SAFETY ANALYSIS REPORT – PACKAGES
GPHS SHIPPING PACKAGE
SUPPLEMENT 2 TO THE PISA SHIPPING PACKAGE
(Packaging of Fissile and Other Radioactive Materials)

MASTER

FINAL REPORT

June 1981

Compiled by

G. G. Chalfant

E. I. du Pont de Nemours and Company
Savannah River Plant
Aiken, South Carolina 29808

Prepared for the U.S. Department of Energy under Contract DE-AC09-76SR00001

DISTRIBUTION STATEMENT IS UNCLASSIFIED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

SAFETY ANALYSIS REPORT - PACKAGES
PISA AND GPHS SHIPPING CONTAINERS

Abstract

Safety Analysis Report DPST-78-124-1 is amended to permit shipment of 6 General Purpose Heat Source (GPHS) capsules (max.). Each capsule contains an average of 2330 curies of ^{238}Pu , and each pair of capsules is contained in a welded stainless steel primary containment vessel, all of which are doubly contained in a flanged secondary containment vessel. This is in addition to the forms discussed in DPST-78-124-1 and Supplement 1.

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CHAPTER 0.0 - GENERAL INFORMATION

	<u>Page No.</u>
0.1 Introduction	0-1
0.2 Package Description	0-1
0.2.1 Primary Containment Vessel and Contents	0-1
0.2.2 Operational Features	0-5
0.2.3 Contents of Packaging.	0-5
0.2.4 Transport Index	0-5
0.3 Reference	0-5

CHAPTER 0.0 GENERAL INFORMATION

0.1 Introduction

One hundred fifty grams (nominal) of $^{238}\text{PuO}_2$ is hot pressed into 1.082 inch diameter right circular cylinder and then encapsulated in iridium to form a radioisotopic heat source. This assembly (figure 0.1) referred to as the General Purpose Heat Source or GPHS is doubly contained in a shipping package described below and shown on page 9-12.

The PISA Shipping Package, discussed in [1], will be modified to transport a maximum of six GPHS capsules.

0.2 Package Description

A new primary containment vessel, shown in figure 0.2 and page 9-11 was designed to contain two GPHS capsules and special-form tested to reduce packaging time and cost. Three primary containment vessels containing a total of six GPHS capsules are then packaged into the secondary containment vessel [1] in the configuration shown in figure 0.3 and page 9-12.

0.2.1 Primary Containment Vessel and Contents

The GPHS primary containment vessel (Figure 0.2 and page 9-11) is a 300 series stainless steel cylinder, 1.87-inch ID x 2.00 inch OD x 4.32-inch long. The containment vessel weighs 940 grams with radioactive contents. The top and bottom of the primary containment vessel are flat stainless steel disks which are fusion welded by gas tungsten arc welding in a helium atmosphere in accordance with the procedure shown in 1.10.2.5. A 17-4 Ph stainless steel disk (magnetic) is counterbored and edge-welded to the top surface of the primary containment vessel for attachment of a magnetic pickup device.

A serial number is electro-etched onto the bottom surface of the primary containment vessel for accountability and quality control purposes. The two GPHS capsules are surrounded by four solid graphite supports which act as heat transfer conductors within the primary containment vessel. The GPHS is also cushioned from shock by graphite felt above and below the solid graphite supports.

FIGURE 0.1 GPHS CAPSULE

FIGURE 0.2 GPHS SHIPPING CONTAINER

FIGURE 0.3 GPHS SHIPPING CASK ASSEMBLY

0.2.2 Operational Features

Two grooves are machined in the circumference of the primary containment vessel at about the centerline of the two GPHS capsules. This groove is used for locating a cutting tool for opening the containment vessel and removal of the GPHS capsules. The top of each primary containment vessel has a magnetic stainless steel insert for lifting the vessel with a magnetic handle.

0.2.3 Contents of Packaging

Authorized contents of the SP 5320 cask are ammended to include:

Material Type and Form

Six GPHS capsules (Figure 0.1)

Maximum Quantity

- (i) 155 grams plutonium oxide with an isotopic content of ^{238}Pu 75-100 weight percent per capsule.

Maximum Internal Decay Heat

466 watts

Maximum Storage Time After Iridium Encapsulation

1 year

Additional Permissible Contents

Primary Containment Vessel - All components shown on page 9-11.

0.2.4 Transport Index

The loaded cask will be transported in safe-secure transport vans or other DOE transport trucks and will be classified in most shipments as Fissile Class III packages. Criticality evaluation alone would allow the shipment as Fissile Class I but the radiation level of the cask measured at the time of shipment will limit the shipment to Fissile Class II or III.

0.3 Reference

1. Chalfant, G. G., Safety Analysis Report-Packages, PISA Shipping Container, November 1979, USDOE report DPST-78-124-1,
E. I. du Pont de Nemours and Company, SRP, Aiken, S.C. 29801

CHAPTER 1.0 - STRUCTURAL EVALUATION

	<u>Page No.</u>
1.1 Structural Design	1-1
1.1.1 Discussion	1-1
1.1.1.1 Primary Container	1-1
1.1.2 Design Criteria	1-1
1.2 Weights and Centers of Gravity	1-1
1.5 Standards for Type B and Large Quantity Packaging	
1.5.1 Load Resistance	-
1.5.2 External Pressure	1-1
1.5.3 Internal Pressure	1-3
1.6 Normal Conditions of Transport	1.3
1.6.1 Heat	1-3
1.6.1.1 Summary of Pressures and Temperatures	1-3
1.6.1.2 Differential Thermal Expansion	1-5
1.6.1.3 Stress Calculations	1-5
1.6.1.4 Comparison with Allowable Stresses	1-5
1.8 Special Form.	1-5
1.8.1 Description of Tests	1-6
1.10 Appendices	
1.10.1 Calculations	1-10
1.10.1.4 Establishing Maximum Allowable Working Pressure of GPHS Primary Containment Vessel	
1.10.2 Qualification Test Procedures and Reports	
1.10.2.5 DPSOP 215 Welding Specification SC-30-A	1-11
1.10.2.6 GPHS Primary Containment Vessel Proof Test.	1-24
1.10.2.7 GPHS Primary Containment Vessel Special Form Test Procedure	1-25

1.10.2.8	GPHS Primary Containment Vessel Special Form Drop Test Procedure	1-28
1.11	References	1-30

1.1 Structural Design

1.1.1 Discussion

1.1.1.1 Primary Container

The GPHS Primary Containment Vessel is the same as stated in [1] with the exception that the structural material is 304 stainless steel, rather than 304L stainless steel as specified in [1], to improve availability and high temperature strength of the containment vessel.

1.1.2 Design Criteria

Design criterion for the GPHS primary containment vessel is 125 psig at 700°F per the requirements of 1977 Edition, Section VIII, of the ASME Boiler and Pressure Vessel Code. All other components, with the exception of the above are of the same criteria as specified in Table 1.0 of reference [1].

1.2 Weights and Centers of Gravity

The weight and center of gravity of the PISA Cask when modified for shipment of the GPHS capsules will be essentially the same as reported in paragraph 1.2 of reference [1]. Actually the three GPHS capsules result is 1.2 lbs. total additional weight which is negligible.

1.5.2 External Pressure

Consider the ability of the GPHS Primary Containment Vessel to withstand an external pressure of 25 psig.

2.00-in. OD x 1.87-in. ID, type 304 SS (see page 9-11)

Body

$$S_1 = \frac{PR}{2t} \quad [2, \text{Table XIII, Case 1}]$$

where S_1 = meridional membrane stress, psi

P = pressure, external = 25 psig

R = mean radius of circumference, in.

t = wall thickness, in.

$$S_1 = \frac{25 \times 0.968}{2 \times 0.065}$$

$$S_1 = 186 \text{ psi (less than 18,700 psi allowable stress per Table 1.1)}$$

$$S_2 = \frac{PR}{t}$$

S_2 = hoop membrane stress, psi

$$S_2 = \frac{25 \times 0.968}{0.065} = 372 \text{ psi (less than 18,700 psi allowable stress per Table 1.1)}$$

At radius notch (0.015 in. radius groove, 0.015 ± 0.005 in. deep)
Assume stress concentration factor of 3

$$S_1 = \frac{3 \times 25 \times 0.968}{2 \times 0.045} = 807 \text{ psi (less than 18,700 psi allowable stress)}$$

Flat Cap

$$(\text{at edge}) \text{ Max } S_r = \frac{3 W}{4 \pi t^2} \quad [2, \text{ Table X, Case 6}]$$

where: S_r = stress in radial direction (maximum at edge), psi

W = total applied load, lb = unit applied load, psi x area, in²

t = wall thickness = 0.095 ± 0.005

$$\text{Max } S_r = \frac{3 \times 25 \times \pi \times 1^2}{4 \pi \times 0.090^2} = 2315 \text{ psi (less than 18,700 psi allowable stress per Table 1.1)}$$

There will be no loss of contents from the primary container at 25 psig external pressure. The secondary container is hydrotested at 425 psig (see note 3a of page 9-2 at assembly and is also capable of supporting 25 psig external pressure without any failure.

1.5.3 Internal Pressure

The GPHS primary containment vessel is designed with a pressure rating of 125 psig at 700°F (see note 1 on page 9-11). The closure welds on the top and bottom of the primary containment vessel are not ASME code welds, therefore, their formulas could not be used to verify the strength of the primary containment vessel. Instead, a burst test, described in paragraph UG-101 of [3] fulfills this requirement. Three primary containment vessels, which met the material and dimensional tolerances shown on page 9-11, were modified with a 1/8-inch OD x 1/16-inch ID pressurization tube and hydraulically pressurized to failure as specified in 1.10.2.5. All three failed from typical hoop stress in the cylindrical body (figure 1.1). Using the lowest burst pressure obtained in this test and the formulas specified in paragraph UG-101M2a, the allowable working pressure was calculated to be 550 psig at 700°F, which is far above the design rating (appendix 1.10.1.4).

1.6 Normal Conditions of Transport

1.6.1 Heat

1.6.1.1 Summary of Pressures and Temperatures

With three GPHS primary containment vessels, each with two GPHS capsules or a total of six GPHS capsules inside the 5320 casks, average calculated temperature of the primary containment vessel from the $^{238}\text{PuO}_2$ reaches 541°F (see 2.1.1) and causes an internal pressure of 13 psig. If the iridium encapsulation fails on all six capsules after its longest storage time (1 year), the internal pressure in the primary containment vessel would be raised to 116 psig at 541°F (see 2.4.4). Heat is constantly being removed from the cask through the aluminum tank and cooling fins. This causes a differential temperature through the cask of approximately 50°F. The average temperature of the cooling fins is 209°F.

CALCULATED STEADY STATE CONDITIONS FOR NORMAL TRANSPORT

Number of GPHS Primary Containment Vessels	Solar Heat Load Btu/hr.	Nuclear Heat Load, Btu/hr	Total Heat Load, Btu/hr	Cask Outer Surface Temperature, °F	Outer Surface Temp., OF	
					Secondary Container	Primary Container
3	132.5	1590	1722.5	209	258	541

TABLE 1.1
MECHANICAL PROPERTIES OF MATERIALS

Description	Spec No.	Grade	S. Allowable ksi at 100°F	Syp Ksi	Sult, ksi	E ksi x 10 ³ at 70°F	Ultimate Strain, % in 2-in.	Density, lb/in. ³	Coeff of Thermal Expansion in/in/°F x 10 ⁻⁶	Source
PISA Primary Container	ASTM A-213	TP 304L	15.6	25.0	70.0	28.3	35	0.29	9.21(100°F)	a
Body	ASTM A-213	TP 304L	15.6	25.0	70.0	28.3	35	0.29	9.21(100°F)	a
Cap	ASTM A-240	304L	15.6	25.0	70.0	28.3	35	.29	9.21(100°F)	a
GPHS Primary Container										
Body	ASTM A-213	TP 304	18.7	30.0	75.0	28.3	35	.29	9.21(100°F)	a
Cap	ASTM A-240	304	18.7	30.0	75.0	28.3	35	.29	9.21(100°F)	a
Secondary Container										
Pipe	ASME SA-312	TP 304	18.7	30.0	75.0	28.3	35	.29	9.21(100°F)	a
Bar	ASME SA-479	304	18.7	30.0	75.0	28.3	35	.29	9.21(100°F)	a
Flange	ASME SA-240	304	18.7	30.0	75.0	28.3	35	.29	9.21(100°F)	a
Gasket	Commercial									
Bolts	ASME SA-453	660	21.2	85	130	29.1	15		9.17(100°F)	b
Cooling Fin										
Shell										
Model C	ASME SB-209	1100-0	2.3	3.5	11.0	10	-	.098	13.1(212°F)	b & c
Model D	ASME SB-241	6061-T6	10.5	35.0	42.0	10	-	.098	13.0(212°F)	b & c
Baseplate	ASTM A-36		12.6	36.0	58.0	27.9	-	.30	6.20(100°F)	d
Water-Ex- tended	Ashland Chem- ical Co.	Type 661-P Polyester		Ten. 1.2 Comp 3.2						
Polyester (WEP)						0.106	-	0.386	-	e

a ASME, B & PV Code, Section VIII, Table UHA-23.

b ASME, B & PV Code, Section VIII, Table ABM-1

c Alcoa Alum. Handbook

d ASME, B & PV Code, Section VIII, Table UCS-23

d DPSPU 74-124-1

1.6.1.2 Differential Thermal Expansion

Differential thermal expansion between the GPHS primary containment vessel and the inside of the secondary containment vessel is less severe than the case examined in paragraph 1.6.1.2 of [1].

