Detonation of 100g Anti-personnel Mine Surrogate Charges in Sand: A Test Case for Computer Code Validation. Bergeron, D., Walker, R. and Coffey, C. SR668, October, 1998.

Executive Summary

From January 1991 to December 1995, the Canadian Forces (CF) suffered 44 mine strikes while deployed on UN peacekeeping missions in Somalia and the Former Republic of Yugoslavia. Roughly, 2 out of 3 mine strikes were against vehicles, and the remainder against dismounted personnel. These casualties made it clear that mine protection is important to the CF and other Western armies.

The acquisition of mine-protected equipment is a challenging task. The Army normally states its requirements in terms of threat, e.g., " vehicle protection against a 6.5kg. TNT anti-tank mine" or "personnel protection against a 100-gram TNT anti-personnel mine". Although these statements clearly identify the interest of the Army, they are difficult to translate to technical specifications for design and engineering purposes, i.e., loading functions and material response. Usually, requirement officers in charge of contracts cannot provide this technical information to industry. This presents the inherent danger that the CF can, and have been, put in a position where they are forced to waive the statements on mine protection and accept whatever industry can deliver. From contacts with scientists in other countries, it appears that the CF are not alone in facing this kind of situation.

The Defence Research community is addressing this problem by conducting research into mine blast output. Early in this project, it became apparent from a review of the literature that detailed quantitative information on mine blast output is not available. This is further compounded by the fact that the blast output of the same mine is greatly influenced by how it is buried, what the soil conditions are, etc. Results from previous mine blast work are typically presented in terms of time-independent integral quantities, i.e., total impulse imparted to free-flying plugs or total deflection of floor plates. Integral quantities are useful for vehicle design purposes, but not sufficient to check the accuracy of computer codes. It is the time variation of physical variables (pressure, density, velocity, etc.) that is required to ensure that the relevant physics of the mine explosion and its interaction with the soil and target are properly accounted for in computer codes.

It was therefore decided to commission small-scale experiments with 100-gram explosive charges, about the size of an anti-personnel mine, to further the understanding of the physics of mine explosions and to generate a high quality data set that could be used to calibrate and validate computer codes. The quantitative results produced herein are directly applicable to the anti-personnel mine problem. The physics apply equally well to anti-tank mines, but further work is required to scale the results. Some of the important conclusions to be retained from this work are outlined below.

One key characteristic of mine explosions is the strong directionality of the resulting flow field. The soil constrains the hot detonation products to expand along the path of least resistance, i.e., upwards. The explosion happens very quickly, within 1 to 100 thousandths of a second, this time being proportional to the mass of explosive. Three distinct phases exist. The first phase encompasses the detonation of the explosive and its early interaction with the soil. When the hot gasses break through the soil surface, it marks the beginning of the gas expansion phase. Later

on, soil material flows within an annulus surrounding the core of gaseous products. This third phase is called late ejecta flow.

The principal parameter varied during the present small-scale experiments is Depth of Burial (DoB). This parameter has a strong influence on mine output, as quantified by physical variables such as the ejection velocity of the soil cap, the propagation speed of the air shock, the incident pressure behind the air shock and the expansion velocity of the hot detonation products. The table below summarises some of the important flow variables observed during these experiments.

Description	**DoB**	**Value/Range**
Soil cap maximum ejection velocity (m/sec)	3 8	1690 425
Initial propagation speed of air shock (m/sec)	0 3 8	3730 1200 440
Average incident pressure of air shock 30cm above surface (psi)	0 3 8	437 257 21.3
Average incident pressure of air shock 190 cm above surface (psi)	0 3 8	20.1 13.1 3.0
Initial expansion speed of detonation products (m/sec)	0 3 8	2660 940 400

These experiments have shown that the physical processes taking place in the near-field of an explosion are highly stochastic. Each experiment was repeated at least three times. In spite of the tight control over the experimental geometry and procedures, the variance of the results is between 20% and 80%. Variables such as the explosive charge geometry, the location of the initiation point and the size of detonator are important.

As with any research project, one learns as events unfold. Some important information is missing from the data set. For new experiments, it is recommended that:

- A camera be positioned directly above the charge to observe the processes in the cloud of expanding detonation products;

- Additional in-soil pressure transducers be used to establish the final wave propagation velocity in the soil medium. These new transducers should be located near the bottom of the soil container; and that

- Total or pitot pressure measurements be attempted within the region of strong vertical flow.

New experiments should investigate the effect of soil variations. Important variables are soil particle size, bulk density, compaction, water content and cohesion. Two or three combinations should be selected to bracket a wide range of conditions encountered in real life situations. Possibilities include gravel, silty sand and clay. Fully dry and water saturated conditions should be investigated.

New experiments may also be needed to quantify the effect of explosive mass and chemical composition. It is known that the fuel-to-oxidiser ratio varies from one explosive to another. It is possible that his factor plays a significant role on target loads in the near-field.