Afterburning and Combustion in Explosions in Barometric Calorimeters

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1 Experiments

Experiments were conducted in cylindrical bomb calorimeters (Fig. 1). Three different chambers were used (6.6, 21.2 and 40.5 liters) to investigate the change in efficiency with volume.

The SDF charge construction is shown in Fig. 2. It begins with a 0.5-g spherical PETN booster (initial density of 1 g/cc). The booster is surrounded by fuel. For the composite charge, the fuel consists of 1.0-g spherical shell of TNT (initial density of 1.0 g/cc). For the Al-SDF charge, the booster is surrounded by a thin paper cylinder, and the void space is filled with 1.0-g of flake Aluminum (initial bulk density of 0.63 g/cc). SEM photographs of the Al powder indicates a flake-like structure of characteristic dimension 100 microns and a thickness of 1 micron. The booster is initiated by an exploding bridge wire located at the center of the charge.

Detonation of the booster created an expanding fuel cloud of explosion products gases and hot aluminum particles (or TNT detonation products gases). When this fuel mixed with air, it formed a turbulent combustion cloud that consumed the aluminum (or TNT products), and liberated 31 kJ/g (or 14.5 kJ/g for TNT) of energy in addition to the energy of the booster that created the explosion. Explosions in a nitrogen atmosphere (which suppresses combustion) allow one to confirm the heat of detonation of the charge, while explosions in an air atmosphere allow one to study the dynamics of afterburning and combustion in a confined explosion.

The main diagnostic consisted of 8 piezo-electric pressure gages (Kistler 603B). They were located at 5 and 7.5 cm radii on the lid of the vessel. To protect against heat transfer effects from the hot combustion products gases, the gauges were thermally insulated with a 0.1mm thick layer of silicon rubber. To check the influence of heating on the pressure, a pressure gage based on a different measurement principle (a piezo-resistive gage that is less sensitive to heat transfer effects) was employed.

2 Results

Figure 3 presents a comparison of waveforms measured in the explosion of a 1.5-g composite TNT charge (0.5-g booster + 1.0-g TNT) in different chambers. The red curves denote experiments with an air atmosphere, while the blue curves correspond to experiments with a nitrogen atmosphere. In calorimeters *A* and

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B, and tunnel *F*, the thermo-baric effect (i.e. enhancement in pressure due to afterburning of TNT detonation products with air) is most pronounced.

Figure 3 presents a comparison of waveforms measured in the explosion of a 1.5-g Al-SDF charge (0.5-g booster + 1.0-g Al flake) in different chambers. The red curves denote experiments with an air atmosphere, while the blue curves correspond to experiments with a nitrogen atmosphere. Thermo-baric effects (i.e., the enhancement in pressure due to combustion of Al with air) is quite evident in all cases, but is most dramatic in calorimeter A and tunnel F.

3 Conclusions

Experiments from 1.5-g SDF charges have been conducted in three different chambers. Pressure waveforms for explosions in air were significantly larger than those in nitrogen for all cases—thereby demonstrating a strong thermo-baric (combustion) effect in this test series. This was true for both Aluminum and TNT-SDF charges. This effect was stronger in chamber A, corresponding to smaller chamber volume where the mixture richness approaches 1.

The charge design is very important. If one uses the SDF charge design, the Aluminum reacts with the air, while if one distributes the Aluminum throughout the explosive, it reacts with the detonation products gases—producing very little exothermic effect. Additional studies are needed to explore scaling effects in SDF explosions.

Acknowledgements

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References

[1] Neuwald P, Reichenbach H, Kuhl AL (2003), “Shock-dispersed fuel charges—combustion in chambers and tunnels, Energetic Materials, 34th ICT Conference, pp. 13.1-13.14.

