Soon to be rebranded as "Explosive Solutions Specialists" (ESS)

Gun Loading Facility

MENAPS-11-03 Gun Loading Facility (GLF)

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ABSTRACT

Our mission at Walker's Holdings Inc. was to produce a line of Gun Loading Facilities (GLF) capable of containing a significant accidental detonation of energetic materials within the structure's primary facilities. This includes the mitigation of primary and secondary fragments and the controlled venting of the explosion's combustion products that produce the blast over pressure and thermal-dynamic effects. The GLF includes a pipe handling system / loaded gun storage rack, a loading / processing area, and in some models an internal magazine facility.

Our intent was to provide a GLF structure capable of meeting and exceeding the new Q-D requirements as specified by NRCan (Canadian Regulatory Body) for the wire line industry and other industries of similar nature such as avalanche control, mining, military, and police force that utilize limited quantities of "packaged explosives". The GLF structure is designed to facilitate safe and economical energetics loading and storage. These structures provide a modular solution to scalability. As loaded energetic materials quantity requirements at a particular site increase, more structures can be added with a minimal impact on the land utilization footprint required as the "buffer zone". Conversely, these facilities can be re-located to other areas as market demands change, at a minimal cost of shipping and with minimal time and man-power requirements.

Analytical techniques and computational fluid dynamics (CFD) software programs were used in assessing the blast loads on the Walker's Holdings Gun Loading Facilities for a variety of situations. One aspect in the integrity of the GLF, and therefore the protection of surrounding personnel and structures, is the accurate prediction of blast loads on the GLF structural components, using analytical and advanced numerical tools taking into account the complexity of the structure, its geometry, and the surrounding environment. Functional Destructive Testing was also carried out on a number of occasions to obtain real world results to a variety of targets, providing: validation of various materials composition analysis; construction techniques; and assembly methodologies. Data gathered via this testing helped validate such things as jet, fragmentation and over pressure mitigation, sympathetic propagation of detonation, near target effects, and standoff distances for a variety of functions. Design and engineering of the Gun Loading Facilities is conducted through the utilization of AutoCAD 2006.

1 INTRODUCTION

Walker's Holdings Inc. is a privately held Alberta incorporated company in good standing, and is wholly Canadian owned. It was the first company in Canada to be licensed as a qualified door and explosive magazine builder to the then new NRCan door and magazine requirements. Meeting the market demands of the energetics storage and loading requirements, is our only business.

Industry History

The basis of our research and design was founded on three elements.

1.1 FEDERAL GOVERNMENT REQUESTS & CHANGING REGULATIONS

In response to the ongoing concerns voiced by NRCan. Explosives Regulatory Division to find a solution to the **quantity distance compliancy issues**.

Most present day loading bays do not adequately address the risk of injury to personnel and equipment should an accidental detonation or incident occur. In particular, blast over-pressure, and both primary and secondary fragments (shrapnel) generated by an incident can pass into adjacent open spaces or separated work areas injuring personnel who are not at all involved in the handling of explosives (categorized as D7) or into spaces of associated personnel (categorized as D4). To mitigate this risk, it has been proposed that in the near future any gun loading operations take place in a stand alone facility designed and built for handling perforating gun explosives, and that it will be isolated to provide a "safe quantity distance" between the loading operations and both adjacent related and unrelated shop personnel, and the public. As can be appreciated, this has complicated perforating gun loading operations, as it is often very difficult to provide safe quantity distance around the entire bay.

On April 20, 2005 NRCan released a 6 page document, of which the opening paragraph is quoted below.

> Effective immediately and until such time alternative tables are developed by the ERD-CERL Q-D Committee and accepted by the ERD policy group, it is proposed to supplement our existing Q-D Principles Manual for explosive materials and to adopt:
>
> a) NFPA 495/LCC5/Tb9.4.1/A05/ROC "Metric American Table of Distances for Storage of Explosive Materials As Revised and Approved by the Institute of Makers of Explosives" for quantities of high explosive up to 250 kg and IHBD to 600 kg (attachment #1).
>
> b) NFPA 495/L11/CA/A05/ROC Table X.3.3 (a) Minimum Intraline (Intraplant) Separation Distances Between Barricaded Operating Buildings Containing Explosives Division 1.1 or 1.2 Mass Explosion Hazard (attachment #2).

This table indicates minimum quantity distance (Q-D) measurements for the following categories:

- D1/D2 A) Inter-magazine, or B) Inter-process and magazine, and related processes.
- D4/D3/D5 Distance between unrelated process areas, personnel associated with licensed operations, parking lots and lightly traveled roadways.
- D6/D7 Distance between the public and personnel non-associated with the licensed operations, also distance to heavily traveled roadways.

ATTACHMENT #3 : 7 APR'05 SUMMARY

Q kg	D1	D2	D4	PTR D5	D7:	D6
1	0.8	1.8	9.1	15.5	21.3	
2	1.0	1.8	9.1	15.5	21.3	
3	1.2	1.8	11.7	15.5	21.3	
4	1.3	2.6	11.7	21.2	29.4	
5	1.4	2.6	11.7	21.2	29.4	
6	1.5	3.4	13.9	25.1	34.0	
7	1.5	3.4	13.9	25.1	34.0	
8	1.6	3.4	13.9	25.1	34.0	
9	1.7	3.4	13.9	25.1	34.0	
10	1.7	3.4	13.9	25.1	34.0	
11	1.8	3.7	15.6	29.0	39.0	
12	1.8	3.7	15.6	29.0	39.0	
13	1.9	3.7	15.6	29.0	39.0	
14	1.9	3.7	15.6	29.0	39.0	
15	2.0	3.8	15.6	29.0	39.0	
16	2.0	3.8	17.2	32.0	43.6	
17	2.1	3.8	17.2	32.0	43.6	
18	2.1	3.8	17.2	32.0	43.6	
19	2.1	3.8	17.2	32.0	43.6	
20	2.2	4.4	17.2	32.0	43.6	
21	2.2	4.4	19.5	35.6	48.2	
22	2.2	4.4	19.5	35.6	48.2	
23	2.3	4.4	19.5	35.6	48.2	
24	2.3	4.4	19.5	35.6	48.2	
25	2.3	4.6	19.5	39.5	48.2	
26	2.4	4.6	21.6	39.5	53.1	
27	2.4	4.6	21.6	39.5	53.1	
28	2.4	4.6	21.6	39.5	53.1	
29	2.5	4.6	21.6	39.5	53.1	
30	2.5	4.6	21.6	39.5	53.1	
31	2.5	4.6	21.6	39.5	53.1	
32	2.5	4.6	21.6	39.5	53.1	
33	2.6	4.6	21.6	39.5	53.1	
34	2.6	4.6	21.6	39.5	53.1	
35	2.6	4.6	21.6	39.5	53.1	
36	2.6	4.9	23.0	42.7	58.2	
37	2.7	4.9	23.0	42.7	58.2	
38	2.7	4.9	23.0	42.7	58.2	
39	2.7	4.9	23.0	42.7	58.2	
40	2.7	4.9	23.0	42.7	58.2	
41	2.8	4.9	23.0	42.7	58.2	
42	2.8	4.9	23.0	42.7	58.2	
43	2.8	4.9	23.0	42.7	58.2	
44	2.8	4.9	23.0	42.7	58.2	
45	2.8	4.9	23.0	42.7	58.2	
46	2.9	4.9	23.0	42.7	58.2	
47	2.9	4.9	23.0	42.7	58.2	
48	2.9	4.9	23.0	42.7	58.2	
49	2.9	4.9	23.0	42.7	58.2	
50	5	10	30	42.7	58.2	45.0