1.6.1.3 Stress Calculations

The thermal gradient across the primary and secondary containment vessels will be within the range analyzed in paragraph 1.6.1.3 of [1].

1.6.1.4 Comparison With Allowable Stresses

1.6.1.4.1 Primary Containment Vessel

The allowable stress was not calculated for the primary containment vessel (see 1.5.3), but the allowable internal pressure at temperature was calculated using the Code [3], paragraph UG-101M2a as shown in 1.10.1.4.

The maximum allowable working pressure is 550 psig at 700°F (1.10.1.4). The maximum normal operating pressure is 116 psig at 541°F (see 2.4.4).

1.6.1.4.2 Secondary Containment Vessel

Pressures, temperatures, and resulting stresses in the secondary containment vessel, assuming primary containment and GPHS capsule failure, are less than that investigated in [1, paragraph 1.6.1.4.2.]

1.8 Special Form

The SP 5320 Cask, arranged for the PISA assembly was accident tested and reported in reference [1]. The SP 5320 Cask, arranged for the $^{238}\text{PuO}_2$ assembly (different primary containment vessels and contents), was later tested and reported in reference [4]. To avoid repeating the two previous tests, the new GPHS primary containment vessel is being declared "special form" and so tested as specified in 1.10.2.7 without the cask and secondary containment vessel. The GPHS primary containment vessel was subjected to appendix D of 10CFR71 with the following exceptions: The heating test will be controlled to produce a skin temperature of 1625°F instead of the required air temperature of 1475°F for 10 minutes. The above exception takes into account the self heating effect of $^{238}\text{PuO}_2$ heat source.

1.8.1 Description of Tests

Three GPHS primary containment vessels (420-R9-008, 420-R9-021, 420-R9-037) were assembled for the special form test. The contents were as discussed in 0.2.1 with the exception that the two GPHS capsules were replaced with two solid copper capsules of the approximate same weight. The three PCV's were pressurized with helium gas (51 to 53 psig) and seal welded. Leakage tests with a helium mass spectrometer indicated that they were leaktight ($< 10^{-7}$ atm cc/sec air). The three PCV's were dropped 30 feet, each with a different orientation. PCV-SN021 was dropped with its top down and centerline vertical. PCV-SN008 was dropped with its top down but its centerline at an angle of 25° with the vertical. This angle results with the center of gravity of the assembly directly over the point of impact. PCV-SN037 was dropped with its top down and its centerline at an angle of 45° with the vertical. Damage to PCV-SN037 was judged to be the most severe and is shown in Figure 1.1 and Figure 1.2. The primary impact, shown in Figure 1.1 resulted in a 0.040 - inch dent at the top corner. The secondary impact, shown in Figure 1.2, was less in depth but greater in area. The percussion test, resulted in a side wall deflection of 0.025 inch as shown in Figure 1.3. Helium leakage tests after the drop and percussion tests verified containment had not been reduced (leakage rate $< 10^{-7}$ atm cc/sec air).

The three PCV's were then exposed to the special form fire test (1475°F skin temperature for 10 minutes) as described by the procedure shown in 1.10.2.7. Leakage and physical measurements made after the 1475°F fire tests indicated leakage $< 10^{-7}$ atm cc/sec air and no additional permanent deformation. One of the three PCV's (SN021) was removed from testing and kept as a sample of the special form test. The other two containment vessels were subjected to 1625°F for a period of 10 minutes. All three PCV's were then submerged in three feet of water for 24 hours. Helium leakage measurements made after the 1625°F fire and submergence tests indicated containment was not lost (leakage rate $< 10^{-7}$ atm cc/sec air) and permanent deformation was not produced from the fire test. The test reports and data have been filed in the Quality Assurance file No. 730000.484 at Central Files.

FIGURE 1.1 DEFORMATION OF SEAL WELD
AFTER 30 FT DROP TEST

FIGURE 1.2 DEFORMATION OF SEAL WELD
AFTER SECONDARY IMPACT

FIGURE 1.3 SIDEWALL DEFORMATION
FROM PERCUSSION TEST

1.10.1.4 Establishing Maximum Allowable Working Pressure of GPHS Primary Containment Vessel.

[3], Paragraph UG-101(M) Proof tests to establish maximum allowable working pressure, bursting test procedure

$$P = \frac{B}{5} \times \frac{SE}{S_a}$$

$$P = \frac{4900}{5} \times \frac{75,000 \times 0.85}{96,000}$$

$$P = 648 \text{ PSI at } 70^{\circ}\text{F}$$

P = Allowable working pressure, psi

B = Burst pressure = 4900 psig
(Appendix 1.10.2.6)

S = Specified minimum tensile strength, PSI=75,000

E = Efficiency of weld joint
= 0.85 (Container did not fail at weld area)

S_a = Average actual tensile strength of test specimens, PSI
(Appendix 1.10.2.6
96,000 PSI

$$P_o = P_t \frac{S_o}{S_t}$$

$$P_o = 648 \times \frac{15900}{18700}$$

$$P_o = 550 \text{ PSIG AT } 700^{\circ}\text{F}$$

P_o = Maximum allowable working pressure at operating temperature, PSI

P_t = Maximum allowable working pressure at test temperature, PSI

S_o = Maximum allowable stress value at operating temperature
= 15900 PSI

S_t = Maximum allowable stress value at test temperature
= 18,700 PSI

1.10.2.5 - WELDING SPECIFICATION SC-30A

E. I. du Pont de Nemours and Company
Savannah River Plant

PROCEDURE QUALIFICATION FOR: SEMIAUTOMATIC GAS TUNGSTEN ARC WELD-
ING (GTAW) OF GENERAL PURPOSE HEAT
SOURCE (GPHS) PRIMARY CONTAINMENT
VESSEL, TOP CAP TO HOUSING.

I. PROCEDURE SPECIFICATION

Description: The GPHS Primary Containment Vessel (PCV) is used for shipment of radioactive heat sources from the Savannah River Plant. The top cap to housing weld is made using a single pass semiautomatic procedure. A vent notch is closed as the cap to housing weld is completed. Welding by a welding operator trained for SC-30A is required (see Section III).

Process: Semiautomatic GTAW

Base Material: DWG S5-2-10420, Rev 9
Housing - ASTM A-213 tubing type 304 stainless steel
Top Cap - ASTM A-240 plate type 304 stainless steel

Joint Design: Fillet, see Figure 1, minimum throat thickness of .065-inches.

Inert Shielding Gas: Welding grade Helium + 25% $\pm$ 1.5% Argon
(Note: Welds to be made in a Helium filled cell).

Electrode: 1/16-inch diameter, 2% "thoriated" tungsten electrode, (Figure 2, SSK1-7-481) 1/8-inch $\pm$ 1/32-inch stick-out, 25° included straight ground angle.

Gas Cup: No. 5 or 6 ceramic

Position: 45° torch angle with electrode pointed into joint corner (see Figure 1).

Electrical Characteristics: Direct Current Straight Polarity

Weld Current: 120 $\pm$ 5 amps

Arc Initiation: High frequency - start only

Arc Gap: 0.045 $\pm$.005 inch (see Figure 1)

Metal Preparation: Degrease, chemically clean and rinse housing per DPSOL 322-56 prior to welding. Handle cleaned parts with gloves or tongs only. Items shall be wrapped in aluminum foil for handling.

Housing is chemically cleaned to remove contaminants from the original tube surface that has not been machined. Chemical cleaning is not required for caps since all surfaces are machined.

Welding Technique: Single pass weld. Chuck vessel by housing. Adjust torch over joint per Figure 1. Align chill (DWG SSK3-2-289) on top cap. Rotate chuck to start weld 1/4" beyond vent slot. Press start button to start weld. After welding release chuck and remove welded can for inspection. Visually inspect weld for blow holes, incomplete weld, and other irregularities. Check recorder trace for irregularities. If any irregularities or leaks occur in the weld, notify supervision.

Weld Inspection: Helium leak test PCV.

Repair Procedure: If weld repair is necessary, reweld using welding procedure specification SC-30A, but starting and quenching weld as required to effect repair.

Welding Procedure Conditions:

Joint Design	S5-2-10420, Rev 9
Chill, Top	SSK3-2-289
Spindle Speed, Sec/Rev	15 ± 0.1 (4RPM or 25 ipm)
Weld Current, amp	120 ± 5
Puddle Time, sec	0.25 ± 0.1
Downslope Time, sec	1.5 ± 1.0
Arc Gap, in.	0.040 - 0.050
Electrode Type	1/16 inch diameter; 2% ThO ₂ -W
Electrode Tip Shape	(25° included) SSK1-7-481 angle
Torch Gas	He + 25% $\pm$ 1.5% Ar
Gas Flow, cfh	10 ± 1
Torch Type	HW-9 or equivalent
Nozzle Size	5 or 6
Electrode Protrusion, in.	$1/8 \pm 1/32$
Arc Starting Location	$1/4 \pm 1/16$ inch past vent slot
PCV Position	Longitudinal axis vertical
Electrode Position	45° to horizontal, tip in horizontal plane of cap top, 0° lead angle

II. PROCEDURE QUALIFICATION

A total of 6 PCV's were welded to qualify DPSOP 215 Procedure SC-30A

Welding operator: J. W. Kyle

Welding engineer: W. R. Kanne, Jr.

Process: Semiautomatic GTAW

Positioner: W. A. Jones Research Corp. Microtig Model 50

Power Supply: Miller DC arc welder Model ESR 150

Spindle Speed, Sec/Rev	15.0
Weld Current, amp	122
Puddle Time, sec	0.25
Weld Time, sec	16
Downslope Time, sec	1.75
Arc Gap, in.	0.040
Torch Gas Flow, cfh	10
Electrode Protrusion, in.	1/8

Weld Evaluation:

- (1) Visual Examination - The surface of all six welds was examined and showed no evidence of cracks or other defects on the weld surface (Figure 3).
- (2) Helium Leak Test - Three PCV's were pressurized to 52 psig helium and tested using a helium mass spectrometer. All were found to have a leak rate less than 1×10^{-7} atm cc/sec.
- (3) Hydrostatic Pressurization Test - Three PCV's were pressurized with oil until they failed. None failed in the weld (Figure 4).
- (4) Furnace Test - Three PCV's with 52 psig internal helium pressure were exposed at 1620°F for 10 minutes. No welds failed as demonstrated by a post heat treatment helium leak test and venting to assure containment of the helium gas.
- (5) Metallographic Examination - One weld was sectioned, polished, etched (10% oxalic acid) and examined. The weld had full penetration with no cracks or porosity. Throat thickness exceeded the 0.065-inch minimum (Figure 5).

- (6) Dimensional Examination - All PCV's were measured to assure that the maximum diameter at the weld was less than 2.025 inch. External weld widths were also measured. Measurements are listed below.

