DETAIL ④

(IDENTIFICATION PLATE)
MATL 304 SST
SCALE 6"=1'-0" RECD: 1

GENERAL NOTES:

1. WEIGHT 130 POUNDS MAXIMUM.
2. ARRANGEMENT SHOWN ON THIS DRAWING AND REFERENCED DRAWINGS HAS BEEN TESTED AND EVALUATED FOR SHIPMENT IN COMPLIANCE WITH AEC AND DOT REGULATIONS. NO DEVIATIONS ARE ALLOWED WITHOUT APPROPRIATE ANALYSIS.

FIGURE 1. LP-12 SHIPPING CONTAINER PACKAGING - ASSEMBLY. (Du Pont dwg 55-2-5731).

FIGURE 2. LP-12 SHIPPING CONTAINER PACKAGING - INSULATION. (Du Pont dwg S5-2-5732)

6) CONTAINER COVER BRACKET
Mall Aluminum alloy # 356 Req'd ?

ASSEMBLY
Scale 6" = 10'

SECTION (A) (A)
Scale 6"=1'-0"

① HANDLE
Matl Al alloy #356 - Read 1

MARK	QTY	DESCRIPTION	MATL	REMARKS
1	1	H3	4 3/4	
2		Compressor pump	Br	AS 1/4" B16 RH B50 70
3	1	Plug recept-	4-1/2	AS 1/4" B16 RH B50 70
4	1	Compressor gas ke	1	or 1/2" or 3/4" hardness 70
5	1	Gasoline valve	1/2	
6	2	Gasoline cover	1 1/2	
7		Gasoline bucket	1 1/2	
8	1	Compressor	3/4	Type 347
9	1	Compressor cover	3/4	Type 347
10	1	Gasoline bucket	1 1/2	
11	1	Gasoline plate	1 1/2	
12		Gasoline		Line or line #1860
13	4	Gasoline	1/2	1/2" 1/2" 1/2" 1/2"
14		Gasoline valve		
15	2	3/8" hex hd mach scr 3/16	3/16	W/flat washer & lock was
16	1	Hoke valve #45	Comm	
17	6	3/8 3/16" 2 hd cap scr 3/16	3/16	
18	4	1/2 3/16" hex hd mach scr 3/16	3/16	W/flat washer & lock was
19	4	1/2 3/16" hex hd mach scr 3/16	3/16	W/flat washer & lock was
20	1	1" NPT pipe cap	3/16

④ COMPRESSION GASKET
Matl Neoprene Req'd 1

⑤ GASKET WASHER
Matl cds Reqd 1

FIGURE 3. PRODUCT CONTAINER AND DETAILS

④ ADJUSTING KNOB
Matl: SST Req: 1

⑨⑪ TUBE
Matl: SST Req: 1 each
Type 347, 321 or 304ELC

② DUST CAP
Matl: Brass Req: 1

⑦ BONNET
Matl: Brass Req: 1
ASTM B-16
Hardness: Rockwell B-50-70

Dim marked * and P.D. of
this must be concentric
within .001 TIR

⑤ NEEDLE
Matl: SST Req: 1

GENERAL NOTES:

1. All parts to be ϕ unless noted.
2. Remove all burrs & sharp mach edges.
3. Silver solder part ④ & ⑤ together

ASSEMBLY

MARK	REQD	DESCRIPTION	MATL.	RE-MARKS
11	1	Tube	SST	
10	1	Body "Fullon Syphon Co"	SST	Dwg 1-31A
9	1	Tube	SST	
8	1	O-Ring #1820-14 Linear Inc	Type 1 NWS5656	or equal
7	1	Bonnet	Brass	
6	1	O-Ring #1820-1 Linear Inc	Type 1 NWS5656	or equal
5	1	Needle	SST	
4	1	Adjusting Knob	SST	
3	1	Washer	SST	Plain 1/2
2	1	Dust cap	Brass	
1	1	O-Ring 1820-5 Linear Inc	Type 1 NWS6656	or equal

FIGURE 5. PRODUCT CONTAINER VACUUM TANK VALVE - MARK II

FIGURE 6. EFFECT OF 30-FOOT-DROP TEST. DPSPF 13052-2.

FIGURE 7. FIRE TEST - PACKAGE ENTERING FURNACE.
DPSPF 13075-2.

FIGURE 8. FIRE TEST. DPSPF 13075-4.

FIGURE 9. FIRE TEST. Package being removed from furnace. Note the impact impression in the middle of the drum (penetration test). DPSPF 13075-5.

FIGURE 10. FIRE TEST. Shows charring of outer insulation. DPSPF 13075-18

FIGURE 11. FIRE TEST. Shows good condition of insulation. DPSPF 13075-19.

FIGURE 12. FIRE TEST. Shows char depth in insulation. DPSPF 13075-20.

FIGURE 13. FIRE TEST. Shows char depth in insulation. DPSPF 13075-21.

FIGURE 14. FURNACE TEMPERATURE FOR LP-12 FIRE TEST

FIGURE 15. ALUMINUM VESSEL TEMPERATURE FOR FIRE TEST

SUBPART A—PREPARATION OF ARTICLES FOR TRANSPORTATION BY CARRIERS BY RAIL FREIGHT, RAIL EXPRESS, HIGHWAY, OR WATER

§ 173.24 Standard requirements for all packages. (a) Each package used for shipping explosives or other dangerous articles under this chapter shall be so designed and constructed, and its contents so limited, that under conditions normally incident to transportation—

(1) There will be no significant release of the explosive or other dangerous article to the environment;

(2) The effectiveness of the packaging will not be substantially reduced; and

(3) There will be no mixture of gases or vapors in the package which could, through any credible spontaneous increase of heat or pressure, or through an explosion, significantly reduce the effectiveness of the packaging.

