PNL-5591
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Gas Leak Characteristics of Inner Packaging Components Used in the D0T-Spec 6M Container

J. M. Taylor

September 1985

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

PNL-5591

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy	
Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

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USED IN THE DOT-SPEC 6M CONTAINER

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Pacific Northwest Laboratory
Richland, Washington 99352

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SUMMARY AND CONCLUSIONS

A test program was conducted by Pacific Northwest Laboratory^(a) to determine the gas leak characteristics of metal food pack cans and 2R vessels used to package radioactive material in a DOT 6M specification container. The 2R vessels tested had either pipe cap or pipe plug closures with standard taper pipe threads. None of the 2R vessels tested had male threads that were within the pipe thread specification; the female threads were not gauged because of the lack of gauging equipment. A variety of luting compounds were tested by applying the compounds to the threads of the 2R vessel to determine if a gas-tight seal could be obtained under elevated temperature and pressures. A silicon rubber compound proved to be a superior luting compound. The silicon rubber compound produced gas tight seals ($<10^{-5}$ cc/sec) on pipe assemblies that could not be sealed with other luting compounds. The gas-tight seal was maintained to temperatures of 300°F and 100 psig when the pipe cap or plug was tightened with a torque in excess of 100 ft-lb.

The gas leak characteristics of the metal food pack cans tested depended on the quality of the mechanical crimp seal. If high-quality seals were obtained, leak rates as low as 3.5×10^{-8} atm-cc/sec were achieved. Cans that had leak rates <2 cc/sec were made gas tight by applying a silicon rubber compound to the seams. Applying the silicon rubber compound to the can seams enabled the cans to remain gas tight up to pressures of 35 psig. Depending on the type of lids used, the lids deformed irreversibly at different pressures. The flat profile lids deformed at 7 psig, and the ribbed reinforced lids (concentric ring type) deformed irreversibly above 15 psig. To maintain gas tight seals, permanent deformation of the lids should be avoided.

The cans failed under pressures between 25 to 89 psig depending on the quality of the crimp seal. The lids failed either by uncrimping or by the lid tearing along the juncture between the can wall and the lid.

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Several packaging configurations were tested under accident conditions specified in 10 CFR 71.73 to determine which configuration would best protect the product cans inside the 2R vessel of the 6M container. A packaging configuration was developed using spacer plates and empty slip lid cans as impact absorbers that protected the product cans inside a 6M container from damage during a 30-foot drop on an unyielding surface.

It can be concluded from the tests performed that the inner packaging components (2R vessel, metal product cans) used with a 6M container can be sealed so that they will be gas tight ($<10^{-5}$ cc/sec) under elevated temperature and pressure and impact conditions.

To maintain gas tight seals under accident conditions, the metal cans must be sealed with a properly adjusted can-sealing machine; the threads of the 2R vessel must be luted with a sealing compound such as a silicone rubber compound; and the metal cans must be protected inside the 2R vessel with spacer plates and impact absorbers.

FIGURES

1	DOT Specification 6M Container.....	2
2	Typical 2R Vessels with Pipe Cap - Pipe Plug Closures.....	4
3	Basic Form of USA Standard Taper Pipe Thread.....	5
4	USA Standard Taper Pipe Thread Notation.....	6
5	Thread Profile of a New 5-in. Pipe Body Y (~50X).....	7
6	Thread Profile of a New 5-in. Pipe Body A (~50X).....	8
7	Thread Profile of an Old Pipe Body (~50X).....	8
8	Thread Profile of a New Pipe Plug (~50X).....	9
9	Thread Profile of an Old Pipe Plug (~50X).....	9
10	Thread Profile of a Pipe with Thread Damage (~50X).....	11
11	Low Magnification (3X) Photograph of Pipe Body Y.....	11
12	Minor Thread Damage on Pipe Cap.....	12
13	Thread Damage of Old Pipe Body.....	12
14	Apparatus Used for Vacuum Bubble Testing 2R Vessels.....	15
15	Apparatus Used for Bubble Testing 2R Vessels at Elevated Pressures.....	15
16	Apparatus Used for Bubble Testing 2R Vessels at Elevated Temperature and Pressure.....	16
17	Pipe Cap Fixture Used to Torque Pipe Caps on Pipe Bodies....	16
18	Pipe Plug Fixture Used to Torque Pipe Plugs on Pipe Tubes...	17
19	Various Size Cans Used in Pressure Tests.....	17
20	Cross Section of a Crimp-Sealed Lid on a Food Pack Can.....	19
21	Cross Section of the Side Seam of a Food Pack Can.....	19
22	Seams of Food Pack Cans Coated with Silicone Rubber Compound.....	21
23	Apparatus Used for Bubble Testing Crimp-Sealed Cans.....	21
24	Apparatus Used to Bubble Test Crimp-Sealed Cans at Elevated Pressures.....	22

CONTENTS

SUMMARY AND CONCLUSIONS.....	iii
INTRODUCTION.....	1
TEST BASIS AND HARDWARE DESCRIPTION.....	3
2R INNER CONTAINMENT VESSEL.....	4
FOOD PACK CANS.....	14
IMPACT AND HEATING TESTS.....	20
RESULTS AND DISCUSSION.....	27
2R INNER CONTAINMENT VESSELS.....	27
FOOD PACK CANS.....	34
IMPACT AND HEATING TESTS.....	39
REFERENCES.....	45
APPENDIX A - CORRESPONDENCE BETWEEN NRC AND DOT.....	A.1
APPENDIX B - INSTRUCTIONS FOR PROPERLY ADJUSTING SEALING MACHINES.....	B.1
APPENDIX C - OPERATING PROCEDURES.....	C.1

25	Cross Section of DOT-6M Containers Showing Packaging Configurations Used to Protect the Metal Cans During Impact Testing.....	23
26	Cross Section of DOT-6M Container Showing Packaging Configuration Used to Protect the Metal Cans During Impact Testing.....	24
27	Drop Test Facility for Impact Testing of 6M Containers.....	25
28	Thread Profile of Pipe Body Y After Repeated Openings and Closures.....	31
29	Comparison of the Amount of Deformation of Different Size Metal Cans after Pressurization.....	35
30	The Volume Change of Metal Cans 4-1/16-in.D x 4-11/16-in. H Under Pressure.....	37
31	The Volume Change of Metal Cans 4-4/16-in. D x 7-in. H Under Pressure.....	37
32	Lid Failure by Tearing Under Pressure.....	38
33	Lid Failure by Uncrimping Under Pressure.....	38
34	Damage to 6M Container After 30-Foot End-On Impact.....	40
35	Damaged Metal Can Containing Sand After First 30-Foot Impact Test.....	40
36	Damaged Larger Metal Can After First 30-Foot Impact Test....	41
37	Damaged Larger Metal Can After Second 30-Foot Impact Test...	42

GAS LEAK CHARACTERISTICS OF INNER PACKAGING COMPONENTS USED IN THE DOT-SPEC 6M CONTAINER

INTRODUCTION

This report describes the testing that was done to determine the gas leak characteristics of screw-type 2R inner containment vessels of the 6M container and of the food pack cans used to package the radioactive material placed in the 2R vessels. This testing was performed by Pacific Northwest Laboratory for the U. S. Department of Energy.

The Department of Transportation Specification 6M containers (Figure 1) are currently approved by the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT) for packaging of Type B quantities of solid radioactive material. Recently, the NRC expressed concern to the DOT (see Appendix A) that the inner containment vessel (2R vessel) of the 6M container may not be adequate to meet current regulations for Type B packaging. In particular, the NRC indicated that the requirements of 10 CFR Part 71.52, concerning no loss or dispersal of radioactive material to a sensitivity of 10^{-6} A₂ quantity per hour under normal conditions of transport or an A₂ quantity per week under hypothetical accident conditions, have not been demonstrated. To determine if the inner packaging components could meet the above requirements, the metal cans and 2R vessels were subjected to pressure, impact, and heating tests.

The leakage tests were conducted with 2R vessels having screw-type fittings. The testing was confined to these types of vessels because the majority of 6M containers currently in use have 2R vessels with screw-type closures (caps and plugs). The testing was also confined to the 30-gallon size 6M containers because it is the most common size used by DOE contractors.

The sections that follow describe the testing that was performed, the food pack cans and 2R vessels, the sealing methods used to obtain gas tight seals, and the results of the testing. Instructions for properly adjusting can sealers to obtain hermetic seals are provided in Appendix B. Appendix C outlines procedures for sealing 2R vessels and metal cans.

FIGURE 1. DOT Specification 6M Container

TEST BASIS AND HARDWARE DESCRIPTION

Containers that are approved for packaging sizable amounts of radioactive materials must meet certain test criteria, such as hypothetical accident conditions. These conditions consist of dropping the container 9 meters (30 feet) onto an unyielding surface, followed by a drop of 1 meter onto a cylinder 15 centimeters (6 inches) in diameter and 20 centimeters (8 inches) long. After these tests, the package is exposed to a high-temperature environment (usually a fire) of 800°C (1475°F) for 30 minutes. If the package contains fissile material such as plutonium or enriched uranium, the package must next be immersed under a head of water 0.9 meters (3 feet) for eight hours. A separate immersion test on an undamaged package must also be performed. This consists of immersing the container under 15 meters (50 feet) of water for eight hours. All these tests must be conducted sequentially. The test requirements are spelled out in detail in the Code of Federal Regulations (CFR) Title 10 Part 71.73. If, after these tests, the package does not leak radioactive material exceeding a total amount of $A_2^{(a)}$ in one week, it can qualify as a Type B container.

The NRC has indicated that the ANSI N14.5 standard (NRC 1975) describes acceptable test methods to demonstrate radioactive material leakage below the values listed above. ANSI N14.5 describes methods for converting maximum permissible material leakage rates to that of a gas leak rate. The standard defines leak tightness as a gas leak rate below 10^{-7} atm cc/sec.

