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Disclaimer:

Development Of The H1700 Shipping Package

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Abstract

The H1700 Package is based on the DOE-EM Certified 9977 Packaging. The H1700 will be certified by the Packaging Certification Division of the National Nuclear Security Administration for the shipment of plutonium by air by the United Stated Military both within the United States and internationally. The H1700 is designed to ship radioactive contents in assemblies of Radioisotope Thermoelectric Generators (RTGs) or arrangements of nested food-pack cans. The RTG containers are designed and tested to remain leaktight during transport, handling, and storage; however, their ability to remain leaktight during transport in the H1700 is not credited. This paper discusses the design and special operation of the H1700.

Package Design

The H1700 is a slightly modified version of the certified 9977 Packaging design. The principal packaging features and components that comprise the H1700 are illustrated in Figure 1. The packaging consists of an overpack and a 6-inch diameter Containment Vessel (6CV) configuration. The drum and closure lid are fabricated from stainless steel and are joined through an eight-bolt flange. Drum fabrication includes a welded inner liner. The liner is wrapped with an insulating blanket and the volume between the wrapped liner and drum is filled completely with polyurethane foam. The drum closure lid is fabricated from a simple plate enhanced by top and bottom chambers that are filled with thermal insulation and impact absorbing materials. Aluminum Load Distribution Fixtures (LDFs) are used to isolate the 6CV within the drum liner.

The drum overpack supports and protects the 6CV to ensure that shielding, containment and sub-criticality are maintained under both NCT and HAC. The 6CV is closed by a Cone-Seal Plug and Nut Assembly. The Cone-Seal Plug includes dual elastomer O-ring seals and a Port Plug that seals the closure. The containment boundary is formed by the CV weldment, Cone-Seal Plug, Leak-Test Port Plug, and the Outer O–ring. The Inner O-ring serves to facilitate testing the seal provided by the outer O-ring.

Contents

The package contents are maximum 100 grams of mixed plutonium and uranium Heat Source materials in solid form as oxides. No liquid contents are included in the package. The H1700 is

authorized for shipment of radioactive contents in assemblies of Radioisotope Thermoelectric Generators (RTGs), Food-Pack Cans, and Engineered Containers. The Maximum Normal Operating Pressure for the 6CV is 42.85 psig.

Requirements common to all contents and payload configurations are the following.

- The maximum allowable radioactive decay heat rate is:
  - Maintenance Period of one (1) year - 19 watts.
  - Maintenance Period of two (2) years in RTG Configuration - 17 watts.
  - Maintenance Period of two (2) years in FPC/EC Configurations - 15 watts.
- Small concentrations of other actinides, fission products, decay products, and neutron activation products are permitted.
- Inorganic material impurity quantities of less than 100 ppm each are permitted as long as the total mass is less than 0.1 weight percent of the total content mass.

The maximum weight of the payload (everything that goes into the 6CV, including radioactive contents, convenience cans, contamination control devices, packing materials, spacers, etc.) is not to exceed 100 lb.

Annual Maintenance:

Radioactive Material (RAM) packages require periodic maintenance per Regulatory Guide (RG) 7.9 Section 8.2.2, Leakage Tests. In general, RG 7.9 specifies that elastomeric seals should be replaced and leak tested within the 12-month period before shipment. Typically, RAM packages accept an annual maintenance period and, while in service, are operated with a yearly maintenance cycle. The H1700 may be so operated. The annual maintenance consists of a general inspection for wear or damage that would impair the packages ability to perform its safety function, the replacement of the 6CV O-Rings, and testing of the 6CV to demonstrate its leak-tightness. When operated under annual maintenance the operating controls consist of shipping specified contents, in specified configurations, and the package must be closed as documented in the Package Operations chapter of the Safety Analysis Report for Packaging. Such a package has no temperature or insolation restrictions in either transportation or storage.

<u>Extended Maintenance:</u>

Extending the maintenance period for the H1700 is dependant upon no decrease in the O-Ring sealing capability due to the bounding conditions within a loaded package. This requires demonstrating that the O-Rings can withstand the chemical, radiological, and thermal conditions expected over the extended maintenance period.

