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ARH-3113 SUP 1

SAFETY ANALYSIS REPORT FOR PACKAGING TYPE LLD-1 SHIPPING CONTAINER SUPPLEMENT NO. 1

D. A. Hoover

Process Design and Development
Development Engineering Department
Research and Engineering Division

October 24, 1974

PREPARED FOR THE U.S. ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1) 2130

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INTRODUCTION

This supplement was prepared to provide additional information on the pressurization of the 2R vessel in the LLD-1 shipping container by the expansion of the contained air and other gases under the thermal exposure condition specified in the Atomic Energy Commission Manual (AECM) Chapter 0529, "Safety Standards for the Packaging of Fissile and Other Radioactive Materials," Annex 2, Item 3.

The basic safety analysis of the LLD-1 container, being prepared by the Savannah River Plant (SRP), E. I. du Pont de Nemours and Company, covers only the shipment of plutonium metal. This supplement provides additional information on the shipment of plutonium oxide.

The review of both the Normal Conditions of Transport, AECM Annex 1, and the Hypothetical Accident Conditions, AECM Annex 2, indicates that the package performance evaluation is the same for shipments of both plutonium metal and plutonium oxide, except for the amount of pressure generated in the 2R vessel in the LLD-1 shipping container by the release of moisture adsorbed by the plutonium oxide in the form of water vapor.

Plutonium oxide is packaged in the 2R vessel of the LLD-1 container as follows:

1. A maximum of 2.25 kilograms of the oxide is placed in a tinned steel slip-top can. This can is sealed, then sealed in a polyethylene bag and removed from the hood.

2. The bagged slip-top can is then placed in a "tomato can" and the lid is "crimp sealed" in place.

3. Two "tomato can" assemblies are placed in the 2R vessel of the LLD-1 shipping container.

The evaluation of the pressure assumed that the gases would be distributed in the unoccupied space in the 2R vessel. These gases would consist of the air that was sealed in the vessel and the water vapor released due to heating the plutonium oxide.

The polyethylene bag would melt but not decompose [DPSPU 74-124-2, July 1974, J. E. Evans and A. A. Gates, "Safety Analysis Report - Packages, SRP Button Package (Preliminary Report)"].

SAFETY OF LOADING

Plutonium oxide fired at 550° C adsorbs up to 0.7 weight percent of moisture when exposed to hood atmosphere (dew point -20° F). It is reasonable to assume that this moisture would all be driven off as water vapor when the plutonium oxide temperature reaches 308° C. Therefore, the calculations are based on this premise. Since the SRP tests show that polyethylene melts but does not decompose at 308° C, it can be assumed that it will not contribute to the pressure inside the 2R vessel.

The calculated pressure which will be reached inside the 2R vessel of the LLD-1 shipping container is 646 psi. This pressure can be contained by the 2R vessel. The calculations supporting this pressure are in an attachment to this document.

The material yield and tensile strength values for ASTM A-373 steel are taken from the ASTM Standards, 1964 edition, part 4. The calculations were made using the formulae shown in the ASME Code for Unfired Pressure Vessels, Section VIII. Since these calculations show that the stresses in the 2R vessel are less than the minimum yield strength of the ASTM A-373 steel, it is concluded that the loadings meet the requirements of AECM, Chapter 0529.

ATTACHMENT

CALCULATION OF INTERNAL PRESSURE IN LLD-1 PACKAGE - 2R VESSEL

GIVEN: Free volume in 2R vessel = 1.624 liters
Weight of moisture in 4.5 Kg PuO_2 = 4500 g x .007 = 31.5 g

DETERMINE: Pressure in 2R vessel with temperature at 308° C.

CALCULATION: Use Basic Principles and Calculations in Chemical Engineering, Himmelblau, Second Edition, 1967, Prentice Hall, Section 3.2-3, pp 163-172.

Moles of air = 1.624 liters ÷ 22.4 liters/mole = .0725 moles
Moles of H_2O = 31.5 g ÷ 18 g/mole = 1.75 moles

$$P_T = RT\left[\frac{n_A}{V - n_A b_A} + \frac{n_W}{V - n_W b_W}\right] - \frac{1}{V^2}\left[n_W{}^2 a_W + n_A{}^2 a_A\right]$$

P_T = Total pressure in atmospheres.

V = 1.624 liters

T = 581° K

R = 0.08206 liter -atm/mole-°K

n_A = 0.0725 moles air

n_W = 1.75 moles water

a_A = 1.33 liter^2 -atm/mole^2 (Intern. Crit. Tables)

a_W = 5.464 liter^2 -atm/mole^2

b_A = 0.0366 liter/mole (Intern. Crit. Tables)

b_W = 0.03049 liter/mole

$$P_T = (0.08206)(581)\left[\frac{0.0725}{1.624 - (0.0725 \times 0.0366)} + \frac{1.75}{1.624 - (1.75 \times 0.03049)}\right]$$

$$- \frac{1}{(1.624)^2}\left[(0.0725)^2(1.33) + (1.75)^2(5.464)\right]$$

$$= 55.253 - 6.347 = 48.906 \text{ atm}$$

$$P_T = (48.9 - 1)\ 14.7 = 704 \text{ psig}$$

Check on Vessel Stresses

Inner Container Material: ASTMA-373
Tensile Strength: 58,000 psi min.
Yield Strength: 32,000 psi min.

Bottom Head

$$t = d\sqrt{\frac{CP}{\sigma}}$$

Where: c = 0.5 [ASME Code, Fig. UG34(h) and Fig UW-13.2(e)]
P = 704 psi
d = 4.69 in.
t = 0.5 in.
σ = stress in head

$$\sigma = CP\left(\frac{d}{t}\right)^2 = 0.5 \times 704 \times \left(\frac{4.69}{0.5}\right)^2 = 30,970 \text{ psi}$$

σ < yield strength

Top Head

Where: C = 0.75 [ASME Code, Fig. UC-34(q)]
P = 704 psi
d = 4.69 in.
t = 1.0 in.
σ = stress in head

$$\sigma = CP\left(\frac{d}{t}\right)^2 = 0.75 \times 704 \left(\frac{4.69}{1}\right)^2 = 11,614 \text{ psi}$$

σ < yield strength

Thread Shear

$$\text{Thread Shear} = \frac{PA}{\pi dt} = \frac{704 \times (0.785)(4.75)^2}{\pi\ (4.8)(1)} = 827 \text{ psi}$$

Thread Shear < yield strength

CONCLUSIONS:

1. The pressure increase in the 2R Vessel is within the capacity of the vessel.
2. There appears to be no possible leakage of radioactivity from the 2R Vessel during transport.
3. In over 20 years experience with the LLD-1 shipping package, no leakage has occurred.