Measuring the Blast Output of Aluminized Explosive Charges in a Semi-Confined Environment

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The semi-confined Vertically Launched Impulse Plate (VLIP) apparatus was devised to measure of the relative blast output of explosive compositions. The apparatus was used to study the output of two series of aluminized explosive charges of 300g and approximately 900g. In each series the amount of aluminium was varied between 0% and 30% by mass. Besides the primary measure of output of the VLIP, secondary measurements by means of pressure probes and momentum gauges were also made. The method quantified the relative impulse reliably and the results show that if equal volume charges are considered, significant gain in impulse is obtained with the aluminized charges in this environment. However, it also show that the *mass weighted* impulse of the aluminized charges are not significantly higher than the charges containing no aluminium.

INTRODUCTION

The field of Blast Enhanced Munitions (BEM) has been an area of considerable interest internationally lately, particularly in connection with hard target defeat applications [1-2]. The blast output of all explosive compositions, including insensitive munitions, is an important performance parameter. Most commonly the blast output of BEM are characterised in an enclosed facility by means of pressure measurement [1,3], in order to capture the full potential of the afterburning compositions. There are two complications with this approach, namely that most of these munitions will function in an environment that will vent dynamically in practice and secondly, the cost of establishing such an enclosed facility infrastructure. Various small scale approaches have also been investigated for characterization of these explosive compositions [4-5] but it is also of interest to know what the scaling behavior of these compositions are in relation to the confining environments.

In this study a semi-confined apparatus have been devised to measure the relative blast output of explosive compositions by means of the Vertically Launched Impulse Plate (VLIP) method [6]. The aim was to be able to experiment with charges of up to 1kg mass in a semi-confined environment in this apparatus and to be able to directly obtain a single valued parameter representing the relative output of the explosive composition. The design and application of the apparatus as well as the results obtained with two series of aluminized explosive compositions are reported in this paper.

THE VLIP APPARATUS AND THE EXPERIMENTAL LAYOUT

The semi-confined VLIP apparatus consists of a 30mm thick rolled steel cylindrical vessel of diameter 1.5m. The cylinder has a length-to-diameter ratio of 1. Hoops of 30mm thick steel was welded onto the outside of the cylinder, with approximately 100mm spacing between the hoops, to strengthen the apparatus. The bottom of the cylinder was left open and the cylinder was suspended on four legs 300mm above the ground to allow venting and access for hanging of the charge. A heavy circular plate (lid) was placed symmetrically on top of the cylinder with a calibrated mast fastened onto the plate in such a way that it would move with the plate when it is launched upward by the detonation. Measuring ports for the pressure sensors exist at 90^o intervals in the circumference at three axial positions on the cylinder. A schematic drawing and a photograph of the semi-confined VLIP apparatus with the top plate in position, is shown in *Figure 1*.

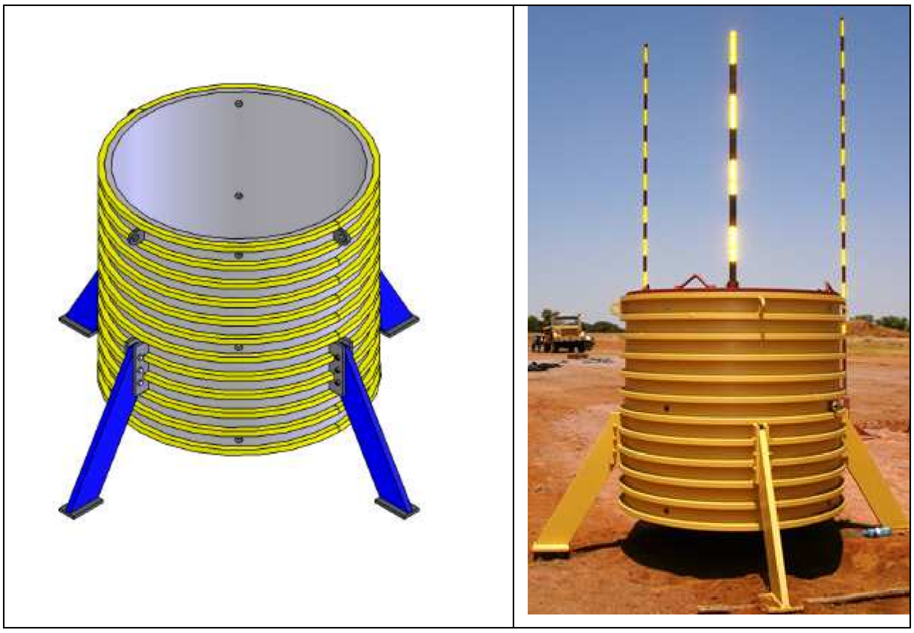

Figure 1 Schematic representation (left) and a photograph (right) of the semi-confined VLIP apparatus

