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Radioactive Material Shipping Packagings and Metal-to-Metal Seals Found in the Closures of Containment Vessels Incorporating Cone-Seal Closures

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ABSTRACT

The containment vessels for the Model 9975 radioactive material shipping packaging employ a cone-seal closure. The possibility of a metal-to-metal seal forming between the mating conical surfaces, independent of the elastomer seals, has been raised. It was postulated that such an occurrence would compromise the containment vessel hydrostatic and leakage tests. The possibility of formation of such a seal has been investigated by testing and by structural and statistical analyses. The results of the testing and the statistical analysis demonstrate and procedural changes ensure that hydrostatic proof and annual leakage testing can be accomplished to the appropriate standards.

INTRODUCTION

The 9975 is a Type B radioactive material (RAM) shipping package designed and manufactured to meet the standards and requirements specified in the Code of Federal Regulations, 10 CFR 71. The 9975 design features double containment through nested high-integrity pressure vessels, the containment vessels (CVs). Each CV design incorporates a double O-ring seal that allows post-load leakage testing of the CV closure, see Figures 1 and 2. Each CV also incorporates a cone-seal closure designed by Gordon Chalfant, known as the Chalfant Closure. As can be seen from the figures, the Chalfant Closure consists of a stayed head welded to the open end of the vessel body weldment. The head includes an internal 10° cone-seal surface. The CV Closure Assembly consists of a Cone-Seal Plug shaped in part like a truncated 10° cone and a threaded Cone-Seal Nut. Both the internal and external Cone-Sealing surfaces are machined to the same angles, surface finishes, and with matching diameters so that they mate with essentially zero clearance. Two O-ring grooves (outer and inner) are machined in the face of the external Cone-Seal Plug. O-rings fit into these grooves to complete the leaktight closure assembly. The O-ring closest to the content cavity is designated as the inner O-ring. These vessels are extensively tested by various methods both during and after the fabrication process is complete. It has been suggested that a metal-to-metal seal could be formed below the elastomer seals, along this line of contact between the Cone-Seal Plug and the stayed head sealing surface. It was further suggested that such a seal could compromise hydrostatic and leakage-rate testing performed on the CV.

BACKGROUND

Acceptance and annual leakage-rate testing of 9975 CVs is performed by filling the vessel cavity with helium through the leak test port. During this test, the inner O-ring is removed and the Cone-Seal Nut is tightened to the required closing torque. In some cases it was found that helium would not flow at sufficient rates through the path provided by the empty O-ring groove to ensure a valid test. The time restriction for the helium leakage testing is based on the permeation rate of helium through the outer elastomeric O-ring, see Figure 2. If the helium is not introduced into the vessel quickly enough (within 2 to 3 minutes), the leakage rate detector will measure helium permeation through the outer O-ring (not leakage), producing a "false-positive" test. To address this issue, the helium leakage test procedure was modified to require the operator to open the Cone-Seal Nut approximately 90 degrees to ensure that a radial gap existed between the Plug and the stayed head. This permits helium to flow and the procedure requires the operator to complete the leakage-rate test in a timely manner. Interviews with qualified leakage test personnel suggest that there was typically a low-flow condition, not a no-flow condition. However, the possibility that a helium no-flow condition could exist in a fully closed CV could not be ruled out based on available data.

A hydrostatic pressure test is performed in a similar manner as the annual helium leakage test with a few notable differences. In preparation for the hydrostatic pressure test, the CV is filled with water to eliminate any compressible gasses in the test volume. As with helium leakage testing, the inner O-ring is removed, the leak test port on the Cone-Seal Plug is opened, and the CV is closed according to instructions provided in the 9975 SARP. Water is then introduced through the leak test port at a much higher pressure than the helium during leakage testing (>1200psig vs. ~5 psig). Since water is an incompressible liquid, very little water needs to flow into the water filled cavity to equalize cavity pressure to that of the supply pump. Hydrostatic pressure testing performed up to this point has not included instructions to open the cone-seal nut 90 degrees prior to applying pressure. Since the volume of water flowing into the vessel is negligible during hydrostatic testing, there is also no practical flow check (comparable to the helium flow check made during leakage rate testing) that can be performed.

