BLAST SIMULATORS BASED ON FUEL-AIR EXPLOSIVES AND SHOCK FOCUSING

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The experimental blast simulation of nuclear weapons effects has traditionally required the use of very large condensed explosive charges. Because of the high cost and large safety template associated with such experiments, linear blast simulators have been developed that allow researchers to assess the vulnerability of particular targets to a specified overpressure and impulse. Unfortunately, in order to reproduce pressure histories that are representative of nuclear explosions, such simulators remain relatively large and are expensive to operate. An alternative approach proposed here is to use explosive configurations that focus the blast energy on a selected target area. The use of fuel-air explosives (FAE) over high explosives (HE) is also proposed to further improve performance and lower costs.

The TNT equivalency of a blast simulator can be expressed in terms of the hemi-spherical TNT charge that would be needed to produce a selected combination of overpressure and impulse in a free-field experiment. The solution to this problem involves the simultaneous determination of the TNT mass and range for the desired overpressure/impulse combination. Large impulses and relatively low overpressures are generally of interest in nuclear blast simulation. These conditions are typically realized in a free-field blast experiment by placing the target at a large distance from a large condensed explosive charge.

The FAE canister configuration used at Defence R&D Canada – Suffield is shown in Figure 1. An explosive ‘burster’ charge inside the canister is used to disperse liquid fuel into a droplet-vapour-air cloud that is subsequently detonated by a ‘secondary’ charge positioned beneath the canister. Three such canisters can be arranged in a triangular array to direct blast onto a target outside the array. The array can be characterized by its apex half-angle, α, and the radius of the arc along which the canisters are positioned, R_C, as shown in Figure 2. A numerical study of this geometry has been carried out using the IFSAS code. The study considered three 200-kg propylene-oxide filled canisters. In the calculations, it was assumed that the fuel was dispersed into air to form three stoichiometric, hemi-spherical, clouds of 9.32-m radius. For modeling purposes, constant volume explosions were assumed with an overpressure of 8.9 atm. A constant γ of 1.4 was used for the combustion products and air. Mesh refinement was employed in the vicinities of the clouds and the axis of symmetry, and an expanded grid was used at the outflow boundaries. Calculations were performed for $R_C = 30$ m and α = 45°, 60° and 90°. The calculations show the formation of a mach stems upon reflection of the shock waves from the clouds at the apex and off axis. These mach stems propagate toward the plane of symmetry where the final wave focusing occurs.

Knowing the peak pressure and impulse at any point along the axis of symmetry, an effective TNT equivalency can be computed. Results of this exercise are shown in Figure 3.

Also included is the result for a single 600 kg hemi-spherical cloud having the same origin as the middle cloud in Figure 2. It can be seen that for $\alpha = 90°$ there exists a range ($24 \text{ m} \leq R \leq 30 \text{ m}$) over which the TNT equivalency is approximately constant near a value of 17 (the higher values at larger distances are thought to be an artifact of the expanded grid).

Experiments have been conducted using 2-liter FAE devices for $R_C = 6.5$ meters and $\alpha = 45°$, 60° and 90°. The instrumentation consisted of high-speed cinematography and 20 piezoelectric pressure transducers mounted flush with the concrete pad. The best results were obtained for $\alpha = 90°$ where the highest peak pressures and impulses correspond to a TNT equivalency of about 15.5. Preparations are underway to repeat the experiments for 10-liter and 66-liter canister devices. An attempt will be made to photographically resolve the wave structure using an illuminated zebra-board backdrop. This approach to nuclear blast simulation is estimated to be 25 times less costly than the use of a large TNT charge, albeit the target area is considerably smaller.

Figure 1: FAE canister and video sequence

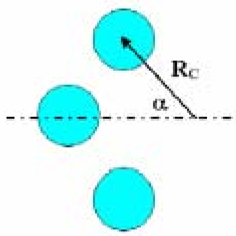

Figure 2: Triple Array

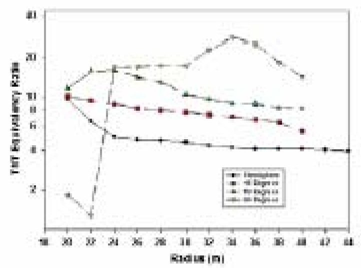

Figure 3: TNT equivalency vs range