Exhibit AS-2 (BCC hearing)

June 14, 2024 CSA Group test report on AES deflagration panels

Laboratory Test Data - Internal Deflagration Test Report

ORIGINAL TEST DATA

The results relate only to the items tested. This report shall not be reproduced, except in full, without the approval of CSA Group Testing & Certification Inc.

Master Contract:	6023038	Model:	AES Spec CEN-E5S Enclosure	
Project / Network:	80202693	Description:	Container BESS	

Customer:	AES Clean Energy
Customer Address:	282 Century Place, Louisville, CO 80027
Attention:	Mike Simpson
Subject:	80202693 – Deflagration Custom Testing

Tested By:	**Witnessed By:**
Andrew Laib, Engineering Technician	Sara Bowen, Product Safety Engineer
Name, Title	*Name, Title*
SAFE Laboratories and Engineering Corp.	CSA Group – Cleveland
Testing Lab Name	*CSA Group Laboratory*
5901 Elwin Buchanan Drive Sanford, NC 27330	8801 East Pleasant Valley Road Independence, OH 44131
Testing Lab Address	*CSA Group Laboratory Address*
Signature on File — 2024-06-14	Sara Bowen — 2024-08-29
Signature — *Date (YYYY-MM-DD)*	*Signature* — *Date (YYYY-MM-DD)*

Report Prepared By:

Jacob Shaw, Product Safety Engineer II

Name, Title

Jacob Shaw — 2024-08-29

Signature — *Date (YYYY-MM-DD)*

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Executive Summary

The purpose of this Custom Testing service was to verify the operation of the Vigilex ARC-VENT INS-60 610x914 deflagration relief panels when installed in the AES Spec CEN-E5S battery energy storage system enclosure. The panels were selected and designed based on *NFPA 68, Standard for Explosion* Protection by AES for this application.

A synthetic blend of gases was developed to simulate the gases produced by thermal runaway of the 145 Amp-Hour Samsung CP1495L101+ lithium ion ($LiNiCoAlO_2$) prismatic cells. The energy storage container was filled with inert volumes to simulate the presence of the energy storage equipment without risk of uncontrolled fire development. The synthetic gas blend was mixed with air at a stoichiometric ratio (Air/Fuel = 3.29) inside of thin-walled gas containment vessels inside the ESS container. Fixed total volumes of gas/air were injected into the gas vessel to simulate potential ignitable volumes from thermal runaway of live cells. Two tests were conducted with gas/air volumes of 450 L and 750 L.

The controlled volumes were then ignited to determine the developing overpressures inside the container and verify operation of the deflagration panels to release the pressure without compromising the structure of the ESS container or releasing gas, flame, or debris in potentially occupied areas surrounding the container. The ignition of the 450 L volume produced container pressures up to 0.68 psi but did not activate the deflagration panels. Flaming was observed inside the container by camera and a small amount of visible smoke escaped around the top of the container. Explosion modeling conducted separately for AES indicated that a stoichiometric gas cloud of 450 Liters in a fully populated battery rack container would achieve an NFPA 68 design P_{red} in the container and would activate the deflagration panels. This did not occur in the test because of deviations in the simulated container fill volume, differences in the gas/air reaction properties in the synthetic gas and model, or from other unknown factors.

The test was then repeated with a larger gas air volume of 750 L. Ignition of the 750 L volume resulted in maximum pressures of 3.13 psi and release of all three deflagration panels on the top of the container and ejection of a visible flame. This test also resulted in minor damage to the internal barrier wall of the container. No other damages to container or the inert fill materials were observed.

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Internal Deflagration Test Summary	
CSA Group project 80202693 is a deflagration test, performed for AES Clean Energy. This custom test project was performed on 2024-06-07 at SAFE Laboratories and Engineering Corp. (Safe-Labs), an ISO 17025 accredited laboratory.	
Manufacturer:	CEN Solutions
Brand name / Trademark:	N/A
Model number:	AES Spec CEN-E5S Enclosure
Exterior Dimensions (m)	12.19 x 2.44 x 2.90
Internal Test Volume (m^3)	43.04
Filled Volume (m^3)	25.47
Approximate Filled Volume (%)	59.2

Synthetic Gas Blend Properties – 4 Primary Components of Cell Vent Gas

Gas	Measured %
Hydrogen	32.7 %
Carbon monoxide	40.9 %
Methane	15.43 %
Ethylene	0.56 %
Ethane	1.06 %
Carbon dioxide	9.2 %
Propene (Propylene)	0.04 %
Propane	0.03 %
C4 Total	0.05 %
C5 Total	0.01 %
Benzene	0.06 %
Total	**100 %**

From 145 Amp-Hour Samsung CP1495L101+ lithium ion (LiNiCoAlO2) prismatic cells
UL9540A Cell Level Test Report 4790746849

Component Gas	UL9540A (%)	Target Synthetic Blend (%)	Actual Synthetic Blend (%)
Hydrogen (H_2)	32.7	33.1	33.0
Carbon Monoxide (CO)	40.9	41.3	39.1
Carbon Dioxide (CO_2)	9.2	9.6	9.3
Methane (CH_4)	15.43	15.9	18.1
Other	1.67	0.0	0.5