<u>CAN NO.</u>	<u>WELD WIDTH (INCH)</u>		<u>WELD DIA.</u>
	<u>ON BODY</u>	<u>ON CAP</u>	
029	0.12	0.11	1.998
034	0.15	0.12	1.997
003	0.15	0.12	1.999
021	0.13	0.15	1.995
037	0.12	0.14	1.998
008	0.15	0.14	1.993

- (7) Bend Test - One can was cut into sections and the wall was bent 270 ° around the weld. The can wall at the weld was then impacted until failure occurred in the cap material adjacent to the weld. (Figure 6)

Welding Operator J. W. Rife DATE 5/20/80
Test Conducted By D. R. Kanne, Jr. DATE 5/20/80

I certify that the statements made in this record are correct and that the test welds were prepared, welded, and tested insofar as practical in accordance with the requirements of Du Pont Specification SW-17W and Section IX of the ASME Boiler Code.

E. I. du Pont de Nemours and Company, Inc.
By G. L. Chalfant Jr. DATE 5/20/80

III. Welding Operator Performance Test

General: This section details the procedure required for testing of welding operators for production of final closure welds on the GPHS primary containment vessel per DPSOP 215 Welding Specification SC-30A. Performance testing is required to determine the welding operator's mechanical ability to operate the welding equipment to produce sound welds.

Welding Procedure: Test welding of an unloaded GPHS primary containment vessel is to be made per Welding Procedure Specification SC-30A using production welding equipment. Performance testing on coupons representative of the GPHS is permitted insofar as material and weld joint dimensions are within specifications of Dwg. S5-2-10420. Approval of coupon design by the welding engineer conducting the qualification test is required.

Weld Acceptance Criteria: The following tests are required for weld evaluation:

- (1) Visual Inspection: Welds are to be free of cracks, porosity or other surface defects. Concavity of the weld surface is unacceptable.
- (2) Dimensional Inspection: The PCV must pass through the 2.025 inch ID ring gage used for production welds.
- (3) Macro Section: Four 90° weld sections shall show sound welds with full penetration and a minimum throat thickness of .065 inch.

Record of Performance Test: Welding variables and weld evaluation results are to be recorded on a Welding Operator Qualification Record.

Re testing : Re testing is required when (a) the welding operator has not made acceptable weldments per Specification SC-30A for a period of three months or more, or (b) there is a specific reason to question the operator's ability to make welds that meet the specifications. The test record must be signed by the welding operator and welding engineer conducting the test.

IV. Weld Specifications

(A.) Sample Welds (One per run)

1. Weld appearance - Welds to be free of cracks, porosity or other surface defects. Concavity of the weld surface is unacceptable.
2. Weld Size - Maximum weld diameter shall not exceed 2.025 inch.
3. Weld Quality - Four 90° weld sections shall show sound welds with a minimum throat equal or greater than the can wall (0.065 inch).

(B.) Production Welds

1. Weld appearance - Welds to be free of cracks, porosity or other surface defects. Concavity of the weld surface is unacceptable.
2. Weld Size - Maximum weld diameter shall not exceed 2.025 inch.
3. Helium Leak Test - Less than 1×10^{-7} atm cc/sec leak rate.

NOTE: CROSS SLIDE ASSEMBLY SHOWN
ONLY ON ONE VIEW

CROSS SLIDE ASSY

SLOT IN PRIMARY
CONTAINMENT VESSEL

ROTATION

PENCIL TORCH
LINDE HW-9

CERAMIC GAS CUP
LINDE NO 6

TUNGSTEN ELECTRODE
SEE DETAIL (2)

WEIGHTED CHILL ASSY
SEE SSK3-2-289

.005 TIR MAX

GPHS PRIMARY
CONTAINMENT VESSEL
SEE SS-2-10420

SLOT IN PRIMARY
CONTAINMENT VESSEL

.25

.125 PROTRUSION

.040
.050

.040
.050

.095

.062

-1-18-

FIGURE 1

MATERIAL: 2% THORIATED TUNGSTEN

W.R. KANNE

J.C. ANDERSON 723-A

EXPERIMENTAL
JA2982

PUFF ELECTRODE

1-B-75 10x FULL DPO SSK1-7-481

EE33445-A

1.5x

Figure 3. Typical Weld Appearance

Mag 1/2x

EE 33456-A

Figure EE 4. GPHS - PCV after hydrostatic failure.

EE 33856-A

20x

Figure 5. Typical Metallographic Section Through Weld

EE 33855-A

3 X

Figure 6. Bend Test Sample

1.10.2.6 GPHS PRIMARY CONTAINMENT VESSEL PROOF TEST
ESTABLISH MAXIMUM ALLOWABLE WORKING PRESSURE

- REFERENCES:
1. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1977 Edition, Paragraph UG-101
 2. S5-2-10420, Rev. 9, SRP GPHS Primary Containment Vessel.

Required Items

1. Four GPHS Primary Containment Vessels built in accordance with reference[1].

STEP

1. Measure "Q" dimensions, record, and check for conformance with reference[2] on the four vessels.
2. Cut four tensile strength specimens from one of the vessels and measure and record the average actual tensile strength of the four specimens.
3. Weld 1/4" high pressure nipples to the top of the remaining three vessels.
4. Hydro test each vessel to failure. Record pressure at which failure occurs.
5. Photograph failures.

GGC:caj

1.10.2.7 - GPHS PRIMARY CONTAINMENT VESSEL

SPECIAL FORM TEST PROCEDURE

- Reference:
1. 10CFR71 - Appendix D - Tests for Special Form Licensed Material, 8/19/77.
 2. S5-2-10420, Rev. 9, SRP GPHS Primary Containment Vessel
 3. GPHS - Special Form & Hydrostatic Failure Test Data

REQUIRED ITEMS

1. Three GPHS Primary Containment Vessels build in accordance with Reference 2.
2. Three GPHS simulated capsules per attached sketch.

STEP

1. All "Q" dimensions shall be measured, recorded, and checked for conformance with the drawings on the GPHS - PCV. Note: The three containers used are #008, 021, 037 and dimensions are shown in Reference 3B.
2. The simulated capsules shall be weighed, their weight recorded and confirmed to weigh greater than 175 grams. Note: A-177.65 gm, B-177.22 gm, C-176.95 gm, D-177-37 gm, E-176.89 gm, 177.50 gm.
3. Drill bottom of GPHS-PCV and add 1/8 OD x 1/16 ID fill stem for pressurization in Step 6.
4. Assemble the GPHS-PCV as shown in Reference 2 with the exception that the simulated capsule shall replace item 4.
5. Weld the top cap to the PCV body per EED Welding Procedure (DPSOP 215).
6. Pressurize the three PCV's with helium gas to a pressure of 51 to 53 psig at 70°F. Pressurization is to be through the 1/8 OD x 1/16 ID fill stem. After pressurization pinch weld, the fill stem closed. Remove excess fill stem. Note: For results see Reference 3H.

7. Leak test each GPHS-PCV in an evacuated envelope with a helium mass spectrometer in accordance with paragraph A3.10 of ANSI N14.5-1977. The sensitivity of the mass spec leak detector is to be $< 1 \times 10^{-9}$ atm cc/sec. Acceptable leakage to be $< 1 \times 10^{-7}$ atm cc/sec air. Record serial number of each PVC and measured leak rate on Proof and Leak Test Data Sheet. Note: For results, see Reference 3J.
- *8. Drop each GPHS-PCV 30 feet as prescribed in 1.10.2.8. Note: For results, see Reference 3K&L.
9. Repeat Step 7. Note: For results, see Reference 3K.
- *10. Drop the three-pound rod as prescribed in 1.10.28.
11. Clamp one thermocouple to the cylindrical body of each PCV on the opposite end from the fill stem.
12. Preheat oven to 1475°F.
13. Open oven door and insert the three PCV's. Make sure the fill tubes are pointed to the rear of the oven.
14. Adjust the oven temperature to procure a skin temperature on the PCV's between 1475 and 1500°F. Hold for 10 minutes. Record temperatures. Note: See Reference 3M for results.
- *15. After a total time at 1475°F of 10 minutes, remove the three PCV's and allow to cool naturally for three hours.
16. Repeat Step 7. Note: See Reference 3Mc for results.
17. Preheat oven to 1650°F.
18. Open oven door and insert two of the three PCV's. Do not use 021, but keep it as a 1475°F sample.
19. Adjust the oven temperature to provide a skin temperature on the PCV's between 1620 and 1650°F. Hold for 10 minutes. Record Temperatures. Note: See Reference 3N for results.

- *20. After a total time above 1620°F for 10 minutes, remove the two PCV's and allow to cool naturally for three hours.
- 21. Submerge the three PCV's into a minimum of three feet of water for 24 hours. Water PH measurements are not required.
- 22. Remove thermocouples and repeat Step 7. Note: See Reference 3.0 for results.

*Note: The steps marked with an asterisk shall be photographed and may be witnessed by a DOE representative.

1.10.2.8 GPHS PRIMARY CONTAINMENT VESSEL

SPECIAL FORM DROP TEST PROCEDURE

Purpose

- o To show that the GPHS-PCV can be subjected to the special form drop and percussion test without loss of its containment capability.

Required Items

- o Three GPHS-PCV which have been helium pressurized to 51 psig helium and leak tested (leakage rate to be $< 1 \times 10^{-9}$ atm cc/sec air).
- o 4" thick steel plate (supplied by W. R. Kennedy)
- o 4" diameter steel bar stock, 3" long, 3 reqd.
- o 4' x 8' x 1/2" thick plywood sheet, 4 reqd.
- o 1/16" diameter (approx) cotton string
- o 1" diameter x 14" long steel rod (minimum wgt. of 3 lbs.)

Pre Drop Steps

1. Hard hats and safety glasses are required in the High Bay area.
- 1a. All personnel going above 0' level in high bay area must remove objects from pockets above waist.
2. Measure and mark 30' length of string from ball of string. Do not cut string.
3. Go to 30' elevation and pass string through eyelet of support bracket.
4. Tie free end of string to plumb bob.
5. Lower string supported plumb bob to 0' level of high bay. Mark contact point of bob.
6. Space bar stock on a triangular pattern at equal distances from contact point.
7. Request T & T to place 4" thick plate onto 3 lengths of bar stock.
8. Erect plywood barricade around 4 sides of plate.
9. Safety rope area a minimum of 4 feet beyond barricade. Attach caution tag and forbid entry.
10. Obtain flame permit for the high bay area.

Drop Steps

11. Lower plumb bob and pre-marked string onto plate. Mark elevation in high bay of 30' location. Drops of the containers must be from above this level.
12. Attach 1/16 diameter string onto each of three GPHS primary containment vessels. The string is to be attached per guidance of the Engineer.
13. Adjust string onto the PCV's until the following orientation is obtained:
 - a) Serial No. 021. ϕ vertical with top down
 - b) Serial No. 008. ϕ at angle of 25° with vertical with top down
 - c) Serial No. 037. ϕ at angle of 45° with vertical with top down
14. Attach string to eyelet of support bracket.
15. Verify the angle of PCV is as prescribed above.
16. Take a short length of string (about 3 inches) and saturate with alcohol. Tie string around PCV support string.
17. Verify that occupants on the 0' level are behind safety rope.
18. Strike match and light alcohol saturated string. Support string should be burnt through, thereby releasing the PCV. If this does not occur, repeat steps 16 thru 18.
19. Repeat steps 13 thru 18 for all PCV's.
20. Photograph damage to each PCV at conclusion of drop test. Include PCV serial number in each photograph.
21. Place a 1/4" thick lead plate on top of 4" steel plate.
22. Place each PCV onto the lead plate with its ϕ horizontal.
23. Drop a hand held 1" diameter rod a minimum distance of 40 inches onto the side wall of each PCV. Person holding rod shall stand within the roped area, but behind the plywood barricade during drop.
24. Repeat step 20.

Post Drop Step

25. Leak test each GPHS-PCV in an evacuated envelope with a helium mass spectrometer in accordance with ANSI N 14.5 paragraph A 3.10.1. Label leak test data sheet "Post Drop Test Leak Test Data". Record serial number of each container and its measured leakage rate.

