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Test Report of Special Form Qualification Testing for the ORNL U ZiPCAN

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October 2018

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Reactor and Nuclear Systems Division

TEST REPORT OF SPECIAL FORM QUALIFICATION TESTING FOR THE ORNL U ZIPCAN

O. A. Martinez, PhD

October 2018

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Test Report of Special Form Qualification Testing for the ORNL U ZiPCan

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Nuclear Security and Isotope Technology Division

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ACRONYMS

ANSI	American National Standards Institute
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
CFR	US Code of Federal Regulations
IBR	incorporated by reference
ISO	International Standards Organization
NDT	nondestructive testing
NSC	Y-12 National Security Complex
ORNL	Oak Ridge National Laboratory
PTP	Package Testing Program
QA	quality assurance
QAPD	quality assurance program description
REDC	Radiochemical Engineering Development Center
RHAC	Research Hazard Assessment and Control
SBMS	Standards Based Management System
TIG	tungsten inert gas
TU	test unit
ZiPCan	Zirconia Pre-Encapsulation Canister

ABSTRACT

Two prototype Zirconia Pre-Encapsulation Canisters (ZiPCans) of the same design were evaluated to determine if the requirements of the following regulation were met:

- Title 49, Code of Federal Regulations (CFR), Part 173.469, *Tests for Special Form Class 7 (Radioactive) Materials*

The results of the special form tests are documented in this test report.

This report describes the special form testing activities performed on the two ZiPCans. One prototype test unit was subjected to the tests stipulated by International Standards Organization (ISO) 2919:1999(E) Class 4 impact test, along with the leak rate test specified in 49 CFR 173.469(a)(4)(i). The other test unit was subjected to a leak rate test as specified in 173.469(a)(4)(i) and a heat test as specified in 49 CFR 173.469(b)(4). Each test unit was leak tested before and after these respective tests, Table 1.2. The leak rate tests performed were helium back-pressure tests and bubble tests, as specified in American National Standards Institute (ANSI) N14.5-2014.The measured leak rates were converted to standard condition leak rates as specified in American Society for Testing and Measurement (ASTM) E 493. The determined standardized leak rates from the test and calculation for both test units met the requirements for special form certification.

The testing was performed by or under the direction of the Oak Ridge National Laboratory (ORNL) Package Testing Program (PTP).

1. INTRODUCTION

Two prototype ZiPCans designed to contain uranium (henceforth referred to as *U ZiPCans*) were tested to determine if the requirements of the following regulation were met:

- Title 49, Code of Federal Regulations (CFR), Part 173.469, *Tests for Special Form Class 7 (Radioactive) Materials*

These prototypes served as test units and are identified as TU-1 (C1-0290), and TU-4 (OPSF1).

The 49 CFR 173. 469 requirement states:

> *(d) A specimen that comprises or simulates Class 7 (radioactive) material contained in a sealed capsule need not be subjected to - (1) The impact test and the percussion test of this section provided that the mass of the special form material is -*
> ***(i)** Less than 200 g and it is alternatively subjected to the Class 4 impact test prescribed in ISO 2919 (IBR [incorporated by reference], see § 171.7 of this subchapter)*

Since the ZipCan is designed to hold less than 200 g, the TU-4 U ZiPCan was subjected to a Class 4 impact test only as prescribed in ISO2919:1999(E) in lieu of the percussion and impact test described in 49 CFR173.469(b). This satisfies the requirements of 49 CFR 469(d)(1)(i).

The ISO2919:1999(E) impact test is specified below:

> ***7.4 Impact Test***
>
> ***7.4.1 Apparatus***

> ***7.4.1.1 Steel hammer,*** *the upper part of which is equipped with a means of attachment, and the lower part of which shall have an external diameter of (25±1) mm and a flat striking surface with its outer edge rounded to a radius of (3.0±0.3) mm.*
>
> *The center of gravity of the hammer shall lie on the axis of the circle, which defines the striking surface; this axis itself passing through the point of attachment. The mass of the hammer for each test class is given in Table 2.*
>
> ***7.4.1.2 Steel anvil****, the mass of which is at least ten times that of the hammer. It shall be rigidly mounted so that it does not deflect during impact and shall have a flat surface, large enough to support the entire sealed source.*

According to Table 2 from ISO 2919:1999(E), the weight of the steel hammer for the Class 4 impact test shall be "2 kg from 1 m or equivalent imparted energy. Additionally, TU-4 was subjected to a leak rate test before and after each of the tests described above to determine test outcome, as follows:

> *Leak Rate Test (49 CFR 173.469(a)(4)(i))*
>
> > *Demonstration of leak tightness of 10^{-4} torr-1/s (3.1×10^{-4} atm-cm^3/s) based on air at 25°C (77°F) and one atmosphere differential for solid radioactive content . . .*

TU-1 underwent one heat stress test, as well as leak rate testing, as described above, before and after the heat stress test:

> *Heat Stress Test (49 CFR 173.469(b)(4)):*
>
> > *The specimen must be heated in air to a temperature of not less than 800°C (1475°F), held at that temperature for a period of 10 minutes, and then allowed to cool.*

All tests (impact test, heat stress tests, and leak rate tests) were performed by or under the direction of the ORNL PTP. This report provides a detailed description of the test methodologies and results.

1.1 DESCRIPTION OF THE U ZIPCAN

The inner container of the U ZiPCan is a titanium triangular assembly with four threaded $^3/_{32}$-inch fill holes over four inner triangular cavities matted with a 0.05-inch thick zirconium oxide felt. The uranium heat stress test unit (TU-1) was manufactured by depositing drops of a nitrate solution into the inner triangular cavities through the fill holes. After the solution was deposited, the filled triangular assembly was slowly heated to concentrate the liquid to a dry salt and then was subsequently fired in a furnace to convert the uranium material to an oxide. Four titanium screws were then inserted into the threaded fill holes. The assembly was then placed in a stainless steel triangular encasement and fitted with a lid which had been welded with a tungsten inert gas (TIG) arc welder. The U ZiPCan is shown in Figure 1.1, Figure 1.2, and Figure 1.3.

A loaded U ZiPCan containing a maximum of 4.58 g (3.2 g ^{238}U element weight) of uranium oxide was used for the heat test, and an unloaded ZiPCan was used for the impact test. The isotopic distribution of TU-1 is shown below.

Table 1.1. Isotopic distribution of the heat test unit, TU-1 (C1-0290)

ORNL U ZiPCan load information				
Tile/serial number	C1-0290		**Weight, g**	**Weight, fraction**
Total weight	35.783 g	**^{234}U**	3.146E-05	9.831E-06
UO_3/U_3O_8 weight	4.58 g	**^{235}U**	1.295E-03	4.048E-04
Uranium weight	3.2 g	**^{236}U**	3.173E-05	9.916E-06
Isotopic mass date	3/23/2017	**^{238}U**	3.199E+00	9.996E-01

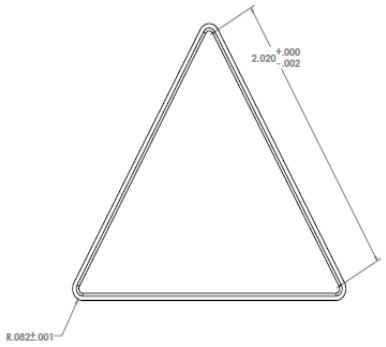


Figure 1.1. Top view of the U ZiPCan triangle encasement.

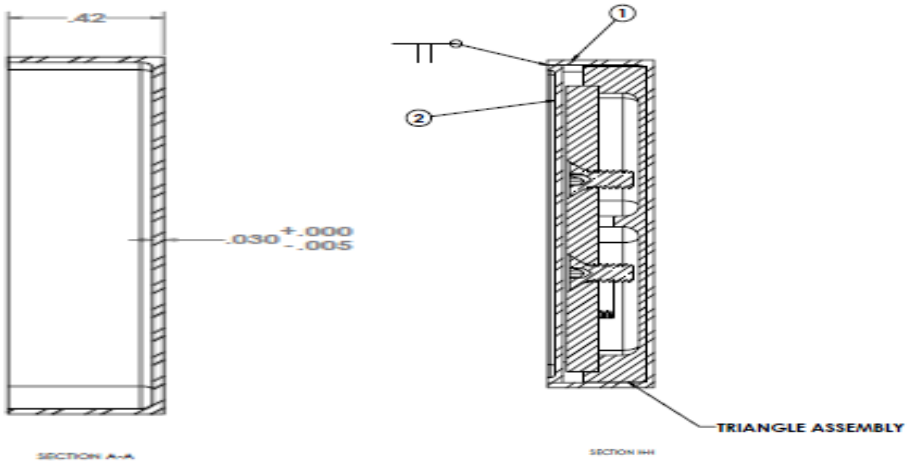


Figure 1.2. Side assembly view.

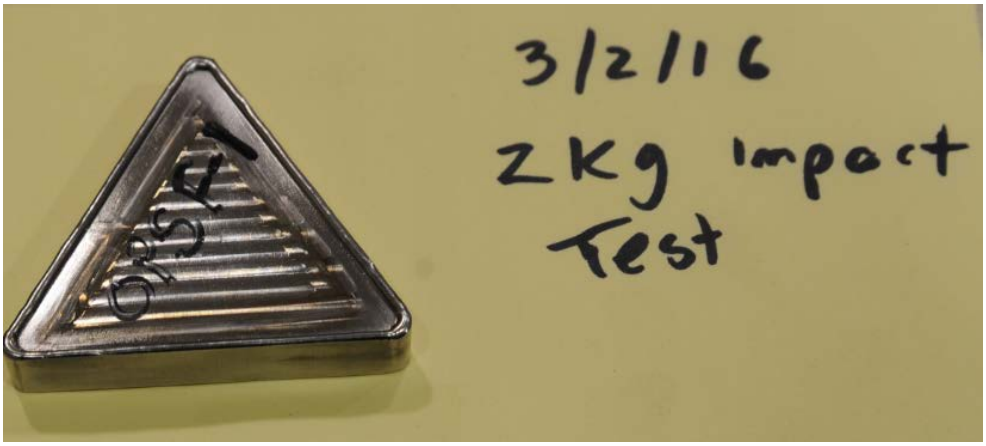


Figure 1.3. U ZiPCan triangle encasement test unit.

1.2 DESCRIPTION OF QUALITY ASSURANCE ACTIVITIES

The ORNL Quality Assurance Program Description (QAPD) addresses the criteria requirements identified in DOE Order 414.1D, *Quality Assurance*, and 10 CFR 830.122, *Quality Assurance Criteria*. Quality principles and methodologies are integrated and flowed down by management systems within the ORNL Standards Based Management System (SBMS).

ORNL's PTP Quality Assurance Program is under the direction of the Reactor and Nuclear Systems Division. All testing performed by the PTP is conducted under the PTP Quality Assurance Program Plan, PTP-QA-001/NTRC-PRF-QAP-001, Rev. 3., Integrated Document Management System ID 018050.