Test Data Summary	**Test 1 (450 L)**	**Test 2 (750 L)**
Start of testing, (YYYY-MM-DD, HH:MM:SS)	2024-06-06, 23:26:20	2024-06-07, 00:56:18

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Internal Deflagration Test Summary		
Synthetic Gas Volume, (L)	105	175
Bottled Air Volume, (L)	345	575
Maximum measured pressure, (psi)**	0.68	3.13
Location of maximum pressure	End Wall – Away from Ignition	Internal Barrier Wall – Below Ignition
Panel activation***	None	Yes – All three

Additional Information:

* UL 9540A cell level report 4790746849 indicates that one cell produces 423 L of vented gas. Under stoichiometric conditions, approximately 1391 L of air would be needed (AFR of 3.29) for each cell. Explosion modeling conducted for AES by an external vendor indicated that a stoichiometric mixture of 450 Liters would achieve the NFPA 68 design P_{red} for the container and activate the deflagration panels. This estimate was provided to CSA and not independently verified. Test 1 was designed to simulate the modeled scenario and Test 2 was conducted with increased volume as Test 1 did not activate the panels. Note that venting of a single cell could produce flammable mixture clouds of greater than the 750 L Test 2 mixture.

** Pressure data was measured at a rate of 1000Hz. Strain was measured on container surfaces, but data was corrupted.

*** Test 1 did not activate the deflagration panels but a small puff of smoke escaped the container through a door seal. Test 2 released all three panels, caused the internal barrier wall to collapse, and produced an external flame. No other damages to container or the inert fill materials were observed.

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Setup and Instrumentation

The following procedure was followed for this test:

1. Produce a synthetic gas blend to simulate the gases produced by the CP1495L101+ 145 Ah prismatic cell. Gas constituents were based on the four primary constituents of gases measured during UL 9540A cell level testing (Report 4790746849). Synthetic gas blend used for testing consisted of 33.0% hydrogen, 39.1% carbon monoxide, 9.3% carbon dioxide, 18.1% methane, and 0.5% balance of unknown gases.

2. Fill an empty enclosure with inert volume that occupies a similar volume to the functional ESS unit racks. The presence of objects greatly impacts the development of ignitable concentrations and the resulting deflagration pressure wave development.

3. Release controlled amounts of bottled air and then synthetic gas blend into thin-walled gas containment vessels (2 mil plastic sheeting sealed into rectangular bags with tape) in fixed locations inside the container at stoichiometric concentrations. After filling, the mixture was ignited by an electronic match inside the vessel.

4. Ignite the gas/air blend and observe the impact of the resulting deflagration on the structure of the container, the resulting pressure wave development, and the activation of the deflagration vent panels.

5. Conduct additional tests as necessary to determine an appropriate amount of gas release needed to activate the panels. The amount of gas released is represented in both total volume and with respect to the volume produced by thermal runaway of individual CP1495L101+ cells.

Figure 1: Photograph of the DUT enclosure

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The CEN-E5S enclosure has two compartments separated by a solid vertical barrier as shown in Figure 2. Each side has its own set of three deflagration vent panels near the center barrier on the rear side of the enclosure. Each panel was a Vigilex Vent panel (610 x 914 mm) with total area of 5545 cm² with a maximum P_{red} of 1.8 bar (26.1 psi).

