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EDS V26 Vessel Clamp Explosive Test Report

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Abstract

This report documents the results of explosive re-qualification tests of the EDS V26 Vessel that were conducted at Sandia National Laboratories in Albuquerque, New Mexico in May 2015 following the retrofitting of the vessel with a three piece clamp for use on the P2A system. The V26 containment vessel is the second EDS vessel to be fabricated under Code Case 2564 of the ASME Boiler and Pressure Vessel Code, which provides rules for the design of impulsively loaded vessels. The explosive rating for the vessel, based on the code case, is nine (9) pounds TNT-equivalent for up to 637 detonations. The goals of the tests were to qualify the vessel, particularly the clamping system, for explosive use. The explosive tests consisted of a 9 pound bare charge of Composition C-4 (equivalent to 11.25 pounds TNT), followed by a 7.2 pound bare charge of Composition C-4 (equivalent to 9 pounds of TNT). Helium permeation measurements of the seal and strain measurements using a pi tape and strain gauges were made. *All vessel acceptance criteria were met.*

Contents

1 BACKGROUND

The Explosive Destruction System (EDS), which was developed at Sandia National Laboratories, is designed to destroy recovered chemical munitions. The apparatus treats chemical munitions through explosive access using shaped charges followed by chemical neutralization of the agents. The process is conducted inside a stainless steel vessel which both contains the detonation and serves as a chemical reactor. As part of the acceptance process, each vessel is subjected to a 25% explosive over-test. The qualification test for the V26 vessel was conducted at Sandia National Laboratories Site 9920 in Albuquerque New Mexico in July of 2013 and consisted of the detonation of an 11.25 pound TNT equivalent bare charge of explosive in the center of the vessel. This test was documented previously.[1] After the explosive qualification test, the vessel was retrofitted for use on the P2A system by replacing the existing two-piece door closure clamp with a three-piece clamp[Figure 1]. This report details the explosive requalification of the vessel with the new clamps.

The vessel was fabricated by Grayloc Products of Houston Texas, serial number JH3584001, part number H90063-119-4. It was designed and fabricated per Section VIII Division 3 and Code Case 2564-2 of the 2010 ASME Boiler and Pressure Vessel Code. Code Case 2564 prescribes criteria for the design of impulsively loaded vessels. The static pressure rating is 2800 psi. The explosive rating, based on the Code Case, is 9 pounds TNT equivalent for up to 637 detonations. This is the second EDS vessel to be designed per the Code Case. Earlier vessels were designed based on Sandia defined criteria that limited the pressure rating to 4.8 pounds TNT equivalent.

The vessel consists of a cylindrical cup, a flat cover (hinged as a door), and clamps to secure the door. The vessel is sealed with a Grayloc metal gasket. A fragment suppression system is used to protect the vessel from high-velocity fragments during the detonation. Basic dimensions are shown in Table 1. The materials of construction are listed in Table 2. The Manufacturer's Design Report [2] contains Certificates of Conformity, Assembly Drawings, Design Reports, Material Certification and Test Reports, and documentation of welding, inspection, and hydrostatic test for the original vessel. A second Manufacturer's Design Report [3] documents the details of the modified vessel. The revised serial number in the design book is JH3445301 and part number H91623-21. The stamp on the vessel lists assembly serial number is JH5188601. The modification was performed by BKG Machine and Fabrication, Inc., as contracted and supervised by Grayloc. The ASME R-stamp is labeled R-6416, 11-20-14. The modifications include:

- Changed the clamp from a two-piece to a three-piece design including mountings.
- Changed the bolting material from A286 to 17-4 PH stainless steel.
- Changed the nut (trunnion) material to 4140 steel.
- Added a steam port to the door.

Consistent with the Code requirements, the modified vessel was hydrostatically tested to 4200 psi and explosively tested with 11.25 pounds TNT equivalent. A similar three-piece clamp was tested extensively on the P2P system. However, because that vessel was rated for 4.8 pound TNT equivalent, it was explosively tested to only 6 pounds TNT equivalent.

