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COMMERCIAL EXPLOSIVES AND INITIATORS- A HANDBOOK

B. D. Rossi, et al

Army Foreign Science and Technology Center
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DEPARTMENT OF THE ARMY
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220 SEVENTH STREET NE.
CHARLOTTESVILLE, VIRGINIA 22901

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AUTHOR: B. D. Rossi and Z. G. Pozdnyakov

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ABSTRACT: Basic information on commercial explosives and initiators of the current product line in the USSR is presented, including the latest products permitted in explosive practice. Besides formulations, standardized quality indicators of explosives produced and design features of initiators, state-standard covered methods of control testing, kinds of bagging and packing, wholesale prices, and use warranty schedules are given. Calculation and experimental characteristics of explosives and initiators are set forth, along with their laboratory test methods. The fields of application of each kind or group of explosives and initiators are stated. The fundamentals of the theory of explosions are presented.

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AUTHORS' ABSTRACT

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Basic information on commercial explosives (E) and initiators (I) of the present-day domestic product line is presented in the handbook, including the latest kinds of products permitted for explosive practice. In addition to formulations, standardized technical quality indicators of E produced, and design features of I, state-standard covered methods of control testing, kinds of bagging and packing, wholesale prices, and use warranty schedules are given. Calculated and experimental features of E and I are set forth, along with their laboratory test methods. The fields of use of each kind or group of E and I are stated. The basic principles of the theory of explosions are set forth.

The handbook is published with the aim of familiarizing users with the product line and service properties of E and I and also of assisting in the more proper selection of the required variety or kind of product for specific explosion conditions. It can serve as a practical manual for all personnel designing and carrying out explosion operations and can also prove useful in planning deliveries of explosive materials and in training engineers, technicians, and foremen in explosive practices in educational institutions.

43 tables, 55 illustrations, and 33 bibliographical references.

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FOREWORD

With the advances made in the technology of extracting minerals and methods of explosion practice, there has been a continuous improvement in the product line and quality of commercial explosive materials. With the appearance of the first concise *Spravochnik po Promyshlennym Vzryvchatym Materialam* [Handbook on Commercial Explosive Materials] (Ugletekhizdat, 1958), the product line of domestic E [explosives] and initiators has been greatly expanded and extended. New kinds of explosive materials have been developed and introduced -- granulated and slurry E exhibiting several advantages compared with the earlier-used dynamites and powdered ammonites and permitting the mechanization of the laborious process of charging blastholes, drillholes, and chambers, and also the attaining of marked progress in explosive practice. New safety E have appeared differing in their enhanced safety properties; their use makes operations in mines with dust-gas conditions much safer. Improved initiators, intermediate detonators, and shaped charges for secondary blasting previously not employed in blasting work have been developed. New kinds of explosive materials (EM) are gaining in growing acceptance year by year; the volume of their use will rise at the expense of a cutback in the obsolescent varieties and grades of this kind of product.

There has also been improvement in the technology of manufacturing and packing commercial E that means advances in the preservation of their initial properties for specified periods of service. All this has been reflected in the present handbook. It sets forth basic information about all E and initiators permitted for prominent use, as well as certain new kinds of EM at the stage of introduction. The classification of E given in the handbook corresponds to the *Yedinaya Klassifikatsii Promyshlennykh VV* [Unified Classification of Commercial Explosives], adopted in 1962 at the International Scientific and Technical Conference of CEMA member-countries; explosive materials are classified into groups by the most characteristic features, properties, and conditions of use. Both of the information on E and initiators is given in numerical form. The tables and specifications present the norms and allowances set by the corresponding standards or departmental technical conditions. The tabulated material on the properties and service characteristics of E is presented in minimum and maximum values, and sometimes in mean values of the indicators obtained after studying each kind of explosive, and also from control tests of plant lots of growth product.

The technical-economic effectiveness and the safety of using E and I [I = initiators] presented in the handbook depends greatly on the proper selection of the kind of EM as applied to the specific explosion conditions and their competent application. This necessitates a knowledge of the properties and service characteristics of the EM, costs, and rules of handling them. This information is also incorporated into the handbook to familiarize persons encountering explosive materials in their work.

Chapters I-V, dealing with explosives, have been written mainly by Z. G. Pozdnyakov, Chapter VI dealing with initiators, and also Sections 5 and 7, and part of Section 20, "Determination of Gas Hazard" are written by B. D. Rossi, part of Section 10, "Igdanit" was written by the authors together. Section 16 was written by D. I. Adamidze.

All critical remarks and suggestions for improvement of the handbook will be gratefully received by the authors.

The authors express their deep gratitude to Professor and Doctor of Technical Sciences L. V. Dubnov, Professor and Doctor of Technical Sciences M. M. Dokuchayev, A. V. Kuz'min, and Candidate of Technical Sciences B. Ya. Svetlov for valuable comments and recommendations given during the preparation of this handbook.

INTRODUCTION

Commercial E and initiators in the USSR are being improved in accordance with advances in the mining industry and in the technology of explosive practice.

Before the 1930's, predominantly nitroglycerin E were used in explosive practice: 93 percent fulminating gel, 88 percent and 83 percent explosive gelatins, 62 percent potassium nitrate-based dynamite, and also 29 percent and 12 percent ammonium nitrate-based grisoutines. Of the non-nitroglycerin E, the following were used in small amounts: schneiderite (82 percent nitrate and 18 percent dinitronaphthalene), ammonal containing 5 percent aluminum and 9 percent trotyl, and also black powder.

In 1932-1936, owing to the mounting volume of explosive work and in order to cut their costs, the Production-Experimental Administration of the Soyuzvzryvprom [State Trust for Drilling and Blasting Operations of the Glavspetspromstroy [Main Administration of Specialized Trusts of the Ministry of Urban and Rural Construction, RSFSR]] Trust developed and introduced the first inexpensive double-base ammonites: No 2T containing 12 percent trotyl, No 2K containing 12 percent trinitroxylol, No 3T containing 14 percent trotyl and trinitroxylol, and No 3TM containing 13 percent trotyl oil.

At that time, along with the ammonites development and introduction was begun on fine-dispersed ammonium-nitrate explosive mixtures not containing nitro compounds, called dynammons. Dynammon K based on pine bark meal was used, along with peat-based dynammon T, wood meal-based dynammon DM, and also dynammon based on several other accessible and low-cost flammable materials, including mazut, kerosene, and paraffin in combination with peat. During the years of the Great Patriotic War dynammons were the main kind of commercial explosives: they were manufactured at mining enterprises in workshops specifically built for this purpose. At the conclusion of the war, the local-level manufactured dynammons were halted. Since this time, in our country, compared to many foreign countries, ammonium-nitrate nonnitroglycerin E are used predominantly; compared with dynamites, these are several times cheaper, nontoxic, and much safer to handle. The use of high-percentage dynamites in the 1950's was completely discontinued, and ammonium-nitrate E with small content of nitro esters (detonites and uglenites) have found use on relatively small scale.