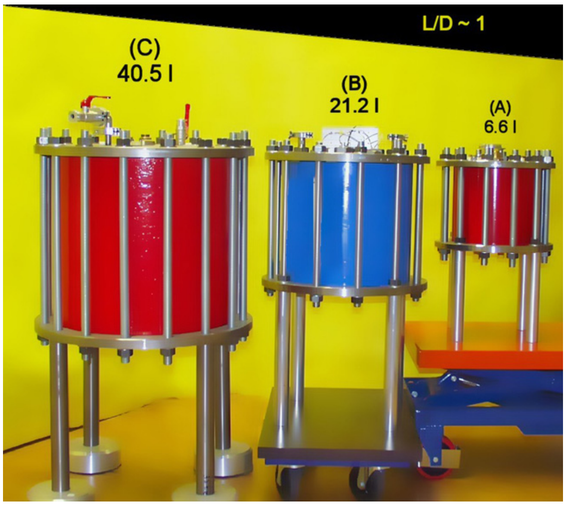

Figure 1. Cylindrical bomb calorimeters.

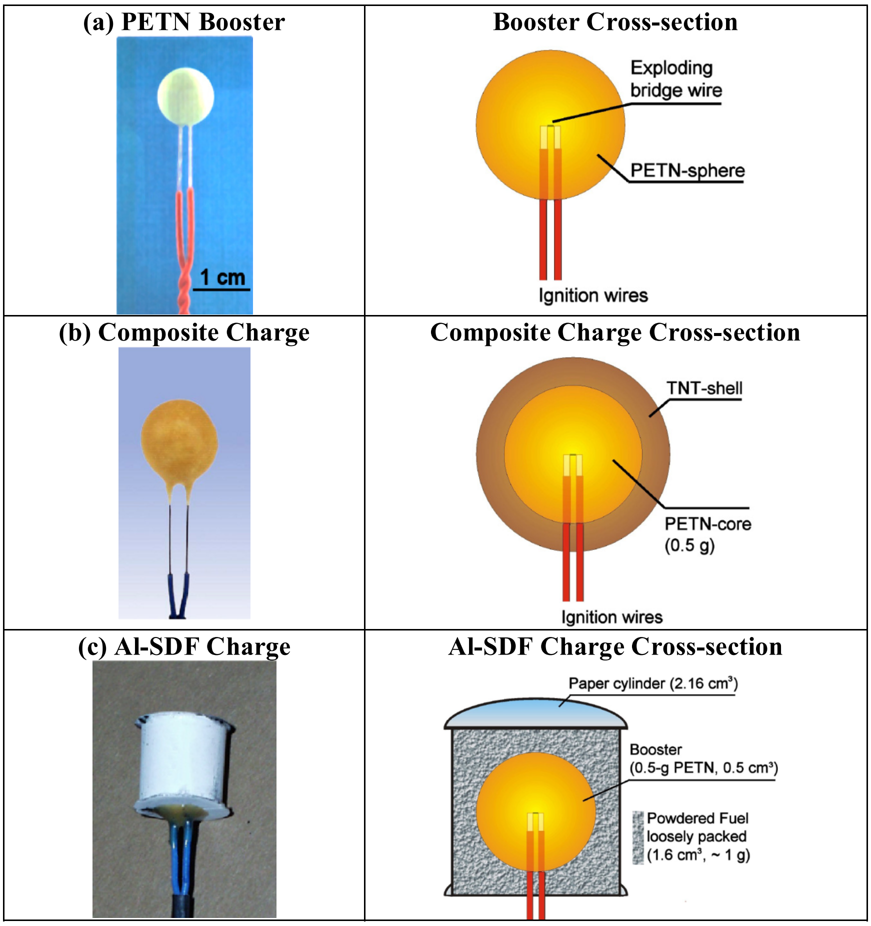

Figure 2. Charge construction: (a) 0.5-g PETN booster charge; (b) composite charge (0.5-g PETN booster + 1-g TNT shell); (c) Al-SDF charge (0.5-g PETN booster + 1-g Aluminum flake).