To determine if the metal cans and the 2R vessels could meet the gas leak rate standards, they were sealed and pressure tested at room temperature and also at 300°F. The cans inside the 2R vessels were also loaded into 6M drums and subjected to 30-foot drops, with subsequent heating (300°F) of the 2R vessel. The furnace heating of the 2R vessel to 300°F simulated the temperatures achieved during the fire test. It has been shown (Chalfant 1984) that the 2R vessel inside a 6M container heats to less than 300°F during fire tests, if the radioactive material packaged inside the 2R vessel does not exceed 10 watts of thermal output. The puncture and the immersion tests were

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(a) For definitions of A_2 quantity see 49 CFR 173.403 (b).

omitted from the required sequential test series because these tests would not damage the 2R vessel or the metal cans sufficiently to have an effect on the leak rate characteristics of these components.

2R INNER CONTAINMENT VESSEL

The specification for the 2R inner containment vessel is stated in the 49 CFR Part 178.34. The specification states that the ends of the vessel must be fitted with screw-type or flange-type closures. One end of the vessel may be permanently closed by a welded plate.

Typical 2R vessels with threaded closures are shown in Figure 2. Almost all the 2R vessels presently in use with the cap closure are made from a standard 5-inch pipe with an inside diameter of 5.047 inches and an outside diameter of 5.563 inches. The 2R vessel with the plug closure is made from tubing having an inside diameter of 5.250 inches and an outside diameter of 5.750 inches. The specification allows different sizes of 2R vessels as long as the inside diameter does not exceed 12 inches. Another limitation on the size of the 2R vessel is the minimum thickness of the insulation media inside the 6M drum. The inner vessel must be protected by at least 3.75 inches of insulation material.

FIGURE 2. Typical 2R Vessels with Pipe Cap -
Pipe Plug Closures

The screw-type closure can be either caps or plugs and the number of threads per inch must not be less than that specified for the USA standard taper pipe thread. The types of threads used on pipe and pipe fittings may be classed according to their intended use. The threads for 2R vessels, caps and plugs are intended to produce pressure-tight joints when assembled with a sealer or luting compound. The basic form of the USA standard taper pipe thread is shown in Figure 3. The tolerances for a 5-inch schedule 40 pipe thread are given in Table 1. The basic pitch diameter (E_0) of a taper thread is determined by the following formula.

$$E_0 = D - (0.05D + 1.1) p \quad (1)$$

where D = outside diameter of pipe

E_0 = pitch diameter of thread at end of pipe

p = thread pitch.

The location of the pitch diameters is shown in Figure 4.

TABLE 1. Tolerances on 5-Inch External and Internal Taper Pipe Threads, NPT

Outside Diameter, D	5.563 inches
Pitch Diameter, E_0	5.391 ± 0.0078 inches
Threads Per Inch, n	8
Height of Thread, h	0.0964 ± 0.036 inches
Truncation, f	0.006 ± 0.0019
Equivalent Width of Flat, F_C or F_R ^(a)	0.0069 ± 0.0021
Pitch, P	0.125 ^(b)
Pitch Angle Degrees	$+18'$ $1^\circ 47' - 9'$
Angle of Threads, Degrees	$60^\circ + 1.5^\circ$

(a) F_C = Crest; F_R = Root

(b) No tolerances listed

Notation

H = height of 60 deg. sharp V thread
 h = height of thread on product
 $p = 1/n$ = pitch (measured parallel to axis)
 n = number of threads per inch

f_c = depth of truncation at crest
 f_r = depth of truncation at root
 F_c = width of flat at crest
 F_r = width of flat at root

FIGURE 3. Basic Form of USA Standard Taper Pipe Thread

FIGURE 4. USA Standard Taper Pipe Thread Notation

Several new and old 2R pipes and pipe plugs were optically gauged to determine conformance to the specifications. Profiles of these threads are shown in Figures 5, 6, 7, 8 and 9. The measured values obtained from optically gauging the threads are given in Table 2.

Except for pipe body Y (Figure 5), the thread profiles shown in Figure 6, 7, 8 and 9 appear uniform. Since the threads shown in Figure 5 are new threads, it appears that they were cut with a badly worn die. The measured values listed in Table 2 show that the pipe threads for pipe Y and the new plug A do not conform to the specifications. The other pipes and plugs listed in Table 2 are within the tolerance allowed except for the pitch diameter for the plugs and other minor deviations (truncations and flats). Using Equation (1), the thread pitches were calculated and compared to the measured pitch values. The calculated values for the thread pitches are shown in parentheses in Table 2.

FIGURE 5. Thread Profile of a New 5-in. Pipe Body Y (~50X)

FIGURE 6. Thread Profile of a New 5-in. Pipe Body A (~50X)

FIGURE 7. Thread Profile of an Old Pipe Body (~50X)

FIGURE 8. Thread Profile of a New Pipe Plug (~50X)

FIGURE 9. Thread Profile of an Old Pipe Plug (~50X)

2R vessels that have been used repeatedly sometimes develop worn threads if the threads are not properly lubricated. Figure 10 shows a thread profile of a used pipe body. The picture shows damage at the root of the thread.

Visual examination under low magnification (3X) is of value in determining thread condition. The thread profile shown in Figure 5 is also shown in Figure 11 at 3X magnification. Even at low magnification, the threads show tool chatter and surface cracking. Other types of thread damage are shown in Figures 12 and 13.

Prior to leak testing, the threads were examined visually under low magnification (3X). If the threads appeared to be in good condition, the threads were luted with a luting compound. Some pressure tests, however, were made with threads in poor condition. The following luting compounds were tried:

- Teflon® tape
- high-temperature silicone grease
- LA-CO T-O-T® pipe joint compound
- LA-CO SLIC-TITE®
- G.E. Silicone Hi-Temp Gasket Material (GEC 56002)®.

TABLE 2. Measured Values for 5-Inch 2R Pipes and Plugs

Pipe Designation	Thread Height (h), in.	Thread Angle	Pitch Angle	Pitch Diam. (E_o), in.	O.D., in.	Thread Pitch in.	Truncation ($f_c^{(a)}$), in.	Equivalent Width of Flat, ($f_c^{(a)}$), in.
New Pipe Y	0.079	63°4'	56'	5.401	5.569	0.122	$f_R = 0.0074$ $f_c = 0.0184$	$F_R = 0.0094$ $F_c = 0.0215$
New Pipe A	0.063	59°34'	1°49'	5.397	5.572	0.128(.127)	$f_R = 0.0068$ $f_c = 0.0070$	$F_R = 0.0074$ $F_c = 0.0074$
Old Pipe	0.100	64°31'	1°23'	5.401	5.582	0.128(.131)	$f_R = 0.006$ $f_c = 0.005$	$F_R = 0.010$ $F_c = 0.007$
Old Plug	0.093	60°10'	1°20'	5.307	--	0.122	$f_R = 0.0133$ $f_c = 0.0042$	$F_R = 0.016$ $F_c = 0.053$
New Plug A	0.093	60°	1°45'	5.307	--	0.123	$f_R = 0.0046$ $f_c = 0.0088$	$F_R = 0.0048$ $F_c = 0.0150$

(a) f_R - Truncation at root of thread (see Figure 3)
 f_c - Truncation at crest of thread (see Figure 3)

(b) F_R - Width of flat at root
 F_c - Width of flat at crest

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® LA-CO T-O-T and LA-CO SLIC-TITE are registered trademarks of Lake Chemical Co.

® GEC 560002 is a registered trademark of the General Electric Co.

FIGURE 10. Thread Profile of a Pipe with Thread Damage (~50X)

FIGURE 11. Low Magnification (3X) Photograph of Pipe Body Y

FIGURE 12. Minor Thread Damage on Pipe Cap

FIGURE 13. Thread Damage on Old Pipe Body

The Teflon® tape was the standard material commonly used to tape pipe threads. At least three layers of tape were usually wrapped over the threads. The silicone grease was a high-temperature vacuum grease, with a temperature range of 5°F to 480°F.

The LA-CO T-O-T® pipe compound is a common pipe compound used to make up water and steam lines. The material contains silicone for lubrication. The temperature range listed by the manufacturer (Lake Chemical Co.) is from -20°F to 200°F.

The LA-CO SLIC-TITE® paste luting compound is the compound applied to the 2R vessels by FBF Incorporated, the principal supplier of the 6M containers. The pipe compound has Teflon® suspended in a neutral vehicle. The compound can be used when temperatures range from -50°F to 500°F.

The silicone rubber is a high-performance silicone sealant. The material used in the testing program was a high-temperature variety manufactured by General Electric. The temperature range listed for the material is from -80°F to 500°F.

To compare the sealing characteristics of the various compounds, a series of pipe assemblies was used. All the compounds listed were usually applied to each assembly tested so that a comparison could be made between them. The procedure used for a single pipe assembly was as follows:

1. Clean threads thoroughly.
2. Examine threads using magnifying glass.
3. Apply luting compound to threads of both cap, plug or pipe.
4. Screw cap or plug onto pipe and torque to 100 ft-lb.
5. Pressure test assembly at 15 psig under water. If leakage is detected, tighten assembly in 50 or 100 ft-lb increments until assembly is leak tight or 400 ft-lb is reached.
6. Repeat above steps using a different luting compound.

The pipe threads that had been luted with the pipe thread compounds and greases were successfully cleaned with trichloroethylene. After degreasing the threads, they were blown dry by compressed air. Removal of the silicone rubber was more difficult. The threads were soaked in xylene for 12 to 14 hours, which caused the rubber to soften and swell. After soaking, the rubber was stripped off by using a wire brush and applying the trichloroethylene while brushing.