Q kg	D1	D2	D4	PTR D5	D7:	D6
60	5	10	32	42.6	62.8	45.0
70	5	10	33	46.0	70.0	46.0
80	5	11	35	49.2	70.0	48.0
90	5	11	36	52.2	74.8	50.0
100	5	12	38	55.0	74.8	53.0
120	5	12	40	60.2	79.6	55.0
140	5	13	42	65.1	84.5	60.0
160	5	14	44	69.6	84.5	63.0
180	5	14	46	73.8	92.3	65.0
200	5	15	47	77.8	92.3	65.0
250	6	16	51	87.0	100.0	70.0
300	6	17	54	95.3	106.0	75.0
350	6	17	57	102.9	112.0	80.0
400	6	18	59	110.0	118.0	83.0
450	7	19	62	116.7	121.0	88.0
500	7	20	64	123.0	129.0	90.0
600	7	21	68	134.7	141.0	95.0
700	8	22	72	134.7	145.5	100.0
800	8	23	75	137.4	155.6	105.0
900	8	24	78	142.9	165.0	108.0
1000	8	24	80	148.0	173.9	113.0
1200	9	26	86	157.2	190.5	120.0
1400	9	27	90	165.5	205.8	125.0
1600	10	29	94	173.1	220.0	130.0
1800	10	30	96	180.0	233.3	135.0
2000	11	31	105	180	270	140.0
2500	11	33	110	185	275	153.0
3000	12	35	120	205	305	163.0
3500	13	37	125	220	330	170.0
4000	13	39	130	235	350	178.0
5000	14	42	140	255	380	190.0

D1: extrapolation from 0 to 50 kg
NFPA Tables
D5: PTR 60 <Q<700 kg uses D7 = 5.5Q^1/2
D5: PTR 700 <Q<2000kg uses D5 =14.8Q^1/3
Existing Q-D Tables
D7: 700 <Q<2000 kg uses D7 = 5.5Q^1/2
Repeated or Modified Value for consistency

Table 1. NATO Reduced Q-D Table

1.2 PERFORATING SHOP EXPLOSION (Kenai, Alaska, April 2, 1994)

A known incident of an oil well explosives assembly facility destroyed as the result of an accident. As a basis of comparison, some details related to this accident are included as observation.

Perforating Shop Explosion

The following photos are of the Kenai, Alaska 1994 incident which resulted in one fatality and four other persons that were injured by shrapnel (primary and secondary fragments).

Front view of the building after explosion and subsequent fire that resulted from a barrel of methanol stored in the area, and the perforation of a gas line within the building.

View of the loading table & the rear of the destroyed building

View within the building. Note stored barrels and cap magazine in center of photo.

Close up view of loading table.

Interior view of a hole in the building's roof that was perforated by shrapnel.

Remnants of the detonator magazine, located within the loading facility.

Shop magazine, note debris left from stored charges within the magazine.

Shop floor littered with shaped charges, many of which did not detonate even during the fire.

Alaska Incident Conclusions

- Shrapnel/debris projectile from gun caused fatality.
- Over-pressure effects and building material shrapnel injured bystanders.
- Projectile pierced the building's roof after hitting a main roof support beam.
- Charge's jet stream pierced a barrel of methanol in the load bay.
- Charge's jet stream pierced overhead natural gas line in building.
- Explosion magnified by fire caused by gas and methanol fuel.
- Although loose charges and loaded guns were in bay, signs of sympathetic detonation were not reported in the Alaska Occupational Safety & Health report # 124076050.
- No disturbance of the stored detonators in loading bay reported.

1.3 PRESENT CANADIAN STANDARDS (PSAC Industry Code of Practice)

To comply with the industry pace, these present day guidelines give credibility to the explosive loading process incorporated into a blast resistant gun loading magazine.

While the development and implementation of rules and regulations for the importation, safe storage, and processes involving energetic materials (explosives) in Canada are the responsibility of Natural Resources Canada Explosives Divisions, organizations such as PSAC (Petroleum Services Association of Canada) work closely with government to provide integrated industry specific applications of these.

PSAC provides for its members several publications including:

- Perforating Industry Code Of Practice
- PSAC's Dangerous Goods Emergency Response Plan
- Transportation of Dangerous Goods Forms (specific to the industry)

During the various design phases and technology developments of equipment contained within the Gun Loading Facility, several member companies of PSAC were consulted on numerous occasions for their valued suggestion and critiques.

Gun Loading Facility History

Walker's Holdings is one of the largest specialty explosives storage manufacturers in North America, and produced magazines for every major explosives distributor and many of the explosives users throughout the country. Walker's Holdings developed the first Gun Loading Facility in 2001. We currently have our buildings in use by every major service company throughout the world. Since the GLF inception, the company has been working toward a "total solution" approach, which includes:

- ✓ GLF structure needs to be a portable, self-contained, stand alone facility
- ✓ GLF structure must securely and safely contain a loaded gun storage area, a processing area (gun loading area), and internals magazine(s).
- ✓ GLF must provide increased safety and productivity in the gun loading operation phase.
- ✓ GLF must be able to mitigate the blast effects resulting from a worst case scenario incident within the facility (maximum initiation of licensed NEQ/NEEQ per given area).

Product enhancement has been our major objective, with facility safety and productivity being our focused goals, thereby providing both risk management and limiting potential liability to our customers. To accomplish this several new methodologies and technologies have been developed:

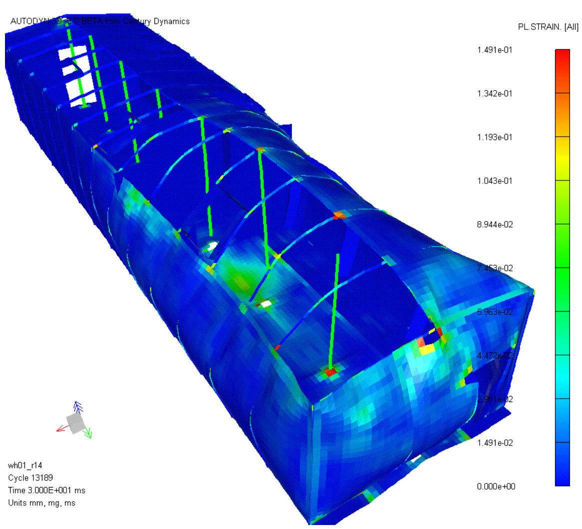
- ✓ Internal Explosives Storage Magazines within GLF.
- ✓ Blast Mitigation Walls.
- ✓ Increased Internal Storage Of Loaded Guns.
- ✓ Materials Processing Tables (providing minimal materials handling, increased proficiency, and safety.
- ✓ Reduced Q-D "footprint"
- ✓ Frangible translucent venting system provides improved venting while allowing ambient lighting within the facility.

2 SOFTWARE TOOLS

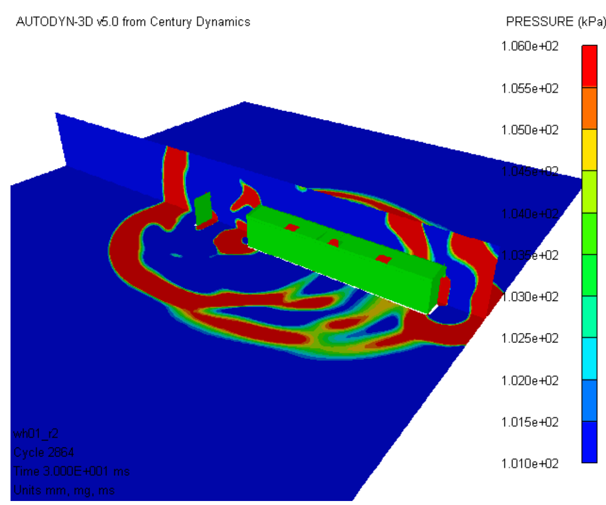
To undertake the design of the structural components of the Gun Loading Facility, several types of software was employed. This included software for the design and engineering of the structural layout, mechanical functions, materials flow paths, and human ergo metric analysis. Software was used for analyzing structural member responses to various loadings, as well as used for analyzing various blast scenarios in general. Finally, software for validation of the structure was done through finite element analysis, also known as computational fluid dynamics (CFD) modeling.

