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2R Containers to Meet
Special Form Certification**

by

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INVESTIGATION OF DOT SPECIFICATION 2R CONTAINERS TO MEET SPECIAL FORM CERTIFICATION

by

R. W. Andrae

ABSTRACT

A test program was conducted to investigate the qualifications of 2R, pipe nipple-cap type containers as a special form encapsulation. The testing included a 30-foot (9.14-m) drop, impact with a 3-lb (1.36-kg) weight, heating to 1475°F (1075 K) and immersion in water, as specified in the DOT Spec., Par. 173.398. Results indicate that the use of the 2R, pipe nipple-cap container as a special form encapsulation should probably be restricted to the shipment of solids and then only under the conditions that soluble solids are adequately protected by an inner container.

I. INTRODUCTION

Radioactive materials can be packaged for shipment by common carrier much more conveniently when the material meets special form criteria as defined by the DOT Specification. Special form can be attained either by having the material itself in massive solid form, or by virtue of its encapsulation. This report is concerned with the latter, encapsulation; and in particular with pipe nipple-cap type containment meeting the DOT Specification 2R.

It has been our judgment at LASL that the use of the 2R, pipe nipple-cap container as a special form encapsulation should be restricted to the shipment of insoluble solids and not liquids or gases because of the uncertainty of the leak tightness of the threaded joints. Even such limited usage, however, must soon be supported by appropriate documentation affirming that the special form criteria have been met. Because the DOT Specifications only stipulate the performance specifications for qualification and not the design details of a container to provide compliance, the continued use of 2R containers as a special form encapsulation is dependent upon adequate test data showing their response to conditions of interest.

We also did a limited amount of testing of 2R flanged type closure containers to determine whether or not this type of closure was superior (only the heating and immersion tests were performed).

II. DISCUSSION

As a practical expediency, the test specimens in this study did not contain any radioactive substance. The determination as to whether or not test-incurred damage meant the possible release of radioactivity in an actual case was a matter of interpretation of the test data. Obviously, the loss of a cap or the fracture of the container walls would represent very serious damage, but this would be easily detected by a physical examination of the tested article. Just a loosening of the cap, on the other hand, was a more subtle form of damage that could be serious and required further evaluation. Three such measurements, each involving a different medium, were used for this purpose at various points in the test program. These were (1) leak rates for helium, (2) leak rates for air, and (3) the amount of water leaked in during a 24-hour period. The helium leak test is by far the most sensitive technique used.

III. SPECIMENS

The test specimens were made from off-the-shell, nominal 4-inch sch 40 (101.6-mm) pipe nipple and caps (Fig. 1). A single nipple was cut in half to form two test specimens. The cut end of each specimen was welded shut with a flat plate of the same material. The caps were all 304 stainless steel and the body was either 304 stainless steel or black iron. Twelve specimens of each material combination were used, making a total of 24 specimens. The all stainless steel specimens were numbered 1 - 12 and, those with the black iron bodies 21 - 32.

Three 3-inch (76.2-mm) nominal diameter flanged-closure test specimens (see Fig. 2) were made and tested. The flanges were 1/2 inch (12.7 mm) thick and were connected with 1/2-inch (12.7-mm)-diameter bolts. The container material was low carbon (1019) steel.

IV. APPARATUS

The special tests prescribed in the DOT Specification Par. 173.398 required the following test set-ups: (1) a tower to drop the specimen through a distance of 30 feet (9.14 m) onto an essentially unyielding surface; (2) a device for impacting the specimen with a 1-inch (25.4-mm) cylindrical steel rod weighing 3 lb (1.36 kg) from a height of 40 inches (1.02 m); and (3) a furnace for heating the specimen to 1475°F (1075 K), together with a way of immediately quenching it in water. Figure 3 shows the lower portion of the drop tower, and the way in which the specimen was suspended from the release mechanism. The essentially unyielding surface consisted of thick steel plates resting on a concrete slab. The attitude of the specimen at impact was determined by its attitude at the instant of release because no rotation occurred during its descent (Fig. 4). The percussion test fixture is shown in Fig. 5. The specimen rested on a 1/2-inch (12.7-mm) lead plate (4.2 Vickers hardness). The furnace (Fig. 6) had a clam shell arrangement whereby the heated specimen could be dropped directly into a tank of water.