49 CFR 173.469, Special Form performance testing, was documented by ORNL's test plan, *Test Plan for the Special Form Qualification Testing of the U ZiPCan Triangle Encasement"* (ORNL/NTRC-074, available upon request).

ORNL's Radiochemical Engineering Development Center (REDC) was responsible for all manufacturing activities under two applicable quality assurance (QA) programs: (1) the Quality Management System described in *Quality Manual for the Nuclear Material Processing Group* (NMP-QM-1, Rev. 1), and (2) the Nonreactor Nuclear Facility Division *NNFD Fabrication Control Procedure* (NNFD-017-C, Rev. 1). Both QAPs meet the requirements of DOE O 414.1D and 10 CFR 830.122.

The safety aspects of the activities described in this test plan are controlled by ORNL's Research Hazard Assessment and Control (RHAC) Research Safety Summary (RSS) *General Use and Package Testing Activities Conducted in the NTRC Packaging Research Facility* (1082).

1.3 ZIPCAN TEST MATRIX

TU-1 is a U ZiPCan loaded with 4.58 g of uranium oxide. Table 1.2 presents the sequence of the tests and processes performed on each test unit. The numbers in the second and third columns indicate the sequence in which the process or test was performed on the test unit. TU-4 is a U ZiPCan without radioactive material. It was deemed that the radioactive material provided a negligible amount of support to the titanium structure. The weight added is also irrelevant due to substitution of the ISO class for impact test as applicable to the drop test.

Table 1.2. Sequence of tests and processes for the U ZiPCan

Test or process description	Test unit	
	TU-1 (C1-0290)	TU-4 (OPSF1)
Leak test	1	1
Impact test (ISO 2919)	-	2
Heat test	2	-
Leak test	3	3

1.4 TEST DATA RECORDS

This report documents the tests performed and measurements observed from the U ZiPCan testing. The general data types for these tests are:

- manually derived measurements and observations,
- digital still photography, and
- video recording of the drop and percussion tests.

The primary recording media for each of the general types of data are:

- procedure checklists, data sheets and test forms for data, measurements, and observations,
- computer files (JPG format) of the digital photography, and
- computer files (MPG format) of the video recordings.

The completed data sheets and procedure checklists have been scanned into a digital format and are available upon request. Photographs are presented in the main body of this document as appropriate.

1.5 DEVIATIONS FROM THE TEST PLAN

Per the test plan (ORNL/NTRC-074), 3 test units were subjected to the preheat leak test and a heat test.

Table 1.3 provides a detailed sequence for the tests originally planned to be conducted on Test Units TU-1, TU-2, and TU-3.

Table 1.3. Detailed sequence of tests and processes for Test Units 1–3 (TU-1 through TU-3)

Test Units TU-1, TU-2, TU-3 Sealed encapsulated specimen with radioactive material (U)	**Acceptance criteria**
Test sequence #1: Leaktightness	**Leak Test - 49 CFR 173.469 (a)(4)(i)**[a,b,c] Leak pretest to ensure there is no leakage prior to performance of heat test
Test sequence #2: Heat test	**Heat Test - 49 CFR 173.469 (b)(4):** The specimen may not melt or disperse when subjected to the heat test (Ref. 49 CFR 173.469 [a][3])[a]
Test sequence #3: Leaktightness	**Leak Test - 49 CFR 173.469 (a)(4)(i)**[a,b,c] Leakage post-test to ensure there is no leakage after heat test

[a] After each test, leaktightness of the specimen must be determined (49 CFR173.469[a][4]).

[b] Perform test for leaktightness per 49 CFR 173.469 (a) (4) (i). NOTE: The test specimen capsule must be fabricated from material that is resistant to corrosion by water and must have an internal void volume greater than 0.1 millimeters. Must demonstrate a leak tightness of 10^{-4} torr-l/s (1.3×10^{-4} atm-cm^3/s) based on air at 25°C (77°F) and one atmosphere differential pressure for solid radioactive content. This test method is more sensitive than the leaching assessment methods specified by 49CFR 173.469 (4)(c).

[c] Leaching assessment methods for indispersible solid material do not apply (49 CFR 173.469 [4][i]).

Table 1.4 shows data for the test units that were subjected to the heat test, along with the corresponding weight of the radioactive material. The post-test leak test was first performed on the heavy test unit (C1-0290), and that test unit passed the leak test. Therefore, leak tests were not performed for the remaining heat test units because the leak test results for the 3.2 g test unit will cover the 2.5 g and 1.7 g test unit. This report only provides results from leak and heat tests for the 3.2 g test unit (C1-0290).

Table 1.4. Heat Test Units mass distribution

Test unit SN	Test unit number	Uranium weight (g)	Uranium Oxide weight (g)
C1-0290	1	3.2	4.58
C1-0288	2	2.5	3.71
C1-0289	3	1.7	2.74

2. PRE-TEST ACTIVITIES

The test units were delivered in a ready-to-test condition, so there were no specific pretest activities.

3. SPECIAL FORM TESTS

Special form testing requirements are specified in 49 CFR 173.469 (b). The weight of the capsule is less than 200 grams, so ISO 2919:1999E may be used in lieu of the impact test per 49 CFR 173.469 (d). For this design, three tests were required: the Class 4 impact test per ISO 2919:1999(E), a heat test, and a leak test. The bending test was not required because the length-to-width ratio of the design is not greater than 10. After each test, each unit was subjected to a leakage rate test as specified in 49 CFR 173.469(a). Two leakage tests were conducted to ensure conclusive compliance with the 49 CFR 173.469(d) requirement. The two types of leakage tests performed were the helium back pressurization test and the bubble test. The helium test was considered as the fine leak test, and the bubble leak test was considered as the gross leak test. The results of these tests are described below.

3.1 IMPACT TEST (ISO 2919:1999(E))

Test unit 4, or TU-4 (OPSF1), was subjected to the ISO 2919:1999(E) Class 4 impact test, which was carried out at the indoor drop pad located at the National Transportation Research Center in Knoxville, Tennessee. This drop pad has a total mass of ~13.6 metric tons and meets the specifications for the impact test target according to the *Design and Certification of Targets for Drop Testing at the NTRC Package Research Facility Rev. 0* (May 2003, ORNL/NTRC-001). The test was performed according to the procedure outlined in the *Test Plan for the Special Form Qualification Testing of the U* ZiPCan *Triangle Encasement* (ORNL/NTRC-074, Section 3.7.1). Testing activities and results were recorded on Test Form 1 from the test plan.

The TU-4 U ZiPCan was centered on the indoor drop pad. A 1-inch diameter steel billet weighing 2 kg was placed on the release mechanism and raised to a height of 1 meter. A calibrated meter stick was used to measure the height from the bottom surface of the billet to the top surface of the U ZiPCan (Figure 3.1). The steel billet was released so that the billet made a direct impact on the vertex of TU-4.

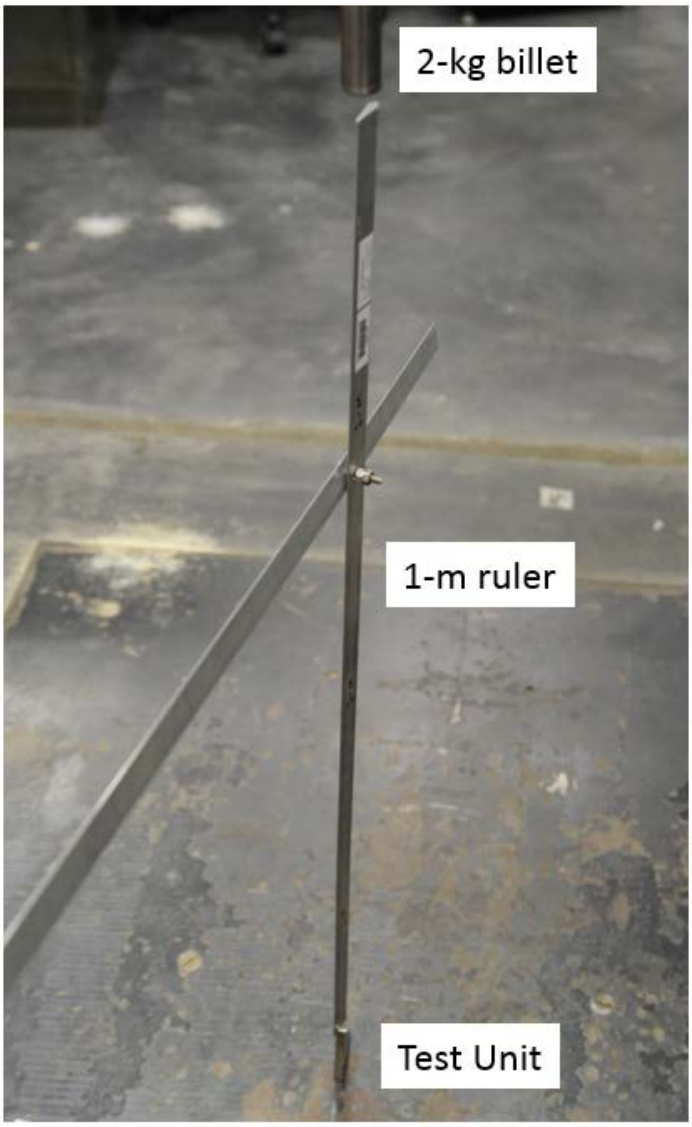


Figure 3.1. Impact billet 1 m above the ZiPCan.

When released, the billet impacted TU-4 squarely on the vertex. The impact resulted in a slight indentation in TU-4 at the point of impact. Figure 3.2 photos show TU-4 before and after the impact test. After the impact test, TU-4 was subjected to a fine and gross leak test as described in Section 3.3.

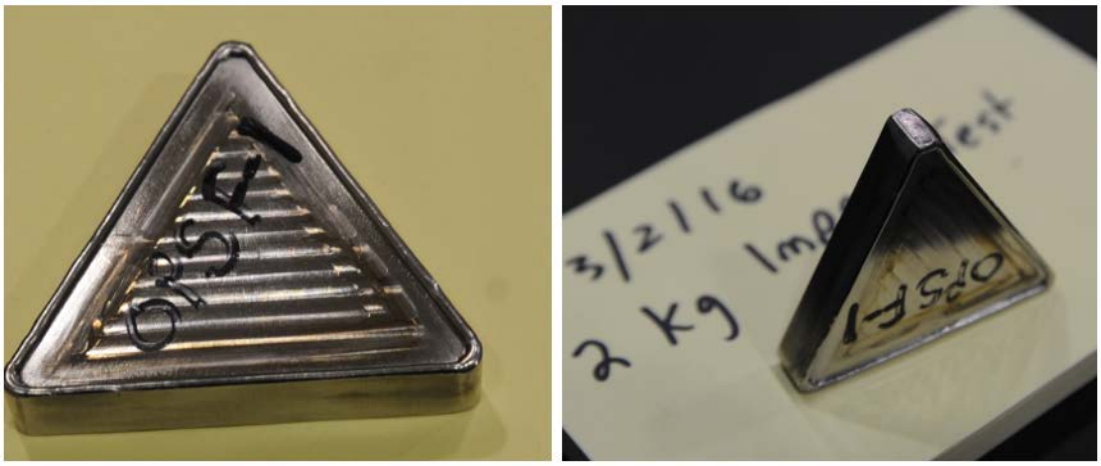


Figure 3.2. Before and after impact of the U ZiPCan.