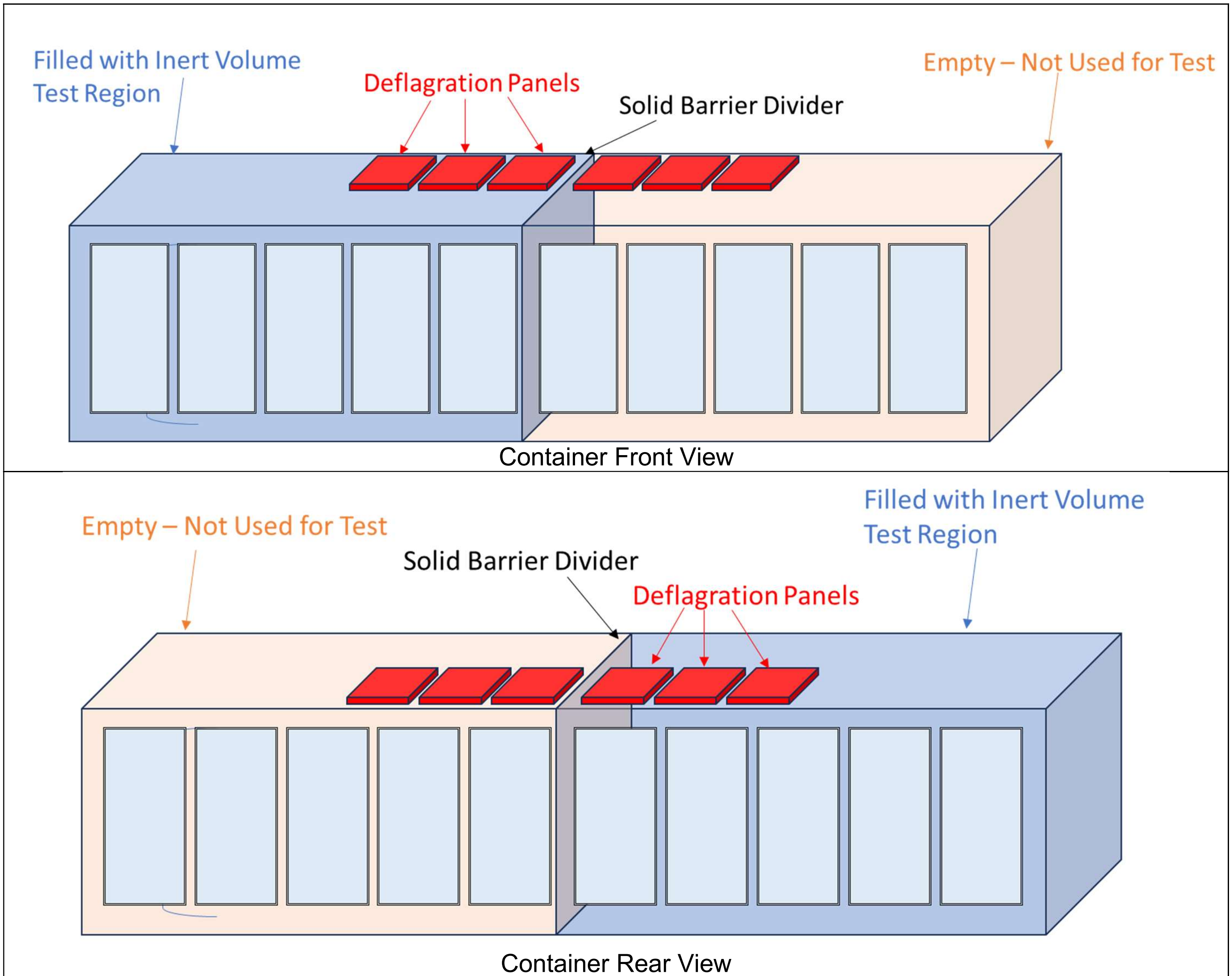

Figure 2: Separated enclosure with the test region (blue) as viewed from the front (top) and rear (bottom) of the enclosure

Flammable gases, inert volumes, and instrumentation were only included on one side of the enclosure. A combination of sandbags, pallets, plywood, and plastic totes were used to simulate filled volumes in an operational ESS installation as shown in Figures 3 and 4.

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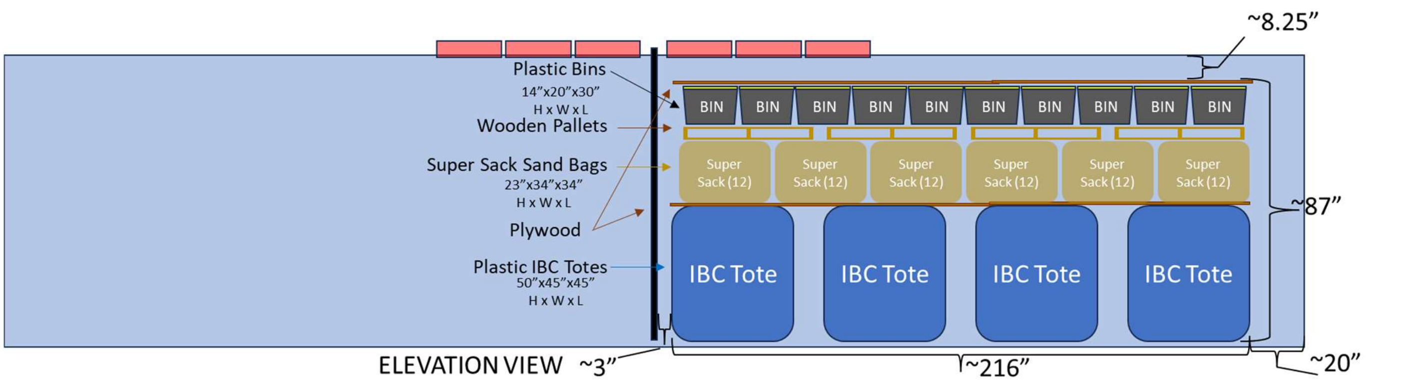

