Visualization of Turbulent Combustion of TNT Detonation Products in a Steel Vessel

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Abstract

Effects of turbulent combustion of TNT detonation products in confined explosions have been studied recently in works [1÷4]. In the papers [1-2], the heat effects were measured in an calorimetric bomb of 3.6-liter volume. The bomb was filled with argon, air or oxygen at a pressure of 1 MPa. Experiments indicated the heat effects of 939 cal/g and 3611 cal/g in argon and air (or oxygen) atmosphere, respectively. Other experiments were conducted in an explosion chamber of 150-liter volume ([2-3]). The chamber was filled with argon, air or oxygen enriched air at one atmosphere pressure. Measured pressure histories showed enhancements due to after-burning effects. In the work [4], effects of turbulent combustion induced by explosion of a 0.8 kg charge of TNT in a 17 m^3 chamber filled with air were conducted.

In this work, flow visualization experiments were conducted in the specially designed 107-liter steel vessel. The chamber was equipped with 30-cm optical windows and placed in the optical beam of a schlieren system. The chamber was filled with nitrogen, air or 50% oxygen enriched air at one atmosphere pressure. Charges of 0.5 and 1 g of TNT were detonated by using a fuse (0.15 g RDX and 0.15 g PETN). A high speed SFR camera was used to record the process of mixing of detonation products with a gas filling the chamber. Selected pictures are presented in Figs. 1 and 2.

For some visualization tests, overpressure histories at the chamber wall were recorded by using a pressure gauge. Selected overpressure records are shown in Fig. 3. The histories were averaged (Fig. 4) and the values of mean overpressure of 0.024, 0.060 and 0.065 MPa were obtained for nitrogen, air and oxygen-enriched air, respectively. These values enabled us to estimate the energy released during combustion of the detonation products in air or oxygen-enriched air. By applying the Oppenheim-Kuhl theory “Thermodynamics of Closed Combustion Systems” presented in the paper [5], the Le-Chatelier diagram was constructed for confined combustion of detonation products in air (Fig. 5). The Le Chatelier diagram is a plot of the loci of states of reactants and products on the plane of dimensionless specific internal energy, U, and the thermodynamic reference coordinate, W, defined in the following manner

$$W_k = P_k v_k$$

where P and v denote the dimensionless thermodynamic pressure and specific volume, while k = Φ, Ω, R, P, and S, referring, respectively, to fuel (detonation products of TNT and fuse), oxidizer (air), reactants (fuel and air being in the stoichiometric ratio), products of combustion and system. From thermodynamic analysis, the profiles of thermodynamic parameters, W_k, the mass fraction of fuel, Y, and the heat released in the chamber, Q, can be obtained with respect to pressure (Fig. 6). The thermochemical calculations were performed by the use of CHEETAH code [6]. From the comparison of the ratio of mean pressure values in the chamber filled with air and nitrogen with the maximal value of dimensionless pressure in Fig. 5, it follows that the detonation products are consumed and additional energy about 2100 cal/g is released during the combustion process. Similar effect is observed in tests with the oxygen enriched air.