(b) Materials for which detailed specifications for packaging are not set forth in this part must be securely packaged in strong, tight packages meeting the requirements of this section.

(c) Packaging used for the shipment of explosives or other dangerous articles under this chapter shall, unless otherwise specified or exempted therein, meet all of the following design and construction criteria:

(1) Each specification container shall be marked in an unobstructed area with letters and numerals identifying that specification (e.g., ICC-6J, DOT-6L, DOT MC 306, ICC-105A200-F);

(i) The marking is a certification that the packaging complies with all specification requirements.

(ii) The name and address or the symbol of the manufacturer, or the user, who assumes responsibility for compliance with the specification requirements, shall be included. Symbol letters must be registered with the Bureau of Explosives. Duplicate symbols are not authorized.

(iii) The markings shall be stamped, embossed, burned, printed, or otherwise marked on the packaging to provide adequate accessibility, permanency, and contrast so as to be readily apparent and understood.

(iv) Unless otherwise specified, letters and numerals shall be at least 1/2 inch high.

(v) Packaging which does not comply with the applicable specification listed in Parts 178 and 179 must not be marked to indicate such compliance.

(2) Steel used shall be low-carbon, commercial quality steel. Stainless, open hearth, electric, basic oxygen, or other similar quality steels are acceptable. Steel sheets of specified gauges shall comply with the following:

Gauge No.	Nominal thickness (inches)	Minimum thickness (inches)
12.....	0.1046	0.0946
13.....	0.0897	0.0817
14.....	0.0747	0.0677
15.....	0.0673	0.0603
16.....	0.0598	0.0533
17.....	0.0538	0.0478
18.....	0.0478	0.0428
19.....	0.0418	0.0378
20.....	0.0359	0.0324
22.....	0.0299	0.0269
24.....	0.0239	0.0209
26.....	0.0179	0.0159
28.....	0.0149	0.0129
30.....	0.0120	0.0110

(3) Lumber used shall be well seasoned, commercially dry, and free from decay, loose knots, knots that would interfere with nailing, and other defects that would materially lessen the strength.

(4) Welding and brazing shall be performed in a workmanlike manner using suitable and appropriate techniques, materials, and equipment.

(5) Packaging materials and contents shall be such that there will be no significant chemical or galvanic reaction among any of the materials in the package.

(6) Closures shall be adequate to prevent inadvertent leakage of the contents under normal conditions incident to transportation. Gasketed closures shall be fitted with gaskets of efficient material which will not be deteriorated by the contents of the container.

(7) Nails, staples, and other metallic devices shall not protrude into the interior of the outer packaging in such a manner as to be likely to cause failures.

(8) The nature and thickness of the packaging shall be such that friction during transport does not generate any heating likely to decrease the chemical stability of the contents.

(9) Polyethylene used must be of a type compatible with the lading and must not be permeable to an extent that a hazardous condition could be caused during transportation and handling.

(d) For specification containers, compliance with the applicable specifications in Parts 178 and 179 shall be required in all details, except as otherwise provided in this chapter.

§ 173.28 Reuse of containers. (a) Containers used more than once (refilled and reshipped after having been previously emptied) must be in such condition, including closure devices and cushioning materials, that they comply in all respects with the prescribed requirements for those containers. Repairs must be made in an

efficient manner in accordance with requirements for materials and construction as prescribed in Parts 178 and 179 for new containers, or as otherwise prescribed. Parts that are weak, broken, or otherwise deteriorated must be replaced.

(1) Retest of carboy packages must have been made by or for shippers, or their authorized agents, as required by applicable provisions of the specifications in Part 178 before carboys which are to be offered for transportation are filled.

NOTE 1: Tests not required by shipper who fills and ships or who reships filled carboys for one shipment only carboy packages which have been properly tested by another shipper or a duly authorized agency.

(b) Markings applied as prescribed by the specifications must be maintained in a legible condition.

(c) If, on account of painting or any other reason, the markings as prescribed for any container cannot be kept plain and legible, a metal plate, brazed or soldered, or otherwise securely fastened to the container, with a reproduction of the prescribed markings plainly stamped thereon, will be permitted.

(d) Containers previously used for the shipment of any explosive or other dangerous article must have the old markings, including name of contents, addresses, and labels, if any, thoroughly removed or obliterated before being used for the shipment of other articles.

(e) Boxes previously used for high explosives containing a liquid explosive ingredient not contained in an inside metal container must not be again used for shipments of any character.

(1) Boxes that have been contaminated by liquid explosive compositions must not again be used for shipments of any character.

(f) Kegs previously used for any chlorate must not be again used for shipments of any character.

(g) Metal kegs previously used for black powder not contained in an interior package must not be again used for shipment of any explosive.

NOTE 1: Because of the present emergency and until further order of the Department metal kegs, previously used for the shipment of black powder not contained in an interior package, may be used provided the kegs are in good physical condition and are not liable to permit escape of contents during transportation. Empty kegs previously used for shipment of black powder must be entirely free of black powder on the inside and outside before being offered for transportation.