When the VLIP is accelerated by the detonation event the trajectory of the mast (or the plate, if it is not obscured by the fireball or the detonation products) is captured on a high speed video recording (normally around 10000 frames per second). The impulse is derived from the motion of the lid in two independent ways, by measuring the height that the plate is lifted, as well as by analyzing the displacement of the plate as a function of time from the high speed video recording. This is obtained from monitoring the pixels in the digital recording frames and using the mast calibration marks as a measurement scale. A typical recording of the displacement versus time is shown in *Figure 2*.

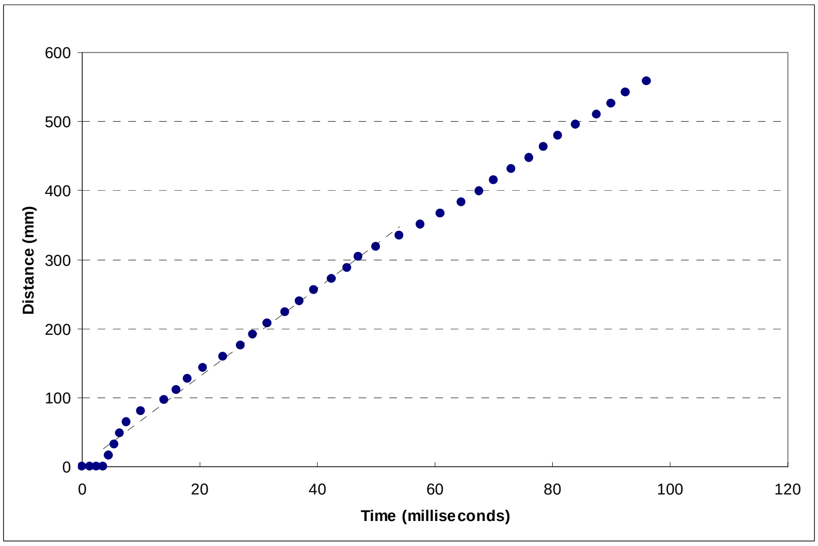

Figure 2 Displacement versus time of the VLIP as measured off the high speed video recording (367kg plate and 300g charge)

The charges are hung from the lid in a wire cradle in the centre of the apparatus in such a way that it is on the symmetry axis of the VLIP apparatus as well as in the middle of the cylinder.

Two static overpressure PCB137 probes were positioned in the VLIP apparatus wall directly opposite each other and level with the charge in clamping fixtures. These fixtures were fasted into the apparatus by means of heavy threads. On a line perpendicular to this orientation but on the same level, a momentum gauge and a Kulite 11-375M reflected pressure sensor was also similarly fixed. The momentum gauge consisted of a steel barrel with two laser gates to measure the velocity of a cylindrical mass projected out of the barrel over a distance of 100mm. The barrel diameter was 25mm and an aluminium cylinder of mass 75.5g was used in the momentum gauge. A digital oscilloscope was used to monitor the laser receiver output as well as the output of the pressure sensors. Five average velocity measurements can be obtained from the momentum gauge output. The pressure probes inside their fixtures and the momentum gauges are shown in *Figure 3*. A typical recording of the momentum gauge is shown in *Figure 4* and a typical output of the overpressure sensors are shown in *Figure 5*. A Photron high speed digital video camera was placed approximately 50m from the VLIP apparatus. Vertical masts with calibration marks were also placed behind the VLIP apparatus for additional distance calibration on the high speed video frames.

Figure 3 (from left to right) Reflected pressure sensor, overpressure sensor fixture and momentum gauge

