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Abstract

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ON THE EXPLOSIVE DECOMPOSITION OF RDX

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A number of studies (1−3) indicate a dependence of the reaction of explosive decomposition on the density of the charge, the power of the initiator, the strength of the casing, and the size and shape of the charge. The action of these factors is to a considerable extent reduced to a change in the pressure in the front of the detonation wave and to the influence of pressure on the equilibrium reactions:

$$2CO \rightleftarrows CO_2 + C + 41.2 \text{ kcal}; \tag{1}$$

$$CO + H_2 \rightleftarrows C + H_2O + 31.4 \text{ kcal}; \tag{2}$$

$$H_2O + CO \rightleftarrows CO_2 + H_2 + 9.7 \text{ kcal}. \tag{3}$$

Changes in the heat of explosion and in the volume of gaseous explosion products have been established for TNT, tetryl, picric acid, and a number of other high explosives with a negative oxygen balance. However, until recently, for RDX (cyclotrimethylenetrinitroamine) the heat of explosion has been given on the assumption that it does not depend on the conditions of explosion, in particular on the density of the charge.

In (4,5) for RDX the heat of explosion is taken as 1370–1390 kcal/kg with liquid water, or 1290–1370 kcal/kg with water in the vapor state. Tonégutti (6) determined for pressed RDX the heat of explosion $Q = 1370$ kcal/kg. Medard (7) gives an even more accurate value, $Q = 1359.5$ kcal/kg, but does not indicate to what charge density of RDX this heat of explosion refers. However, it makes no sense to determine heats of explosion with great accuracy if the constancy of the explosion conditions is not maintained.

Table 1

Heat of explosion of RDX at different initial charge densities (kcal/g)

Fig. 1. Dependence of the heat of explosion of hexogen on the initial charge density: 1 —liquid water; 2 —vaporous water

Figure 1: Fig. 1. Dependence of the heat of explosion of hexogen on the initial charge density: 1 —liquid water; 2 —vaporous water

$\rho,\ \frac{\text{g}}{\text{cm}^3}$	water—liquid	water—vapor
0.50	1,290	1190
0.65	1320	
0.70	1330	
1.00	1370	
1.15	1400	1300
1.70	1490	
1.73	1490	1400
1.74	1500	
1.78	1510	1420

Of greatest significance in a complete explosion is maintaining the constancy of the charge density. We have experimentally established that the heat of explosion of RDX increases strongly with an increase in the charge density. The experiments were carried out as follows. A charge of RDX weighing 30–50 g and 20–30 mm in diameter was placed in a copper cylindrical casing with wall thickness of 3–4 mm and suspended at the center of a steel calorimetric bomb of volume 4.75 l and weight 250 kg. Before the explosion, air was removed from the bomb by means of a vacuum pump to a pressure of 0.1–1.0 mm Hg. Thoroughly dried RDX with a melting temperature of 202–203° was used for the experiments. High-density charges were obtained by pressing, while low-density charges were prepared from finely precipitated RDX.

Table 1 gives the heats of explosion of hexogen as a function of the charge density. The experimental error was less than 1%.

As can be seen from Table 1, when the charge density changes from 0.50 to 1.78 g/cm^3, the heat of explosion changes from 1290 to 1510 kcal/kg. This dependence is linear in character (Fig. 1).

Experiment shows that the reaction of the explosive transformation of hexogen, and consequently the heat of explosion, the volume, and the composition of the explosion products, depend strongly on the initial density of the explosive. The heat of explosion is not a constant of the explosive. If one agrees to refer the heat of explosion to a definite density of the explosive charge, then for hexogen at $\rho = 1.00$ g/cm^3, $Q = 1370$ kcal/kg with water in the liquid state and $Q = 1270$ kcal/kg with water in the vapor state.

Fig. 1. Dependence of the heat of explosion of hexogen on the initial charge

density: 1 —liquid water; 2 —vaporous water

When the charge density changes, the volume and composition of the products of the explosion of hexogen also change; solid carbon appears in the explosion products of hexogen. Table 2 gives data showing the influence of the initial charge density on the volume and composition of the explosion products. As the density increases from 0.50 to 1.78 g/cm^3, the content of carbon dioxide in the explosion products increases, while the volume of gases decreases by more than 10%.

At an initial density of hexogen $\rho = 1.10$ g/cm^3, explosion products of the following composition are obtained (in vol.%): CO_2 10.47; CO 22.64; H_2O 23.97; CH_4 0.68; N_2 33.78; H_2 8.46. On the basis of these data, one can write an approximate equation for the explosive decomposition of hexogen at $\rho = 1.10$ g/cm^3:

$$\mathrm{C_3H_6O_6N_6} \to 0.93\mathrm{CO_2} + 2.01\mathrm{CO} + 2.13\mathrm{H_2O} + 0.06\mathrm{CH_4} + 3\mathrm{N_2} + 0.75\mathrm{H_2}. \quad (4)$$

Table 2

Volume and composition of the products of the explosion of hexogen at different initial charge densities

ρ, g/cm^3	V, l/kg, water—liq.	V, l/kg, water—vap.	CO/CO_2
0.50	730	930	4.7
1.00	690	890	2.2
1.78	630	820	1.8

Comparison of the heats of explosion obtained from calorimetric measurements and on the basis of analysis of the explosion products gives good agreement. Generally speaking, if one assumes that, in the explosion of a charge of high density, all carbon monoxide were converted into carbon dioxide and free carbon, the limiting heat of explosion of hexogen would be still higher—up to 1650 kcal/kg. For a correct estimate of the magnitude of the heat of explosion, of course, it is necessary to take into account the degree of displacement of the equilibria in the explosion products under the conditions of high pressure in the detonation wave. At present, satisfactory data on the heat, temperature, composition, and volume of the explosion products can be obtained by calculation.

The most important consequence following from this work is that, in the narrow zone of the detonation wave, equilibrium processes in the explosion products have time to become established to a considerable degree, while during the longer time of expansion of the explosion products the established equilibria do not have time to shift substantially in the reverse direction; i.e., a very strong "quenching" of the equilibria takes place.

Thus, experimental determination of the heats of explosion, of the composition and volume of the explosion products in a steel bomb makes it possible to obtain data that more or less reflect the true picture of the course of the process in a

under the conditions of a detonation wave. A change in the "quenching" regime, as well as a more precise determination of the heat of explosion and of the composition of the explosion products for explosives that contain metallic and inert additives of various dispersities, will make it possible to form a more correct picture of the mechanism by which reactions proceed in the detonation wave.

Determination of the heats of explosion and of the composition of the explosion products for explosive charges whose diameter approaches the critical one will make it possible to judge the degree of pressure drop in the detonation wave and the magnitude of the losses.

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Note: Figure translations are in progress. See original paper for figures.