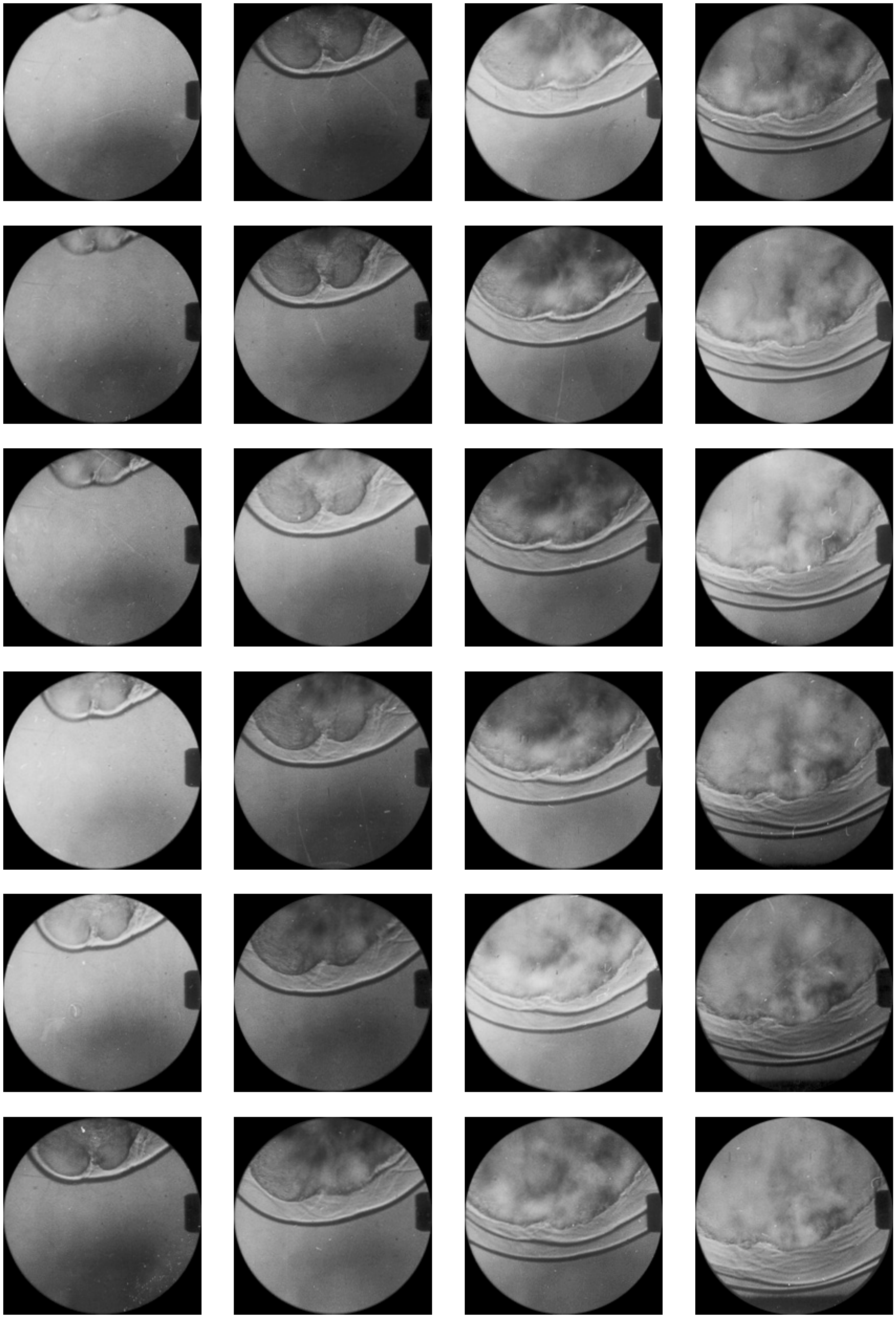

Fig. 1. The high speed Schlieren pictures of the 0.5 g of the TNT explosion in the 50% oxygen enriched air.