Leak tests with the pipe assemblies were also conducted at higher temperatures and pressures. Pipe assemblies that had been luted with the silicone rubber compound were pressurized to 100 psig and heated to 320°F.

The apparatus used for leak testing the 2R vessels are shown in Figures 14, 15 and 16. The vacuum bubble tester (Figure 14) was limited to a pressure difference of one atmosphere. The gas pressure units shown in Figures 15 and 16 were used to pressurize the 2R vessels to 100 psig. Silicone oil was used in the bath (Figure 16) when the 2R vessel was heated to 320°F. The 2R vessels were also heated in furnaces to 300°F to test the sealing quality of the various luting compounds.

In order to apply a known torque force to a cap or plug, special fixtures were fabricated (Figures 17 and 18). Also, a 1-15/16-in. bolt head was welded to a cap so that a 1-15/16-in. socket could be used to tighten the cap. The torque wrench used was calibrated to a $\pm 2\%$ accuracy.

FOOD PACK CANS

The metal cans that were tested were common food pack cans used to package and preserve food. The various sizes of cans tested are shown in Figure 19. The cans conform to a Federal specification, PPP-C-96D. The specifications classify the cans as Type I Class 3 (Packer's Can). A Type I Class 3 can has a round, open top with compound-lined double-seamed ends. The double seam consists of five thicknesses of plate interlocked or folded and pressed firmly together (Figure 20). At the junction of the side seam with the lid, there are seven thicknesses of plate. The side seam of the can is crimped as shown in Figure 21. This seam is soldered or welded after crimping. The food pack cans tested were made from tin plate ranging in thickness from 0.008 inch to 0.010 inch. Tin plate is made from carbon steel sheets coated with tin. The tin plate must conform to the specification

FIGURE 14. Apparatus Used for Vacuum Bubble Testing 2R Vessels

FIGURE 15. Apparatus Used for Bubble Testing 2R Vessels
at Elevated Pressures

FIGURE 16. Apparatus Used for Bubble Testing 2R Vessels at Elevated Temperature and Pressure

FIGURE 17. Pipe Cap Fixture Used to Torque Pipe Caps on Pipe Bodies

FIGURE 18. Pipe Plug Fixture Used to Torque
Pipe Plugs on Pipe Tubes

FIGURE 19. Various Size Cans used in Pressure Tests

FIGURE 20. Cross Section of a Crimp-Sealed Lid on a Food Pack Can

FIGURE 21. Cross Section of the Side Seam of a Food Pack Can

QQ-T-425. The tin coating is usually very thin ranging in thickness from 0.00015 in. to 0.000060 in. In addition to the tin coating, these cans are usually coated with different kinds of coatings or enamel (epoxy) to protect the surface from certain types of foods that may be packaged.

The specification PPP-C-96D states that the seaming compounds used in the lids and side seams of the can shall comply with commercial standards. The material commonly used is a butyl rubber-type material that is applied under pressure to the lids. Cans that require hermetic seals must be tested for leakage. The specification requires that the cans be pressurized to 3 psig for 30 minutes without evidence of leakage. The leak test method prescribed by the regulation is method 5009 of Federal Standard No. 101. This test amounts to a hot water bubble test that will provide the 3 psig pressure required. Leakage is defined by the recurring formation of bubbles in the bath from any surface on the can in the time interval specified.

In order to obtain hermetically sealed cans, a proper crimp seal must be made. Several things can influence the type of seals that are obtained.

Among these are:

- condition of the sealing compound (gasket)
- condition of the can body
- condition of the flange (before crimping)
- proper setup of the can sealer.

The specifics on obtaining good seals are discussed in Appendices B and C.

Sealing compounds such as glyptal enamel and silicone rubber were used to seal cans that leaked. The sealing compounds were applied to the seams after they had been crimped (Figure 22). Usually two applications of the sealant were required to obtain hermetic seals. The sealant was allowed to dry 12 to 14 hours between applications and testing.

The leak testing performed on the metal cans was more severe than required by the Federal specification. The sealed cans were vacuum bubble tested and gas pressure tested. The setup for the vacuum bubble tester and gas pressure tester was similar to the one used to leak test the 2R vessels (Figures 23 and 24).

In the gas pressure unit, the leak rate was measured by in-line rotometers. Two sizes of rotometers were used. One rotometer was capable of sensing flow rates between 0.4 std. cc/min to 120 cc/min and the other could

measure flow rates between 100 cc/min to 5500 cc/min at a 10 psig pressure differential. The rotometers were calibrated using a bubbler pipet.

An absolute leak rate cannot be obtained with the vacuum bubble test. However, the sensitivity of this test (King 1965) has been determined by preparing a number of calibrated leaks, measuring the hole sizes microscopically and measuring the leak rates. Leak rates as small as $\sim 4 \times 10^{-6}$ atm cc/sec can be detected by using good lighting and low power magnification (3X) to inspect the part being leak checked.

In order to obtain quantitative leak rates below 10^{-5} cc/sec, metal cans were sealed containing a helium atmosphere. The cans were placed in a vacuum chamber that was connected directly to a helium leak detector. Calibrated leak sources were used to determine the helium leak rate of the metal cans.

IMPACT AND HEATING TESTS

Impact and heating tests were performed on loaded 30-gallon 6M containers. Different packaging arrangements of the metal cans inside the 2R vessel were tested. In all the arrangements tested, two columns of cans were stacked inside the 2R container. The difference in the packaging arrangements was the method used to protect the metal cans inside the 2R vessel. Rubberized horsehair and empty metal cans were used as impact limiters. The packaging configurations are shown in Figures 25 and 26.

The inner food pack cans (4-1/16-in. D x 4-11/16-in. h) shown in Figures 25 and 26 were loaded with either sand or sand and lead shot. When sand alone was used, the amount of sand loaded into a single 4-1/16-in. D x 4-11/16-in. h can was between 1100 to 1200 g. When sand and lead shot were added to the cans, the cans were loaded to approximately 2.3 kg each. The sand and shot provided the ballast needed to simulate loadings of radioactive material such as UO_2 and PuO_2 powders. The cans containing the sand were either vacuum bubble tested or pressure tested and were gas tight ($< 10^{-5}$ cc/min) prior to the test. The cans containing the sand and shot were placed in the larger cans 4-1/4-in. D x 7-in. h with either rubberized horsehair or an empty metal can filling the void space. The cans were then stacked inside the 2R vessel as shown in Figures 25 and 26.

FIGURE 22. Seams of Food Pack Cans Coated with Silicone Rubber Compound

FIGURE 23. Apparatus Used for Bubble Testing Crimp-Sealed Cans

FIGURE 24. Apparatus Used to Bubble Test Crimp-Sealed Cans at Elevated Pressures

The metal spacers shown (Figure 26) were used in tests after the horsehair and metal lid spacers were tested. The spacer plates were machined so that the cans would not shift horizontally during impact. By eliminating the horizontal movement, the impact forces would be transmitted to the side walls rather than the lids of the cans. The column of cans along with the spacer cans were stacked in such a manner that the column was compressed when the plug or cap was screwed onto the pipe body.

After loading, the 2R vessels were shaken and no rattling could be detected. The threads of the 2R vessels were luted either with high-temperature silicone grease, LA-CO SLIC TITE® paste or silicone rubber. The specification for the 6M container {49 CFR 178.104(e)} requires bearing plates to be used on the top and bottom of the 2R vessel inside the 6M drum when the container weight exceeds 480 pounds. The 30-gallon size 6M containers do not require bearing plates but the larger containers do, so the effect of the bearing plates on impact loading needed to be determined. For one of the impact tests a 10-in. x 10-in. x 1-1/8-in. thick plywood plate was placed on top of the 2R vessel inside the 6M drum. All the other drop tests were done with the 2R in contact with the celotex packaging material.

FIGURE 25. Cross Section of DOT-6M Containers Showing Packaging Configurations Used to Protect the Metal Cans During Impact Testing

FIGURE 26. Cross Section of DOT-6M Container Showing Packaging Configuration Used to Protect the Metal Cans During Impact Testing

After loading the 2R vessel into the 6M drum, the drums were dropped 30 feet (Figure 27) onto a concrete pad embedded with a steel plate. The drums were dropped end on because it was reported (Blankenship 1980) that the cans received the most damage when the drums were dropped in that position.

After impact, the 2R vessel was pressure tested to determine leakage. The 2R vessel was then placed in a furnace, heated to 300°F, held at 300°F for at least one hour, and then removed from the furnace. During the heating and soaking, the pressure inside the 2R vessel was monitored. The 2R vessel was also vented during some of the heating tests so that the differential pressure (ΔP) inside the cans would be greater. The metal cans were examined after the impact and heating tests, and were either vacuum bubble tested or pressure tested.

FIGURE 27. Drop Test Facility for Impact Testing of 6M Containers

RESULTS AND DISCUSSION

This section discusses the results of leak testing 2R vessels and metal cans. The effect of impact and heating tests on the leak rate of the 2R vessels and the metal cans is also discussed.

2R INNER CONTAINMENT VESSELS

Four pipe cap-pipe body and two pipe-plug pipe body assemblies were tested. A comparison was made between new and used pipe assemblies. The results of the leak tests are given in Table 3. Some correlation between the leak rate and the thread specifications given in Table 2 was attempted. It was assumed that the pipe bodies and plugs within specifications would seal at lower torques than those that were out of specification. However, when the pipe assemblies were leak tested, no conclusive correlation could be made based on the data in Table 2.

The correlation between thread specification and sealing ability held up no better with the pipe-plug pipe tube assemblies. Both the new and the old plugs were not within specifications; however, when the A plug was screwed into the pipe tube, the fit was quite loose as compared to the make up of the old plug in the pipe tube. It was possible to seal (air tight $<10^{-5}$ cc/sec) the used plug assembly with all of the pipe compounds tried. But no seals were obtained with the A plug assembly with any of the compounds tried, except the silicon rubber compound.