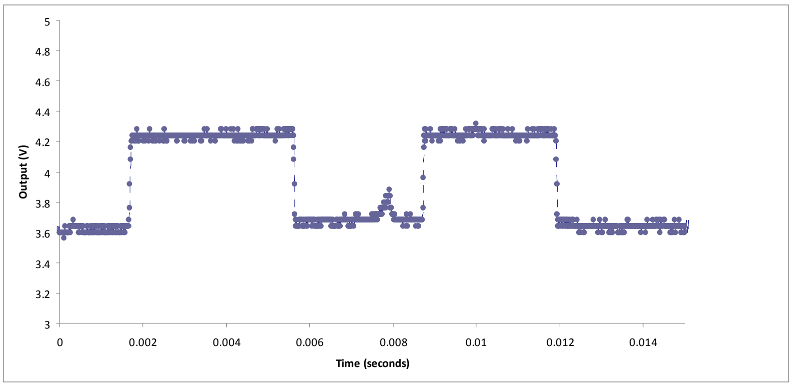

Figure 4 Typical output of the momentum gauge measuring system

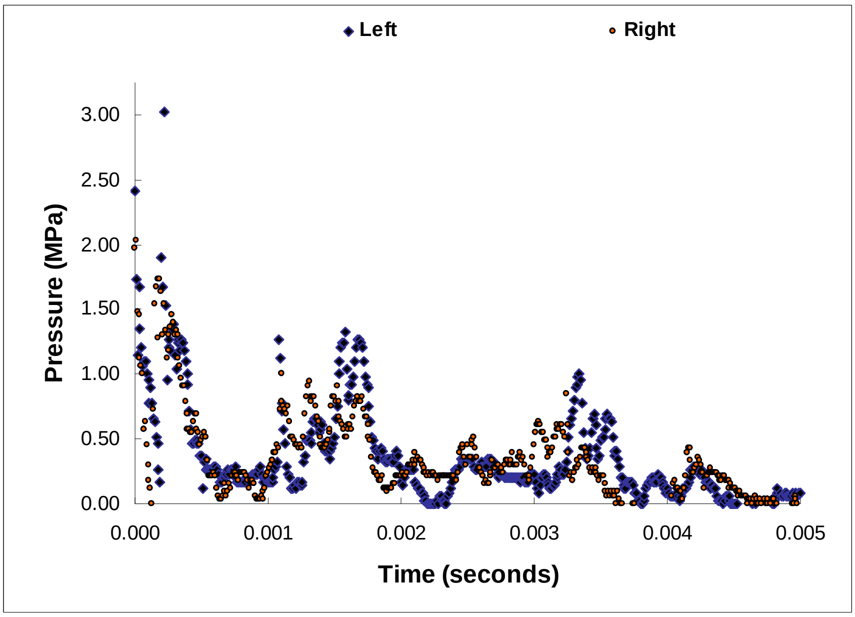

Figure 5 Typical output of the overpressure sensors (two directly opposite sensors)

EXPLOSIVE CHARGES

Two different series of RDX based cast PBX charges were made by Rheinmetall Denel Munition (RDM) for separate tests. In the first series charges containing no aluminium, 20% aluminium and 30% aluminium by weight were used. In the second series charges containing no aluminium, 15% aluminium, 20% aluminium and 25% aluminium were used. In both series of charges two mass classes of approximately 300g and 900g were used. The smaller charges had diameters of 60mm and the larger charges diameters of 90mm. All charges had an L/D ratio of 1. In *Table 1* below the designation, composition and other attributes of the charges used are shown.

Table 1 Explosive charges used in the two series of tests

Series	Designation	Size	% Al	Density (g/cc)
Series 1	RXHT8403	Small	0	1.55-1.57
		Large		1.56-1.57
	RAHT6401	Small	20	1.65-1.67
		Large		1.67-1.68
	RAHT5401	Small	30	1.71-1.73
		Large		1.72-1.73
Series 2	RXHT8405	Small	0	1.57-1.58
		Large		1.57-1.59
	RAHT6901	Small	15	1.62-1.64
		Large		1.62-1.64
	RAHT6402	Small	20	1.66-1.67
		Large		1.65-1.67
	RAHT5901	Small	25	1.69-1.70
		Large		1.68-1.69

All the charges were initiated in the downward direction with standard military detonators and a 38mm diameter CH6 booster of 55g.

RESULTS

Two firings were conducted with each charge type to asses of the variation in the measured output from shot to shot. In *Figure 6* the "specific impulse" of the VLIP is shown for the different series of firings. The specific impulse was obtained by dividing the maximum momentum of the plate with the surface area of the plate. It can be noted from *Figure 6* that although the variation between results of similar firings are typically very small, a larger variation was obtained between series 1 and series 2.