Figure 3: AES Deflagration Inert Mass Diagram – totes layout and heights

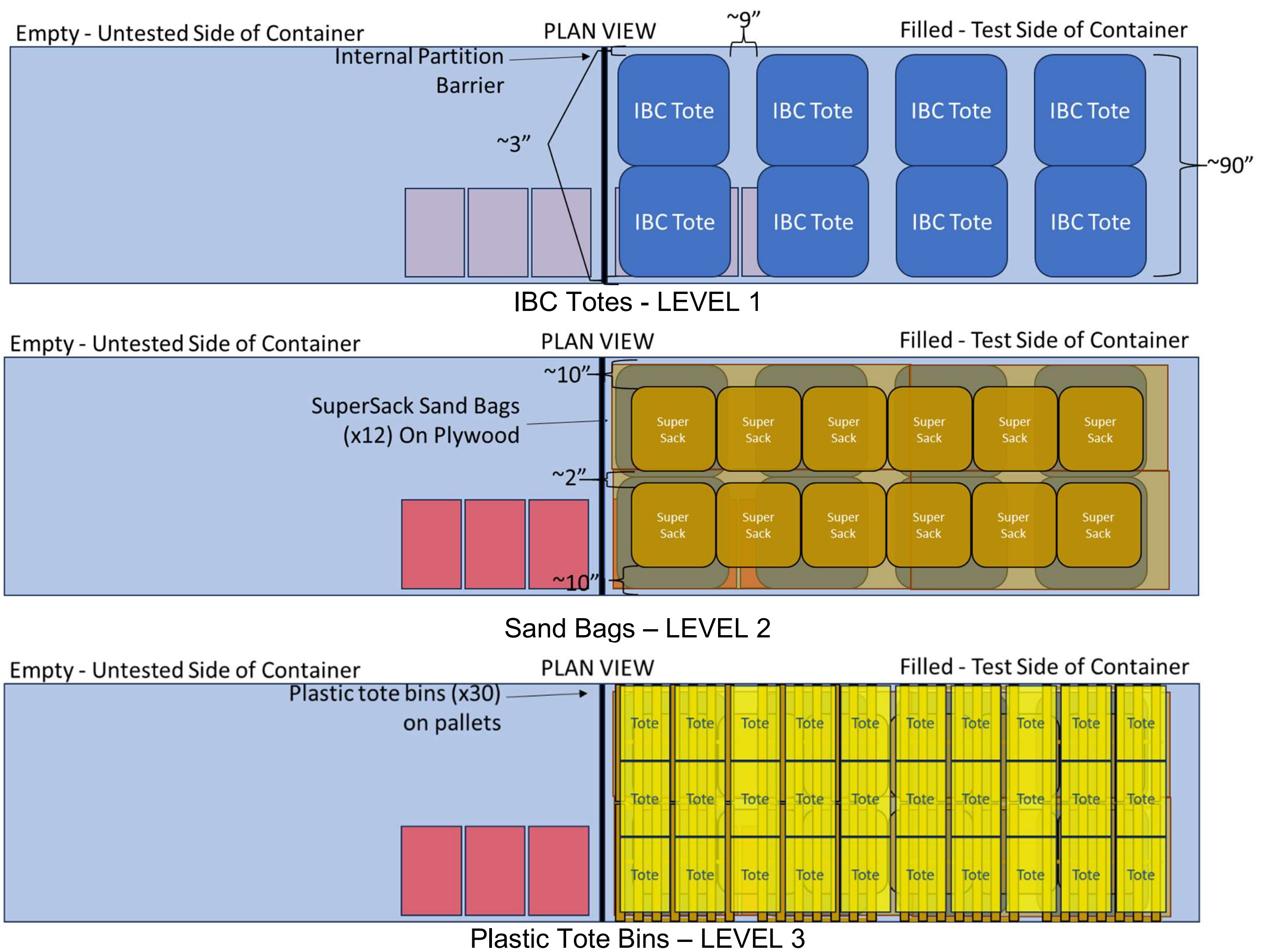

Figure 4: AES Deflagration Inert Mass Diagram – totes layout and super sack layout

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The testing was initiated using a synthetic blend of gases developed to simulate the gases produced by thermal runaway of the 145 Amp-Hour Samsung CP1495L101+ lithium ion ($LiNiCoAlO_2$) prismatic cells. Synthetic gas blend used for testing consisted of 33.0% hydrogen, 39.1% carbon monoxide, 9.3% carbon dioxide, 18.1% methane, and 0.5% balance of unknown gases. Thin-walled vessels of 2 mil plastic sheeting were filled first with bottled air and then the gas blend to the desired test volume. Electric match igniters were placed inside the bags and actuated after all air/gas had been filled. Figures 5 and 6 show the location of the gas containment vessels and igniters.