The fit between the mating parts determines how well a pipe assembly seals. A condition might prevail, although remote, where a cap or plug that was out of specification might compensate for a pipe body that was out of specification, the result being that when the two were fastened together they might fit better than two parts that were within the specifications. Unfortunately, pipe ring and plug gauges were not available to gauge both the inside and outside threads. The optical comparator that was used could only measure outside threads.

TABLE 3. Leak Test Data for Pipe Cap, Pipe Plug, Pipe Body Assemblies

Pipe Assembly	Condition	Test No.	Optical Profile	Luting Compound	Tightening Torque, ft-lbs	Pressure psig	Leak Rate, cc/sec	Comments
Pipe Cap "A"	New	7	Fig. 5	LA-CO T-O-T	200	10	<2	Used different pipe cap.
Pipe Cap "A"	New	8	Fig. 5	LA-CO T-O-T	400	11	Leaks	Same pipe cap as in test 7.
Pipe Cap "A"	New	9	Fig. 5	LA-CO Slic-Tite	200	100	No leaks	
Pipe Cap "A"	New	10	Fig. 5	LA-CO Slic-Tite	100	20	Leaked	
Pipe Cap "A"	New	11	Fig. 5	LA-CO Slic-Tite	200	100	No leaks	
Pipe Cap "A"	New	12	Fig. 5	LA-CO Slic-Tite	200	100	No leaks	Heated to 300°F in silicon bath and pressurized. Used new pipe compound.
Pipe Cap	Slightly Used	1	--	Silicon Grease	300	75	No leaks	
Pipe Cap	Slightly Used	2	--	Silicon Grease	300	15	~0.2	Assembly torqued to 300 ft-lbs and loosened 12 times.
Pipe Cap	Slightly Used	3	--	Silicon Grease	100	15	~10	
Pipe Cap	Slightly Used	4	--	Silicon Grease	200	15	~7	
Pipe Cap	Slightly Used	5	Fig. 9	Silicon Grease	500	30	~0.3	No leaks until 30 psi.
Pipe Cap	Slightly Used	6	Fig. 9	Teflon Tape	500	15	>80	3 or more layers of tape applied to threads.
Pipe Cap	Slightly Used	7	Fig. 9	Silicon Rubber	300	100	No leaks	Pressurized while assembly was heated to 320°F.
Pipe Plug "A"	New	1	Fig. 7	LA-CO T-O-T	450	10	>80	Not a good interference fit between pipe and plug.
Pipe Plug "A"	New	2	Fig. 7	Teflon Tape	400	10	>80	At least 3 layers of tape applied to threads.
Pipe Plug "A"	New	3	Fig. 7	LA-CO Slic-Tite	400	10	>80	
Pipe Plug "A"	New	4	Fig. 7	LA-CO Slic-Tite	300	11	~15	Recoated threads with compound & tightened.
Pipe Plug "A"	New	5	Fig. 7	LA-CO Slic-Tite	400	21	Leaks	Recoated threads with compound.
Pipe Plug "A"	New	6	Fig. 7	Silicon Grease	400	10	>80	
Pipe Plug "A"	New	7	Fig. 7	Silicon Rubber	200	90	~43	No leaks until 90 psi.
Pipe Plug "A"	New	8	Fig. 7	Silicon Rubber	~20	15	No leaks	Did not test to higher pressures. Reserved for heat test. Plug put on with socket wrench, strap wrench.
Pipe Plug "A"	New	9	Fig. 7	Silicon Rubber	~20	60	No leaks	Heated to 375°F.

TABLE 3. (contd)

Pipe Assembly	Condition	Test No.	Optical Profile	Luting Compound	Tightening Torque, ft-lbs	Pressure psig	Leak Rate, cc/sec	Comments
Pipe Cap "Y"	New	1	Fig. 4	LA-CO T-O-T	300	96	~37	No leaks until 96 psi.
Pipe Cap "Y"	New	2	Fig. 4	LA-CO T-O-T	200	100	~10	No leaks until 100 psi.
Pipe Cap "Y"	New	3	Fig. 4	LA-CO Slic-Tite	200	10	~4	Set overnight, pipe compound hardened somewhat.
Pipe Cap "Y" &	New	4	Fig. 4	LA-CO Slic-Tite	300	10	~7	Cleaned thread, recoated with compound tested.
Pipe Cap "Y"	New	5	Fig. 4	LA-CO Slic-Tite	400	100	No leaks	
Pipe Cap "Y"	New	6	Fig. 4	LA-CO T-O-T	300	100	No leaks	Torqued to 300 ft-lbs & loosened 12 times.
Pipe Cap "Y"	New	7	Fig. 4	LA-CO T-O-T	200	80	~10	No leaks until 80 psi.
Pipe Cap "Y"	New	8	Fig. 4	LA-CO T-O-T	300	21	~1	Pipe heated to 300°F. Before heating assembly was leak tight to 90 psi.
Pipe Cap "Y"	New	9	Fig. 4 T-O-T	LA-CO	100	20	~30	
Pipe Cap "Y"	New	10	Fig. 4	Silicon Rubber	~60	50	<0.1	Pipe cap put on with strap wrench.
Pipe Cap "Y"	New	11	Fig. 4	LA-CO Slic-Tite	100	100	No leaks	
Pipe Cap "Y"	New	12	Fig. 4	LA-CO Slic-Tite	60	100	No leaks	Lower limit of torque wrench.
Pipe Cap	Used	1	Fig. 6	LA-CO T-O-T	200	11	~8	
Pipe Cap	Used	2	Fig. 6	LA-CO T-O-T	300	90	~2x10 ⁻²	No leaks until 90 psi.
Pipe Cap	Used	3	Fig. 6	LA-CO Slic-Tite	300	100	No leaks	
Pipe Cap	Used	4	Fig. 6	LA-CO Slic-Tite	200	100	No leaks	
Pipe Cap	Used	5	Fig. 6	LA-CO Slic-Tite	100	100	No leaks	
Pipe Cap	Used	6	Fig. 6	LA-CO Slic-Tite	60	10	Leaks	
Pipe Cap "A"	New	1	Fig. 5	LA-CO Slic-Tite	200	100	No leaks	
Pipe Cap "A"	New	2	Fig. 5	LA-CO Slic-Tite	200	40	<2	Heated to 300°F, cooled and pressure tested.
Pipe Cap "A"	New	3	Fig. 5	LA-CO T-O-T	100	10	>80	
Pipe Cap "A"	New	4	Fig. 5	LA-CO T-O-T	200	10	~4	
Pipe Cap "A"	New	5	Fig. 5	LA-CO T-O-T	300	11	<2	
Pipe Cap "A"	New	6	Fig. 5	LA-CO T-O-T	400	10	<2	

TABLE 3. (contd)

Pipe Assembly	Condition	Test No.	Optical Profile	Luting Compound	Tightening Torque, ft-lbs	Pressure psig	Leak Rate, cc/sec	Comments
Pipe Plug	Used	1	Fig. 8	LA-CO T-O-T	200	11	~15	Threads not completely coated with pipe compound.
Pipe Plug	Used	2	Fig. 8	LA-CO T-O-T	200	100	No leaks	Recoated threads with thread compound.
Pipe Plug	Used	3	Fig. 8	LA-CO SLIC-Tite	300	50	<2	No leaks up to 50 psi.
Pipe Plug	Used	4	Fig. 8	LA-CO SLIC-Tite	400	100	No leaks	
Pipe Plug	Used	5	Fig. 8	Silicon Grease	400	10	80	Threads seized some thread damage.
Pipe Plug	Used	6	Fig. 8	Silicon Rubber	200	100	No leaks	

A pipe thread compound must properly lubricate the threads as well as act as a sealant. When silicon grease was used, a number of thread seizures occurred at the higher torques. The silicon grease evidently does not lubricate the threads sufficiently to prevent thread galling. The thread profile shown in Figure 10 is the profile of a pipe that had been luted with silicon grease. The cap pipe assembly had been tightened and loosened repeatedly (Test 2, Table 3, slightly used assembly). The threads seized after repeated tightings, which caused the thread damage shown in Figure 10. Because of the potential problem of thread seizure, silicon grease should not be used as a luting compound.

If the thread compound provides the proper lubrication, the pipe assembly can be tightened and loosened repeatedly without damage to the thread. If thread damage does not occur, the pipe assembly can be sealed repeatedly using essentially the same tightening torques. The Y pipe assembly was repeatedly tightened and loosened 12 times without evidence of thread change, Figure 28 (compare with Figure 5). After the repeated tightenings and loosening, plus applying higher tightening torques, the assembly could still be sealed when the cap was tightened to 300 ft-lb torque. Also, the A pipe-cap pipe-body assembly was tightened and loosened many times and could be sealed consistently by torqueing the cap to 200 ft-lb.

The ability of the LA-CO T-O-T® pipe thread compound to maintain a seal degraded when it was heated. The silicon rubber compound, however, maintained its sealing ability at elevated temperature under all testing conditions. The LA-CO SLIC-TITE® compound maintained its sealing ability when heated in a silicon bath, but not when heated in a furnace.

FIGURE 28. Thread Profile of Pipe Body Y
After Repeated Openings and Closures

The Y pipe assembly luted with the LA-CO T-O-T® compound was leak tight to 90 psig before heating. After heating to 300°F, the assembly leaked at 21 psig. The LA-CO SLIC-TITE® performed better: before heating, it was leak tight to 100 psig (200 ft-lb torque); after heating at 300°F, it leaked at 40 psig. Another heating test was conducted using the LA-CO SLIC-TITE® compound. The A pipe cap pipe body assembly was luted with the new LA-CO SLIC-TITE® compound and the cap was torqued to 200 ft-lb. The assembly was heated to 300°F in a silicon oil bath, and while at 300°F, it was pressurized to 100 psig. No leaks were observed. These tests demonstrate that if the LA-CO SLIC-TITE® compounds dries out or bakes during heating, leaks will develop. Heating the LA-CO SLIC-TITE® compound under silicon oil prevented it from drying out and a seal was maintained.