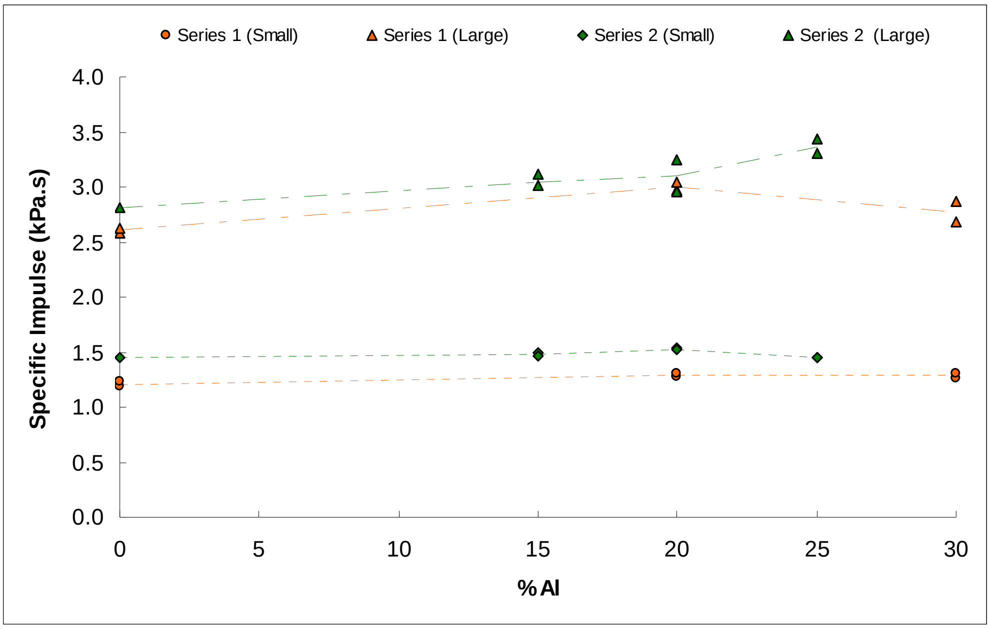

Figure 6 Specific Impulse calculated from the VLIP results

The momentum gauge average velocity measurements for the small charge firings are shown in *Figure 7.* It can be seen that the cylinder actually decelerates before exiting the barrel due to external pressure build-up of the expanding gasses from the top and bottom of the VLIP apparatus.

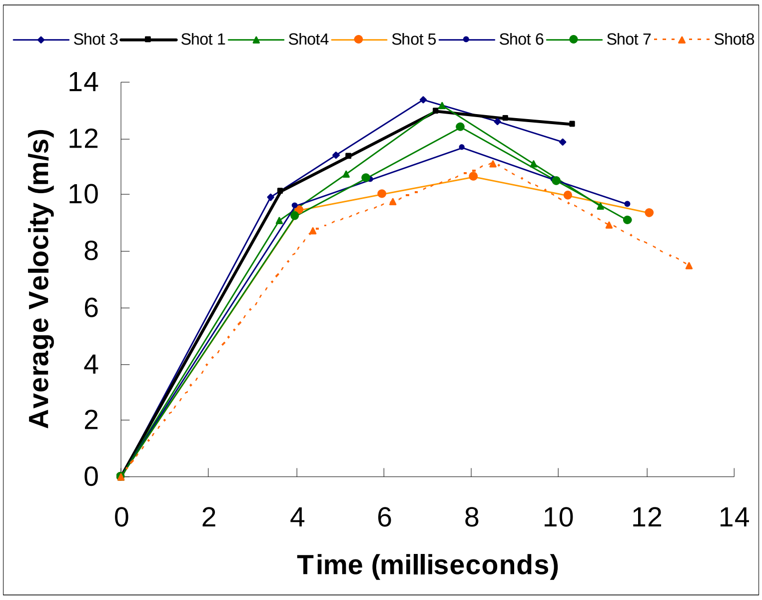

Figure 7 Momentum gauge average velocity measurements

From the average velocity measurements obtained from the momentum gauges, the average of the first, second and third measuring points was used to obtain a specific impulse value. A comparison of these impulse values with the values obtained with the VLIP method is shown in *Figure 8* for series 2.