Program Name	Type / Application	Author	Description
AUTODYN-3D	Numerical - Finite Element Analysis	Century Dynamics Inc.	High explosive blast simulation with structural response, and nearby environmental response to air blast.
ADINA-FEM	Numerical - Finite Element Analysis	DOD	Finite element modeling, conservative in nature, structural analysis.
SDOF	Analytical	"Canned"	Single Degree Of Freedom (Q.C. quality control checks and verification)
CONWEP	Analytical	DOD	Scaling application
MathCAD 7	Analytical	MathSoft Inc.	Comparative assessments
AutoCAD 2006	Design	Auto Desk Inc.	Product design and engineering

Table 3. Software Tools



Example of CFD on plastic strain.



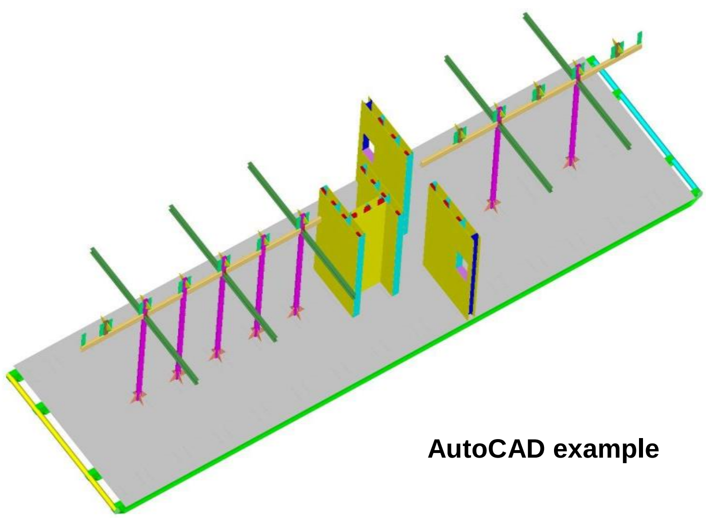
Example CFD of over-pressure propagation.

ANALYTICAL & NUMERIC METHODS

Walker's Holdings conducted various studies on the 16' x 58' GLF structure using three charge weights in various positions, including:

- 25-kg_{TNT} charge in the production area (and / or loaded gun storage area)
- 5-kg_{TNT} line charge in the production area next to the wall (simulating a single perforation gun in production)
- 25-kg_{TNT} charge in the magazine area.

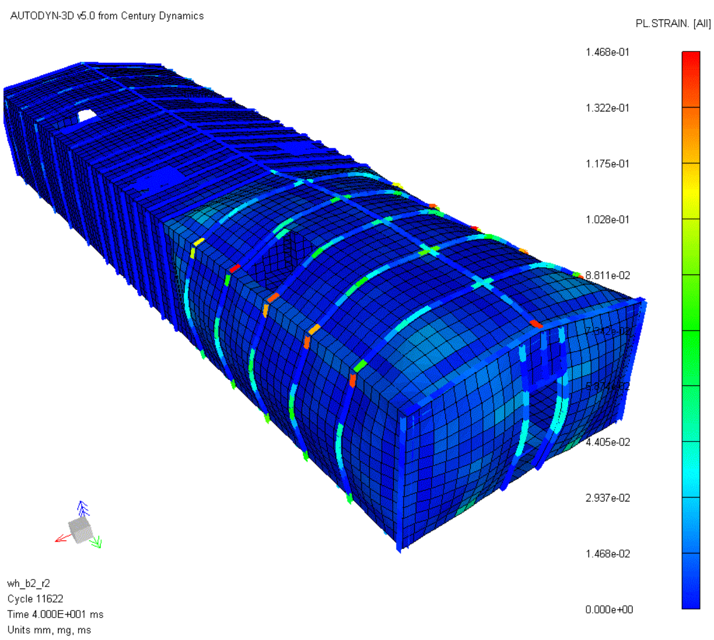
Two primary results for each threat scenario were determined. First, the quantity-distance (QD) relationships, or standoffs necessary for each threat to meet specified pressure levels were determined. Second, the structural response of the building was assessed. The structural response criterion is to sustain internal scenarios without failing catastrophically, potentially producing hazardous fragments. No response limit was set regarding personnel inside the facility or reuse following an event.



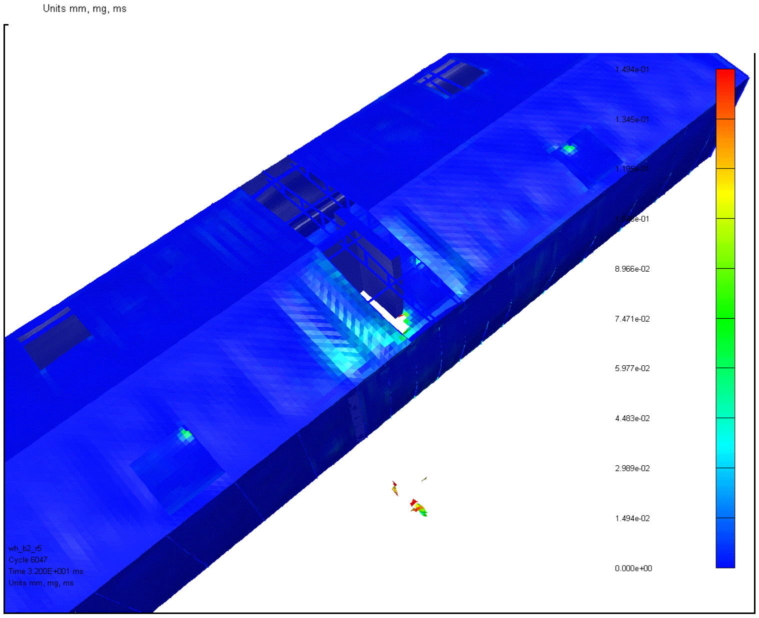
AutoCAD example

Analysis of the building performance for the 25-kg_{TNT} magazine area threat scenario includes moderate deflection (4.6-inch [117-mm]) of the adjacent wall and roof panels. The heavier framing in the magazine area of the building decreases the deflections and plastic strain significantly. It was determined that a frangible venting panel spanning two frames (48-inch [1219-mm]) and the entire width of the roof is necessary to prevent the highly directed blast pressures from producing roof panel fragments.

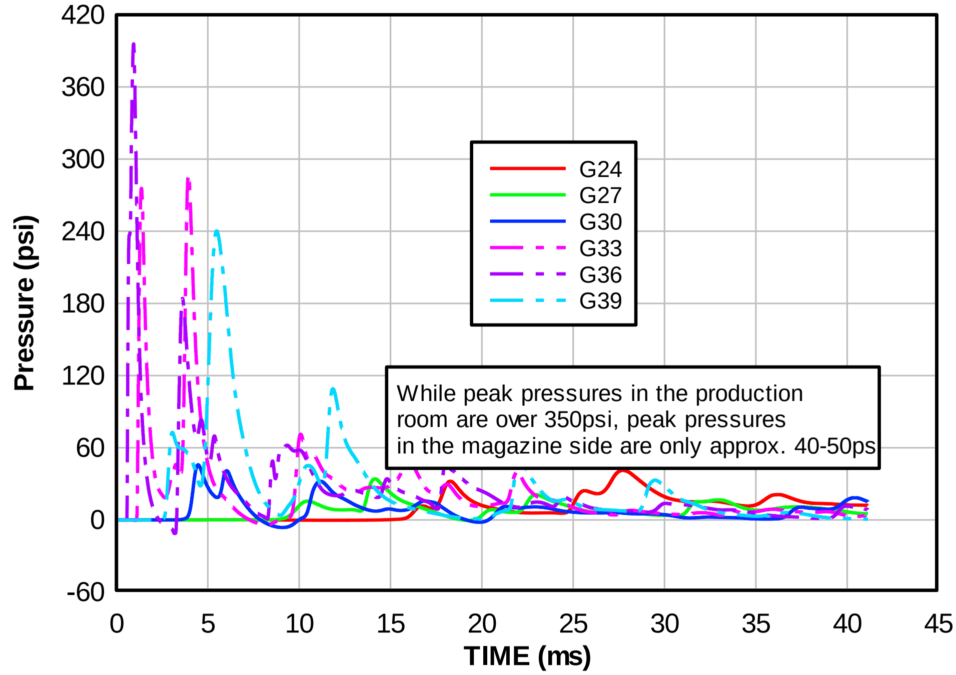
In the figure below, note the deformation of the walls and roof is significantly halted in the area of the mitigation walls and internal magazine. This is due to the significant mitigation walls, robust roof and wall framing on two foot centers in this area, These CFD runs were taken out to 40 msec, as by this point, momentum of various building parts had leveled off, indicating no more deformation would occur. This plot is showing plastic deformation.



