

Effectiveness of Blast Mitigation in a
Containment Vessel by using Hydraulic
Energy Redirection

Research Proposal

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1. Introduction

When an explosive deflagrates or detonates it produces sound, heat, blast, fragmentation and large volumes of gaseous products. This is perfectly acceptable when it functions by design, but not so much when these effects occur unintended.

The ability to store and transport explosives safely is of great concern to the users. Explosives and articles containing explosives undergo stringent testing and classification to determine how it must be stored and transported in order to eliminate or reduce the effects of an unintended explosion.

Many High Explosives, both commercial and military, are deemed to be relatively insensitive and are unlikely to detonate unless sufficient stimulus is applied. There are occasions, however, where an explosive substance or article containing an explosive substance has an unknown history, or is deemed to be unsafe and potentially more sensitive. In these scenarios, it is common practice/procedure to segregate and isolate these prior to disposal. It would be advantageous to be able to place ammunition boxes that are considered to be unsafe in a containment vessel, in addition to these procedures, to further reduce the risk of harm to people and infrastructure.

There are several companies that have manufactured commercially available Total Containment Vessels (TCV). These are all made from high-strength steel, are gas-tight and are able to contain the effects of an explosion of up to approx. 8kg TNT equivalent. These TCVs are designed to put unknown or unsafe explosives inside and are commonly found at large transport hubs, but they are extremely expensive and can weigh up to 5000kg [1]. It isn't practical or realistic for many organisations that conduct explosives related work to have access to one if required.

The primary function of current ammunition or explosives containers is not to contain the blast products. Safety in storage and transport relies on the correct classification and storage procedures. Some High Explosives are classified and stored under the Hazard Classification Code (HCC) 1.4S, which means the packaging is designed to contain the majority of the energetic effects. These are designed primarily for low quantities of explosives. An example of this is the commercially available DCU 500 series of ammunition container which allows for detonators to be stored under HCC 1.4S, as opposed to 1.1B. The maximum Net Explosive Quantity (NEQ) for these containers is generally <20g so they are limited in their use.

This study will look at the effectiveness of using blast mitigating techniques to design a containment vessel in which existing explosive containers could be placed in order to reduce the blast effects if the contents within detonated. There appears to be a gap in the market for a vessel that can achieve this for quantities of explosives between 20g – 200g, and be both affordable and practical.

The following are the general requirements [2] of a containment vessel;

- The detonation shock and blast wave must be absorbed to avoid damage caused by impulsive loading.

- The containment vessel must have sufficient strength to avoid failure from the initial high pressures.
- Fragmentation must not escape the containment vessel.
- Acoustic emission from a containment vessel is not a major concern.

Below shows the damage to the human body that blast pressures can cause [3].

Critical Organ or Event	Maximum Effective Pressure (psi)*
Eardrum Rupture	
Threshold	5
50 percent	15
Lung Damage	
Threshold	30-40
50 percent	80 and above
Lethality	
Threshold	100-120
50 percent	130-180
Near 100 percent	200-250

* Maximum effective pressure is the highest of incident pressure, incident pressure plus dynamic pressure, or reflected pressure.

2. Background Research

As previously explained, it is vital to mitigate blast wave effects in the explosives industry. As a general rule, barricades made of soil, sand or concrete are used but these tend to be permanent fixtures. In 1998, an experimental study [4] was conducted to observe the effect of a water wall on blast wave mitigation in scale model tests. The results showed that the water wall was as effective as a rigid wall for reducing blast pressures immediately behind the wall, and also had the same mitigation as a rigid wall for distances further from the wall.

In another study [5] research into mitigating blast effects behind body worn personal protective equipment was conducted. This study used hydraulic energy redirection and release technology that aimed to mitigate the impact of blast shock wave by utilising the propagation and energy transfer characteristics of a blast wave in a liquid. The concept was to incorporate a layer of water filled plastic tubing, backed by a Kevlar plate. When the blast wave passed through the water tubes it used up energy by forcing the water through the tubes, resulting in a reduced pressure reading behind the Kevlar plate. The results demonstrated that a major part of kinetic energy of the blast shock wave can be transferred into hydraulic energy.

Hajek et al [6] conducted experiments hoping to increase the blast reduction of a barrier using different types of surfaces. Previous research has shown that the effectiveness of smooth surface barriers in reducing blast and shock wave pressure has been proven to be low. This particular study looked at the influence of various materials and shapes on the effectiveness of a barrier. The results showed that a barrier with rough and irregular surfaces produced similar blast mitigating effects to that of a larger smooth surfaced barrier. In addition to this, blast wave mitigation can be further improved by using materials that can deform. The deformation of a non-rigid material uses consumes energy (much like the crumple zone in a vehicle) and therefore it decreases the reflected overpressure.