Chemical and Galvanic Compatibility - No significant galvanic cell interactions exist among other package materials. The radioactive materials are also chemically compatible with polyethylene or polyvinyl chloride bags commonly used to control the spread of radioactive contamination.

Radiation Dose - Radiation dose in excess of 10^4 rad is required before significant changes to physical properties of the O-Ring are observed. Testing by SRNL [Ref. 1] demonstrated that

Viton O-Rings in mock 9975 Primary Containment Vessels (PCV) after exposure to ~2×10^5 rad remained leak-tight. The 9975 PCV is identical in design (with the exception of diameter) and materials to the H1700, and authorizes contents bounding the dose rate of the H1700. Based on a calculated dose rate from the 9975 of approximately 0.1 rad/hr for the primary seal and a possible cumulative dose of 4.38 $\times10^4$ rad for a 5 year period, no significant changes in mechanical properties of the O-Rings are expected. This supports the O-Rings extended service life for up to five-years.

Thermal conditions - Testing done for materials stored in the Savannah River Site K-Area Material Storage has demonstrated that GLT Viton O-Rings demonstrate no significant loss of seal capability for a period of up to 5 years when maintained at a temperature of 200°F or less. [Ref. 2] Therefore, for a RAM package which has undergone constant ambient temperature monitoring to assure that the maximum tested O-Ring temperature has not been exceeded, it should be acceptable to extend the replacement period for the O-Rings from 12 months to 5 years.

The H1700 temperatures have been evaluated under varying thermal loading, content configurations, and ambient temperature conditions to ensure that the maximum O-ring temperatures are 200ºF or less. The limiting thermal loading and ambient temperature conditions imposed during transport and storage for packages with an extended maintenance period are listed in Table 1. [Refs. 3 and 4] The temperature of the O-Rings and H1700 loaded with maximum 19-watt content, in a 100°F ambient environment, with and without insolation are 300°F and 199°F, respectively. Since the maximum allowable O-Ring temperature is 200°F, a package operated under extended maintenance must be shaded at all times. For extended maintenance, the H1700 has been evaluated under three conditions; a full package loaded while in transport or storage without insolation, a full package loaded with limited duration insolation, and a loaded 6CV only in storage. The period of maintenance is determined by the ambient conditions of the package during use (loading, shipment, and unloading) and storage (i.e. when the packaging is empty). The minimum maintenance period is 1 year. If the package is used and stored so that the 6CV O-Rings are kept at 200°F or cooler, the maintenance period may be extended to five years. The H1700 is authorized for two years extended maintenance. For a package operated under extended maintenance, its ambient temperature must be monitored and controlled, if necessary, continuously so as not to exceed the specified maximum ambient temperature for its content and configuration.

Full Package – no insolation

The H1700 meets the Normal Condition of Transport (in shade) thermal requirements of 10 CFR 71. However, these analyses are for 19 watts thermal loading and the regulatory ambient temperature of 100ºF. The H1700 is evaluated for conditions with ambient temperatures higher than 100ºF. In this case, it is possible to exceed the 200ºF O-ring temperature limit if thermal loading of the stored contents is not controlled. Since the packages in the storage and transport are not exposed to the solar thermal loading, the H1700 HAC pre-fire models were used as the basis for calculating the O-ring temperatures under ambient temperature higher than 100ºF, various loading configurations, and thermal loadings less than 19 watts. The thermal loadings under these conditions and configurations that result in O-Ring temperatures less than 200ºF are presented in Table 1. Also, a method was developed for calculating the O-ring

temperatures within the constraints of thermal loading of zero to 19 watts and ambient temperature from 100ºF to 200ºF. [Refs. 3 and 4]

Full Package – limited insolation

While the H1700 shall be shielded from direct sunlight during shipment, staging, and storage, this does not prohibit minimal exposure times while loading or unloading a conveyance. The impact of two hours of solar heat flux on the temperature of the O-rings of an H1700 left in the sun was analyzed. [Ref. 5] This simulates the logistics of unloading H1700 from the transport vehicle and leaving it in the sun until it can be safely brought inside for storage: all at an ambient temperature of 100°F. Prior to the application of insolation the O-Rings were at a temperature of 199°F. After two hours of insolation to the package the O-Rings reach 200°F. As the H1700 package is over-insulated, the thermal energy needs time to dissipate. The peak O-Ring temperature is 205°F and is reached 14 hours after the package is protected from insolation; either by being covered outside or being placed into storage.