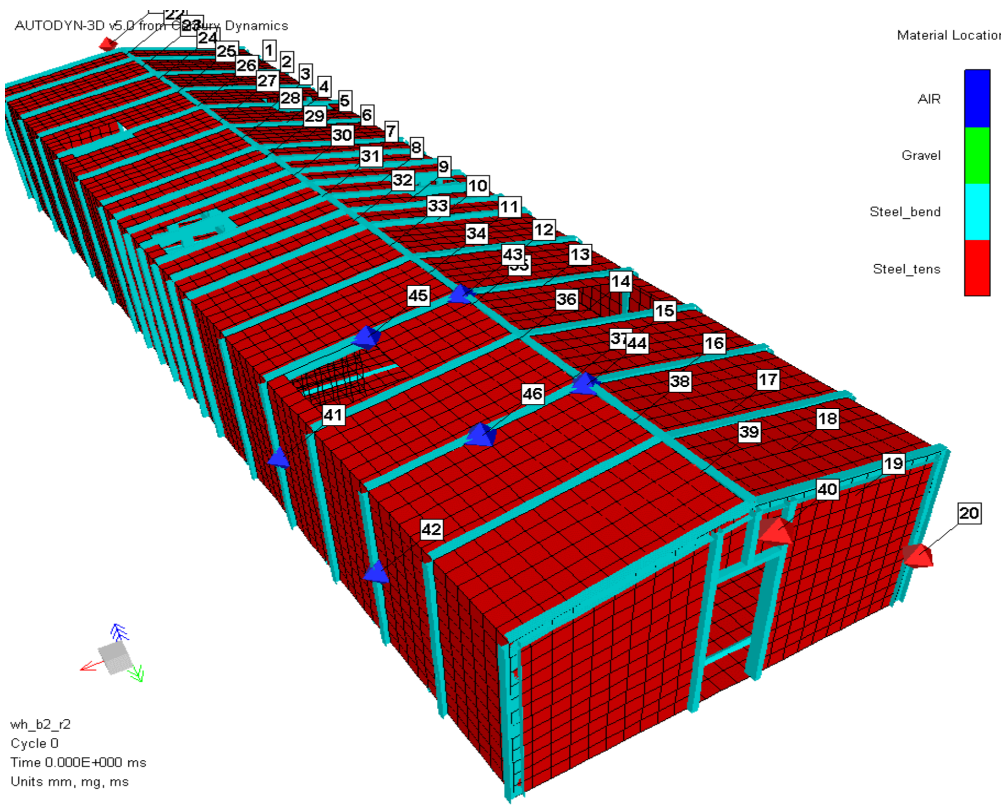
GLF structure 40 milliseconds after a 25-kg_{TNT} blast occurred in the processing area.



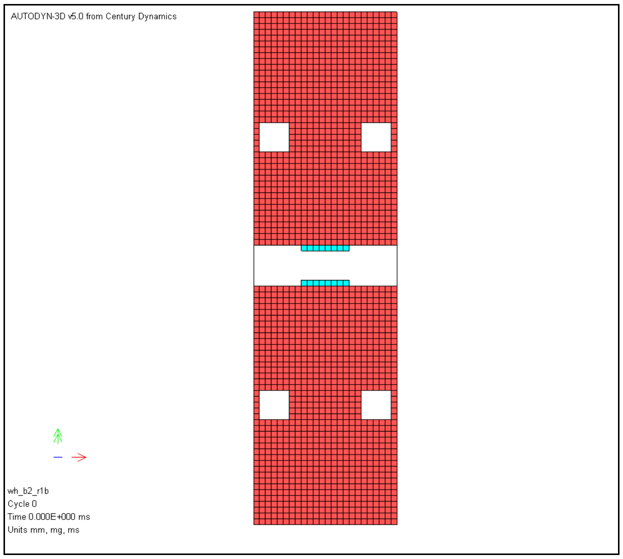
GLF structure 32 milliseconds after a 25kg_{TNT} blast occurred in the larger of the 1/3 – 2/3 mitigated central magazine.

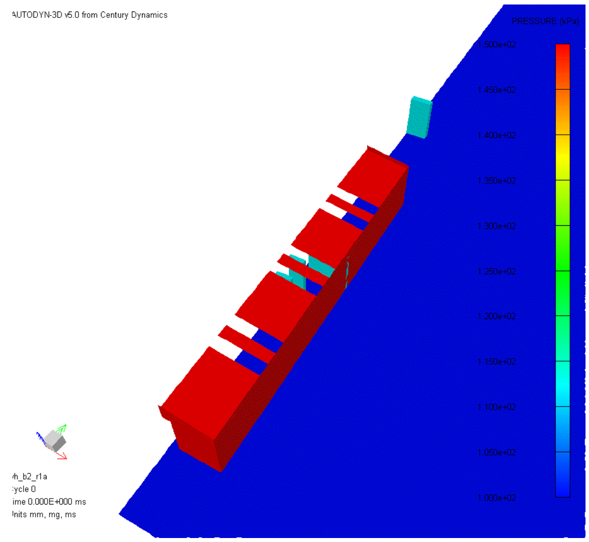


This graph demonstrates pressure versus time in milliseconds for the listed gauge points.

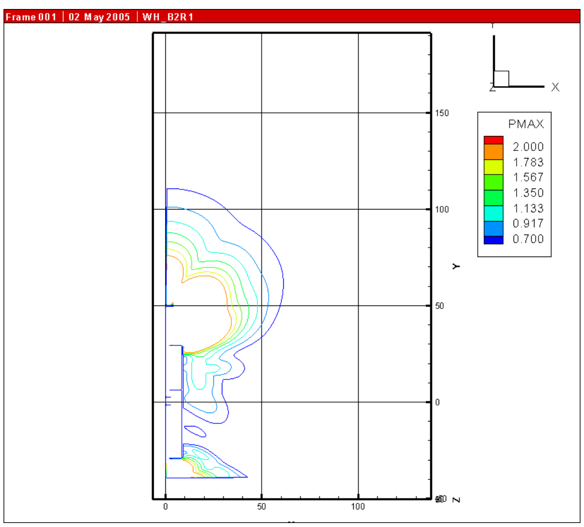


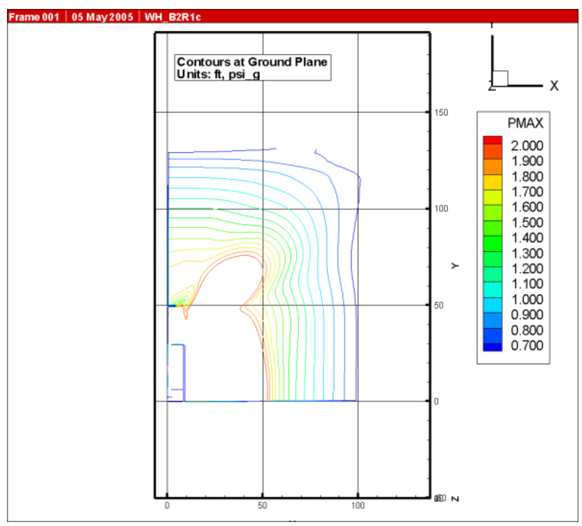
The figure above lists various gauge points that were set for data acquisition and analysis.