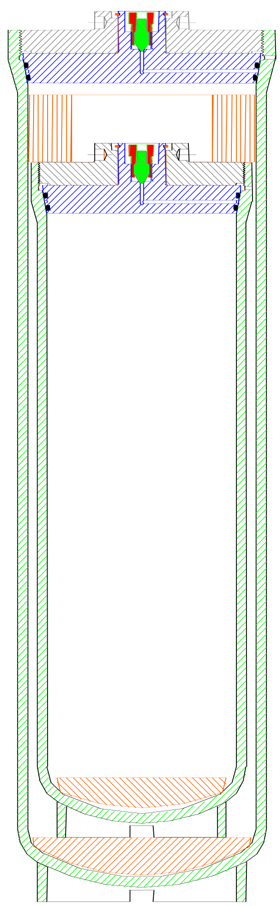

Figure 1—Secondary and Primary Containment Vessel Arrangement

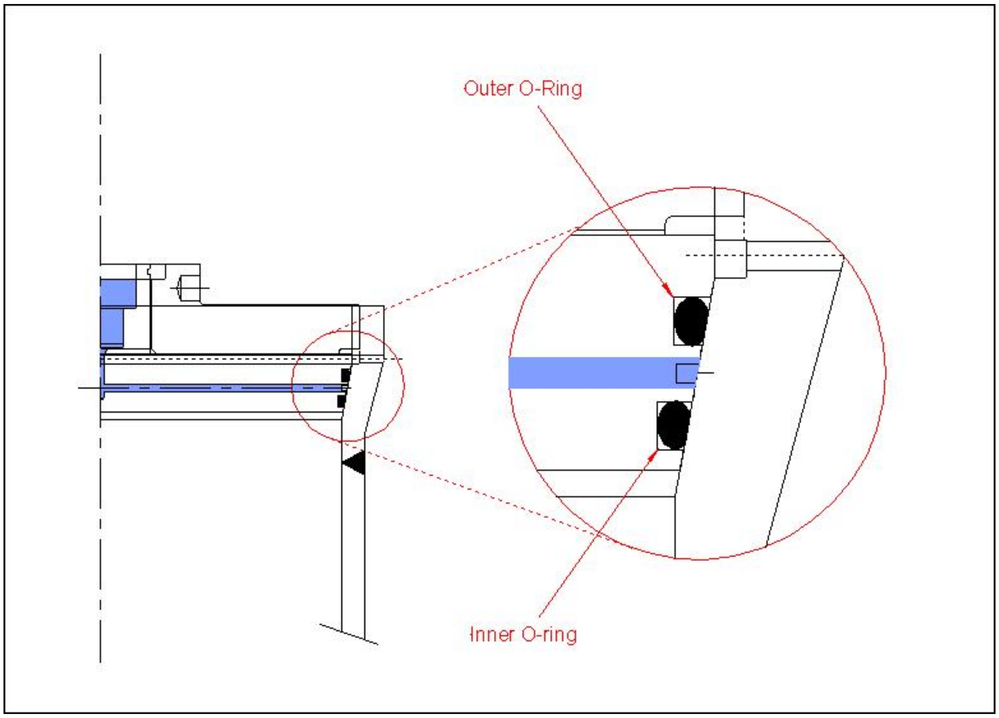

Figure 2—Double O-Ring Arrangement

Because certain steps performed to ensure fluid communication with the vessel cavity during helium leakage testing were not repeated in the hydrostatic testing, the question was raised whether some hydrostatic tests may not have met their test objective of fully pressurizing the vessel cavity. The question was, "Can the machining of the mating surfaces of the 9975 CVs be so precise that a metal-to-metal seal could be achieved between these hard metals such that this seal would prevent the communication of the supply water pressure to the entire containment boundary in the hydrostatic pressure test?" Additional testing and analysis were performed to substantiate the very low probability that a perfect metal-to-metal seal has ever occurred in 9975 CVs.

DISCUSSION

Testing

Tests were carried out to verify the ability of the Primary and Secondary Containment Vessels (PCV and SCV) to communicate water through the metal-to-metal contact of the Cone-Seal Plug and the CV stayed head. These tests were performed to show the ability of water to communicate into the CV during the hydrostatic test.

In the first test, twenty 9975 shipping packages were selected at random. The PCV and SCV were removed from these packages and a rate-of-rise leakage test was performed on each of the forty CVs. This test was used to identify the CVs with the lowest leakage rates.

In the second test, the one SCV and the two PCVs with the lowest leakage rates were used to evaluate water communication. In this test, water pressure was applied to the leak-test port of each of these CVs and water inleakage to the CV cavity was verified by isolation of the test volume from the supply pressure. Unlike the hydrostatic test procedure, water inleakage could be determined because the vessels were not pre-filled with water. The water communication tests all showed water moving across the Cone-Seal plug/stayed head boundary at approximately 80 psig (the pressure of the building supply line). This test was conservative as it was not necessary to pressurize the CVs to the hydrostatic test pressures. This test demonstrated that the metal-to-metal contact between the Cone-Seal Plug and the stayed head produced by the SARP-specified closure torque values is not sufficient to prevent water from passing into the body of the vessel during the hydrostatic pressure test.

These results, as well as actual hydrostatic pressure test results (no known failures), lead to the conclusion that the hydrostatic testing was acceptable. This is also complemented by the structural analysis found in Reference 4 and the design and fabrication defense-in-depth. These Favorable results are documented as Reference 5.

