*Results of 1.0-L Sample Bottle Pressurization
Tests for the Pit Burst Project*

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Results of 1.0-L Sample Bottle Pressurization Tests for the Pit Burst Experiment

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Abstract

Pressurization tests were performed on a 1.0-L sample bottle to verify operational aspects of the pit burst experimental test apparatus. The 1.0-L sample bottle was selected because of its known geometry, certified performance and ready availability. Redundant strain gage instrumentation was installed on the test sample enabling evaluation of the repeatability and consistency of data acquisition. Test results were compared with analytical model predictions to evaluate instrumentation accuracy.

Introduction

A test apparatus for liquid pressurization to failure of plutonium pits was designed and fabricated for operation in a glovebox at TA-55. The system consists of a test article support structure and transfer mechanism; Lexan safety shield; automated fluid pressurization system consisting of pumps, reservoirs and control valves; and a data acquisition and control system. A readily available test article of known geometry was selected for a series of pressurization tests to verify system operation before installation at TA-55. A Whitey 1.0-L sample bottle was selected. Biaxial strain gages were installed on the test sample to enable evaluation of the repeatability and consistency of data acquisition. Measurements were compared with analytical model predictions to evaluate data accuracy.

Control of the test sequence was fully automated using LabView software. These tests provided an opportunity to verify parameter limits, display formats and control features of the software.

In addition, hardware, including pumps, valves, and reservoirs, associated with the liquid pressurization system were exercised and evaluated. The functionality

and performance of the containment structure, instrumentation feedthroughs and the scale for monitoring fluid mass were also verified.

Test Configuration

Pressurization System

Figure 1 shows a schematic of the automated fluid system used for verification of the experimental procedure for the pit burst experiments. For these tests an ISCO D-Series Syringe pump (100 DX, identical to the pump to be used in TA-55) was used to pressurize the test vessel. The pump has a range of flow rates from 0.01 $\mu\text{l}/\text{min}$ to 50 ml/min with an accuracy of $\pm 0.3\%$ and a high pressure limit of 10,000 psi. However, the programmed pressure limit was set to 3500 psi, at which point the pump automatically shuts down. The manifold shown in Fig. 1 also has a pressure relief valve set at 3000 psi. The ISCO pump is fully automated through an RS-232 interface to PC-running LabView software. The pump volume is 102.93 ml, is operated in a constant flow mode and has a displacement resolution of 9.65 nl. The process controls are designed to deliver precisely known constant volume aliquots to the test vessel through valves 2 and 3 (see Fig. 1) by turning on the pump for a set period of time with a fixed flow rate. After delivery, the displaced pump volume is recorded along with the test vessel pressure, pump pressure, temperatures, weight and strain gage readings.

Fig. 1. Pressurization handling system.

The test vessel was fitted with "calibrated" rupture disks obtained from the High Pressure Equipment Company. Run 8/30 used a nominal burst pressure of 1500 psi and the remaining four experiments used a nominal burst pressure of 2500 psi. The test vessel itself sits in a Lexan containment box, all of which rests on a Sartorius top-loading balance (QC64EDE-2).

The gas/liquid-handling manifold is constructed of 316 stainless steel tubing. The high pressure side is fitted with both Taper Seal and high-pressure fittings (from the High Pressure Equipment Company) rated to 10,000 and 60,000 psia respectively. The low-pressure side uses Swagelok fittings. All the valves (except the ones directly connected to the syringe pump) are electrically operated, air-actuated and manually controlled, except valve 3 that is under direct computer control. There is a SCRAM function that can be operated both manually or by computer that opens valves 3, 4, 9, 11 and 13 for depressurization of the test vessel.

An experimental run begins by evacuating the test vessel using a roughing pump through valves 3, 4, 11 and 13. The vessel is backfilled with water from the pressurized reservoir RS-901 through valves 5, 4 and 3. The vessel is then pressurized by the automated process described above until rupture of the burst disk occurs.