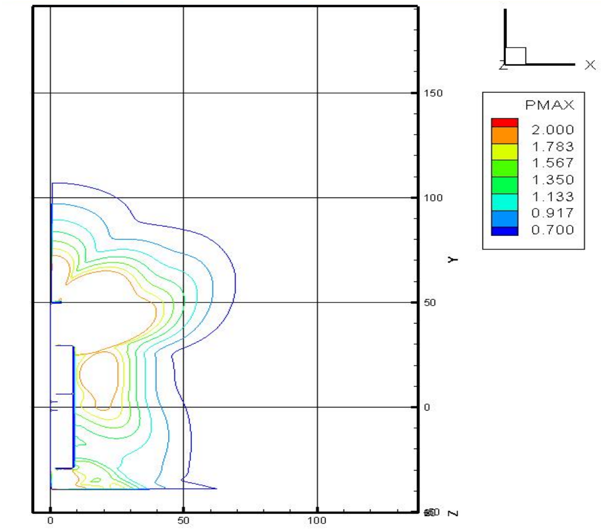


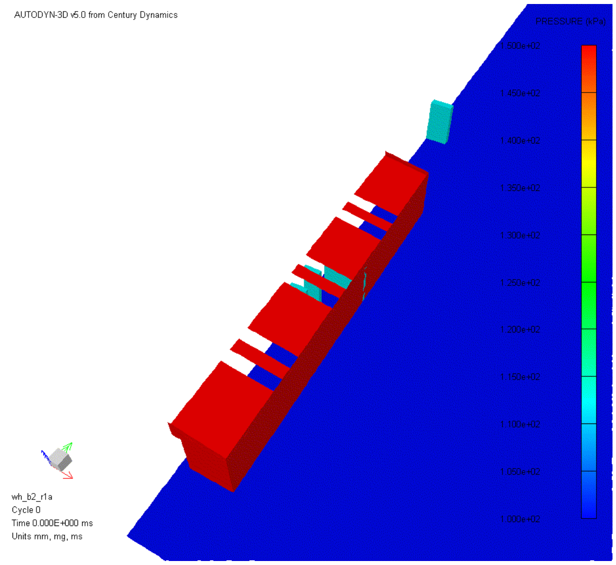
Various vent configurations were tested, and analyzed for performance in venting the internal pressures and associated structural response. Also reviewed were the pressure profile's various vent sizes created toward the ends and sides of the Gun Loading Facility. The vent sizing at either end of the building had significantly less influence overall than the size and shape of the vents over the magazine area for both structural response and pressure contour profiles.





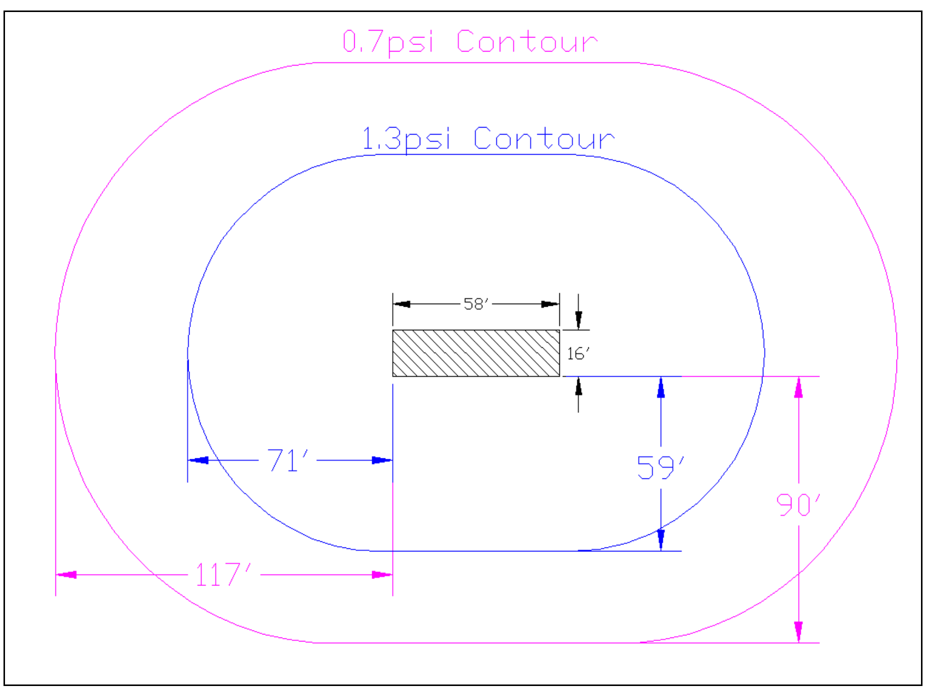
The pressure contours in the figure on the left show the maximum given pressures at specific distances for a 25-kg_{TNT} detonation occurring at either end of the facility with a conventional vent size, while the figure on the right shows pressure contours for a 25-kg_{TNT} detonation occurring on one of the two compartments of the internal magazine. The key numbers in these pressure contours are 0.7 PSI representing maximum pressure exposure to D7 classification, and 1.3 PSI representing maximum pressure exposure to a D4 classification. The figure on the left uses ½ the magazine structure down the Y axis, as this is this model's axis of symmetry (in other words, whatever happens on one side, also happens on the other side); while in the figure on the right, both X and Y axis of symmetry exist because the magazine is centrally located.





The pressure contours in the figure on the left demonstrate how making the vent size larger in the processing and storage sides of the building, changes the pressure contours. All vents have grating to provide security, and act as debris screens. The frangible panel vents have the added advantage of also allowing some ambient light into the workspace of the GLF, and for these reasons, have a long history in the roofs of explosives manufacturing plants throughout North America, for the same purposes.

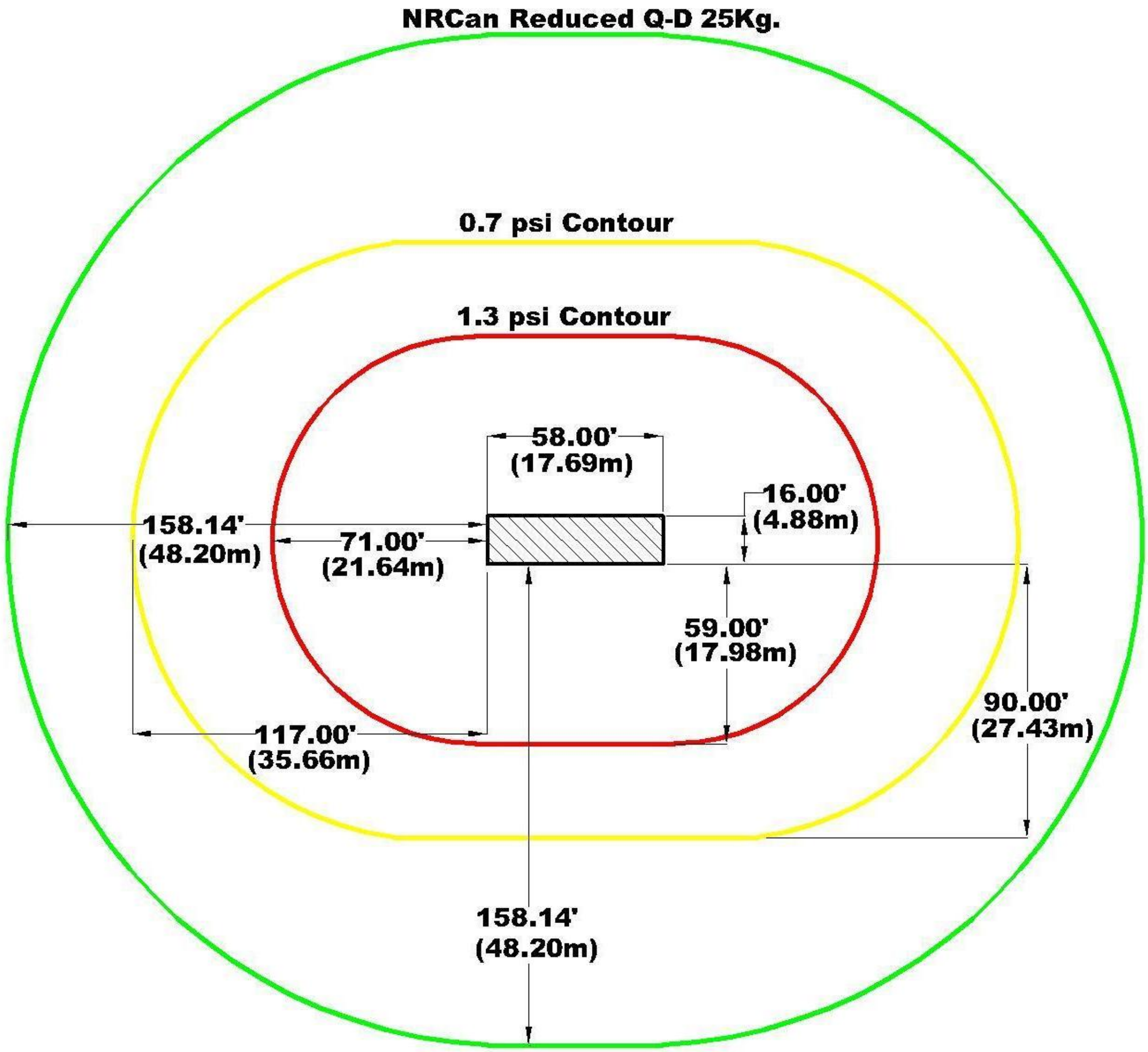
The pressure profiles from both 25 Kg events were then laid upon one another to develop the outer perimeters for both the 0.7 and 1.3 PSI contours, providing the minimum safe distances for these exposures. The diagram to the right indicates these findings.