(h) Except as provided in this section, single-trip containers made under specifications prescribed in Part 178 from which contents have once been removed following use for shipment of any commodity, shall not be again used as shipping containers for explosives or other dangerous articles. Single-trip containers may be reused if retested before each reuse in accordance with methods approved by the Bureau of Explosives for service for specific commodities or classes of commodities. Applications for permission for reuse should be made to the Bureau of Explosives, 2 Pennsylvania Plaza, New York, N. Y. 10001.

(i) Containers which are designated as nonreusable containers, marked NRC, and made under specifications prescribed in Part 178, from which contents have once been removed following use for shipment of any article, must not be again used as shipping containers for explosives, flammable liquids, flammable solids, oxidizing materials, corrosive liquids, or poisons, class B or C, as defined in this part.

(j) Cylinders or other containers which are designated as non-refillable or for single-trip use under the specifications prescribed in Part 178, and from which contents have once been removed following use for the shipment of any article, must not be again used as shipping containers for compressed gases.

(k) Containers used for shipments of etching acid liquid, n.o.s. must not be reused for shipment of any commodity.

(L) Cylinders used in anhydrous hydrofluoric acid service must comply with the requirements of § 173.264 (b) (1) and must not be used in any other service.

§ 173.389 Radioactive materials; definitions. For the purpose of Parts 170-189:

(a) "Fissile radioactive material" means the following material: Plutonium-238, plutonium-239, plutonium-241, uranium-233, or uranium-235, or any material containing any of the foregoing materials. See § 173.396 (a) for exclusions. Fissile radioactive material packages are classified according to the controls needed to provide nuclear criticality safety during transportation as follows:

(1) Fissile Class I. Packages which may be transported in unlimited numbers and in any arrangement, and which require no nuclear criticality safety controls during transportation. For purposes of nuclear criticality safety control, a transport index is not assigned to Fissile Class I packages. However, the external radiation levels may require a transport index number.

(2) Fissile Class II. Packages which may be transported together in any arrangement but in numbers which do not exceed

an aggregate transport index of 50. For purposes of nuclear criticality safety control, individual packages may have a transport index of not less than 0.1 and not more than 10. However, the external radiation levels may require a higher transport index number but not to exceed 10. Such shipments require no nuclear criticality safety control by the shipper during transportation.

(3) **Fissile Class III.** Shipments of packages which do not meet the requirements of Fissile Class I or II and which are controlled to provide nuclear criticality safety in transportation by special arrangements between the shipper and the carrier.

NOTE 1: Uranium-235 exists only in combination with various percentages of uranium-234 and uranium-238. "Fissile radioactive material" as applied to uranium-235 refers to the amount of uranium-235 actually contained in the total quantity of uranium being transported.

NOTE 2: Radioactive material may consist of mixtures of fissile and non-fissile radionuclides. "Fissile radioactive material" refers to the amount of plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination thereof actually contained in the mixture. The "radioactivity" of the mixture consists of the total activity of both the fissile and nonfissile radionuclides. All mixtures containing "fissile material" shall be subject to § 173.396.

(b) "Large quantity radioactive materials" means a quantity the aggregate radioactivity of which exceeds that specified as follows:

(1) Groups I or II (see paragraph (h) of this section) radionuclides: 20 curies.

(2) Groups III or IV radionuclides: 200 curies.

(3) Group V radionuclides: 5,000 curies.

(4) Groups VI or VII radionuclides: 50,000 curies.

(5) Special form material: 5,000 curies.

(c) "Low specific activity material" means any of the following:

(1) Uranium or thorium ores and physical or chemical concentrates of those ores;

(2) Unirradiated natural or depleted uranium or unirradiated natural thorium;

(3) Tritium oxide in aqueous solutions provided the concentration does not exceed 5 millicuries per milliliter;

(4) Material in which the activity is essentially uniformly distributed and in which the estimated average concentration per gram of contents does not exceed:

(i) 0.0001 millicuries of Group I (see § 173.389 (h)) radionuclides; or

(ii) 0.005 millicuries of Group II radionuclides; or

(iii) 0.3 millicuries of Groups III or IV radionuclides.

NOTE: This includes, but is not limited to, materials of low radioactivity concentration such as residues or solutions from chemical processing; wastes such as building rubble, metal, wood, and fabric scrap, glassware, paper and cardboard; solid or liquid plant waste, sludges, and ashes.

(5) Objects of nonradioactive material externally contaminated with radioactive material, provided that the radioactive material is not readily dispersible and the surface contamination when averaged over an area of 1 square meter, does not exceed 0.0001 millicurie (220,000 disintegrations per minute) per square centimeter of Group I radionuclides or 0.001 millicurie (2,200,000 disintegrations per minute) per square centimeter of other radionuclides.

(d) "Normal form radioactive materials" means those which are not special form radioactive materials. Normal form radioactive materials are grouped into transport groups (see paragraph (h) of this section).

(e) "Radioactive material" means any material or combination of materials, which spontaneously emits ionizing radiation. Materials in which the estimated specific activity is not greater than 0.002 microcuries per gram of material, and in which the radioactivity is essentially uniformly distributed, are not considered to be radioactive materials.

(f) "Removable radioactive contamination" means radioactive contamination which can be readily removed in measurable quantities by wiping the contaminated surface with an absorbent material. The measurable quantities shall be considered as being not significant if they do not exceed the limits specified in § 173.397.