1.11 REFERENCES

1. Chalfant, G. G., Safety Analysis Report - Packages, PISA Shipping Container, November 1979, USDOE report DPST-78-124-1, E. I. du Pont de Nemours and Company, SRP, Aiken, S.C. 29801.
2. Roark, Raymond J., Formulas for Stress and Strain, Third Edition.
3. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 and 2. 1974 Edition.
4. Chalfant, G. G., Safety Analysis Report - Packages, Pu Oxide and Am Oxide Shipping Cask, September 1979, USDOE report DPSPU-79-124-1, E. I. du Pont de Nemours and Company, SRP, Aiken, SC 29801.

CHAPTER 2.0 THERMAL EVALUATION

	<u>Page No.</u>
2.1 Discussion	2-1
2.1.1 Normal Transport with 6 GPHS Capsules	2-1
2.1.2 Hypothetical Accident with 6 GPHS Capsules	2-1
2.2 Summary of Thermal Properties of Materials.	2-1
2.3 Design Criteria of Components	2-1
2.4 Thermal Evaluation for Normal Conditions of Transport	2-2
2.4.1 Thermal Model	2-2
2.4.1.1 Analytical Model	2-2
2.4.1.2 Test Model Using the Model C Cask	2-7
2.4.2 Maximum Temperatures.	2-7
2.4.3 Minimum Temperatures	
2.4.4 Maximum Internal Pressure	
2.4.4.1 Calculation of Internal Pressure for - Normal Transport Conditions - Primary Container. . .	2-8
2.4.4.2 Calculation of Internal Pressure for - Normal Transport Conditions - Secondary Container . .	2-10
2.4.5 Maximum Thermal Stress	2-12
2.4.6 Evaluation of Package Performance for - Normal Conditions of Transport	2-12
2.5 Hypothetical Thermal Accident Evaluation	2-12
2.5.1 Thermal Model	2-12
2.5.1.1 Analytical Model	2-12
2.5.1.2 Test Model	2-15
2.5.2 Package Condition and Environment	2-15

	<u>Page No.</u>
2.5.3 Package Temperatures	2-15
2.5.4 Maximum Internal Pressure	2-15
2.5.4.1 Primary Container Internal Pressure - Hypothetical Fire Conditions	2-15
2.5.4.2 Secondary Container Internal Pressure - Hypothetical Fire Conditions	2-16
2.5.5 Maximum Thermal Stresses	
2.5.6 Evaluation of Package Performance for the Hypothetical Thermal Accident	2-17
2.6 References	2-17

2.0 THERMAL EVALUATION

2.1 DISCUSSION

The General Purpose Heat Source (GPHS)^[1] will be transported in the same 5320 cask that is used to transport the PISA heat source.^[2] Two encapsulated GPHS's (maximum 77.7 watts each) will be loaded into a 2-inch diameter x 4.32-inch long primary containment vessel and up to three such primary containment vessels will be loaded into the EP-62 secondary containment vessel of the 5320 cask. This arrangement differs little from the PISA shipment that permits four PISA sources (maximum 125.5 watts each), each loaded into a 2-inch diameter x 2.87-inch long primary containment vessel, to be loaded into the EP-62 secondary vessel.

The thermal analysis that supports safe transport of the GPHS in the 5320 cask is an extension of the existing analysis in the SAR for the PISA shipment.^[2] Therefore, in this supplement, an abbreviated analysis provides the pertinent temperatures and pressures associated with the geometry of the GPHS primary containment vessel. Note that the nuclear heat load of 6 GPHS's (1589 BTU/hr) is lower than 4 PISA heat sources (1719 BTU/hr) resulting in slightly lower steady state temperatures for the normal and accident conditions.

Pertinent calculated results of the thermal analysis are summarized below. Values in parentheses are calculated results for four PISA capsules from the PISA Safety Analyses Report^[2] and are presented for comparison.

2.1.1 Normal Transport with 6 GPHS Capsules

Ambient temperature	130°F	(130°F)
Cask fin temperature	209°F	(231°F)
Surface temperature of secondary container	258°F	(285°F)
Surface temperature of primary container	541°F	(665°F)

2.1.2 Hypothetical Accident with 6 GPHS Capsules

Surface temperature of secondary container	1539°F	(1548°F)
Surface temperature of primary container	1612°F	(1647°F)

2.2 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

The GPHS primary container is composed of 304 SS whose thermal properties are summarized in Table 2.1 of the PISA Safety Analysis Report.^[2] All other cask materials are the same as for the PISA cask and also are given in Table 2.1.

2.3 DESIGN CRITERIA OF COMPONENTS

Primary Container - Section VIII of ASME Boiler and Pressure Code: 125 psi at 700°F

Design Criteria for other cask components are given in Section 2.3 of the PISA Safety Analysis Report.^[2]

2.4 THERMAL EVALUATION FOR NORMAL CONDITIONS OF TRANSPORT

2.4.1 Thermal Model

2.4.1.1 Analytical Model

Calculation of GPHS Cask Temperatures for Normal Transport Conditions

A. Decay Heat Generation in ^{238}Pu

$$\text{Specific Power (P)} = \left(\frac{\ln 2}{\tau_{1/2}}\right) \left(\frac{N_0}{A}\right) E$$

where

$$\tau_{1/2} = \text{Half life} = 86.4 \text{ yrs.}$$

$$N_0 = \text{Avagadro's No.} = 6.023 \times 10^{23} \text{ atoms/gm-at.wt.}$$

$$A = \text{Atomic wt.} = 238 \text{ gms.}$$

$$E = \text{Energy disipation per disintegration} = 5.5 \text{ Mev/dis.}$$

$$P = \text{Mev/sec/gm.}$$

The 5.5 Mev/dis. value conservatively assumes that all of the α decay and associated γ leading to the ground state of ^{234}U is captured to produce heat. The specific power generation in ^{238}Pu is given by:

$$P = \frac{\ln 2}{(86.4 \text{ yr})(3.154 \times 10^7 \text{ sec/yr})} \left(\frac{6.023 \times 10^{23}}{238}\right) (5.5) \times (1.6 \times 10^{-13} \text{ watt-sec/Mev})$$

$$P = 0.567 \text{ watts/gm.}$$

B. Calculational Model and Assumptions

The following calculations conservatively are based on package Model C which has a shield tank of 10.75-inches O.D. and 64 cooling fins rather than on package Model D which has a shield tank of 12.75-inch O.D. and 99 cooling fins.

The following assumptions are made in the calculational model;

- o One dimensional steady state heat transfer occurs through side walls only.
- o 3 GPHS primary containment vessels are concentrically centered on the axial centerline of the EP62 secondary containment vessel.
- o A total of 6 GPHS's are contained each with 137 gms of ^{238}Pu as PuO_2 .
- o A daily average solar radiation heat flux of 144 BTU/hr-ft^2 is incident on the surface of the 5320 cask.
- o Ambient air temperature is 130°F .

C. Temperature Calculations

1. Surface Temperature (T_s) of the 5320 Cask

The heat balance equation that describes convection and radiation heat transfer from the surface of the 5320 cask to the environment is given by:

$$Q_t = h_c A_c (T_s - T_a) + 0.173 F_e F_a A_r \left[\left(\frac{T_s + 460}{100} \right)^4 - \left(\frac{T_a + 460}{100} \right)^4 \right] \quad [3]$$

where:

$$Q_t = \text{nuclear heat load} + \text{solar heat load} = \\ Q_n + Q_s = 1589 + 240 = 1829 \text{ BTU/hr}$$

$$Q_n = 137 \text{ gm } ^{238}\text{Pu} \times 0.567 \text{ watts/gm} \times 3.41 \text{ BTU/hr-watt} \times \\ 6 \text{ GPHS's} = 1589 \text{ BTU/hr}$$

$$Q_s = (144 \text{ BTU/hr-ft}^2)(\alpha)(A_s) = 240 \text{ BTU/hr}$$

where:

$$\alpha = \text{solar absorptance in Al} = 0.8$$

$$A_s = \text{projected surface area of cask} = 2.08 \text{ ft}^2$$

$$h_c = \text{convective heat transfer coefficient} = 0.19 (T_s - T_a)^{0.33} \\ \text{BTU/hr-ft}^2\text{-}^\circ\text{F}$$

$$T_s = \text{surface temperature of cask, } ^\circ\text{F}$$

$$T_a = \text{ambient temperature} = 130^\circ\text{F}$$

$$F_a = \text{geometry shape factor for radiation to surroundings} = 1$$

$$F_e = \text{factor to account for non black-body conditions}$$

$$= \frac{1}{1 + \frac{s}{S} \left(\frac{1}{\epsilon_r} - 1 \right)} = 0.728$$

where:

$$s = \text{average face-to-face distance between fins} = 0.04 \text{ ft.}$$

$$\epsilon_r = \text{surface emissivity of the cask shell and fins} = 0.27$$

$$S = s + 2\ell = 0.290 \text{ ft.}$$

where

$$\ell = \text{fin height} = .125 \text{ ft.}$$

$$A_r = \text{effective radiative surface area} = \pi(D_o + 2\ell)L' + \\ \pi D_o(L - L') = 5.46 \text{ ft}^2$$

where

$$D_o = \text{cask outer diameter} = 0.986 \text{ ft.}$$

$$\ell = \text{fin height} = 0.125 \text{ ft.}$$

$$L = \text{cask length} = 1.65 \text{ ft.}$$

$$L' = \text{fin length} = 1.04 \text{ ft.}$$

$$A_c = \text{effective convective surface area} = (\pi D_o L - n_f y_o L') + n_f (2 \ell L')$$

where

$$n_f = \text{number of fins} = 64$$

$$y_o = \text{fin thickness} = 0.0104 \text{ ft.}$$

$$\eta = \text{fin efficiency} = \frac{\text{Tanh } b}{b}$$

where

$$b = \ell \sqrt{\frac{2h_c}{ky_o}}$$

where

$$k = \text{thermal conductivity of Al} = 118 \text{ BTU/hr-ft.}^\circ\text{F}$$

Assume $T_s = 208.5^\circ\text{F}$, then

$$h_c = 0.19(208.5 - 130)^{0.33} = 0.802 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

$$b = (0.125) \sqrt{\frac{(2)(.802)}{(118)(.0104)}} = 0.143$$

$$\eta = \frac{\text{Tanh } 0.143}{.143} = 0.994$$

$$\begin{aligned} A_c &= (\pi)(.986)(1.65) - (64)(.0104)(1.04) + (.994)(64)(2) \times \\ &\quad (.125)(1.04) \\ &= 20.96 \text{ ft}^2 \end{aligned}$$

$$\begin{aligned} Q_t &= (.802)(20.96)(78.5) + (.173)(.728)(5.46) \left[(6.685)^4 - (5.90)^4 \right] \\ &= 1290.0 + 540.1 = 1830.1 \text{ BTU/hr vs. } 1829 \text{ BTU/hr.} \end{aligned}$$

$$\therefore T_s = 208.5^\circ\text{F}$$

2. Temperature Rise (ΔT_w), From Outer to Inner Aluminum Shell of 5320 Cask

The conservative assumption is made that all internal energy passes from the inner surface to the outer surface of the cask through the eight aluminum webs only. Conduction through the WEP shielding material between the webs is neglected. The temperature rise is given by:

$$\Delta T_w = \frac{L_w Q_n}{A_w k_w}$$

where

$$A_w = \text{cross sectional area for heat transfer} \\ = 8 \text{ webs} \times .01042 \text{ ft.} \times 1.042 \text{ ft.} = .0868 \text{ ft}^2$$

$$L_w = \text{length of heat transfer path} \\ = 1.5 + \frac{2.01}{\cos 20^\circ} + .365 = 4.00 \text{ in.} = 1/3 \text{ ft.}$$

$$Q_n = \text{nuclear heat load} = 1589 \text{ BTU/hr.}$$

$$k_w = \text{thermal conductivity of Al} = 123 \text{ BTU/hr-ft-}^\circ\text{F}$$

then

$$\Delta T_w = \frac{(1/3)(1589)}{(.0868)(123)} = 49.6^\circ\text{F}$$

$$\therefore \text{Temperature of inner surface of the 5320 cask} = 208.5^\circ\text{F} + 49.6^\circ\text{F} = 258^\circ\text{F}$$

3. Temperature Rise from the Inner Surface of the 5320 Cask to the Outside Wall of the Secondary Container (S.C.)

No significant temperature gradient exists because the secondary container is a force (press) fit into the 5320 cask.