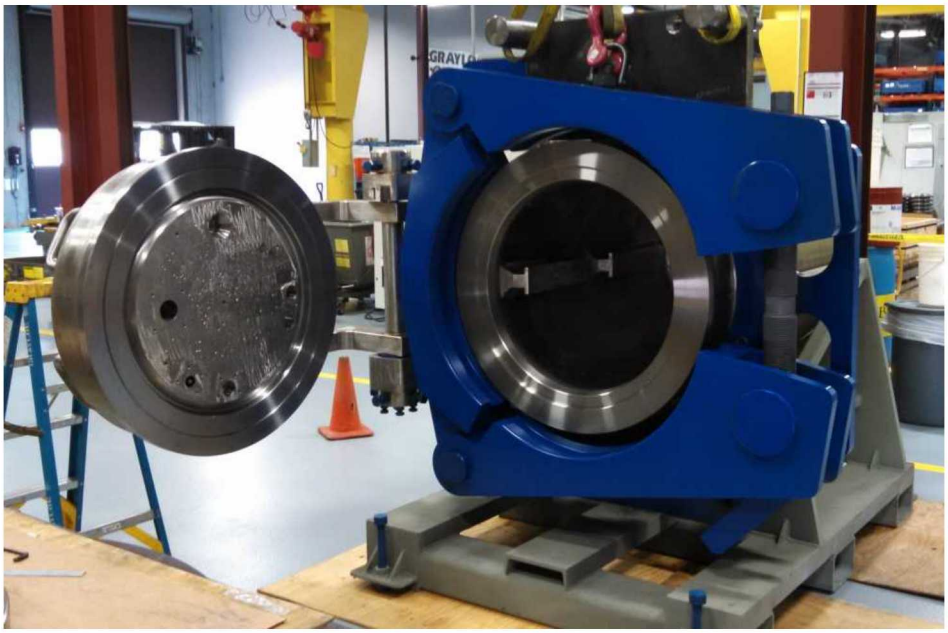

Figure 1: V26 Vessel with Three-Piece Clamp

Table 1 – EDS Vessel Dimensions

Overall length	71.89 inches
Inside length	56.58 inches
Outside diameter	36.53 inches
Inside diameter	29.22 inches
Door thickness	9.00 inches
Cylinder wall thickness	3.65 inches
Aft end thickness	6.30 inches

Table 2 – Materials of Construction

Part	Material	Specification
Body	316 SS	SA336-F316/SA965-F316
Door	316 SS	SA336-F316/SA965-F316
Clamps	4140	SA372 Grade J Class 70
Hinge Pins	4140	SA372 Grade J Class 70
Drive Screw	17-4 PH	SA564 Grade 630 Condition H1100
Trunnions	4140	SA372 Grade J Class 70
Gasket	17-4 PH	AISI 630
		From Grayloc Data Book CH29870-01, 16-Jul-12 and CH40641-DB, 9-Dec-14

A flange with four high-voltage electrical feedthroughs is bolted to the door and sealed with a small Grayloc gasket. These feedthroughs conduct the firing signals for the high-voltage exploding bridgewire (EBW) detonators. Small blast plates on the inside of the door protect fluidic components and electrical feedthroughs. A large blast plate provides additional protection.

The three hinged pieces of the closure clamps are secured with a threaded trunnion screw which is driven by pneumatic wrenches to a closure torque of 7000 ft-lbs. A Rad Tool Smart Socket® with an integrated torque gauge is used to achieve the specified torque.

2 TEST OBJECTIVES

The primary objective of the present tests was to re-qualify the vessel for its intended use by subjecting it to a 25 percent overtest following the retrofit to the three-piece clamp configuration. The vessel and door had been qualified previously with its original two piece clamp in 2013.[1] Testing of the V25 Vessel in 2011 established a precedent for testing V26[4]. As with V25, two tests were performed to satisfy this objective. The first test used 9 pounds of Composition C-4 (11.25 pounds TNT-equivalent), which is 125 percent of the design basis load. The second test used 7.2 pounds of Composition C-4 (9 pounds TNT-equivalent) which is 100 percent of the design basis load. The first test provided the required overtest while the second test served to demonstrate shakedown and the absence of additional plastic deformation. Unlike the previous V26 vessel qualification test, where it was mounted on the EDS P2U3 trailer, the vessel was mounted in a shipping cradle during these tests (Figure 2).

Figure 2: Vessel in the Shipping Cradle

3 INSTRUMENTATION

Dynamic strain gauges (Vishay EP-08-250BG-120, 120 ohm, biaxial) were installed on the EDS vessel and clamp in the configuration shown in Table 3. In addition, plastic strain, or permanent vessel deformation, was measured after each test at five locations along the length of the vessel by measuring the outer diameter using a stainless steel π-tape around the circumference.

