AD/A-00C 197

SENSITIVITY OF LEAD AZIDE TO ELECTRIC SPARK

V. V. StenGach

Army Foreign Science and Technology Center
Charlottesville, Virginia

August 1974

AD/A000197

DEPARTMENT OF THE ARMY

U.S. ARMY FOREIGN SCIENCE AND TECHNOLOGY CENTER
220 SEVENTH STREET NE.
CHARLOTTESVILLE, VIRGINIA 22901

In Reply Refer to:
FSTC-HT-23-444-73
DIA Task No. T70-23-01

Date: August 1974

TRANSLATION

ENGLISH TITLE: SENSITIVITY OF LEAD AZIDE TO ELECTRIC SPARK

FOREIGN TITLE: CHUVSTVITEL'NOST' AZIDA SVINTSA K ELEKTRICHESKOY ISKRE

AUTHOR: V.V. Sten'Gach

LANGUAGE: Russian

SOURCE: Fiz. Goren. I Vzryva, "Nauka", Sib. Otdel, Novosib., 6/1 1972, 113-118.

TRANSLATOR: Universal Language Services, Inc.

REQUESTOR: TD-Kane

FD 70/605089/ E 70

10

SENSITIVITY OF LEAD AZIDE TO ELECTRIC SPARK

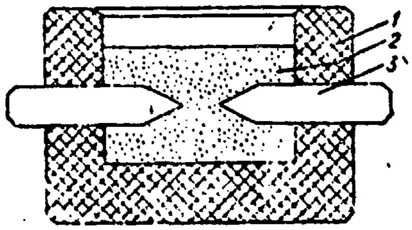
V. V. STEN'GACH
(Moscow)

At present, a number of research works on the sensitivity of explosives to thermal pulses, shocks, pricks, friction, to the action of shock waves, initiators and to other types of pulses are known. Relations between the sensitivity of explosives and various factors have been established and investigations on the excitation and explosion development mechanism have been carried out [1 - 12]. Investigations on the sensitivity of priming and secondary explosives to electric spark were carried out in the recent past [13,14,15].

The results of investigations on the sensitivity of lead azide to electric spark are outlined in this article. Experimental data on the dependence of the sensitivity of lead azide to spark discharge on various factors (density, crystal size, distance between electrodes, temperature, presence of inert admixtures) and views on the mechanism of spark triggering are given.

Lead azide, unflegmatized (GOST 1905-57) as well as flegmatized by paraffin, was used in the experiments. It was pressed in a chamber with a spark gap, formed by two steel electrodes (Fig. 1). The average density of lead azide in the chamber was varied from 1.1 to 2.7 g/cm^3 and the distance between electrodes, from 0.02 to 0.5 mm.

Fig. 1. Specimen.
1 - Plastic coating;
2 - Explosive material;
3 - Electrode.



Sensitivity of an explosive material to electric spark can be characterized by the amount of energy required for triggering the explosion. The higher the energy, the lower will be the sensitivity of the explosive material. The electric circuit, used for measuring this energy, is shown in Fig. 2. During the experiment, capacitor C_1 was charged to the required voltage through resistances R_1 and R_2 and specimen resistance R_0 ($C_2 \gg C_1$). On supplying a voltage pulse to the incendiary electrode of the triple-electrode relay P, it operated, one of the specimen electrodes got connected to the "ground", a potential difference appeared in between the specimen electrodes and the specimen sparked-over, the capacitance C_1 discharged through spark gap of the specimen and energy was liberated. If the amount of energy was sufficient for triggering lead azide, the spark-over was accompanied by an explosion.

