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Test Results Using A Bell Jar To Measure Containment Vessel Pressurization

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ABSTRACT

A bell jar is used to determine containment vessel pressurization due to outgassing of plutonium materials. Fifteen food cans containing plutonium bearing materials, including plutonium packaged in direct contact with plastic and plutonium contaminated enriched uranium oxide have been tested to date. As expected, minimal pressurization occurs and in some cases a slight depressurization has been observed. Linear extrapolation of the greatest pressurization observed in the bell jar to a typical drum shipping container (such as a 9975) has been performed. Pressurization from this particular can packaged for one year in a 9975 container is negligible.

I. INTRODUCTION

The primary purpose of the bell jar is to collect and measure out gassing from a container (e.g., food can) of plutonium materials in support of understanding shipping container pressurization. The bell jars have been designed and sized to accommodate most existing storage containers and collect out gassing without repackaging. The pressurization of the bell jar can be readily extrapolated to the conditions inside the shipping container containment vessel during a shipment. Bell jar testing is used in conjunction with current plutonium surveillance tools (lid deflection measuring device) to demonstrate that the containers bearing plutonium material may be shipped safely. Statistical sampling of similar materials can facilitate the release of larger inventories for shipment.

The ‘bell jars’ are heavy-duty multi-use, "leak tight" steel vessels in which a container of plutonium may be tested for out gassing. The bell jar is instrumented to measure pressure and temperature to very tight tolerances. Temperature and pressure data are continuously recorded through a data acquisition system to a lap top computer. A sample port on the bell jar assembly allows for gas sampling of the cavity space. Constant ambient test temperature has been achieved by using modified low cost temperature controlled insulated enclosures, readily available off the shelf.

The shipping container safety basis requirements can be addressed using a bell jar as a pre-shipment test, rather than extensive sampling and characterization. Acceptance criteria, in terms of "go/no go," are stipulated to comply with the shipping container safety basis. Testing to date has validated the bell jar concept to the extent that the time to lower flammability limit (LFL) (assuming all outgasing is hydrogen) and pressurization in the shipping container PCV are readily determined.

Bell Jar Tech Specs:

Bell Jar Material:	304 Stainless Steel
Bell Jar Size (internal):	4.31 in. ID, 7.15 in. height
Data Logger:	Field Point Data Acquisition, Labview Software on laptop
Pressure Transducer:	PTX 6600, absolute pressure, 0.8% accuracy, detector threshold system +/- 0.5 psi
Thermocouple:	0.5°F accuracy
Temperature Enclosure:	+/- 1.0°F

II. TESTING AND PRODUCT CANS

Sufficient bell jar equipment is available at the Savannah River Site to simultaneously test up to six product cans containing plutonium bearing material. Each test is nominally two weeks long with a single can tested per bell jar unit. Fifteen cans have been tested to date.

Packaging configurations for plutonium bearing materials nominally consist of can/bag/can where the outer can is a crimp-sealed food can. Inner cans may be slip lid (tape sealed), screw top, or crimp-sealed cans. The bag (nominally polyethylene) is used for contamination control and may be heat sealed or tape sealed. In some cases filtered outer cans are used.

An implicit assumption in the bell jar test is the free flow of gas generated from its source through the inner can, bag, and outer can. Generated gas which can not leak out will pressurize internal containers. Pressurization of the outer can is readily detected using a lid deflection tool. Several sizes and types (ribbed or smooth) of lids have been tested, and the lid deflection has been calibrated as a function of pressure. Details of this aspect of the pre shipment test are a subject of another paper.

Cans are retrieved from storage and smeared for contamination prior to testing. All cans had less than 20 dpm/100 sq. cm alpha contamination when loaded into the bell jars. At the end of the test all cans were found to have less than 20 dpm/100 sq. cm alpha contamination and the bell jar inside surface was also found to have less than 20 dpm/100 sq. cm alpha contamination. There was no evidence of loss of contamination control during the test.

The ambient test temperature is maintained by the constant temperature enclosure and heater controller. A temperature of 35°C (95°F) is typically used.

III. TEST RESULTS

Fifteen cans containing plutonium oxide or plutonium contaminated enriched uranium oxide have been tested to date. Table 1 provides a listing of items, fissile mass (grams), and remarks concerning materials or packaging configuration.

The threshold of pressure detection is considered to be +/- 0.05 psig. As seen in Table 2, only items 2, 14, and 15 exceeded this threshold. Items 2 and 14 resulted in a slight pressurization and item 15 showed a distinctive depressurization.

