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Title: The Design, Analysis, Testing, and Use of a Small Confinement Vessel for Material Shock Physics Experiments

Author(s): Robert Valdiviez
Peter P. Sandoval
Wendy V. McNeil

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THE DESIGN, ANALYSIS, TESTING, AND USE OF A SMALL CONFINEMENT VESSEL FOR MATERIAL SHOCK PHYSICS EXPERIMENTS

Robert Valdiviez, Peter P. Sandoval, Wendy V. McNeil
Los Alamos National Laboratory, Los Alamos, NM

ABSTRACT

This paper describes the design, supporting analyses, fabrication, acceptance testing, and deployment of the Small Experiment Confinement Vessel (SECV). The vessel is used in a radiographic imaging facility for confining shock physics experiments where materials are driven to extreme loading conditions by the detonation of high explosives. The SECV provides an inexpensive means for confining a small shock physics experiment primarily due to its relatively simple design as compared to other confinement vessels.

The main function of the SECV is to protect the nearby diagnostic equipment from damage by materials of the dynamic experiment. The vessel has been designed to the criteria of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 3, Code Case 2564, with the exception of the materials of construction. The SECV is intended for reuse, with the total number of firings for any one vessel structure being primarily dependent on the accumulated wall damage.

The main body of the SECV is made of pipe material per the American Petroleum Institute standard ANSI/API 5L. Machined end flange weldments are joined to the pipe body to enable the closure covers to be bolted to the body. The closure covers have various devices mounted to them, for example a manually actuated valve for venting the vessel interior of detonation gasses, and feed through devices for sending electrical and optical signals across the pressure boundary.

INTRODUCTION

The Small Experiment Confinement Vessel (SECV) is one style of vessel amongst many styles used to confine the detonation products from a material shock physics experiment. A typical vessel design has features that allow for the radiographic imaging of the experiment, along with various other feed through devices to obtain data of the experiment while maintaining the integrity of the pressure boundary. The need to allow for the radiographic imaging, and the other experiment diagnostic signal access to the interior of the vessel results in structurally vulnerable locations in the pressure retaining boundary design. The access features are vulnerable to both pressure pulse and fragment damage. Typically, much of the design verification effort for a given confinement vessel design is spent on these vulnerable locations.

The SECV has one advantage in that the radiographic imaging is done directly through the 1.5 centimeter (0.59 inch) thick wall. The inclusion of radiographic windows is not required in the SECV because the radiographic facility has enough output, on the order of a few hundreds of rads of x-ray radiation, that good quality imaging of the dynamic experiment can be accomplished directly through the pressure boundary wall.

PERFORMANCE REQUIREMENTS FOR THE SECV

The SECV is required to confine the products of detonation from a maximum charge size of 34 grams of TNT. The charge would be centered in the vessel, both in longitude and in radius. If the charge is cylindrically shaped it may be end detonated, which can produce a slightly asymmetrical pressure loading of the confining walls. Slight amounts of gas leakage from the SECV are allowed because no toxic materials are used in the material shock physics experiments. The gas venting cannot be in the form of a jet that is energetic enough to damage the nearby diagnostic equipment.

The SECV structure can withstand the impact of fragments from a dynamic experiment. However, the more damage that is sustained by the vessel wall the lower the number of reuse cycles available for a particular vessel structure. The requirement for use is that the experiment configuration itself will be designed to confine all primary fragments so that the vessel wall only has to withstand relatively low damaging secondary fragments, or no fragments at all from the experiment. This will greatly reduce the pressure boundary wall damage due to fragment impact, and allow for more reuse cycles of a particular vessel weldment structure.

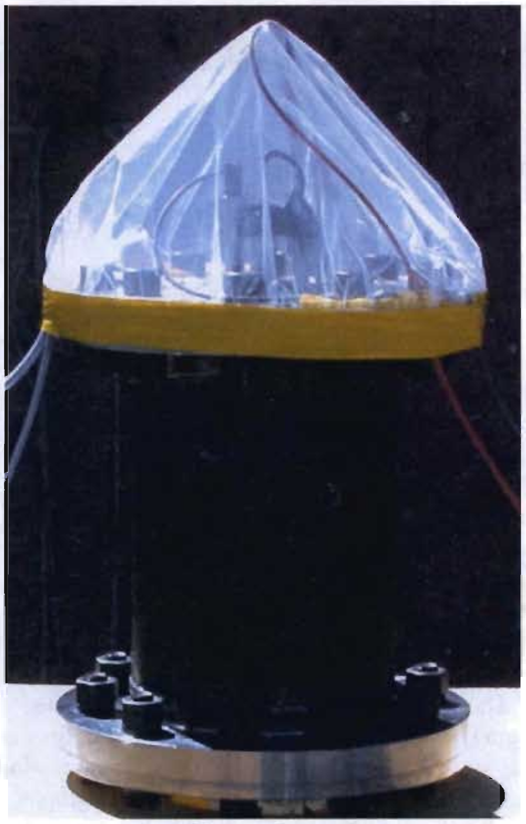

Figure 1
SECV assembly, top tent and cabling in place for testing

BASIC DESIGN OF THE VESSEL

The SECV main body is made of pipe material per the standard ANSI/API 5L[1]. The end nozzle weld attachments are made of the high strength low alloy steel HSLA-100 [2]. The vessel has an internal diameter of 24.3 centimeters (9.56 inches), and an internal usable length of 35.0 centimeters (13.76 inches). Figure 1 is an image of the vessel assembly configured for testing. The assembly weight is approximately 195 kilograms (430 pounds).