Table 3: Strain Gage Location

Gauge #	Hoop/Axial	Channel	Location
1	Axial	2	Trunnion rod at mid-point
3	Axial	5	Lower Clamp inside, at 5:00 o'clock position
3	Hoop	6	Lower Clamp inside, at 5:00 o'clock position
4	Axial	7	Side Clamp inside, at 9:00 o'clock position
4	Hoop	8	Side Clamp inside, at 9:00 o'clock position
5	Axial	9	Vessel body 1/2 (33" from aft end)
5	Hoop	10	Vessel body 1/2 (33" from aft end)

The strain gages were verified during a hydrostatic test to ensure that they were working properly. Figure 3 shows reasonable agreement between the measured hoop strain from channel 10, pi-tape measurements of the vessel diameter, and predicted values using standard thick-walled pressure vessel equations [5].

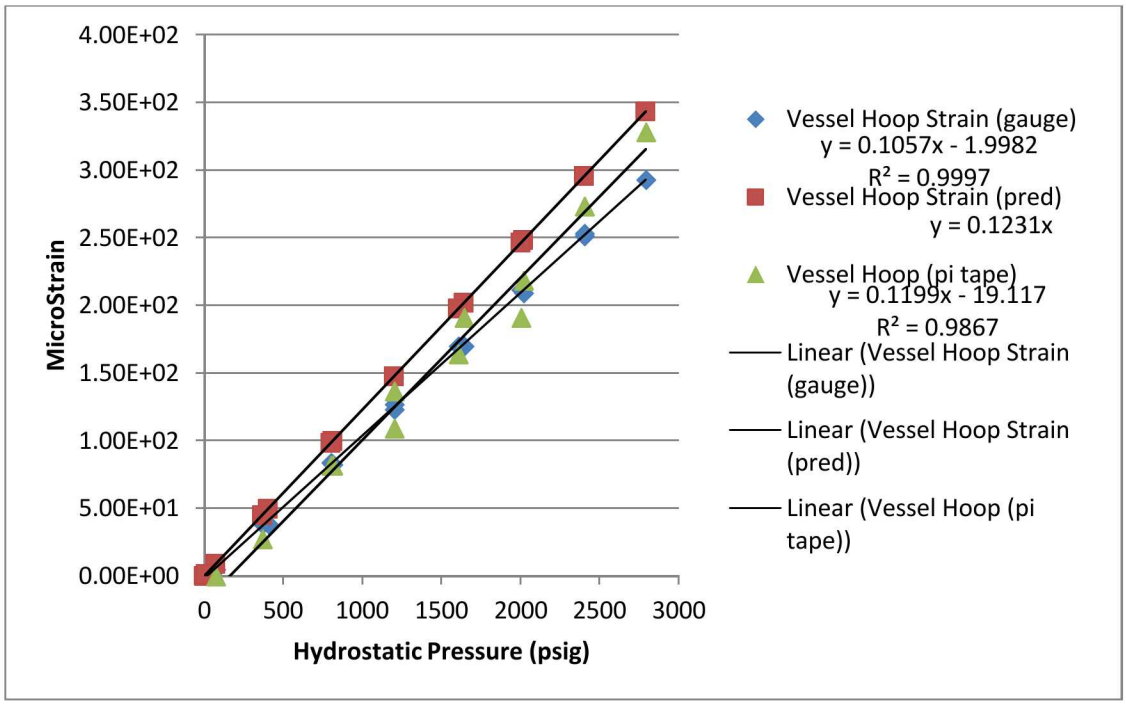

Figure 3: Measured and Predicted Micro-Strain during Hydrotest

A helium leak test was performed on the main Grayloc seal and the smaller feedthrough flange seal before each test using 10 psi of helium. Latex balloons were placed over leak check ports and other fittings in an effort to detect any transient leaks that might occur. The vessel was inspected and photographed after each test.

Visual inspections of the vessel, surroundings, and diagnostics were completed before and after each test event. This visual inspection included analyzing the seals, fittings, and interior surfaces of the EDS vessel and documenting any abnormalities or damages. Photographs were used to visually document vessel conditions and findings before and after each test event.