4. Temperature Rise (ΔT_s) Across the Wall of the Secondary Container (EP62)

The radial heat flow by conduction through a hollow circular cylinder is given by:

$$\Delta T_s = \frac{Q_n \ln(r_o/r_i)}{2\pi k_s L'} \quad [3]$$

where

$$Q_n = 1589 \text{ BTU/hr}$$

$$k_s = \text{thermal conductivity of 304 SS at } 250^\circ\text{F} = 9.12 \text{ BTU/hr-ft-}^\circ\text{F}$$

$$L' = \text{fin length} = 1.04 \text{ ft.}$$

$$r_o = \text{outer radius of EP62} = 0.09808 \text{ ft.}$$

$$r_i = \text{inner radius of EP62} = 0.08592 \text{ ft.}$$

then

$$\Delta T_s = \frac{(1589) \ln \frac{.09808}{.08592}}{2\pi (9.12) (1.04)} = 3.5^\circ\text{F}$$

$$\text{Temperature of inner wall of EP62 } (T_{is}) = 258 + 3.5 = 261.5^\circ\text{F}$$

5. Temperature Rise (ΔT_{sp}) Across Air Gap Between Secondary (SC) and the Primary Containment (PC) Vessel

$$\Delta T_{sp} = \frac{Q_n}{\frac{2\pi k_{air} L'}{\ln(r_1/r_2)} + h_r A_{op}} \quad [3]$$

where

$$k_{air} = \text{thermal conductivity of air} = 9.71 \times 10^{-5} \left(\frac{T_{is} + T_{op}}{2} + 460 \right)^{0.8}$$

$$Q_n = 1589 \text{ BTU/hr}$$

$$L' = 1.04 \text{ ft.}$$

$$r_1 = \text{inner radius of EP62} = 0.08592 \text{ ft.}$$

$$r_2 = \text{outer radius of primary containment vessel} = 0.08333 \text{ ft.}$$

$$A_{op} = \text{outer surface area of primary containment vessels} \\ = (3 \text{ vessels}) \times \frac{(2.00)(\pi)(4.156)}{144} = 0.544 \text{ ft.}^2$$

$$h_r = \frac{.173 F_e F_a}{\Delta T_{sp}} \left[\left(\frac{T_{op} + 460}{100} \right)^4 - \left(\frac{T_{is} + 460}{100} \right)^4 \right]$$

where

$$T_{op} = \text{temperature of outer surface of the PC}$$

$$T_{is} = \text{temperature of inner surface of the SC} = 261.5^\circ\text{F}$$

$$F_a = \text{geometry view factor} = 1.0$$

$$F_e = \frac{1}{\frac{1}{\epsilon_1} + \frac{r_2}{r_1} \left(\frac{1}{\epsilon_2} - 1 \right)} = 0.43$$

where

$$\epsilon_1 = \text{emissivity of outside surface of PC} = 0.6$$

$$\epsilon_2 = \text{emissivity of inside surface of SC} = 0.6$$

assume $T_{op} = 541.5^\circ\text{F}$ ($\Delta T = 280^\circ$), then

$$k_{air} = 9.71 \times 10^{-5} \left[\frac{261.5 + 541.5}{2} + 460 \right]^{0.8} = 0.02165$$

$$h_r = \frac{(.173)(0.43)(1)}{541.5 - 261.5} \left[\left(\frac{541.5 + 460}{100} \right)^4 - \left(\frac{261.5 + 460}{100} \right)^4 \right] = 1.9528$$

$$\Delta T_{sp} = \frac{1589}{\frac{2\pi(.02165)(1.04)}{\ln \frac{.08592}{.08333}} + (1.9528)(.544)} = 279.5^\circ\text{F}$$

This is in good agreement with the assumed $T_{sp} = 280^\circ\text{F}$

The surface temperature of the primary container (T_{sp}) = $261.5 + 279.5 = 541^\circ\text{F}$.

6. Temperature Rise (ΔT_p) Across the Wall of the Primary Container

$$\Delta T_p = \frac{Qn \ln(r_2/r_3)}{2\pi k_p L'}$$

where

L' = active length of 4 GPHS's $\approx$ 1.04 ft. (conservative)

r_3 = inner radius of PC = .07804 ft.

k_p = thermal conductivity of 304 SS at 550°F
 = 10.45 BTU/hr-ft-°F

$$\Delta T_p = \frac{1589 \ln \frac{.08333}{.07804}}{2\pi (10.45)(1.04)} = 1.5^\circ\text{F}$$

•• Temperature of inner wall of the primary container = 541 + 1.5 = 543°F.

2.4.1.2 Test Model Using the Model C Cask

A thermal test was completed in support of the SAR for the PISA shipping package. Test conditions and results are reported in Table 2.2 of Reference 2. The experimental temperature data are equally valid for comparison with the GPHS thermal analyses.

2.4.2 Maximum Temperatures

The maximum measured temperatures of the thermal test have been linearly adjusted to the 1589 BTU/hr heat load corresponding to six GPHS's and are compared with calculated temperatures in Table 2.1.

Table 2.1

Maximum Temperature Distribution for Normal Transport

	Adjusted Temp. From Expt., °F	Calculated Temp., °F
Surface of primary container	598	541
Surface of secondary container	247	258
Secondary container gasket	217	-
WEP	217	-
Cask fin	182	209
Personnel barrier	162	-
Ambient temperature	150	130

The calculated temperatures were used to establish normal transport limits for the primary and secondary containers.

2.4.3 Minimum Temperatures

The analysis for a minimum temperature of -40°F is given in Section 2.4.3 of Reference 2.

2.4.4 Maximum Internal Pressures

The maximum internal pressure in the secondary containment vessel under normal conditions of transport is calculated to be 20.7 psig at 258°F . The calculation assumes that all primary containers fail, all GPHS encapsulations fail and a He gas generation buildup from α -decay over a 1-year period.

The maximum internal pressure in the primary containment vessel under normal conditions is calculated to be 116 psig at 541°F . The calculation conservatively assumes that both GPHS encapsulations fail and a He gas generation buildup from α -decay over a 1-year period.

The calculations are summarized in detail below.

2.4.4.1 Calculation of Internal Pressure for Normal Transport Conditions - Primary Container

A. He Gas Formation from ^{238}Pu Alpha Decay

The rate of He formation from 1 gram of ^{238}Pu is given by:

$$\frac{dn}{dt} = -2N \quad [4]$$

where

$$\lambda = \frac{\ln 2}{\tau_{1/2}}$$

where

$$(\tau_{1/2})_{^{238}\text{Pu}} = 87.74 \text{ yr}$$

$$N = \frac{(\text{gms of } ^{238}\text{Pu})(N_0)}{238}$$

where

$$N_0 = 6.023 \times 10^{23} \text{ atoms/gm-at.wt.}$$

The number of He atoms produced in one year from one gram of ^{238}Pu is given by $N(1-e^{-\lambda}) = 1.99 \times 10^{19}$ He atoms/yr/gm of ^{238}Pu .

The volume of He formed (V_{He}) at STP is given by:

$$V_{\text{H}} = \frac{2.00 \times 10^{19}}{6.023 \times 10^{23}} \times 22.4 = 7.438 \times 10^{-4} \text{ l/yr/gm of } ^{238}\text{Pu}$$

Since 1 GPHS contains 137 grams of ^{238}Pu , in one year a total of .1019 liters of He (STP) will be formed or 1.821×10^{-2} gms at STP.

Note: Process control and iridium encapsulation exclude moisture from the GPHS and primary containment vessel.

R. Free Volume in GPHS

The minimum internal volume of the GPHS = 16.678 cm^3

The maximum volume of PuO_2 = $\frac{155.5\text{g}}{11.46\text{g/cc}} = 13.572 \text{ cm}^3$

$\therefore$ minimum free volume = $16.678 - 13.572 = 3.106 \text{ cm}^3/\text{GPHS}$

C. Free Volume in the Primary Containment Vessel

Minimum internal volume of the PC vessel = 173.88 cm^3

$$\begin{aligned} \text{Maximum volume of graphite} &= 4 \text{ pcs} \times \pi \left[\left(\frac{1.868^2}{2} \right) (.76) - \left(\frac{.74^2}{2} \right) (.29) - \right. \\ &\quad \left. \left(\frac{1.185^2}{2} \right) (4.7) \right] \\ &= 5.7591 \text{ in}^3 = 94.374 \text{ cm}^3 \end{aligned}$$

$$\text{Maximum volume of graphite felt} = \pi \left(\frac{1.85^2}{2} \right) (.850) = 2.285 \text{ in}^3 = 37.442 \text{ cm}^3$$

$$\text{bulk density} = .102 \text{ gm/cm}^3$$

$$\text{theoretical density} = 2.25 \text{ gm/cm}^3$$

$$\text{effective volume} = (37.442) \left(\frac{.102}{2.25} \right) = 1.697 \text{ cm}^3$$

$$\text{maximum volume of PuO}_2 = 2 \times \frac{155.5 \text{ gm PuO}_2}{11.46 \text{ gm/cm}^3} = 27.138 \text{ cm}^3$$

$$\text{maximum volume of Ir} = 2 \times \frac{28.0 \text{ gm}}{22.42 \text{ gm/cm}^3} = 2.50 \text{ cm}^3$$

$$\text{Free volume in the primary containment vessel} = 173.88 - 94.374 - 1.697 - 27.138 - 2.50 = 48.171 \text{ cm}^3$$

D. Surface Temperature of the Primary Containment Vessel at Time of Closure

Assuming heat transfer from the surface of the primary containment vessel by convection and radiation to the surroundings:

$$Q_n = h_c A_c (T_s - T_a) + 0.173 F_e F_a A_r \left[\left(\frac{T_s + 460^4}{100} \right) - \left(\frac{T_a + 460^4}{100} \right) \right]$$

where

$$Q_n = 530 \text{ BTU/hr}$$

$$A_c = A_r = .1813 \text{ ft}^2$$

$$T_a = 76^\circ\text{F}$$

$$F_a \approx 1.0$$

$$F_e = 0.6$$

$$k_c = 0.19 (T_s - T_a)^{.33}$$

$$\text{Assume } T_s = 715^\circ\text{F, then } T_s - T_a = 639^\circ\text{F}$$

$$Q_n = (0.19)(639)^{.33} (.1813)(639) + (.173)(.6)(.1813) \times$$

$$\left[\left(\frac{715 + 460^4}{100} \right) - \left(\frac{76 + 460^4}{100} \right) \right]$$

$$Q_n = 185.6 + 343.2 = 529 \text{ BTU/hr}$$

Assume He cover gas entrapped during welding of the primary container is at the temperature of the surface of the primary container, i.e. 715°F.

E. He Mass Entrapped Inside the Primary Containment Vessel

Assume:

100% He atmosphere

Free volume = 48.2 cm³

Gas Temperature ≈ 715°F

Pressure = 14.7 psia

$$\text{He Mass} = \frac{Pv}{RT} = \frac{(14.7)(144)(48.2)3.532 \times 10^{-5}}{(386)(715 + 460)} = 7.95 \times 10^{-6} \text{ lb}_m$$

F. Internal Pressure in the Primary Containment Vessel

Assume conservatively that the GPHS encapsulation fail

$$P_p = \frac{RT_n M}{V}$$

where

P_p = pressure in the primary containment vessel

T_n = temperature of the He gas in the primary containment vessel ≈ 600°F* = 588.6°K

M = moles of He = 1.00 x 10⁻²

V = free volume = .0544 l

R = gas content = .08206 l-atm/mole-°K

$$P_p = \frac{(.08206)(588.6)(1.0 \times 10^{-2})}{.0544} = 8.88 \text{ atms} = 131 \text{ psia}(116 \text{ psig})$$

*The temperature of the gas in the primary containment vessel is assumed to be closely the same temperature as the surface of the primary containment vessel; viz, 598°F.

