TITLE: CONTAINED HIGH EXPLOSIVE FIRING FACILITY (CHEFF)

AUTHOR(S): H.L. Stacy, W. L. Seitz, Jerry Wackerle, LANL, M-7
M.A. Polcyn, E.D. Esparza, Southwest Research Inst.

SUBMITTED TO: Joint AIRAPR/APS Conference - American Physical Society
June 28 - July 2, 1993 / Colorado Springs, CO

CONTAINED HIGH EXPLOSIVE FIRING FACILITY (CHEFF)*

H. L. Stacy, W. L. Seitz and Jerry Wackerle
Los Alamos National Laboratory
Group M-7, MS P952
Los Alamos, NM 87545
Michael Polcyn and Edward Esparza
Southwest Research Institute
P. O. Drawer 28510
San Antonio, Texas 78209-1128

A cylindrical vessel capable of totally containing the products and shrapnel resulting from the detonation of 10 kg of TNT (or equivalent) has been designed and built by Southwest Research Institute for and according to the requirements of the Detonation Systems Group (M-7) of Los Alamos National Laboratory. The vessel is 6.0-m long by 3.6-m diameter and is manufactured of 50-mm (elliptical end caps) and 38-mm (cylindrical walls) thick high-strength steel (HY-100). The cylindrical walls of the vessel are lined with 13-mm thick replaceable steel plates for shrapnel protection. The floor is made of steel-covered concrete. Ten large-aperture (254 mm) optical ports are available for instrumentation and four ports are provided for cabling and plumbing. Two qualifying detonation tests of 8.8 kg of C-4 explosive (equivalent to 10 kg TNT) have shown that the maximum strain produced is less than 78% of the elastic limit. The vessel is installed in a converted outdoor firing facility that has been modified to include an insulated and heated metal building to house the vessel and additional instrumentation. A computer-based system for data acquisition, firing control, and the monitoring of vessel response is described.

INTRODUCTION

With the increasing cost of firing explosive experiments, an efficient method of gathering more data from a single experiment is needed. It seems logical that if the experiment can be placed in the center of a room and surrounded with diagnostics, rather than looking through a single port window, that more data can be obtained from each experiment. The center of the room idea led to the containment vessel concept. The containment vessel provides a configuration suitable for surrounding the experiment with diagnostics and lends itself more easily to experiments that must have tight environmental controls than does outdoor firing. The contained approach to firing is environmentally friendly but is not the answer to all explosive testing. These concepts are the governing ideas behind the Contained High Explosive Firing Facility (CHEFF). A photograph of CHEFF is shown in Figure 1.

Figure 1. M-7's Contained High Explosive Firing Facility (CHEFF).

VESSEL DESIGN AND FABRICATION

In 1990, the Detonation Systems Group (M-7) of Los Alamos National Laboratory contracted

*Work performed under the auspices of the U.S. Department of Energy

with Southwest Research Institute to design and fabricate a cylindrical vessel capable of totally containing the products and shrapnel resulting from the detonation of 10 kg of TNT (or equivalent). Certain requirements were specified by M-7, such as ten large-aperture (254 mm) optical ports, four ports for cabling and plumbing, and limitations on the physical size and weight. Southwest Research Institute designed a 68 metric-ton vessel that is 6.0-m long by 3.6-m diameter manufactured of 50-mm (elliptical end caps) and 38-mm (cylindrical walls) thick high-strength steel (HY-100). The cylindrical walls are lined with 305-mm square tiles that are made of 13-mm thick neoprene covered with 13-mm thick steel for shrapnel protection, as seen in Figure 2. The tiles are bolted to the inside walls of the vessel and are designed to be replaced when necessary. A 2.1-m by 1.2-m door located in one of the elliptical end caps provides for easy access. The large physical size of the door prevents the vessel from being considered a confined space. Air circulation in and out of the vessel is provided through two 152-mm diameter tubes with butterfly valves on each tube. An 8.5-m^3/min fan on the exhaust tube provides circulation of fresh air through the vessel and removes particulate matter from exhausting gases by using HEPA filters.

