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The explosive properties of solutions of ozone in liquid oxygen have been studied rather fully: their sensitivity to thermal effects [1 — 5], the lower limit of the explosive concentration range [3], the detonation velocity [6 and 7], as well as the dependence of the critical stable-detonation diameter on the composition of the solution [7], have been determined.

The work described in the present article dealt with a determination of the sensitivity of ozone-oxygen solutions to a pressure pulse, regarding which there is no data in the literature.

The experiments were conducted on an apparatus [8], the basic element of which was an explosion vessel — a tube 20 mm in diameter and 400 mm in length (Fig. 1a). A shock tube (diameter 20 mm, length 1080 mm), which was divided into two unequal sections by a rupture diaphragm, was inserted into the enlarged upper section of the vessel. In order to avoid a change in the concentration of the ozone-oxygen solution in the course of the experiment, the explosion vessel was placed in a liquid-oxygen thermostat.

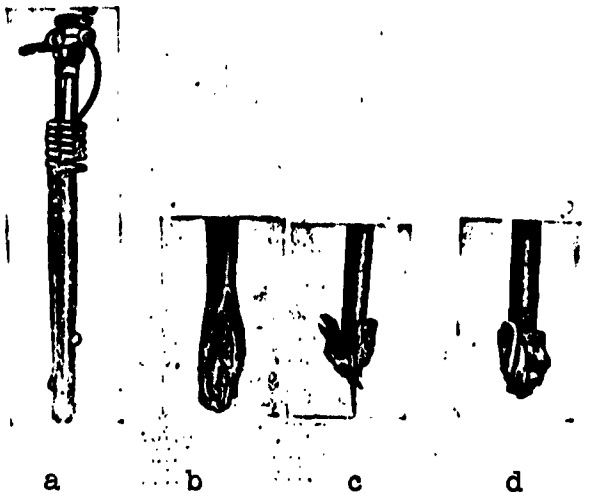

Fig. 1. Explosion vessels before and after explosion of solutions: a) before explosion; b) after explosion of a 21% solution; c) the same, 29%; d) the same, 77%.

In conducting the experiments we adhered to the following method. First we filled the vessel with liquid oxygen to slightly above the inlet of the upper tube of the manometer, which served to determine the concentration of the solution [9]. A gaseous ozone-oxygen mixture (2-4% ozone) was prepared from medicinal liquid oxygen in a semi-industrial ozonizer and then liquified in a coil pipe, which had been lowered into the thermostat before entry into the explosion vessel. The feeding of the mixture was stopped, after the desired concentration of the solution had been reached.

In order to obtain concentrations of more than 69% by weight, the mixture was introduced until the ozone content was 40 — 50%, and then the mixture was additionally concentrated by the evaporation of the liquid oxygen.*

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* Experiments were not conducted on 29.5 — 68.5% solutions, since they stratified before the diaphragm burst.

In experiments the amount of solution varied between 30 and 50 ml.

When the shock wave was applied directly to the surface of the charge, a splattering of the ozone-oxygen mixture and an explosion of the droplets of concentrated solution occurred. In order to prevent this from occurring, liquid oxygen was carefully poured down the wall onto the surface of the solution, until the vessel was filled. A sharp boundary was maintained between the layer of liquid oxygen and the ozone-oxygen solution throughout the experiment.

The ozone was apparently diluted by the oxygen in the upper portion of the solution all the same.* However, with the method we have chosen this is of no consequence, for when a pressure pulse of minimum intensity is selected, the explosion occurs in that part of the charge where the ozone concentration remains unchanged.

When a certain pressure (P_r) was attained in the shock tube, into which nitrogen was being forced, the diaphragm burst.

The pressure (P_{ref}) caused by the reflection of the shock wave from the bottom of the vessel after the rupturing of the diaphragm was measured by a lead crusher gage in liquid oxygen, as well as by an MID-3 membrane pressure gage in water.

The method of measuring with lead crusher gages has been described by Belyayev [10]. In our case the calibration of the lead crusher gages was carried out in a liquid-oxygen medium using static nitrogen pressure. The pressure in the reflected wave was calibrated with the formula for instantaneous deformation taken into account [11].