16 x 58 GLF Simplified QD Standoffs

3 BLAST OVER PRESSURE EFFECTS

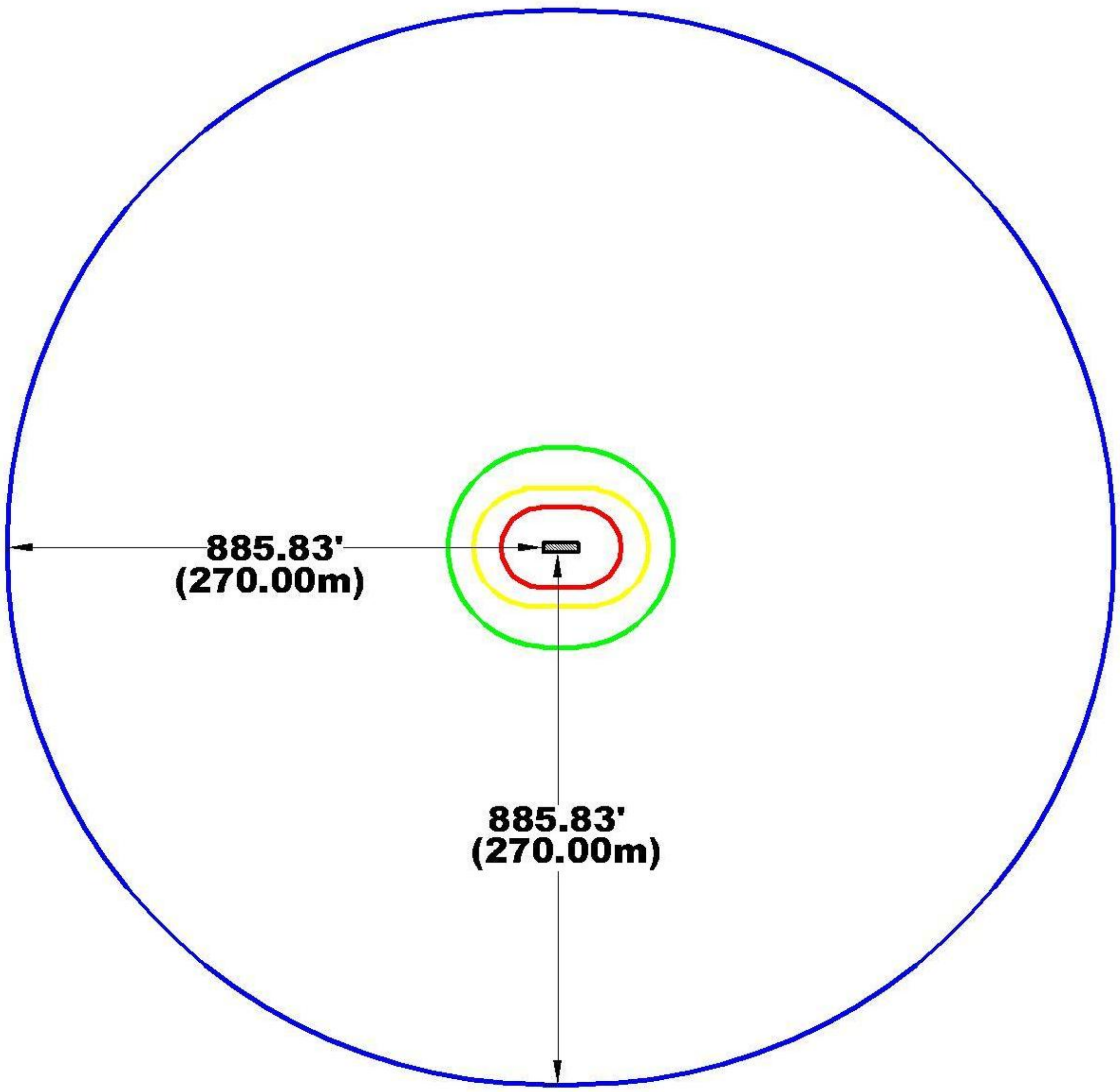
Computational Fluid Dynamics Modeling (CFD) and Finite Element Analysis (FEA) were utilized to develop pressure contour profiles around the Gun Loading Facility with the charge limits for each area of the Gun Loading Facility, as previously described. The following series of diagrams depict graphically the GLF capabilities at maximum NEQ/NEEQ in each area of the facility. Due to cost restrictions, data has not yet been developed to create similar graphical depictions with lower amounts or combinations thereof in each of the facilities areas, however it is anticipated to fulfill this function in the future.



Simplified QD Standoffs for 16 x 58 GLF having internal magazine (25kg NEEQ=125 Kg NEQ) + 25 Kg Loaded Guns + 25 Kg Processing Area

Diagram Key

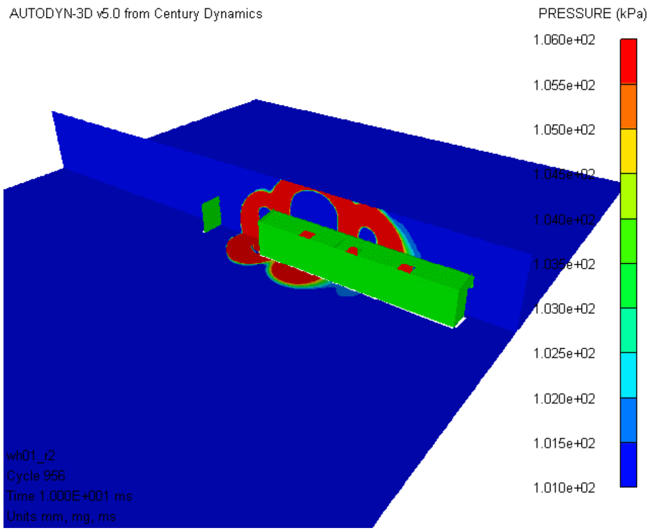
- Red line = D4 - 1.3 PSI (Authorized Personnel)
- Yellow line = D7 - 0.7 PSI (GLF Safe Distance)
- Green Line = NRCan “April 20, 2005 Revision of Q-D Requirements” (NRCan Safe Distance with Full Mitigation)
- Blue Line = NRCan Storage, Possession, Transportation, Destruction & Sale Manual (Safe distance without mitigation)