6CV – no insolation

The loaded 6CV may be removed from the drum overpack and stored separately. Removing the insulated overpack allows the 6CV to better reject the content decay heat and withstand higher ambient temperatures. The 6CV was analyzed standing vertically and laying horizontally. Temperatures of 100°F and 150°F were considered reasonable bounding ambient storage conditions. The calculated O-Ring temperatures are listed in Table 3. It will be noted that the temperatures are all well below the corresponding full package temperatures and the 200°F limit.

Summary

Table 2 lists the maximum allowable ambient temperatures for use and storage of the package as a function of content decay heat rate and configuration. The package's content packing configuration, decay heat rate, and ambient temperature conditions must be monitored continuously and certified by the User as being within the limits specified. Ambient temperatures in excess of those listed are documented and reported to the Design Authority as "temperature versus time" for the period of the event. For a package identified with an extended maintenance period a "Periodic Maintenance Data Label" is attached to the drum.

Table 1 – O-Ring Temperatures for Extended Maintenance

	Food Pack Can Configuration		RTG Configuration	
Content Decay Heat Rate	Ambient Temperature [a]	O-Ring Temperature [b]	Ambient Temperature [c]	O-Ring Temperature [b]
Watts	°F	°F	°F	°F
0	200	200	200	200
2	175	185	175	184
4	175	194	175	193
5	175	198	175	197
6	150	178	150	176
7	150	184	150	180
8	150	188	150	184
10	150	198	150	192
12	125	184	125	176
13	125	189	na [d]	na [d]
14	125	193	125	183
15	125	198	125	187
16	125	207	125	190
17	100	185	100	171
18	na	na	100	175
19	100	194	100	178

a Listed values are from the Reference 3, N-CLC-A-00339, *Evaluation of 9977 Package O-ring under Varying Thermal Loadings and Ambient Temperature Conditions.*

b The O-Ring temperature is calculated for the listed ambient temperature and decay-heat rate.

c Listed values are from the Reference 4, N-CLC-A-00365, *Evaluation of H1700 O-ring Temperatures for the Different Thermal Loading and Storage Ambient Conditions.*

d not analyzed

Table 2 - Ambient Temperature Limits for Extended Maintenance

Decay-Heat Rate	FPC/EC Configuration	RTG Configuration
Watts	°F	°F
0 to 8	150	150
10	142	148
12	131	139
13	126	135
14	122	132
15	117	128
16	not permitted	125
17	not permitted	120
18 to 19	not permitted	not permitted

