PROOF-OF-PRINCIPLE LEAKAGE TESTING ON THE MODEL FL CONTAINMENT VESSEL*
PART I – CONTAINMENT VESSEL LEAKAGE TESTS

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SUMMARY

The Model FL packaging was designed to ship payloads of various sizes, weights, and shapes between U.S. Department of Energy (DOE) facilities while meeting the strict requirements of 10 CFR 71. As part of a recent recertification effort, it was decided that the Model FL containment vessels should meet the ANSI N14.5-1987 definition of "leaktight."

Proof-of-Principle Leakage Testing was performed at the Lawrence Livermore National Laboratory (LLNL) on three Model FL containment vessels. The purpose of the testing was twofold: 1) to develop a set of leakage test procedures that could be used to redefine the allowable leakage rate criteria for the Model FL containment vessel from 10^{-4} cm^3/sec to 10^{7} cm^3/sec, i.e., the ANSI N14.5-1987 definition of "leaktight," and 2) to develop a set of leakage test methods that could be used to prove that the Model FL containment vessel can meet the redefined allowable leakage rate criteria.

The data obtained from the leakage testing on the Containment Vessel Bodies has shown that a set of leakage test procedures can be developed to redefine the allowable leakage rate criteria for the Model FL Containment Vessel Bodies to meet the ANSI N14.5 definition of "leaktight." (See Hafner 1997).

The data obtained from the tests on the O-ring sealing surfaces and the O-rings themselves are presented in Part II of this discussion, *Proof-of-Principle Leakage Testing on the Model FL Containment Vessel, Part II—O-Ring Leakage Tests*, also published in this Proceedings (Hafner 1998). The test data resulted in several conclusions, primarily that the silicone O-rings used for the Model FL containment vessels are too porous to be used for leakage testing at, or below, the 10^{-7} cm^3/sec region, using conventional helium leakage testing techniques.

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TEST METHODOLOGY AND OVERVIEW

The test methodology used can be subdivided into two independent sets of tests. In the first set of tests, leakage testing was performed on the Containment Vessel Body; in the second set of tests, leakage testing was performed on the O-ring sealing surfaces and the O-rings themselves. To meet the leakage rate criteria in the ANSI N14.5 definition of "leaktight," the sum of the results from the two independent leakage tests must be less than 1.0×10^{-7} std cm^3/sec (ANSI N14.5 1987). To meet the sensitivity requirements specified by ANSI N14.5, the sensitivity for each of the two independent leakage tests must be at least 5.0×10^{-8} std cm^3/sec (ANSI N14.5 1987).

In the first set of tests, total integrated leakage tests were performed on the Model FL Containment Vessel Bodies using a Test Flange equipped with two sets of neoprene O-rings. The purpose of this set of tests was to demonstrate that the Model FL containment vessel *body* could be shown to be "leaktight," without the interference from permeation normally expected when using silicone O-rings (required for the Model FL Containment Vessel by the Safety Analysis Report for Packaging (Rocky Flats 1992)). The configuration used for this set of tests is shown schematically in Figure 1-1. A detailed view of the test flange connections used is shown in Figure 1-2. Details of the results from this set of tests are shown graphically in Figures 1-3 and 1-4 and are discussed below under the heading of Containment Vessel Leakage Tests.

In the second set of tests, leakage testing was performed on the O-ring sealing surfaces and the O-rings themselves, using the same Test Flange used in the first test. The results from this set of tests are presented in a separate paper entitled *Proof-of-Principle Leakage Testing on the Model FL Containment Vessel, Part II – O-Ring Leakage Tests*, also published in this Proceedings (Hafner 1998).

CONTAINMENT VESSEL LEAKAGE TESTS

Ideally, the preferred configuration for this set of tests would have been to evacuate and backfill the Model FL Containment Vessel with helium while it was inside an evacuated envelope (e.g., a bell jar), and to measure the flow of helium *out of* the Containment Vessel. The fundamental purpose of these tests, however, was to measure the flow of helium through porosity in the welds and/or through any flaws in the fabrication materials of the Containment Vessel Body. Since the detection of these types of defects is not normally dependent on the flow direction at differential pressures as low as one atmosphere, the configuration used for this set of tests called for evacuation of the containment vessel after it had been placed inside a helium envelope (i.e., "a baggy"), and measurement of the flow of helium *into* the containment vessel (see Figure 1-1).

The Containment Vessel Body Leakage Tests were designated as Tests A, B, and C. Test A was performed on Containment Vessel Serial Number 33024-00-0067. Tests B and C were performed on Containment Vessel Serial Numbers 33024-00-0258 and 33024-00-0277, respectively. For simplicity, the Containment Vessels will be referred to in the remainder of this report by the last four digits of their respective serial numbers, i.e., #0067, #0258, and #0277.

Before each test in this series began, a system response time measurement was performed using a calibrated helium leak with a value of 2.3×10^{-7} cm^3/sec. This particular calibrated leak was mounted on the Test Flange at a point as far away from the leak detector inlet as possible without violating the integrity of the containment vessel body, i.e., at a point on the Test Flange approximately 180° from the inlet of the leak detector (see Figure 1-2). The results of these measurements are shown collectively in Figure 1-3. Analysis of these data shows that the response time for the system was very short, i.e., on the order of 15 seconds or less.

After the completion of each test in this series, an independent verification calibration run was performed on the leakage detector. This second calibrated leak, which had a value of 2.9×10^{-7} cm^3/sec, was mounted directly on the inlet of the leak detector (see Figure 1-1). Because these independent calibration runs were performed as an integral part of each of the individual tests, the results of the individual tests, i.e., Tests A, B, and C, and the results of the independent calibration runs are shown together in Figure 1-4.

The individual test difficulties and nuances with each of these tests are discussed below.