In the third test, a standard hydrostatic pressure test was performed on a SCV closed as required by the SARP. The SCV was modified to allow direct measurement of the pressure in the vessel cavity. The purpose of this test was to determine if the SCV cavity was subjected to the full hydrostatic test pressure. As with all previous hydrostatic pressure tests, no special steps were taken to ensure water communication (i.e., the cone-seal nut was not backed-off). The test assembly was configured as illustrated in Figure 3. Throughout the test there was essentially no difference between the supply pressure readings and pressure readings taken directly from the vessel cavity as the hydrostatic pressure was increased. This data is listed below in Table 1. The results of this test demonstrate that the metal-to-metal contact of a typical SCV is not sufficiently tight to cause a delay in cavity pressure rise.

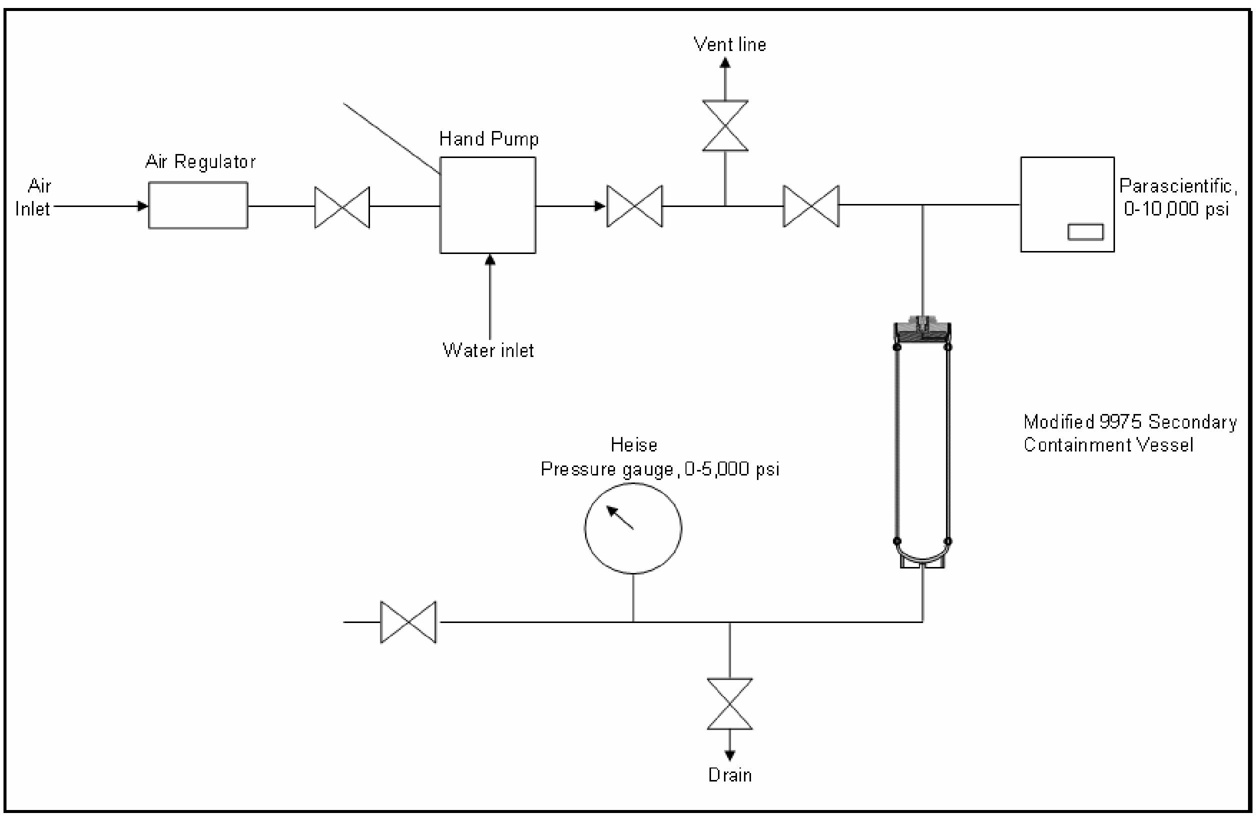

Figure 3—Hydrostatic Test Assembly

	Pressure Guage	
	Paroscientific	Heise
Pressure (psig)	85	85
	210	210
	503	504
	702	701
	1001	1001
	1239	1235
	1239	1239 *

* Hydrostatic pressure was held at 1239 psig for >10 minutes

Table 1—Hydrostatic Test Pressure Readings

Analysis

An analysis was performed (Reference 4) that shows that metal-to-metal contact between the Cone-Seal Plug and the stayed head is relieved when pressure is applied to the CV cavity. When the hydrostatic test pressure is applied to the region between the lower corner of the plug and the bottom of the upper O-ring seal, the outward diametric strain on the top portion of the CV will open a flow path past the contact area into the CV body. This region can be seen in Figure 4.