3.2 HEAT TEST

The 49 CFR 173.469(b)(4) heat test was performed on the TU-1 (C1-0290) test unit, which had been loaded with 3.2 grams of depleted uranium. The special form tile loading log can be found in ORNL Log Book H00034-RSTD Fabrication. The uranium was depleted in the Y-12 National Security Complex (NSC) cauldrons to a high percentage of ^{238}U as batch number D7. The isotopes for the batch D7 uranium can be found in Table 1.1. The test was conducted in the ORNL REDC, Building 7930, Lab 212 Fume Hood (IE-960). The safety aspects of activities for this heat test are controlled by the ORNL RHAC RSS 919, *REDC Bldg. 7930 Development Laboratory Operations*. The furnace used was a Thermolyn Model #F47925, Serial No. 0152853201110405, property number 18334 (Figure 3). The furnace has a noncalibrated integrated controller; this was acceptable because calibrated thermocouples and a calibrated fluke thermometer was used during the test. Two 12-inch Type K thermocouple probes (BF3874 and BF3F05) were calibrated before the test, inserted into the top of the furnace, and extended into the center of the furnace cavity (Thermocouple 1 - BF3874; Thermocouple 2 - BF3F05 Figure 3.4). The probe was connected to a calibrated fluke thermometer B1332, Serial No. 36370410WS, with a calibration due date of 9/27/2017.

Figure 3.3. Heat test furnace in REDC.

Job# 3054371					Tech: 30220
Date: 1/24/17	**Technical Support Department**				Std: A001277
	Instrument Data Continuation Sheet				M210101
					A002021

Furnace	Standard	UUT Reading			
	Type S	BF3874	Error	BF3F05	Error
21.5	**21.5**	20.9	-0.6	21.1	-0.4
750.0	**754.1**	755.0	0.9	754	-0.1
800.0	**803.5**	804.5	1.0	803.6	0.1
850.0	**854.0**	855.0	1.0	854.4	0.4
900.0	**904.3**	905.4	1.1	905.1	0.8
950.0	**955.4**	956.9	1.5	956.3	0.9

Thermocouple 1 - BF3874; Thermocouple 2 - BF3F05

Figure 3.4. Type K thermocouple calibration record.

The test was performed according to the procedure outlined in the *Test Plan for the Special Form Qualification Testing of the U ZiPCan Triangle Encasement,* ORNL/NTRC-074, Section 3.7.2, and testing activities and results were recorded on Test Forms 2, 3, and 4 from the test plan. The furnace was preheated above 800°C for three hours. After a three-hour heat soaking period at a constant temperature of 980°C, the furnace door was opened, and TU-1 was inserted into the furnace cavity. The furnace door was closed, and when both thermocouples reached a furnace reading above 800°C, the 10-minute thermal test was started (Figure 3.5 and Figure 3.6). Thermocouple 1 is BF3874, and thermocouple 2 is BF3F05.

A noncalibrated stop watch was used to record the temperatures from both thermocouples every 30 seconds for 10 minutes. After the 10-minute period, the door was opened, and TU-1 was removed from the furnace and allowed to cool naturally. The thermal test resulted in an out-of-plane bulge (pillow effect) of the test unit, which is shown in Figure 3.7. There was a discoloration on the outer surface of the test unit. The test unit was helium leak tested and bubble tested after the thermal test.

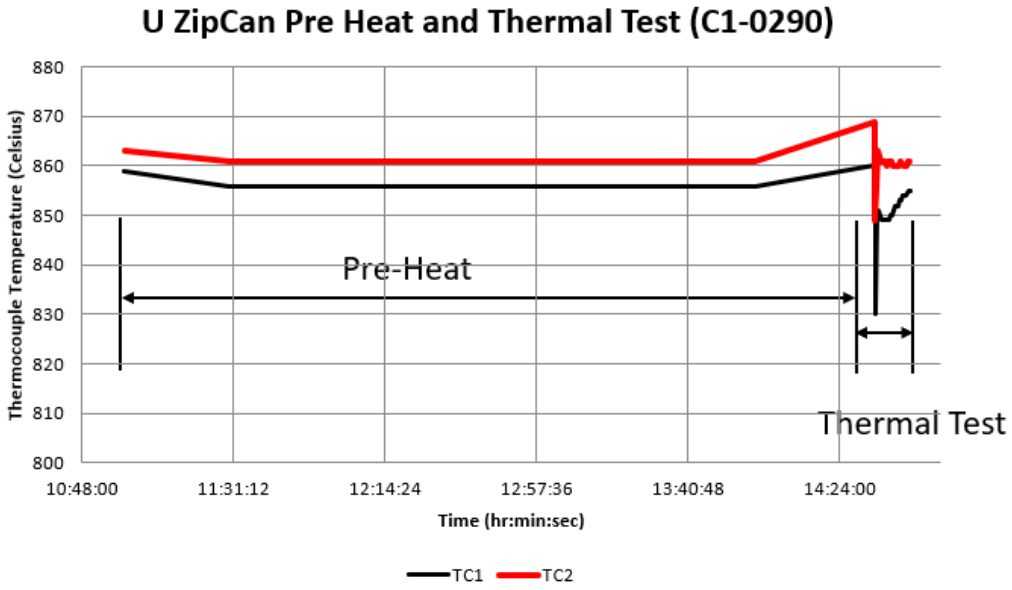


Figure 3.5. Pre-heat and heat test temperature profile.

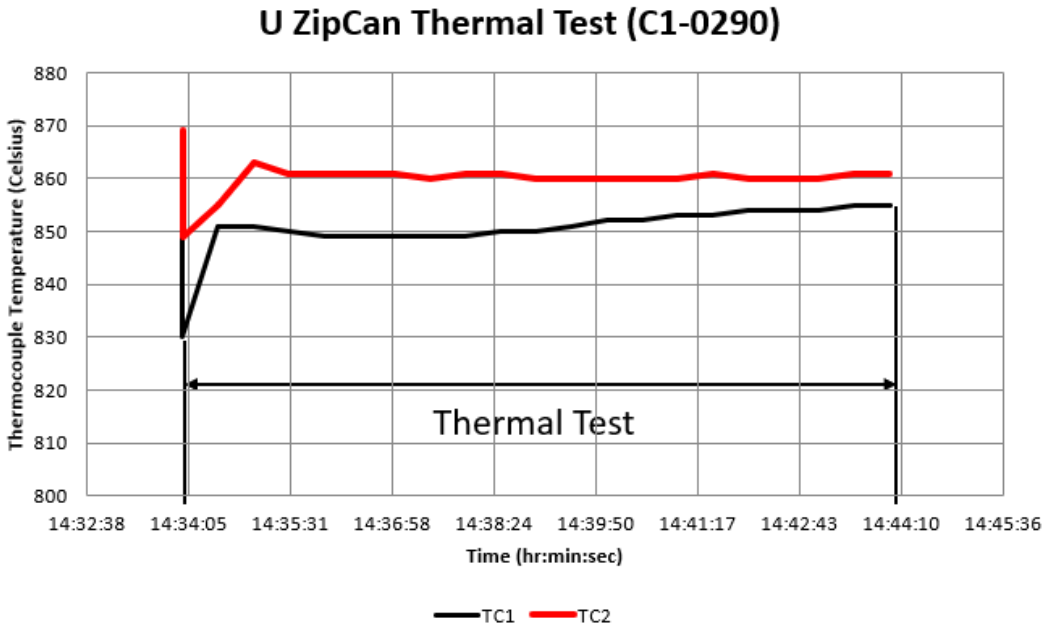


Figure 3.6. Heat test temperature profile.

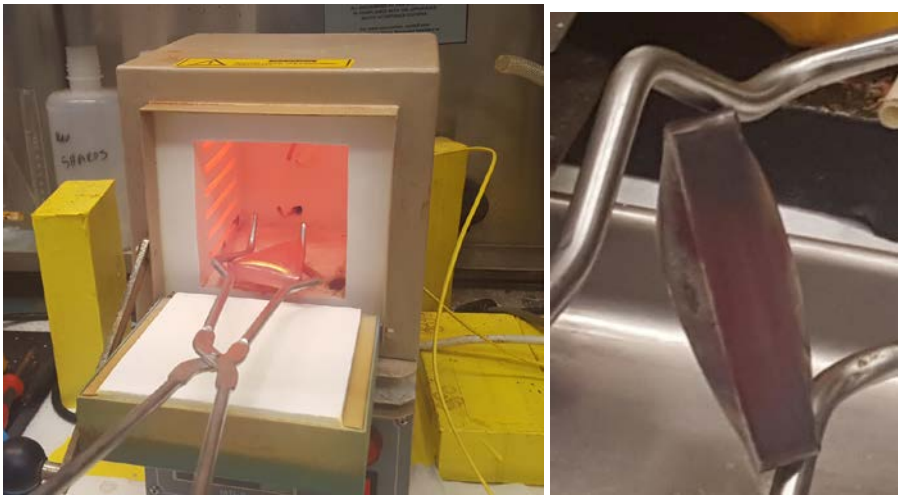


Figure 3.7. U ZipCan post heat test results.

3.3 LEAK RATE TESTING

3.3.1 Evacuated Envelope (with Back Pressurization)

Leak rate tests that met the test requirements of 49 CFR 173.469 (a)(4)(i) were performed individually on each test unit before and after each special form test. The leak rate tests were performed using American National Standards Institute (ANSI) N14.5-2014 *American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment*, Table A.1, Test Description A.5.5, "Evacuated Envelope (with back pressurization)" and Test Description A.5.6 "Gas bubble techniques." The ANSI document indicates that the back-pressure method
". . . is ideal for welded capsules from very small sizes up to the sizes limited by the dimensions of the pressurizing chamber," and that the "nominal test sensitivity = 10^{-3}- 10^{-8} ref-cm/s" and the bubble test method are used for hermetically sealed test specimens.

Section A.5.5 of ANSI N14.5-1997, *Evacuated Envelope with Helium Back Pressure* references American Society for Testing and Measurement (ASTM) E 493, *Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode*. This standard provides the method for converting a measured leak rate using the evacuated envelope with the helium back-pressure method into the standardized leak rate that must be compared to the pass/fail criteria specified in 49 CFR 173.469(a)(4)(i), which is 10^{-4} torr-l/s (1.3×10^{-4} atm-cm^3/s).