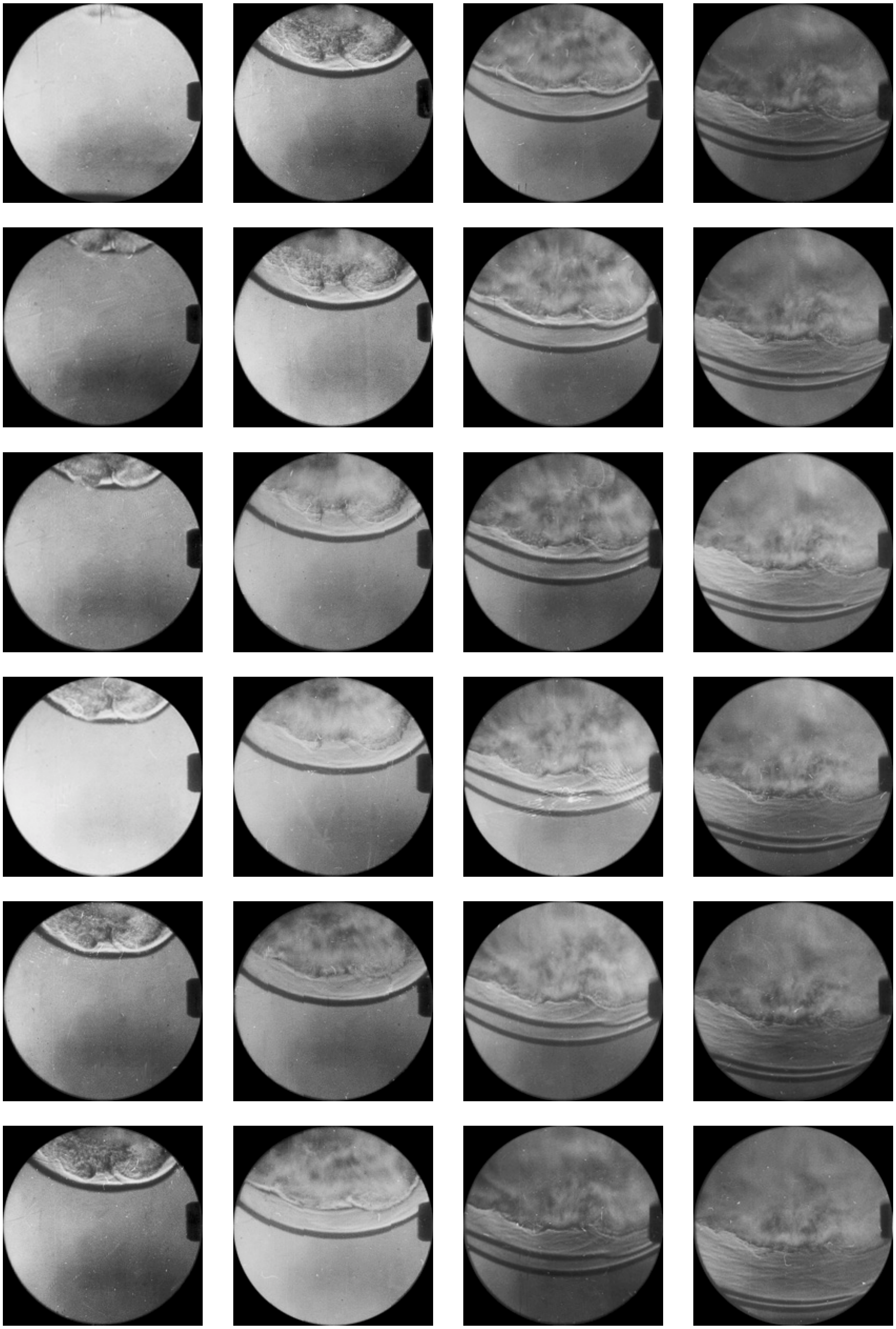

Fig. 2. The high speed Schlieren pictures of the 1.0 g of the TNT explosion in the 50% oxygen enriched air.