The silicon rubber compound proved to be a superior luting compound under all testing conditions. The A plug-tube assembly could not be sealed using any of the standard pipe thread compounds. However, when the silicon rubber compound was applied to the threads, a leak tight seal was obtained to 90 psig (test no. 7, Table 3). The silicon rubber compound provided leak tight seals at low tightening torques. To simulate practices used in the field, the A plug-tube assembly and the Y cap-pipe assembly were luted with the silicon rubber compound and tightened using a strap wrench and an ordinary socket wrench.

The Y cap-pipe assembly was tightened by using a strap wrench on the cap. The pipe body was held in a vice during the tightening operation. A torque wrench was applied to the cap after tightening to measure the tightening torque. It was estimated that the cap had been tightened to about 60 ft-lb.

The A plug-tube assembly was tightened by holding the tube with a strap wrench and screwing the plug into the tube with a socket wrench with a 10-in. handle. The estimated tightening torque was about 20 ft-lb. The results shown in Table 3 indicate that the Y assembly was leak tight to 50 psig and the A assembly was leak tight to 60 psig.

Heating the silicon compound to 300°F did not affect its ability to seal. The silicon rubber compound was applied to the damaged threads of the slightly used cap-pipe assembly (test no. 7, Table 3) and torqued to 300 ft-lb. The assembly did not leak at 100 psig at room temperature. After heating to 320°F and holding for over one hour, the assembly still did not leak at 100 psig.

The sealing mechanism for the pipe thread compounds that were tested is different. The LA-CO T-O-T® compound depends on ^{viscosity} ~~high surface tension~~ to provide seals. The LA-CO SLIC-TITE® compound relies on ^{viscosity} ~~surface tension~~ but also has the ability to plug openings due to the Teflon® particles suspended in the neutral vehicle. Under internal pressure, the pipe compound is pushed around. As the compound is forced into openings, it dams up and plugs the openings. If the internal pressure continues to increase, ultimately a pressure is reached where the compound collapses and a leak path is opened. When pipe threads are tightened, a point is reached where the threads will not advance any further regardless of the torque applied. If at this point the mismatch area is too great and the pipe compound does not have sufficient viscosity or the potential leak path is not long enough to allow enough pipe compound to dam up to resist the applied pressure, then it would not be possible to obtain a leak tight seal. Consequently, threads not within the specifications might have areas of mismatch that would be continuous at the roots, crests or flanks of the threads and that could not be sealed with standard pipe compounds regardless of the tightening torques applied. If standard pipe compounds are to be used for sealing pipe assemblies, it is recommended that the threads be gauged and that the assemblies be within specifications.

When silicon rubber is used as a luting compound, if properly cured, it provides a plastic material between the threads. The sealing ability of the silicon rubber depends on its mechanical strength and its adherence to the thread surfaces. The resistance to pressure for a plastic (rubber) material

is higher than a paste or liquid because of its greater molecular bonding (mechanical strength vs viscosity). Consequently, the silicon rubber is capable of sealing areas of greater mismatch between mating parts.

The tests performed have demonstrated that if leak tight seals are to be obtained, then mating parts of a pipe assembly must match and a proper luting compound must be used. The silicon rubber compound that was tested proved to be a superior luting compound. When the silicon rubber compound was used as a luting compound, a wider mismatch between mating parts could be tolerated. Leak tight seals were obtained with pipe assemblies using the silicon rubber compound that could not be sealed using other luting compounds.

FOOD PACK CANS

The results of the pressure tests with the food pack metal cans are given in Table 4. The results show leak rates ranging from $<10^{-5}$ to >2 cc/sec. The variance in the leak rate depends on the quality of the seal. Two cans that had no evidence of leakage when vacuum bubble tested were helium leak checked. The helium leak rate was 3.5×10^{-8} cc/sec for one can and 4.8×10^{-8} cc/sec for the other can. The helium leak checks tend to confirm that, under careful test conditions (King 1965) leaks as small as $\sim 4 \times 10^{-6}$ atm cm^3/sec can be detected using a vacuum bubble tester. Based on the helium leak tests, it was assumed that if the cans showed no leakage when vacuum bubble tested, they could be considered leak tight ($<10^{-7}$ cc/sec). The leaky cans that were sealed with glyptal enamel paint and silicon compound become leak tight providing the initial leak rate was not too large. If the mechanical seal appeared to be good, i.e., no visible defects such as droops or lips (see Appendix B), and the leak rate did not exceed ~ 2 cc/sec, then the can could be sealed with silicon compound or glyptal. As the data show in the table, the silicon compound provided leak tight seals to higher pressures than did the glyptal.

The deformation of the can lids varied from can to can. In all the pressure tests performed, only the lids deformed. The sidewall of the cans did not plastically deform. Below about 15 psig the deformation appeared to be reversible except for the flat profile lids that did not have the reinforced rings began to deform irreversibly at about 7 psig. The rings provided additional strength to the lids that ~~prevented~~

Prevented

psig. The smaller can lids of the 3-7/16-in. D x 4-9/16-in. h deformed less than the larger cans. The amount of deformation for a 3-7/16-in. D x 4-9/16-in. h can, a 4-1/16-in. D x 4-11/16-in. h can, and a 4-4/16-in. D x 7-in. h can after they have been pressurized to 35 psig. is shown in Figure 29. The lids of the larger cans are bulged and crinkled, where the lids on the smaller can are only slightly bulged. In some cases, the crinkling of the lid caused leaks to occur at the sites of the crinkles. However, in other cases, greater deformation of the lid at higher pressure sealed leaks that were present at lower pressures (see Table 4).

To ensure leak tight seals, irreversible deformation of the lids should be avoided. If internal pressures greater than one atmosphere are anticipated, it is recommended that the seams of the can be coated with silicone rubber compound. Cans coated with silicone rubber (except flat profile lids) will remain leak tight to about 35 psig. A can sealed with silicone rubber was also pressurized to 50 psig and heated to 320°F without leaking (Table 4).

FIGURE 29. Comparison of the Amount of Deformation of Different Size Metal Cans after Pressurization

TABLE 4. Pressure Test Data for Mechanically Sealed Metal Cans

Can Size	Wall Thickness in.	Lid Thickness in.	Can No.	Pressure psig	Leak Rate cc/sec	Comments
3-7/16"D x 4-9/16"h	0.009	0.009	1	5	$<3 \times 10^{-3}$	Good appearing seal, slight deformation but reversible when pressure released.
3-7/16"D x 4-9/16"h	0.009	0.009	1	16	7×10^{-2}	Lids no more distorted than at 5 psi, reversible deformation.
3-7/16"D x 4-9/16"h	0.009	0.009	1	25	$<1 \times 10^{-5}$	Glyptal paint applied to seams, lids distorted but not above sidewalls.
3-7/16"D x 4-9/16"h	0.009	0.009	1	30	$<3 \times 10^{-3}$	
3-7/16"D x 4-9/16"h	0.009	0.009	1	80-85	--	Can failed, top lid blown off. Side seams split.
3-7/16"D x 4-9/16"h	0.009	0.009	2	16	1	Seams appeared to be good.
3-7/16"D x 4-9/16"h	0.009	0.009	2	35	$<1 \times 10^{-5}$	Silicone rubber compound applied around seam of top lid. Lids distorted beyond sidewall.
3-7/16"D x 4-9/16"h	0.009	0.009	2	40	0.04	Bubble appeared in rubber compound. Lids bulged above sidewall, crinkles starting to form in lids.
3-7/16"D x 4-9/16"h	0.009	0.009	3	16	>2	Seams look all right.
3-7/16"D x 4-9/16"h	0.009	0.009	3	50	$<1 \times 10^{-5}$	Silicone compound applied to seams. Heated to 320°F under pressure.
3-7/16"D x 4-9/16"h	0.009	0.009	3	70-80	--	Can failed, top lid blew off.
4-1/16"D x 4-11/16"h	0.010	0.009	1	17	$<1 \times 10^{-5}$	Lid deformed, lid sealed with motorized can sealer.
4-1/16"D x 4-11/16"h	0.010	0.009	1	21	$<1 \times 10^{-5}$	Lids deformed, crinkle pattern.
4-1/16"D x 4-11/16"h	0.010	0.009	1	65	$<1 \times 10^{-5}$	Lid highly deformed, bulged and crinkled, no observable deformation of can sidewall.
4-1/16"D x 4-11/16"h	0.010	0.009	1	~89	--	Can failure, top blew off.
4-1/16"D x 4-11/16"h	0.010	0.009	2	16	$<1 \times 10^{-5}$	Slight lid bulge reversible, lid sealed with motorized can sealer.
4-1/16"D x 4-11/16"h	0.010	0.009	2	74	$<1 \times 10^{-5}$	Lid greatly deformed, bulged, crinkled.
4-1/16"D x 4-11/16"h	0.010	0.009	2	80	$>10^{-5}$	Small bubbles forming around lid seams. Lids deformed only slightly more than at 74 psi. No distortion of can sidewall.
4-1/16"D x 4-11/16"h	0.010	0.009	2	84-89	--	Can failed, top lid blew off.
4-4/16"D x 4-11/16"h	0.0082	0.0076	3	5	6×10^{-3}	Seal appeared good.
4-4/16"D x 4-11/16"h	0.0082	0.0076	3	10	0.75	Lid deformed, glyptal paint applied to seams but did not seal because of lid deformation.
4-4/16"D x 4-11/16"h	0.0082	0.0076	5	5	$<1 \times 10^{-5}$	Slight deformation of lid.
4-4/16"D x 4-11/16"h	0.0082	0.0076	5	11	0.6	Lid bulged, crinkled.
4-4/16"D x 4-11/16"h	0.0082	0.0076	5	16	0.8	Lid highly deformed.
4-4/16"D x 4-11/16"h	0.0082	0.0076	5	25-30	--	Can failed, top lid ripped at junction of lid and sidewall.
4-4/16"D x 7"h	0.010	0.010	1	5	6×10^{-3}	Top lid sealed with motorized can sealer. Leak occurred at lid sealed by manufacturer.
4-4/16"D x 7"h	0.010	0.010	1	15	$<1 \times 10^{-5}$	Can lids highly bulged. Deformation stopped leakage.