The equation provided in Section 11.1.9 of ASTM E493 is as follows:

$$S_l = (P_e/P_a) \times (1- e^{(-3600*a*T)}) * (e^{(-a*t)}) \times L \qquad (1)$$

where:

S_l = indicated (measured) leak rate (cc/s),
P_e = bombing pressure of helium (absolute),
P_a = atmospheric pressure (absolute),
T = bombing time (hours),

t = waiting time between bombing and testing (s),
L = actual (standardized) leak rate (atm-cc/s),
a = L/V (where V = internal volume), and
e = 2.71 (natural logarithm).

Since S_l is being measured and the objective is to solve for L, an iterative solver is required to find the solution. The equation was solved using MS Excel. Note that the ASTM standard uses the term *bombing*, while the ANSI standard uses the term *back-pressure*. These terms are synonymous and are used interchangeably in this report.

To solve Eq (1), the internal volume (i.e., void space) within the test units must be known. For the test units, this internal volume consisted of accessible internal void spaces. Based on the dimensions provided by the drawings and queried information from the computer aided design software used to create the drawings (to determine the volume of the irregularly shaped Part #2 shown in Figure 1.1), the void volume is 600 cubic millimeters

Test units TU-1 (C1-0290) and TU-4 (OPSF1) were leak tested at ORNL by certified American Society for Nondestructive Testing (ASNT) Level II and Level III nondestructive testing (NDT) leak testing personnel using the NDE-70 R.6 procedure. See Appendixes D and E for documentation of leak tester certification and the leak testing procedure, respectively. The test units were leak tested before and after each special form test. The test apparatuses used for these tests employed a spectrometer tuned to detect helium, a calibrated helium leak to calibrate the system, and two separate vessels—one for helium back pressurization, and a second one for the subsequent helium leakage rate testing under vacuum conditions. Figure 3.7 provides a schematic of the system used for helium back pressurization, and Figure 3.8 shows a schematic of the system used for the helium leakage rate test. Leak rate test variables and results for TU-1 and TU-4 are shown in Table 3.1. A temperature correlation was performed to determine the measured leak rate at 25°C, per the requirement. The 2.2 cubic centimeters void volume for leak test 2 of the C1-0290 capsule was based on engineering judgement due to the swelling that occurred during testing. As a sensitivity calculation, a void volume of 100 cc was assumed which resulted in a standardized leak test of 9.81×10^{-5}, which is less than the 1.0×10^{-4} requirement. Note that as the void volume rises, so does the calculated standardized leak rate. Therefore, although the void volume is not precisely known, this sensitivity check demonstrates that knowing the exact void volume is not necessary.

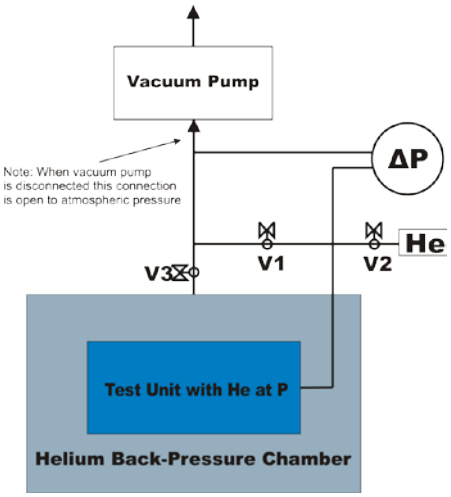


Figure 3.8. Diagram of helium back pressurization test.

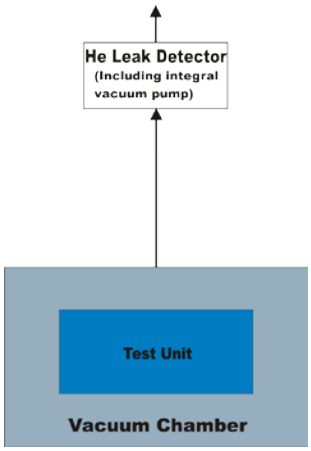


Figure 3.9. Diagram of helium leak testing system.

3.3.2 Gas bubble techniques

The gas bubble test was performed using the methods described in ANSI N14.5-2014, *American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment*, Table A.1, Test Description A.5.6 (b), "Vacuum Bubble." The method involves immersing the test unit in a liquid and then producing a vacuum above the liquid (e.g., water/glycol or isopropyl alcohol) in which the test item is submerged. A leak is indicated by a stream of bubbles. This method applies to welded capsules. The nominal test sensitivity is 10^{-3} ref-cm^3/s (10^{-4} Pa-m^3/s). Test units TU-1 (C1-0290) and TU-4 (OPSF1) were bubble tested, and the results are presented in Table 3.2. See Appendixes D and E for documentation of leak tester certification and the leak testing procedure. While the sensitivity of the bubble test does not meet the minimum leak rate per 49 CFR 173.469 4(i), this test is needed because it is possible that a leak area is large enough that the helium inside the component may have evacuated out before the test unit is placed in the vacuum chamber for helium detection.

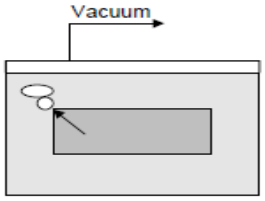


Figure 3.10. Vacuum bubble test.

Table 3.1. Leak rate test variables and results for TU-1 and TU-4

Parameter	Test unit			
	TU-4 (OPSF1)		TU-1 (C1-0290)	
	Leak test 1	Leak test 2	Leak test 1	Leak test 2
Void space – V (cc)	1.057	1.057	1.057	2.2
Bombing pressure – P_e (psig)	30.0	50.0	30	30.0
Atmospheric pressure – P_a (psia)	14.69	14.69	14.69	14.69
Bombing time – T (hr)	0.5	1	0.5	0.5
Time between bombing and testing – t (s)	<3,600	<1,800	3,600	3,600
Measured leak rate (cc/s) – S_l (atm-cc He/s)	2.02×10^{-7}	5.02×10^{-9}	1.72×10^{-7}	7.81×10^{-7}
a = L/V (s^{-1})	5.78×10^{-5}	6.30×10^{-6}	$<9.46 \times 10^{-5}$	3.28×10^{-5}
Standardized leak rate – L (atm-cc He/s)	6.11×10^{-5}	6.66×10^{-6}	$<1.0 \times 10^{-4}$	7.23×10^{-5}

Table 3.2. Bubble test results for TU-1 and TU-4

Parameter	Test unit			
	TU-1 (C1-0290)		TU-4 (OPSF1)	
	Bubble test 1	Bubble test 2	Bubble test 1	Bubble Test 2
Bubble test pass/ fail	pass	pass	pass	pass

4. CONCLUSION

Two prototype U ZiPCans were subjected to the tests specified in 49 CFR 173.469. Both units were subjected to a pretest leak test. One unit was subjected to the impact test followed by a leak rate test, and the other unit was subjected to the heat test followed by a leak rate test. Each unit easily surpassed the leak rate criteria following each test, neither test specimen broke or shattered when subjected to the impact test, and the specimen did not melt or disperse when subjected to the heat test. This testing process has shown that the design of the U Zirconia Pre-Encapsulated Canister meets Special Form Criteria per 49 CFR 173.469 and IAEA special form requirements.

APPENDIX A. U ZIPCAN DRAWINGS

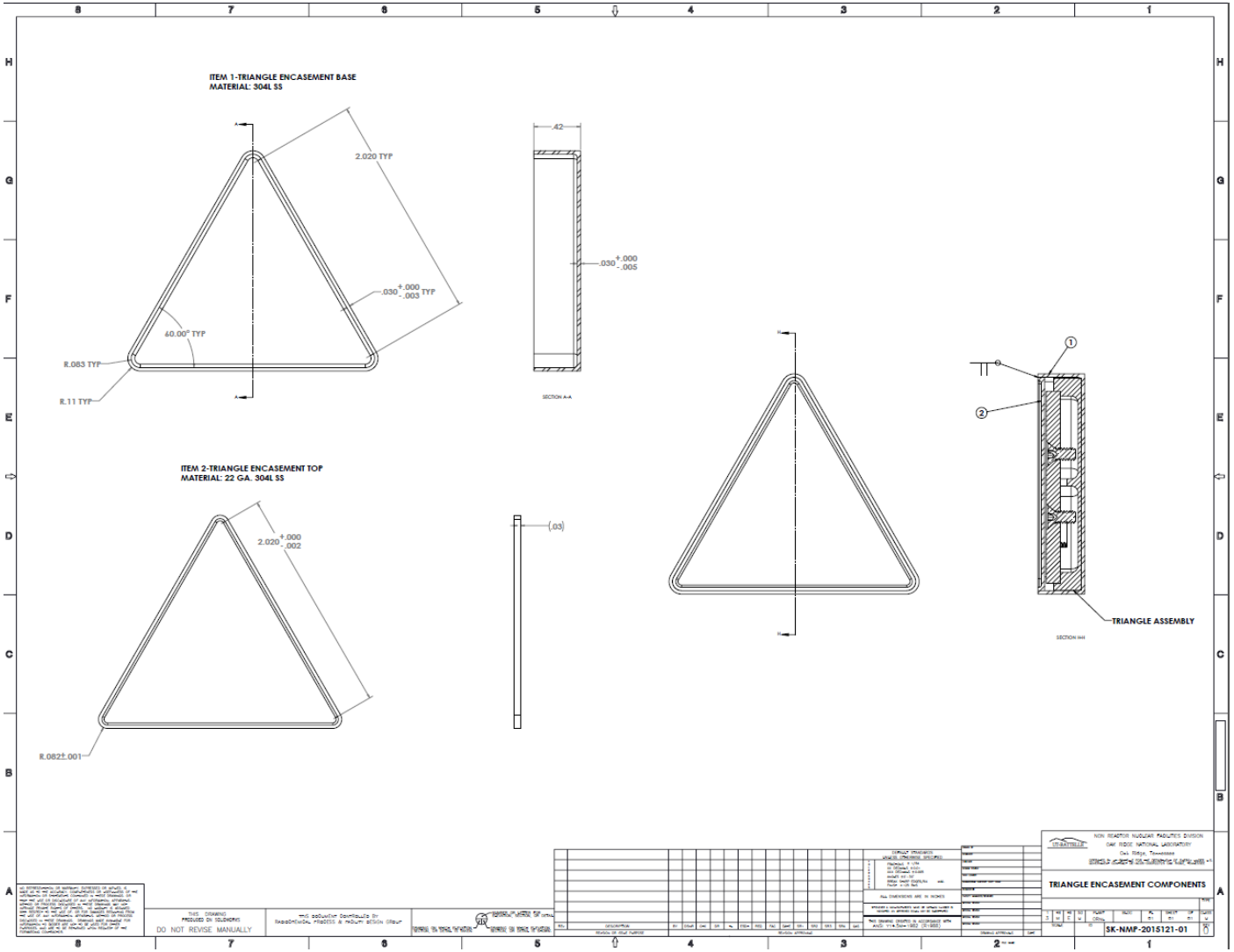


Figure A.1. U ZiPCan engineering drawing.