The materials of construction are not ASME B&PV code listed materials. The ANSI/API 5L pipe material for the main body of the weldment has been selected based on past use of this material to fabricate rather simple yet effective confinement vessels. The pipe material has controlled values on the fracture toughness, as measured by charpy v-notch testing, because it is intended to be used in systems and components for volatile fluid conveying. The HSLA-100 steel has historical effective use in confinement vessel construction. HSLA-100 steel has very high fracture toughness resilience at room temperature, and is a very weldable high strength steel.

The SECV uses two closure covers, one at each end of the assembly. Each closure cover incorporates the interfacing features, such as machined or pipe tap access holes in order for hardware to be fastened to, and sealed to the covers. Each cover uses a sealing configuration to the vessel weldment body that has two piston type seals, and one face type seal. The piston seals are compressed in a slightly tapered region of the body which makes for a robust dynamic seal when the vessel structure is deforming due to the impulsive load of the high explosive detonation. Each closure cover is fastened to the vessel end flanges using a quantity of ten, one inch diameter, course thread, socket head cap screws per the standard ASTM A574[3], along with hex nuts per the standard ASTM A563[4].

The SECV is deployed for experiments in a vertical orientation where the vessel's long axis is vertical. Support rods are placed through four of the top closure cover fastener holes, and support both closure of the vessel, and supporting its weight through the facility interface.

The experiment assembly that is internal to the vessel may be supported from the upper, or lower closure flanges through the use of light weight stand off and support rods.

HYDRODYNAMIC ANALYSIS OF THE VESSEL DESIGN

The pressure-time history loading placed on the vessel is predicted using a hydrodynamic model where the detonation of the high explosive, and the resulting shock front generated is modeled as progressing throughout the vessel's interior volume. The model, created using ANSYS/Autodyn Version 11[5], is an axi-symmetric model with the vessel's longitudinal axis being the line of symmetry. The cylindrical shaped HE charge is modeled as being 30 grams of PBX9501. This charge mass is equivalent in blast energy output to 34 grams of TNT, which is the design required charge. The charge is modeled as being centered in the longitudinal and radial directions within the cylindrical shaped vessel. The cylindrical HE charge is end detonated, so there is some slight asymmetry in the longitudinal direction of the model as the internal blast front develops.

Figure 2 depicts the axi-symmetric hydrodynamic model of the SECV. The vessel's centerline is the axis of symmetry used in the modeling, and is the horizontal lower edge of the model's grid shown. The initial material distribution is shown, with the detonation point on the end of the HE charge shown with a red diamond. The numbered locations are the gage points where pressure is recorded throughout the transient event. The vessel is modeled as being filled initially with atmospheric air at standard conditions.

The hydrodynamic model accounts for the high explosive impulse loading only. The fragment loading and protection of the vessel is addressed with prototype testing, which is described later in this paper.

The model analysis grid contains a total of 35,868 cells, with 98 in the vessel radial direction, and 366 in the vessel axial direction. Each cell has the dimensions of 0.124 cm (0.049 inch) square. The multi-material Eulerian solver is used for analyzing the model. The air and PBX9501 material models in Autodyn are used. The air model uses the ideal gas law as the equation of state, and the PBX9501 model uses the Jones-Wilkins-Lee (JWL) equation of state for the high explosive detonation reaction. The walls of the vessel structure are modeled as being located at the outer rigid boundaries of the analysis grid. This hydrodynamic model, therefore, assumes that the effect of the vessel wall structural deflection is not a dominant feed back effect on the propagation of the reflected shock waves within the vessel throughout the transient event. As will be shown in the structural analysis of the vessel the wall deflections are very low in magnitude, thus supporting the rigid wall modeling approach of the hydrodynamic model.