In 1934-1936 in the USSR a technology was developed for manufacturing high-strength No 2T ammonite (brisance 14 mm), and the first water-resistant ammonium-nitrate E of increased strength was also introduced -- formulated dinaphthalite (88 percent nitrate and 12 percent dinitronaphthalene) with a brisance of 15-16 mm. By this time there had been a nearly complete discontinuance of the use of black powder, owing to its high sensitivity to flame and its low strength. Dinaphthalite even at the present time finds use owing to its characteristic water resistance and reduced caking tendency.

In the prewar and war years the first safety ammonites were developed: No 1 anti-firedamp containing 10 percent common salt and 10 percent trotyl, which was used prior to 1947, and also enhanced safety ammonites -- ammasol (34 percent salt and 12 percent trotyl) and 3/1 ammonite (32 percent salt and 9 percent trotyl).

Thus, the product line of commercial explosives in our country was limited by the end of the war. The brisance values of most explosives did not exceed 12-14 mm, fugacity* -- 360-380 cm^3, and detonation rate -- 3.0-3.5 km/sec. They caked severely and suffered losses in explosive properties during storage. [*also referred to as heaving action]

In the postwar years the mining industry, just as all sectors of the national economy, developed rapidly. Changes also took place in the technology of explosive-drilling practice. Instead of the predominance of blasthole and chamber charges, drillhole charges gained wide development; the volume of explosive work grew, especially at the surface where most often massive blasts with multirow drillhole began to be used. Massive blasts also began to be employed in underground mining operations. With the deepening of coal shafts and the increasing methane hazards, the necessity for formulating qualitatively new safety explosives came to the fore.

During the first postwar years higher strength ammonites No 6 and No 7 were developed and introduced, instead of the ammonites Nos 2T, 3T, and 3TM, and also the relatively inexpensive ammonites Nos 9 and 10, more sensitive than dynammons and less liable to cake. Moreover, of the safety explosives, early in the 1950's three technological modifications of water-resistant increased-strength ammonals were introduced (VA-2, VA-4, and VA-8), and also the inexpensive water-resistant ammonite V-3, which proved to be suitable for production not only in standard-diameter cartridges, but also in worm-conveyor packed charges with diameter 130-210 mm, weight 6.5-17.0 kg, and density 1.25-1.35 g/cm^3, required for charging wet drillholes. In 1955-1956 a powerful water-resistant rock-oriented ammonite No 1 was introduced in pressed cartridges, which up to the present time is one of the most powerful commercial explosives.

In coal shafts, in the postwar years detonating safety ammonite No 1 (20 percent salt and 10 percent trotyl) for operations involving coal, and rock-oriented ammonites AP-1 and AP-2 (14-15 percent trotyl and 15-19 percent flame quenching agent, respectively) have been introduced that were more powerful for that time and better detonating; since 1947 these explosives have completely replaced the anti-firedamp ammonites No 1 and III/I.

With the mass conversion to ammonites, difficulties arose in their application related to their caking tendency and nonwater resistance of the main formulations, and also the inadequate strength of several grades (ammonites Nos 6, 7, 8, and so on). Problems of the water resistance and partial caking tendency of all the main types of commercial explosives were resolved with the development in 1956-1959 of the water-resistant nitrate of grade ZhV, which became the main kind of starting material for powdered type explosives. Based on this nitrate, the ammonites No 6-ZhV and No 7-ZhV began to be manufactured, along with ammonals, rock-oriented ammonite, safety ammonites PZhV-20, AP-4ZhV, AP-5ZhV, and so on. By the beginning of 1960, methods of manufacturing several friable explosives directly at mining enterprises (igdanite and certain zernogranulites), making it possible to raise the technical-economic effectiveness of explosive operations.

The present-day domestic product line of commercial explosives is quite extensive and diverse. In 1970, more than 40 designations of explosive introduced and about 10 at the stage of mastery were recorded. Among these there are nearly all kinds of the most progressive explosives known in world practice.

CHAPTER I
MAIN PRINCIPLES OF THE THEORY OF EXPLOSIVES

1. Concept of Explosives and Explosions

Explosives are chemical compounds or mechanical mixtures of dissimilar substances capable -- when acted on by external forces -- of extremely rapid self-propagating transformation, with the formation of gaseous products and the release of large amounts of heat, heating the substances to high temperatures. Condensed explosive mixtures, which include most commercial explosives, contain some components rich in hydrogen, carbon, and other components that are oxygen-rich. In an explosion, these compounds are oxidized without the participation of air oxygen. A distinguishing feature of condensed explosives is the very large volumetric concentration of energy. The concentration of freed energy within the volume of a charge determines the intensity and scale of destruction of the surrounding medium (rock) during an explosion.

An explosion is the term given to an extremely rapid chemical transformation of an explosive with the evolution of heat and gaseous products. The gaseous products that are strongly heated and compressed during an explosion to an enormous pressure, upon subsequent expansion, perform mechanical work of breaking down the surrounding barrier, for example, cleaving, crushing, and dislodging of rock. An explosion can occur in the form of rapid combustion or as a detonation.

Detonation refers to the phenomenon of the propagation through an explosive charge of an exothermic reaction of chemical transformation, called the shock wave.

A shock wave refers to the perturbation (compression and heating) of the surrounding medium caused by the rapidly-expanding gaseous products from the focus of the explosion. The shock wave spreading from the point of initiation excites and sustains the reaction of the explosive transformation in all areas of the explosive charge. On travelling to the surrounding medium, it breaks it down, then being transformed into an air shock wave, as a result of the irreversible energy losses rapidly weakening and in turn being transformed into an ordinary sound wave.

A shock wave spreading through a charge is called a detonation wave. A detonation is characterized by the rate of the chemical transformation of the explosive that is the greatest for the given conditions of explosion and the state of the charge. The rate of propagation of a detonation wave is called the detonation rate. The constancy of detonation wave parameters (rate and pressure) is sustained by a thermal energy released during exotnermic reactions of the transformation of layers of the explosive at the detonation front.

Excitation of explosion

An explosion can be excited by various external influences: the explosion of a small charge of another explosive (for example, a blasting cap) placed in the explosive to be exploded or at some distance from it (air shock wave), by a strong mechanical blow, or by friction, rapid heating, or ignition. To excite an explosion of an explosive charge, it is necessary that some amount of thermal energy adequate to form local foci of exothermic self-accelerating decomposition be imparted to any point in the explosive by one of the indicated external influences; these foci then lead to a rapid rise in temperature and pressure with the formation ultimately of the detonation shock wave. Excitation of an explosion always begins with the combustion of several regions of the explosive charge induced by a given means, which due to self-acceleration passes into a qualitatively different process — detonation. The combustion of an explosive, however rapid it may be, cannot cause the destruction of the surrounding solid medium as detonation can produce. Only in detonation can the maximum useful work of the explosion be realized.