APPENDIX B. TEST FORMS

Report Number: 2/19/16-2

LEAK TEST REPORT

Test Requested by: J. GARRISSON	Allowable Leak Rate: < 1.0 E-4 Std-Atm-cc/s
Work Order Number: 3760A465	Test Pressure Req. Across Boundary: 1 ATM
Item Tested: 2 EA TRIANGLES OPSF-1, OPSF-2	Customer: BEDC
Technique Used: BOMB / BELSAR ☒ Inside - Out ☐ Outside - In	Procedure/Rev: NDE 70 R6

EQUIPMENT

LEAK DETECTOR

Make and Model: ADIXEN ASM 182 TDT	
Serial Number: HLD0860905	

TEST GAUGES

Temp Gauges: A001067	Due: 6/25/16
Pressure Gauges: MTE 549	Due:

STANDARD LEAK

Manufacturer: VTI	Tracer Gas: He
Model: ~~VSLT-5-3c-He GPPT-7-He-118T~~ BW 2/19/16	Serial Number: TP860 ~~TP9384~~
Leak Rate: 4.2 E-6 Atm-cc/s @ -1 atm @ 21.1 °C	
Correlation Formula: $[1 - (T_{cal} - T_{surf})\ C_T]\ LR$	Temp Coefficient: 3.0 %/°C
Correlated LR: 4.6 E-6 Atm-cc/s @ -1 atm @ 24.0 °C	
Calibration Due Date: 9/14/16	

RESULTS ☒ Quantitative ☐ Semi - Quantitative

MACHINE CALIBRATION

System Pressure: 1.5 E-3	
Background: < 4.0 E-10 Atm-cc/s	
Leak Response: 4.6 E-6 Atm-cc/s	
Minimum Detectable Leak: 1.0 E-7 Atm-cc/s	
System Sensitivity: 2.0 E-7 Atm-cc/s	
Response Time: < 5s	

SYSTEM TEST CONDITIONS

System Temperature: 24.0 °C ☒ Surface ☐ Internal Gas	
delta P Test Boundary: 1 ATM	
Tracer Gas: He	% Concentration: CALC
System Response Time: < 5s	
System Response: 2.0 E-9 Atm-cc/s	
Duration of Test: ~30s	

Aux. Equipment:

☒ ACCEPT ☐ REJECT ☒ SKETCH / DATA ATTACHED

System Leak Rate: < 1.0 E-4 Atm cc/s @ -1 atm @ 24.0 °C
w/ stated tracer gas

COMMENTS:

Pre impact - Oscar M.

Test Conducted By: (Print & Sign Name/Level):	Date:	Time:
E. VIDAL Eric J Vidal LII	2/19/16	1:10

BOMBING TEST REPORT (*Supplement*)

Leak Test Report Number: 2/19/16-2	*Allowable Leak Rate:* $< 1.0E^{-4}$
Item(s) Tested: OPSF-1 , OPSF-2	

TRACER GAS BOMBING AND LEAK TEST

Bombing Pressure (psig): 30	*Tracer Gas:* He	*Bombing Time:* > 30 min
Waiting Time (Sec): < 3600	*Internal Volume (cc):* 1.057	
Measured Leak Rate: $2.0\ E^{-9}$ *Atm cc/s*	*Calculated Leak Rate:* $< 1.0E^{-4}$ *Atm cc/s into vac. @* 24.0 °C	

Test Results: ☒ *ACCEPT* ☐ *REJECT* ☒ *CALCULATIONS / DATA ATTACHED*

COMMENTS:

Test Conducted By: (Print & Sign Name/Level): E. VIDAL Eric S Vidal LII	*Date:* 2/19/16

ASNT Formula

R	1.00E-05	scc/s	*Measured helium leak rate (Q)*
Pe	30	psig	*Bomb Chamber Pressure*
Po	14.696	psia	*Atomspheric pressure*
Ma	28.7	g/mol	*MW of air*
M	4	g/mol	*MW Helium*
T1	1800	sec	*Time of exposure (bomb time)*
T2	3600	sec	*Dwell time (from bomb chamber to test start)*
V	1.057	cc	*Internal volume*
L	7.916E-05	scc/s	*Equivalent air leak rate (estimate value for calc to work)*
Part 1	4.329E-04		*Converts true air leak to helium leak rate*
Part 2	2.427E-02		*Calc amount of helium entering package during bomb*
Part 3	9.520E-01		*Amount of helium at the end of the dwell*
Rcalc	1.000E-05	scc/s	*Ignore this number*
Lcf	4.0384E-05	scc/s	*Corrected for tracer concentration*

ASTM/CFR Formula

L	6.108E-05	scc/s	*Equivalent air leak rate*
Lcf	3.11571E-05	scc/s	Corrected for tracer gas
Rcalc	1.000E-05	Ignor this number	

RESULTS

L (ASNT/MIL)	7.92E-05	scc/s
L(ASTM/CFR)	6.11E-05	scc/s
% Difference	22.8%	

$$R = \left[\frac{LP_e}{P_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right] \times \left\{1 - e^{-\left[\frac{LT_1}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right]}\right\} \times e^{-\left[\frac{LT_2}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right]}$$

Note: formula is modified for uniformity; a = L/V and 3600 converts hours to seconds

$$R = \frac{LP_e}{P_o}\left[1 - e^{-\left(\frac{L}{V}\right)T_1}\right] \times \left[e^{-\left(\frac{L}{V}\right)T_2}\right]$$

Intructions for Use:

1 - Input estimate for "L" in orange block. This esitmate needs only be within a few decades of the expected leak rate. If this calculator fails, the revise estimate closer to measured Q

2 - Input only information in bright yellow blocks specific to test

3 - tab or select away from the last entered value and press the calculate button for results

OPSF-1, OPSF-2 2/19/16

E. VIDAL Eric A Vidal III

Report Number: 2/22/16-1

LEAK TEST REPORT - BUBBLE TEST

Test Requested by: J. GARRISON	Customer: REDC
Work Order Number: 3760A465	Procedure: NDE 70 R6
Item Tested: 2 EA. TRIANGLES OPSF-1, OPSF-2	Test Pressure Required: 15 INHg
Technique Used: VAC BOX	Liquid Media Used: IMMERSIT CIM 150
Test Gas Used: VAC	Liquid Applicator Type: IMMERSION
Inspection Light Intensity: >100 FC	Post Cleaning Method: DEMIN H2O RINSE
Other Apparatus Used: FLASHLIGHT	

Direct Pressure Technique ☐ **Vacuum Pressure Technique** ☒

Component Limits of Test:

Component Test Site BLDG 5500	Component Installation Site

Gauges				Test Pressure		Temperature	
Mfg	ID No	Calibration Date	Range	Beginning	End	Beginning	End
	A002126	8/26/15	0-30 INHg	15 INHg	15 INHg	AMBIENT	AMBIENT

Temperature Measuring Device

Mfg. —	Model —	Range —	I.D. Number —

RESULTS ☒ ACCEPT ☐ REJECT POST CLENING PERFORMED: ☒ Y ☐ N

Comments: AMBIENT SHOP AIR ~ 70°F

Test Conducted By: (Print & Sign Name/Level): E. VIDAL Eric S Vidal LII	Date: 2/22/16

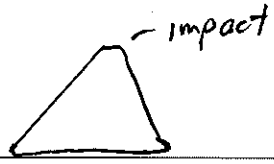
TEST FORM 1 – **Impact Test ISO 2919**

Test Plan ORNL/NTRC-067

Test Unit OPSF-1

VERIFIED	TASK
✓	The weight of the impact billet has been measured and verified to be 2 kg or greater:
	Measured weight of billet 2.000 (kg)
	Scale used for measurement: Mettler Toledo Calibration due: Metrology Scale
✓	The calibration of the 1-m ruler has been verified:
	1-m Ruler Equipment # A00146 Calibration due: 11/3/16
✓	The test unit with supporting device has been placed (centered) on NTRC indoor drop pad.
✓	The drop test release mechanism has been attached to the crane.
✓	The impact billet has been captured by the release mechanism.
✓	The billet has been centered over the test unit and a picture has been taken.
✓	The billet has been raised to height of 1 meter over the highest point of the test unit and a picture has been taken.
✓	The billet was released and impacted the test unit.
✓	All observable damage to the test unit caused by the impact test has been recorded and pictures of the test unit after the impact test have been taken.

Comments: Weight of Test Unit = 57g



Vertex Impact

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician — Date: 3/2/2016

Checked by: Cindy Beatty — Date: 4/1/16

*All photographs will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

Report Number: 3/9/16-2

LEAK TEST REPORT

Test Requested by: C. BLESSINGER	Allowable Leak Rate: ≤ 1.0E-7 Std-Atm-cc/s
Work Order Number: 3760A.465	Test Pressure Req. Across Boundary: 1 ATM
Item Tested: OPSF-1	Customer: REDC
Technique Used: BOMB/BELL JAR ☒ Inside - Out ☐ Outside - In	Procedure/Rev: NDE 70 R.6

EQUIPMENT

LEAK DETECTOR

Make and Model: ADIXEN ASM 182 TDT	
Serial Number: HLD 0860905	

TEST GAUGES

Temp Gauges: A001952	Due: 6/10/16
Pressure Gauges: MTE549	Due: —

STANDARD LEAK

Manufacturer: VTI	Tracer Gas: He
Model: GPPT-8-V-HE-118T	Serial Number: TP5754
Leak Rate: $5.37E^{-8}$ Atm-cc/s @ -1 atm @ 23.4 °C	
Correlation Formula: $[1 - (T_{cal} - T_{surf}) C_T] LR$	Temp Coefficient: 2.0 %/°C
Correlated LR: $5.36E^{-8}$ Atm-cc/s @ -1 atm @ 23.3 °C	
Calibration Due Date: 02/23/17	

RESULTS ☒ Quantitative ☐ Semi - Quantitative

MACHINE CALIBRATION

System Pressure: $1.5E^{-3}$ mb	
Background: $7.3E^{-11}$ Atm-cc/s	
Leak Response: $5.4E^{-8}$ Atm-cc/s	
Minimum Detectable Leak: $1.0E^{-9}$ Atm-cc/s	
System Sensitivity: $2.0E^{-9}$ Atm-cc/s	
Response Time: < 5s	

SYSTEM TEST CONDITIONS

System Temperature: 23.4 °C ☒ Surface ☐ Internal Gas	
delta P Test Boundary: 1 ATM	
Tracer Gas: He	% Concentration: CALC
System Response Time: < 5s	
System Response: $5.0E^{-9}$ Atm-cc/s	
Duration of Test: ~1 MIN	

Aux. Equipment:

☒ ACCEPT ☐ REJECT ☒ SKETCH / DATA ATTACHED

System Leak Rate: w/ stated tracer gas < $1.0E^{-7}$ Atm cc/s @ -1 atm @ 23.4 °C

COMMENTS:

FINE LT - POST DROP TEST / IMPACT TEST

Test Conducted By: (Print & Sign Name/Level):	Date:	Time:
E. VIDAL LII	3/9/16	3:00

BOMBING TEST REPORT (*Supplement*)

Leak Test Report Number: 3/9/16 - 2	*Allowable Leak Rate:* ≤ 1.0 E-7
Item(s) Tested: OPSF-1	

TRACER GAS BOMBING AND LEAK TEST

Bombing Pressure (psig): 50	*Tracer Gas:* He	*Bombing Time:* > 1 Hr
Waiting Time (Sec): < 1800	*Internal Volume (cc):* 1.057	
Measured Leak Rate: 5.0 E-9 *Atm cc/s*	*Calculated Leak Rate:* < 1.0 E-7 *Atm cc/s into vac. @* 23.4 *°C*	

Test Results: ☒ *ACCEPT* ☐ *REJECT* ☒ *CALCULATIONS / DATA ATTACHED*

COMMENTS:

Test Conducted By: (Print & Sign Name/Level): E. VIOAL Eric S Vail LTT	*Date:* 3/9/16

ASNT Formula

R	5.00E-07	scc/s	*Measured helium leak rate (Q)*
Pe	50	psig	*Bomb Chamber Pressure*
Po	14.696	psia	*Atomspheric pressure*
Ma	28.7	g/mol	*MW of air*
M	4	g/mol	*MW Helium*
T1	3600	sec	*Time of exposure (bomb time)*
T2	1800	sec	*Dwell time (from bomb chamber to test start)*
V	1.057	cc	*Internal volume*
L	9.450E-06	scc/s	*Equivalent air leak rate (estimate value for calc to work)*
Part 1	8.612E-05		*Converts true air leak to helium leak rate*
Part 2	5.849E-03		*Calc amount of helium entering package during bomb*
Part 3	9.971E-01		*Amount of helium at the end of the dwell*
Rcalc	5.022E-07	scc/s	*Ignore this number*
Lcf	6.6722E-06	scc/s	*Corrected for tracer concentration*

ASTM/CFR Formula

L	6.664E-06	scc/s	*Equivalent air leak rate*
Lcf	4.7051E-06	scc/s	Corrected for tracer gas
Rcalc	5.030E-07	Ignor this number	

RESULTS

L (ASNT/MIL)	9.45E-06	scc/s
L(ASTM/CFR)	6.66E-06	scc/s
% Difference	29.5%	

$$R = \left[\frac{LP_e}{P_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right] \times \left\{1 - e^{-\left[\frac{LT_1}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right]}\right\} \times e^{-\left[\frac{LT_2}{VP_o}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right]}$$

Note: formula is modified for uniformity; a = L/V and 3600 converts hours to seconds

$$R = \frac{LP_e}{P_o}\left[1 - e^{-\left(\frac{L}{V}\right)T_1}\right] \times \left[e^{-\left(\frac{L}{V}\right)T_2}\right]$$

Intructions for Use:

1 - Input estimate for "L" in orange block. This esitmate needs only be within a few decades of the expected leak rate. If this calculator fails, the revise estimate closer to measured Q

2 - Input only information in bright yellow blocks specific to test

3 - tab or select away from the last entered value and press the calculate button for results

OPSF-1

3/9/16

Report Number: 3/10/16-2

LEAK TEST REPORT - BUBBLE TEST

Test Requested by: C. BLESSINGER	Customer: BEDC
Work Order Number: 3760A465	Procedure: NDE 70 R.6
Item Tested: OPSF-1	Test Pressure Required: 15" Hg
Technique Used: VAC BOX	Liquid Media Used: IMMERSIT CIM 200
Test Gas Used: VAC	Liquid Applicator Type: IMMERSION
Inspection Light Intensity: >100FC	Post Cleaning Method: DEMIN. H_2O RINSE.
Other Apparatus Used: FLASHLIGHT / MIRROR	

Direct Pressure Technique ☐ **Vacuum Pressure Technique** ☒

Component Limits of Test:

Component Test Site BLDG 5500	Component Installation Site

Gauges				Test Pressure		Temperature	
Mfg	ID No	Calibration Date	Range	Beginning	End	Beginning	End
PUMP GAGE	A002126	8/26/15	0-15 INHg	15 IN Hg	15 INHg	(~68°F) AMBIENT	AMBIENT

Temperature Measuring Device

Mfg.	Model	Range	I.D. Number

RESULTS ☒ ACCEPT ☐ REJECT POST CLEANING PERFORMED: ☒ Y ☐ N

Comments:

Test Conducted By: (Print & Sign Name/Level):	Date:
E. VIDAL [signature] LII	3/10/16

Report Number: 11/22/16-1

LEAK TEST REPORT

Test Requested by: J. GARRISON	Allowable Leak Rate: < 1.0 E-4 Std-Atm-cc/s
Work Order Number:	Test Pressure Req. Across Boundary: 1 ATM
Item Tested: 4 EA. RSTD SPECIAL FORM CAPSULES	Customer: RSTD
Technique Used: BOMB / BELL >AR ☒ Inside - Out ☐ Outside - In	Procedure/Rev: NDE 70 R.6

EQUIPMENT

LEAK DETECTOR

Make and Model: ADIXEN ASM 340	
Serial Number: HLD 1601393	

TEST GAUGES

Temp Gauges: A001957	Due: 6/22/17
Pressure Gauges: MTE549	Due: –

STANDARD LEAK

Manufacturer: VTI	Tracer Gas: He
Model: VSLT-5-3C-He	Serial Number: TP860
Leak Rate: 4.82 E-6 Atm-cc/s @ -1 atm @ 22.1 °C	
Correlation Formula: $[1 - (T_{cal} - T_{surf}) C_T] LR$	Temp Coefficient: 3.0 %/°C
Correlated LR: 4.56 E-6 Atm-cc/s @ -1 atm @ 20.3 °C	
Calibration Due Date: 9/9/17	

RESULTS ☒ Quantitative ☐ Semi - Quantitative

MACHINE CALIBRATION

System Pressure: 5.0 E-3 mb	
Background: 2.0 E-10 Atm-cc/s	
Leak Response: 4.5 E-6 Atm-cc/s	
Minimum Detectable Leak: 1.0 E-7 Atm-cc/s	
System Sensitivity: 2.0 E-7 Atm-cc/s	
Response Time: ~ 10 s	

SYSTEM TEST CONDITIONS

System Temperature: 20.3 °C ☒ Surface ☐ Internal Gas	
delta P Test Boundary: -1 ATM	
Tracer Gas: He	% Concentration: CALC
System Response Time: ~ 1 MIN	
System Response: 1.7 E-7 Atm-cc/s	
Duration of Test: 90 s	

Aux. Equipment:

☒ ACCEPT ☐ REJECT ☒ SKETCH / DATA ATTACHED

System Leak Rate: w/ stated tracer gas < 1.0 E-4 Atm cc/s @ -1 atm @ 20.3 °C

COMMENTS:

S/N: C1-0286, 288, 289, 290 FINE LT

Test Conducted By: (Print & Sign Name/Level):	Date:	Time:
E. VIDAL LII	11/22/16	1:15

BOMBING TEST REPORT (*Supplement*)

Leak Test Report Number: 11/22/16-1	*Allowable Leak Rate:* < 1.0 E-4

Item(s) Tested: 4 EA. SPECIAL FORM CAPSULES

TRACER GAS BOMBING AND LEAK TEST

Bombing Pressure (psig): 30	*Tracer Gas:* He	*Bombing Time:* > 1800 s
Waiting Time (Sec): < 3600 s		*Internal Volume (cc):* 1.057
Measured Leak Rate: 1.7 E-7 *Atm cc/s*		*Calculated Leak Rate:* < 1.0E-4 *Atm cc/s into vac. @* 20.3 °C

Test Results: ☒ *ACCEPT* ☐ *REJECT* ☒ *CALCULATIONS / DATA ATTACHED*

COMMENTS:

Test Conducted By: (Print & Sign Name/Level):	*Date:*
E. VIDAL [signature] LTI	11/22/16

Report Number: 11/22/16-2

LEAK TEST REPORT - BUBBLE TEST

Test Requested by: J. GARRISON	Customer: RSTD
Work Order Number:	Procedure: NDE 70 R.6
Item Tested: 4 EA. SPECIAL FORM CAPSULES	Test Pressure Required: -15 "Hg
Technique Used: VAC BOX	Liquid Media Used: IMMERSIT CIM 200 @ 20% SOLN
Test Gas Used: VAC	Liquid Applicator Type: IMMERSION
Inspection Light Intensity: > 100 FC	Post Cleaning Method: RINSE / WIPE
Other Apparatus Used: FLASHLIGHT	

Direct Pressure Technique ☐ **Vacuum Pressure Technique** ☒

Component Limits of Test:

Component Test Site 7606 A	Component Installation Site –

Gauges				Test Pressure		Temperature	
Mfg	ID No	Calibration Date	Range	Beginning	End	Beginning	End
GAST	A002124	8/11/16	0-30 in Hg	-15 in Hg	-15 in Hg	20.3 °C	20.3 °C

Temperature Measuring Device

Mfg. OMEGA	Model HH804	Range K-TYPE	I.D. Number A001951

RESULTS ☒ ACCEPT ☐ REJECT POST CLEANING PERFORMED: ☒ Y ☐ N

Comments:

C1-0286, 288, 289, 290

Test Conducted By: (Print & Sign Name/Level): E. VIDAL Eric S Vidal LII	Date: 11/22/16

TEST FORM 2 – **Thermal Test Checklist**

Test Plan ORNL/NTRC-074 Rev. 0

Test Unit 1 – C10290

VERIFIED	TASK
✓	The test unit tray has been placed in the furnace.
✓	Two calibrated Type K thermocouples have been installed in the working area of the furnace and attached to the Fluke thermocouple reader. Fluke Equipment # B1332 Calibration Due: 9/27/2017
✓	The furnace doors has been closed and the furnace has been turned on with a set point of 850° C. Furnace Equipment # 18334 Calibration Due: No cal record
✓	Thermocouple readings have been made every 30 minutes for at least 3 hours.
✓	Any changes in the furnace set point during the three-hour preheat period have been recorded on TEST FORM 5.
✓	Just prior to test unit insertion, a final preheat temperature recording was made.
✓	The furnace door has been opened, the test unit inserted, the furnace door closed and the furnace activated with a set point of 850° C (1560° F) (or as adjusted during the preheat process).
✓	When both thermocouple readings have reached 800° C (1475° F), the 10-minute thermal test was started.
✓	Thermocouple readings were taken every 30 seconds for the duration of the 10-minute thermal test.
✓	Adjustments were made to the furnace set point as directed by the test director.
✓	When the 10-minute test period was finished, the furnace was turned off and furnace door was opened to the maximum extent possible.
✓	As soon as conditions permitted, the test unit was removed from the furnace and allowed to cool naturally.
✓	Any deformation or other unusual circumstances regarding the test or the test unit was recorded.