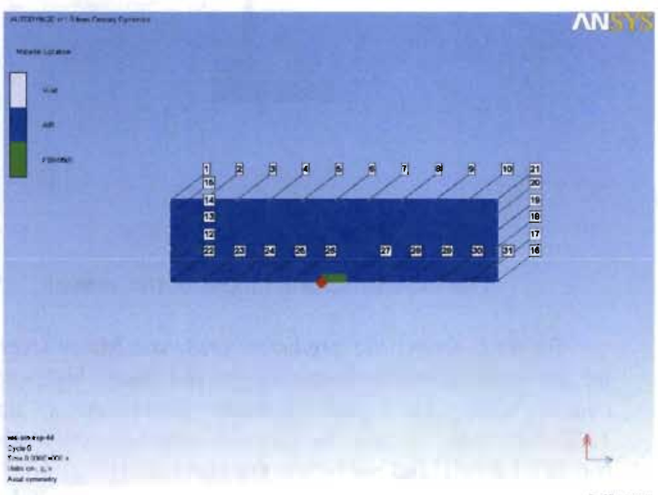

Figure 2
Hydrodynamic model of vessel interior

The pressure time histories at the various tracked locations are predicted in the model, and the simulation is ended when all of the pressures have decayed to low values. Figure 3 is a plot of the shock front just prior to the first impact with the vessel wall.

The predicted pressure in the shock front just prior to impingement on the cylindrical shaped wall of the main vessel body is 11 megapascals (MPa) (1,595 psi). The predicted peak pressure in the shock front at the upper portion, the portion that will eventually impinge on the upper closure cover, is 11.5 MPa (1,668 psi). The associated predicted pressure in the lower portion of the shock front is 8.4 MPa (1,218 psi). The asymmetry of the pressure field of the shock front is due to the cylindrical charge having the detonation initiated at one end of the cylinder, the lower end of the charge. The highest field pressure develops opposite to this location due to the nature of the progression of the detonation wave through the high explosive. The asymmetry of the shock front pressure field diminishes by the time that the vessel end closure covers are impacted by the first shock front. The two covers are predicted to experience peak shock impingement pressures that are less than 1.0 MPa (145 psi) different from each other. The pressure difference is not significant structurally in this case, however, asymmetry in the shock front pressure field can be significant in some cases for the structural response of the vessel by putting a high net reaction load on the vessel and its support structure.

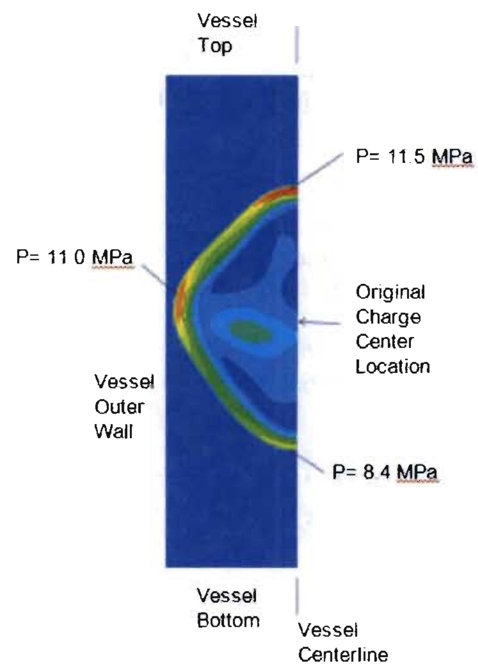

Figure 3
The shock front just prior to the first wall impact

Figure 4 is a plot of the predicted pressure time history at the center height location of the cylindrical vessel body. This is the location of the highest dynamic pressure in the vessel structure.

The first pulse in the pressure time history has a pulse length of approximately 5.0E-5 seconds. The dominant structural response mode for the SECV is the breathing mode, with a frequency of 3568 Hz, and thus a period of 2.8E-4 seconds. The pressure time history's first pulse width is approximately 18% of the dominant response mode period of the vessel. Code Case 2564 states that a load is considered impulsive if the pulse length of the load is less than 35% of the period of the fundamental structural response mode, breathing mode, of the vessel structure being analyzed.

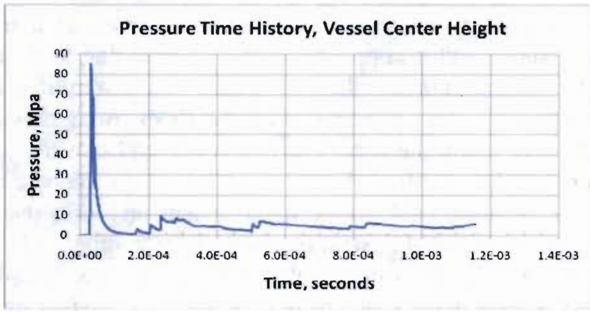

Figure 4
Pressure time history predicted for the vessel center height location

STRUCTURAL ANALYSIS OF THE VESSEL DESIGN

The predicted pressure time histories from the hydrodynamic analysis are used to drive a dynamic structural model of the vessel structure in order to predict the transient stresses, strains, and larger scale deflections. The pressure time histories become the forcing functions in the dynamic structural modeling.