Trigger energy of the explosive was calculated from the formula

$$Q = \frac{(C_1 + C_0)\, U_0^2}{2} = \frac{(C_1 U_1)^2}{2(C_1 + C_0)} \qquad (1)$$

and was slightly increased (but not much) since, firstly, resistance of air to spark was neglected as compared to the resistance of specimen spark gap and secondly, since arc was formed in the relay due to capacitances of the kilovoltmeter, relay and feeder C_3. Oscillograph plates (O.P.) were connected to capacitance C_2 through resistance R_3 for recording spark-over of the specimen. Oscillograph trigger was synchronized with the supply of voltage pulse to the incendiary electrode of the relay P. When the relay closed, voltage between capacitances C_0, C_1 and C_2 was redistributed differently depending upon the presence or absence of spark-over in the specimen. Onset of the spark-over could be ascertained from the shape of the oscillogram (Fig. 3)

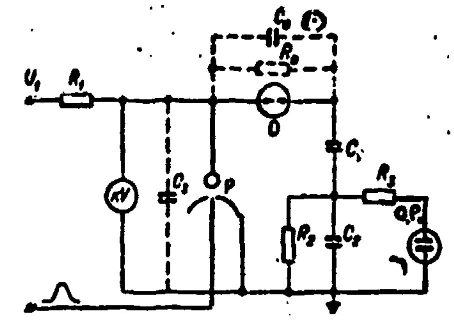


Fig. 2. Electric circuit for measuring trigger energy of an explosive by spark discharge. $R_1 = 10^6$ ohm, $R_2 = 10^6$ ohm, $R_3 = 50$ ohm, $R_0 = 10^4-10^8$ ohm, $C_0 = 0.2-1$ micromicrofarad, C_1 = var, C_2 = var, C_3 = 30 micromicrofarad.

Energy required for triggering 50% specimens was taken as the measure of sensitivity. The dependence of the frequency of explosions on energy as well as the dependence of triggering of 50% specimens on a certain factor (density, temperature, etc.) was studied.

EFFECT OF VARIOUS FACTORS. Sensitivity of lead azide to spark increases with an increase in density (Figs. 4 and 5). Experiments conducted on three lead azide precipitates with different crystal sizes, show that the sensitivity of lead azide to spark discharge decreases on increasing crystal size (Table 1). Frequency of explosions due to an energy of about 30 erg (distance between electrodes - 0.16 mm) decreases with an increase in crystal size. Crystal size was determined by means of microphotography.

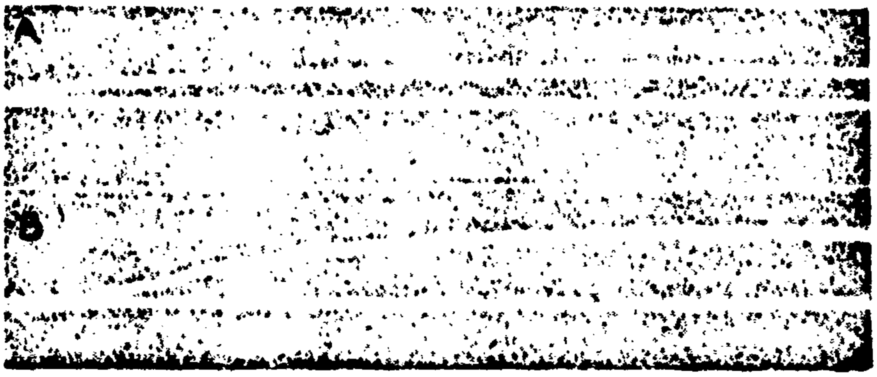


Fig. 3. Oscillograms. a) without spark-over; b) in the case of spark-over.

The results of the effect of the distance 1 between electrodes (it was varied from 0.02 to 0.5 mm) on Q at average lead azide density of 2.7 g/cm^3, are shown in Fig. 6 and it is obvious from the Fig. that the energy increases, to the first approximation, according to a linear law on increasing the distance 1 between electrodes. On raising the temperature of lead azide, its sensitivity to spark discharge increases (Fig. 7).

EFFECT OF ADMIXTURES. The results obtained on measuring the energy at 1 = 0.06 mm with lead nitrate, barium titanate and graphite admixtures are given in Table 2.

Particle size of barium titanate was 1-5μ, lead nitrate 1-10μ and of graphite 1-10μ. The admixtures were introduced in the reactor while getting lead azide (the mass was thoroughly mixed) and the mixture was then pressed at a pressure of 400 kG/cm^2.