V. TESTING

The basic test philosophy was not only to find out the effects of the prescribed sequence of tests on the given container configuration, but also to gain knowledge that might be useful in the event a better container is required. A summary of the test program used is shown in Fig. 7. The decision on which containers were to be tested was made as the program progressed.

The initial assembly was done in as uniform a manner as possible in order to have a common starting point for each container. The threads were luted with a high temperature, anti-seize, sealing compound* and the cap was installed by torquing it to 200 ft-lb (271.2 J). No attempt was made to clean up the threads which were especially rough in some of the caps. As will be shown in Table I, in spite of the care taken during assembly, the leak tightness of the containers was far from uniform, probably due to the lack of uniformity at the thread interfaces. It was first thought that a low initial leak rate was an important factor in determining a container's ultimate leak rate at the conclusion of the testing sequence, but the phenomenon encountered during the quench following the heating to 1475°F (1075 K) effectively nullified any gain realized from a low initial leak rate.

The helium leak test was made by internally pressurizing the container to 30 psi (0.207 MPa) and reading the leak rate directly or, in cases where the leak rate was higher than the scale on the detector, by calculating the leak rate as the product of the pressure drop (atmos.) and the container volume (cm^3) divided by the time (s). The latter approach for finding leak rates was also used for the air measurement which began with an internal pressurization of 30 psi (0.207 MPa). All the leak rates shown in the tables have been normalized to the condition of helium at 30 psi (0.207 MPa).

A physical examination of the dropped specimens showed a slight flat spot on the cap (Fig. 1) and a hand-tight cap on all the containers with

*Fol-Pro-GSA

stainless steel bodies. Although the cap could be turned through a small angle, it could not be removed easily, indicating an out-of-roundness condition had occurred. Table I shows the effects of the drop on both the leak rates and the amount of water taken on during a 24-hour immersion. The leak rates were higher after the test, as indicated by the air check, but they still do not represent a high enough value for water leakage. A possible clue to account for the better performance of the containers with black iron bodies is that the combination of stainless steel and black iron assembled more smoothly during the torquing operation.

The percussion test caused little or no damage. No water immersion check was made, but the leak rates shown in Table II are essentially unchanged as a result of this test. The flat, circular end of the steel rod impacted the container on the body just below the cap.

It took approximately 30 minutes to first bring the furnace to 1475°F (1075 K) and then hold at this temperature for 10 minutes as required by the criteria. After this period, the clam shell door of the furnace was opened and the specimen released into the can of water. Although the DOT specifications do not specify a quench but simply an immersion, we felt that this was a possibility and would represent the most severe condition. This quench phase proved to be a very disastrous experience for these containers. Apparently the body, with a larger exposed area but a smaller mass than the cap, cooled more rapidly, causing a greater radial contraction to occur in the body. The result was a temporary gap between the body and cap through which water could pour in. Eventually, when the entire container reached the same temperature, this gap would close again. An additional inducement for such leakage, at this point in time, was created by a lower pressure inside the specimen apparently caused by a loss of air during the heating period. To support this theory, four specimens were air cooled after heating before they were immersed in water (Experiment 1). The results of these tests are shown in Table III.

A total of eight test runs were made using the three flanged-closure test specimens. Runs made with asbestos and copper gaskets resulted in an extreme amount of water leakage. We attributed the

primary cause of this leakage to a loose-gasket condition after the test, apparently resulting from permanent gasket deformation. A number of different things were tried. Subsequent runs were made with stainless steel bolts, no gasket, and a modified flange design incorporating a lead dam. The best results were an 18% water leakage over a period of 24 hours for the "no gasket" and "lead dam" runs.