System Response Time Measurements – Test A

The data presented in Figure 1-3 for Test A show that the measured helium leakage rate for this system response time measurement overshot the expected value of 2.3×10^{-7} cm^3/sec by about an order of magnitude. A review of the test configuration revealed that the calibrated leak had been connected directly to the Test Flange, without the appropriate isolation valves and secondary vacuum pump shown in Figure 1-1. This configuration allowed the helium from the calibrated leak to build-up in the volume of the tubing. When the isolation valve on the calibrated leak was opened, this build-up of helium was introduced into the system as an oversized pulse, which caused the instrument to overshoot its expected reading. Rather than halt the testing and correct the plumbing at this point, it was noted that this particular test configuration could be used to provide an insight into the system clean-up times for the tests to follow. The data presented in Figure 1-3 for Test A, therefore, show the clean-up time for the system after the system had been exposed to an oversized pulse input.

One additional anomaly worth noting with respect to the Test A data presented in Figure 1-3 is that the zero time from the beginning of the test was difficult to ascertain from the output data. (This was a recurring problem for all of the testing.) The response time shown for Test A was about 15 seconds. Based on the response times determined from Tests B and C, this value of 15 seconds appears to be conservative.

System Response Time Measurements – Test B

The data presented in Figure 1-3 for Test B show that the measured helium leakage rate for this test was exactly as expected from a calibrated leak with a value of 2.3×10^{-7} cm^3/sec. These data were obtained after the plumbing problems associated with Test A were corrected. Also, the system response time from the beginning of this test was also difficult to ascertain from the output data. In spite of the difficulties, however, the output data from Test B suggest that the system response time should be closer to three to five seconds, as opposed to the 15-second response time determined in Test A.

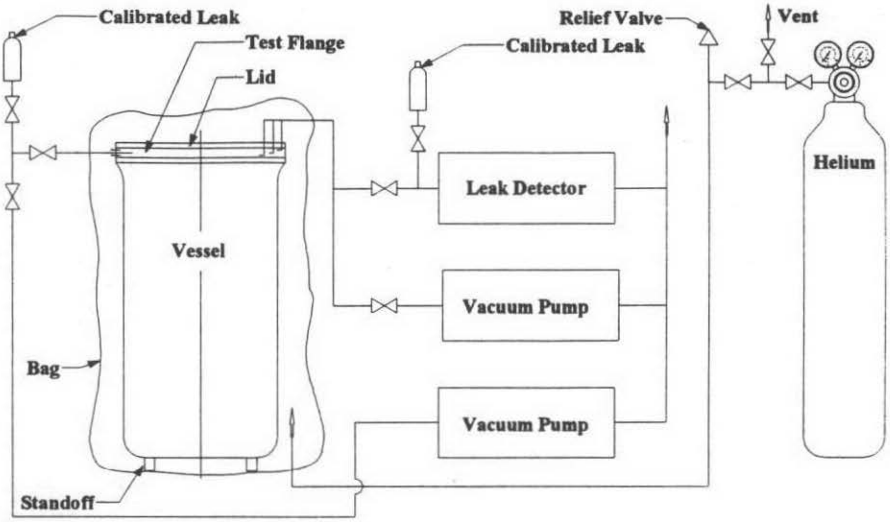

Figure 1-1. Containment Vessel Body Leakage Test Configuration

System Response Time Measurements – Test C

The data presented in Figure 1-3 for Test C show that the measured helium leakage rate for this test was also exactly as expected from a calibrated leak with a value of 2.3×10^{-7} cm^3/sec. Again, these data were obtained after the plumbing problems associated with Test A were corrected and that the system response time from the beginning of this test was also difficult to ascertain from the output data. And again, the output data from Test C suggest that the system response time should be closer to three to five seconds, as opposed to the 15-second response time determined in Test A.

SYSTEM RESPONSE TIME MEASUREMENTS – CONCLUSIONS

The data obtained from Test A System Response Time Measurements were used to determine the minimum test duration used for each of the actual tests to follow in this series. The system response time shown for Test A was about 15 seconds, and based on the system response times determined from Tests B and C, this value of 15 seconds appears to be conservative. An examination of the Test A data presented in Figure 1-3 shows that the system clean-up time, following the input of an oversized helium pulse, is about four minutes, from the baseline measurement before the pulse input to the baseline measurement after the pulse clean-up. To insure that the actual testing would be able to differentiate between the input of an anomalous pulse and the input of a true, steady-state leak, the minimum test duration time was set at 20 minutes.