(g) "Special form radioactive materials" means those which, if released from a package, might present some direct radiation hazard but would present little hazard due to radiotoxicity and little possibility of contamination. This may be the result of inherent properties of the material (such as metals or alloys), or acquired characteristics, as through encapsulation. The criteria for determining whether a material meets the definition of special form are prescribed in § 173.398 (a).

(h) "Transport group" means any one of seven groups into which normal form radionuclides are classified according to their radio-

toxicity and their relative potential hazard in transportation, and as listed in § 173.390.

(i) "Transport index" means the number placed on a package to designate the degree of control to be exercised by the carrier during transportation. The transport index to be assigned to a package of radioactive materials shall be determined by either subparagraph (1) or (2) of this paragraph, whichever is larger. The number expressing the transport index shall be rounded up to the next highest tenth; e.g., 1.01 becomes 1.1.

(1) The highest radiation dose rate, in millirem per hour at three feet from any accessible external surface of the package; or

(2) For Fissile Class II packages only, the transport index number calculated by dividing the number "50" by the number of similar packages which may be transported together (see § 173.396), as determined by the procedures prescribed in the regulations of the U. S. Atomic Energy Commission, Title 10, Code of Federal Regulations, Part 71.

(j) "Type A packaging" means packaging which is designed in accordance with the general packaging requirements of §§ 173.24 and 173.393, and which is adequate to prevent the loss or dispersal of the radioactive contents and to retain the efficiency of its radiation shielding properties if the package is subject to the tests prescribed in § 173.398 (b).

(k) "Type B packaging" means packaging which meets the standards for Type A packaging, and, in addition, meets the standards for hypothetical accident conditions of transportation as prescribed in § 173.398 (c).

(l) "Type A quantity" and "Type B quantity" radioactive materials means a quantity the aggregate radioactivity of which does not exceed that specified as follows:

Transport group (see § 173.389(h))	Type A quantity (in curies)	Type B quantity (in curies)
I.....	0.001	20
II.....	0.05	20
III.....	3	200
IV.....	20	200
V.....	20	5,000
VI and VII.....	1,000	50,000
Special form.....	20	5,000

173.393 General packaging requirements. (a) Unless otherwise specified, all shipments of radioactive materials must meet all requirements of this section, and must be packaged as prescribed in §§ 173.391 through 173.396.

(b) The outside of each package must incorporate a feature such as a seal, which is not readily breakable and which, while intact, will be evidence that the package has not been illicitly opened.

(c) The smallest outside dimension of any package must be 4 inches or greater.

(d) Radioactive materials must be packaged in packagings which have been designed to maintain shielding efficiency and leak tightness, so that, under conditions normally incident to transportation, there will be no release of radioactive material. If necessary, additional suitable inside packaging must be used. Each package must be capable of meeting the standards in § 173.398 (b) (see also § 173.24). Specification containers listed as authorized for radioactive materials shipments may be assumed to meet those standards, provided the packages do not exceed the gross weight limits prescribed for those containers in Part 178.

(1) Internal bracing or cushioning, where used, must be adequate to assure that, under the conditions normally incident to transportation, the distance from the inner container or radioactive material to the outside wall of the package remains within the limits for which the package design was based, and the radiation dose rate external to the package does not exceed the transport index number shown on the label. Inner shield closures must be positively secured to prevent loss of the contents.

(e) The packaging must be so designed, constructed, and loaded that, when transporting large quantities of radioactive material:

(1) The heat generated within the package because of the radioactive materials present will not, at any time during transportation, affect the efficiency of the package under the conditions normally incident to transportation, and

(2) The temperature of the accessible external surfaces of the package will not exceed 122° F. in the shade when fully loaded.

assuming still air at ambient temperature. If the package is transported in a transport vehicle consigned for the sole use of the consignor, the maximum accessible external surface temperature shall be 180° F.

(f) Pyrophoric materials, in addition to the packaging prescribed in this subpart, must also meet the packaging requirements of § 173.134 or § 173.154. Pyrophoric radioactive liquids may not be shipped by air.

(g) Liquid radioactive material must be packaged in or within a leak-resistant and corrosion-resistant inner container. In addition—

(1) The packaging must be adequate to prevent loss or dispersal of the radioactive contents from the inner container, if the package were subject to the 30-foot drop test prescribed in § 173.398 (c) (2) (i); or

(2) Enough absorbent material must be provided to absorb at least twice the volume of the radioactive liquid contents. The absorbent material may be located outside the radiation shield only if it can be shown that if the radioactive liquid contents were taken up by the absorbent material the resultant dose rate at the surface of the package would not exceed 1,000 millirem per hour.

(h) There must be no significant removable radioactive surface contamination on the exterior of the package (see § 173.397).

(i) Except for shipments described in paragraph (j) of this section, all radioactive materials must be packaged in suitable packaging (shielded, if necessary) so that at any time during the normal conditions incident to transportation the radiation dose rate does not exceed 200 millirem per hour at any point on the external surface of the package, and the transport index does not exceed 10.

(j) Packages for which the radiation dose rate exceeds the limits specified in paragraph (i) of this section, but does not exceed at any time during transportation any of the limits specified in subparagraphs (1) through (4) of this paragraph, may be transported in a transport vehicle (except aircraft) assigned for the sole use of that consignor, and unloaded by the consignee from the transport vehicle in which originally loaded.

