After-burning of Nitropenta Products in a Calorimeter

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Abstract

Explored here are the "after-burning" effects for explosions of Nitropenta (NP) charges in air. Detonation of the charge transforms the solid explosive ($C_5H_8N_4O_{12}$, also known as PETN) into gaseous products that are rich in carbon and CO, which subsequently act as a fuel. When these hot (~3500 K) gases mix with air, rapid combustion (after-burning) takes place. The dynamics of this exothermic process was studied in "pressure calorimeter" experiments performed at EMI.

Calorimeter

Experiments were conducted in an explosion calorimeter (Fig. 1) made of Monix 20 stainless steel; it had a mass of 4908 g, a volume of 603 cm^3, a surface area of 400 cm^2, and a heat capacity of 2,300 J/K. Two thermocouples (PT 100, class A, type 4192) were attached to the outside wall, to measure the calorimetric heat of the explosion. Two piezo-electric pressure transducers (Kistler 603B) were used to measure the dynamics of the explosion and combustion processes. The gauges were mechanically- and thermally-isolated from the calorimeter by a special mounting system (Fig. 2). A thermocouple, also mounted on this endplate, was used to measure the temperature of the explosion gases. The NP charge was mounted on the opposite wall by means of a threaded bolt fixture. The entire assembly was surrounded by an air bath, and a styrofoam box with 10-cm thick walls was used to thermally isolate the air bath from the surrounding environment.

Results

Spherical NP charges with a density of ~1 g/cm^3 were used. Results of the calorimetric heat of explosion are depicted in Fig. 3 for various charge masses: $0.07 < W(g) \leq 0.6$. Experiments performed in nitrogen indicate a *"heat of detonation"* = **1475** cal/g — in excellent agreement with the value of 1490 cal/g as measured by Ornellas [1] for 25-g PETN charges detonated in a vacuum. Experiments performed in air indicate a *"heat of combustion"* = **2038** cal/g — in good agreement with the value of 1916 cal/g as measured by Ornellas [1] for 25-g PETN charges detonated in oxygen. This suggests that the *"after-burning energy"* = **563** cal/g for combustion of NP explosion products gases in air.

After-burning increases the strength of the blast wave—as demonstrated by the waveforms depicted in Fig. 4. This can be seen more directly in the "mean" (time-averaged) pressure histories of Fig. 5 (derived by applying a sliding time-average filter with a 20-□s window to the waveforms of Fig. 4), and in the differential pressure history: $\delta p \equiv \langle p_{air} \rangle - \langle p_{nitrogen} \rangle$ presented in Fig. 5. At its peak intensity, combustion induces a 20-bar increase in the mean pressure waveform.

Conclusions

After-burning of the NP detonation products gases in air deposits 563 cal/g, in addition to the 1475 cal/g deposited by the detonation wave. Under these conditions, the burning rate is controlled by the turbulent mixing rate rather than by chemical kinetics. Mixing is enhanced by wall confinement and blast wave reflections. The present results are qualitatively similar to the combustion of TNT products gases in air [2], and to the combustion of an explosion-driven acetylene jet in a narrow channel [3]. However, the more extreme confinement associated with the calorimeter walls leads to much more intense burning than was observed in the cases studied previously [2,3].

References

[1] Ornellas, D. L., *Calorimetric Determination of the Heat and Products of Detonation for Explosives: October 1961 to April 1982*, Lawrence Livermore National Laboratory, **UCRL-52821**, Livermore, CA, 1982.

[2] Kuhl, A., L., Ferguson, R. E., Spektor, R., Oppenheim, A. K., "Combustion of TNT Products in a Confined Explosion", *Book of Abstracts: 17th-ICDERS*, University of Heidelberg Press, 1999.

[3] Kuhl, A. L., Ferguson, R. E., Reichenbach, H., Neuwald, P., and Oppenheim, A.K., "Dynamics of an Explosion-Driven Planar Exothermic Jet", *JSME Int. Journal—Series B*, **41** (2), 1998, pp. 416-423.