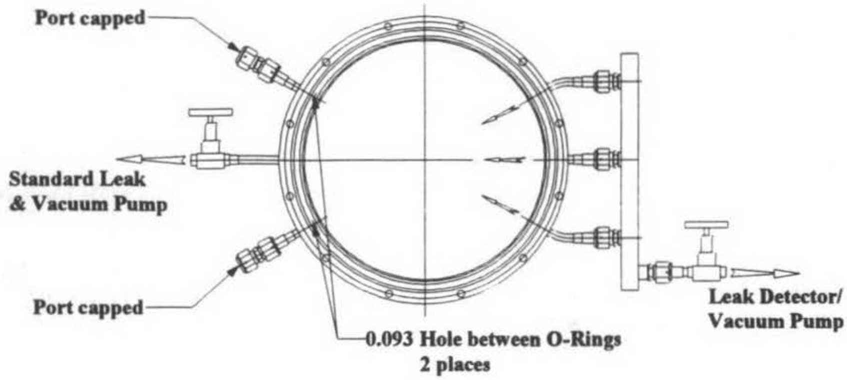

Figure 1-2. Test Flange Connections, Containment Vessel Body Leakage Tests

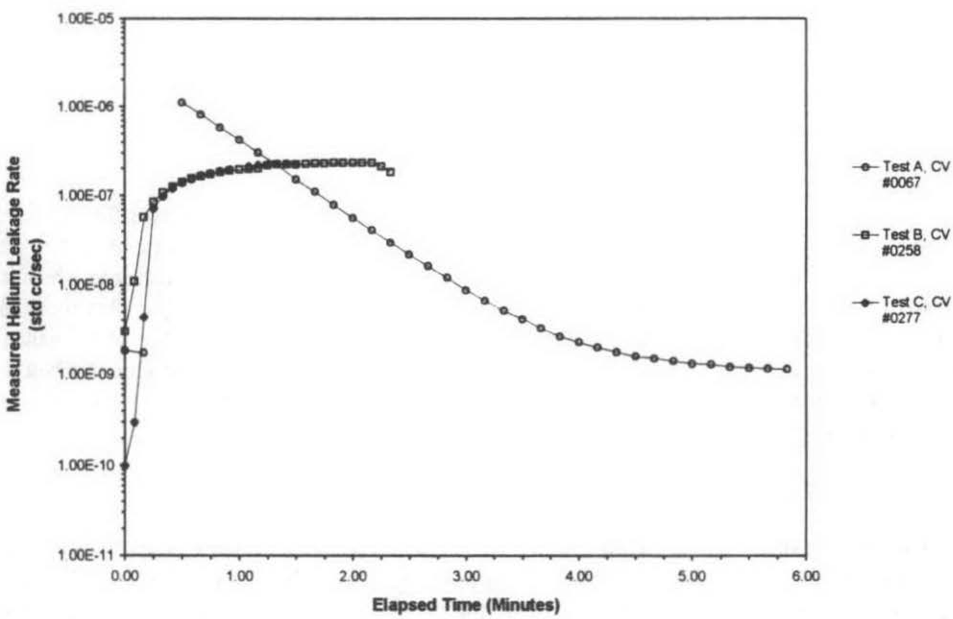

Figure 1-3. System Response Time Measurements

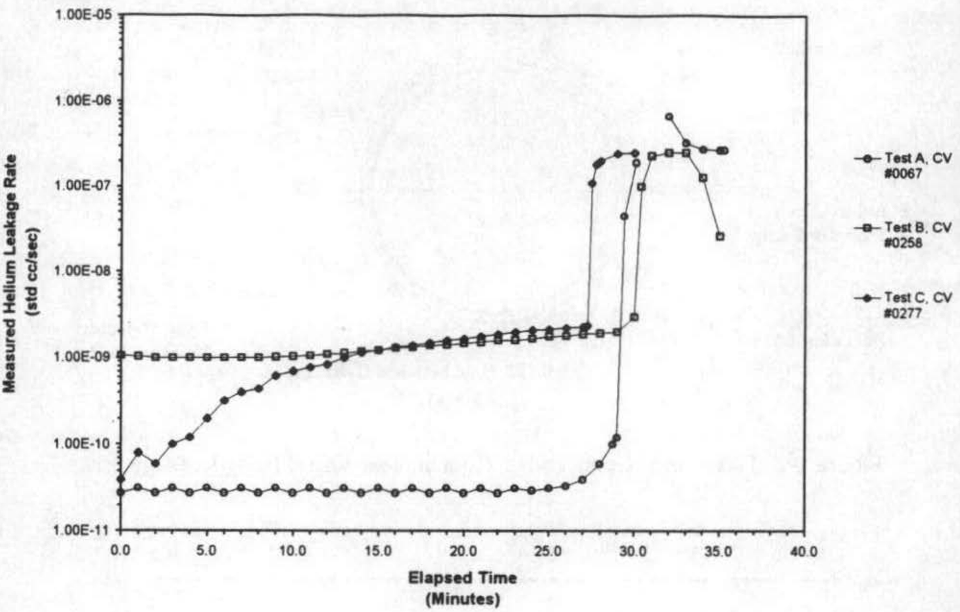

Figure 1-4. Containment Body Test Results

Containment Vessel Body Leakage Tests – Test A

The data presented in Figure 1-4 for Test A show that the baseline measurements for the system started in the low 10^{-11} cm^3/sec region and remained in that region for about 25 minutes. From the 25-minute mark to about the 29-minute mark, the data began to show a small increase which was attributed to the beginning influences of permeation through the neoprene O-Rings that were used for this test. At the 29-minute mark, the calibrated leak was opened to verify the performance of the leakage detector. As expected, the initial reading overshot the expected reading as a result of the plumbing problems noted above. But, because the isolation valve on the calibrated leak was left open for this part of the test, the final reading stabilized at a value of 2.3×10^{-7} cm^3/sec.

Containment Vessel Body Leakage Tests – Test B

The data presented in Figure 1-4 for Test B show that the baseline measurements for the system started in the low 10^{-9} cm^3/sec region and remained in that region for about 10 minutes. From that time-frame to about the 29 minute time-frame, the data again began to show an increase, which, again, was attributed to the influences of permeation through the neoprene O-Rings. (Note: Because the same set of neoprene O-Rings was used for all three tests in this series, the O-Rings, themselves, began to behave as a virtual leak at the low to very low detection levels used for these tests.) At the 29- to 30-minute mark, the calibrated leak was opened to verify the performance of the leakage detector. Because the plumbing problems referred to previously had been corrected, the system response was as expected, and the final reading stabilized at a value of 2.3×10^{-7} cm^3/sec.