The structural model of the SECV has been created in ABAQUS, Version 6.7[6]. Figure 5 shows the finite element mesh used in the model. The model is axi-symmetric, with the vessel vertical axis being the axis of symmetry. A restraining boundary condition (vertical DOF restrained) is placed on a small portion of the top surface of the top cover to simulate the bolting to the support structure. The four node hexagonal element in ABAQUS, type CAX4R, which has a linear shape function is used as the predominant element in the dynamic structural model.

The model incorporates the cylindrical body with end weldment nozzles, along with the closure flanges connected to the nozzles with the fastener material. The fastener material mass is distributed as a small cylindrical volume that connects the cover to the nozzle in the axi-symmetric model. This enables a representative structural joining of the cover to the vessel end nozzle, and the prediction of representative transient stresses in the fastener material, albeit for an altered geometry in the model.

In order to model the dynamic structural response of the vessel to the impulsive load of the high explosive detonation the simulation time to use needs to be predicted first. Because late time strain growth[7] can occur in impulsively loaded structures due to the cumulative modal response the simulation time needs to be long enough to capture this phenomena in case it occurs. The approach to use is to have the simulation time be equal to, or greater than fifty structural response cycles of the vessel after the forcing functions diminish to near zero loading. This requires that the predominant structural response mode of the vessel be used to obtain a structural response period, and this value multiplied by fifty gives the time delta value to add to the forcing function time duration to arrive at the total simulation time to use.

In the case of the SECV structure the breathing mode is the predominant response mode, and the period is 2.8E-4 seconds. The period multiplied by fifty, and added to the longest forcing function time duration gives 1.5E-2 seconds as the minimum simulation time to use. The analysis used 3.0E-2 seconds as the simulation time.

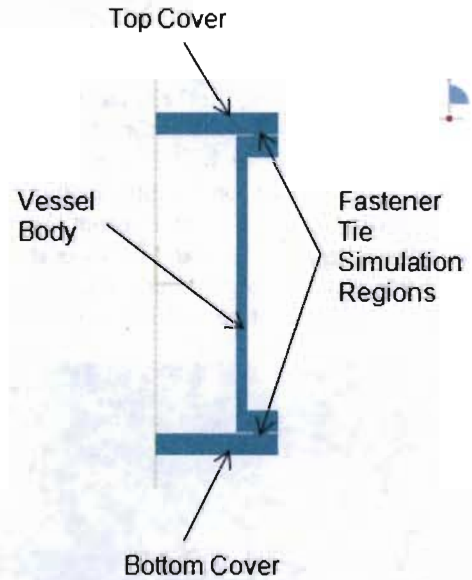

Figure 5
The FEA structural model of the vessel

Figure 6 shows the predicted peak von Mises stress state for the vessel assembly responding to the design high explosive charge case. The peak stresses occur at a time of 1.7E-4 seconds, in the covers, are approximately 456 MPa (66.2E3 Lb/in^2), and are below the material, HSLA-100, tensile yield strength of 689 MPa (100E3 Lb/in^2). The predicted peak von Mises stresses in the vessel cylindrical body, that occur at an earlier time than the peak stresses in the covers, are approximately 276 MPa (40.0E3 Lbf/in^2), and are below the vessel body API 5L material yield strength of 450 MPa (65,300 Lb/in^2).

Figure 7 shows the predicted maximum displacement of the vessel assembly. The peak displacements are predicted to occur at a time of 2.6E-4 seconds. The cover centers are predicted to be the locations where maximum deflection occurs, with a magnitude of approximately 0.069 cm (0.027 inch). The peak cylindrical wall deflection is predicted to be approximately 0.01 cm (0.004 inch).

The predicted response of the vessel for the design high explosive charge case is that all materials remain well within their elastic limit. The predicted equivalent plastic strain level for the vessel structure is zero everywhere. The design requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 3, Code Case 2564 for impulsively loaded vessels have been met for the SECV with the design high explosive charge size.

The Code Case 2564 also requires that an impulsively loaded vessel design be analyzed for the impulse load increasing by 75%. Within the vessel design a plastic instability state, as manifested by the formation of a complete plastic hinge, must not be created in order for the design to be acceptable.

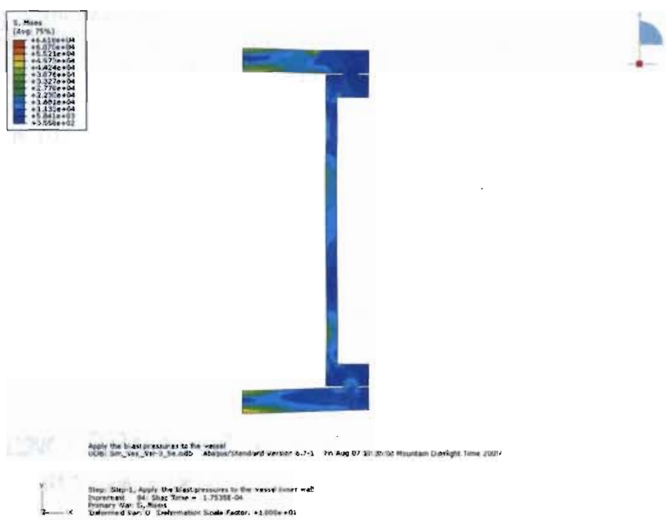

Figure 6
The predicted peak von Mises stresses, units are lb/in^2

The design analysis of the SECV has the pressure magnitudes in the pressure time history forcing functions increase by 75% in order to increase the impulsive loading by 75%. The predicted result is that some material plasticity is predicted to occur. Figure 8 is a plot of the total equivalent plastic strain predicted for the increased impulse transient.