(1) 1,000 millirem per hour at 3 feet from the external surface of the package (closed transport vehicle only);

(2) 200 millirem per hour at any point on the external surface of the car or vehicle (closed transport vehicle only);

(3) 10 millirem per hour at 6 feet from the external surface of the car or vehicle; and

(4) 2 millirem per hour in any normally occupied position in the car or vehicle, except that this provision does not apply to private motor carriers.

(k) When radioactive materials are loaded by the shipper into a transport vehicle assigned for the sole use of that shipper, the shipper must observe all applicable requirements of Part 174, 175, or 177, as appropriate.

(l) Packages consigned for export are also subject to the regulations of the foreign governments involved in the shipment. See §§ 173.8 and 173.9.

§ 173.395 Radioactive material in normal form. (a) Type A quantities of normal form radioactive materials must be packaged as follows:

(1) Spec. 5B, 5D, 6A, 6B, 6C, 6J, 6K, 6L, 6M, 17C, 17H, 42B, or 42C (§§ 178.82, 178.84, 178.97, 178.98, 178.99, 178.100, 178.101, 178.103, 178.104, 178.107, 178.108, 178.115, and 178.118) metal drums.

(2) Spec. 21C (§ 178.224) fiber drums.

(3) Spec. 14, 15A, 15B, 15C, 15D, 19A, or 19B (§§ 178.165, 178.168, 178.169, 178.170, 178.171, 178.190, and 178.191) wooden boxes.

(4) Any Spec. 12 series (§§ 178.205 through 178.212) fiberboard boxes, 200-pound test minimum; or Spec. 23F or 23H (§ 178.214 or § 178.219) fiberboard boxes.

(5) Any Spec. 3 or 4 series (§§ 178.36 through 178.44 or §§ 178.47 through 178.58) cylinders.

(6) Spec. 55 (§ 178.250) metal-encased shielded container.

(7) Spec. 7A (§ 178.350) Type A general package.

(8) Foreign-made packagings which bear the symbol "Type A" may be used for transportation of radioactive materials from their point of entry in the United States to their destination in the United States or through the United States en route to a point of destination outside of the United States.

(b) Type B quantities of radioactive materials in normal form must be packaged as follows:

(1) Spec. 6M (§ 178.104) metal packaging. Authorized only for solid or gaseous radioactive materials which will not decompose at temperatures up to 250° F.

2A(2) Any other Type B packaging for which the Department has issued a certificate of compliance.

(c) Large quantities of radioactive materials in normal form must be packaged as follows:

(1) Spec. 6M (§ 178.104) metal packaging. Authorized only for solid or gaseous radioactive materials which will not decompose at temperatures up to 250° F. Radioactive thermal decay energy must not exceed 10 watts.

2A(2) Any other Type B packaging which meets the pertinent requirements for large quantities of radioactive materials in the regulations of the U.S. Atomic Energy Commission (10 CFR Part 71), or the 1967 regulations of the International Atomic Energy Agency, and for which the Department has issued a certification of compliance. In applying for Departmental certification, a copy of the U.S. Atomic Energy Commission license amendment or other approval of that Commission may be accepted in place of the package structural integrity evaluation.

§ 173.396 Fissile radioactive material. (a) The following materials are not classified as fissile radioactive materials, are exempted from this section, and must instead be packaged in accordance with the other provisions of this subpart, as appropriate:

(1) Not more than 15 grams of fissile material;

(2) Thorium, or uranium containing not more than 0.72 percent by weight of fissile material;

(3) Uranium compounds other than metal (e.g., UF⁴, UF⁶, or uranium oxide in bulk form, not pelleted or fabricated into shapes), and aqueous solutions of uranium, in which the total amount of uranium-233 and plutonium present does not exceed 1.0 percent by weight of the uranium-235 content, and the total fissile content does not exceed 1.00 percent by weight of the total uranium content;

(4) Homogenous hydrogenous solutions or mixtures containing not more than:

(i) 500 grams of any fissile material, provided the atomic ratio of hydrogen to fissile material is greater than 7,600; or

(ii) 800 grams of uranium-235, if the atomic ratio of hydrogen to fissile material is greater than 5,200, and the content

of other fissile material is not more than 1.0 percent by weight of the total uranium-235 content; or

- (iii) 500 grams of uranium-233 and uranium-235, if the atomic ratio of hydrogen to fissile material is greater than 5,200, and the content of plutonium is not more than 1.0 percent by weight of the total uranium-233 and uranium-235 content.

(5) A package containing less than 350 grams of fissile material, if there is not more than 5 grams of fissile material in any cubic foot within the package.

(b) Fissile radioactive materials containing not more than Type A quantities of radionuclides, in either normal form or special form, must be packaged as follows:

(1) Specification 6L (§ 178.103) metal packaging. Authorized only for enriched uranium, the fissile content not to exceed 14 kilograms of uranium-235 as metal or oxide, or as compounds or alloys which will not decompose at temperatures up to 750° F. Each package shipped as Fissile Class II must be assigned a transport index of 1.3 (unless external radiation levels require a higher assignment). The atomic ratio of hydrogen to uranium-235 must not exceed three, all sources of hydrogen within the specification 2R inner containment vessel being considered. The gross weight of the loaded package must not exceed 350 pounds for the 55-gallon size or 480 pounds for sizes up through 110 gallons.

(2) Spec. 6M (§ 178.104) metal packaging. See paragraph (c) (2) of this section for authorized contents.