Figures

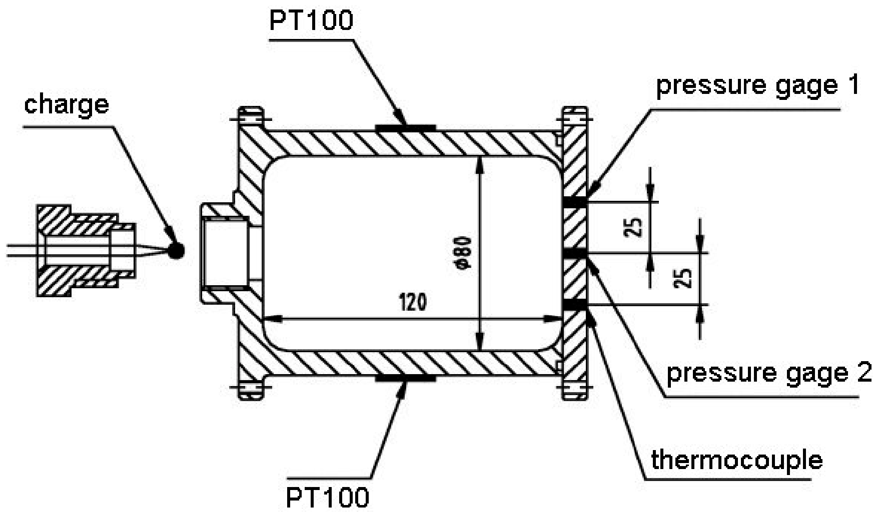

Figure 1. Schematic of the 0.6-liter chamber used for "pressure calorimeter" experiments with spherical 0.5 g Nitropenta charges (dimensions in mm). Shock-isolated pressure gauges and a thermocouple gauge were mounted on an end plate. The charge assembly was located on the opposite endplate. Two PT 100 thermocouples on the outside wall were used to measure the calorimetric heat of explosion.

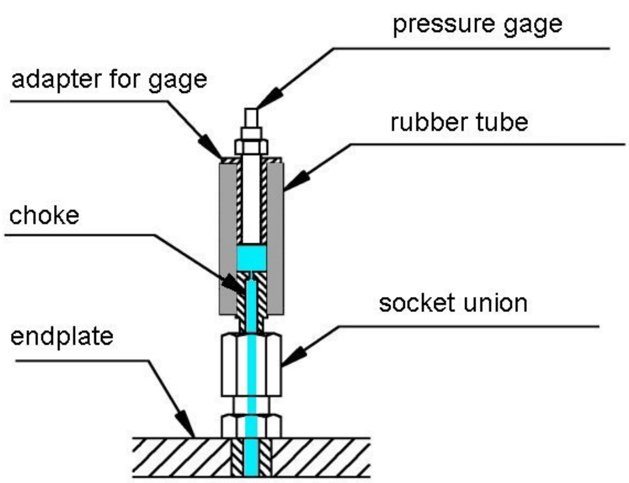

Figure 2. Schematic of the shock-isolated mounting of the pressure gauges. The rubber tube decouples the gauge from acoustic waves in the calorimeter walls, the choke reduces peak pressures to avoid gauge overload and, in addition ; shields the gauge against the hot product gases.

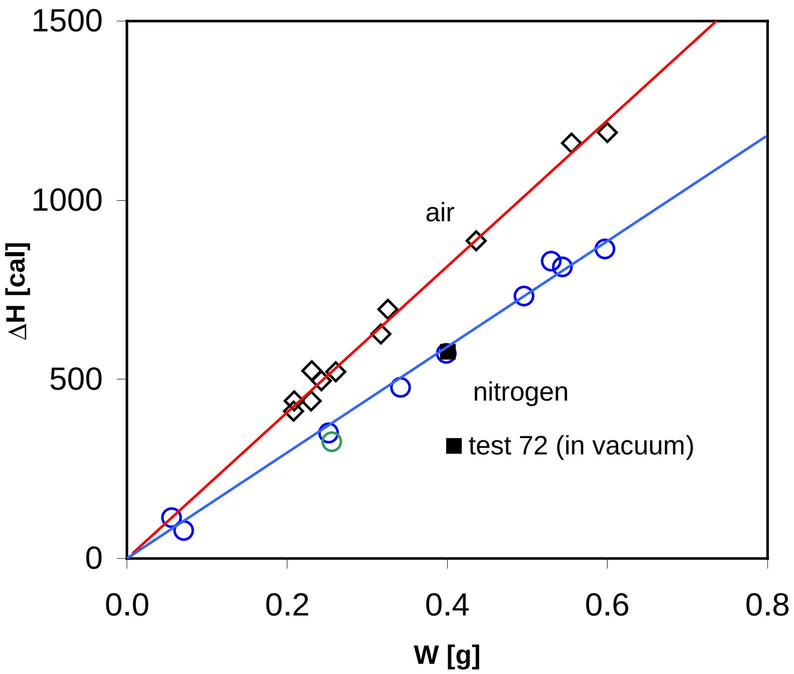

Figure 3. Heat of explosion for spherical NP charges detonated in a 0.6-liter chamber: ΔH = 2038 (cal/g) × W in 1-bar air, and ΔH = 1475 (cal/g) × W in 1-bar nitrogen.