Items 2 and 14 consist of plutonium oxide packaged in plastic jars that are double bagged within an inner crimp sealed food can (314 × 509). The outer can is a 404 × 700 crimp sealed food can. These items were packaged in the 1980's. These specific items were selected to be tested (among the several within this material group) because lid deflection measurements indicated no outer can pressurization or depressurization. Therefore, these two items were judged to be potential leakers. As evidenced by the test results, all layers of containers are not tightly sealed (a tightly sealed container would retain gas generated and not allow for bell jar pressurization). The likely mechanism for pressurization is radiolysis of the plastic.

Items 1 and 4 through 13 consist primarily of highly enriched uranium oxide with plutonium contamination. These items were recently repackaged in late 2001 or early 2002. The packaging consists of a bagged out slip lid can, within a crimp sealed 404 × 700 can. The oxide was originally made in the 1970's at Rocky Flats and packaged in a bag/can configuration. The material has been stored at SRS for a number of years in the original packaging in 30 gallon 6M shipping containers. It is interesting to note that for most of these uranium oxide items depressurization is occurring (albeit below what is considered detectable).

Table 1: Description of Cans Tested

Item #	Fissile mass (g)	Remarks
1	502	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
2	1100	Plutonium oxide packaged in plastic jar, double bagged, double crimp sealed cans, packaged mid 1980's
3	346	Plutonium and depleted uranium oxide; outer can is 404X414, inner can slip lid, (can/bag/can)
4	559	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
5	265	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
6	658	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
7	622	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
8	1220	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
9	1074	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
10	579	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
11	864	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
12	143	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
13	679	Enriched uranium oxide; inner can slip lid (can/bag/can), packaged 9/01
14	1643	Plutonium oxide packaged in plastic jar, double bagged, double crimp sealed cans, packaged mid 1980's
15	153	Plutonium oxide and depleted uranium oxide; inner can slip lid (can/bag/can), outer can filtered, packaged 1/02, original cans were collapsing

Item 15 is unique in that the outer can is filtered. The material consists of plutonium oxide and depleted uranium oxide. Item 15 is a mixture of several cans which showed definite depressurization as evidenced by lid deflection measurements of the outer can. The original cans came from Los Alamos National Lab and Oak Ridge Y-12. The oxide was high fired, and the material is in excess of 20 years old. Item 15 clearly shows depressurization during the test. The filtered can allows for the gas inside the bell jar to readily flow into the slip lid can and react with the material. Despite the age of the material, reactions which consume gas (most likely oxygen) continue.

Table 2: Test Results (2 Week Test)

Item #	Pressure Change (psi)	Remarks
1	-0.046	Pressure increased slightly, then decreased; negative slope at test end
2	0.185	Pressure increased and leveled off
3	0.010	Minimal change in pressure
4	-0.014	Negative slope at test end
5	0.009	Short temperature excursion during test, enclosure door left open during rounds
6	-0.003	Minimal change during test
7	-0.002	Minimal change during test
8	-0.004	Minimal change during test
9	-0.011	Negative slope at test end
10	-0.022	Negative slope at test end
11	-0.003	Minimal change in pressure
12	0.045	Data suggests positive pressure offset, minimal change during test
13	0.005	Minimal change during test
14	0.099	Relatively constant pressure increase
15	-0.230	Consistent pressure decrease

The test results for items 2, 14, and 15 are provided in Figures 1 through 3.

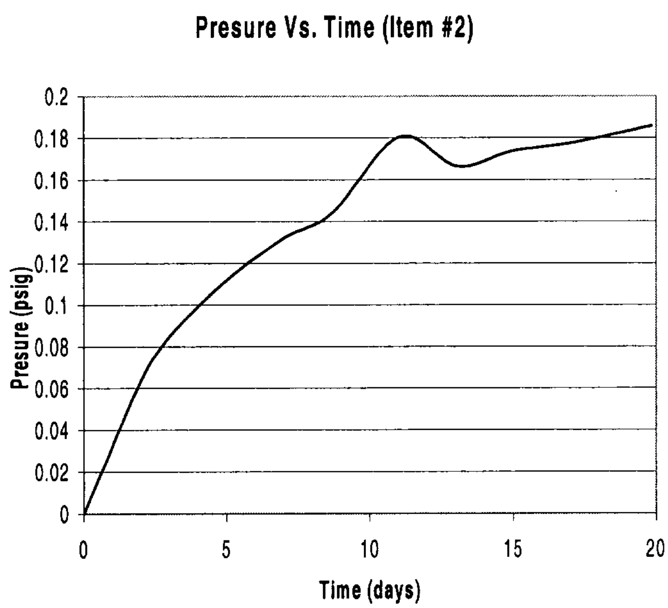

Figure 1

The pressurization rate in Figure 1 is not constant, and an equilibrium pressure appears to exist. Additional testing at different ambient temperatures may provide insight into the reaction rate. The mechanism for pressurization during testing of items #2 and #14 may be radiolysis of the plastic. The mechanism for depressurization occuring with item #15 is less clear. One interesting aspect is that for all three items the reactions are occurring despite the age of the materials.