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* Approximate calculation shows that for the conditions under which the experiments were conducted a 50% ozone-oxygen solution may be diluted by 0.1% as a result of diffusion (for a diffusion coefficient of the liquid of 0.4 cm^2/hr).

The results of the measurements are presented in Fig. 2, from which it is apparent that the values of P_{ref} measured in liquid oxygen and in water are nearly equal.

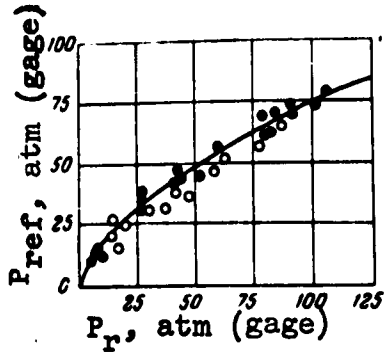

Fig. 2. Dependence of reflection pressure on diaphragm rupture pressure: O) determined by lead crusher gages in liquid oxygen; ●) determined by an MID-3 in water.

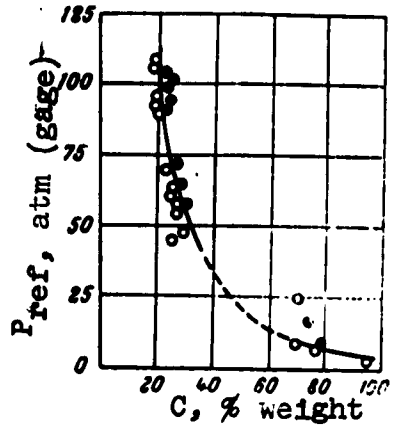

Fig. 3. Dependence of the sensitivity of solutions to a pressure pulse on their ozone content: O) experiments without explosion; ●) experiments with explosion.

The curve of the dependence of P_{ref} on P_r corresponds to the following formula:

$$P_{ref} = 2.9\ P_r^{0.705}$$

The intensity of the explosion was determined in terms of the nature of the damage to the explosion vessel. In the case of a low ozone concentration damage was slight: usually the tube encurred a longitudinal rupture accompanied by a bulge (Fig. 1b). When the concentration was increased, the vessel burst into several longitudinal strips, which were bent upwards against the outer wall of the tube (Fig. 1c). Finally, solutions with a large ozone content (more than 69%) were detonated; in the explosion zone the tube shattered into thin slivers, while the portion that remained burst into a multiplicity

of strips, which were crimped up against the outer tube wall (Fig. 1d). Using the results of the experiments, the dependence of the sensitivity of ozone-oxygen soltuions to a pressure pulse P_{ref} on their ozone content (C) was plotted (Fig. 3)*.

For comparison we tested nitroglycerine and oxyliquit on a carbon-black absorbent.

The experiments with nitroglycerine were conducted in a vessel 20 mm in diameter and with a capacity of 5.5 cm^3. The shock wave was applied directly to the surface of the charge. The explosion was observed at P_{ref} = 96 atm (gage) [(P_r = 138.5 atm (gage)]. In testing oxyliquit the explosion vessel was filled 1/3 full with carbon black (density 0.33 g/cm^3) and was then filled to the brim with liquid oxygen. The shock was produced through an inert layer of liquid oxygen. The explosion was observed at P_{ref} = 82 atm (gage) [(P_r = 112 atm (gage))].

The results obtained show that ozone-oxygen solutions possess a very high sensitivity to pressure pulses. The dilution of liquid ozone with oxygen leads to a sharp decrease in the pressure pulse necessary to excite an explosion in the solution. The dependence found may be expressed by the equation

$$P_{ref} = 173e^{-0.0882C}$$

Similar relationships had been found previously for mixtures of liquid oxygen with hydrocarbons by one of the authors [8]. As was shown, there is a direct connnection between the sensitivity of these mixtures to pressure pulses and the minimum self-ignition point of

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* In the calculations the density of ozone was taken equal to 1.58 g/cm^3 [12].

liquified hydrocarbons in a gaseous oxygen atmosphere. Such a relationship was also noted for ozone-oxygen mixtures.

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