VI. SUMMARY AND CONCLUSIONS

The special tests prescribed in Par. 173.398 of the DOT Specification were strictly adhered to in testing a particular 2R, pipe nipple-cap container configuration to find out whether or not this container met the special form encapsulation criteria. On the basis of the test data, the following conclusion was reached:

A 2R pipe nipple-cap container made with a stainless steel cap and having either a stainless steel or black iron body can be considered a special form encapsulation, providing it is used for the shipment of solids only, and, further, if these solids are water soluble, they are adequately protected by an inner container. It should be noted that the problem of criticality can be avoided if the shipment is confined to a single container whose inner diameter is less than 5 inches (127 mm).

The tests on the flanged-closure specimens, although very limited, seemed to indicate that this type of closure was not affected by the "quench," but encountered some problems during the heating phase itself.

Finally, we concluded that whereas the leak problems of the screwed-cap closure are inherent to this design, those of the flanged closure might be overcome through relatively simple modifications.

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All of the testing was done at the WX-3 Drop Tower site under the supervision of Norman K. Kernodle (WX-3). Helium leak rates were determined at the WX-1 facilities by Paul M. Dugan.

TABLE I
EFFECT OF DROP TEST

Specimen Number	Leak Rate Before Test		Leak Rate After Test	Water Leaked over 24 h	
	cm ³ /s He	cm ³ /s Air		g	%
1	1.1	0.87	270.	23.4	1.8
3	5.2x10 ⁻⁶	0.50	46.	27.3	2.1
4	0.61	-	90.	11.7	0.9
7	0.19	-	300.	-	-
8	0.066	0.12	640.	19.5	1.5
10	7.6	0.26	914.	24.7	1.9
11	0.19	0.19	61.	6.5	0.5
12	8.0	7.3	256.	6.5	0.5
21	<1.8x10 ⁻¹⁰	0.0	7.1	2.6	0.2
22	4.0	0.0	7.3	0.0	0.0
23	0.034	0.12	142.	0.0	0.0
24	0.053	-	60.	2.6	0.2
25	0.059	0.0	21.	0.0	0.0
26	0.059	0.0	7.3	0.0	0.0
29	0.68	0.12	11.	0.0	0.0
31	<1.9x10	0.0	4.4	0.0	0.0

TABLE II
EFFECT OF PERCUSSION TEST

Specimen Number	Leak Rates Before Test		Leak Rates After Test
	cm ³ /s He	cm ³ /s Air	
1		270.	250.
3		46.	1600.
4		40.	36.
5	<1.8x10 ⁻¹⁰	0.42	1.5
6	<2.1x10 ⁻¹⁰	0.0	0.0
7		20.	4.4
8		640.	800.
10		914.	1100.
11		61.	200.
12		256.	400.
21		7.1	11.
22		7.3	17.
23		142.	80.
24		6.7	4.7
25		21.	74.
26		7.3	2.8
27	0.057	0.027	0.0
29		11.	20.
31		4.4	6.3
32	0.11	0.11	0.029

TABLE III
EFFECT OF HEAT-QUENCH TEST

Specimen Number	Leak Rate Before Test		Water Leaked over 24 h		Remarks
	cm ³ /s He	Air	g	%	
2	<1.6x10 ⁻¹⁰		468.	36.	Untested
9	<1.6x10 ⁻¹⁰		377.	29.	
28	<2.0x10 ⁻¹⁰		936.	72.	
30	<1.9x10 ⁻¹⁰		975.	75.	
5		1.5	429.	33.	Percussion only
6		0.0	468.	36.	
27		0.0	975.	75.	
32		0.03	910.	70.	
Experiment I					
11		200	130.	10.	Air cooled
12		400	136.5	10.5	
26		2.3	23.4	1.8	
31		6.3	10.4	0.8

Fig. 1. Pipe nipple-cap container after 30-foot (9.14-m) drop.

Fig. 2. Flanged closure test container after fire test.

Fig. 3. Specimen suspended from release mechanism of drop tower.

Fig. 4. Specimen impacting.

Fig. 5. Percussion test setup.

Fig. 6. Heat-quench test setup.