The energy required to excite an explosion is called the initial impulse, while the process of the excitation itself is called initiation. The minimum initial impulse for various explosives differs. It depends on the chemical nature and the physical state of the initiating explosive [initiator]. For most finely dispersed commercial explosives, several tenths of a gram of the initiating explosive is sufficient to cause a detonation. For failure-free excitation of a detonation, in practice a No 8 blasting cap is used containing 0.5 g mercury fulminate or 0.2 g lead azide and, as the main charge, 1 g of pressed tetryl. An intermediate detonator — a charge of a powerful explosive — is needed to initiate granulated, slurry, and several other kinds of explosives.

Sensitivity of explosives

Sensitivity refers to the ability of an explosive to respond to a given kind of external influence. To determine the conditions for safe application and safety in handling, commercial explosives are tested for sensitivity to the initial impulse of the blasting cap or the intermediate detonator and for sensitivity to mechanical (impact or friction) and thermal (heating, spark, flame) actions.

The sensitivity to a No 8 blasting cap is the main criterion for estimating the safety of an explosive [1]. A measure of the safety of explosives insensitive to blasting caps is the size of the intermediate detonator, which is usually expressed in grams of pressed trotyl.

2. Conditions for Stable Propagation of Detonation and the Detonatability of Explosives

A detonation in an explosive charge is capable of being stably propagated only at a specific rate and for specific conditions of explosion. Condensed explosives can detonate at rates of not less than 1.8 km/sec. At slower rates and for other critical conditions, the energy losses in the detonation front are so large that the energy is insufficient to sustain the normal process. Optimal detonation rates of commercial explosives are within the limits 2.5-6.5 km/sec. Essential conditions for stable detonation of charges are these: their adequate initiation, the required diameter and density, satisfactory chemical composition, and normal physical state of the explosive.

The critical conditions are the following: critical diameter of the detonation of the explosive charge and critical density. The critical diameter of a detonation refers to the diameter of a charge below which the detonation process becomes impossible. With increase in the charge diameter, the detonation rate rises to some limiting value typical of the given state of the explosive. A diameter above which the detonation remains constant is called the limiting diameter, and the rate is called the limiting or optimal detonation rate.

The size of the critical diameter is a measure of the detonatability of an explosive. The smaller the diameter, the higher the detonatability of a given explosive. Commercial explosives whose composition includes a high-sensitivity sensitizer — a component (hexogen or nitro esters) rendering them sensitive to detonation — exhibit the smallest critical diameter.

Among the factors adversely affecting the stability of detonation and the critical diameter of commercial explosives are these: unfavorable chemical composition of explosive or unsatisfactory physical state of the

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[1] In America, all explosives that are insensitive to a blasting cap are called explosive agents in order to emphasize their distinction from sensitive explosives.

explosive (coarse-dispersed structure, caking tendency, excessive compaction, and excessive moisture content) and unfavorable explosion conditions (insufficient excitation of the detonation by the initiator, the presence of a large gap between the charge diameter and the shell diameter). Stability of a detonation can be augmented and the critical diameter reduced by placing a charge in a strong shell free of gaps, for example, in rock.

The critical density of an explosive refers to the density above which the detonation rate and the actual explosive effect are reduced in charges with given diameter and in given explosion conditions. The critical density depends on the same factors as does the critical diameter and supplements the characteristics of detonatability of the explosive. The characteristic of detonation sensitivity or detonatability of commercial explosives is also the distance to which a detonation is transmitted through air between explosive cartridges, or else this characteristic can be the susceptibility to detonation from an air shock wave of constant parameters, produced by the explosion of a charge of any explosive taken as the reference standard (for example, 200 g trotyl charge).

3. Parameters of Explosive Transformation

Explosion parameters include the rate and pressure of detonation, heat and temperature of explosion, and volume and composition of explosion products.

The <u>detonation rate</u> for each explosive in specific conditions of explosion is a constant, but it can vary with wide limits depending on the aggregate effect of various factors: dispersion of the explosive, density and diameter of the charge, presence of a strong shell, and so on. The detonation rate in specific conditions of explosion depends on the energy of the explosive, and also its density, and it can be determined experimentally (Section 20) or by the formula

$$D = 64{,}6\sqrt{2(n^2 - 1)Q_V}, \quad \text{m/sec}, \qquad (1)$$

where 64.6 is the conversion factor of units from the CGS system;
n is the polytrope index, approximately 3; and
Q_V is the heat of the explosion at constant volume, kcal/kg.

The <u>explosion pressure</u> is proportional to the density of the explosive and to the square of its detonation rate and can be calculated, approximately, by the formula

$$P_з \cong \frac{\rho_0 D^2}{4}, \quad \text{bar}, \qquad (2)$$

where ρ_0 is the density of the explosive, g/cm^3.

For commercial explosives, it varies from 50 to 250 kbar.

The <u>heat of explosion</u> refers to the amount of heat released in the explosive transformation of 1 mole or 1 kg of an explosive. The heat of explosion is one of the principal, most important characteristic of an explosive governing its strength.

The heat of explosion can be found experimentally (Section 20) or by the formula

$$Q_{\text{вз}} = q_1 - q_2. \qquad (3)$$

The calculation rests on a law, according to which the thermal effect of the explosive transformation reaction does not depend on its path but is determined by the initial and end states of the system, that is, it is expressed as the difference between heat of formation of the explosion products q_1 and the heat of formation of the initial explosive or its constituents q_2.

The heat of explosion can be calculated at constant pressure (Q_p) or at constant volume Q_V, by inserting into Eq. (3) the appropriate heats of formation of constituents, available from their table (cf. Appendix 1) or from handbooks of thermochemical values. To convert from one kind of heat to another, we have the function

$$Q_V = Q_p + 0{,}58 n_1, \text{ kcal/mole}, \qquad (4)$$

where n_1 is the number of moles of the gaseous explosion products.

The <u>explosion temperature</u> refers to the maximum temperature to which the explosion products are heated owing to the heat of the explosive transformation. The explosion temperature to some extent characterizes the safety properties of explosive used in mines that are hazardous as to gas or dust. The lower this temperature, the less dangerous is the safety explosive. The explosion temperature can be usually be determined by the formula

$$T = \frac{Q_V}{C_V} + 273, \text{ deg}, \qquad (5)$$

where C_V is the mean heat capacity of the explosion products, kcal/kg·deg.

The <u>volume of gaseous explosion products</u> to some extent determines the efficiency of an explosive. The larger the volume of gases, the more (under otherwise equal conditions) the energy of the explosion is converted into mechanical work. By knowing the reaction of the explosive transformation of an explosive, we can calculate the specific volume of gaseous products by the formula

$$V = \frac{22,4 n_2 \cdot 1000}{NM}, \quad 1/\text{kg}, \tag{6}$$

where n_2 is the number of gaseous molecules in the explosive products;

N is the number of molecules of the starting substance participating in the reaction; and

M is the molecular weight of the starting substance.

The number of gram-moles of gaseous products is calculated starting from the chemical composition of the explosive and general laws of chemistry and thermodynamics.