(3) Any packaging listed in § 173.395 (a). Authorized only for not more than the following:

- (i) 500 grams of uranium-235 as Fissile Class III, or not more than 40 grams of uranium-235 as Fissile Class II. For Fissile Class II shipments, the transport index to be assigned to each package shall be 0.4 for each gram of uranium-235 above 15 grams up to a maximum of 40 grams (transport index of 10).
- (ii) 320 grams of plutonium-239 as plutonium-beryllium neutron sources in special form. Total radioactivity content must not exceed 20 curies. The transport index to be assigned to each package shall be 0.5 for each 20 grams, or fraction thereof, of fissile plutonium.

2A (4) Any other Type A or B packaging which also meets the standards for packaging for fissile radioactive material in the regulations of the U.S. Atomic Energy Commission (10 CFR Part 71), or the 1967 regulations of the International Atomic Energy Agency, and for which the Department has issued a certificate of com-

pliance. In applying for Departmental certification, a copy of the U.S. Atomic Energy Commission license amendment or other approval of that Commission may be accepted in place of the package structural integrity and nuclear safety evaluation.

(c) Fissile radioactive materials containing Type B quantities of radionuclides, in either normal form or special form, must be packaged as follows:

(1) Specification 6L (§ 178.103) metal packaging. Authorized only for enriched uranium, the fissile content not to exceed 14 kilograms of uranium-235 as metal or oxide, or as compounds or alloys which will not decompose at temperatures up to 750° F. Each package shipped as Fissile Class II must be assigned a transport index of 1.3 (unless external radiation levels require a higher assignment). The atomic ratio of hydrogen to uranium-235 must not exceed three, all sources of hydrogen within the specification 2R inner containment vessel being considered. The gross weight of the loaded package must not exceed 350 pounds for the 55-gallon size or 480 pounds for sizes up through 110 gallons.

(2) Spec. 6M (§ 178.104) metal packaging. Authorized only for solid radioactive materials which will not decompose at temperatures up to 250° F. Radioactive thermal decay energy output shall not exceed 10 watts. Large quantity radioactive materials in normal form must be packaged in one or more sealed and leaktight metal cans or polyethylene bottles within the Spec. 2R containment vessel.

- (i) Fissile Class I packages. The following quantities of fissile radioactive material are authorized for Fissile Class I packages: 1.6 kilograms uranium-235; 0.9 kilograms of plutonium (see Note); 0.5 kilograms of uranium-233. The maximum ratio of hydrogen to fissile material must not exceed three, all sources of hydrogen within the Spec. 2R containment vessel being considered.

NOTE: Because of the 10-watt thermal decay heat limitation, the limit for plutonium-238 is only 0.02 kilograms.

- (ii) Fissile Class II and III packages. Quantities of fissile radioactive material as shown in the following table are authorized for Fissile Class II and Fissile Class III packages. Where a maximum ratio of hydrogen to fissile material is specified in the table, only the hydrogen interspersed with the fissile material need be considered. For Fissile Class II packages, the minimum transport index to be assigned is shown in the table. For Fissile Class III packages, the maximum number of similar packages per transport vehicle is shown. Fissile Class III shipments are also subject to paragraph (g) of this section.

TABLE OF AUTHORIZED CONTENTS¹ :

Uranium-235 ²			Plutonium ^{3,4}			Fissile Class II transport index	Fissile Class III, maximum number packages per transport vehicle
Metal or alloy H/X=0	Compounds		Metal or alloy H/X=0	Compounds			
	H/X=0	H/X≤3		H/X=0	H/X≤3		
7.2	7.6	3.2	3.1	4.1	3.4	0.1	1,250
8.7	9.6	6.4	3.4	4.5	4.1	0.2	625
11.2	13.0	8.3	4.2		4.5	0.5	250
13.5	16.0	10.1	4.5			1.0	125
.....	26.0	16.1				5.0	25
.....	32.0	19.5				10.0	12

¹ Quantity in kilograms.

² Maximum uranium-235 enrichment is 93 weight percent.

³ Minimum percentage of plutonium-240 is 5 weight percent.

⁴ 4.5 kilogram limitation on plutonium due to 10 watt decay heat limitation.

2A (3) Any other Type B packaging which also meets the standards for packaging for fissile radioactive materials in the regulations of the U.S. Atomic Energy Commission (10 CFR Part 71), or the 1967 regulations of the International Atomic Energy Agency, and for which the Department has issued a certification of compliance. In applying for Departmental certification, a copy of the U.S. Atomic Energy Commission license amendment or other approval of that Commission may be accepted in place of the package structural integrity and nuclear safety evaluation.

(d) Petitions for authorization of non-specification packagings for fissile radioactive materials must be submitted as prescribed in Part 170 and must also include the following:

(1) Type and amount of fissile radioactive materials which are to be carried in each package, including:

- (i) The transport index to be assigned to the package for the proposed package loadings when shipped as Fissile Class II; and
- (ii) The maximum number of packages proposed when shipped as Fissile Class III.

(2) A nuclear criticality safety evaluation demonstrating that the packaging design and limitation on its contents are adequate

to assure nuclear criticality safety. Any tests performed in this respect should be described.

NOTE: In applying for Departmental authorization of packages for fissile radioactive materials to be used in shipments by the U. S. Atomic Energy Commission, or one of its contractors or licensees, a copy of the license amendment or other approval issued by that Commission will be accepted in place of the nuclear criticality safety evaluation and the package structural integrity evaluation.

(e) Mixing of packages of other types of radioactive materials, including Fissile Class I, with Fissile Class II packages is permitted if the total transport index in any one transport vehicle or storage location does not exceed 50.