TABLE 1

Frequency of Azide Explosion Depending on Crystal Size.

Crystal size, μ	Frequency of Explosions, %
0.3-1	88
1-3	73
3-7	67

It is obvious from Table 2 that addition of up to 10% of solid inert admixtures does not have a significant effect on the sensitivity of azide to electric spark.

Substances which can cover particles of explosive materials (paraffin, ceresin, wax, castor oil, camphor, etc.) are often taken as flegmatizers while using explosives. Experiments were conducted to determine the sensitivity of lead azide containing different amounts of paraffin; these experiments show that the sensitivity of lead azide to electric spark decreases on adding paraffin (Fig. 8). Moreover, sensitivity of lead azide to electric spark, flegmatized by paraffin, decreases on reducing pressure in the same manner as unflegmatized lead azide. In particular, the energy, required for 50% explosions of lead azide with 8% paraffin at a density of 2.8 g/cm^3, is equal to 40 ergs and it increases to 200 ergs at a density of 2.2 g/cm^3.

TABLE 2

DEPENDENCE OF Q ON ADMIXTURES

Admixture	Amount of Admixture C,%	Q, erg		Number of Specimens Tested
		100% Explosions	Isolated cases of Explosions	
Lead nitrate	6.4	50	12	40
Barium titanate	10.0	70	15	40
Graphite	4.2	60	8	40
Pure lead azide	---	60	10	40

The effect of moisture η in lead azide on its sensitivity to electric spark was verified on specimens with electrode-to-electrode distance of 0.2 mm when lead azide with different moisture contents was pressed to a density of 2.4 g/cm^3. Water was added to lead azide by washing it with water and incomplete drying.

It is seen from these experiments (Fig. 9) that the energy required for triggering lead azide increases on increasing moisture content in it.

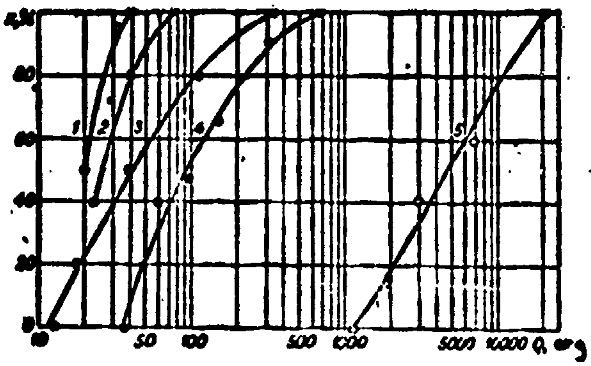


Fig. 4. Dependence of explosion frequency k on energy Q at different lead azide densities.
Density, g/cm^3: 1-2.7; 2-2.45; 3-2; 4-1.65; 5- 1.1

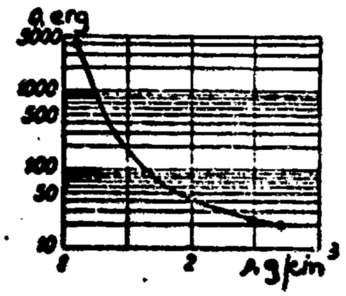


Fig. 5. Dependence of energy Q on lead azide density (ρ) in the case of 50% explosions.

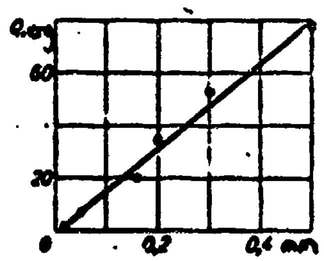


Fig. 6. Dependence of energy Q on distance between electrodes in the case of 50% explosions.

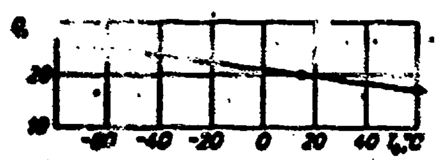


Fig. 7. Dependence of energy Q on temperature of lead azide in the case of 50% explosions.