Comments: C1-0290 Furnace Hood IE 960
Set - 850°C TC's and Fluke are calibrated ✓
TC1-856°C TC2-861°C

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Checked by	Date
[signature]	1/25/17	Matthew R Feldman	8/18/2017

*All photographs will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

TEST FORM 3 – **Thermal Test Preheat Data Sheet**

Test Plan ORNL/NTRC-074 Rev. 0

Test Unit 1 - C1-0290

VERIFIED	TASK
✓	Record the temperature in the furnace every thirty (30) minutes for the duration of the preheat (at least 3 hours):

Time	Thermocouple 1 (°C)	Thermocouple 2 (°C)
11:00	859	863
11:30	856	861
12:00	856	861
12:30	856	861
1:00	856	861
1:30	856	861
2:00	856	861

Comments: Three hour pre heat above 850°C

Thermocouple 1 = BF3874

Thermocouple 2 = BF3F05

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Checked by	Date
[signature]	1/27/17	Matthew R Feldman	8/18/2017

*All photographs/movies will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

TEST FORM 4 – **Thermal Test Data Sheet**

Test Plan ORNL/NTRC-074 Rev. 0

Test Unit C1-0290

VERIFIED ✓

TASK

Record the temperature in the furnace every 30 seconds for the duration of the test:

Furnace @ 850°C

Time	Thermocouple 1 °C	Thermocouple 2 °C
0	830	849
30	851	855
100	851	863
130	850	861
200	849	861
230	849	861
300	849	861
330	849	861
400	849	860
430	850	861
500	850	860
530	851	860
600	852	860
630	852	860
700	853	860
730	853	861
800	854	860
830	854	860
900	854	860
930	855	861
1000	855	861

Comments: 1/26/2017 @ 2:34 pm (start)
To pillowed after test. TC1 = BF3874 TC2 = BF3F05

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Checked by	Date
[signature]	1/27/17	Matthew R Feldman	8/18/2017

*All photographs/movies will be uniquely identified with test unit, date and time to ensure that the proper sequence can be reconstructed

Report Number: 2/1/17 - 1

LEAK TEST REPORT

Test Requested by: J. GARRISON	Allowable Leak Rate: < 1.0 E-4 Std-Atm-cc/s
Work Order Number:	Test Pressure Req. Across Boundary: 1 ATM
Item Tested: 1 EA. TRIANGLE C1-0290	Customer: NSLT
Technique Used: BOMB/BELL JAR ☒ Inside - Out ☐ Outside - In	Procedure/Rev: NDE 70 R.6

EQUIPMENT

LEAK DETECTOR

Make and Model: ADIXEN ASM 340	
Serial Number: HLD 1601393	

TEST GAUGES

Temp Gauges: A001952	Due: 6/22/17
Pressure Gauges: MTE 549	Due: -

STANDARD LEAK

Manufacturer: VTI	Tracer Gas: He
Model: VSLT-5-3C-He	Serial Number: TP860
Leak Rate: 4.82 E-6 Atm-cc/s @ -1 atm @ 22.1 °C	
Correlation Formula: $[1 - (T_{cal} - T_{surf})\ C_T]\ LR$	Temp Coefficient: 3.0 %/°C
Correlated LR: 4.08 E-6 Atm-cc/s @ -1 atm @ 17.0 °C	
Calibration Due Date: 9/9/16	

RESULTS ☒ Quantitative ☐ Semi - Quantitative

MACHINE CALIBRATION

System Pressure: 1.0 E-2 mb	
Background: 1.2 E-9 Atm-cc/s	
Leak Response: 4.2 E-6 Atm-cc/s	
Minimum Detectable Leak: 1.0 E-7 Atm-cc/s	
System Sensitivity: 2.0 E-7 Atm-cc/s	
Response Time: ~5 s	

SYSTEM TEST CONDITIONS

System Temperature: 17 °C ☒ Surface ☐ Internal Gas	
delta P Test Boundary: -1 ATM	
Tracer Gas: He	% Concentration: CALC
System Response Time: 90 s	
System Response: 7.6 E-7 Atm-cc/s	
Duration of Test: 90 s	

Aux. Equipment:

☒ ACCEPT ☐ REJECT ☒ SKETCH / DATA ATTACHED

System Leak Rate: w/ stated tracer gas < 1.0E-4 Atm cc/s @ -1 atm @ 17 °C

COMMENTS:

FINE LT

POST HEAT TEST

Test Conducted By: (Print & Sign Name/Level):	Date:	Time:
E-VIDAL Enrique Vidal LTII	2/1/17	1:40

BOMBING TEST REPORT (*Supplement*)

Leak Test Report Number: 2/1/17-1	*Allowable Leak Rate:* < 1.0 E-4

Item(s) Tested: 1 EA. TRIANGLE C1-0290

TRACER GAS BOMBING AND LEAK TEST

Bombing Pressure (psig): 30	*Tracer Gas:* He	*Bombing Time:* 30 MIN
Waiting Time (Sec): < 3600 s	*Internal Volume (cc):* * 1.057 (PRE-HT)	
Measured Leak Rate: 7.6 E-7 *Atm cc/s*	*Calculated Leak Rate:* < 1.0 E-4 *Atm cc/s into vac. @* 17 °C	

Test Results: ☒ *ACCEPT* ☐ *REJECT* ☒ *CALCULATIONS / DATA ATTACHED*

COMMENTS:

* ESTIMATED 2.2 cc USED FOR CALC

Test Conducted By: (Print & Sign Name/Level): E. VIOAL LII	*Date:* 2/1/17

Report Number: 2/1/17-2

LEAK TEST REPORT - BUBBLE TEST

Test Requested by: J. GARRISON	Customer: NGIT
Work Order Number:	Procedure: NDE 70 RG
Item Tested: 1 EA TRIANGLE C1-0290	Test Pressure Required: 15" Hg
Technique Used: VAC BOX	Liquid Media Used: IMMERSIT CIM 200 @ 20%
Test Gas Used: VAC	Liquid Applicator Type: IMMERSION
Inspection Light Intensity: >100 FC	Post Cleaning Method: DI RINSE
Other Apparatus Used: FLASHLIGHT	

Direct Pressure Technique ☐ **Vacuum Pressure Technique** ☒

Component Limits of Test:

Component Test Site 7606 A	Component Installation Site —

Gauges				Test Pressure		Temperature	
Mfg	ID No	Calibration Date	Range	Beginning	End	Beginning	End
	A002124	8/11/16	0-30" Hg	15" Hg	15" Hg	17°C	17°C

Temperature Measuring Device

Mfg. OMEGA	Model HH804	Range K-TYPE	I.D. Number A001952

RESULTS ☒ ACCEPT ☐ REJECT POST CLENING PERFORMED: ☒ Y ☐ N

Comments:
POST HEAT TEST

Test Conducted By: (Print & Sign Name/Level): E. VIDAL [signature] LII	Date: 2/1/17

APPENDIX C. WELD INSPECTION REPORT

WELD INSPECTION REPORT

DRAWING TITLE: Triangle Encasement Components (SI Units Version)	DATE: 12/6/2016
	REPORT NUMBER:
SYSTEM: C1-0288, C1-0289, C1-0290	DRAWING NUMBER: SK-NMP-20160616-01
	WORK ORDER NUMBER:
WELD NUMBER: W-1	SHOP: REDC 7930
INSP. SPEC.: FHRD-T-NDE 21 Rev 2	
WELD SPEC.: GT88-A (PP), *GT88-1 (PP)	WELD PROCESS: GTAW
JOINT TYPE: ☐ FILLET ☒ SINGLE WELDED ☐ DOUBLE WELDED	

BASE MATERIAL(S)

TYPE	304/304L SS	304/304L SS	
IR NO.	N/A	N/A	
HEAT NO.	177228	843690	
MFG.	Ta Chen International	ATI	
FORM	.500" Plate ASTM A240-2015	.0600" Plate ASTM A240-13C	
PART	1	2	
PIECE	Triangle Encasement Base	Triangle Encasement Top	
SIZE	See Drawing	See Drawing	

FILLER MATERIAL(S)

TYPE	308L	
IR NO.	N/A	
HEAT NO.	DACU	
MFG.	Techalloy	
SIZE	.045"	

JOINT PREPARATION: Accept	CLEANER: ☒ ACETONE ☒ ALCOHOL
FIXTURE: Copper Fixture	
WELDER: B Leffew	WELDER:
CRAFTSMAN: Jay Kehn	CRAFTSMAN:

INERT GAS

COVER	BACKUP
☒ ARGON CFH 25	☒ ARGON CFH glovebox
☐ HELIUM CFH	☐ HELIUM CFH
☐ MIXED CFH	

FIT UP: Accept	WORK CONDITION: Accept

INSP. \ STAGE	ROOT PASS	SECOND LAYER	INTERM.	FINAL
VISUAL	/	/	/	SAT
PENETRANT	/	/	/	/
RADIOGRAPH	/	/	/	/

PREHEAT TREATMENT	POSTHEAT TREATMENT
N/A	N/A

BATCH NO.	SKL-SP1	SKC-S	SKD-S2
	/	/	/

ULTRASONIC: /

MACHINE WELDING VARIABLES	VOLTS	AMPS	INTERPASS TEMP.
	7-17	5-50	N/A

REPAIRS

REMARKS

*Weld filler metal used only if necessary.

INSPECTOR'S SIGNATURE	DATE	FINAL ACCEPTANCE	DATE
	12/6/2016		

APPENDIX D. LEAK TESTER CERTIFICATION

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

NDT Personnel Qualification and Record of Certification

Name: Eric Vidal | Badge No: 712805 | Certification Date: 10/12/2015

Division: IOSD | Job Function: Full Time NDT Tech | Expiration Date: 10/12/2018

NDT Method: LT | NDT Level: II | Endorsement(s): BT

Restrictions: None

Meets Current Vision Requirements (as of Certification Date): Jul 15, 2015 ☐ Corrected ☒ Un - Corrected

Educational Background

☐ High School / G.E.D. ☒ 2 Yr. Technical Degree or More Last School Attended:

NDT Training Satisfactorily Completed

Company or Institution	Subject(s)	Hours
ORNL	Bubble Test	6

NDT Experience

Company or Institution	Job Description	From (Date)	To (Date)	Method	Level	Hours
ORNL	Full Time NDE	Apr, 13, 2015	Present	LT	II	38

Examination Results

INITIAL EXAM	Date	No. Questions	Pass / Fail	Administered by
General Knowledge	Oct.12, 2015	40	P	J. M. Pryor, ASNT Level III
Procedure Specific	Oct. 7, 2015	30	P	J. M. Pryor, ASNT Level III
Hands-On-Practical	Oct. 7, 2015	20	P	J. M. Pryor, ASNT Level III
Composite Score:	92			

REQUALIFICATION EXAM	Date	No. Questions	Pass / Fail	Administered by

I have reviewed the above information and believe it true and accurate to the best of my knowledge. I hereby certify this employee meets the requirements of NDT technician as stated in accordance with ORNL written practice FHRD-ACP-11 *Qualification / Certification Requirements for NDE Examiners* and Recommended Practice No. ASNT SNT-TC-1A.