TABLE 4. (contd)

Can Size	Well Thickness in.	Lid Thickness in.	Can No.	Pressure psig	Leak Rate cc/sec	Comments
4-4/16"D x 7"h	0.010	0.010	2	7	3×10^{-3}	Bubbles formed at bottom lid installed by manufacturer.
4-4/16"D x 7"h	0.010	0.010	2	11	10^{-4}	Lids deformed. Deformation stopped leakage from bottom lid. Top lid leaks slightly.
4-4/16"D x 7"h	0.010	0.010	2	55	$< 1 \times 10^{-5}$	Lids bulged about 3/8" above sidewall. Deformation stopped leaks.
4-4/16"D x 7"h	0.010	0.010	2	60	--	Can failed, bottom lid blown off.
4-4/16"D x 7"h	0.010	0.010	3	10	> 2	Leaks from bottom lid installed by manufacturer.
4-4/16"D x 7"h	0.010	0.010	3	70	--	Can failed, bottom lid blown off.

An attempt was made to determine quantitatively the amount of deformation a can undergoes as it is pressurized. A water displacement method was used to measure the volume change of a can as it was pressurized. Figures 30 and 31 show plots of the volume change versus pressure for the 4-1/16-in. D x 4-11/16-in. h and the 4-4/16-in. D x 7-in. h cans. The curves have the same general shape except for the one smaller can. The plots show that the percent volume change versus pressure varies from can to can. It can be concluded from the tests performed that it would be difficult to predict the pressure inside a can by its volume change. However, if a better setup were used, possibly a better correlation could be made. Due to the insensitivity of the apparatus used, the uncertainty in the measurements is about $\pm 50\%$.

At least one can from each of the different size cans tested was pressurized to failure. The cans failed by one of the lids separating from the can body. Two types of lid failure were noted. The lids failed either by tearing at the junction of the lid and the can body (Figure 32) or by uncrimping (Figure 33). Failure by tearing was observed only with the cans that had lid thicknesses of 0.0076 inch or if the lid had a cut-over type of defect (see Appendix B, Figure B.6) that weakened the lid at the junction of the lid and the can body. The thicker can lids (0.009 inch) had greater strength to withstand the bending and shear stresses set up at the lid-can body junction so the can failed by uncrimping the mechanical seal. The lid that uncrimped first was usually the one that leaked first. In any event, the lid that failed first did not have as tight a seal as the other lid. The pressure tests indicate that when the cans are properly sealed, they are gas tight at pressures far in excess of the pressure listed in the Federal Specification. If the cans are hermetically sealed, they will not leak powders such as UO_2 or PuO_2 .

FIGURE 30. The Volume Change of Metal Cans
4-1/16-in. D x 4-11/16-in. H Under Pressure

FIGURE 31. The Volume Change of Metal Cans
4-4/16-in. D x 7-in. H Under Pressure

FIGURE 32. Lid Failure by Tearing Under Pressure

FIGURE 33. Lid Failure by Uncrimping Under Pressure

IMPACT AND HEATING TESTS

The packaging configuration shown in Figure 25 (horsehair padding) was the first 6M configuration tested. Only slight damage occurred to the 6M drums after the 30-foot end-on impact (Figure 34). The 2R vessels were unmarked. The only noticeable damage to the celotex insulation was to the top disc which was in contact with the top of the 2R vessel. The disc was indented about 1/2 inch due to the impact of the 2R vessel. The 2R vessel was leak tested after the impact and no leaks were detected. After heating to 300°F for a little over an hour, it was leak tested again and had a leak rate of ~4 cc/sec at 15 psig. The silicone grease used as a luting compound did not maintain a seal when heated to 300°F. The pressure buildup inside the 2R vessel continued to increase during heating until the vessel was removed from the furnace. The maximum pressure recorded was 19.5 psig. Calculations indicate that the pressure buildup due to the expansion of air should have only been about 6 psig. The steady increase in pressure was indicative of outgassing from the rubberized horsehair. Inspection of the horsehair after the heating test showed some discoloration of the horsehair.

The food pack cans were damaged such that a pressure test could not be performed. A screw fitting that had been screwed into the lid of the can containing the sand had been torn loose (Figure 35). The sand inside the can was dispersed inside the larger food pack can (Figure 36). The horsehair packing did not provide enough resistance to prevent the top can from damaging the bottom can during impact.

The packaging configuration shown in Figure 25 (bottom half) was the second configuration tested. After impact the drum sidewall on one side of the drum was compressed about 1 inch shorter than its original height. Other than this, the drum was not damaged. The 2R container was undamaged and the celotex board on top of the 2R pipe was indented about 1/2 inch, as in the first test. The 2R container was leak checked after impact and no leaks were detected using a bubble leak detector. The pressure buildup during furnace heating did not exceed the pressure (~7 psig) expected for expansion of the air inside the 2R vessel. The 2R vessel was leak checked after the heat test and no leaks were detected using a bubble leak detector. The threads of the 2R assembly were luted with silicon rubber.

FIGURE 34. Damage to 6M Container After 30-Foot
End-On Impact

FIGURE 35. Damaged Metal Can Containing Sand after
First 30-Foot Impact Test

FIGURE 36. Damaged Larger Metal Can after First 30-Foot Impact Test

The can on the bottom of the column, which was the first to be impacted, was damaged (can #4, Figure 37). The top of the can was indented about $3/4$ inch on one side. The indent was caused from the shifting of the empty can used as an impact limiter. If the empty can had remained in line with the other can, the loaded can (#4) would not have sustained as much damage. Can #3, which was positioned on top of the other loaded can, had only minor dents. The inner food pack cans containing the sand were undamaged. However, the empty cans used as spacers and impact limiters were crushed about $1/2$ inch. The empty cans proved to be adequate impact limiters. The cans containing the sand were leak checked after the impact and heating and no leaks were detected using a bubble leak detector.

For the third impact test performed, a 2R vessel with a plug closure was used. The cans were stacked inside the 2R vessel between disk spacers as shown in Figure 26 (top figure). The drum had no noticeable damage after the impact, except the locking ring on the drum head was slightly displaced. The 2R container was undamaged; however, the celotex board on top of the pipe was more indented than in the other tests. This was due to the smaller surface area of the pipe plug impacting on the celotex board. The 2R container was leak checked after impact and no leaks were detected. Silicon rubber compound had been applied to the threads prior to installing the plug. The pipe plug had been tightened in the tube by using a socket wrench (10-inch handle) with a strap wrench securing the tube. The estimated tightening torque was about 60 ft-lb.

FIGURE 37. Damaged Larger Metal Can after Second 30-Foot Impact Test

To determine the effect of higher pressure buildup during heating, the 2R vessel was vented so that a differential pressure could build up between the metal cans and the 2R vessel. This situation might occur if the 2R vessel was breached during an accident. Also, one of the larger metal cans containing the smaller can with sand inside was vented by means of a loose fitting plug installed in the top lid of the can. The other larger can was sealed so that it was leak tight and would be pressurized under heating. The smaller cans containing the sand were also sealed so that during heating, they would be pressurized.

The combination of the spacer disks and empty cans (impact absorbers) proved effective in protecting the metal cans. The larger metal can that was vented was not damaged and retained its original shape. The other larger can that was sealed was distorted. The lids were bulged similar to the large can shown in Figure 28. It was speculated that the can must have been pressurized between 45 and 55 psig to cause the lids to deform as much as they did. It was speculated that some water must have gotten into the can when it was pressure tested under water prior to the impact and heating test. Examination of the can after the tests showed corrosion around the top lid. The can leaked when bubble tested.

The smaller cans were also distorted indicating that they had been pressurized. The amount of distortion was more than could be accounted for just from expansion of air inside the can. It was estimated that the pressure must have been in excess of 50 psig. A thermogravimetric analysis was made of the sand to determine if any volatile material was being released when the sand was heated to 300°F. A weight loss of between 0.3 to 0.5% was observed when different samples of sand were heated from 80° to 300°F. The most likely substance to be released in that temperature range would be water. The vaporization of water could account for pressures in excess of 50 psig inside the metal cans. The small cans were bubble tested and both cans leaked.

A fourth impact test was made with a packaging arrangement shown in Figure 26 (bottom figure). The impact absorbers were placed on either end of the cans to protect the 4-1/16-in. D x 4-11/16-in. h and the 4-1/4-in. D x 7-in. h cans during impact. The impact absorbers were placed at either end since during an accident it cannot be predicted beforehand which end of the container might be impacted. The same metal plates that were used to align the cans in test number 3 were used in the number 4 test. Since the height of the spacer cans was reduced from those used in test number 3, smaller cans were placed inside the larger cans to stiffen the absorber assemblies so that they would not bottom out and transmit the impact force to the product cans.

The 2R vessel was sealed with a silicon rubber compound. After impact the 2R vessel was leak tested, and no leaks ($<10^{-5}$ cc/sec) were observed.

The damage to the 6M drum was similar to the damage incurred in the previous tests. The celotex insulation was damaged very little. A plywood plate 10-in. x 10-in. x 1-1/8-in. thick was placed on top of the 2R vessel to protect the celotex and to determine if the impact absorbers would protect the cans under a higher g force.