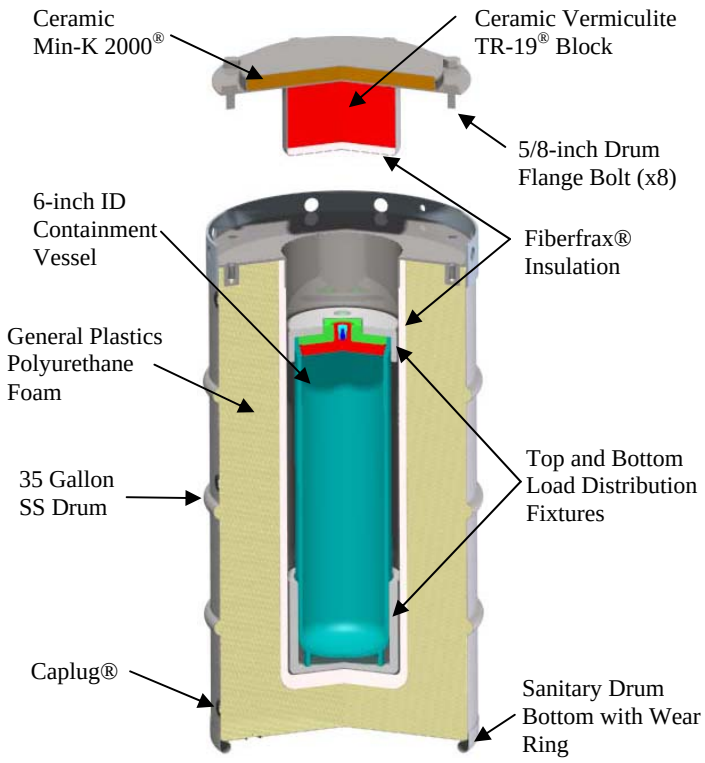

Figure 1 - 3-Dimensional Illustration of the H1700

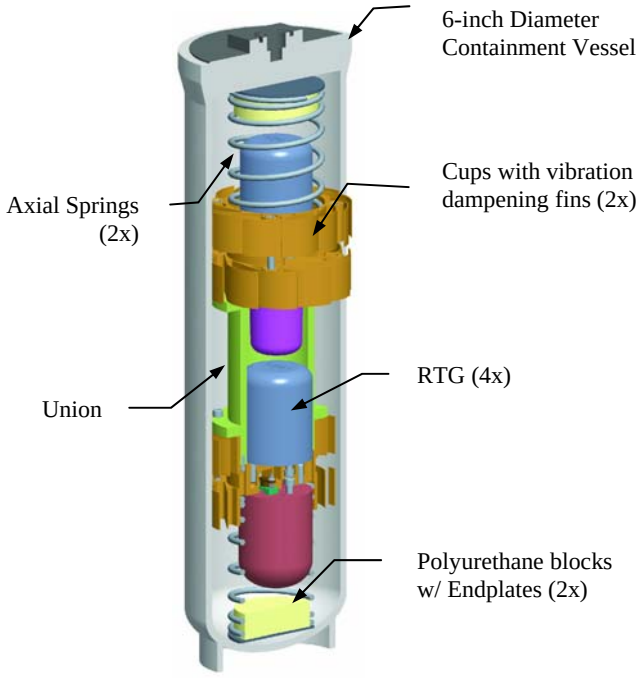

Figure 2 – RTG Assembly in the H1700

Table 3 - Maximum O-Ring Temperatures for Bare 6CV

CV Orientation	**Storage Ambient Temperature, T_a** (°F)	**O-Ring Temperature** (°F)
Upright	100	128
	150	179
Horizontal	100	128
	150	176

References

1 K. M. Counts, E.B. Fox, and T.E., Skidmore, *Second Interim Status Report: Model 9975 PCV O-Ring Long-Term Leak Performance (U), WSRC-TR-2007-00073, Rev 0*, Westinghouse Savannah River Company, Aiken, SC (June 2007)

2 Letter, K. A. Dunn to J.S. Bellamy, *Viton GLT O-Ring Performance at 200°F*, SRNL-MST-2008-00127, Westinghouse Savannah River Company, Aiken, SC (June 2008)

3 N. K. Gupta, *Thermal Evaluation of 9977 Package O-Rings under Varying Thermal Loading and Ambient Temperature Conditions*, M-CLC-A-00339 Revision 1, Savannah River National Laboratory, Aiken, SC, (September 2008)

4 N. K. Gupta, *Evaluation of H1700 Package O-Ring Temperatures for Different Thermal Loading and Storage Ambient Conditions*, M-CLC-A-00365 Revision 0, Savannah River National Laboratory, Aiken, SC, (May 2009)

5 N. K. Gupta, *Thermal Evaluation of H1700 Shipping Package Containment Vessel (CV) O-Rings under Storage Conditions*, M-CLC-A-00362 Revision 0, Savannah River National Laboratory, Aiken, SC, (May 2009)