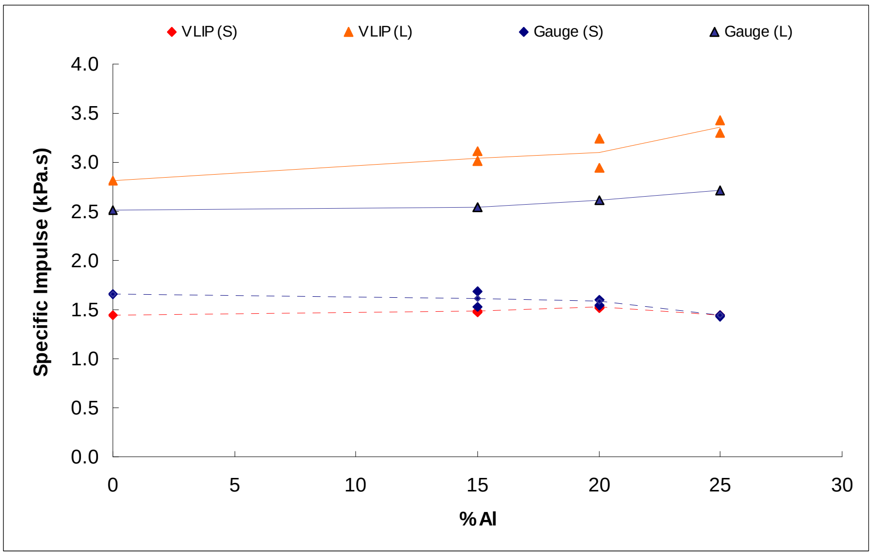

Figure 8 Comparison of the Gauge and the VLIP Measurement

Although both the overpressure and reflected measurements yielded interesting information on the pressure build-up and reflected shocks inside the VLIP apparatus (see *Figure 5*), the measurements were not consistent enough to obtain integrated impulse values. A late time 'drift' in the overpressure sensors was observed, and although the reflected pressure sensor used yielded excellent results of the incident pressure pulse it could not be used to quantify the important afterburning behaviour of the compositions in the later time regime.

DISCUSSION

It can be noted from *Figure 6* that the direct measurement of the relative blast impulse of the charges by means of the VLIP method gives reliable values as measured in terms of the variation between similar shots of each series. The variation between the two series sets was traced back to the venting arrangements that existed beneath the VLIP apparatus during firings of the two series of charges. With series 1 the trench that was dug to allow easy access for placing of the charges inside the VLIP apparatus, was left uncovered during the firings and in series 2, metal plates were used to cover this trench. This serves also as illustration of the sensitivity of the blast output to the degree of confinement.

It can also be observed from *Figure 6* that the general trend of the two series of firings are similar. A general optimum can be observed for these specific charges at between 20% and 30% aluminium. There are however, a qualitative difference between the smaller charges and the larger charges. With the detonation direction downward more detonation products escapes from the bottom of the apparatus. With the smaller charges not enough aluminium remains available in the apparatus to obtain for optimum reaction with the volume of air, while the abundance of aluminium in the larger charges still saturates the apparatus. This illustrates an important difference between confined and semi-confined testing of these type of charges. It is interesting to note that if the blast impulse obtained is divided with the mass of the explosive used (i.e. *mass weighted* impulse) very little gain is obtained with the aluminised compositions. This is illustrated in *Figure 9*.

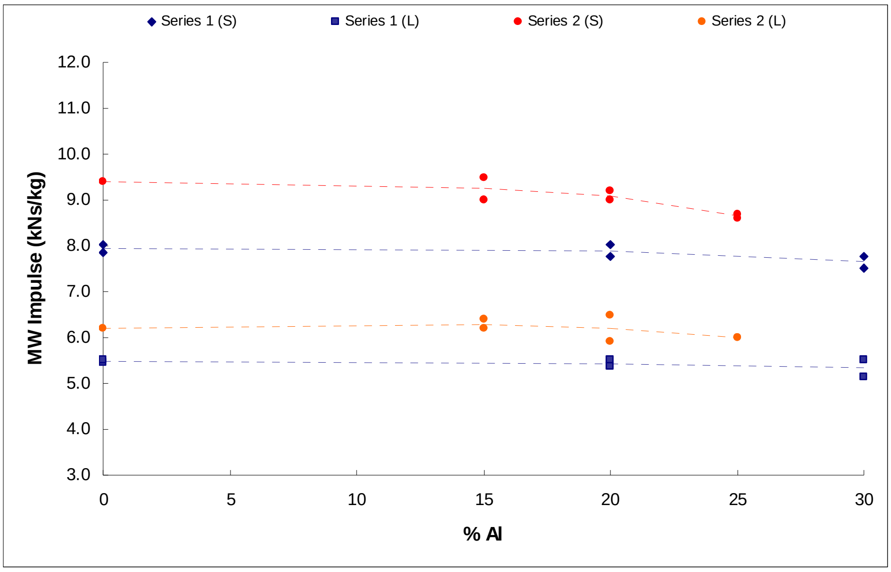

Figure 9 Mass Weighted Impulse

It is recognised that the ‘secondary’ measurements of the blast parameters with the pressure measurements and momentum gauge methods were not optimum in this study. The aim is to improve these ‘’secondary’ diagnostics in follow-up tests.

CONCLUSION

A technique and apparatus was devised to quantify the relative blast impulse from explosive charges in a semi-confined environment. Reliable results were obtained during tests with aluminized charges containing varying percentages of aluminium. The method showed that, for the charges used, significant gain in impulse can be obtained if equal volume charges are considered. However, the mass weighted impulse of the aluminized charges is not significantly higher than that of the charges containing no aluminium.

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