2.4.4.2 Calculation of Internal Pressures for Normal Transport Conditions - Secondary Container

A. Free Volume in the Secondary Containment Vessel

$$\begin{aligned} \text{maximum external volume of the PC vessel} &= \pi \left(\frac{2.005^2}{2} \right) 4.161 + \\ &\pi \left(\frac{1.945^2}{2} \right) .100 + \pi \left(\frac{1.945^2}{2} \right) .070 = 13.643 \text{ in}^3 = 223.56 \text{ cm}^3 \end{aligned}$$

maximum volume of energy absorber spacers

3 spacers at 1.6" diam. x 1/2" high = 15.73 cm³

2 spacers at 3.75" diam. x 2" high = 361.98 cm³

(361.98 + 15.73)(.6042 gm/cm³) = 228.21 gms of SS

$$\text{volume of SS} = \frac{228.21}{8.03} = 28.42 \text{ cm}^3$$

volume of EP62 secondary containment vessel = 1860.6 cm^3

free volume inside EP62 = $1860.6 - (3)(223.56) - 28.42 = 1161.5 \text{ cm}^3$

B. Internal Pressure in the Secondary Containment Vessel

a) Case 1 - Integrity of the primary containment vessel maintained.

P_s - secondary container pressure at closure = 14.7 psia

T_s - secondary container temperature at closure = 70°F

T_{sn} - secondary container temperature during normal transport = 262°F

P_{si} - secondary container pressure during normal transport

$$P_{si} = \left(\frac{T_{sn}}{T_s}\right)P_s$$

$$= \left(\frac{262 + 460}{70 + 460}\right)(14.7) = 20.0 \text{ psia (5.3 psig)}$$

b) Case 2 - All primary containers fail and all GPHS encapsulations fail.

Assume that all of the gaseous products are uniformly mixed. Regions, temperatures and volumes are summarized below.

<u>Region</u>	<u>Aug Temp.</u>	<u>Free Volume, cm^3</u>
6 - GPHS's	1472°F	18.7
3 - Primary Container's	543°F	144.5
Secondary Container	401°F	<u>1161.5</u>
Total		1.324 ℓ

The volume weighted average temperature is 432°F (495°K)

The gaseous contents are summarized below:

a) 2.73×10^{-2} moles of He from α -decay (6 GPHS's)

b) 2.71×10^{-3} moles of He entrapped in three primary containers

c) 4.85×10^{-2} moles of air based on $\rho_{\text{air}} = 1.208 \times 10^{-3} \text{ gm/cm}^3$,
($M_{\text{air}} = 29$)

The total pressure is given as the sum of partial pressures.

For He

$$P_{\text{He}} = \frac{\text{MRT}}{V} = \frac{(2.73 \times 10^{-2} + 2.71 \times 10^{-3})(.08206)(495)}{1.324} =$$

.92 atms.

For air

$$P_{\text{air}} = \frac{(4.85 \times 10^{-2})(.08206)(495)}{1.324} = 1.49 \text{ atms}$$

$$\text{Total Pressure} = 1.49 + .92 = 2.41 \text{ atms} = 35.4 \text{ psia} (20.7 \text{ psig})$$

2.4.5 Maximum Thermal Stress

The heat generation and temperature associated with the GPHS loading in the PSIA cask are less than for the PISA loading. Therefore, thermal stresses are no more severe.

2.4.6 Evaluation of Package Performance for Normal Conditions of Transport

The heat generation and temperatures associated with the GPHS loading in the PISA cask are less than for the PISA loading evaluated in the PISA Safety Analysis Report [2]. Therefore, the analyses in the PISA Safety Analysis Report are conservatively valid for the GPHS loading.

2.5 HYPOTHETICAL THERMAL ACCIDENT EVALUATION

A description of the protection afforded to the primary and secondary containers by the WEP overpack during the hypothetical accident is given in Section 2.5 of the PISA Safety Analysis Report [2]. The tests conducted to support the adequacy of the PISA cask for the PISA heat source are equally valid to support the safe use of the PISA cask for the GPHS capsules.

2.5.1 Thermal Model

2.5.1.1 Analytical Model

Calculation of GPHS Cask Temperatures for Hypothetical Accident Conditions

A. Calculational Model and Assumptions

The calculational model used for the hypothetical accident conditions assumes that the aluminum tank and fins and the WEP shielding are destroyed and removed or melt away in the accident and ensuing fire. Other assumptions are listed below:

- o one dimensional steady state heat transfer occurs through side walls only in a fire at 1475°F
- o 3 GPHS primary containment vessels are concentrically centered on the axial centerline of the EP62 secondary containment vessel
- o a total of 6 GPHS's are contained each with 137 gms of ^{238}Pu as PuO_2 .

B. Temperature Calculations

1. Surface Temperature (T_{ss}) of the Secondary Containment Vessel (EP62)

Conservatively assuming heat removal by thermal radiation only:

$$Q_n = 0.173 F_a F_e A_{os} \left[\left(\frac{T_{ss} + 460^4}{100} \right) - \left(\frac{T_f + 460^4}{100} \right) \right] \quad [5] \text{ Page 134}$$

where

F_a = geometry view factor ≈ 1

A_{os} = radiative surface area of EP62 = $\pi DL'' = 0.640 \text{ ft}^2$

where

$L'' = (3)(\text{length of primary container}) = 1.039 \text{ ft}$

D = O.D. of EP62 = 0.196 ft

T_f = temperature of fire = 1475°F

F_e = factor to account for gray body conditions

$$= \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_f} - 1} = .734$$

where

ϵ_1 = emissivity of EP62 = 0.8 [6]

ϵ_f = flame emissivity = 0.9

Q_n = nuclear heat load = 1589 BTU/hr

$$1589 = (0.173)(1)(.734)(0.640) \left[\left(\frac{T_{ss} + 460^4}{100} \right) - \left(\frac{1475 + 460^4}{100} \right) \right]$$

$T_{ss} = 1539^\circ\text{F}$

2. Temperature Rise (ΔT_s) Across the Wall of the Secondary Container (EP62) by Conduction

$$\Delta T_s = \frac{Q_n \ln(r_o/r_i)}{2\pi k_s} \quad [3]$$

where

Q_n = 1589 BTU/hr

r_o = outer radius of EP62 = .09808 ft.

r_i = inner radius of EP62 = .08592 ft.

k_s = thermal condition of SS at 1540°F = 14.82 BTU/hr-ft- $^\circ\text{F}$

then

$$T_s = \frac{(1589)(1\pi \frac{.09808}{.08592})}{2\pi(14.82)} = 2.2^\circ\text{F}$$

• Temperature of inner wall of EP62 (T_{is}) = $1539 + 2.0 = 1541^\circ\text{F}$

3. Temperature Rise (ΔT_{sp}) Across Air Gap Between Secondary Container (SC) and the Primary Containmentment (PC) Vessel

$$\Delta T_{sp} = \frac{Q_n}{\frac{2\pi k_{air} L'}{\ln(r_1/r_2)} + h_r A_{op}} \quad [3]$$

where

$$k_{air} = \text{thermal conductivity of air} = 9.71 \times 10^{-5} \left(\frac{T_{is} + T_{op}}{2} + 460 \right)^{0.8}$$

$$Q_n = 1589 \text{ BTU/hr}$$

$$L' = 1.04 \text{ ft}$$

$$r_1 = 0.08592 \text{ ft}$$

$$r_2 = \text{outer radius of the PC vessel} = 0.08333 \text{ ft}$$

$$A_{op} = \text{outer surface area of the PC vessels} = 0.544 \text{ ft}^2$$

$$h_r = \frac{.173 F_a F_e \left[\left(\frac{T_{op} + 460}{100} \right)^4 - \left(\frac{T_{is} + 460}{100} \right)^4 \right]}{\Delta T_{sp}}$$

where

$$T_{op} = \text{temperature of outer surface of the PC}$$

$$T_{is} = 1541^\circ\text{F}$$

$$F_a = 1$$

$$F_e = \frac{1}{\frac{1}{\epsilon_1} + \frac{r_2}{r_1} \left(\frac{1}{\epsilon_2} - 1 \right)} = 0.43$$

where

$$\epsilon_1 = \text{emissivity of outside surface of PC} = 0.6$$

$$\epsilon_2 = \text{emissivity of inside surface of SC} = 0.6 \quad [3]$$

assume $T_{op} = 1610.5^\circ\text{F}$, then $\Delta T_{sp} = 69.5$ and

$$k_{air} = 9.71 \times 10^{-5} \left(\frac{1541 + 1610.5}{2} + 460 \right)^{0.8} = .04307$$

$$h_r = \frac{(.173)(.43)}{66} \left[(20.705)^4 - (20.01)^4 \right] = 25.112$$

$$\Delta T_{sp} = \frac{1589}{\frac{2\pi(.04307)(1.039)}{\ln(\frac{.08592}{.08333})} + (25.112)(.544)} = 69.5^\circ\text{F}$$

This is in good agreement with the assumed $\Delta T_{sp} = 69.5^{\circ}\text{F}$

∴ The surface temperature of the primary container (T_{os}) =
 $1541 + 69.5 = 1610.5^{\circ}\text{F}$

4. Temperature Rise (ΔT_p) Across the Wall of the Primary Container

$$\Delta T_p = \frac{Q_n \ln\left(\frac{r_2}{r_3}\right)}{2\pi k_p L'}$$

where

$$L' = 1.04 \text{ ft}$$

$$Q_n = 1589 \text{ BTU/hr}$$

$$r_2 = 0.08333 \text{ ft}$$

$$r_3 = 0.07804 \text{ ft}$$

$$k_p = \text{thermal conductivity of 304 SS at } 1610^{\circ}\text{F} = 15.13$$

$$\Delta T_p = \frac{.589 \ln\left(\frac{8333}{7804}\right)}{2\pi (15.13)(1.04)} = 1.1^{\circ}\text{F}$$

∴ Temperature of inner wall of the primary container = $1611 + 1 = 1612^{\circ}\text{F}$.

2.5.1.2 Test Model

The test model used to qualify the PISA cask for shipment of PISA capsules is equally valid for use of the PISA cask to ship the GPHS capsules.

The test model used to qualify the GPHS primary containment vessel for special form is described in 1.8.1.

2.5.2 Package Condition and Environment

Test results reported in Section 2.5.2 of the PISA Safety Analysis Report [2] are valid for a package containing three GPHS capsules.

2.5.3 Package Temperatures

Measured package temperatures of the test model reported in Section 2.5.3 of the PSIA Safety Analysis Report [2] are lower than those calculated by the same methods used in the GPHS evaluation of this report. The calculated temperatures conservatively have been used to establish accident condition limits for the primary and secondary containers.

2.5.4 Maximum Internal Pressure

2.5.4.1 Primary Container Internal Pressure - Hypothetical Fire Conditions

Assume conservatively that the GPHS encapsulations fail:

$$P_{pf} = \frac{RT_A M}{V}$$

where

P_{pf} = pressure in the primary containment vessel

T_A = temperature of primary container = 1612°F (1151°K)

M = moles of He = $9.11 \times 10^{-3} + 9.02 \times 10^{-4} = 1.00 \times 10^{-2}$

V = free volume = .0544 l

R = .08206 l-atm/mole-°K

$$P_{pf} = \frac{(.08206)(1151)(1.00 \times 10^{-2})}{.0544} = 17.4 \text{ atms} = 256 \text{ psia} (242 \text{ psig})$$

The maximum pressure within the GPHS primary containment vessel is 242 psig at 1612°F under hypothetical accident conditions. The special form test reported in 1.8.1 resulted in an internal pressure of 243 psig at 1625°F inside the GPHS-PCV. No permanent deformation or loss of containment was measured. Burst tests, performed in accordance with 1.10.2.6 indicate a burst strength of 4900 psig at 70°F. The burst pressure is reduced to 737 psig at 1612°F. Thus, the primary containment vessel is capable of supporting an internal pressure of 242 psig at 1611°F without failure or leakage of its contents.

2.5.4.2 Secondary Container Internal Pressure - Hypothetical Fire Conditions

Assume that all primary containers fail and all GPHS encapsulations fail.

Regions, temperatures and volumes are summarized below:

<u>Region</u>	<u>Aug. Temp.</u>	<u>Free Volume, cm³</u>
6 - GPHS's	2600°F (estimated)	18.7
3 - Primary Containers	~1612	144.5
Secondary Container	~1539	<u>1161.5</u>
Total		1.324 l

The volume weighted average temperature is 1563°F (1123°K)

The analysis is identical to Section 2.4.4.2,B,b with $T = 1123^\circ\text{K}$

The total pressure = $2.09 + 3.38 = 5.47 \text{ atms} = 80.4 \text{ psia} (65.7 \text{ psig})$

The maximum pressure within the secondary container is 66 psig at 1539°F under hypothetical accident conditions. The secondary container was hydrostatically tested to 425 psig at 70°F. The hydrostatic test pressure would be reduced to 106 psig at 1550°F. Thus the secondary container is capable of supporting an internal pressure of 66 psig.