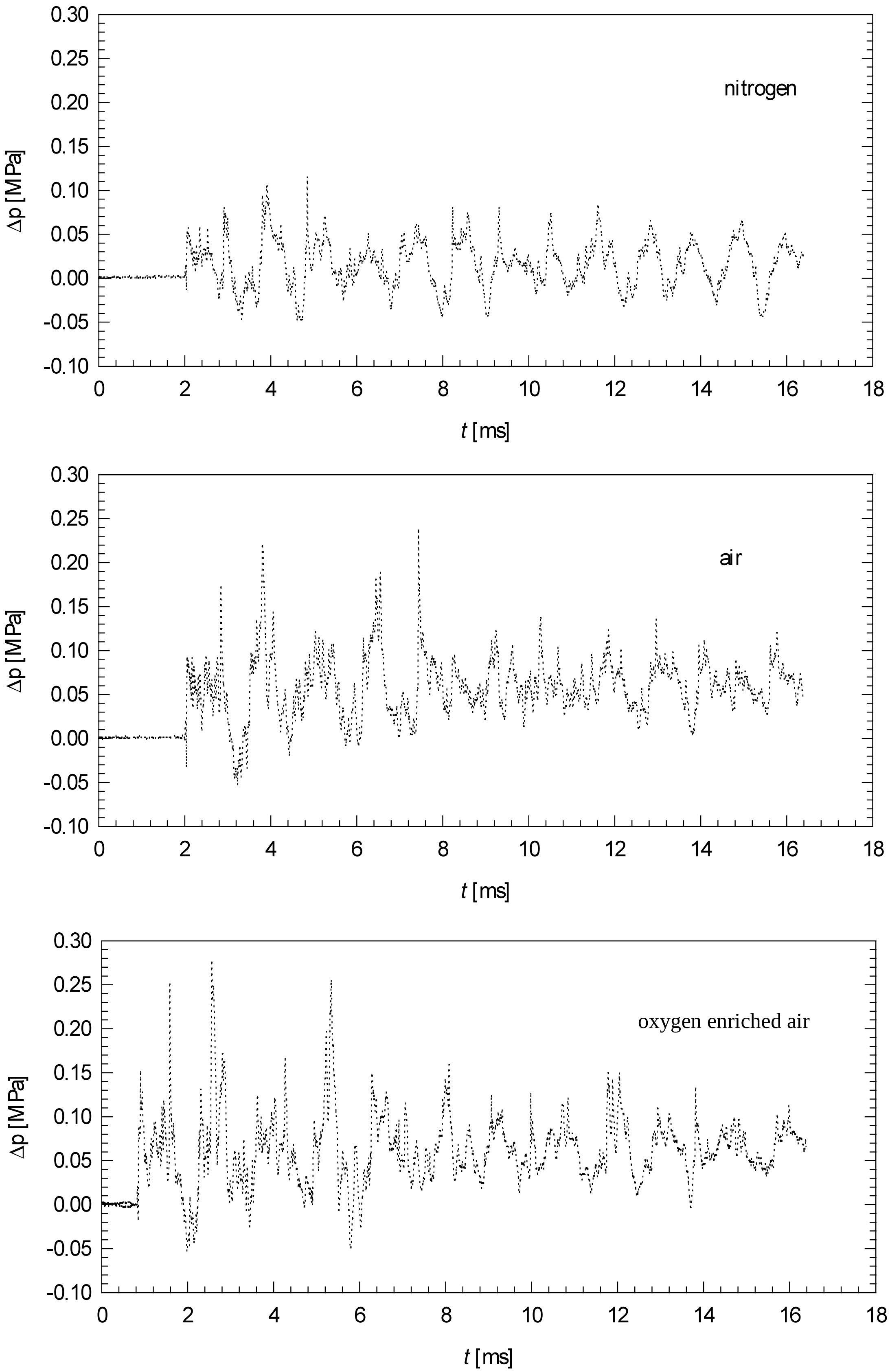

Fig. 3. Variation of the overpressure pressure inside the chamber after detonation of 1g of TNT