Containment Vessel Body Leakage Tests – Test C

The data presented in Figure 1-4 for Test C show that the baseline measurements for the system started in the mid 10^{-11} cm^3/sec region. From the zero-point mark to the end of the test (i.e., the 27-minute mark), the data show a slow, but steady increase in the "measured helium leakage rate." Because the same set of neoprene O-Rings had been used for all three tests in this series, this slow, but steady increase in the "measured helium leakage rate" was again attributed to the influences of permeation. At the 27-minute mark, the calibrated leak was opened to verify the performance of the leakage detector. Again, because the plumbing problems referred to previously had been corrected, the system response was as expected, and the final reading stabilized at a value of 2.3×10^{-7} cm^3/sec.

CONTAINMENT VESSEL BODY LEAKAGE TESTS – CONCLUSIONS

The data obtained from this Proof-of-Principle leakage testing on the Model FL Containment Vessel Bodies has shown that a set of leakage test procedures can be developed to redefine the allowable leakage rate criteria for the Model FL Containment Vessel Bodies from 1.0×10^{-4} cm^3/sec to 1.0×10^{-7} cm^3/sec, i.e., the ANSI N14.5-1987 definition of "leaktight." Although the testing was performed on only a limited number of samples, i.e., Containment Vessel Serial Numbers #0067, #0258, and #0277 (which represents only about 1% of the total Model FL containment vessel inventory), the basic methods described above can easily be extended to the remainder of the fleet.

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PROOF-OF-PRINCIPLE LEAKAGE TESTING ON THE MODEL FL CONTAINMENT VESSEL* PART II – O-RING LEAKAGE TESTS

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SUMMARY

The Model FL packaging was designed to ship payloads of various sizes, weights, and shapes between U.S. Department of Energy (DOE) facilities while meeting the strict requirements of 10 CFR 71. As part of a recent recertification effort, it was decided that the Model FL containment vessels should meet the ANSI N14.5-1987 definition of "leaktight."

Proof-of-Principle Leakage Testing was performed at the Lawrence Livermore National Laboratory (LLNL) on three Model FL containment vessels. The purpose of the testing was twofold: 1) to develop a set of leakage test procedures that could be used to redefine the allowable leakage rate criteria for the Model FL containment vessel from 10^{-4} cm^3/sec to 10^{7} cm^3/sec, i.e., the ANSI N14.5-1987 definition of "leaktight," and 2) to develop a set of leakage test methods that could be used to prove that the Model FL containment vessel can meet the redefined allowable leakage rate criteria.

The first part of this paper, *Proof-of-Principle Leakage Testing on the Model FL Containment Vessel, Part I—Containment Vessel Leakage Tests*, also published in this Proceedings (Hafner 1998), describes the data obtained from the leakage testing on the Model FL containment vessel bodies. These data show that a set of leakage test procedures can be developed to redefine the allowable leakage rate criteria for the Model FL Containment Vessel Bodies to meet the ANSI N14.5 definition of "leaktight."

The data obtained from the tests on the O-ring sealing surfaces and the O-rings themselves showed that the silicone O-rings used for the Model FL containment vessels are too porous to be used for leakage testing at, or below, the 10^{-7} cm^3/sec region, using conventional helium leakage testing techniques. Although variations in the test methods were attempted, none of the variations altered the original conclusion, which suggested two options: 1) A new type of helium leakage detector should be developed to accommodate the continued use of silicone O-rings, or 2) The O-rings themselves should be changed from silicone to an entirely different elastomer.

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* **Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.**

TEST METHODOLOGY AND OVERVIEW

The test methodology used can be subdivided into two independent sets of tests. In the first set of tests, leakage testing was performed on the Containment Vessel Body; in the second set of tests, leakage testing was performed on the O-ring sealing surfaces and the O-rings themselves. To meet the leakage rate criteria specified by the ANSI N14.5 definition of "leaktight," the sum of the results from the two independent leakage tests must be less than 1.0×10^{-7} std cm^3/sec (ANSI N14.5 1987). To meet the sensitivity requirements specified by ANSI N14.5, the sensitivity for each of the two independent leakage tests must be at least 5.0×10^{-8} std cm^3/sec (ANSI N14.5 1987).

In the first set of tests, total integrated leakage tests were performed on the Model FL Containment Vessel Bodies using a Test Flange equipped with two sets of neoprene O-rings. The purpose of this set of tests was to demonstrate that the Model FL containment vessel *body* could be shown to be "leaktight," without the interference from permeation normally expected when using silicone O-rings (required for the Model FL Containment Vessel by the Safety Analysis Report for Packaging (Rocky Flats 1992)). The results from this set of tests are presented in Hafner 1998.

In the second set of tests, leakage testing was performed on the O-ring sealing surfaces and the O-rings themselves, using the same Test Flange used in the first test. The purpose of this set of tests, however, was to allow for, and differentiate between, permeation vs. leakage. The configuration used is shown schematically in Figure 2-1. A detailed view of the test flange connections used is shown in Figure 2-2. Details of the results from this set of tests are shown graphically in Figures 2-3 through 2-7, and are discussed below.

O-RING LEAKAGE TESTS

Having shown that the Model FL containment vessel bodies can meet the redefined leakage rate criteria of 1.0×10^{-7} cm^3/sec (see Hafner 1997), the purpose of this second set of tests was to develop an independent set of leakage test methods that can be used on the O-rings, and the O-ring sealing surfaces, using the same Test Flange used in the first series of tests. In this second series, however, the underlying criteria were far more stringent—requirements specified in ANSI N14.5 state that permeation, "...should not be considered as leakage or release unless the fluid itself is hazardous or radioactive..." (ANSI N14.5 1987). Since the O-rings specified for the Model FL containment vessels were silicone O-rings (Rocky Flats RFE-9101 1992), and since silicone O-rings have a well-established reputation for being susceptible to permeation, the procedures developed in this part of the testing had to allow for, and differentiate between, permeation vs. leakage.