For explosives with a positive or a zero oxygen balance, the amount of gases can be determined from the following scheme of the chemical equation:

$$C_aH_bN_cO_d = a\,CO_2 + \frac{b}{2}H_2O + \frac{C}{2}N_2 + \frac{1}{2}\left(d - \frac{b}{2} - 2a\right)O_2, \tag{7}$$

where a, b, c, and d are the numbers of atoms of the elements carbon, hydrogen, nitrogen, and oxygen in the explosive molecule.

The volume of the gaseous products can also be determined experimentally by exploding a weighed sample of the explosive in a closed volume (bomb) followed by measurement of the cooled gases and calculation of their volume (Section 20).

4. Forms of Useful Work of An Explosion

The transformation of the energy of explosion into mechanical work is carried out by expansion of severely compressed and heated gaseous products of detonation and the formation of shock waves of compression and expansion propagating in the surrounding medium (for example, rock mass) and causing its deformation and breakdown. Only a slight fraction of the total energy of the explosion is converted into useful work. The rest of it is expended in nonuseful forms of work: incompleteness of chemical reactions (chemical losses), residual heat and pressure in the explosion products, overpulverization and heating of the surrounding medium, ejection of rock fragments, formation of air shock wave, and so on. The useful work of an explosion depends heavily on the selection of the most rational method of carrying out the explosive operations and the appropriate kind of explosive.

Of the useful forms of mechanical work in an explosion, a differentiation is made between *brisant* and *heaving* action. Brisant action involves the intensive fragmentation and deformation of the barriers directly adjoining the charge by means of the sudden impact of the detonation products compressed to high pressures. The intensity of the fragmentation and detonation is determined mainly by the concentration of energy per unit volume of the detonation wave front and by the detonation pressure, which is directly proportional to the density of the explosion and to the square of the detonation rate (2). Brisance of commercial explosives rises to critical values, after which it drops off sharply. The detonation rate, and therefore, the brisant action of commercial explosives can also be augmented by increasing their comminution and eliminating energy losses in the lateral scattering of explosion products. There are several ways of estimating brisance (based on the compression of lead cylinders, deflection of a ballistic pendulum, and so on), which characterize only the relative fragmenting action of the explosive, manifested in the explosion of rock. For laboratory comparative evaluation of an explosive, most often a test based on the compression of lead cylinders is used (the Hess test; Section 19).

The heaving action of an explosion in rock includes the breakdown and expulsion of the rock from the explosion zone, with the formation of a cavity, seismic vibrations of the solid mass, and also the breakdown of barriers at a considerable distance from the explosion site caused by the shock waves and movement of elastic media. Heaving action, called otherwise the efficiency of an explosive, is determined principally by the heat of explosion, specific volume, heat capacity, and expansion of the gaseous products of the explosion. Efficiency increases with increase in heat and volume of gases. It is estimated by the expansion of the channel of a lead bomb when a weighed explosive sample is exploded (Trauzl test; Section 19), from the deflection of the ballistic pendulum or a ballistic mortar, and also by the formation of an explosion funnel in the ground or the solid rock. When testing with the ballistic pendulum, the criterion of the estimate of efficiency is the <u>trotyl equivalent</u>, which is the ratio of the deflection of the pendulum when a charge of the test explosion is exploded to the deflection obtained when the same charge (200 g) of trotyl, taken as the reference standard, is exploded.

Included among the specific forms of the work of an explosion is cumulative or directed action. <u>Cumulation</u> refers to the intensification of the local action of the explosion (breakthrough, cleaving, or initiating) in a specific direction. It is manifested in explosive charges of specific design provided with a conical, spherical, or parabolic recess in a face (less often side) surface, where the recess refracts and forms a severely compacted jet of detonation products travelling in the direction of the recess axis at a considerably greater velocity (up to 8-10 km/sec) than the detonation rate of the charge itself. The cumulative effect rises by many times when the recess is lined with copper or steel. The metal of the recess raises the density of the energy and increases the length of the active section of the cumulative jet, by means of which the destructive or initiating action of the explosion is greatly augmented.

The cumulative effect is used in exterior charges (Section 15) to intensify the fragmentation of oversize pieces of rock in a secondary explosion, and also in blasting caps to raise their initiating action.

5. Composition of Explosion Products. Toxic Gases

The explosive transformation of an explosive is accompanied, in addition to the evolution of a large amount of energy (heat), also by the formation of large amounts of gases performing work due to the abrupt pressure rise in their region of formation. In addition to the gases, the explosion products can also include oxides of the following metals as a solid residue: Al_2O_3, K_2O, Na_2O, and so on.

The volume of gaseous products of the explosion of various commercial explosives varies from 600 to 950 l per kg of explosive. Determining the volume of explosion gases, as well as the composition of gaseous products, is carried out in special apparatuses -- Dolgov or Bichel bombs, and also directly in field conditions.

Gaseous products of an explosion contain various components: water vapor, carbon dioxide gas CO_2, carbon monoxide CO, oxygen O_2, nitrogen N_2, nitric oxide NO, nitrogen dioxide NO_2, and nitrogen tetroxide N_2O_4. There is a possibility of the formation of methane CH_4, hydrogen H_2, and sulfur gases: sulfur dioxide SO_2 and hydrogen sulfide H_2S.

When blasting caps are exploded, vapor of mercury or lead is formed. Some of the gaseous products of the explosion are toxic: carbon monoxide, oxides of nitrogen, sulfur gases, and vapors of mercury and lead. The most toxic are the oxides of nitrogenaand carbon monoxide, and the less least toxic are the sulfur gases forming during explosions in rocks containing sulfur compounds. Vapors of mercury or lead can be formed not only in the explosion of blasting caps, but also in explosive operations in rock containing compounds of mercury or lead.

<u>Carbon monoxide</u> is a colorless gas with a faint odor, and its density with respect to air is 0.967. It dissolves in water of 15° C to the extent of 0.025 percent. A mixture of air with carbon monoxide (12.5-74.2 percent) has explosive properties.

When inhaled, carbon monoxide causes headaches and dypsnea. The maximum allowable CO concentration when persons are present in a room for a long time is more than 0.0016 percent of volume, or 0.02 mg/l. First aid in case of carbon monoxide poisoning involves removing the patient into fresh air and applying artificial respiration. Complete rest is also necessary.

Nitrogen oxides in large amount are brown in color, darkening with an increase in their concentration and in the air temperature. They have a strong odor.

Nitric oxide is a colorless gas, and its density is 1.037 with respect to air. At high temperatures, it readily reacts with oxygen, converting into the dioxide. In air it oxidizes slowly at low temperatures.

Nitrogen dioxide is a brown gas, and its density is 1.58 with respect to air. It readily dissolves in water, producing nitric and nitrous acids at low concentrations.

The allowable concentration of nitrogen oxides in air for NO or NO_2 is 0.0002 percent.