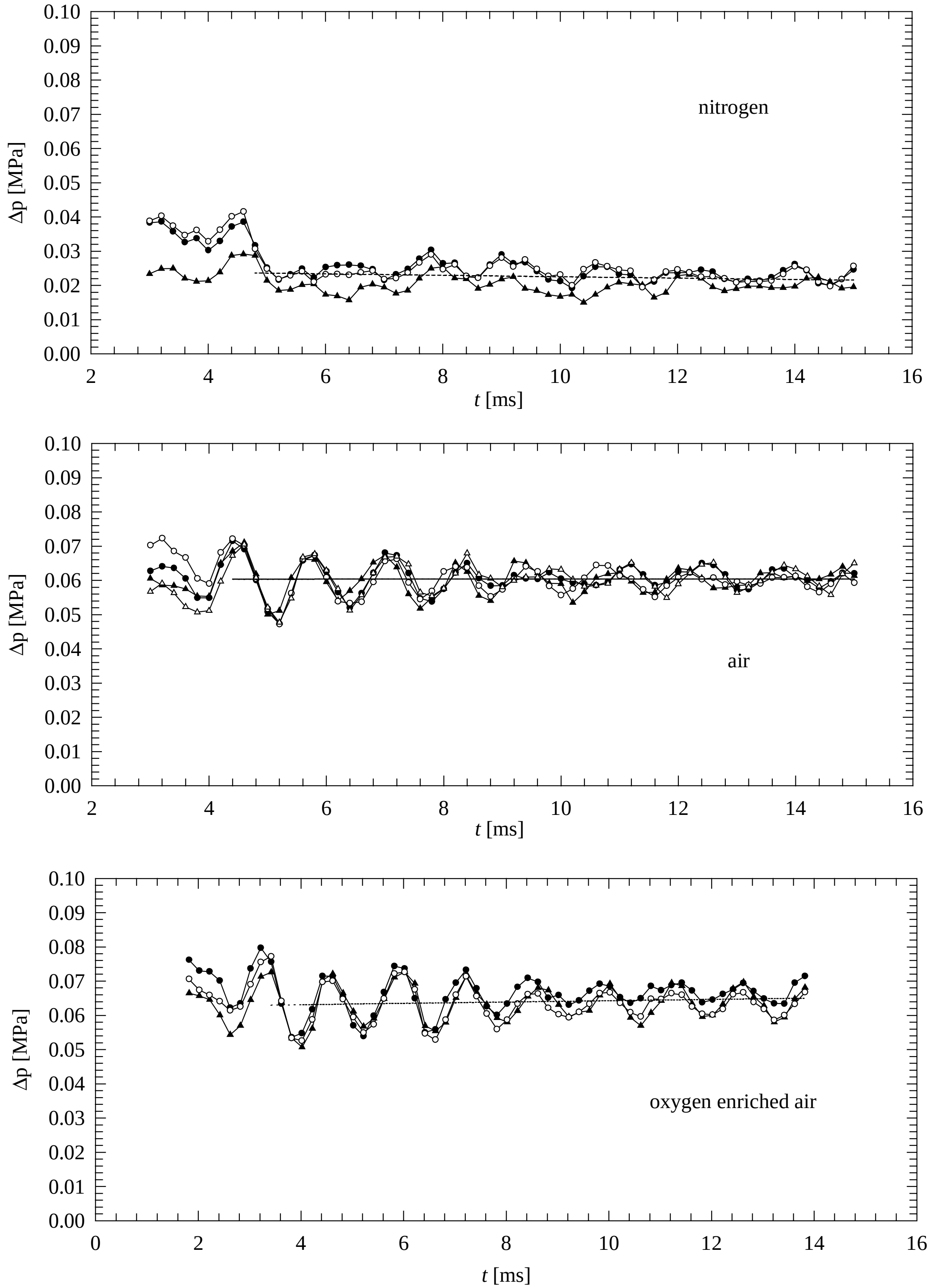

Fig. 4. Averaged overpressures at the chamber wall

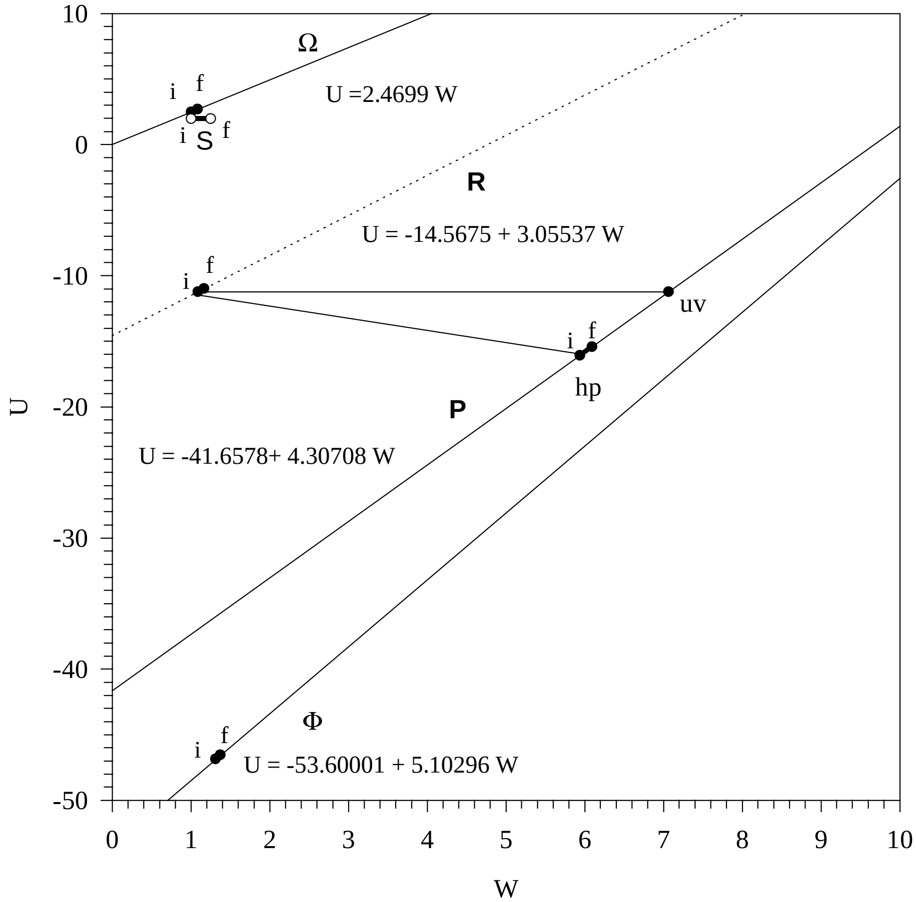

Fig. 5. Le Chatelier diagram for confined combustion of explosion products in air