Small regions in the top surface of the covers, near the fastener connection, are predicted to develop some plastic deformation, approximately 0.9%, however, nothing approaching a complete plastic hinge is predicted to form. A complete plastic hinge would be where plastic deformation is predicted to occur through the thickness of the component. A very small region of plastic strain is predicted in the cylindrical body, at the inside surface, middle point height. The level is approximately 0.07%, and extends to a very shallow depth in the wall, thus being very far from producing a plastic hinge.

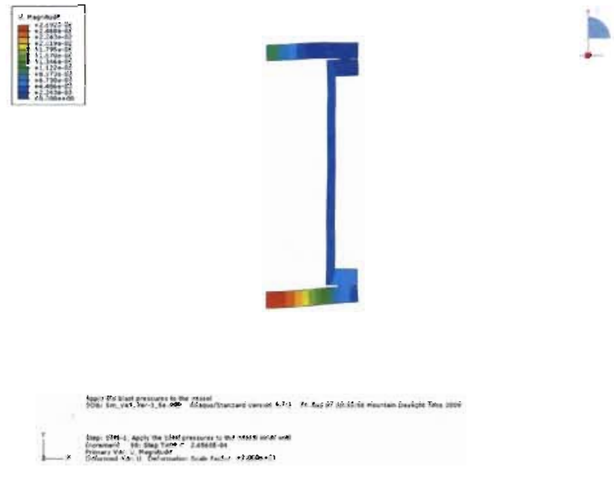

Figure 7
The predicted peak displacements, units are inch

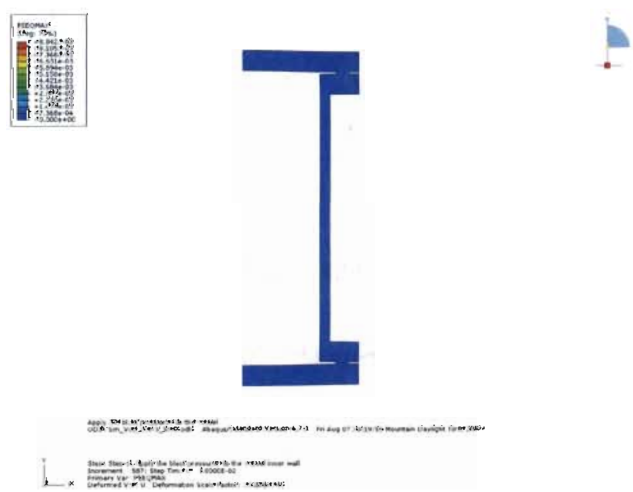

Figure 8
The predicted total equivalent plastic strain for the SECV for the increased impulse case

The design requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 3, Code Case 2564 for impulsively loaded vessels have been met for the SECV design for the increased impulse case. No plastic instabilities have been predicted for the 75% higher impulse loading condition. Based on the equivalent plastic strain levels predicted in the increased impulse analysis there is much structural margin in the SECV design to prevent a plastic instability from forming for the vessel being exposed to higher than design level loads.

FATIGUE FRACTURE ANALYSIS OF THE VESSEL DESIGN

Code Case 2564 requires that a fracture mechanics fatigue evaluation be conducted on the SECV design. This fatigue fracture analysis serves to set a lifetime for the vessel structure in the presence of flaws that can grow in each impulsive loading event.

The vessel cylindrical weldment design, along with the cover design, have been evaluated for fatigue fracture resistance ability. The summary of the assessment, along with the predicted results, are given in this section.

The vessel assembly is designed to be a low use cycle vessel, where each vessel is anticipated to be used to confine an experiment at the full HE loading on the order of three to four times. Figure 9 shows a plot for the predicted crack growth for the cylindrical body of the vessel weldment. The crack geometry used is a surface type A crack as defined in Appendix D, Section D-300 of the ASME code, Section VIII, Division 3. This plot is for the vessel being used for fifty experiments at full HE load. The vessel's response cycling for one given experiment confinement event is included in the numerical analysis of the crack growth, so each cycle in the plot encompasses the collective loading cycles of a single event, thus giving the crack growth for each actual confinement event. Fifty cycles, or confinement events are used in the fatigue analysis, where only three to four are anticipated for the vessel assembly.