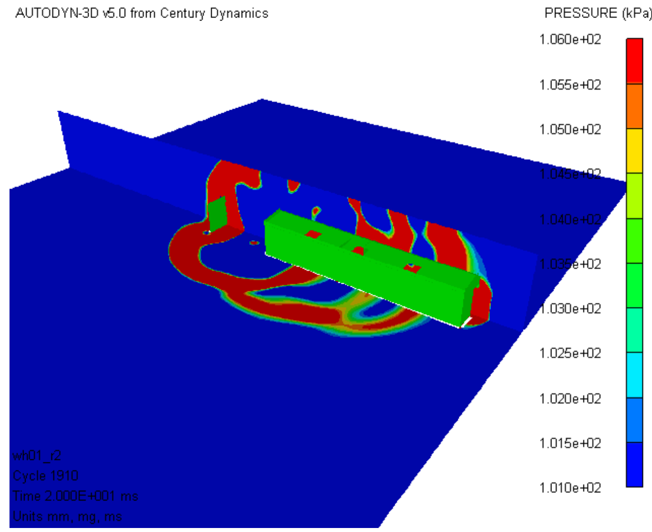
Simplified QD Standoffs for 16 x 58 GLF having internal magazine

(25kg NEEQ=125 Kg NEQ) + 25 Kg Loaded Guns + 25 Kg Processing Area

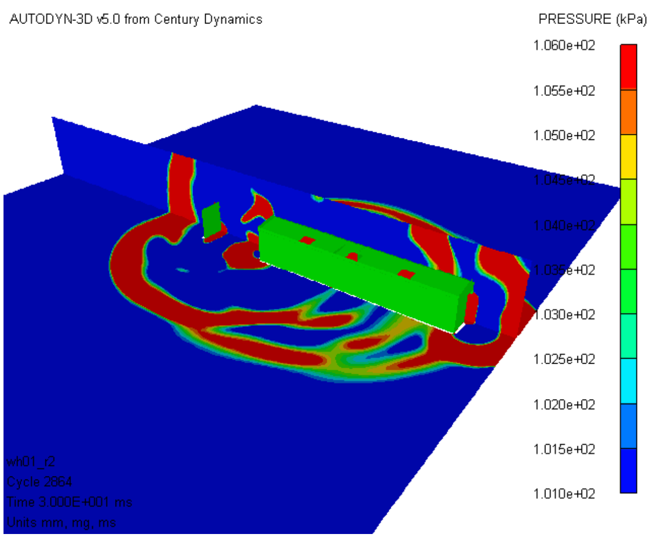
The following series of figures demonstrate the pressures around the Gun Loading Facility in 10 msec increments.