Initially, the intent of the test plan was to perform leakage tests on all three containment vessels using silicone O-rings, with the O-Ring Leakage Tests designated simply as Tests #1, #2, and #3. After the first results were obtained, however, the initial plan was extended to include testing on neoprene and EPDM O-rings. The numbering system for the sequence of tests performed in this series, therefore, quickly became dependent on individual test situations, e.g., Test #1, Test #2, ... Test #5, Test #5A, ... Test #9, Test #9A, Test #9B, Test#9C, etc. The test plan was later extended to include testing on Viton GLT (Good Low Temperature) O-rings, which became Tests #10 and #11.

Silicone O-Ring Tests

The results from the silicone O-ring tests are shown collectively in Figure 2-3. The data shown in Figure 2-3 produced several, very interesting results: 1) The permeation rates for Tests #1, #5A, and #6, which were conducted with dry silicone O-rings, remained on the baseline for between five and 30 seconds; 2) The permeation rate for Test #7, which was conducted using lubricated silicone O-rings, remained on the baseline for only about 35 seconds; 3) The measured helium permeation rates for all of the silicone O-ring tests remained below the 10^{-7} cm^3/sec region for less than one minute, regardless of lubrication status of the O-rings; and 4) All of the silicone O-ring tests saturated the leakage detector in time-frames that ranged from three to six minutes, regardless of lubrication status of the O-rings.

In an attempt to slow the system response time, the helium flow direction for the tests that followed was reversed. Since the results of these tests showed only about a 10% improvement in the baseline response time to helium permeation, the system plumbing was returned to its initial configuration for the remainder of the testing.

The data shown in Figure 2-3 also produced a second, very important set of results. From the outset, the results obtained from Test #5 clearly showed a leak. (Note: After the completion of Test #5, the test apparatus was disassembled and a small, white fiber was found at the bottom of the inner O-ring groove of the containment vessel.) Rather than showing the classic S-shaped curve that would be expected from permeation, the data presented in Figure 2-3 for Test #5 have