4 TEST DESCRIPTIONS

The electrical feedthrough flange contained four of the standard feedthroughs with PTFE sleeves. The small blast plates were installed on the door interior, but the large plate was not. Screws and plastic washers were inserted in all open bolt holes for protection from flying debris. All of the fasteners were treated with Loctite N-7000 anti-seize and tightened firmly. The external door configuration is shown in **Figure** 4. There was no valve panel. A valve was attached to the liquid and vapor sample ports. The valve on the vapor port, which was closed during the detonation, was connected to a pressure gauge. The valve on the liquid port was used to fill and vent the vessel. The steam and drain sample ports were plugged.

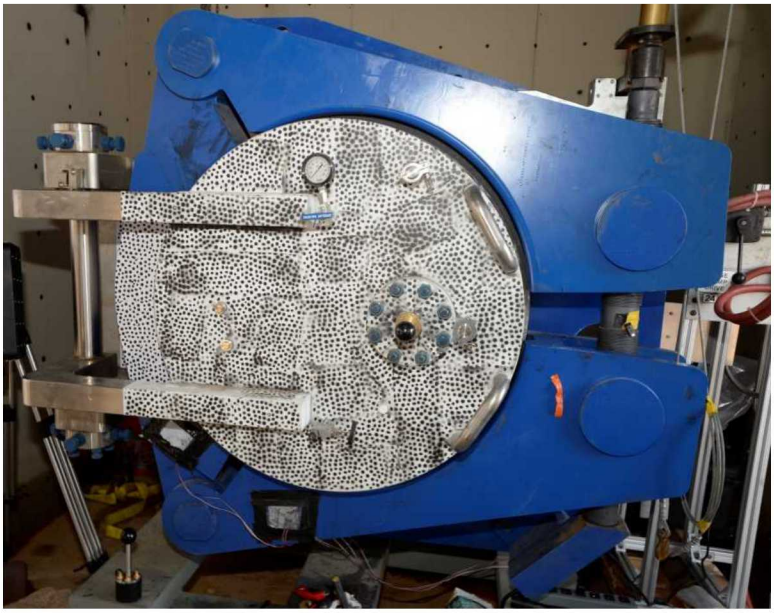

Figure 4: V26 Door Configuration

The first explosive test (Figure 5 top) consisted of a 9 pound cylindrical charge of Composition C-4 (11.25 pound TNT equivalent). The explosive was packed into a 5-inch inside diameter cardboard shipping tube to a density of 1.6 g/cc. A Reynolds RP-1, exploding bridgewire (EBW) detonator was placed at both ends. The two detonators were detonated simultaneously (within 200ns). A 1/4 inch thick disk of 10 lb/ft^3 polyurethane was placed at the midpoint of the cylinder. The intent of the disk was to prevent radial jetting that occurs when detonation fronts from both ends of the cylinder meet. The total length of the explosive and disk was 8.19 inches. The thickness of the cardboard tube was 1/8 inch. The charge was located at dead center along the length and diameter and held with ~1.25-inch thick sheets of 20 lb polyurethane foam board.