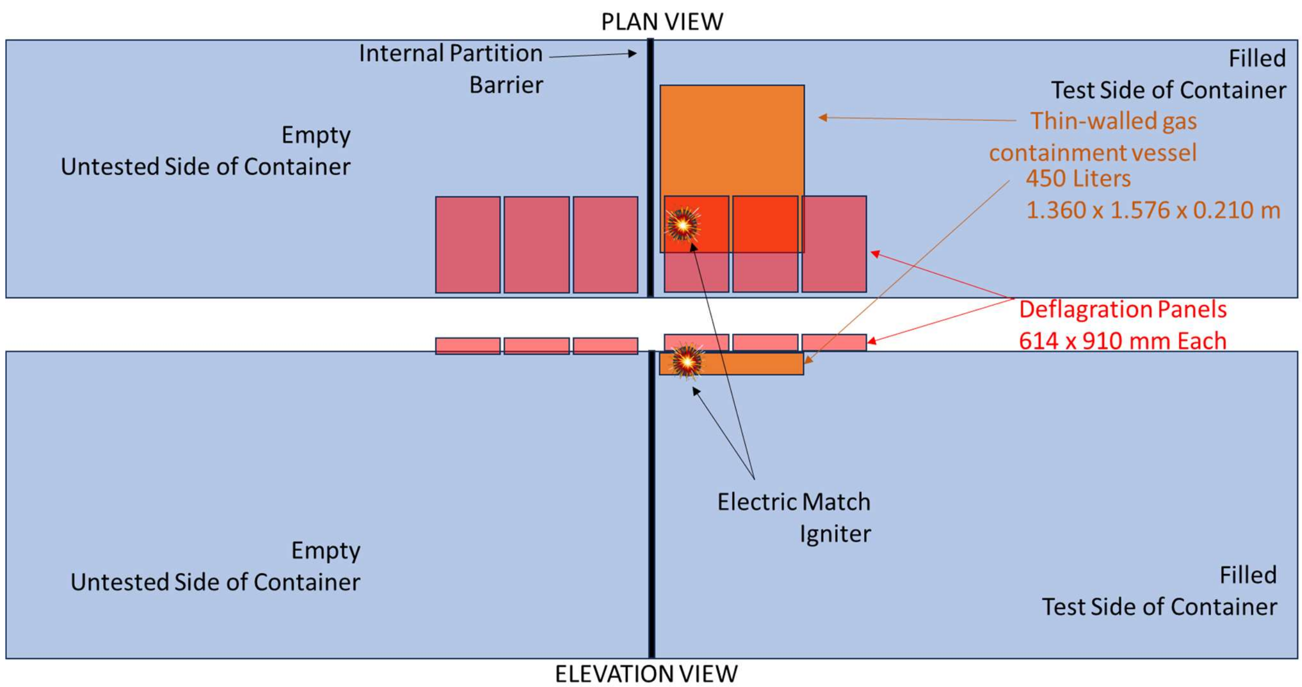

Figure 5: Thin-walled gas containment vessel position – Deflagration Test 1 (450 L)

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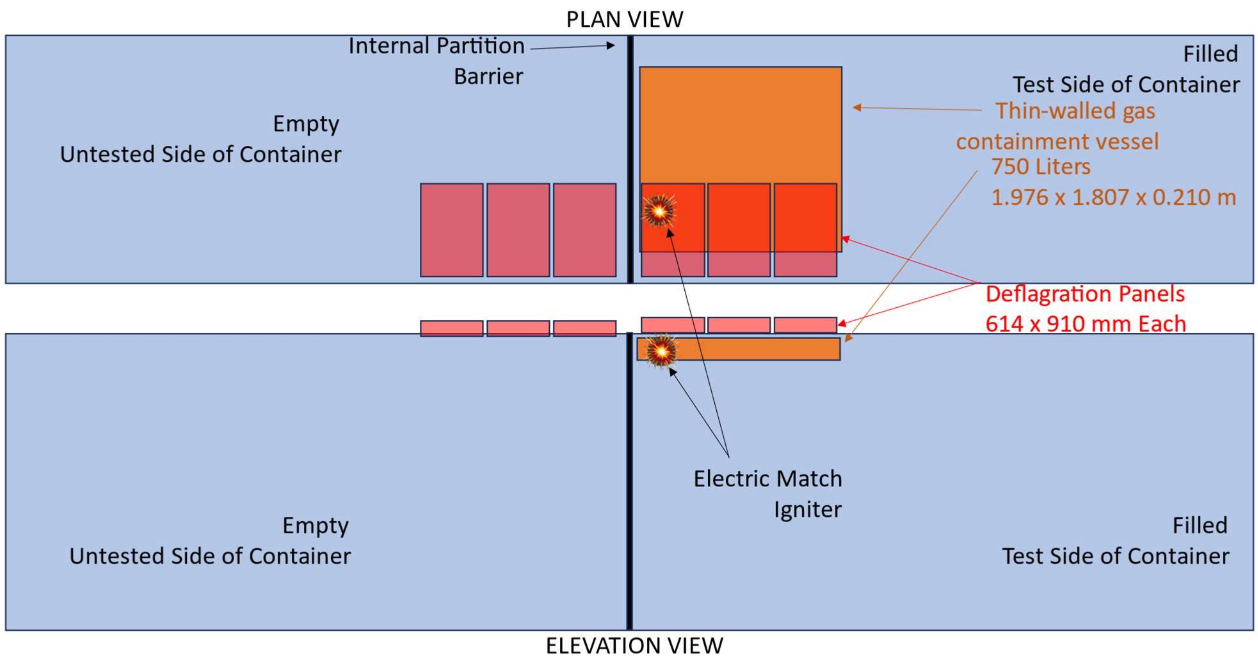
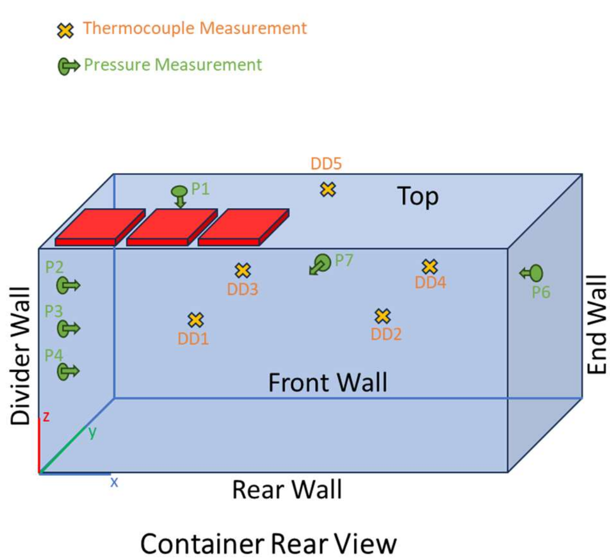