2.5.5 Maximum Thermal Stresses

The temperature differential throughout the primary container is relatively small and will cause no significant thermal stresses. There is no rigid constraint between the primary container and the secondary container.

Thermal stresses in the remainder of the PISA cask have been tested in Section 2.5.5 of the SAR for the PISA cask. [2]

2.5.6 Evaluation of Package Performance for the Hypothetical Thermal Accident

The substitution of three GPHS primary containment vessels for four PISA primary containment vessels in the PISA cask does not compromise the conclusions of an adequate, safe design that were stated in Section 2.5.6 of the SAR for the PISA cask. [2]

2.6 REFERENCES

1. Snow, E. C. & Zocher, R. W., General Purpose Heat Source Development, Phase I Design Requirements, LA -7385-SR, September 1978.
Snow, E. C., Zocher, R. W., Grinberg, I. M., and Hulbert, L. E., General Purpose Heat Source Development, Phase I Conceptual Design, LA-7546-SR, November 1978.
2. Chalfant, G. G., Safety Analysis Report - Packages, PISA Shipping Container, November 1979, USDOE Report DPST-78-124-1, E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, SC 29801.
3. Kreith, F., Principles of Heat Transfer, 3rd Edition, IEP, New York (1973).
4. Glasstone, S., and Edlund, M.C., The Elements of Nuclear Reactor Theory, 2nd Edition, D. Van Nostrand Co., Inc. (1954).
5. Shappert, L. B., Cask Designers Guide, USDOE Report ORNL-NSIC-68, Nuclear Safety Information Center, Oak Ridge, TN.
6. Code of federal regulations 10 CFR 71, packaging of radioactive material for transport and transportation of radioactive material under certain conditions, Appendix B - hypothetical accident conditions.

CHAPTER 3.0 CONTAINMENT

Page No.

3.1	Containment Boundary	3-1
3.1.2	Containment Vessel	
3.1.3	Seals and Welds	
3.2	Requirement for Normal Conditions of Transport	3-1
3.2.1	Release of Radioactive Material	3-2
3.3	Containment Requirements for the Hypothetical - Accident Conditions	3-2
3.4	References	3-2

3.0 CONTAINMENT

Package containment for normal conditions of transport and for the hypothetical accident conditions are the same as [1] with the following exceptions:

3.1 CONTAINMENT BOUNDARY

The GPHS primary containment vessel is a thin-wall type 304 ss cylindrical pressure vessel of all welded construction without penetrations. The secondary container is as stated in [1].

3.1.2 Containment Vessel

The two GPHS encapsulated heat sources are removed from the primary containment vessel by cutting the vessel on the two scribe index marks.

3.1.3 Seals and Welds

Destructive testing (1.10.2.5) indicates that with full penetration welds, the GPHS primary containment vessel fails in the cylindrical wall, at 4900 psig.

To insure that all containers will be of adequate strength, a fully documented QA/QC program has been implemented for the GPHS primary containment vessel. The bottom welds on the GPHS primary containment are produced by an ASME code fabricator and the top seal weld is applied by DuPont at the Savannah River Plant by a trained welding operator performing in accordance with welding specification and procedure stated in 1.10.2.5.

3.2 REQUIREMENTS FOR NORMAL CONDITIONS OF TRANSPORT

During shipment of the GPHS capsule, the effects of normal transport conditions are:

- o Heat: 130°F ambient plus 466 watts (6 GPHS's) decay heat load results in an average helium atmosphere temperature in the primary containment vessel of 600°F. This, in turn, results in a primary containment vessel outside surface temperature of 541°F. The secondary container surface reaches an average temperature of 258°F.
- o Cold: Same as stated in [1].

3.2.1 Release of Radioactive Material

To prevent release of radioactive material and to meet the requirements of 10CFR71.42, the cask has two boundaries:

- a) GPHS Primary Containment Vessel - all welded construction, rated for 125 psig at 700°F.
- b) Secondary Container - Same as stated in [1]

3.3 CONTAINMENT REQUIREMENTS FOR THE HYPOTHETICAL ACCIDENT CONDITIONS

The "special form" test of the GPHS primary containment vessel under accident conditions in chapter 1.0 demonstrates that there will be no failure of the primary containment boundary. The secondary containment boundary was tested and reported in [1].

The thermal analysis presented in chapter 2.0 shows a maximum surface temperature of 1612°F (with an internal pressure of 242 psig) for the GPHS primary containment vessel, and 1540°F (with an internal pressure of 66 psig) for the secondary containment vessel. The "special form" test of the GPHS primary containment vessel was performed at a surface temperature of 1620°F (minimum) for a period of 10 minutes and resulted in an internal pressure of 243 psig. At the conclusion of the "special form" test, the post accident leak rate of the GPHS-PCV was measured and found to be less than 1×10^{-7} atm cc/sec. air (1×10^{-9} atm cc/se helium actual).

The EP62 secondary containment vessel has been accident tested on two occasions [1 & 2]. In the first accident test [1], the EP62-SCV surface reached a measured maximum temperature of 1500°F while containing an internal pressure of 40 psig (calculated). In the second test [2], the EP62-SCV surface reached 1350°F while containing an internal pressure of 480 psig (measured). The post accident leak rates for test one & two are 4.5×10^{-5} atm cc/sec. air, and 2×10^{-5} atm cc/sec. air respectively.

The above tests on the GPHS-PCV and EP62-SCV verify that the two containment vessels remain leaktight throughout the hypothetical accident conditions in Appendix B and C of 10CFR Part 71 and meet the regulatory acceptance standards for containment.

3.4 REFERENCES

1. Chalfant, G. G., Safety Analysis Report-Packages, PISA Shipping Container, November 1979, USDOE report DPST-78-124-1, E. I. du Pont de Nemours and Company, SRP, Aiken, S.C. 29801.

2. Chalfant, G. G., Safety Analysis Report-Packages, Pu Oxide and Am Oxide Shipping Cask, September 1979, USDOE report DPSPU 79-124-1, E. I. du Pont de Nemours & Company, SRP, Aiken, S.C. 29801

4.0 SHIELDING EVALUATION

The Shipment of six GPHS capsules as described in Chapter 0 is within the range of evaluation shown in chapter 4.0 of DPST-78-124-1.

5.0 CRITICALITY EVALUATION

The shipment of six GPHS capsules as described in chapter 0 is within the range of the analysis shown in chapter 5.0 of DPST-78-124-1.

6.0 OPERATING PROCEDURES

Same as specified in DPST-78-124-1 with the exception that a maximum of three primary containment vessels (each containing a maximum of two GPHS capsules) are used instead of the four PISA primary containers.

7.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Same as specified in DPSP-78-124-1 for the PISA package with the exception of the last sentence of paragraph 7.1.1.2 which is to be changed to read "The welded primary container will pass through a 2.025 inch ring gage (checking OD)".

8.0 QUALITY ASSURANCE REQUIREMENTS

Same as specified in DPST-78-124-1 for the PISA package with the following addition: The GPHS primary containment vessel has undergone a thorough assessment to determine which components are critical to safety or function ("Q" items) and what is required to verify them adequacy. The following Savannah River Plant report documents these assessments:

- o DPSPU-80-272-35, Quality Assessment of the GPHS Container
See 8.1 Appendix for above document.

8.1 APPENDIX

January 29, 1980

CC: T. R. Sloan, 723-A

W. R. Kennedy, 723-A

~~G. G. Chalfant, 723-A~~

R. A. Brownback, 704-F

C. W. Wilds, 704-F

D. S. Duarte, 235-F

D. F. Bickford, 235-F

PRD File Copy, 704-F

TO: GPHS QA FILE

QUALITY ASSESSMENT OF THE GPHS CONTAINER

A QA assessment of the GPHS primary containment vessel was conducted in January, 1980 and reviewed by the following:

- o Gordon G. Chalfant - EED, SCDG, GPHS primary containment vessel designer.
- o E. N. Dixon - EED, Welding Development Group
- o D. F. Bickford - Separations Technology, Area Supervisor 235-F
- o D. A. Brakensiek - Separations - PuFF QA/QC Coordinator

"Q" Items were defined as those that are critical to the function or safety of the container. The following documents were used to determine which items are to be designated "Q".

- o DPST-78-124-1, Supplement 2, Safety Analysis Report - Packages PISA Clad
- o DPSP-79-1007, Specifications for General Purpose Heat Source Fueled /Acceptance
- o DPSTS-235-F-PuFF, Technical Standards, $^{238}\text{PuO}_2$ fuel form facility.

Each item required by the design specification (print S5-2-10420) has been designated "Q" (requiring formal quality assurance), or "S" (standard). The criteria of DPW-78-111-2.4, Savannah River QA manual were used to determine the appropriate designation.

- o "Q" Item - Nuclear safety of quality related item, judged to have a significant impact on plant reliability or other important design criteria, and assessed to need a formal QA plan.
- o "S" Item - Any item that is assessed to need no formal Quality Assurance Plan beyond the extensive informal QA applied in normal DuPont commercial design, procurement, construction, and operational activity.

A "Q" item requires that formal documentation of compliance be retained in the PuFF QA file. Revisions to "Q" items must be based on prototype testing or an engineering study and authorized by the Superintendents of Separations, Separations Technology, and Supervisor of the EED Shipping Container Development Group and by DOE-SR prior to implementation.

An "S" item designation does not imply relaxed tolerances. With this designation all design parameters must still be met but documentation of compliance is not required. Changes to "S" items may be implemented after approval by the Separations Technology and Separations Department Superintendents and the Equipment Engineering Department Superintendent. All changes ("Q") and ("S"),

must be incorporated into subsequent SARP revisions.

The attached tables list the design parameters and their designation. The basis of the designations and fabrication control requirements are shown.

Approval of deviations from design specifications must be documented in the PuFF QA file per DPSOL 235-F PuFF 3268, Request for Approval of Deviation, or Equivalent. Deviations must be approved by the PuFF QA/QC Coordinator and the following:

- o "S" Items - Separations and Separations Technology Department Area Supervisors.
- o "Q" Items - Separations Department Area Superintendent, Separations Technology Chief Supervisor, EED Shipping Container Development Group Supervisor.

A Copy of S5-2-10420, the SRP GPHS Primary Containment Vessel design print, is attached with all "Q" parameters marked. Changes in program objectives or packaging requirements may require a future reassessment of the classifications.

QA records for GPHS containers must be maintained for a minimum of 2 years after shipment from SRP and may not be destroyed before completion of the container's use.

QA records traceable to individual containers must include:

- o Materials certifications and traceability records.
- o Dimensional checksheets and instrument calibration certifications.
- o Certification of container cleaning, ring gauge testing, magnetic check of top cap insert.
- o Inspection reports of weld penetration.
- o Deviation reports.