(f) For Fissile Class II packages shipped under the exclusive use provisions of § 173.393 (j) to provide for packages with high radiation dose rates, the transport index number which is calculated for nuclear criticality control purposes must not exceed 10 for any single package or a total of 50 for the full load, unless specifically authorized by the Department for Fissile Class III shipments.

(g) Fissile Class III shipments may be made only in accordance with subparagraph (1) or (2) of this paragraph, or in accordance with other procedures authorized by the Department. The transport controls must provide nuclear criticality safety and shall be carried out by the shipper or carrier, as appropriate, to protect

against loading, transporting, or storing of that shipment together with other fissile material.

(1) Transportation in a transport vehicle assigned for the sole use of that consignor, with a specific restriction for such sole use to be provided in the special arrangements, and with instructions to that effect issued with the shipping papers; or

(2) Transportation under escort by a person in a separate vehicle, with the escort having the capability, equipment, authority and instructions to provide administrative controls adequate to assure compliance with this paragraph.

[2A] (h) The numerical values for package assignments as fissile class I, the transport indices for fissile class II packages, and the vehicle limitations for fissile class III packages must be determined in accordance with §§ 71.36 through 71.40 of Title 10 of the Code of Federal Regulations.

§ 173.397 Contamination control. (a) Removable radioactive contamination is not significant if the average amount of radioactive contamination which can be removed by wiping the external surface of the package with an absorbent material, as measured on the wiping material, does not exceed—

(1) 10^{-11} curie per square centimeter beta-gamma (2,200 disintegrations/min. per 100 square centimeters) and 10^{-12} curie per square centimeter alpha (220 disintegrations/min. per 100 square centimeters) for all contaminants except natural or depleted uranium and natural thorium; or

(2) 10^{-10} curie per square centimeter beta-gamma (22,000 disintegrations/min. per 100 square centimeters) and 10^{-11} curie per square centimeter alpha (2,200 disintegrations/min. per 100 square centimeters) where the only contaminant is known to be natural or depleted uranium or natural thorium.

(b) Each transport vehicle used for transporting low specific activity radioactive materials in carload or truckload lots under § 173.392 (d) must be surveyed with appropriate radiation detection instruments after each use. Vehicles must not again be placed in service until the radiation dose rate at any accessible surface is not more than 0.5 millirem per hour, and there is no significant removable radioactive surface contamination (see § 173.399).

(1) This paragraph does not apply to any closed transport vehicle (except aircraft) used solely for the transportation of radioactive materials, if a survey of its interior surface shows that the radiation dose rate does not exceed 10 millirem per hour at the interior surface or 2 millirem per hour at 3 feet from any interior surface. These vehicles must be stenciled with the words "For Radioactive Materials Use Only" in lettering at least 3 inches high in a conspicuous place or places, on both sides of the exterior of the vehicle. These vehicles must be kept closed at all times other than loading and unloading.

§ 173.398 Special tests. (a) Special form material: To qualify as special form material, the radioactive material must either be in massive solid form or encapsulated. Each item in massive solid form or each capsule must either have no overall dimension less than 0.5 millimeters, or must have at least one dimension greater than 5 millimeters. Each item, or the capsule material, must not dissolve or convert into dispersible form to the extent of more than 0.005 percent, by weight, by immersion for 1 week in water at pH 6-8 and 68° F., and a maximum conductivity of 10 micromhos/centimeter, and by immersion in air at 86° F. If in massive solid form, the radioactive material must not break, crumble, or shatter if subjected to the percussion test prescribed in this section, and must not melt, sublime, or ignite at temperatures below 1,000° F. If encapsulated, the capsule must retain its contents when subjected to all of the performance tests prescribed in this section, and must not melt, sublime, or ignite at temperatures below 1,475° F.

(1) **Free drop.** A free drop through a distance of 30 feet on to a flat essentially unyielding horizontal surface, striking the surface in such a position as to suffer maximum damage.

(2) **Percussion.** Impact of the flat circular end of a one inch diameter steel rod weighing three pounds, dropped through a distance of 40 inches. The capsule or material shall be placed on a sheet of lead, of hardness number 3.5 to 4.5 on the Vickers scale, and not more than one inch thick, supported by a smooth, essentially unyielding surface.

(3) **Heating.** Heating in air to a temperature of 1,475° F. and remaining at that temperature for a period of 10 minutes.

(4) **Immersion.** Immersion for 24 hours in water at room temperature. The water shall be at pH6-pH8, with a maximum conductivity of 10 micromhos/cm.

[2A] Added, effective November 5, 1969.

(b) Standards for Type A packaging:

(1) Type A packaging must be so designed and constructed that, if it were subject to the environmental and test conditions prescribed in this paragraph:

- (i) There would be no release of radioactive material from the package;
- (ii) The effectiveness of the packaging would not be substantially reduced; and
- (iii) There would be no mixture of gases or vapors in the package which could, through any credible increase of pressure or an explosion, significantly reduce the effectiveness of the package.

(2) Environmental conditions:

- (i) **Heat.** Direct sunlight at an ambient temperature of 130° F. in still air.
- (ii) **Cold.** An ambient temperature of -40° F. in still air and shade.
- (iii) **Reduced pressure.** Ambient atmospheric pressure of 0.5 atmosphere (absolute) (7.3 p.s.i.a.).
- (iv) **Vibration.** Vibration normally incident to transportation.