Figure 6: Thin-walled gas containment vessel position – Deflagration Test 2 (750 L)

A combination of pressure transducers, thermocouples, and strain gauges were placed around the enclosure to measure the effects of the gas deflagration as shown in Figure 7. The data obtained from the strain gauges placed on the various surfaces was corrupted during testing and the locations are not shown in the diagram.



ID	Surface	x (in)	y (in)	z (in)
P1	Top	36.00	66.00	101.50
P2	Divider	0.00	42.75	76.10
P3	Divider	0.00	42.75	50.75
P4	Divider	0.00	42.75	25.40
P6	End	240.00	42.75	76.10
P7	Front	120.00	85.50	76.10
DD1	Rear/Exterior	80.00	0.00	76.00
DD2	Rear/Exterior	160.00	0.00	76.00
DD3	Front/Interior	80.00	96.00	76.00
DD4	Front/Interior	160.00	96.00	76.00
DD5	Top/Interior	120.00	96.00	114.00

Figure 7: Instrumentation locations inside the half container

Test Observations

Observations from testing are shown below:

Elapsed Time (HH:MM:SS)	Local Time (HH:MM:SS)	Comment
Deflagration Test 1 (450 L)		
00:00:00	23:26:20	Start of air injection
00:07:14	23:33:42	Start of gas injection
00:11:14	23:37:42	Gas injection stopped
00:11:20	23:37:52	Ignition
00:11:20	23:37:52	Stress ripple observed in top of container; small amount of smoke appears to escape from the top of the doors
Deflagration Test 2 (750 L)		
00:00:00	00:56:18	Start of air injection
00:09:33	01:05:51	Start of gas injection
00:14:33	01:09:51	Gas injection stopped
00:16:31	01:11:09	Ignition
00:16:31	01:11:09	Release of all three deflagration panels / Visible Ejection of Flame

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Just Before Ignition – 450 L Test 1

Visible Distortion on Container Surface – 450 L Test 1

Light smoke escaping from top of door – 450 L Test 1

Figure 8: Container stress distortion and light smoke escaping from the door – Test 1

Figure 9: Flames ejected from deflagration panels as viewed from the rear of the container – Test 2

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Figure 10: Deflagration panels post-test 2

Post-Test Analysis

Post-test analysis consisted of inspecting the DUT for the extent of damage. The deflagration panels were only activated during the second test (750 L). The internal divider wall in the center of the container also collapsed during Test 2. The collapse of the wall would provide a volume for expansion of hot gases and reduction of overall measured test pressure in the container if the collapse occurred earlier than or faster than the activation of the deflagration panels. No other damages to container or the inert fill materials were observed.

Conclusions

Testing was performed at SAFE Laboratories and Engineering Corp. (Safe-Labs) on 2024-06-06 and 2024-06-07. All equipment was verified by CSA Group personnel to be in calibration and acceptable for testing.

The gases inside of the DUT were blended by Safe-Labs per the volume concentrations outlined in the provided UL 9540A report (4790746849). Synthetic gas and air were mixed into a thin-walled plastic vessel at an air to fuel ratio of 3.29 and ignited by electric match. The total volume of air/fuel was selected based on gas dispersion modeling provided to CSA by AES. Based on the release of 423 total liters of fuel from one

The deflagration panels were activated during the second test only with 750 Liters of air/fuel mixture ignited.

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Attachment 1 – Photos

General sample photos

Figure 1.1: Containers as received

Figure 1.2: Inside of container as received

Figure 1.3: Top of containers as received

Figure 1.4: Vent panel label (top of container)

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Attachment 1 – Photos

Photos during test in progress

Figure 1.5: DUT at start of test 1, container closest to camera (23:26:20) (Camera 1-1)

Figure 1.6: Inside of DUT at start of test 1 (23:26:20) (Camera 1-2)

Figure 1.7: DUT at time of ignition, note small puff of smoke from top of door (23:37:52) (Camera 1-1)

Figure 1.8: Inside of DUT at time of ignition (23:37:52) (Camera 1-2)

Figure 1.9: Inside of DUT immediately after ignition, flame still visible as light in back of DUT (23:37:53) (Camera 1-2)

Figure 1.10: Smoke cloud filling DUT after ignition (23:38:00) (Camera 1-2)