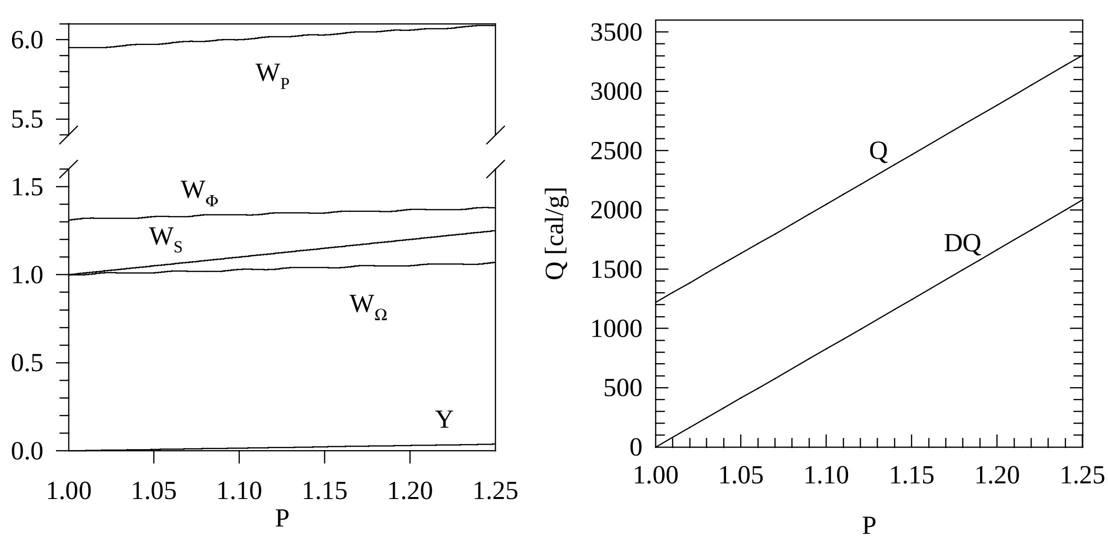

Fig. 6. Profiles of thermodynamics parameters with respect to dimensionless pressure

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