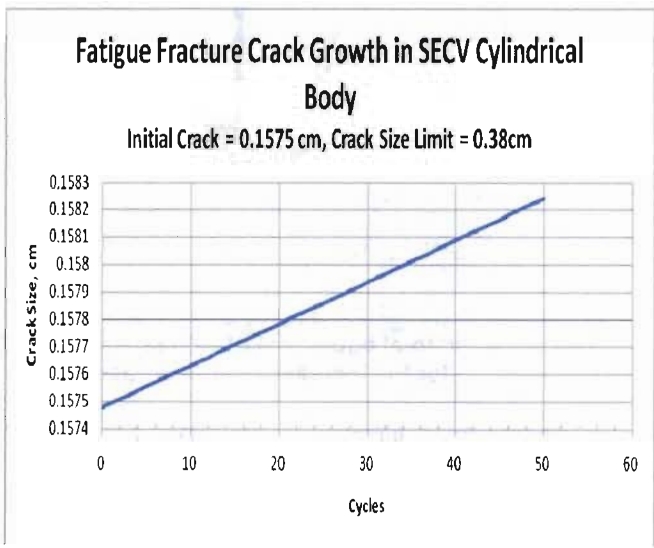

Figure 9
Predicted fatigue crack growth for the vessel cylindrical body weldment

The fatigue fracture analysis of the cylindrical vessel weldment begins with a crack size of 0.1575 cm (0.062 inch) that is 0.472 cm (0.186 inch) long, and occurs at a location of peak stresses for the body. As the plot shows the crack is predicted to increase to 0.1582 cm (0.06230 inch) size in fifty use cycles. The crack size limit is 0.38 cm (0.15 inch) size.

Figure 10 is a prediction of the fatigue crack growth for the vessel assembly cover design. The crack geometry used is a surface type A crack as defined in Appendix D, section D-300 of the ASME code, Section VIII, Division 3. The fatigue fracture analysis of the vessel assembly cover begins with a crack size of 0.1575 cm (0.062 inch) that is 0.472 cm (0.186 inch) long, and occurs at a location of peak stresses for the cover. As the plot shows the crack is predicted to increase to 0.178 cm (0.07 inch) size in fifty use cycles. The crack size limit is 0.378 cm (0.149 inch) size.

The nonmandatory guidance in section 3.3 of the Code Case 2564 is used in general for performing the fatigue fracture assessment. One exception to the guidance is taken where after the calculation of L_r (reference stress load ratio) and S_f/S_y (ratio of material beyond yield capability average stress, S_f, to material yield stress, S_y) is done, K_{IC} (plane strain fracture toughness) and the crack size iteration are calculated, skipping the calculation of fracture toughness transition due to high strain rate, and upper shelf at low strain rate evaluation because an alternate equation for K_{IC} is used. The calculation of K_{IC} is taken from Section VIII, Division 3 of the Code, Appendix D, section D-600, instead of using the equation given in the Code Case 2564, section 3.3.

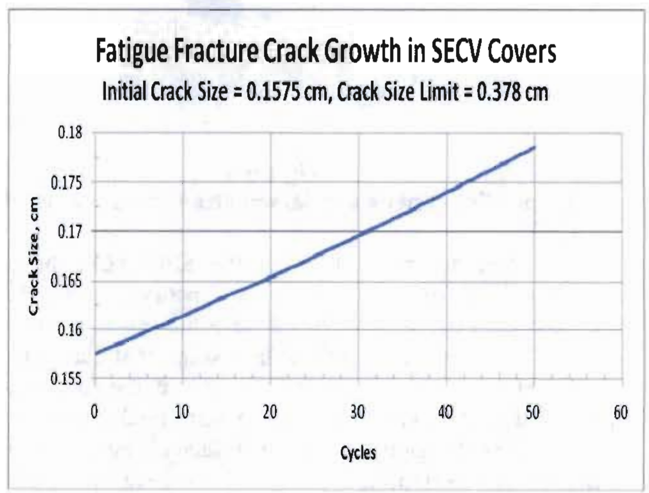

Figure 10
Predicted fatigue crack growth for the vessel cover

Fatigue fracture failure of the SECV body, or covers is not indicated to occur for a low use cycle profile of the vessel assembly.

FABRICATION PROCESS FOR THE VESSEL

The SECV is of a rather simple design, and the fabrication effort was not difficult to exercise because of the simplicity.

The most important aspect of the fabrication is the welding operation. AWS D1.1[8] has been used as the welding and inspection standard for the vessel weldment. ASME Section VIII, Division 3 was not used as the welding standard due primarily to the lack of qualified welders to the standard in the region of Los Alamos National Laboratory (LANL). The intent was to have a rather short fabrication period so as to facilitate the pressing schedule for delivering the first unit for experiment execution.