Prepared by:

Donald A. Hunt 3/3/80
Equipment Engineering Date

Approved by:

Donald A. Hunt 3/3/80
PuFF QA/QC Coordinator Date

Donald A. Hunt 3/3/80
Separations Technology Date
Area Supervisor

Donald A. Hunt 3/3/80
Separations Area Superv. Date

W. K. K. K. 3/11/80
EED Weld Dev. Engr. Date

Donald A. Hunt
Container Designer Date

Approved by: 167/Kennedy 3-11-80
EED Shipping Container Date
Group Supervisor

Authorized by: [Signature] 3/18/80
Separations Technology Dept. Supt. Date

EOKeren 3/17/80
Separations Department Supt. Date

GGC:caj

Attachments

QA ASSESSMENT "Q" ITEMS

	<u>ITEM</u>	<u>BASIS</u>	<u>REQUIREMENT</u>
Q _{1A}	Maximum top cutting groove depth	Container Strength	Independent Verification
Q _{1B}	Maximum bottom cutting groove depth	Container Strength	Independent Verification
Q ₂ & Q ₃	Outgas Notch dimensions	Weld Quality	Independent Verification
Q ₄ & Q ₅	Inside and Outside Housing Diameters	Container Strength and Weld Quality	Independent Verification
Q ₆	Top Cap Diameter Concentricity	Weld Quality	Independent Verification
Q ₇ & Q ₈	Top Cap Diameters	Weld Quality	Independent Verification
Q ₉	Top Cap Lip Thickness	Weld Quality	Independent Verification
Q ₁₀	Bottom Cap Lip Thickness	Weld Quality	Independent Verification
Q ₁₁ & Q ₁₂	Bottom Cap Diameters	Weld Quality	Independent Verification
Q ₁₃	Bottom Cap Thickness	Container Strength	Independent Verification
Q ₁₄	Chemical Cleaning & Degreasing	Weld Quality Product Quality	Certification & Inspection
Q ₁₅	Ring Gauge Testing	Assembly in 5320-1 Cask	Certification & Inspection
Q ₁₆	Identification	Traceability	Certification & Inspection
Q ₁₇	Bottom Cap Weld	Weld Quality	Certification & Inspection
Q ₁₈	Top Cap Weld	Weld Quality	Procedural Control, Visual Inspection and Example Weld Analyses
Q ₁₉	Housing Material	Container Strength and Weld Quality	Material certifications, traceability

	<u>ITEM</u>	<u>BASIS</u>	<u>REQUIREMENT</u>
Q ₂₀	Top Cap Material	Container Strength and Weld Quality	Material certifications, traceability
Q ₂₁	Bottom Cap Diameter Concentricity	Weld Quality	Independent Verification
Q ₂₂	Bottom Cap Material	Container Strength and Weld Quality	Material certification, traceability
Q ₂₃	Cushion Material	Product Quality	Material Certification
Q ₂₄	Graphite Support Material	Product Quality	Material Certification

QA ASSESSMENT "S" ITEMS

<u>ITEM</u>	<u>BASIS</u>	<u>REQUIREMENT</u>
Top cap insert - material, design, weld details	Not critical to function or safety	Standard DuPont practice
Top cap overall thickness	Not limiting item for strength	Standard DuPont practice
Top cap - location and design of V-groove	Not critical to weld quality	Standard DuPont practice
Surface finishes and corner breaks	"	Standard DuPont practice
Cushion Height	Cushions compressible for minor differences	Standard DuPont practice
Location, width, shape of cutting groove	Not critical for GPHS removal	Standard DuPont practice
Bottom cushion dimensions	Cushions compressible	Standard DuPont practice
Top cushion dimensions	Not critical to function or safety	Standard DuPont practice
Post weld surface finishing	"	Procedure Control
Housing Height	Not critical to function or safety	Standard DuPont practice

9.0 DETAIL ENGINEERING DRAWINGS

<u>DRAWING NO.</u>	<u>REVISION NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
26Y-79702	1	GPHS-Ir Clad Reference Design-Cladding Capsule Assy-62.5 Watts	9-10
S5-2-10420	9	SRP-GPHS Primary Containment Vessel	9-11
S5-2-10780	0	SRP-GPHS Shipping Cask EP 62D (12" Diameter Cask) Assembly	9-12

SIMETRIC

QTY	REF	DESCRIPTION
1	1	10110101
2	1	
3	1	CLAD - 0.15 THK
4	1	FRIT PLATE
5	1	PM PELLET-BY USER

-1 -2
SHOWN SIMILAR
SCALE 3/4

NO.	DESCRIPTION	QTY
1	10110101	1
2		1
3		1
4		1
5		1

REV	DATE	BY	CHKD	DESCRIPTION
1	11/1	11/1	11/1	10110101

1	11/1	11/1	11/1	10110101
2	11/1	11/1	11/1	10110101
3	11/1	11/1	11/1	10110101
4	11/1	11/1	11/1	10110101
5	11/1	11/1	11/1	10110101

1	11/1	11/1	11/1	10110101
2	11/1	11/1	11/1	10110101
3	11/1	11/1	11/1	10110101
4	11/1	11/1	11/1	10110101
5	11/1	11/1	11/1	10110101

1	11/1	11/1	11/1	10110101
2	11/1	11/1	11/1	10110101
3	11/1	11/1	11/1	10110101
4	11/1	11/1	11/1	10110101
5	11/1	11/1	11/1	10110101

Analyze this print for
SAFETY CONSIDERATIONS

FULL PENETRATION
WELD BY SRP
FUSION WELD ON
AUTOMATIC TIG
WELDER

FUSION WELD BY
AUTOMATIC TIG
WELDER - FULL
PENETRATION IS
REQUIRED

ITEM	MATL	RECD	PRD	DESIGN	BY	DATE
6	4	SOLID GRAPHITE SUPPORT				
5	2	CUSHION				
4	2	GPHS				
3	1	BOTTOM CAP				
2	1	HOUSING				
1	1	TOP CAP WELDMENT				

TOLERANCES UNLESS OTHERWISE SPECIFIED	ITEM	MATL	RECD	PRD	DESIGN	BY	DATE
ONE PLACE DEC. 0.05	1	SS 2-10A10-A	2x FULL				
TWO PLACE DEC. 0.01	2	SS 2-10A10-B	2x FULL				
THREE PLACE DEC. 0.005	3	SS 2-10A10-C	2x FULL

NOTE
ITEMS 1A & 1B TO BE WELDED
PRIOR TO FINAL MACHINING

ITEM	MATL	RECD	PRD	DESIGN	BY	DATE
15	1	SS 2-10A10-A	2x FULL			
1A	1	SS 2-10A10-B	2x FULL

ITEM 2
(HOUSING)
MATL 2" OD X .065" WALL SEAMLESS
TUBING PER ASTM A 213
GRADE TP 304

ITEM 1A
MATL 304 SST ASTM A 240 PLATE (NO SUBSTITUTE)
REQD 1

ITEM 3
(BOTTOM CAP)
MATL 304 SST ASTM A 240 PLATE (NO SUBSTITUTE)
REQD 1

ITEM 5
(CUSHION)
MATL GRAPHITE FELT SHEET
STYLE RYG 1000
STYLE RYG 2000
STYLE RYG 4000
CARBONE LORRAINE CORP
BOONTON, NJ
(NO SUBSTITUTE)
REQD AS NEEDED

ITEM 6
(SOLID GRAPHITE SUPPORT)
MATL AXM-5G GRAPHITE
POCO GRAPHITE CO
DECATUR, TX
REQD 4

GENERAL NOTES

- DESIGN PRESSURE OF PRIMARY CONTAINMENT VESSEL IS 125 PSIG @ 700°F MAXIMUM LEAK RATE OF ASSEMBLED CAN CONTAINING GPHS IS 10 L/ATM CC/SEC HELIUM
- MATERIAL CERTIFICATION IS REQUIRED FOR ITEMS 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100
- CHEMICALLY CLEAN AND DEGREASE ITEMS 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100
- NO POST WELDING SURFACE FINISHING PERMITTED EXCEPT ON INSERT IN TOP CAP WELDMENT
- THE ASSEMBLY MUST PASS THRU A 2.025 DIA RING GAGE
- IDENTIFY EACH CONTAINER WITH THE LAST THREE DIGITS OF THE DWG NO FOLLOWED BY THE REVISION NO AND AN INDIVIDUAL SERIAL NUMBER WHICH WILL BE SUPPLIED TO THE VENDOR
EXAMPLE XXX-RX
SM XXX
- IDENTIFICATION TO BE DONE BY ELECTRO CHEMICAL ETCHING AFTER CHEMICAL CLEANING
- DIMENSIONS MARKED WITH A Q SHALL BE MEASURED WITH CALIBRATED EQUIPMENT (TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS) THE MEASUREMENTS SHALL BE RECORDED AND ENTERED INTO THE QA/QC FILE FOR THE SPECIFIED VESSEL
- FOR QUALITY ASSURANCE, DOCUMENTATION OF ALL DIMENSIONS, TEST MATERIAL CERTIFICATION, AND CLEANING PROCEDURES MUST ACCOMPANY THE SHIPMENT OF ITEMS DESIGNATED Q

THIS DRAWING CONTAINS INFORMATION ON
SHIPPING PACKAGES FOR RADIOACTIVE MATERIAL

REVISIONS REQUIRE
DESIGN AGENCY (EED) APPROVAL

REVISIONS
1. REVISED ASSEMBLY
2. ADDED DIM A WAS 0.05
3. WAS 1.920 DIA
4. WAS 1.920 DIA
5. WAS 1.920 DIA
6. WAS 1.920 DIA
7. WAS 1.920 DIA
8. WAS 1.920 DIA
9. WAS 1.920 DIA
10. WAS 1.920 DIA
11. WAS 1.920 DIA
12. WAS 1.920 DIA
13. WAS 1.920 DIA
14. WAS 1.920 DIA
15. WAS 1.920 DIA
16. WAS 1.920 DIA
17. WAS 1.920 DIA
18. WAS 1.920 DIA
19. WAS 1.920 DIA
20. WAS 1.920 DIA
21. WAS 1.920 DIA
22. WAS 1.920 DIA
23. WAS 1.920 DIA
24. WAS 1.920 DIA
25. WAS 1.920 DIA
26. WAS 1.920 DIA
27. WAS 1.920 DIA
28. WAS 1.920 DIA
29. WAS 1.920 DIA
30. WAS 1.920 DIA
31. WAS 1.920 DIA
32. WAS 1.920 DIA
33. WAS 1.920 DIA
34. WAS 1.920 DIA
35. WAS 1.920 DIA
36. WAS 1.920 DIA
37. WAS 1.920 DIA
38. WAS 1.920 DIA
39. WAS 1.920 DIA
40. WAS 1.920 DIA
41. WAS 1.920 DIA
42. WAS 1.920 DIA
43. WAS 1.920 DIA
44. WAS 1.920 DIA
45. WAS 1.920 DIA
46. WAS 1.920 DIA
47. WAS 1.920 DIA
48. WAS 1.920 DIA
49. WAS 1.920 DIA
50. WAS 1.920 DIA
51. WAS 1.920 DIA
52. WAS 1.920 DIA
53. WAS 1.920 DIA
54. WAS 1.920 DIA
55. WAS 1.920 DIA
56. WAS 1.920 DIA
57. WAS 1.920 DIA
58. WAS 1.920 DIA
59. WAS 1.920 DIA
60. WAS 1.920 DIA
61. WAS 1.920 DIA
62. WAS 1.920 DIA
63. WAS 1.920 DIA
64. WAS 1.920 DIA
65. WAS 1.920 DIA
66. WAS 1.920 DIA
67. WAS 1.920 DIA
68. WAS 1.920 DIA
69. WAS 1.920 DIA
70. WAS 1.920 DIA
71. WAS 1.920 DIA
72. WAS 1.920 DIA
73. WAS 1.920 DIA
74. WAS 1.920 DIA
75. WAS 1.920 DIA
76. WAS 1.920 DIA
77. WAS 1.920 DIA
78. WAS 1.920 DIA
79. WAS 1.920 DIA
80. WAS 1.920 DIA
81. WAS 1.920 DIA
82. WAS 1.920 DIA
83. WAS 1.920 DIA
84. WAS 1.920 DIA
85. WAS 1.920 DIA
86. WAS 1.920 DIA
87. WAS 1.920 DIA
88. WAS 1.920 DIA
89. WAS 1.920 DIA
90. WAS 1.920 DIA
91. WAS 1.920 DIA
92. WAS 1.920 DIA
93. WAS 1.920 DIA
94. WAS 1.920 DIA
95. WAS 1.920 DIA
96. WAS 1.920 DIA
97. WAS 1.920 DIA
98. WAS 1.920 DIA
99. WAS 1.920 DIA
100. WAS 1.920 DIA

S5-2-10420

9-11

SEPARATIONS

235 F PA 8 0 07 83
G G CHAFFANT L WILLIAMSON
G G CHAFFANT J F MBEK'S
SRP
GPHS
PRIMARY
CONTAINMENT
VESSEL

7-18-79 2x FULL 20 MECH S5-2-10420

SEE NOTE N° 8

SEE NOTE N° 7

1 MATERIAL:

- S5-2-10780

THIS DOCUMENT CONTAINS NEITHER RECOMMENDATIONS NOR
CONCLUSIONS OF THE NATIONAL BUREAU OF STANDARDS
AND IS NOT TO BE REPRODUCED OR DISTRIBUTED WITHOUT
APPROPRIATE AUTHORIZATION

-12

[illegible]