Certified By: _____ Date: Oct. 12, 2015

J. M. Pryor, ASNT Level III
Certificate # 126138
ORNL Certifying Authority

Authorized By: _____ Date: Oct. 12, 2015

S. D. Mobley
ORNL Welding Program Manager

Note: This certification is void on the indicated Expiration Date, upon termination of current employment, or revocation by employer, whichever comes first. Certification examinations and full training records are on file at ORNL building 7003; viewable upon request.

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

NDT Personnel Qualification and Record of Certification

Name: Eric Vidal | Badge No: 712805 | Certification Date: 7/9/2015

Division: IOSD | Job Function: Full Time NDT Tech | Expiration Date: 7/8/2018

NDT Method: LT | NDT Level: II | Endorsement(s): MS

Restrictions: None

Meets Current Vision Requirements (as of Certification Date): 7/13/2015 ☐ Corrected ☒ Un - Corrected

Educational Background

☐ High School / G.E.D. ☒ 2 Yr. Technical Degree or More Last School Attended: Pellissippi State Technical University

NDT Training Satisfactorily Completed

Company or Institution	Subject(s)	Hours
Leak Testing Specialists	Mass Spec	40

NDT Experience

Company or Institution	Job Description	From (Date)	To (Date)	Method	Level	Hours
Babcock & Wilcox	Full Time Insp.	May 10, 2010	May 2014	LT MS	II	>700
ORNL	Full Time Insp.	April 13, 2015	Present	LT MS	II	N/A

Examination Results

INITIAL EXAM	Date	No. Questions	Pass / Fail	Administered by
General Knowledge				
Procedure Specific				
Hands-On-Practical				

Composite Score:

REQUALIFICATION EXAM	Date	No. Questions	Pass / Fail	Administered by
	7/9/2015	30	Pass	Jeff Pryor, ASNT Level III Cert. #126138

I have reviewed the above information and believe it true and accurate to the best of my knowledge. I hereby certify this employee meets the requirements of NDT technician as stated in accordance with ORNL written practice FHRD-ACP-11 *Qualification / Certification Requirements for NDE Examiners* and Recommended Practice No. ASNT SNT-TC-1A.

Certified By: _____ Date: 7/9/2015

J. M. Pryor, ASNT Level III
Certificate # 126138
ORNL Certifying Authority

Authorized By: _____ Date: 7/9/2015

S. D. Mobley
ORNL Welding Program Manager

Note: This certification is void on the indicated Expiration Date, upon termination of current employment, or revocation by employer, whichever comes first. Certification examinations and full training records are on file at ORNL building 7003; viewable upon request.

The American Society for Nondestructive Testing, Inc.

Be it known that

Jeff M Pryor

has met the established and published Requirements for Certification by ASNT as

NDT Level III

in the following Nondestructive Testing Methods:

Method	Issue Date	Expiration Date
Leak Testing	6/15	6/20
Liquid Penetrant Testing	6/15	6/20
Magnetic Particle Testing	6/15	6/20
Radiographic Testing	6/15	6/20
Ultrasonic Testing	6/15	6/20
Visual Testing	6/15	6/20

126138

Certificate Number

ASNT President

Certification Management Council Chair

APPENDIX E. LEAK TESTING PROCEDURE

ORNL Leak Test Procedure not available for public release.
Procedure number is NDE-70 R.6

APPENDIX F. CALIBRATION RECORDS

OAK RIDGE NATIONAL LABORATORY

METROLOGY DEPARTMENT

TEST REPORT

ITEM: 39.38" LENGTH STANDARD Serial Number: A001146

CUSTODIAN: M. FELDMAN

	AS FOUND	REQUIREMENT	INSPECTION METHOD
LENGTH	39.4000/39.4099	39.38	CMM

Temperature: 68 ° F

Date 11/03/11

Inspector '024294

Reviewed by Brad K. Synnes 28642 11/3/11

Date Due 11/03/16

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY TRACEABILITY
ESTABLISHED THROUGH ORNL PRIMARY STANDARDS

Standards used:

ID#	Calibration Due Date
M212632	5/19/14

ISO 9001:2008 (10101/2)

Certificate of Calibration

Everett Service Center

Certificate Number:	291652		
Data Type:	Found-Left	**Calibration Date:**	07-Nov-2016
Result Summary:	In Tolerance	**Calibration Due:**	07-Nov-2017
Manufacturer:	Fluke	**Certificate Date:**	07-Nov-2016
Model:	52 II	**Temperature:**	24.2 °C
Serial Number:	36370410WS	**Humidity:**	35.9 %
Description:	Thermometer		
Procedure:	Fluke 52-II:(1 YEAR) ZCAL VER /5520	**Revision:**	1.2
Customer:	MCMASTER-CARR SUPPLY COMPANY		
City:	DOUGLASVILLE	**Country:**	US
State:	GA		
Purchase Order:	COC	**RMA:**	31143929

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced other than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 118 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 9/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

Cert # : 291652
Date: 07-Nov-2016
Due: 07-Nov-2017
www.fluke.com

JACOB MILLER
Issued By

FLUKE.

Certificate Number: 291652 **Date of Calibration:** 07-Nov-2016

Standards Used

Asset	Description	Cal-Date	Cal-Due
B1322	Fluke 5520A Calibrator	27-Sep-2016	27-Sep-2017

Job# 3054371

Date: 1/24/17

Technical Support Department

Instrument Data Continuation Sheet

Tech: 30220

Std: A001277

M210101

A002021

Furnace	Standard	UUT Reading			
	Type S	BF3874	Error	BF3F05	Error
21.5	**21.5**	20.9	-0.6	21.1	-0.4
750.0	**754.1**	755.0	0.9	754	-0.1
800.0	**803.5**	804.5	1.0	803.6	0.1
850.0	**854.0**	855.0	1.0	854.4	0.4
900.0	**904.3**	905.4	1.1	905.1	0.8
950.0	**955.4**	956.9	1.5	956.3	0.9

UT-BATTELLE
Management Contractor for DOE's
Oak Ridge National Laboratory

Calibration Results

Oak Ridge National Laboratory

ORNL Metrology Laboratory
Bethel Valley Rd. Bldg. 5510A
Oak Ridge, TN 37831-6366

Unit Under Test Information	Customer Information	Test Information
Manufacturer: Oak Ridge National Laboratory	Anthony D Mcbee	Certificate Number: **2016002594**
Description: Type S Thermocouple Dual Junction	Building: 2547	Overall Result: Pass
Model Number: N/A	Room: 002	Performed on: 1/18/2017
Serial Number: N/A	Mail Stop: 6300	Next Cal Due: 1/18/2018
Asset / ID Number: A001277	865-574-6293	Performed by: Greg Strickland
Custodian: Anthony D Mcbee		Environment: 23.4°C 46.8%Rh
Work Order Number: 2016002594		Received: In Tolerance

Notes:

Asset No.

Work Order No.

ORNL Metrology Laboratory (ORNL ML) certifies that the above listed instrument meets or exceeds all specifications as stated in the referenced procedure unless otherwise noted. This Report of Calibration applies only to the item being calibrated, identified above.

This calibration report documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI). Calibration data and conformity assessment (Pass/Fail decision) is limited to the performance of the instrument at the time of test. The "Next Cal Due" date is based on manufacturer's recommendations or best calibration practices and with customer agreement (in the case of external ORNL customers); the instrument should not be used past this date without recalibration. This report shall not be reproduced, except in full, unless written permission for an approved abstract is obtained from ORNL ML. Any report containing accredited data shall not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government. Calibration reports without authorizing signature(s) are not valid.

For accredited data, measurement uncertainties at the time of test, expressed in base units, are given on the following pages, where applicable. They are calculated in accordance with the methods described in EA-4/02, NIST TN1297, DKD-3, or other applicable documents that comply with the Guide to the Uncertainty in Measurement (GUM), using a coverage factor of k=2, corresponding to a confidence level of approximately 95%. Unless otherwise indicated, any conformity determination in this report is based on a Test Uncertainty Ratio (TUR) of 4:1 or greater. Any TUR less than 4:1 will be identified in the test data. It is the responsibility of the instrument custodian, with the assistance of his/her Quality Representative, to determine whether this level of confidence for the determination of conformance is adequate for the intended use of this instrument.

This calibration was performed using measurement standards traceable to the appropriate standard(s), maintained by the National Institute of Standards and Technology (NIST), to accepted intrinsic standards of measurement, or is derived by ratio type self-calibration techniques. The calibration system used to derive accredited data complies with the requirements of NIST Handbook 150, ANSI/NCSL Z540.1-1999 (R2002), ISO/IEC 17025.

Standards Used

ID	Description	Service Date	Due Date
0078611	Isotech MicroK-100 Thermometry Bridge	6/2/2016	6/2/2017
0078621	Isotech ITL-M-17673 Silver Freeze Point Cell	9/4/2009	9/4/2017
A001412	Rosemount 162CE SPRT	11/15/2016	2/15/2017

FOUND_LEFT

Procedure used: Manual Data File Reader, Rev. 1.0

Test Data

UUT Range / Comment	Standard Reading	Standard Modifier	UUT Reading	UUT Tolerance	UUT Error	% Tol	Measurement Uncertainty	Accred	Test Status

INITIAL INSPECTION
No Calibration Seals found on the UUT.
Instrument was received in good, functional condition.
Procedure used: Manual Data
UUT Specification is based on (Type S Special Grade +/- 0.6 Deg C or 0.1 % WIG Plus Indicator Specification of +/- 0.6 Deg C)

Standard Temperature (Deg C)	UUT Temperature (Deg C)	UUT Error (Deg C)	UUT Specification (Deg C)	% TOL	Measurement Uncertainty (Deg C)	Result
A001277-A						
231.97	231.7	-0.3	1.20	27	3.1E-01	*Pass
418.97	419.0	0.0	1.20	1	3.1E-01	*Pass
594.01	593.2	-0.8	1.26	67	1.0E+00	*Pass
961.78	961.2	-0.5	1.56	35	1.0E+00	*Pass
A001277-B						
231.99	231.7	-0.3	1.20	25	3.1E-01	*Pass
419.05	419.1	0.0	1.20	2	3.1E-01	*Pass
594.01	593.1	-0.9	1.26	73	1.0E+00	*Pass
961.78	961.3	-0.5	1.56	33	1.0E+00	*Pass

* Test Uncertainty Ratio < 4:1
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-- End of measurement results--

Approved By: Greg Strickland 1/18/2017
Technical Manager
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