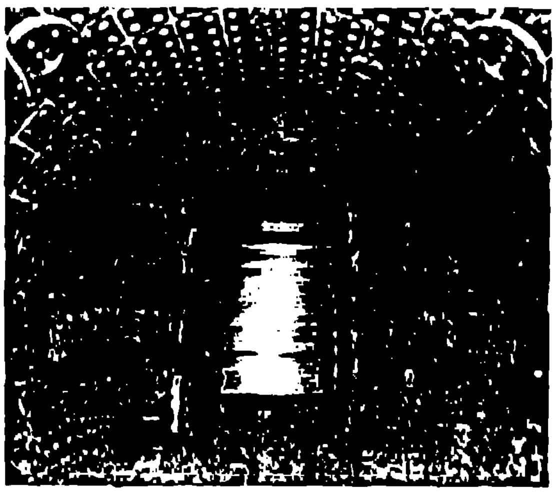

Figure 2. Interior view of the containment vessel showing the replaceable tiles, the end cap containing the door frame, and gusset supports.

Blast loads in the vessel consist of both a shock loading phase and a quasi-static gas loading phase. The quasi-static load is predicted with confidence using empirically-based data [1]. The shock loading phase is much more difficult to predict because of the reverberation of shock waves within the vessel. Therefore, the shock loading was predicted using a combination of blast predictive methodologies and explosion test data from a similar vessel. Similarly, the response of most of the structural components to the blast loads was calculated using simple single-degree-of-freedom dynamic response methods. However, the response of the door, door frame, elliptical end cap, and cylinder (in the axial direction) are coupled and, thus, required a more complicated multi-degree-of-freedom dynamic analysis to predict the response.

TESTING

M-7 required that three air leak tests and two 10-kg TNT-equivalent explosive tests be conducted to qualify the vessel for acceptance. To confirm the design parameters and check the manufacturing process, Southwest Research Institute implemented additional tests that included a hydrostatic, several low pressure air, and additional small-scale explosive tests. All the testing, thus far, has taken place at the Southwest Research Institute facility in San Antonio, Texas. All tests were monitored using strain gauges, pressure gauges, displacement gauges, and thermocouples.

The explosive tests were divided into two distinct categories. The first category was the preliminary tests, which included two 2.27 kg and one 4.54 kg TNT equivalent explosive experiments, that were used to calibrate the instrumentation, check reproducibility, and check design calculations. The second category was the qualifying tests, which included two 10 kg TNT equivalent (8.8 kg C-4) explosive experiments each followed by the air leak test mentioned above. All explosive charges were spherical in shape and positioned at the geometrical center of the vessel when detonated.

Thirty three strain gauges, one static pressure gauge, two quasi static pressure gauges, four blast pressure gauges, three displacement gauges, and two thermocouples were used for each test. Three of the blast pressure gauges were located in areas where high pressure was indicated by standard blast pressure calculations [2]. One gauge was located in the center of the elliptical end cap (opposite the door) and the other two gauges were in the cylindrical wall, on opposite sides of the vessel and in a vertical plane with the explosive charge. The last blast pressure gauge was located in a low pressure area and used for comparison with the other blast pressure gauges. Strain gauges were located in areas that included most of the geometrically different regions of the vessel, with a high concentration of gauging in areas of greatest calculational uncertainties, such as the area where the door frame intersects the elliptical end cap (see Figure 2).

The hydrostatic test involved filling the vessel with approximately 50 m^3 of water and then gradually pressurizing it to the 5.4-MPa design pressure. Measurements of strain for several previously determined pressures were compared to the predicted values. The hydrostatic test also checked the integrity of the vessel's construction before the steel-covered concrete floor was installed.

The air leak tests consisted of pressurizing the vessel to 1.1 MPa and verifying, over a four hour period, that all observed pressure changes were temperature induced. A total of three air leak tests were performed, one before any of the explosive tests and one after each of the two qualifying explosive tests.