A LANL weld procedure for joining low alloy, high strength steels to lower strength common carbon steels that is qualified to AWS D1.1 was used for setting the welding parameters for joining the vessel cylindrical body made of API 5L pipe material to the machined end nozzles made of HSLA-100 material. These two welds are the only weld joints in the design of the SECV.

The subsequent Non-Destructive Examination (NDE) used to inspect the welds was a visual inspection (VT) process, and an ultrasonic inspection (UT) process. The NDE acceptance criteria stated in AWS D1.1 for VT and UT examination has been used to determine the acceptability of the welds.

The end covers for the SECV were machined from HSLA-100 flat plate. At the completion of parts fabrication the seals were installed on the covers, and the covers mated to the vessel. A helium gas leak check was performed by evacuating the interior of the vessel with a helium mass spectrometer unit, and spraying helium gas around the vessel exterior. The SECV assembly had no detectable helium gas leaks.

FRAGMENT AND IMPULSE TESTING OF THE VESSEL

The vessel inner wall surfaces are subject to fragment damage from the experiment being conducted. The SECV is not intended to be used for experiments that involve a high fragment loading to the pressure boundary walls. The small experiments to be fielded in the vessel will have fragment shielding extensive enough to prevent any major damage (greater than 20% penetration) to the vessel inner wall surfaces, and to keep the damage locations to very few (less than approximately eight impact locations).

For the first experiment planned to be confined in the SECV different analytical approaches exist for predicting the fragment generation, and thus the vessel protection needed. Instead of taking an analytical approach to predicting the fragment threat to the vessel an actual test has been conducted. In this particular case testing is preferred over analytical predictions of fragment threats because an applicable test will produce more reliable results than an analysis because of the uncertainty of some of the analytical input information. Examples of uncertain analytical input information are HE to fragment producing material interfacing, and fragmenting material properties relevant for predicting the breaking up into fragments.

Figure 11 shows pictures of the test configuration conducted in an open configuration with witness plates used to map the fragment pattern. The test used a high HE amount, 48 grams of PBX9501 compared to the vessel design value of 30 grams of PBX9501. A dense material, tungsten, was used to produce a worst case fragment condition as compared to the anticipated experiment materials. The tungsten piece is 2.54 cm (1 inch) in diameter, and 0.63 cm (0.25 inch) thick. The fragment protection scheme was comprised of one layer of a fragment catching foam, density 0.320 grams/cm^3, that is 2.54 cm (1.0 inch) thick and 10.2 cm (4 inches) in diameter, one layer of type 6061-T6 aluminum, 1.3 cm (0.5 inch) thick, 30.5 cm (12 inches) square, another layer of 2.54 cm (1.0 inch) thick catching foam, and another layer of 1.3 cm (0.5 inch) thick aluminum.

Figure 12 shows the results of the fragment test. The fragment damage pattern on the first plate has two notable attributes, i) the dent in the middle of the plate indicating that the first foam disc was completely penetrated, and ii) the fragment damage radius extends to near the edge of the 30.5 cm (12 inch) by 30.5 cm (12 inch) plate. The first attribute is not a problem for the vessel design because a 1.3 cm (0.5 inch) thick aluminum baffle plate will be used as the first metal plate in the experiment layout. A second 1.3 cm (0.5 inch) thick aluminum plate will be used as the second metal plate. The first protective disc will be a foam disc 2.54 cm (1 inch) thick, 10.2 cm (4 inch) diameter. The second foam disc, in between the two aluminum plates, may be omitted from the experiment configuration because it sustained no fragment damage, meaning that it is extraneous.

Figure 11
Fragment generation test configuration

The second attribute, the fragment impact radius extending to near the edge of the 30.5 cm (12 inch) by 30.5 cm (12 inch) aluminum shield plate indicates that the fragment pattern has the ability to strike the vessel inner wall surface with the 5.1 cm (2 inch) separation distance used.

The outer zone crater marks on the shield plate would be strikes with relatively low velocity fragments as indicated by the shallow dents of the craters in the aluminum at the outer radii, and thus not much of a threat to the 1.5 cm (0.59 inch) thick vessel wall. The damage to the vessel can be prevented by using a cylindrical aluminum piece, approximately 0.32 cm (0.125 inch) thick, covering most of the length of the vessel as a replaceable liner to protect the vessel inner wall from fragment damage.

The SECV underwent an impulse loading test as a key acceptance step for the design prior to executing an actual material shock physics experiment. The design charge mass of 30 grams of PBX9501 is required to be increased by 25% for this test per the requirement in Code Case 2564. The 25% impulsive load increase requirement is for testing materials not permitted by Part KM of the Code, as well as for an application where personnel are protected by other barriers beyond the vessel itself. This particular test actually used a charge mass of 45 grams of the high explosive, made of PBX9501 and C-4 parts, a 50% increase over the design charge mass. PBX9501 and C-4 have the same detonation power output per mass. C-4 was used because it is hand formable, and this made the test charge more adaptable in the field installation.