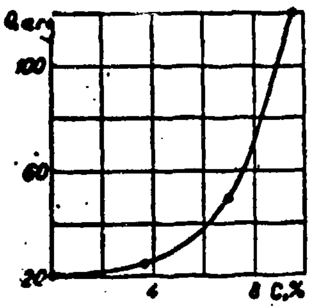


Fig. 8. Dependence of energy Q on the amount of paraffin in lead azide in the case of 50% explosions.

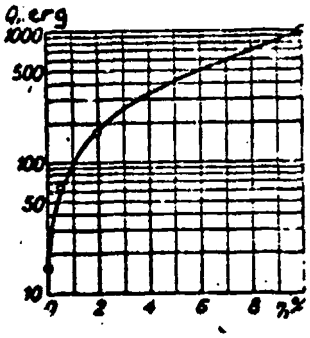


Fig. 9. Dependence of energy Q on moisture content in lead azide in the case of 50% explosions.

The trigger energy at a fixed moisture content in lead azide varies from experiment to experiment by 20-30 times. It is most probably due to non-uniform distribution of moisture in lead azide bulk as a result of which there is different amount of moisture in different specimens at the spark-over place (the same is observed in experiments with paraffin).

DISCUSSION OF RESULTS

According to the modern concepts, excitation of explosion in an explosive material leads to the formation of "hot points" and to thermal triggering. Increase of temperature above self-ignition temperature is the main cause leading to the beginning of explosive dissociation of an explosive material.

The pressed lead azide sparks over in air channels, formed by air gaps in between lead azide crystals. In the case of a spark-over in air, temperature in the spark channel can go up to 10^4-4 x 10^4 °K [16]. In order to explode lead azide, it is apparently necessary to heat a layer of spark channel to self-ignition temperature. As a result, detonation takes place as lead azide is not capable of stable combustion and can detonate in extremely small quantities.

The energy required for triggering an explosion in the same material under certain fixed conditions is not constant. An increase in the concentration of energy in bulk and with time reduces [2] the total amount of energy required for triggering an explosive material. In the case of spark discharge, the energy liberated in the substance during a short interval of time of the order of 10^{8} sec. can be localized in a small volume (in the spark channel of the order of a few microns). It should be expected that an explosive material can be spark-triggered by comparatively small amount of energy. Actually , at small clearances (0.02 mm) and at low density (3 g/cm^3), triggering of lead azide is observed at an energy of the order of 1 erg.

The obtained results can be qualitatively explained by the crude assumption that immediately after spark-over, the energy liberated in the spark gap is localized in the air channel between crystals. Owing to this energy, thin layers of crystals, adjoining the spark channel, get heated to ignition temperature. The larger the volume of spark channel, the more will be the amount of energy, necessary to be introduced in the channel for getting the same energy density (or temperature).

If it is assumed that the spark channel is a cylinder of length l and cross section s and that the same energy density w in spark channel is required for triggering lead azide, the total energy required for triggering lead azide is expressed by the formula

$$Q = slw. \tag{2}$$

It has been experimentally established that sensitivity of lead azide to electric spark decreases: a) on reducing the density of lead azide; b) on increasing crystal size; c) on increasing the distance between electrodes; d) on reducing the temperature of lead azide, and e) on increasing the amount of paraffin or water in lead azide.

Presence of up to 10% of solid inert admixtures (lead nitrate, barium titanate, graphite and others) in lead azide practically has no effect on the sensitivity of lead azide to spark discharge.

Formula (2) qualitatively confirms the experimental dependences obtained. Actually, the lower the density of lead azide or the larger its crystals, the bigger will be the cross section s of air channels where spark-over takes place and the more will be the amount of energy Q, required for triggering, at the same length l of the spark gap. The experimentally established direct proportionality between energy Q, required for triggering, and length l of the spark (at constant cross section s and energy density w) also follows from formula (2).