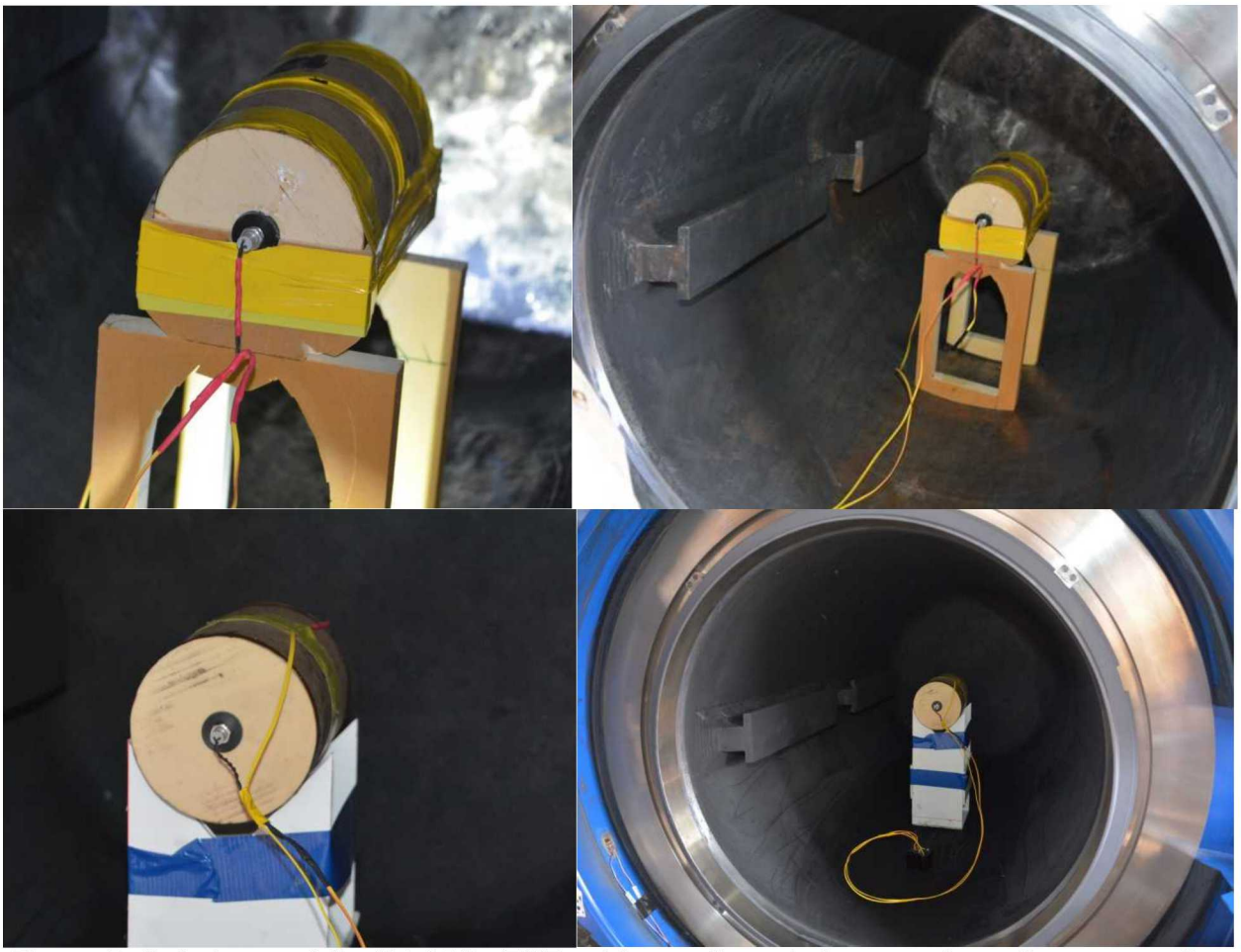

Figure 5: C-4 charge, 9 lb. (11.25 lb. TNT eq) in cardboard sleeve, polyurethane mounting boards, placed in vessel for first test, and 7.2 lb. C-4 charge (9 lb. TNT eq) in cardboard sleeve, Styrofoam mounting boards for the second.

Dynamic strain data were not collected on the first test due to operator error, but static data before and after the detonation were recorded.

The second explosive test consisted of a 7.2 pound cylindrical charge of Composition C-4 (9 pound TNT equivalent) (Figure 5 bottom). The explosive was again packed into a 5-inch inside diameter cardboard shipping tube to a density of 1.6g/cc with an RP-1 detonator at both ends. The intent was to maintain the same diameter on both tests. The total length of the explosive and disk was 6.60 inches. The charge was located at dead center and held with 1/2-inch sheets of Styrofoam insulation board. The lighter polystyrene foam holder was used to reduce the post-detonation gas pressure and residual soot.

5 VESSEL QUALIFICATION

Certification of the vessel is based primarily on the amount of plastic or permanent strain sustained by the vessel and clamps. The Code Case specifies allowable levels of plastic strain for both bending and membrane loads. Since the vessel body and cover were explosively tested and qualified in 2013, only data related to the clamps are presented here. Strain data for the vessel were consistent with the previous tests. Table 4 shows pre and post detonation strain gage data for the threaded rod and the inside surface of the clamps for the 9 pound C-4 shot. The small offsets between the before and after strains indicate that there was little or no plastic deformation in the clamps or rod. Table 5 shows corresponding data for the 7.2 pound shot.

Table 4: Strain gauge data for shot 1, 9 pounds C-4.