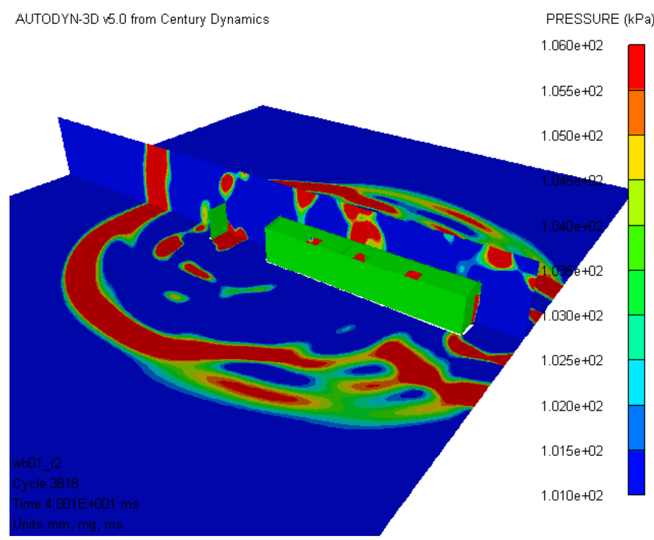
10 msec



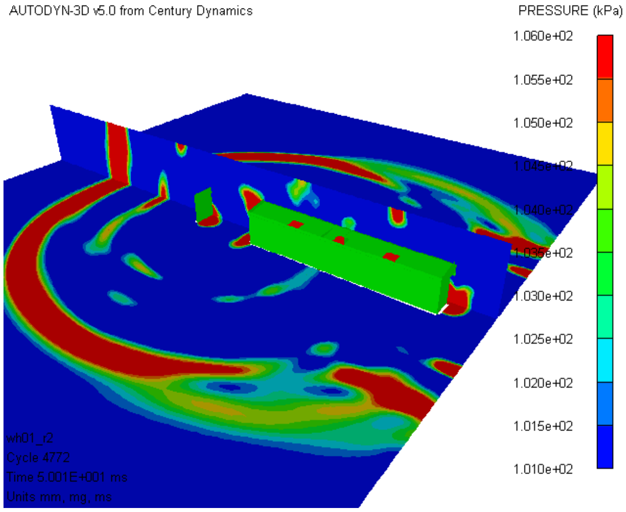
20 msec



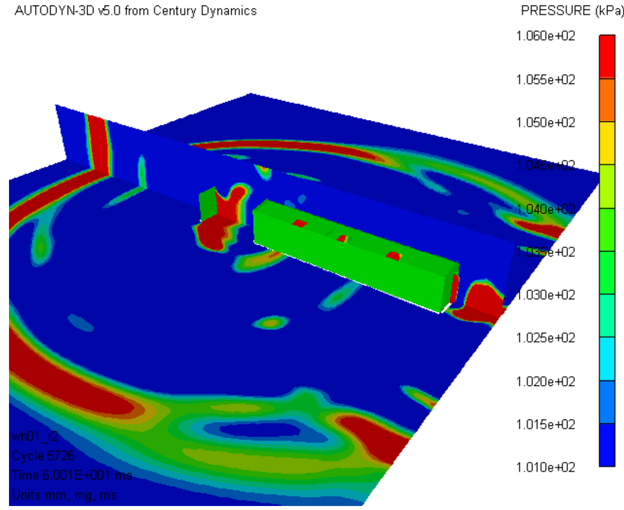
30 msec



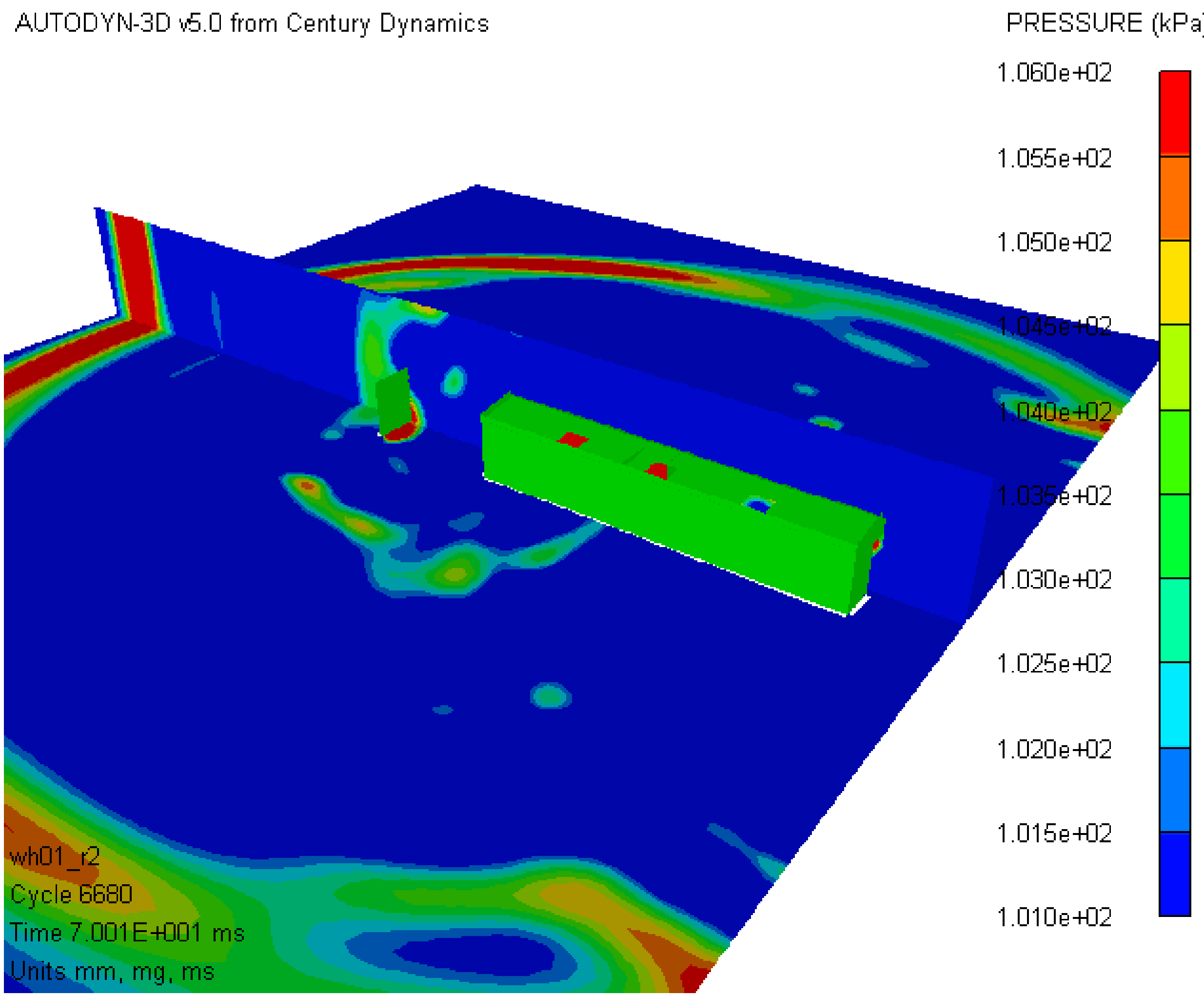
40 msec



50 msec



60 msec



70 msec

4 FUNCTIONAL DISTRUCTIVE TESTING

- Was carried out on a number of occasions to obtain real world results to a variety of targets, providing: validation of various materials composition analysis; construction techniques; and assembly methodologies. Data gathered via this testing helped validate such things as jet, fragment and over pressure mitigation, sympathetic propagation of detonation, near target effects, and standoff distances for a variety of functions.

4.1 Test Methodology

The test methodology utilized in the Walkers Holding Gun Loading Facility testing was modeled after the CANMET Canadian Explosives Research Laboratory report of 2004 –38 (TR), published December 2004. With the exceptions of:

- Witness panels were not utilized on either side or behind the charge holding stand, as the CANMET report states that the casings from the charges create fragments that will not penetrate 1/8" steel plate at 1.8 meters and the inside of the GLF
- As well as shooting at a standoff distance of 0.9 meters and 2.1 meters, Walkers testing also involved a number of tests at 10 inches and 2 inches standoff.
- CANMET testing utilized a steel frame with a 3.2mm thick steel plate bolted to this frame, which was then covered with 50mm ridged foam and craft paper. Walkers testing utilized standard rigid foam construction insulation 2" thickness (approx. 50mm) purchased as 4' x 8' sheets, these were cut into 2' x 2' witness panels. Panels were inserted onto pins that protruded 8" from the top of the stands. The first panel was placed as per CANMET tests at 3 meters behind the target being tested, however then two more witness panels were placed at 2 meter increments behind the first panel (with the objective of witnessing effects at various ranges). The first panel was covered in large graph paper. A laser was used to aim the charge and align the panels.
- The charge holder utilized in Walkers testing was a heavy steel plate with a 90° angle cut into it. Each charge was mounted in a 12" x 12" pieces of ridged foam that had a hole drilled about 3" x 3" from one corner of the panel.

4.2 Quality Control

Along with the physical testing of products, **Walker's Holdings Inc.** utilizes the latest technologies for R&D Through this extensive research, computer analysis and product testing Walker's has become a leader in the development of stronger, safer and more secure explosive magazines. This dedication to detail has earned recognition and certification from numerous compliance bodies.

- ISO 9001-2008 materials tracking and construction compliance, quality control, and certification.
- CWB – Canadian Welding Bureau compliance.
- IBC (International Building Code) standards compliance for materials and construction techniques.
- SODF - Single Degree Of Freedom (Q.C. quality control checks and verification).

5 Standard & Optional Components

5.1 Wiring / Lighting

The electrical feed to the GLF is normally provided via underground buried cable, and can be wire as 220 VAC single phase or three phase, as specified by the client at the time of ordering. All wiring, lighting and switches meet Class 1 / Div.1 and or Class 1 / Div.2 requirements. Wiring is done by a contract electrician, who draws permits for each facility.

5.2 Environmental Controls

Heating is provided by an electric Roughneck heater located in an expanded metal cage housing within the processing area of the facility. A second heater can be installed in the loaded gun storage area, as an option. Optional cooling the interior of the GLF is provided by an explosion proof air conditioning unit, these units can be installed windowed mounted or is special circumstances apply, roof mounted.

5.3 Fire Suppression

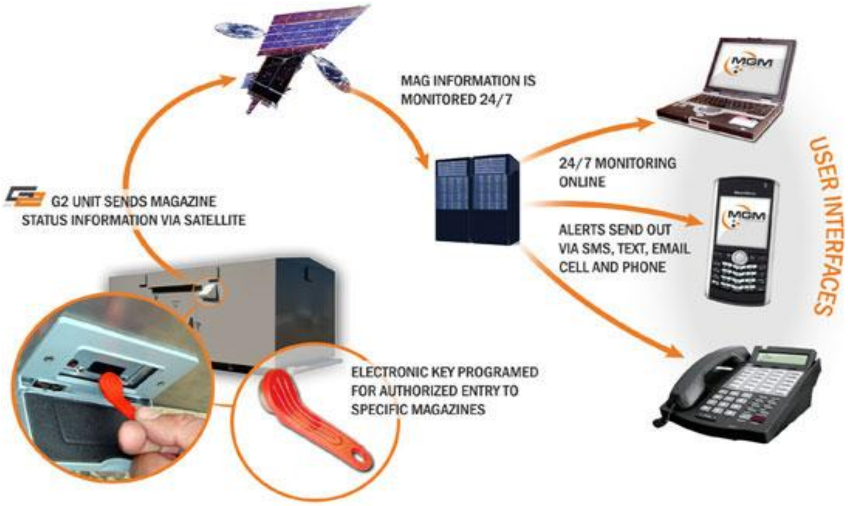
An automatic fire suppression system is available at the time of purchase as an option.

5.4 Lightening Detection

Automatic alarming lightening detection system is available as an option at the time of purchase.

5.5 Mag Guard Monitoring – Security Systems

Mag Guard Monitoring (MGM) specializes in providing security solutions for the storage of energetic materials including explosive magazines and nuclear storage compartments.



Conclusion

The work conducted within this project was intended to design a blast resistant building that will be able to offer a vastly improved solution to the industry. In conclusion, the main technical advancements in Gun Loading Facilities create a viable option to help minimize the hazards associated with oilfield explosives. (People, property and environment):

- It is designed to increase security.
- It offers safer solution to today's present loading practices.
- It can be scaled for different applications.
- It is economically more practical than moving entire operations from existing locations.
- It has been tested, proven and is available.
- It can be located and re-located anywhere, including remote oilfield sites.
- Responsible oil industry leaders have adopted **Gun Loading Facilities** without being mandated to do so.
- The design of a **Gun Loading Facility** is a product of feedback received from gun loaders, blasting experts and other industry leaders.
- **Gun Loading Facilities** are a practical solution to today's oilfield explosives industry's need.