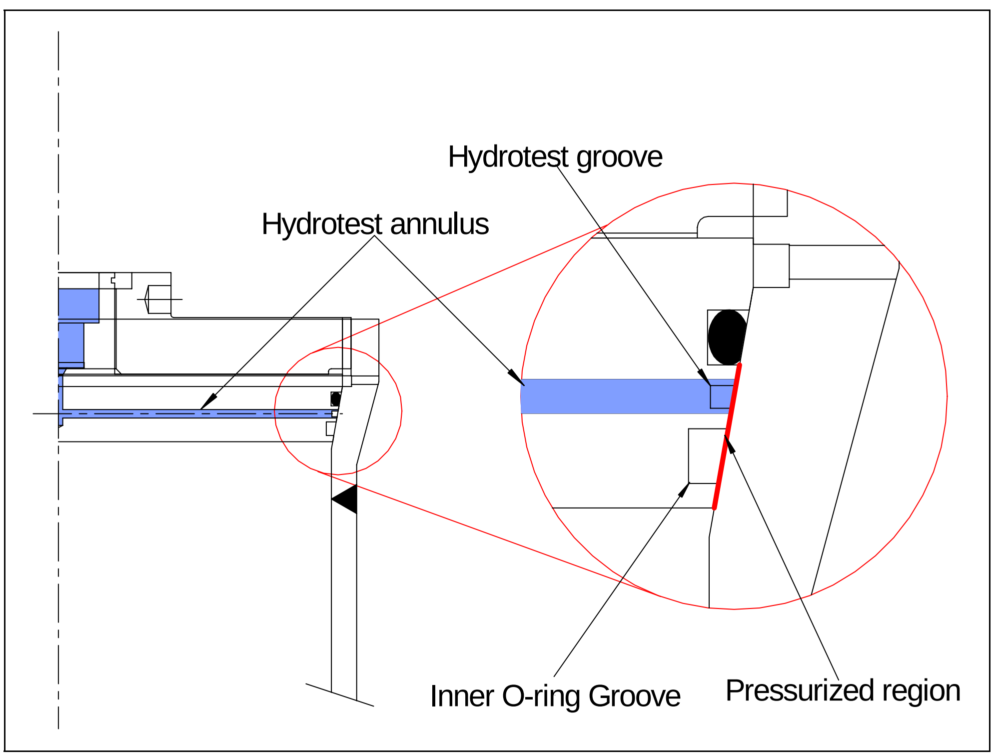

Figure 4—Analyzed Areas of the Cone-Seal Plug/CV Body Mating Surfaces

Other Testing--Pre-Fabrication, Fabrication, and Post-Fabrication Testing

The PCVs and the SCVs are tested in accordance with the ASME Boiler and Pressure Vessel Code Section III, *Rules for Construction of Nuclear Power Plant Components*, Division 1 - Subsection NB *Class 1 Component*s. This includes pre-fabrication, fabrication, and post-fabrication tests. These various tests provide assurance that the vessels are free of material and manufacturing flaws and will perform their intended design functions for containment and structural integrity. There is no anecdotal or documented evidence of any 9975 CV failure during a hydrostatic pressure test.

CONCLUSIONS

Testing and analysis support the conclusion that metal-to-metal contact between the machined surfaces of a 9975 CV closure does not prevent successful hydrostatic pressure testing during fabrication acceptance.

More than five thousand 9975s have been fabricated, and, thus, more than 10,000 CVs have been hydrostatically pressure tested. There is no evidence of any 9975 CV ever failing the hydrostatic pressure test. This success rate, along with the Quality Assurance programs of both the manufacturing processes and the testing protocols, supports a conclusion that metal-to-metal seals formed by CVs fabricated to the 9975 specification would pass properly administered hydrostatic pressure and leakage-rate tests.

DISCLAIMER

REFERENCES

1. Code of Federal Regulations, Title 10, Energy, Part 71, Packaging and Transportation of Radioactive Material, 10 CFR 71.

2. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III, Rules for Construction of Nuclear Power Plant Components, Division 1-Subsection NB Class 1 Components.

3. Abramczyk, G. A., Blanton, P. S., and Houghtaling, T. K., *Safety Analysis Report for Packaging Model 9975 B(M)F-85*, WSRC-SA-2002-00008, Revision 0 and Addendum 1, Revision 1, April 2005.

4. Rothermel, R. R., *Evaluation of Hypothetical Flange Seal Lockup During 9975 CV Hydrostatic Test (U)*, M-CLC-G-00355, January 2006.

5. Trapp, D. J., *Test Report for 9975 Water Pressure Communication Study (U)*, SRNL-EDS-2006-00008, February 2006.