Test Article Instrumentation

A 1.0-L cylindrical sample bottle (item No. 304L-HDF4-1000) with a 90-mm o.d. (3.5 in.) and a 5.5-mm (0.213 in.) wall thickness was selected as a test article. In addition to availability and convenience, the selection was easy to model. Biaxial strain gages were mounted at several locations on the sample bottle as shown in Fig. 2. For a thin-walled cylinder, the hoop stress is twice the axial stress. In the analytical model, correction was made for the finite thickness of the cylinder wall, and strains were calculated along the principle axes. The system was pressurized until rupture of the burst disk because the intent of the testing was not to rupture the sample bottle but instead to verify the performance of the test apparatus, instrumentation and data acquisition system. After testing was completed, the sample bottle was cut normal to the long axis at the circumferential strain gage location for verification of the cylinder wall thickness, which was required input to the analytical model.

Fig. 2. Instrumentation location for 1.0-L sample bottle.

Results and Discussion

Five tests were run on a single sample bottle with parameters as shown in Table 1. The burst-disk pressure was increased to 2500 psig after the first test to increase the strain gage response on the relatively thick-walled sample bottle. In the last test an additional strain gage was added (No. 4 in Fig. 2) near the axial midplane of the cylinder to verify the uniformity of the strain in the cylindrical section of the test article.

Table 1. Sample Bottle Test Summary

Test ID	Max Pressure (psig)	Biaxial Strain Gages
8/30	1500	3
9/4	2500	3
10/16	2500	3
10/16-2	2500	3
10/24	2500	4

Figure 3 shows a comparison of the biaxial strains for all runs from one of the gages mounted on the cylindrical section of the bottle. Except for an initial offset in the hoop strain of this gage, the linearity and repeatability of the data are consistent, as shown in Table 2, where the slopes of the microstrain data versus pump pressure data are tabulated. The slopes should be the same for all runs. Because of the cylindrical geometry of the sample bottle, the hoop strains are larger than the axial strains, and therefore the hoop strain data have a correspondingly larger slope.

Fig. 3. Gage 1 strain data for all tests of 1.0-L sample bottle.

Results for the 3 biaxial gages installed on the cylindrical section of the test cylinder from Run 10/24 are shown in Fig. 4. Gages 2 and 4 are at the same circumferential position, but gage 1 is located 90° along the circumference from gage 2. Variations in wall thickness of ± 0.2 mm (0.008 in.) were measured on the sample bottle circumference between the location of gages 2 and 4 and the location of gage 1, which is consistent with the lower strain measured for gage 1 shown in Fig. 4. The slopes of the microstrain data versus pump pressure data shown in Table 3 also reflect this variation in wall thickness.

Fig. 4. Gage 1, 2 and 4 strain data for 10/24 test of 1.0-L sample bottle.

Table 2. Slope of Microstrain versus Pump Pressure Test Data for Gage 1

Run	Gage-1 Hoop	Gage-1 Axial
8/30	0.202	0.052
9/4	0.204	0.050
10/16	0.202	0.054
10/16-2	0.202	0.051
10/24	0.204	0.051

Table 3. Slope of Microstrain versus Pump Pressure Test Data for Run 10/24

Gage	Hoop	Axial
1	0.204	0.051
2	0.213	0.052
4	0.215	0.053

Figure 5 compares the measured strains from gage 1 with the predictions from the analytical model. For the model, the elastic modulus was assumed to be 0.2 MPa (29,000 ksi) with a Poisson's ratio of 0.3, typical values for stainless steel. Account was taken for the finite thickness of the cylinder wall in calculating the stresses.

Comparison of the pumped volume versus the delivered volume to the test article is shown in Fig. 6. Compressibility of the liquid accounts for the difference between the fluid volume delivered to the pump and the volume delivered to the test article. Results output from the data acquisition system are compared with results provided by the analytical model as shown in Fig. 6.

Fig. 5. Comparison of measured strains with analytical model.

The very favorable agreement between the analytical results and the measurements for both the measured strains and the fluid volumes provides a verification of the data acquisition system. In addition, the linearity, consistency and repeatability of the strain gage measurements provide confidence in the gage installation and measurement techniques.

1.0 L Sample Bottle Run 9/4
V tube = 36 ml; V pump = 100 ml

Fig. 6. Comparison of measured fluid volumes with analytical model.

The next phase of testing will use a thin-walled spherical test article of 304 stainless steel pressurized to failure. These tests will verify analytical model predictions of the plastic behavior of the test article before failure. These tests will also provide data for evaluating the design parameters for the experiment and the containment apparatus as well as providing much-needed information for a realistic criticality evaluation.