Increase in the sensitivity of lead azide to spark with an increase in its temperature can be explained by the fact that the amount of heat, required for heating a certain lead azide layer to self-ignition temperature, depends upon its initial temperature. The energy must decrease on increasing the latter (which agrees with the experimental data).

Addition of up to 5-10% inert solid admixtures to lead azide does not have a significant effect on its sensitivity to electric spark since still there is sufficient amount of lead azide crystals along spark channel which are unimpededly heated to self-ignition temperature. Solid inert admixtures play a "passive" role -- they neither help nor hinder triggering an explosion -- whereas in the case of mechanical actions, solid refractory admixtures act as sources of "hot points" and therefore, have a significant effect on the sensitivity of explosives to mechanical actions.

It has been established that presence of moisture in lead azide or its flegmatization with paraffin reduces its sensitivity to a spark. In the presence of moisture as well as in the case of its flegmatization with paraffin, lead azide crystals get covered by an inert film (of paraffin or water). The higher the percentage of paraffin or moisture, the thicker will be the inert film. For triggering lead azide, it is necessary to heat not only its certain layer to the self-ignition temperature but also the inert film which requires additional energy. The thicker the inert film, the more will be the energy required, i.e. sensitivity of lead azide to spark discharge decreases on increasing the amount of admixtures, capable of covering the crystals.

As a result of nonuniform distribution of the covering substance (paraffin, water, etc,) in bulk, various specimens strongly differ (by 20-30 times) from each other in the amount of energy required for triggering lead azide.

The obtained experimental data agree with the thermal mechanism of lead azide explosion excitation worked out by Soviet scientists.

Received in the Editorial Office
on September 23, 1968.

LITERATURE

1. Yu. B. Khariton, Sbornik Statey po Teorii VV (Collection of articles on the theory of explosives). Moscow, Oborongiz, 1940.

2. A.F. Belyayev, Sbornik statey po teorii VV (Collection of articles on the theory of explosives). Moscow, Oborongiz, 1940.

3. F.A. Baum, Izvestiya Artakademii, vol. 30a, Moscow, 1941.

4. N.A. Kholevo, Sb. "Teoriya VV" (Collection "Theory of explosives"). Moscow, Oborongiz, 1963.

5. K.K. Andreyev, Sb. "Theoriya VV" (Collection "Theory of explosives"). Moscow, Oborongiz, 1963.

6. Ya. I. Leytman, Voprosy teorii vzryvchatykh veshchestv (Questions on the theory of explosives). Moscow, Izd-vo AN SSSR, 1947.

7. P.F. Bubnov, Initsiiruyushchiye vzryvchatye veshchestva (Priming explosives). Moscow, Oborongiz, 1940.

8. F. Bouden, A. Ioffe, Vozbushdeniye i razvitiye vzryva v tverdykh i zhidkikh veshchestvakh (Triggering and development of explosion in solid liquid substances). Moscow, IL, 1955.

9. F.A. Baum, K.P. Stanyukovich, B.N. Shekhter, Fizika Vzryva (Physics of explosion). Moscow, Fizmatgiz, 1959.

10. K.K. Andreyev, A.F. Belyayev, Teoriya vzryvchatykh veshchestv (Theory of explosives). Moscow, Oborongiz, 1960.

11. F.Bouden, A. Ioffe, Bystrye reaktsii in tverdykh veshchestvakh (Rapid reactions in solid substances). Moscow, IL, 1962.

12. R.H. Dinegar, R.H. Rochoster, M.C. Millican. Explosivstoffe, 1963, 9.

13. J. Nakano, J. Tanaka, M. Kusakabe. J. Ind. Expl. Soc. 1963, 24, 6.

14. J. Nakano, J. Tanaka, J. Mizushima. J. Ind. Expl. Soc., 1965, 26, 5.

15. R.M.H. Wyatt. P.W.J. Moore a.o. Proc. Roy. Soc. 1958, A 246, 1245.

16. G.G. Dolgov, S.L. Mandel'shtamm, ZhETF, 1953, 24, 6.