All experimental measurements were in good agreement with calculated values. Table 1 gives a summary of measured peak amplitudes obtained from the explosive testing. Considering each specific geometry, the highest stress calculated from the measured strains was less then 78% of the elastic limit (690 MPa) of the steel used. The fact that there were no air leaks after the large

Table 1. Summary of Measured Peak Amplitudes for Explosive Tests

	Location*	2.27 kg TNT Test	2.27 kg TNT Test	4.54 kg TNT Test	10 kg TNT Test	10 kg TNT Test
Strain (μm/m)	A	527	522	1133	2222	2282
	B	>-400^	-580^	-886^	1429	1388
	C	411	415	811	1118	1037
Peak Stress (MPa)	A	136	134	271	521	532
	B	>-110^	-176^	299	439	430
	C	108	103	127	242	216
Blast Pressure (MPa)	B	1.19	1.62	3.28	4.46	6.55
	C	3.17	3.38	6.00	11.6	14.5
Quasi static Pressure (MPa)	D	0.23	0.24	0.43	0.78	0.79
Gas Temperature(°C)	D		244	490		638
Displacement (mm)	A	1.85		4.01	6.76	6.58
	E	0.94		1.83	2.46	1.07
	F	0.30		0.68	1.29	1.24

*A Door Center, B Cylindrical Head, C Circumference at Center of Cylinder, D Internal to the Vessel, E Edge of the Door on the Horizontal Center Line, F Door Frame on the Horizontal Center Line

^Negative Values Indicate Compression

test demonstrated that the seals, gaskets, and the port glass will withstand the pressures and shocks of multiple full-scale experiments.

FACILITY

The vessel is installed in a converted outdoor firing facility that has been modified to include an insulated and heated metal building to house the vessel and additional instrumentation. The outdoor firing site was built in the mid 1950s and had a small load limit of 2 kg, dictated by the proximity of other inhabited structures [3]. With the addition of the vessel to the firing site, the load limit was increased from 2 kg to 10 kg without endangering the other inhabited structures and actually decreasing the sound level at these structures. As a part of the renovation the electrical service was brought up to modern code by a complete rewiring of the firing site. This renovation has made CHEFF a clean modern facility in which to conduct explosive experiments.

A computer-based control system is currently under development. This system will not only monitor the vessel performance and operating controls, but it will also be an integral part of the data-gathering capabilities of the firing site and interlock-monitoring system for the firing controls. The data-gathering capabilities of CHEFF include, but are not limited to, laser velocimetry capabilities [4], digital oscilloscopes, streak cameras, image intensifier cameras, framing cameras, and digitizers. The operation of the instrumentation will be controlled and/or monitored by the computer system. Digitizers and digital oscilloscopes not used on any given experiment will be used to monitor the performance of the vessel by measuring strains. The measured strains will be analyzed and placed into a data base so that any long term deterioration of the vessel integrity can be detected.

CONCLUSIONS

Contained firing provides a practical solution to the increasing cost of performing explosive experiments and the encroachment of civilization on what were once remote firing sites. When CHEFF comes on line in late 1993, it will give the Detonation Systems Group (M-7) an invaluable tool for explosive experimentation that will not only be cost effective but also environmentally friendly.

ACKNOWLEDGMENTS

The authors acknowledge the hard work and cooperative attitudes displayed by both the Los Alamos team and the Southwest Research Institute team in bringing the vessel and renovation together in a timely manner. Without their hard work, dedication, and cooperation the merging of these two tasks would have been difficult, if not impossible. The people involved in this project are too numerous to mention individually, but a special thank you goes to: Ronald L. Rabie whose foresight and dedication made CHEFF possible, Thomas O. Davis for his untiring effort in preparing the statement of work, Doyle D. Simes for his major role in the facility design, Gary L. Green for his invaluable help in understanding the welding, steel selection, and mechanical processes, and Francis Caroline for his oversight and control of the fabrication effort.

REFERENCES

[1] M. A. Polcyn, E. D. Esparza and M. G. Whitney, *Minutes of the 25th Explosives Safety Seminar*, 1992.

[2] W. E. Baker, P. A. Cox, P. S. Westine, J. J. Kulesz and R. A. Strehlow, *Explosive Hazards and Evaluation*, Elsevier Press, Amsterdam, 1983.

[3] A. R. Martinez, S. A. Sheffield, M. C. Whitehead and H. D. Olivas, *New LANL Gas Driven Two-stage Gun*, This Conference, 1993.

[4] W. L. Seitz, H. L. Stacy and Jerry Wackerle, in *Proceedings of the Ninth Symposium (International) on Detonation*, ONCR Report 113291-7 pp. 157-169 (1989).