Nitrogen oxides cause pulmonary irritation, and in severe cases -- edema. The action of nitrogen oxides shows up after 4-5 hours. First aid in the event of poisoning with nitrogen oxides includes fresh air and complete rest.

The toxicity coefficient of nitrogen oxides with respect to carbon monoxide is 6.5.

Hydrogen sulfide is a colorless gas with the odor of rotten eggs. Its density with respect to air is 1.19 and it dissolves readily in water. When inhaled, it strongly irritates the lungs and causes edema. The maximum allowable concentration of hydrogen sulfide for prolonged inhalation by man is not more than 0.0006 percent, or 0.015 mg/l.

Sulfur dioxide is a colorless gas with a strong irritating odor and an acid taste. Its density with respect to air is 2.21 and it dissolves readily in water. It causes sneezing, coughing, spasms of the glottis, and emphysema.

The allowable concentration for prolonged inhalation is 0.02 mg/l, and in brief inhalation -- 0.04 mg/l, or 0.307 percent. In the event of intoxication by sulfur gases, the following are required: fresh air and artificial respiration.

The coefficient of toxicity of both sulfur gases with respect to carbon monoxide is 2.5.

Mercury vapor upon prolonged inhalation causes chronic intoxication of the nervous system and the kidneys. The allowable concentration is 0.00001 mg/l.

Lead vapor also causes intoxication of the nervous system.

Carbon dioxide gas CO_2 is not a toxic gas, but it adversely affects workers employed underground. Large concentrations of CO_2 in air upset respiratory rhythm and cause headaches and ringing noises in the ears.

The total amount of toxic gases in an explosion is given in the formula

$$X = a\,CO + 6.5b\,NO_2 + 2.5c\,(SO_2 + H_2S),\quad 1/kg, \qquad (8)$$

where a, b, and c are the total amounts, respectively, of CO, NO_2, and sulfur gases.

The amount of toxic gases formed in explosive operations depends on the following factors:

oxygen balance of the explosive;

physicomechanical properties of rock in which the explosive operations are carried;

moisture content and density of the explosive, and the provision of a paper-paraffin wrapper; and

conditions under which the explosive operations are carried out; location of the blasting cap in the charge, diameter and length of the blastholes, clearance in the material blastholes and properties of the stemming.

Oxygen balance is the difference between the amount of oxygen in the composition of a given explosive and the amount of oxygen needed for total oxidation of all of the carbon in the carbon dioxide gas, hydrogen in water, and also other elements capable of being oxidized (aluminum and so on).

Oxygen balance can be positive, zero, or negative.

Positive oxygen balance is the ratio between the weight of oxygen and the weight of flammable elements in the explosive, where the amount of oxygen in the composition exceeds its amount needed for oxidizing the flammable elements. In the explosive transmation of an explosive containing a positive oxygen balance, nitrogen oxides are formed. These explosives include, in particular, ammonium nitrate with an oxygen balance of +20 percent.

Adverse oxygen balance is the ratio between the weight of oxygen and the weight of the fuel in the explosive composition, where the available amount of oxygen is sufficient to oxidize all the flammable components. In this case in the explosion of the explosive, much carbon monoxide is formed. Trotyl has a negative oxygen balance of 74 percent.

Zero oxygen balance of an explosive is the balance when the amount of oxygen in the explosive composition corresponds precisely to its amount required for the complete oxidation of all the flammable elements. Dinitroglycol has a precisely zero balance.

TABLE 1. GROUPS OF ROCK BASED ON THE AMOUNT OF TOXIC GASES FORMING WHEN VARIOUS EXPLOSIVES ARE EXPLODED IN FIELD CONDITIONS

1 Горные породы	2 Количество ядовитых газов, *л/кг*		
	3 окись углерода	4 окислы азота	5 всего
	6 I группа		
7 Апатитовая руда	13,0—21,5	0,06—1,06	14,6—28,0
8 Иолит-уртитовая руда (нефелин)	13,9—19,5	0,01—0,21	14,3—19,6
9 Калийные соли	7,9—11,6	3,1—4,1	31,1—38,4
10 Молибденовые руды	4,1—7,4	4,3—4,8	32,0—38,6
11 Медные руды	6,6—11,2	3,1—4,3	28,5—39,5
12 Полиметаллические руды	4,2—37,4	0,7—2,8	10,3—44,1
	13 II группа		
14 **Уголь**			
15 Угольные забои	12,0—42,0	3,0—7,4	48,5—81,3
16 Породные забои	8,7—30,0	2,6—6,5	37,6—66,0
17 **Антрацит**			
18 Угольные забои	3,5—6,8	9,5—15,5	54,3—97,8
19 Глинистый сланец	3,6—7,1	1,3—6,1	12,2—44,1
20 **Свинцово-цинковые руды**			
21 Руда	18,0—33,4	3,7—9,5	44,4—95,5
22 Порода	13,8—22,5	2,7—10,3	32,0—90,5
23 **Железные руды**			
24 Мартитовая	13,1—26,3	5,1—10,5	54,7—78,5
25 **Медные руды**			
26 Кварцево-альбитовые порфироиды	4,8—30,5	1,7—9,6	35,8—82,2
27 Золотоносные руды	41,6—43,5	4,9—5,9	75,3—79,9
	30 III группа		
28 **Железные руды**			
29 Джеспилиты	22,3—44,0	12,0—22,6	105,3—169,5

KEY: 1 -- Rock
2 -- Amount of toxic gases, l/kg
3 -- carbon monoxide
4 -- nitrogen oxides
5 -- total
6 -- Group I
7 -- Apatite ore
8 -- Cordierite-urtite ore (nepheline)
9 -- Potassium salts
10 -- Molybdenum ores
11 -- Copper ores
12 -- Polymetallic ores
13 -- Group II
14 -- Coal
15 -- Coal faces
16 -- Rock faces
17 -- Anthracite
18 -- Coal faces
19 -- Clay shale
20 -- Lead-zinc ores
21 -- Ore
22 -- Rock

[KEY continued on following page]

KEY [Continuation of TABLE 1]:

22 -- Rock	27 -- Gold-bearing ores
23 -- Iron ores	28 -- Iron ores
24 -- Martite	29 -- Jaspilites
25 -- Copper ores	30 -- Group III
26 -- Quartz-albite porphyroids	

TABLE 2. EFFECT OF ROCK TOUGHNESS ON CO FORMATION

1 Взрываемая среда	2 Коэффициент крепости по шкале проф. М. М. Протодьяконова	3 Количество ядовитых газов, л/кг		
		4 окись углерода	5 окислы азота	6 всего в пересчете на CO
7 Мартитовая руда (влажная)	4	10,3	5,1	43,5
8 Гидрогематитовая мартитовая (сухая)	4	7,0	5,4	42,1
9 Хлоритовые сланцы (сухие)	6	18,6	1,3	27,0
10 Гидрогематитовые мартитовые роговики (сухие) . .	8	29,8	1,2	37,6
11 Джеспилиты, сильно трещиноватые (сухие)	12	20,4	4,5	49,7
12 Джеспилиты трещиноватые (сухие)	12	34,1	1,2	41,9
13 Джеспилиты (влажные) . .	14	33,4	1,6	43,8

