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TRANSLATION

ENGLISH TITLE: Effect of Initial Temperature of Certain Explosive Liquids on their Sensitivity to Explosion Excitation by Cavitation

FOREIGN TITLE: Vliyaniye Nachal'noy Temperatury Nekotorykh Vzryvchatykh Zhidkostey na ikh Chuvstvitel'nost ' k Vozbuzhdeniyu Vzryva Kavitatsiyey

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Abstract: The assumption that the effectiveness of cavitation as a means of initiating detonation decreases during heating of liquid explosives and increases during cooling is experimentally checked for four explosives (nitroglycerin, stoichiometric solutions of benzene, heptane, and methanol in tetranitromethane). The effect of the vapor tension of the liquid explosives at various temperatures on detonation by cavitation is discussed.

KEY WORDS:

Liquid Explosive
Explosive R and D
Detonation
Test Method
Explosive Test
Cavitation

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Comparatively small pressure changes in certain liquid explosives (LE) may cause cavitation and detonation [1, 2]. Stimulation of detonation occurs during the collapse of cavities (caverns). During the collapse of a cavern the vapors of the liquid in it experience rapid and very substantial compression. This leads to combustion of the vapors, which can also cause an explosion.

The greater the ratio of the pressure causing collapse to the initial pressure of the vapors, the higher the temperature of the vapors compressed in a closing cavity will be. It follows, then, that a change in the vapor tension of a given LE may lead to a change in its sensitivity to cavitation stimulation of detonation. Since during cooling of a liquid its vapor tension decreases, and increases during heating, it can be assumed that the cooling of LE will increase the temperature of the vapors in closing cavities, and heating will lower it. During heating of LE, therefore, the effectiveness of cavitation as a means of initiating detonation should decrease, but increase during cooling.

For the purpose of experimental checking of this assumption tests were conducted in this work on the stimulation of detonation by caviation at various temperatures in four explosives: nitroglycerin (NG) and stoichiometric solutions of benzene, heptane and methanol in tetranitromethane (TNM). The sensitivity of the stated LE to stimulation of detonation by cavitation at room temperature was investigated earlier [1, 2]. The change of cavitation sensitivity as a function of initial temperature was analyzed as follows [1, 2]: a piston, inserted into a test tube with a bell mouth, filled with LE, was suddenly extracted from it, causing the formation and closing of cavities. The ratio of the number of tests ending with detonation to the total number of attempts to cause detonation by cavitation can be used for each LE as the characteristic of its sensitivity to cavitation initiation of detonation.

It is assumed for comparison of the various LE with respect to their sensitivity that the conditions of the formation and closing of cavities in the compared LE average out to be about the same (i.e., by the same methods of creating cavities their dimensions will be about the same for the various liquids, and their closing in various LE is the result of the same average pressures in the liquid). A comparatively small change of

initial temperature of the investigated LE did not have a very strong influence on the size of the cavities formed during the tests, and therefore the results of testing each LE at different temperatures are completely comparable.

The initial temperature of the LE in the test tube was changed by immersing the test tube into a Dewar flask filled with water of the prescribed temperature. The temperature of the LE was measured with a mercury thermometer prior to each test. The piston was also cooled (or heated) to the temperature of the LE prior to insertion into the test tube. At least 10 tests were conducted at each initial temperature. During testing of NG glass test tubes with an inside diameter of 12 mm and plexiglass pistons in the form of cylinders with flat ends were used. Solutions of benzene, heptane and methanol were tested in test tubes of the same diameter, but made of aluminum, as were the pistons.

The test results were as follows.

The benzene-TNM solution constantly detonated at temperatures not above 10°C and with further cooling down to the appearance of solid phase in it. At 10°C the vapor tension of this solution is 17 mm Hg, i.e., about half of the vapor tension at room temperature (30 mm Hg), when only one-third of the tests ended with the detonation [1]. At 40°C there were only three detonations in 20 tests. The vapor tension at this temperature is 70 mm Hg. When the solution is heated to 60°C (vapor tension 160 mm Hg) not one of the 20 tests resulted in initiation of detonation.

The heptane-TNM solution detonated at temperatures not higher than +2°C (vapor tension 3 mm Hg). As we know [2], at room temperature (vapor tension 14 mm Hg) this solution detonated in only 2 out of 50 tests. On heating to 40°C (vapor tension about 200 mm Hg) detonation could not be initiated in one out of 100 tests.

The methanol-TNM solution was insensitive to cavitation, both on heating to 50°C (vapor tension 280 mm Hg) and cooling to 10°C (40 mm Hg).