(3) Test conditions: The packaging shall be subject to all of the following tests unless specifically exempted therefrom, and also to the consecutive application of at least two of the following tests from which it is not specifically exempted:

- (i) **Water spray.** A water spray heavy enough to keep the entire exposed surface of the package except the bottom continuously wet during a period of 30 minutes. Packages for which the outer layer consists entirely of metal, wood, ceramic, or plastic, or combinations thereof, are exempt from the water spray test.
- (ii) **Free drop.** Between 1½ to 2½ hours after the conclusion of the water spray test, a free drop through a distance of 4 feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.
- (iii) **Corner drop.** A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 1 foot onto a flat essentially unyielding horizontal surface. This test applies only to packages which are constructed primarily of wood or fiberboard, and do not exceed 110 pounds gross weight, and to all Fissile Class II packagings.
- (iv) **Penetration.** Impact of the hemispherical end of a vertical steel cylinder 1¼ inches in diameter and weighing 13 pounds, dropped from a height of 40 inches onto the exposed surface of the package which is expected to be most vulnerable to puncture. The long axis of the cylinder shall be perpendicular to the package surface.
- (v) **Compression.** For packages not more than 10,000 pounds in weight, a compressive load equal to either five times the weight of the package or 2 pounds per square inch multiplied by the maximum horizontal cross section of the package, whichever is greater. The load shall be applied during a period of 24 hours, uniformly against the top and bottom of the package in the position in which the package would normally be transported.

(c) Standards for hypothetical accident conditions of transportation for Type B packagings:

(1) Type B packaging must meet the applicable Type A packaging standards and must be designed and constructed and its contents so limited that, if subjected to the hypothetical accident conditions prescribed in this paragraph, it will meet the following conditions:

- (i) The reduction of shielding would not be enough to increase the radiation dose rate at three feet from the external surface of the package to more than 1,000 millirem per hour.
- (ii) No radioactive material would be released from packages containing Type B quantities of radioactive material. The allowable release of radioactivity from packages containing large quantities of radioactive material is limited to gases and contaminated coolant containing total radioactivity exceeding neither 0.1 percent of the total radioactivity of the package contents nor 0.01 curie of Group I radionuclides, 0.5 curie of Group II radionuclides, and 10 curies of Groups III and IV radionuclides, except that for inert gases the limit is 1,000 curies.

(2) Test conditions: The conditions which the package must be

capable of withstanding must be applied sequentially, to determine their cumulative effect on a package, in the following order:

- (i) **Free drop.** A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal target surface, striking the surface in a position for which maximum damage is expected.
- (ii) **Puncture.** A free drop through a distance of 40 inches striking, in a position for which maximum damage is expected, the top end of a vertical cylindrical mild steel bar mounted on an essentially unyielding horizontal surface, the bar shall be 6 inches in diameter, with the top horizontal and its edge rounded to a radius of not more than one-fourth inch, and of such a length as to cause maximum damage to the package, but not less than 8 inches long. The long axis of the bar shall be perpendicular to the unyielding horizontal surface.
- (iii) **Thermal.** Exposure to a thermal test in which the heat input to the package is no less than that which would result from exposure of the whole package to a radiation environment of 1,475° F. for 30 minutes with an emissivity coefficient of 0.9 assuming the surfaces of the package have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hours after the test period unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hours.
- (iv) **Water immersion (fissile radioactive materials packages only).** Immersion in water to the extent that all portions of the package to be tested are under at least 3 feet of water for a period of not less than 8 hours.

(d) It is not necessary to actually conduct the tests prescribed in this section if it can be clearly shown, through engineering evaluations or comparative data, that the material or item would be capable of performing satisfactorily under the prescribed test conditions.

§ 173.399 Labeling of packages of radioactive materials. (a) Each package of radioactive materials, unless exempted by

§ 173.391 or § 173.392, shall be labeled as provided in this section (see § 173.414 for description of labels). The label to be used shall be determined by the transport index or other considerations as follows:

(1) **Radioactive white-I label.** (i) Each package not exceeding 0.5 millirem per hour at any point on the external surface of the package, and which does not come within the provisions of subparagraph (2) or (3) of this paragraph. Not authorized for Fissile Class II packages.

(2) **Radioactive yellow-II label.** When the limit in subparagraph (1) of this paragraph is exceeded but the provisions of subparagraph (3) of this paragraph are not met; and—

- (i) Each package not exceeding 10 millirem per hour at any point on the external surface of the package and not exceeding 0.5 millirem per hour at 3 feet from the external surface of the package; or
- (ii) Each package for which the transport index does not exceed 0.5 at any time during transportation.

(3) **Radioactive yellow-III label.** When either of the limits in subparagraph (2) of this paragraph is exceeded. In addition, the following types of packages must also bear this label:

- (i) Each Fissile Class III package;
- (ii) Each package containing a large quantity of radioactive material as defined in § 173.389; or
- (iii) Each package being transported under a permit issued as authorized in § 173.23 (c).

(b) Radioactive materials having other hazardous characteristics, as defined elsewhere in this part must also be labeled with other labels as required by this part according to the hazards of the commodity (see §§ 173.2 and 173.402). For example:

(1) Packages containing the solid nitrates of uranium or thorium must bear both a "radioactive" label and a "yellow" oxidizing materials label.

(2) Packages containing nitric acid solutions of radioactive materials must bear both a "radioactive" label and a "white" corrosive acid label.