KEY:
1 -- Medium exploded
2 -- Coefficient of toughness on scale of Professor M. M. Protod'yakov
3 -- Amount of toxic gases, l/kg
4 -- carbon monoxide
5 -- nitrogen oxides
6 -- total, on a CO basis
7 -- Martite ore (moist)
8 -- Hydrohematite martite (dry)
9 -- Chlorite shales (dry)
10 -- Hydrohematite martite cherts
11 -- Jaspilites, strongly fissured (dry)
12 -- Jaspilites, fissured (dry)
13 -- Jaspilites (moist)

Since the explosive transformation of an explosive with a positive or a negative oxygen balance involves the formation of toxic gases, for explosive work in underground excavations explosives with zero or near-zero oxygen balance are permitted. By the amount of the toxic gases formed, rocks can be divided into the following groups: up to 40 l per kg of explosive, from 40 to 100, and more than 100 l/kg (Table 1).

TABLE 3. EFFECT OF EXPLOSIVE DENSITY ON FORMATION OF TOXIC GASES

1 ВВ	2 Плотность, г/см³	3 Количество ядовитых газов (л/кг) при взрывании								
		4 в песке			5 в железной руде			7 в медной руде		
		CO	NO	6 всего	CO	NO_2	6 всего	CO	NO_2	6 всего
8 Аммонит № 6 порошкообразный	1,0	25,7	21,0	162,2	12,3	3,5	35,1	—	—	—
9 Аммонит № 6 прессованный	1,3	21,3	13,6	109,7	10,5	2,5	26,3	—	—	—
10 Игданит	0,7	—	—	—	—	—	—	2,24	5,4	37,94
11 То же	0,87	—	—	—	—	—	—	1,72	3,9	27,07

KEY:
1 -- Explosive
2 -- Density, g/cm³
3 -- Amount of toxic gases (l/kg) during an explosion
4 -- in sand
5 -- in iron ore
6 -- total
7 -- in copper ore
8 -- Ammonite No 6, powdered
9 -- Ammonite No 6, pressed
10 -- Igdanite
11 -- As above

TABLE 4. EFFECT OF WEIGHT OF CARTRIDGE WRAPPER ON CARBON MONOXIDE FORMATION

1 ВВ	2 Вес оболочки патронов в г на кг ВВ		5 Количество CO	6 Примечание
	3 бумага	4 парафин		
7 Аммонит № 6 прессованный	10 Нет	10 Нет	7,5	
	0,5	0,6	17,1	
	1,2	1,7	28,3	
	2,0	2,5	29,6	
	4,0	5,0	35,9	
8 Аммонит № 6	2,0	2,5	40,8	11 Уголь-Донбасс
То же	Полиэтилен		18,2	13 »
9 12	2,0	2,5	39—42	Северо-Уральский бокситовый рудник (СУБР)
9 То же	12 Полиэтилен		12—20	То же 9

[KEY on following page]

KEY [to TABLE 4]:
1 -- Explosive
2 -- Weight of cartridge wrapper in g per kg of explosive
3 -- paper
4 -- paraffin
5 -- Amount of CO
6 -- Remark
7 -- Ammonite No 6, pressed
8 -- Ammonite No 6
9 -- As above
10 -- None
11 -- Coal--Donbass
12 -- Polyethylene
13 -- North Ural Bauxite Mine (SUBR)

TABLE 5. EFFECT OF GAP IN BLASTHOLES ON THE FORMATION OF TOXIC GASES OF EXPLOSION

1 ВВ	2 Диаметр, мм		5 Зазор, мм	6 Количество ядовитых газов, л/кг		
	3 шпура	4 патрона		CO	7 окислы азота	8 всего
9 Аммонит № 6ЖВ	42	32	10	49—57	1,4—3,6	65—72
10 То же	34	32	2	30—31	1,4—1,9	39—42
11 Детонит 10А . . .	42	32	10	37—45	1,3—1,5	46—54
10 То же	34	32	2	31—32	1,0—1,1	37,5—39,0

KEY:
1 -- Explosive
2 -- Diameter, mm
3 -- of blasthole
4 -- of cartridge
5 -- Gap, mm
6 -- Amount of toxic gases, l/kg
7 -- nitrogen oxides
8 -- total
9 -- Ammonite No 6ZhV
10 -- As above
11 -- Detonite 10A

TABLE 6. EFFECT OF FLOODING OF WORKINGS ON FORMATION OF TOXIC GASES OF EXPLOSION

1 Степень обводненности шпура	Количество ядовитых газов, л/кг			5 НВ
	2 CO	3 окислы азота	4 всего	
6 Сухие стенки шпуров . .	37—43	1,1—1,5	46—52	9 Аммонит № 6
7 Стенки шпуров орошены водой	34—37	1,3—1,7	44—45	10 То же
8 Шпуры наполнены водой	11—18	4,5—6,6	41—58	»

[KEY on following page]

KEY [to TABLE 6]:

1 -- Degree of flooding of blasthole
2 -- Amount of toxic gases, l/kg
3 -- nitrogen oxides
4 -- total
5 -- Explosive
6 -- Dry walls of blastholes
7 -- Walls of blastholes sprayed with water
8 -- Blastholes filled with water
9 -- Ammonite No 6
10 -- As above

TABLE 7. EFFECT OF PLACEMENT OF CARTRIDGE-STRIKER IN EXPLOSIVE CHARGE ON THE FORMATION OF TOXIC GASES OF EXPLOSION

1 ВВ	2 Расположение патрон-боевика	3 Количество ядовитых газов, л/кг		
		CO	4 окислы азота	5 всего
6 Аммонит № 6	10 У дна шпура	45	0,6—2,0	49—58
7 То же	11 В середине	60—65	0,6—1,6	64—82
8 То же	12 У устья шпура	40—65	0,8—5,3	70—74
9 Детонит 10А	10 У дна шпура	24	0,5	27
7 То же	11 В середине	36	0,6	40
7 То же	12 У устья шпура	42	1,0	48,5

KEY:
1 -- Explosive
2 -- Placement of cartridge-striker
3 -- Amount of toxic gases, l/kg
4 -- nitrogen oxides
5 -- total
6 -- Ammonite No 6
7 -- As above
8 -- As above
9 -- Detonite 10A
10 -- At bottom of blasthole
11 -- In middle
12 -- At mouth of blasthole

A dependence was established between the toughness of rock and the amount of toxic gases in an explosion: here the toughness factor, the more carbon monoxide is formed and in several cases the less nitrogen oxides (Table 2).

The density of an explosive and the cartridge wrapping also affects the amount of toxic gases in an explosion (Tables 3 and 4).