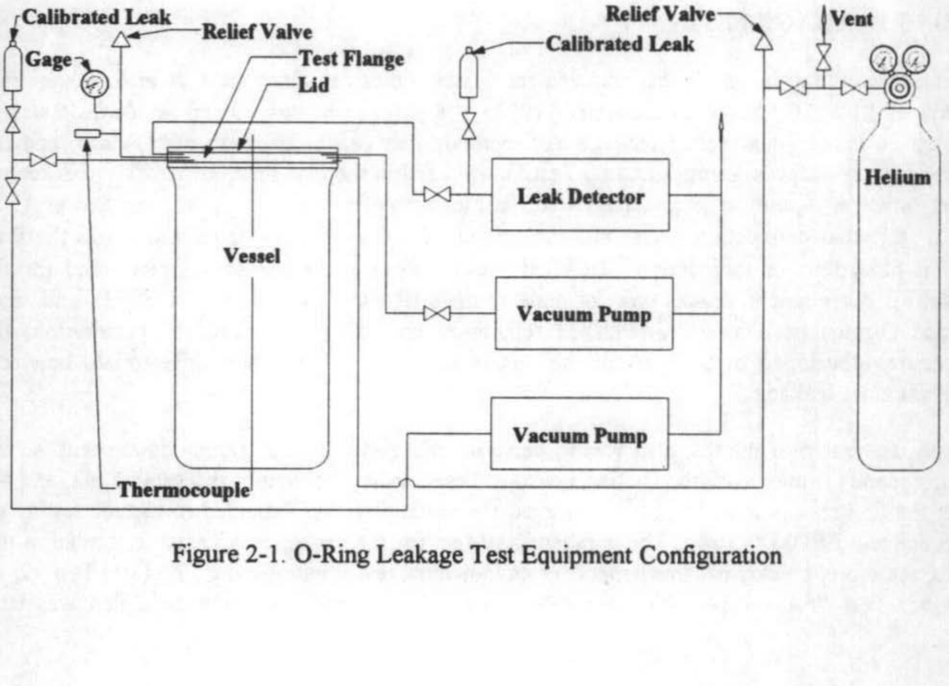

Figure 2-1. O-Ring Leakage Test Equipment Configuration

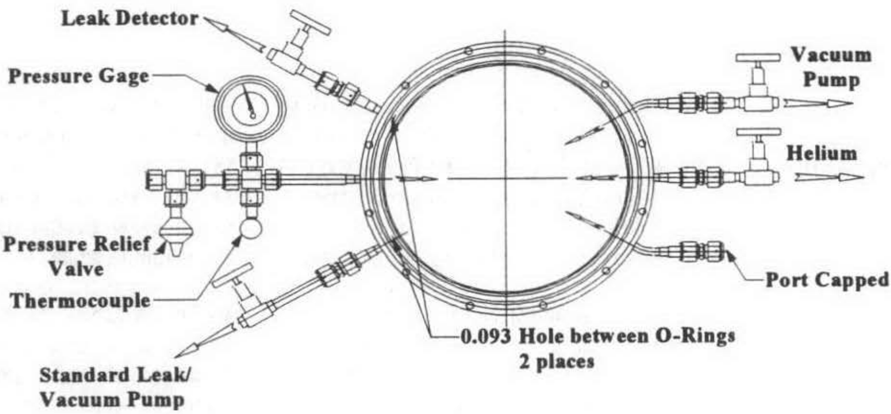

Figure 2-2. Test Flange Connections, O-Ring Leakage Tests

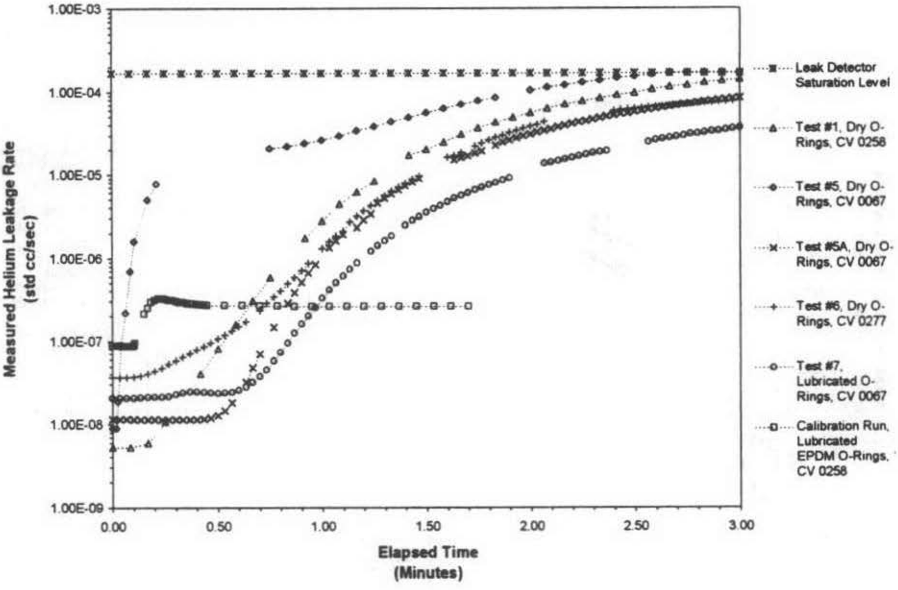

Figure 2-3. Silicone O-Ring Test Results

a curve shape that more closely resembles the data shown in Figure 1-3 for the System Response Time Measurements and the data shown in Figure 2-3 for the helium test leak calibration run using lubricated EPDM O-rings.

EPDM O-Ring Tests

The results from the EPDM O-ring tests are shown collectively in Figure 2-4 with the leak detector saturation level. The data in Figure 2-4 are for the full test duration of the longest tests: Test #4 (dry O-rings on CV0067) and #8 (lubricated O-rings on CV0258). As a result, the data presented in Figure 2-4 are shown on a time scale of 0 to 60 minutes. To better view the baseline data and early permeation breakthrough measurement times, an expanded view of the data obtained from the same set of tests is shown in Figure 2-5 on a zero- to seven-minute scale.

From the data presented in Figures 2-4 and 2-5, for Tests #3 (dry O-rings on CV0258), #4, and #8, the initial stages of permeation breakthrough were virtually indistinguishable between any one of these tests and any other. Also, for these three tests, the initial stages of permeation breakthrough were detected within two and three minutes. Both of these findings were attributed to baseline sensitivity starting at about the 1.0×10^{-8} cm^3/sec region. Test #9C (dry O-rings on CV0258) started with a background that was much more sensitive, so the initial stages of permeation breakthrough for this test were detected after about 30 seconds. For all four tests, however, the data presented in Figures 2-4 and 2-5 show that the permeation rates remained below the 1.0×10^{-7} cm^3/sec level for between 5 and 6-1/2 minutes.