Wadley et al [7] explored looked at concepts using cellular materials for passive and active blast mitigation. The passive method requires a cellular medium that compresses and dissipates the kinetic energy. However, in order for this to be realistic in most blast scenarios, the thickness of the material required is considered unfeasible. The alternative method is a cellular medium that is released (via some form of propellant) just prior to the arrival of the blast wave. This medium accelerates towards the blast wave and creates momentum opposing that of the blast. This was shown to achieve mitigation in a more compact solution than the passive method.

There are also many commercial organisations that sell blast mitigating products. One such company [8] uses advanced polyurethane foam and polyurea coatings to absorb some of the blast forces and helps to direct the blast energy away from infrastructure and people. This is primarily used in protecting critical infrastructure from an explosive event nearby.

2.1 Review summary

The water wall study [4] had a limited number of tests, but does show that water can be used as an effective barrier for blast. Water alone, however, will not achieve the requirements of containing fragmentation.

The concept of using an active mitigation technique, by using a reactive material that forces a mass towards the blast can be very effective but it does require sufficient distance between the explosive and the mass. This may be difficult to achieve in a containment vessel due to the time required for the reactive material to initiate. In the Wadley study [7] the distance between the explosive and cellular medium was much greater than would be possible in a containment vessel. Therefore, it is likely that by the time the reactive material initiates, the majority of the blast wave's energy has already passed it by.

The other blast mitigation methods described [6],[8] are effective at mitigating blast but they would be difficult to replicate in a containment vessel i.e. the vessel would have to be impractically large to contain 'crumple zones' or vast amounts of polyurethane foam.

The concept of converting the energy of the blast wave into other forms of energy by forcing the blast pressure to push water out of the containment vessel and vent has shown success in reducing blast pressures. It can be replicated in a containment vessel and therefore it is this method that is being proposed to take forward in this study.

3. Aims and Objectives

3.1 Research Purpose

To determine if the method of hydraulic energy redirection can be incorporated into a containment vessel that successfully reduces the effects of blast and fragmentation to an acceptable level.

3.2 Objectives

- To study and collate a variety of blast mitigation techniques that have proved successful in reducing the blast effects.
- To select a method that is feasible/practical and can be scaled down and be reproduced in a containment vessel.
- To design and develop containment vessel prototypes with various methods of hydraulic energy redirection
- To test (trial) these prototypes against varying quantities of explosives
- To evaluate the results of these tests

3.3 Outcomes/deliverables

The outcome is to produce a prototype blast containment vessel that uses hydraulic energy redirection to convert blast energy into kinetic and hydraulic energy, thereby reducing the explosion effects outside of the vessel. It is hoped that this containment vessel can be used to store standard ammunition containers and reduce the effects of an explosion, if one occurred.

4 Experimental Design

4.1 Project Design Outline

This project is an experimental evaluation of the effectiveness of using hydraulic energy redirection in a containment vessel. Several containment vessel prototypes will be designed and tested with different variables. These variables are;

- Quantity of water (i.e., the thickness of the water barrier surrounding the internal container)
- The water tube pattern (i.e., vertical tubes or circular)
- Materials used to enclose (sandwich) the water tubing (Steel or Kevlar)
- Quantity of explosives detonated (20g, 50g, 100g, 200g TNT equivalent)

The prototypes will undergo explosive testing and the data will be recorded, compared and evaluated.

This project hopes to develop a product that shows improved blast reduction capability and could be used to store boxes of explosives of unknown or unsafe condition to further mitigate the risks of injury to nearby personnel.

Reliability and validity - The experiment will be repeated in order to show a reliable set of results. The experiment will be conducted with materials and energetics of known characteristics.

4.2 Data collection

The primary data to be collected is the overpressure of the blast wave. Multiple pressure gauges will be situated in all directions surrounding the containment vessel, including above, and at varying distances. This data is being recorded to show the effects of localised near field blast pressure. These readings can be compared for each of the prototypes, and also to that of previous research.

Another major design function of the containment vessel is to prevent the escape of fragmentation. The fragmentation effects will be recorded by way of fragmentation screens situated around the containment vessel.

High speed video of the blast will also be recorded. This will help to show how the blast wave propagates through the containment vessel and show possible weak points in the vessel that may need to be addressed.

Images of container pre and post explosion will be recorded to show the effects visually.

The data from the pressure gauges will be compared and the fragmentation screens will be inspected. The results will be compared with the blast injuries pressures to determine if the reduction in blast pressure is sufficient to continue the development of the containment vessel and conduct further testing.

This research project will not look at the effects of the venting gas and water and how they might cause harm to nearby personnel. This data is more difficult to capture. If the testing proves that hydraulic energy redirection is effective against the major hazards, i.e. it reduces the blast sufficiently and is also successful in containing fragmentation, then further testing can be conducted to look at the effects of the vented products.

4.3 Risks & Limitations

4.3.1 Health & Safety

All personnel involved in the trial phase will be trained and competent in the handling of energetic materials.