TABLE 8. EFFECT OF STEMMING MATERIALS ON THE FORMATION OF TOXIC GASES

1 ВВ	2 Материал забойки	3 Количество ядовитых газов, л/кг			6 Примечание
		CO	4 окислы азота	5 всего	
7 Аммонит № 6	9 Без забойки	34—35	2,8—3,3	50—52	СУБР 13
	10 Глина 20 см	32—41,5	1,1—2,0	45—50	
То же 8	11 Водяная	11,7—18,5	1,8—3,2	30—32	То же 14
	12 Свободно-подвешенный заряд	33—35	20,5—22,8	167—183	То же 14

KEY:
1 -- Explosives
2 -- Stemming material
3 -- Amount of toxic gases, l/kg
4 -- nitrogen oxides
5 -- total
6 -- Remark
7 -- Ammonite No 6
8 -- As above
9 -- Without stemming
10 -- Clay, 20 cm
11 -- Water
12 -- Freely suspended charge
13 -- SUBR [cf. item 13 in key to Table 4]
14 -- As above

The formation of toxic gases is affected by the conditions under which the explosive operations are carried out: the placement of the detonator in the charge, properties of the stemming, and so on (Tables 5, 6, 7, and 8).

From the data in these tables it follows that the smallest amount of toxic gases in an explosion can be attained when total detonation of the explosive is ensured, for optimum explosive density, lowest moisture content, and the least amount of wrapper material. The greatest effect is given by igdanite, which is introduced into blastholes by the pneumatic charging method: in this case the amount of carbon monoxide in the explosion products is sharply reduced.

Producing the amount of toxic products of an explosion is also attained by using all kinds of stemming.

6. Physicochemical Characteristics of Commercial Explosives

Among the physicochemical characteristics of commercial explosives of practical value in their use are the following: density, dispersion or granulometric composition, friability, plasticity, fluidity, hygroscopicity, moisture content, caking tendency, water resistance, segregating tendency, and chemical resistance, which taken altogether determine the constancy (stability) of the charge and the explosive properties of the explosive.

Density. A differentiation is made between the density of an explosive, the density of the cartridge, load, or charge, and the charging density.

The density of an explosive refers to the ratio of the weight of the explosive to the volume it occupies, neglecting the shell. For free-flowing explosives, the density obtained in free packing will be referred to as the heaping or gravimetric density, while for continuous explosives (liquid, melted, pressed, or cartridge-packed powders) it is called the actual density or simply the density of the explosive. The density of the cartridge, load, charge, or other article refers to the ratio of its weight to the volume occupied, taking the shell into account.

The charging density is the ratio of the weight of the charge to the entire volume of the charging chamber, including the voids. Each explosive has its optimal density values, beyond the limits of which there is a deterioration in the explosive characteristics of the explosive, extending to the complete loss of detonatibility. An increase in density up to the optimal values leads to a concentration of energy per unit volume, a rise in the detonation rate and in the brisant action on the surrounding medium, and overall — to a rise in the explosive effect when blasting tough rock.

The dispersion of powdered explosives refers to the degree of their comminution (pulverization), while the granulometric composition of granulated and coarse-grain explosives refers to the characteristic of the distribution of their granules (grains) by size. Both these characteristics usually are determined by sieve analysis -- by sieving into fractions with the use of a set of sieves with successively reducing mesh sizes.

Friability refers to the ability of an explosive to freely, under its own weight, flow from a container, readily fill — during charging — a charging cavity in a free heap, and travel freely along a hose during pneumatic charging. Friability is an important characteristic of noncartridge explosives intended for pneumatic charging. Friability can be evaluated by the angle of natural repose or the rate at which the explosive travels through the calibrated opening of a funnel (hopper). The smaller the angle and the greater the stream velocity, the higher the friability. Good friability is exhibited by granulated explosives. The friability of powdered explosives in most cases is inadequate for high-capacity charging by heaping or by the pneumatic method. In such explosives, friability depends especially strongly on the moisture content: with rise in moisture content to 0.5-1.0 percent, friability drops off sharply.

Plasticity is a characteristic of nonfriable explosives, in which the solid components are held together by a liquid thickened (gel-like) phase. Explosives that are capable of being readily deformed when acted on by external loads and preserving the form imparted to them are also referred to as plastic. High-percentage plastic gelatin dynamites exhibit some elasticity. Slurry [water-filled] plastic explosives as a rule do not exhibit this capability. The ability of plastic explosives to be readily deformed enables charging densities to be obtained that are close to the density of the explosives per se, which is practically within the limits 1.3-1.7 g/cm^3. Plastic explosives, in addition to high density, are characterized by high indicators of water resistance and detonation parameters. The plasticity of nearly all explosives decreases with time. It can be restored by kneading cartridges manually or by mixing the mass by mechanical means.

Fluidity is a characteristic of slurry explosives of liquid-viscous consistency, in which the gel-like phase exceeds 35-40 percent. It depends heavily on temperature, degree of thickening of the liquid phase, and the duration of explosive storage. The fluidity of explosives decreases with time. A sharp drop is observed when the temperature is reduced and when there is a reduction in the liquid phase of the explosive. Fluidity can be restored by heating and by mechanical mixing. A rise in the fluidity of a slurry explosive facilitates its pumping from a dispensing vessel through the charging hose into a drillhole, but in addition facilitates segregation and leakage of the charge through cracks in the rock. To eliminate this effect, an explosive is prepared not long before it is charged or at the time of charging, by using a highly effective thickening agent and special binding additives, that rapidly raise the viscosity of the suspension after it has been loaded into the blasthole.

Hygroscopicity of a substance refers to ability to absorb moisture from the air and to be humidified. Humidification begins only at certain values of relative humidity and temperature of the ambient air typical of the given substance and dependent on its chemical composition. Hygroscopicity of a substance is characterized by the hygroscopic point, which is the ratio of the vapor pressure above a saturated solution of the given substance to the vapor pressure of water saturating the air at the same temperature. The hygroscopic point is expressed in percentages of relative humidity and characterizes the condition of the substances in which it does not dry out and does not become humidified. The higher the hygroscopic point of a substance, the less hygroscopic is the substance. The hygroscopic point depends on temperature: with temperature rise, in most hygroscopic substances it decreases, while the rate of moisture absorption rises. Hygroscopic substances include ammonium nitrate (its hygroscopic point at 25° C is 62.7 percent), potassium nitrate (44 percent), sodium nitrate (74.5 percent), and sodium chloride (75.5 percent). All commercial explosives incorporating these or other hygroscopic constituents are hygroscopic to some extent. The greater hygroscopicity is exhibited by ammonium-nitrate explosives. The hygroscopic point of most ammonium-nitrate explosives does not exceed 60-68 percent at 15-20° C. Therefore, they rapidly humidify in the course of a year. Humidification disrupts their physical stability (promotes caking and exudation) and reduces sensitivity to detonation and water stability.

Moisture content of an explosive refers to its content of water at a given instant introduced into the substance with the components during its formulation or acquired by it after formulation.