The impact absorbers worked well. No damage occurred to the 4-1/4-in. D x 7-in. h cans, and no gas leaks were observed when the cans were bubble tested. A small amount of damages to the lid of one of the 4-1/16-in. D x 4-11/16-in. h cans was noted. The damage was due to the force exerted on the lid during impact by the inner 3-1/2-in. D x 3-1/2-in. h can that contained lead shot and sand. The other 4-1/16-in. D x 4-11/16-in. h can that contained loose packed lead shot and sand was not damaged. After the impact test, the metal cans were placed in an oven and heated at 300°F for one hour. After

heating, the cans were bubble tested and no gas leaks were observed. The cans did not deform irreversibly during heating so the pressure exerted during heating must have been below 15 psig.

The impact and heating tests have shown that gas tight seals can be maintained under accident conditions for the packaging configuration shown in Figure 26 (bottom figure) for the 6M container.

In order to maintain hermetic seals, the product cans must be sealed using a properly adjusted can sealing machine. Instructions are given in Appendix B for properly adjusting several types of sealing machines. Appendix C also provides instruction for properly sealing metal cans.

Material that is to be packaged in the 6M container should be stable and not decompose or outgas when subjected to temperatures up to 300°F. Pressures in excess of 15 psig will plastically deform the can lids and could cause leakage to occur.

To reduce the differential pressure between the atmosphere inside the sealed metal cans and the 2R vessel, the 2R vessel should be sealed. The 2R vessels can be sealed when the threads are luted with a high temperature silicon rubber compound and the cap or plug is tightened using a torque of at least a 100 ft-lbs. The seal will remain gas tight ($<10^{-5}$ cc/sec) even up to pressures of 100 psig and temperatures of 300°F. Appendix C contains a procedure for obtaining gas tight seals with 2R vessels.

Finally, the metal cans must be protected from being damaged in the event of an accident by properly packaging them inside the 2R vessels. The stacking arrangement shown in Figure 26 protected the metal cans with payloads of up to 2.4 kg from damage when the 6M drum was dropped 30 ft end on.

REFERENCES

- Blankenship, R. W. 1980. Hypothetical Accident Conditions Free Drop and Thermal Tests Specification 6M. LA-8366-MS, Los Alamos National Laboratory. Los Alamos, New Mexico.
- Chalfant, G. G. 1984. Safety Analysis Report - Packages USA/9965/BLF USA/9968/BLF. DPSPU 83-124-1, E.I. de Pont de Nemours and Co., Inc., Aiken, South Carolina.
- King, C. R. 1975. Vacuum Leak Testing of Radioactive Source Capsules. ORNL-3664, Oak ridge National Laboratory, Oak Ridge, Tennessee.
- U.S. Nuclear Regulatory Commission (NRC). 1975. U.S. Nuclear Regulatory Guide 7.4. NRC, Washington, D.C.

References

Waller, J. A. 1964. Reproductive Potential of the Female Rat
in Journal of Mammalogy, 45: 1-12.

Waller, J. A. 1965. Reproductive Potential of the Female Rat
in Journal of Mammalogy, 46: 1-12.

Waller, J. A. 1966. Reproductive Potential of the Female Rat
in Journal of Mammalogy, 47: 1-12.

Waller, J. A. 1967. Reproductive Potential of the Female Rat
in Journal of Mammalogy, 48: 1-12.

APPENDIX A

CORRESPONDENCE BETWEEN NRC AND DOT

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 16 1980

Mr. Richard R. Rawl
U. S. Department of Transportation
Office of Hazardous Materials Operations
Washington, D.C. 20590

Dear Mr. Rawl:

This is in regard to your letter of June 6, 1979, concerning the DOT Specification 6M package and its ability to meet the 1973 IAEA criteria.

The 6M packaging consists of an inner Spec. 2R containment vessel and a steel drum overpack containing a media to provide impact and thermal protection for the inner vessel. We believe the current 6M specification is sufficient for the overpack but not for the inner vessel.

We believe package specifications should contain sufficient information to assure that hardware fabricated in accordance with the specification will meet all pertinent requirements. While this may be possible with the current specifications, the information and requirements are not sufficient to assure the 2R vessel would meet the newly quantified leak-rates in IAEA regulations. Secondly, the 6M Specification requires that large quantities of radioactive material in normal form must be packaged in one or more sealed and leak tight metal cans or polyethylene bottles within the 2R vessel. However, 10CFR971.42 has been amended to require additional containment for plutonium. We believe the 6M Specification should be consistent with the requirements of 10 CFR Part 71. Finally, the maximum heat load permitted in various configurations of the package should be tabulated.

The basic need is for a Specification that will assure the 2R vessel and the secondary inner container will meet the proposed DOT/NRC requirements. This need also extends to other DOT Specification packages which are authorized for greater than Type A quantities in normal form.

We believe that consideration should be given to restructuring DOT specification packages to limit the contents in normal form to no more than a Type A quantity. The administrative reasons that previously existed for authorizing Type B packaging through engineering specifications in Federal Rules have been eliminated by improvements made to the NRC licensing mechanism. Package designs are now authorized by Certificate of Compliance rather than by specific amendment of individual possession or facility licenses; also

Mr. Richard R. Rawl

-2-

other users may now simply register under 10CFR§71.12 or 49CFR173.393a without submitting an application or obtaining a specific approval. Under the present system, there appears to be essentially no need to continue authorizing Type B packages through DOT Specifications.

Sincerely,

Charles E. MacDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and
Material Safety, NRCSS

APPENDIX B

INSTRUCTIONS FOR PROPERLY ADJUSTING SEALING MACHINES

APPENDIX B

INSTRUCTIONS FOR PROPERLY ADJUSTING SEALING MACHINES

Mechanically sealed food pack cans have been in existence for many years. The process relating to the manufacture of the food pack cans has been refined to the point that very few rejects are obtained. However, the key step in producing hermetically sealed food pack cans is to use a properly adjusted sealing machine and cans that are in good shape. Three common styles of sealing machines are shown in Figures B.1 through B.3. The information that follows has been abstracted from the operating instructions for the can sealers shown. Before operating a can sealer, it is imperative that the operating instructions supplied with the sealing machine be read and followed. If the instructions are not available, contact the manufacturer to obtain a copy.

The information concerning the kinds of defects and their causes was taken from a publication entitled Top Double Seam Inspection and Evaluation Round Sanitary Style Steel Cans published by the American Can Company. All the sealing machines shown use the same principal for making mechanical seals. The can is placed on a turntable or base plate, then it is raised until the lid to be sealed is engaged in a chuck. A flywheel, crank or pulley is then turned either by hand or motor, and the first seaming roller contacts the can lid. This operation tucks the curled edge of the lid underneath the flange of the can body as illustrated in Figure B.4. As the can continues to rotate, the first roller backs off and the second seaming roller moves in against the lid and presses the folds of metal tightly together, squeezing the compound lining into the spaces between the metal (Figure B.5).

Various kinds of defects can occur if the sealing machine is not adjusted properly. These are:

- cut overs
- cut seams
- droop or lips
- false seams
- spinners.

FIGURE B.1. Hand-Operated Can Sealer

FIGURE B.2. Hand-Operated Can Sealer with Fly Wheel

FIGURE B.3. Motorized Can Sealing Machine

FIGURE B.4. Section View of Crimp Seal After First Seaming Roll Operation

FIGURE B.5. Section View of Completed Seam After Second Seaming Roll Operation

A cut over is a sharp edge that forms where the lid folds over the can body (Figure B.6). A slight cut over is not too serious and probably will not cause leakage. Severe cut overs, however, can cause a fracture to occur in the lid. The possible causes of cut over are:

- incorrect vertical alignment of first seaming roll groove to chuck (clearance between the shoulder of the seaming roller and the top of the chuck should be 0.001 to 0.002 inch.)
- vertical play of first operation roller plug not to exceed 0.002 inch
- worn chuck around the top edge
- first or second seaming rolls set too tight
- worn seaming roll grooves
- solid or semisolid product trapped under lid
- excess solder at can body lap
- excessively long body, hooks.

A cut seam is a fracture in the outer rim of the lid (Figure B.7). The possible causes of this type of defect are:

- seam too tight
- excess solder at can body lap
- defective lid
- excess sealing compound.

FIGURE B.6. Section View of Cut Over

FIGURE B.7. Section View of a Cut Seam

A droop or lip is a projection below the rim of the lid (Figure B.8).

Droops and lips are caused by:

- first operation seaming roll too loose
- worn first operator roll groove
- body hook too long
- product trapped under lid
- can body out of round not cylindrical
- excess solder at body seam
- excessive amount or unequal distribution of end lining (rubber) compound.

A false seam is a seam or portion of a seam that is entirely unhooked as shown in Figure B.9. Causes are:

- mushroomed can flange
- bent can flange
- damaged or bent lid
- mis-assembly of can and lid.

FIGURE B.8. Illustration of Droops and Lips

FIGURE B.9. Section View of a False Seam

An incomplete seam as shown in Figure B.10 is known as a spinner. The causes for this type of defect are:

- insufficient lifter pressure
- improper sealing of can lid in chuck
- worn chuck
- chuck set too high in relation to base plate
- seaming roll bending
- oil or grease on chuck
- excessive vertical play of chuck spindle.

The illustrated defects can be avoided if the can sealers are adjusted properly. The adjustment procedure will be outlined for the can sealer shown in Figures B.1 and B.2. The motorized can sealer (Figure B.3) adjustments are similar to the sealer shown in Figure B.2.

A detailed drawing of the small hand-operated can sealer is shown in Figure B.10. The first seaming roller is on the right side of the sealer (Figure B.11).