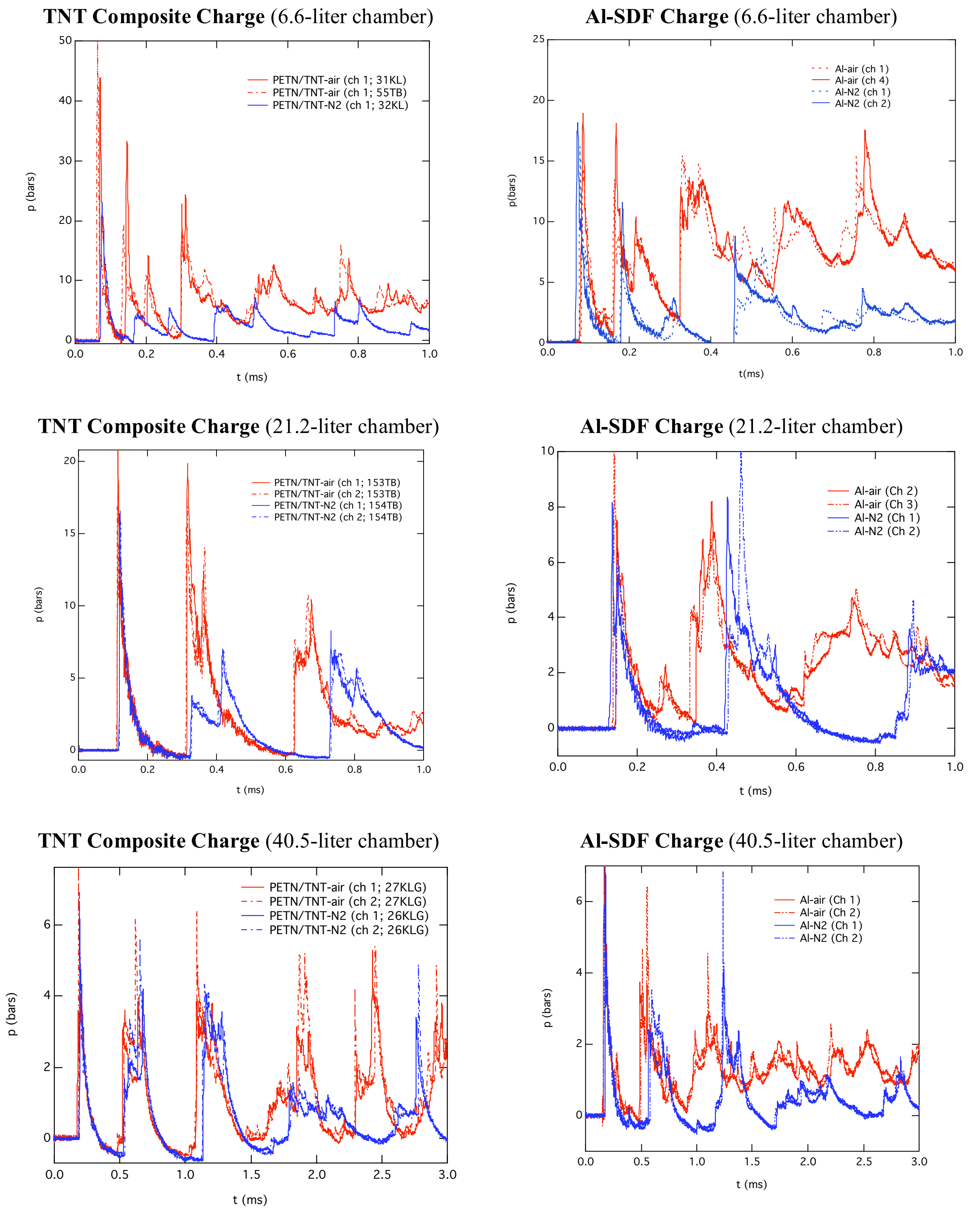

Figure 4. Comparison of pressure waveforms created by the explosion of an 1.5-g TNT composite charge and an 1.5-g Al-SDF charge in calorimeters A, B and C. Red curves represent experinents in air while blue curves represent experiments in nitrogen. Pressure enhancement (red curves versus blue curves) is a consequence of combustion with air.