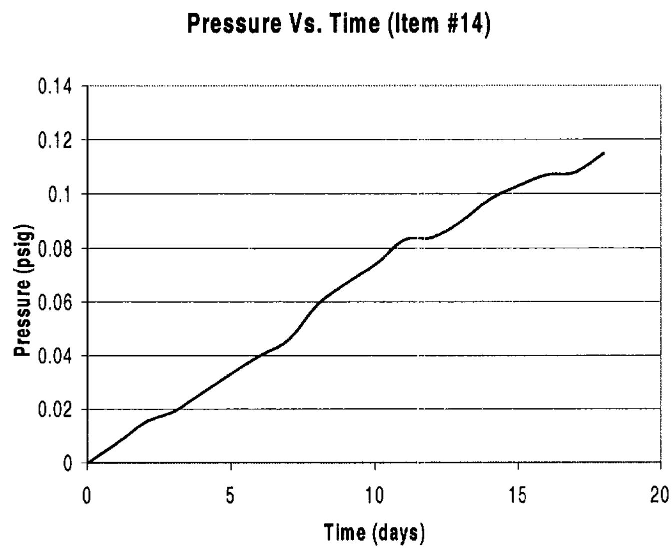

Figure 2

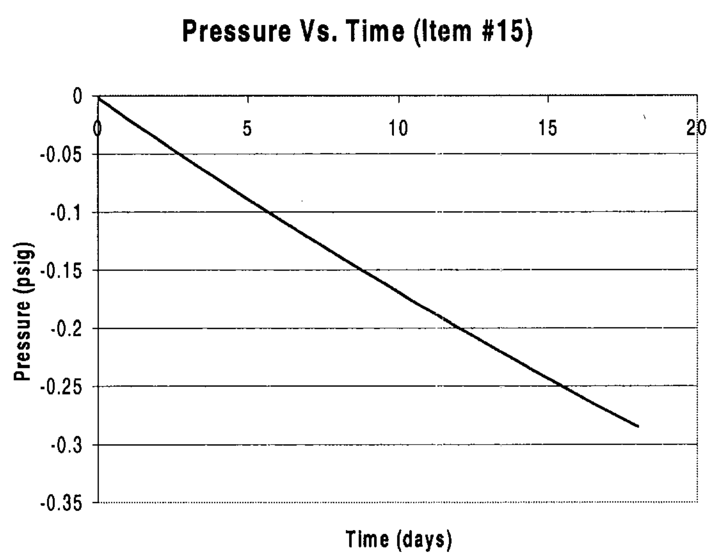

Figure 3

IV. APPLICATION TO TRANSPORTATION

The bell jar free volume outside the 404 × 700 can is about 195 cc. Using a threshold detection capability of 0.05 psi, the bell jar system can measure leakage rates (from 404 × 700 cans) of 1.1×10^{-6} std cc/sec in a one week test.

Consider the 9975 shipping package which has a primary containment vessel free volume of 5130 cc. Two 404 × 700 cans would consume a volume of 3100 cc and an additional 50 cc is taken by an aluminum honeycomb spacer. The resulting free volume external to the 404 × 700 cans is 1980 cc.

One concern with plutonium oxide gas generation is creation of a flammable hydrogen air mixture. A limit of 4% hydrogen may be used to ensure against flammability ($0.04 \times 1980 = 79$). Thus, 79 cc of gas would have to be generated and leak out of the cans to create a flammable mixture in the 9975 container. This corresponds to a leak rate of 2.5×10^{-6} cc/sec for one year, which equates to a bell jar pressurization of 0.59 psig per can (considering two 404 × 700 cans in the 9975 container) per week.

Consider the test results for Items 2 and 14 in Table 2. Both items may be shipped and the 9975 containment vessel gas space (outside the cans) would not be flammable. Shipment of two cans of Item 2 would result in a 9975 pressurization of only 0.046 psig in one year due to gas generation (assuming no pressurization from thermal heating).

V. CONCLUSIONS

Fifteen items have been tested in the bell jar to date to determine if pressure generation in a shipping container containment vessel should be expected. Only two items generated any pressurization. Both items are plutonium oxide packaged in direct contact with plastic, which is expected to generate gas via radiolysis of the plastic. Some materials are consuming gases at a relatively slow rate. Even materials which have been stored for a period of time (such as item #15) continue to react slowly such that depressurization occurs in a sealed container. Items 2 and 14 were chosen (out of a pool of hundreds) because they were thought to be the most likely candidates for seeing pressurization in the bell jar. Nevertheless, additional testing is needed to provide more conclusive evidence that significant pressurization does not occur for plutonium bearing solid materials.

VI. ACKNOWLEDGMENTS

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