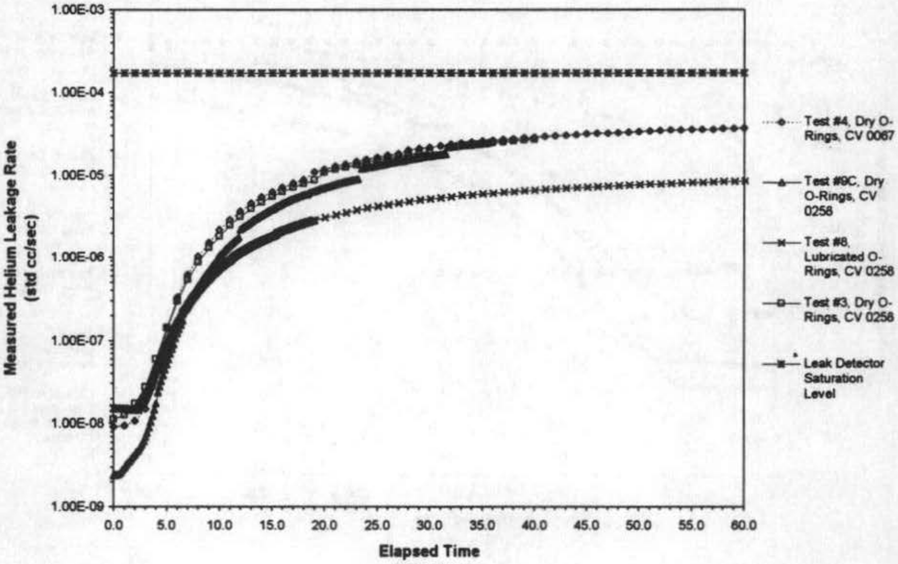

Figure 2-4. EPDM O-Ring Test Results

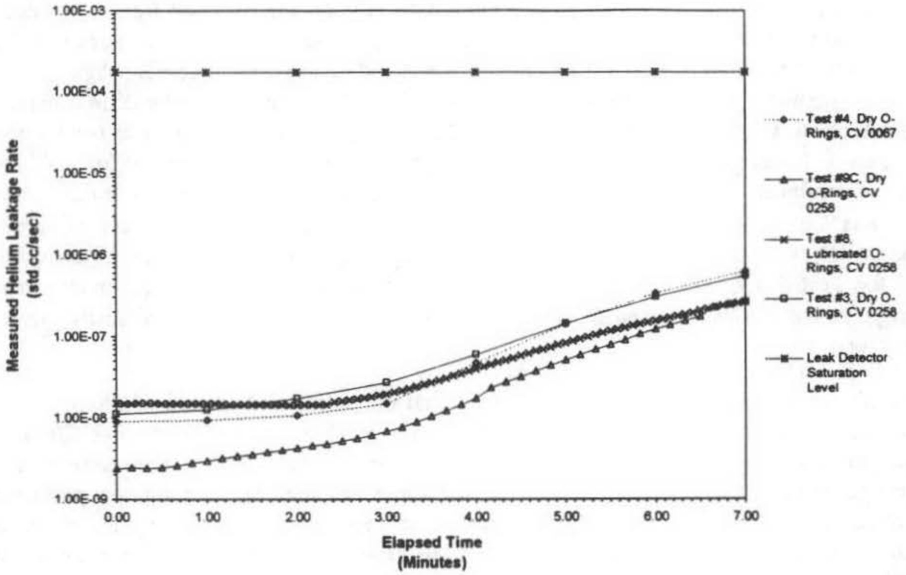

Figure 2-5. Expanded View, EPDM O-Ring Test Results

As the data presented in Figure 2-5 show clearly for tests #3, #4, and #8, the initial stages of permeation breakthrough were virtually indistinguishable between one another. At about the four-minute time-frame, the permeation rate through the lubricated O-rings used for Test #8 begins to slow relative to the comparable permeation rates for Tests #3 and #4. At about seven minutes, the permeation rate through the non-lubricated O-rings used for Test #9C begins to exceed that of the lubricated O-rings used for Test #8. From that point on, the permeation rate through lubricated O-rings is noticeably slower than that through non-lubricated O-rings.

The steady-state value for the permeation rate through the lubricated O-rings used for Test #8 was about an order of magnitude lower than the rate through the non-lubricated O-rings used for Tests #3, #4, and #9C. However, the steady-state permeation values are properties of interest for the long-term. Also note that the primary purpose of the O-ring tests was to develop a generic set of methods that can be used to allow for, and differentiate between, permeation and leakage. Since, for purposes of these tests, the differentiation between permeation and leakage is of primary interest for the short-term, there are few, if any, short-term permeation benefits to be gained from the use of lubricated EPDM O-rings.

Viton GLT O-Ring Tests

For the Viton GLT O-ring tests, the data obtained from Tests #10 and #11 are shown together in Figure 2-6. The data presented in Figure 2-6 are for the full test duration of the longest test, which was Test #10, shown on a time scale of 0 to 210 minutes. To better view the baseline data and early permeation breakthrough measurement times for Tests #10 and #11, an expanded view of the data obtained from both tests is shown in Figure 2-7, on a time scale of 0 to 12 minutes.

It can be seen that, after about the eight-minute mark, the results obtained from both tests were again virtually indistinguishable between one another. But note that in Test #10 in Figure 2-6, the baseline started at about the 1.0×10^{-8} cm^3/sec region and continued to decrease slightly for about 5-1/2 to 6 minutes. At about the six-minute mark, the initial stages of permeation breakthrough were detectable as the helium levels began to rise slowly, but continuously. The results obtained from Test #11 were even more dramatic. Although the baseline started in the low 10^{-9} cm^3/sec region, it continued to decrease all the way down the absolute sensitivity of the leakage detector, which was 1.0×10^{-11} cm^3/sec. Due to the increased sensitivity, the initial stages of permeation breakthrough were detected, in this case, at about the 4-1/2-minute mark. The measured helium levels for Test #11 began to increase from that point on until about the eight-minute mark, at which point the results obtained from both Test #10 and Test #11 became virtually identical to each other.

The results presented in Figure 2-7 show clearly that the permeation rates for helium through the Viton GLT O-rings remained below the 10^{-7} cm^3/sec level for about 12 minutes. Because the results obtained from the silicone and EPDM O-ring tests had shown that there were no obvious benefits to be gained from the use of lubricated O-rings, no additional testing was performed on lubricated Viton GLT O-rings. Also, because the results obtained from the reversed-flow direction tests had shown that there was no obvious benefit to be gained for either the silicone or EPDM O-ring tests, no additional testing was performed on the Viton GLT O-rings using that particular test configuration.