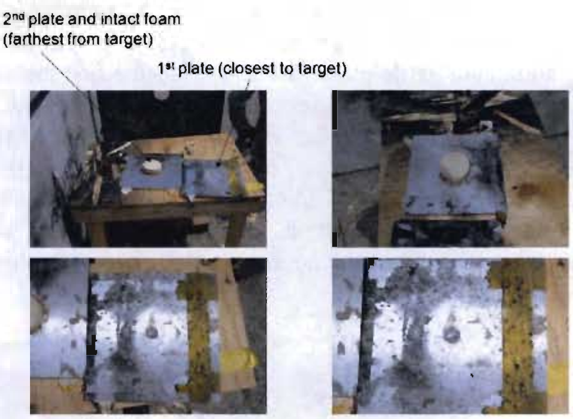

Figure 12
Fragment test results as damage to foam discs and aluminum plates, front disc not recovered

Figure 13 is a view of the vessel in the testing configuration, and mounted at a laboratory firing site for conducting internal impulse load testing.

Figure 14 is a view of some of the damaged internal support and shielding hardware of the mock experiment assembly that held the high explosive charge. The broken pieces are nonmetallic materials used for lightweight support, and the aluminum shields are whole, with charring and fragment damage. No significant damage was done to the vessel assembly itself, only charring and minor scratching due to the debris interaction. A piece of tungsten material was included in the design of the mock charge to create a representative fragment pattern of a material shock physics experiment assembly. The fragment shielding configuration was effective at preventing significant fragment damage to the vessel structure.

DEPLOYMENT OF THE VESSEL

The SECV is supported inside of a 1.83 meter (6 foot) inner diameter Confinement Vessel (CV) that is fielded on the radiographic facility firing point. The CV is not sealed, i.e. nozzle covers are not installed when the SECV is installed and used.

Figure 15 shows the support arrangement for the SECV. The support structure is comprised of a cross member, support cross, that attaches and aligns to the CV top nozzle, and four support legs that connect to the cross member, and the upper portion of the SECV.

Figure 13
SECV configured and mounted for impulse testing

The SECV supports the experiment subassembly inside of the vessel. Figure 16 is an image of one material shock physics experiment supported in a small frame, known as a racklet. The racklet also supports shields to provide some level of protection from generated fragments for the vessel interior surfaces.

The SECV was successfully installed and aligned in the radiographic facility. The first experiment conducted in the SECV produced high quality images of the material shock physics experiment. The SECV as a confinement vessel performed as required. There was no detectable material leakage from the SECV.

Figure 14
Post test debris and vessel

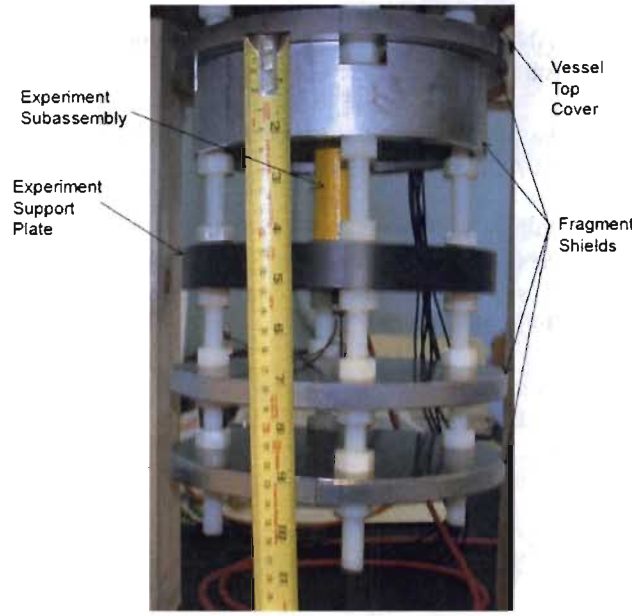

Figure 16
Experiment subassembly racklet, mounted underneath the top cover of the SECV

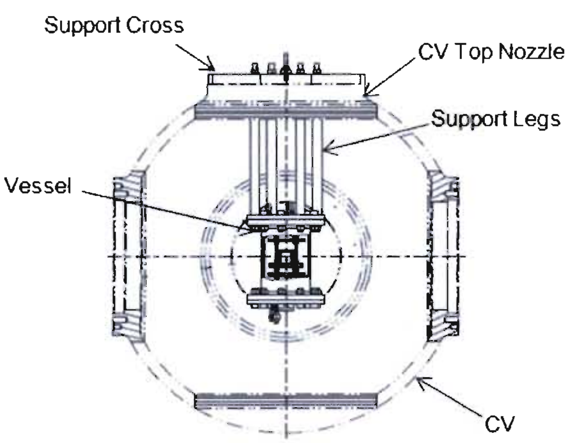

Figure 15
SECV supported in the confinement vessel

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