FIGURE B.10. Illustration of a Spinner

FIGURE B.11. Detailed Drawing of Hand-Operated Can Sealer

ADJUSTMENT PROCEDURE

1. Turn crank until "1" appears in indicating window (Figure B.12). Loosen the roller screw with the pin and loosen the thumb screw two or three turns.
2. Slide the seaming roller assembly back until the 3-hole fixture touches the thumb screw or stops against the frame (Figure B.13).
3. Remove the pin and retighten the roller screw by hand.
4. Insert a wire gauge 0.069 inch (wire gauges are supplied with machine) in diameter between the chuck and the first seaming roller (Figure B.14).
5. Tighten the thumb screw until a drag is felt on the gauge wire as it is being pulled forward, then tighten the thumb screw with the pin.
6. Check to see that the gauge wire cannot be pulled out easily. If it can, loosen the roller screw slightly and tighten the thumb screw slightly.
7. Lock the roller screw in place and recheck to see that the gauge wire cannot be pulled out easily. If the gauge wire can be pulled out easily, repeat the previous steps until it cannot.
8. To remove the gauge wire, turn the crank clockwise.
9. After the adjustment is complete and the roller screw is locked into place, tighten the thumb screw.

The second seaming roller is on the left side of the sealer. Turn the crank until "2" appears in the center of the window. A smaller gauge wire 0.020 inch in diameter is used to adjust this seaming roller (Figure B.14). Follow the same procedure used for the first seaming roller, except turn the crank counterclockwise to remove the gauge wire. Each time the chuck is changed and the seaming rollers moved to a different position to seal a different size can, the above procedure must be repeated.

FIGURE B.12. Indicating Window on Hand-Operated Can Sealer

FIGURE B.13. First Seaming Role Fixture

FIGURE B.14. Position of Gauge Wires in Seaming Rollers

It is also important to have the proper height adjustment so the can will not slip when it is being rotated on the turntable. Slippage of the can on the turntable is one of the main causes of spinners. Table B.1 gives the proper spacer or washers to be used for the different size cans to be sealed.

The details of the hand-operated flywheel sealer are shown in Figure B.15. The first seaming roller is on the left (top, Figure B.16) and the second seaming roller is on the right (bottom, Figure B.16), just opposite of the small hand operated sealer previously described. When operating the sealer, make sure the flywheel is in the proper position. That is, if the flywheel is cranked in a clockwise rotation, the first seaming roller (one on left) should advance first. If it doesn't, then remove the can and take out the chuck.

Crank the fly wheel until the first seaming roller advances, stop and crank the flywheel counterclockwise a couple of times or until the first seaming roller returns to its original position. Now the sealer is ready for sealing the can in the proper sequence.

The first item to check in the flywheel sealer is the space between the chuck and the top flange on the seaming rollers. To check this adjustment, push the chuck (Figure B.15) upward until it seats firmly and then turn the fly wheel until the seaming roller rests on top of the chuck. The clearance between the chuck and the top flange of the seaming roller should be about 0.001 inch. If the spacing needs to be adjusted loosen screw 9-LS (Figure B.16) and slide the roller up or down until proper spacing is achieved. Tighten screw 9-LS as tight as possible after alignment. This adjustment should be made to both seaming rollers.

TABLE B.1. Spacer and Seaming Roller Positions for Corresponding Can Sizes

	#2 Can (307 x 409)	#2-1/2 Can (401 x 411)	#3 Can (404 x 414)
Chuck size	307	401	404
Spacer Required - Thickness	one - 5/16"	one - 3/16"	none
Position of Seaming Roller in 3-Hole Fixtures	#2 hole	#2-1/2-3 hole	#2-1/2-3 hole

FIGURE B.15. Detailed Drawing of Hand-Operated Can Sealer with Flywheel

Using the gauge shown in Figure B.17, check the seams of the can after each seaming operation. After sealing the can with only the first operation roll, slip the gauge over the seam. The groove marked first on the gauge should slide over the seam. If the gauge will not slip over the seam, tighten seaming roll by loosening the lock nut and adjusting the screw 24-AS (Figure B.16). Tighten the screw a quarter of a turn to the right and recheck.

In order to check the seam, the can will have to be removed from the machine. To do this, back the first seaming roller away from the can by turning the fly wheel counterclockwise until the roller backs away from the chuck. After gauging the seam, place the can back on the turntable and reposition the can on the chuck by raising the turntable. If the gauge was too loose, then a new can must be used; whereas, if the gauge would not slip over the seam, the same can can be used.

After a proper first roll seam has been obtained, finish sealing the can with the second seam roller and check the seam with the groove marked second on the gauge. If the gauge will not slip over the seam, the roller must be adjusted by advancing the screw 24-AS (Figure B.16). If the seam is too loose, the screw must be backed off. However, if there is only a slight looseness the seam will usually be hermetically sealed.

The proper number of washers or height adapter (Figure B.15) must be used for the particular can being sealed. When a No. 3 can (404 x 411) is being sealed, use the height adaptor but no washers. If A No. 3 tall can (404 x 700) is being sealed, then the height adapter is removed and replaced by seven 1/4-inch washers. When sealing a No. 2-1/2 size can (401 x 411), the height adapter plus a 3/16-inch washer must be used.

The instructions and procedures presented are fairly complete to properly adjust the types of can sealers described; however, the complete instructions for the particular can sealer being used should be followed.

If poor seals are obtained after following the instructions, replacement parts may be needed. Usually, the items that need replacing the most frequently are the seaming rollers and the chucks. If you suspect this is the case, consult with the manufacturer of the can sealer for advice and for listings of current replacement parts.

FIGURE B.16. Detailed Drawing of the Top View of a Hand-Operated Can Sealer with Flywheel

FIGURE B.17. Gauge Used to Check For Can Seam Specifications

Additional inspection procedures are outlined in the American Can publication. Some of these procedures call for cutting through the seam to inspect the cross section of the seam. Usually, specialized equipment is needed to do this type of inspection. The real proof of the seam, however, is if it is hermetically sealed. This can be tested by placing the can in a vacuum bubble tester. Very small leaks ($\sim 10^{-5}$ cc/sec) can be detected using this technique.

APPENDIX C

OPERATING PROCEDURES

APPENDIX C

OPERATING PROCEDURES

These operating procedures are provided to establish methods for assuring that gas tight seals are obtained with 2R vessels having pipe thread closures and metal food pack cans having mechanical crimped seals.

PROCEDURE FOR SEALING 2R VESSELS WITH THREAD CLOSURES

1. Visually inspect threads on the 2R pipe body and pipe cap or plug. If the thread is damaged such that the damage is continuous from the bottom of the thread to the top, reject the part. Repair minor damage by using a thread dressing tool.
2. Clean threads using a degreasing agent such as trichloroethylene or trichloroethane. If the threads have silicone rubber attached to them, soak the threads for 12-14 hours in xylene and then rinse in one of the above degreasing chemicals and wire brush.
3. Coat the threads of the pipe body and pipe cap or plug with a liberal amount of Hi-Temp G.E. silicone gasket material (GEC 56002)®. Make sure that all the threads are covered with the silicone rubber.
4. Place pipe body in vice and secure the pipe so it will not slip during tightening of cap or plug.
5. Thread cap or plug onto the pipe body by hand to make certain the cap or plug is engaging the pipe body properly.
6. Using a torque wrench with a pipe cap clamp or plug fixture, torque the caps or plugs to 200 ft-lbs.
7. Allow the silicone gasket material to set up for 12 hours.

8. Check the seal using a vacuum bubble tester. If no streaming bubbles are observed the seal is gas tight.

PROCEDURE FOR SEALING MECHANICALLY SEALED CANS

1. Inspect can body to make certain it is not dented or damaged.
2. Inspect the flange on the can body. If the flange has been severely bent or creased it should not be used. Small creases can usually be straightened by using needle nose pliers. Run your finger around the flange to make certain it is smooth and no discontinuities are present. Generally, there is a small ridge in the flange where the side seam intersects it. If the ridge is quite abrupt, smooth it off carefully with a fine tooth jeweler's file.
3. Inspect the lid and make sure the rim where the rubber compound has been applied is smooth and uniform. There should be no exposure of metal showing through the rubber compound. If there are scratches, shiny spots (metal showing through), discard the lid. Also, make sure the curl or roll over at the rim of the lid is uniform and not dented.
4. Place the lid on the can and check to see that the lid is seated properly. The curl on the rim of the lid should be below the flange on the can. Do not rotate the lid or the rubber compound may be scratched or damaged.
5. Center the cans on a properly adjusted can sealer (see Appendix B). Rotate the base plate to make certain the can is centered.
6. Raise the can, making sure the lid to be sealed is properly engaged in the chuck. Position the can so that the part of the lid directly over the side seam on the can does not contact the seaming roller first.

7. Before cranking the handle of the sealer (motorized can sealers return to correct starting position automatically), make certain that the seaming rollers are in the proper starting position (see Appendix B for discussion on properly setting up sealer).
8. Crank the handle in a clockwise direction. Try to maintain a uniform rotation throughout the sealing operation. If a motorized can sealer is being used, only use one complete cycle to seal the cans. Repeating the cycle will not provide better seals but may degrade the first sealing operation.
9. Lower the turntable and remove the can if the can is struck on the chuck. The second seaming roller is set too tight.
10. Visually examine the can for obvious defects as illustrated in Appendix B. If defects are present, the can sealer is out of adjustment and it must be fixed.
11. If the seal looks good, bubble test the can. If no bubbles are observed, the can is hermetically sealed. If small leaks are observed, these can be sealed by applying silicone rubber compound around the seam of the can, allow 12 hours for the compound to dry. Leak check again and if bubbles appear, apply another thin coat of silicone compound. Application of the silicone rubber is an effective way to stop leaks in the manufacturer's seams. However, a properly adjusted sealer will produce seams that don't leak.

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