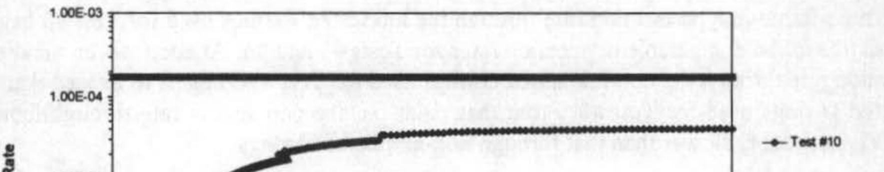

Figure 2-6. Viton O-Ring Test Results

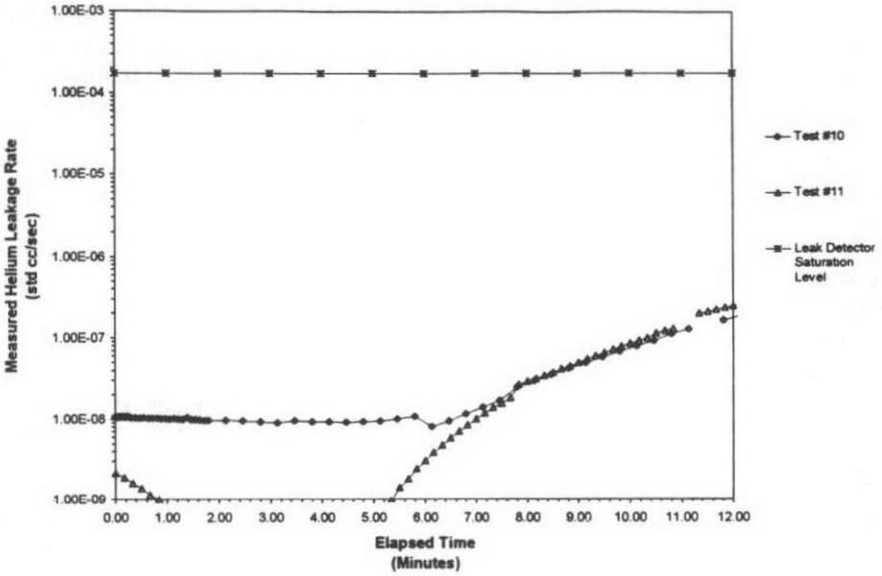

Figure 2-7. Expanded View, Viton O-Ring Test Results

O-RING LEAKAGE TEST MEASUREMENTS—CONCLUSIONS

The procedures developed in this part of the testing were designed to allow for, and differentiate between, permeation and actual leakage. For the silicone O-ring tests, the results presented above show clearly that silicone O-rings are too porous to be used for leakage testing at, or below, the 10^{-7} cm^3/sec region, using conventional helium leakage testing techniques.

To continue to use the silicone O-rings for the Model FL containment vessel, a new type of helium leakage detector would have to be developed. This new type of leakage detector would be fully automated to determine acceptable background helium levels, to open and close individual test valves, and to determine the appropriate starting and stopping times for individual leakage test functions. Also, because the silicone O-rings are so porous, this new type of leakage detector would have to take advantage of computer processing to differentiate between permeation and actual leakage. Mathematically, this type of differentiation can be handled quite easily because the curve-shapes that result from permeation can be expected to have the classic, backward-S shape already shown for all of the individual O-ring test results except for Test #5. The curve-shape that results from actual leakage, on the other hand, can be expected to have a classic, time constant curve-shape, observed in Test #5. Also note that the classic, time constant curve-shapes have also been shown in Part I in the System Response Time Measurement results and the Leakage Detector Cross-Check Calibration results shown in Figures 1-3 and 1-4, respectively.

Because developing an entirely new leakage detector would require significant investment in terms of both time and money, serious consideration must also be given to the possibility of using O-rings made from an entirely different elastomer. Such considerations were factored into these tests from the outset. In addition to the testing performed on silicone O-rings, comparison testing was also performed on neoprene O-rings, on EPDM O-rings, and on Viton GLT O-rings. Should it be desirable to select an entirely new O-ring, the permeation data obtained from the testing described herein must be combined with the manufacturer's recommended temperature ratings to determine the most suitable O-ring replacement.

Testing was performed on neoprene O-rings as part of this set of tests. Although the results are not discussed in this report, the most interesting feature of the neoprene O-ring is that, of all the O-rings tested, neoprene appears to have the best permeation characteristics. With a maximum temperature range of only 250° to 300°F, however, neoprene O-rings have the poorest overall temperature rating (Parker Hannifin Corporation 1991). Because the temperature ratings for neoprene O-rings were well below the minimum requirements for the Model FL containment vessel during the hypothetical accident, no additional testing was performed.

The results from the EPDM O-ring tests are shown graphically in Figures 2-4 and 2-5. Although the permeation characteristics for EPDM O-rings are not as good as those for neoprene, the results clearly demonstrate that EPDM O-rings are much more resistant to permeation than are silicone O-rings. However, the temperature ratings for EPDM O-rings are -65°F to 300°F, with an extended temperature range up to 400°F for short durations (Parker Hannifin Corporation 1991). Because the ratings for EPDM do not meet the maximum temperature requirements for the Model FL containment vessel during the hypothetical accident, EPDM O-rings should not be considered as a possible replacement for silicone at this time.

The results from the Viton GLT O-ring tests are shown graphically in Figures 2-6 and 2-7. Like their EPDM counterparts, the testing performed on the Viton GLT O-rings showed that the permeation characteristics for the Viton GLT O-rings are not as good as those for neoprene. However, the permeation characteristics for Viton GLT O-rings are noticeably better than those for EPDM, and are substantially better than those for silicone. Viton GLT O-rings have a nominal recommended temperature range of -40°F to 400°F, with an extended temperature range up to 600°F for short periods (Parker Hannifin Corporation 1991). Since this is well beyond the temperature requirements for the Model FL containment vessel during the hypothetical accident, Viton GLT O-rings would appear to be an ideal replacement candidate.

The options developed from the O-ring leakage tests are: 1) continue to use silicone O-rings and develop a new type of leakage detector to differentiate between permeation and actual leakage, or 2) continue to use conventional helium leakage test methods and replace silicone O-rings with Viton GLT O-rings. The potential disadvantages for the first option are outlined above.

The Model FL shipping container has not been tested with Viton GLT O-rings; however, they have been used successfully on a variety of radioactive material shipping containers for more than 30 years. Typical examples include the T-3 Spent Fuel Shipping Container (Westinghouse Hanford Corporation 1990); the PAS-2 and PAS-2A Radioactive Liquid Shipping Containers (Westinghouse Hanford Corporation 1992); the NAC-1 Irradiated Hardware and Spent Fuel

Shipping Container (Nuclear Assurance Corporation 1994); and the so-called Chalfant Packages, i.e., the 9965 and 9968 containers used for the shipment of plutonium metals and oxides (Westinghouse Savannah River Company 1996). The Viton GLT compound has been used in the Chalfant Packages since the early 1980s and continued testing shows that Viton GLT O-rings are capable of maintaining a leaktight seal ($<1.0 \times 10^{-7}$ cm^3/sec, helium) after continued exposures to temperatures as low as -40°F, and after exposures to temperatures as high as 600°F for as long as 1,000 hours (Westinghouse Savannah River Company 1996).

Based on the conclusions from these tests, and tests performed at Savannah River on the Chalfant Packagings, it can be concluded that Viton GLT O-rings are a suitable replacement for silicone O-rings on the Model FL shipping container with neither loss in packaging effectiveness nor sacrifice in performance or safety.

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