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Attachment 1 – Photos

Figure 1.11: Lingering smoke after ignition (23:39:00) (Camera 1-2)

Figure 1.2: Lingering smoke after ignition (23:40:00) (Camera 1-2)

Figure 1.13: DUT at start of test 2, container closest to camera (00:56:18) (Camera 1-1)

Figure 1.14: Inside of DUT at start of test 1 (23:26:20) (Camera 1-2)

Figure 1.15: Inside of DUT at start of gas injection (01:05:51) (Camera 1-2)

Figure 1.16: Inside of DUT at gas injection end (01:05:51) (Camera 1-2)

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Attachment 1 – Photos

Figure 1.17: Outside of DUT during ignition (01:11:09) (Camera 1-1)

Figure 1.18: Inside of DUT during ignition (01:11:09) (Camera 1-2)

Figure 1.19: Outside of DUT during ignition (01:11:09) (Camera 1-1)

Figure 1.20: Inside of DUT during ignition (01:11:09) (Camera 1-2)

Figure 1.21: Outside of DUT during ignition (01:11:09) (Camera 1-1)

Figure 1.22: Inside of DUT during ignition (01:11:09) (Camera 1-2)

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Attachment 1 – Photos	
	
Figure 1.23: Outside of DUT immediately after ignition (01:11:10) (Camera 1-1)	Figure 1.24: Inside of DUT immediately after ignition (01:11:10) (Camera 1-2)
	
Figure 1.25: Outside of DUT after ignition (01:11:30) (Camera 1-1)	Figure 1.26: Inside of DUT after ignition (01:11:30) (Camera 1-2)

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Attachment 1 – Photos

Photos after test

Figure 127: Inside of deflagration panel through roof after test 2 showing remains of gas containment vessel inside of DUT

Figure 1.28: Inside of DUT after test 2 showing collapsed divider wall

Figure 1.29: Gas containment vessel removed from DUT after test 2

Attachment 2 – Temperature graph during testing

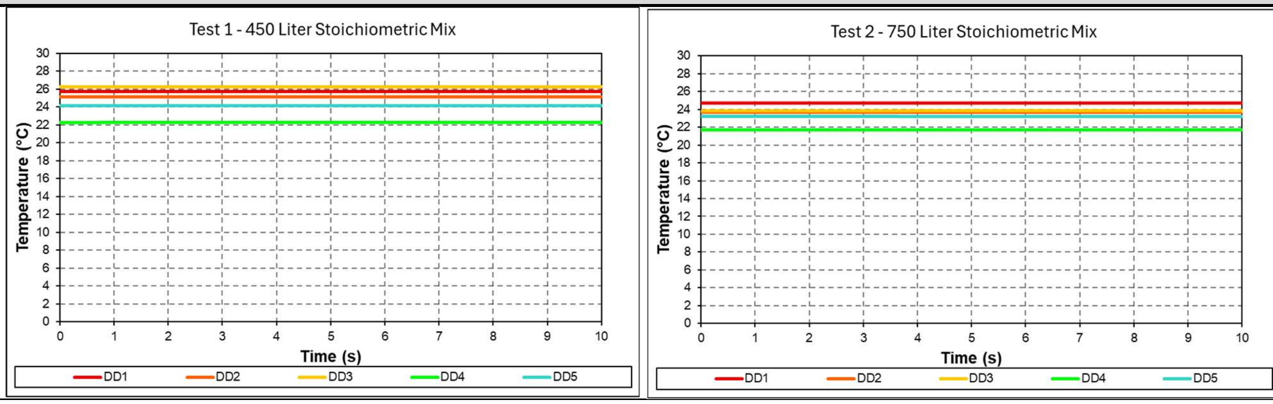

Figure 2.1: Container Temperatures during testing, no thermal response measured

Location	Measured Maximum Temperature (°C)	Location	Measured Maximum Temperature (°C)
450L Test			
DD1	25.79	DD4	22.32
DD2	25.18	DD5	24.24
DD3	26.32		
750L Test			
DD1	24.80	DD4	21.73
DD2	24.45	DD5	23.22
DD3	24.97		

Figure 2.2: Maximum temperatures measures on container surface

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Attachment 3 – Pressure Data