NG was tested at initial temperatures of 0, 20, 40, 60 and 70°C. In these tests technical NG, extracted from solution in methanol with the aid of water, and then placed in a desiccator with calcium chloride for several days, was used. The measured vapor tensions above such NG differed greatly from the vapor tension of pure NG. Thus, at 0°C the vapor pressure was 5 mm Hg, at 20° -- 15, at 40° -- 22, at 60° -- 30, at 70° -- 40 mm Hg. We know that these values for pure NG should exceed 10^{-4}-10^{-2} mm Hg.

We felt it worthwhile to compare the cavitation sensitivity of technical NG containing impurities with high vapor pressures to the analogous sensitivity of NG purified of volatile impurities to the extent that the vapor tension over its surface did not exceed at least 0.5 mm Hg.

The volatile impurities were removed from technical NG by alternate heating (to 70-90°C) and cooling (to 20°C) with continuous pumping of the

vessel using a fore-vacuum pump. Heating was accompanied by careful shaking of the evacuated vessel containing NG, leading to the abundant liberation of gas bubbles, which completely ceased a few hours after the beginning of evacuation.

The vapor tension of the NG thus purified after changing the temperature from 0 to 70°C was so slight that it could not be measured with the usual mercury manometer, the accuracy of which did not exceed 0.5 mm. More precise measurements were not undertaken.

The tests of purified NG for sensitivity to cavitational stimulation of detonation revealed that even at room temperature it does not fail to detonate. Lowering of the temperature to 0°C had practically no effect on its sensitivity, and heating to 70°C also had little effect.

Thus purified NG was most sensitive to cavitation of all the LE tested heretofore in relation to this form of initiation.

Tests with technical NG, not subjected to purification in a vacuum, revealed the extremely unique behavior of its sensitivity to cavitation after change of the initial temperature. Such NG was completely insensitive to the cavitational stimulation of detonation at all temperatures except 70°C, when 2 out of 20 tests ended with detonation. As known [1, 2], NG detonates at room temperature only if the end of the piston inserted into the test tube is pointed. The tests described in these works were done with nitroglycerin not subjected to purification of volatile impurities, and its vapor tension was not measured. The vapor tensions of NG stated in these works were found in reference materials and are valid only for pure NG. Consequently the results of tests [1, 2] pertain to technical NG, inhibited by the volatile impurities it contains.

The increased sensitivity of unpurified technical NG to cavitational initiation with increased initial temperature compels the assumption that it is caused by an easing of the conditions of thermal detonation and by heating of the LE and is not related to an increase in initial vapor pressure in the cavity. Since even at 70°C the absolute magnitude of this pressure in the cavity is tens of times less than the pressure causing the cavity to close, hot points nevertheless occur and the chemical reaction proceeds more rapidly in hot NG than in cold. Thus the initiation of detonation is possible.

This simple assumption was substantiated by tests in which the detonation of LE was stimulated by electrical detonation of an aluminum wire 0.27 mm in diameter and 7 mm long, through which was discharged a capacitor with a capacitance of 6 microfarad, charged to 4 kV. On discharge practically all of the energy stored in the capacitor was released through the wire in 10 microsec.

It turned out that at temperatures not exceeding 2°C unpurified liquid NG, poured into a test tube with an inside diameter of 12 mm, did not detonate under the influence of the electrical discharge through an aluminum

wire inserted into it, whereas at higher temperatures the detonations took place without failure. Under the same conditions a stoichiometric solution of methanol in TNM detonated only at temperatures not lower than 50°C. Solutions of benzene and heptane in TNM, on the other hand, detonated even in the frozen state (at the boiling point of nitrogen). NG purified of volatile impurities detonated at 0°C.

Electrical discharge through a wire, during which several tens of joules of energy are released, is a much stronger means of initiation of detonation in LE than the closing of cavities, when the energy released does not exceed a few tenths of a joule. And if a cold solution of methanol in TNM cannot be detonated by electrical discharge, then the stimulation of detonation by cavitation is all the more impossible. When this solution is heated its "natural" sensitivity, not related to cavitation, increases, but cavitation cannot lead to initiation of detonation, since the increased vapor tension prevents the formation of hot points during the closing of cavities.

In solutions of benzene and heptane in TNM, in purified in NG the conditions for the development of a detonation center during weak initiation and during cooling remain unfavorable. Therefore the effect of vapor tension on sensitivity to cavitational initiation of detonation in these solutions was not obscured by a change in "natural" sensitivity as a function of temperature and was quite clearly revealed.

The composition of the inhibiting volatile impurities in technical NG was not investigated. Apparently the main constituents are water, methanol and air. When purified NG is stored in air for one hour the material again acquires the properties of unpurified NG: the vapor tension over its surface increases and its high sensitivity to cavitation gradually diminishes.

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