Strain Gauges	Rod axial	Clamp 5:00 axial	Clamp 5:00 tangential	Clamp 9:00 axial	Clamp 9:00 tangential
Pre-detonation	546 με	770 με	-810 με	587 με	-777 με
Post-venting	619	813	-843	624	-769
Difference	73	43	-33	37	8

Table 5: Strain gauge data for shot 2, 7.2 pounds C-4

Strain Gauges	Rod axial	Clamp 5:00 axial	Clamp 5:00 tangential	Clamp 9:00 axial	Clamp 9:00 tangential
Pre-closure	55 με	30 με	-16 με	11 με	2 με
Re-zeroed	0	1	1	12	17
Pre-det closed	453	608	-735	536	-758
Post-det 200 psig	508	705	-811	635	-856
Post-det vented	479	695	-816	616	-849
Opened	29	24	-15	20	6
Difference	26	87	-81	80	91

Dynamic strain data from the 7.2 pound C-4 test at the 5 o'clock position on the inside of the clamp are shown in Figure 6. The gage at the 9 o'clock position showed similar behavior with somewhat lower strain levels. The peak strain was 3300 με in the axial direction and 1920 με in the hoop direction. These peaks coincided, so the peak effective or Von Mises Strain was 2870 με. These strains are consistent with the conclusion that there was little if any plastic yielding. The yield strength of the clamps is 101,000 psi [3]. Using 30,000,000 psi as the

modulus, the strain at yield is 3400 με. Therefore the strain in the clamps is within the limits of the Code Case. For the threaded rod that holds the clamps, the strain is uniaxial during the detonation. The measured peak dynamic strain was 3450 με. This is well below the yield strain of 4700 με.

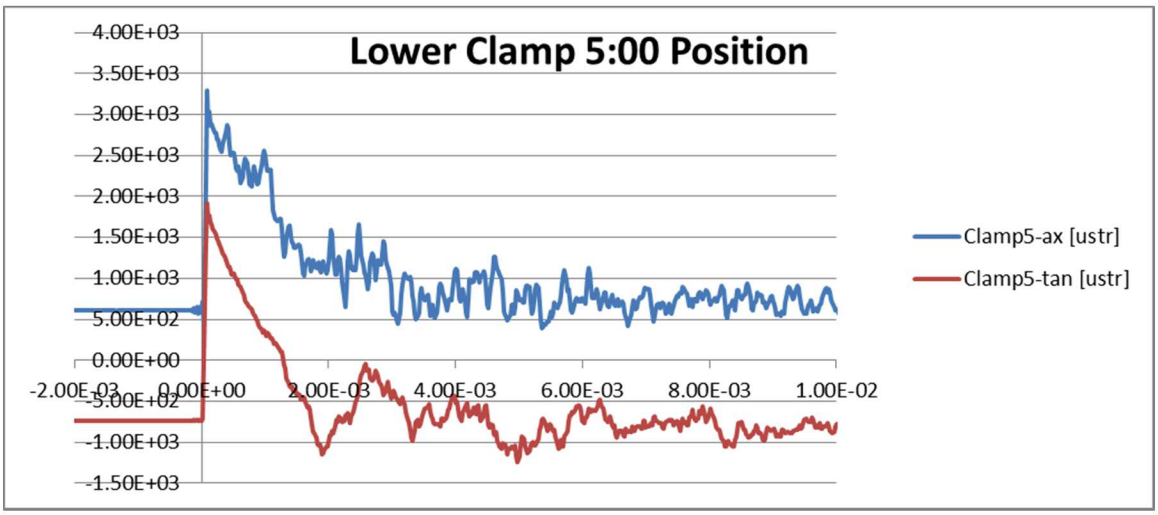

Figure 6: Dynamic Strain in the Clamp from the 7.2 pound C-4 Detonation

6 CONCLUSIONS

The focus of these tests was qualification of the three-piece clamp on the V26 vessel. The vessel body and cover were previously qualified. The basic acceptance criterion is the amount of plastic or permanent strain sustained as a result of the detonation. Hoop and axial strain were measured at two locations on the inside surface of the clamps and axial strain was measured on the threaded rod that secures the clamps. Dynamic strains were within the elastic range of the material and changes in the pre and posttest static strains were negligible. Therefore, the vessel meets the design requirements and is fit for use.

7 REFERENCES

[1] R Crocker, B Haroldsen, J Stofleth, **EDS V26 Containment Vessel Explosive Qualification Test Report**, Sandia National Laboratories Report SAND2013-9718, November 2013, Unlimited Release

[2] **Data Book CH29870-01**, Grayloc Products, 16 July, 2012.

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[4] **EDS V25 Containment Vessel Explosive Qualification Test Report**, John Joseph Rudolphi, SAND2012-3521, April 2012.

[5] Young, Budynas**, Roark's Formulas for Stress and Strain,** 7th edition, McGraw Hill 2002.


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