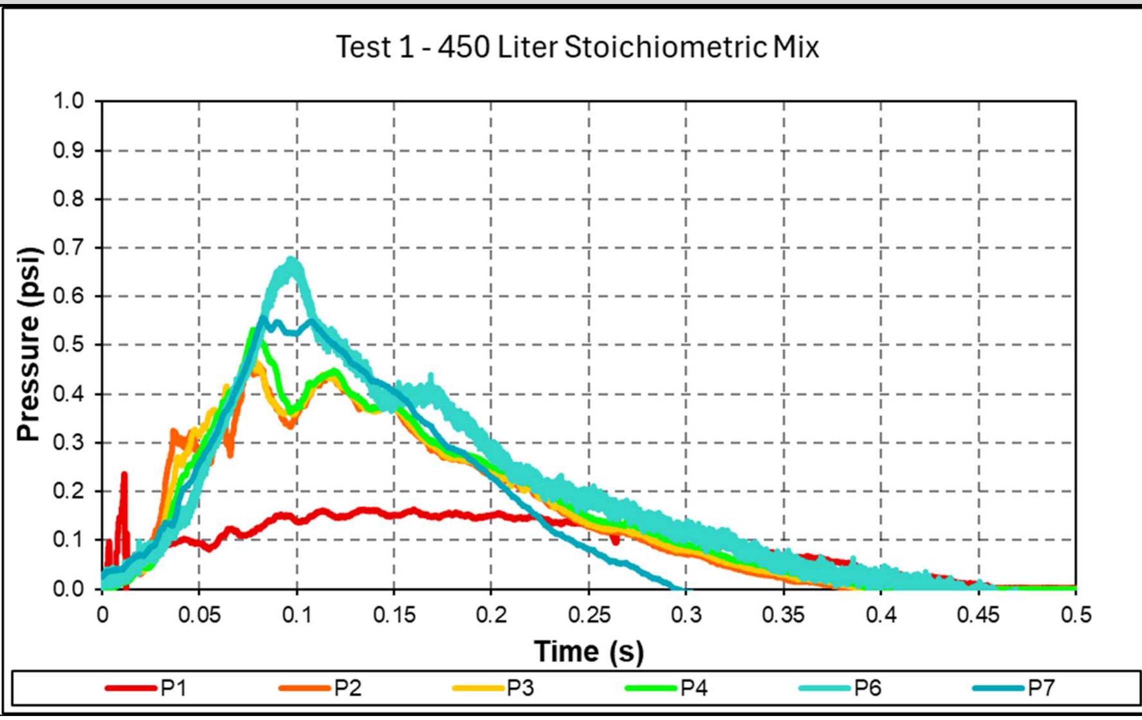

Figure 3.1: Pressures measured during 450L Test

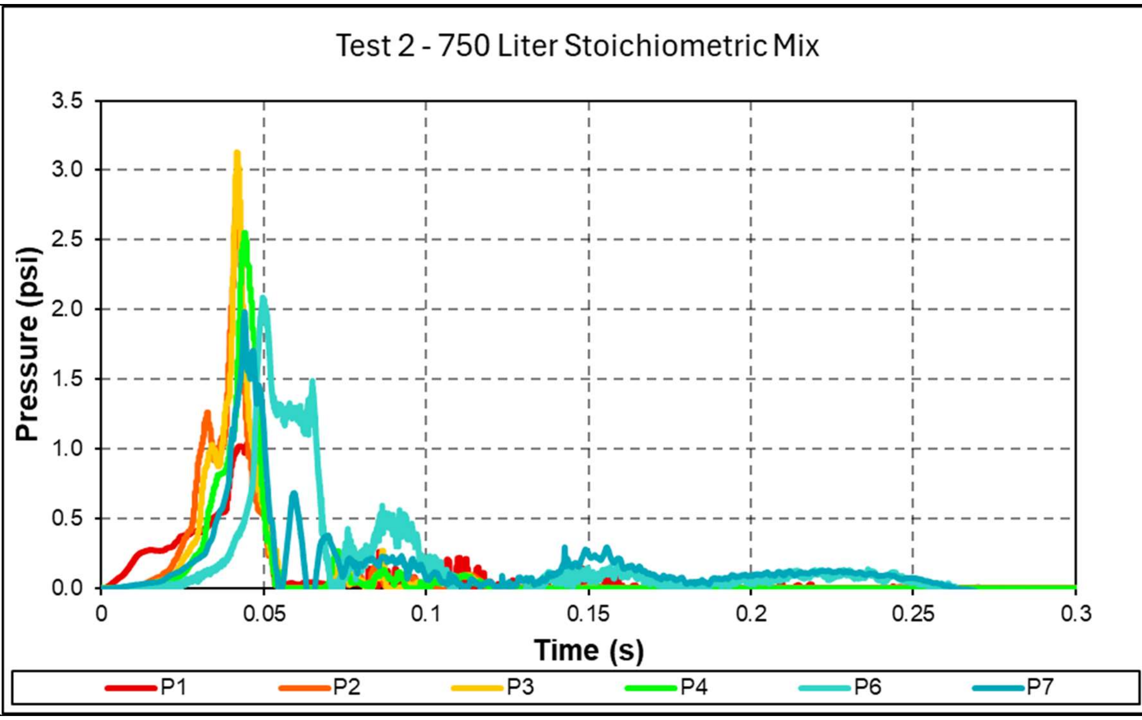

Figure 3.2: Pressures measured during 750L Test

Attachment 3 – Pressure Data

Location	Measured Maximum Pressure (psi)	Location	Measured Maximum Pressure (psi)
450L Test			
P1	0.24	P4	0.53
P2	0.50	P6	0.68
P3	0.49	P7	0.56
750L Test			
P1	1.07	P4	2.55
P2	2.75	P6	2.09
P3	3.13	P7	1.98

Figure 3.3: Maximum pressures measured in Test 1 and Test 2

End of Report…