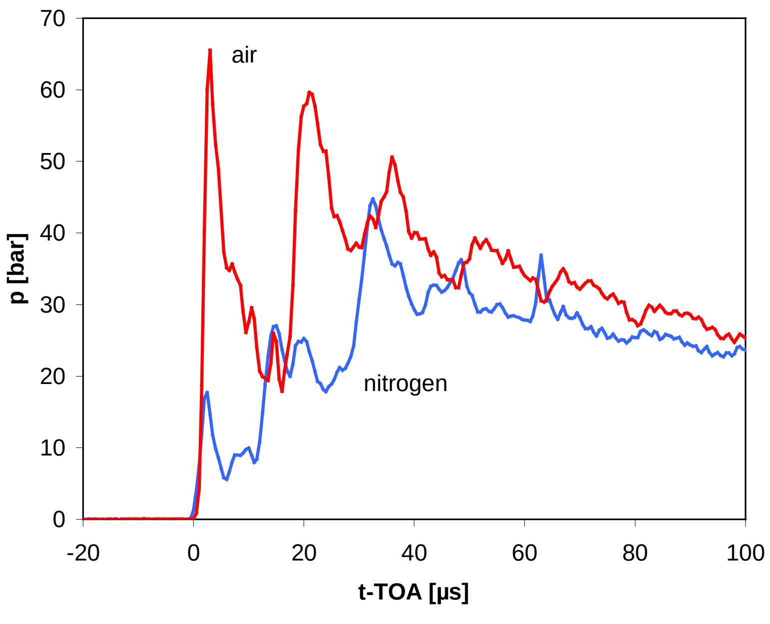

Figure 4. Pressure histories for spherical NP charges detonated in the 0.6-liter chamber in air and nitrogen atmospheres. Charge weight W=0.436 g (for air) or W=0.450 g (for nitrogen).

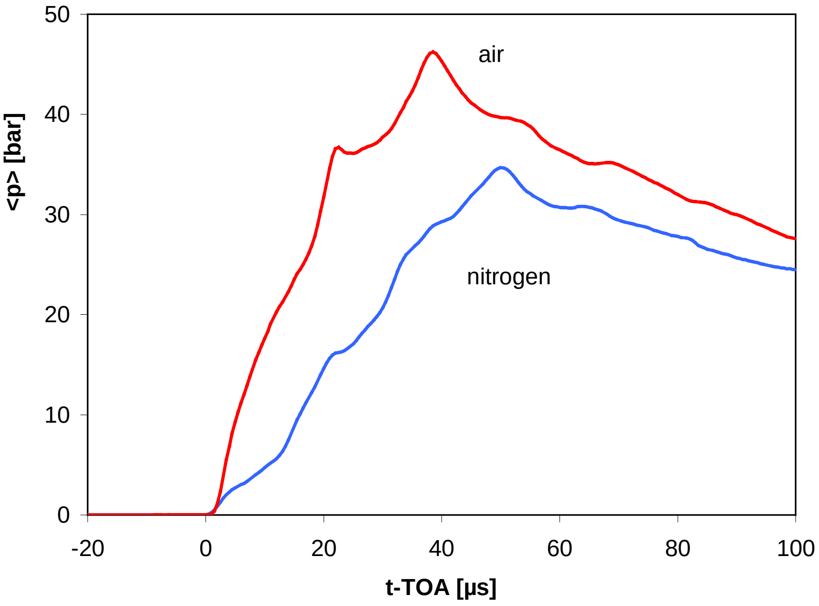

Figure 5. Mean pressure histories for spherical NP charges detonated in the 0.6-liter chamber. Charge weight see Fig. 4.

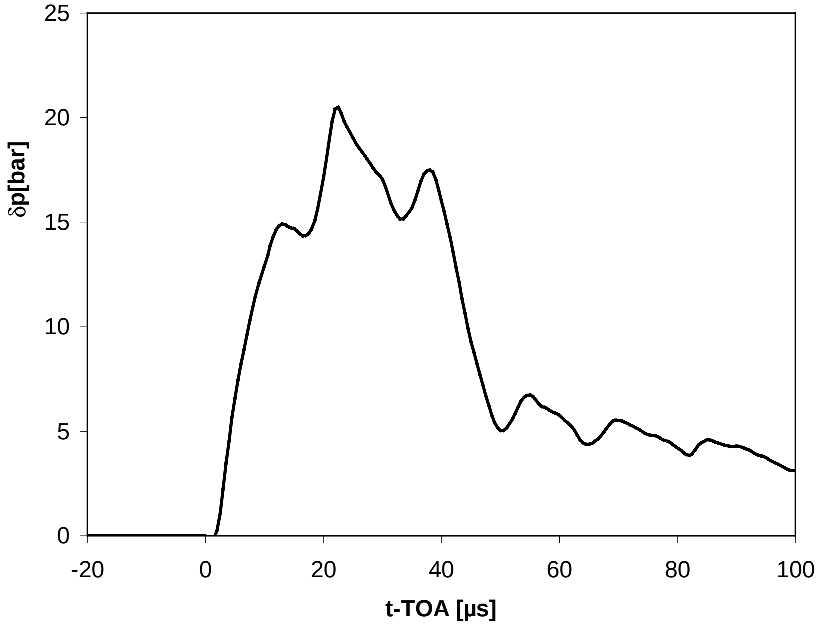

Figure 6. Differential mean pressure history (induced by after-burning) of 0.436-g NP charge in air.