A risk assessment and Trials Plan will be written and authorised by Line Management and the Health & Safety team.

Limitations – The research must be conducted in line with all safety documentation.

4.3.2 Financial

Due to a general reduction in research funding across MOD there are limited funds available. Where possible, where this research links into an existing work project, project funds can be acquired. The apprenticeship team also have additional funding that can be used to ensure the research is completed.

Limitations – The research will have a maximum budget allowance that will influence the scale of the trial phase.

4.3.3 Technical

This research relies on key personnel remaining employed by DSTL. Collaboration with experts outside of DSTL may also be required to assess the findings of the research.

The introduction of further blast mitigating techniques may result in other factors that need to be considered such as; increased cost to manufacture, increased size of container.

Limitations – The trial phase of the research must adhere to the Explosive Range limits. The principal researcher may have limited access to previously published research where expensive subscriptions are required.

5 Resources and planning

5.1 Resources Required

Manpower - Trials team, H&S, Management approval

Range facilities – Suitable Range to conduct explosive activities

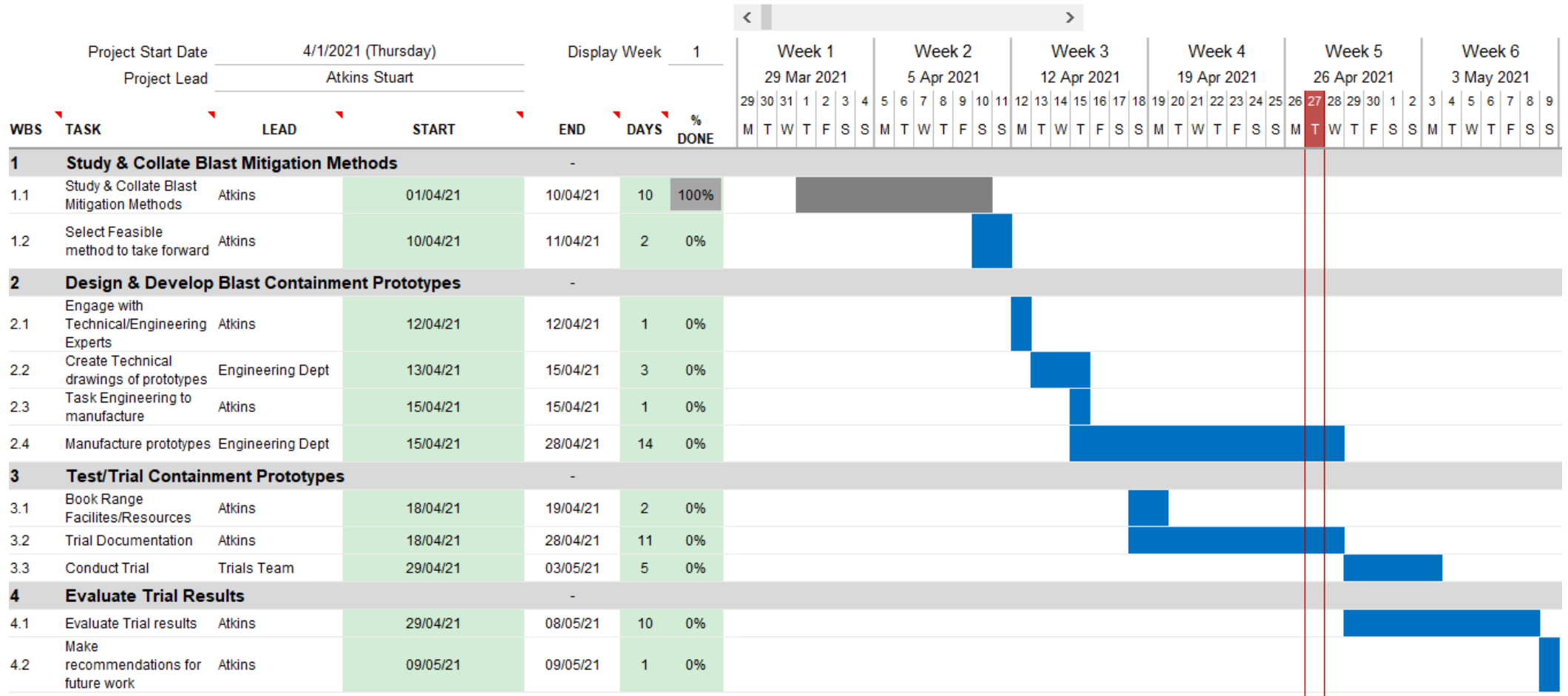
Energetics – Detonators, High Explosives & initiating accessories

Instrumentation – Pressure gauges, High Speed video and associated monitors and cabling.

5.2 Gantt Chart

Blast Mitigation Containment Project Schedule

Gantt Chart Template © 2006-2018 by Vertex42.com.



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