Caking refers to the ability of friable explosives to be converted into a coherent mass with total loss of friability and, as a rule, considerable reduction in detonatibility.

Caking usually results from crystallization from a film solution of readily soluble salts that are part of mixture explosives, which bind their solid particles with microcrystalline bridges. The extent of caking depends on the number and strength of these bridges. The number and strength of the bridges, in turn, are directly related to the initial moisture content and the temperature of the explosive, the ability of the components to be dissolved in water, and the variation of solubility as a function of temperature.

Since ammonium nitrate dissolves readily in water, then all explosives based on it are capable of caking strongly if their composition has no anti-caking additives.

Caking is promoted by modifying transformations of ammonium nitrate crystals in the transition through the temperature point of 32.3° C causing their fragmentation and change in solubility. Therefore, a fluctuation in the temperature of an ammonium-nitrate explosive during storage, with a transition through the temperature point of the modification transformation is highly undesirable. Also undesirable is any temperature fluctuation of a humidified explosive, since it causes repetitive processes of the dissolution of the nitrate and its crystallization from a film solution, permanently increasing the strength of the intercrystalline bridges.

The degree of caking depends heavily on the compaction of the explosives by external loads, for example, in cartridging or as the result of multirow stacking in a noncartridged state in a soft container, and also due to dispersion. Finely-disperse ammonites can cake severely, while granulated explosives are not caked at all in normal conditions. There are several methods of determining caking (Section 20). An explosive is assumed to be severely caked if it does not undergo breakdown from the force of a hand and requires mechanical breaking. Covering of explosives with loosening, powdering, or waterproofing additives of certain substances protects explosives against caking.

The water resistance of a powdered-structure explosive refers to the ability of the explosive to withstand the penetration of water within its cartridges (charges) that can upset their structure, cause phlegmatization and lead to a decrease in the explosive effect, or to total extinction of the detonation. Penetration of water is blocked by the capillary forces of waterproofing pores forming between particles of the compacted powder, whose surface is not wetted with water. The smaller the diameter and the higher the waterproofing ability of the pores, the higher is the water resistance of the powdered explosives. It can be increased by increasing the dispersion (the fineness of the grind) of the explosive and by compaction of the cartridges or charges when noncartridge charging is employed. Cartridges of finely-dispersed, well waterproofed ammonites are capable of withstanding many hours of storage in flooded blastholes and drillholes. In noncartridged form, ammonites are however unsuitable for charging by heaping into water, in which they cannot float, and upon forced immersion they mix with water and become severely phlegmatized.

Continuous explosives (plastic dynamites, slurry thickened akvatols, and akvanites, cast chunks, and charges of trotyl) are water-resistant because they have nearly no pores through which water could penetrate, while leaching of water-soluble components occurs slowly, mainly due to diffusion. The ability to withstand diffusive leaching determines the degree of water resistance of these explosives, which in most cases can withstand many days of storage in flooded blastholes or drillholes without appreciable reduction in explosive properties. The degree of water resistance of powdered and continuous explosives can be characterized by the hydrostatic pressure of the column of water needed for its penetration within the charge, or by the time during which the charge withstands the penetration of water at a certain specified pressure.

The water resistance of friable granulated explosives refers to the ability of granules not to be dissolved in water or to withstand the penetration of water internally and to stably detonate when heaped into water, which in this case fills all the air gaps between granules in the charge. The degree of water resistance of these explosives depends on the size and density of the granules, and their ability not to dissolve and not to break down in water. Water resistance can also be characterized by the time during which slurry charges do not lose their ability to detonate and do not suffer a reduction in their explosive effect.

Segregation refers to the spontaneous, or externally caused, segregation of an explosive into its constituents or components. This effect can occur with several friable and plastic explosives consisting of components that are dissimilar as to form or physical state, size, and specific weight. Minor segregation sometimes is observed when zernogranulites prepared by mechanical mixing of granulated nitrate with granulated or flaked trotyl is loaded by heaping or in pneumatic charging. At a high stream velocity, during pneumatic charging wood meal in granulite S-2 can separate and segregate aluminum powder -- in granulites AS-4 and AS-8, and diesel oils -- in igdanite. When these explosives are stored, they may become humidified and under the effect of their own weight stream into lower layers of the liquid component can occur.

Segregating of slurry akvatols is observed, in which -- when there is inadequate thickening of the liquid phase and when the explosive is in prolonged storage -- gradual settling and accumulation in the lower layers of large solid particles of components occurs. Large salt particles can separate out in safety explosives before they are cartridged.

Well-prepared explosives produced at present time, under normal conditions of storage and use, segregate only negligibly and this phenomenon in most cases does not appreciably affect the practical results of blasting.

Dusting refers to the ability of friable explosives, when handled, to contaminate the surrounding atmosphere with their fine-disperse (dust-like) particles or to make it explosive-hazardous. Dusting is directly dependent on the dispersion of an explosive, the surface state of its particles (extent of wetting and oiling), and on the velocity of the streams produced during pneumatic charging. Usually, powdered ammonites in a dry finely pulverized state dust heavily. All granulated explosives produce in practice little dust, while some of them such as alyumotol, granulotol, igdanite, and granulite M, whose granules lack dust fractions or are strongly oiled, do not dust at all, practically speaking, during charging.

Testing is observed most often when charging is carried out with the pneumatic method. It can be markedly reduced or completely eliminated by wetting or additional oiling of the explosive with oil, and by selecting the appropriate pneumatic chargers with dust catchers and the appropriate charging conditions.

Volatility refers to the ability of certain explosive components to partially or completely volatilize (evaporate or sublimate) during storage or use. Volatility depends on the temperature of evaporation (vapor pressure) of the constituents and the ambient conditions in which the explosive exists. The lower the temperature of evaporation (the higher the vapor pressure) and the higher the ambient temperature or the more air exchange there is over the explosive, the more rapidly such components will be vaporized from it. Nitro esters vaporize partially from nitro ester explosives, which are related to the toxic action, and water also evaporates from slurry explosives when they are not sealed tight enough.

Exudation refers to the ability of liquid constituents to migrate from the composition of explosive under the action of capillary forces. Exudation is promoted by wetting and alternating heating and cooling of an explosive, and also by external compressive loads acting on the explosive. Nitro ester explosives can exude, especially if the nitro esters in them are not adequately bound with a thickening agent or an absorbing agent. Exudation of such explosives increases the danger of handling them and requires the use of suitable cautionary measures.

Ageing. This term is applied to plastic explosives, whose gel structure becomes modified with time, its viscosity and plasticity are reduced, and air bubbles are removed, which promote the detonation transformation of charges. By kneading and remixing, the plastic properties of the agent explosive can be restored.

Stability refers to the ability of an explosive to retain its initial physicochemical and explosive characteristics during the established guarantee period of use.

Physical stability refers to the ability of an explosive to retain its physical characteristics and structure in normal conditions of storage and use (low moisture content, moderate temperature, absence of external compacting loads, and so on).

Chemical resistance refers to the ability of an explosive to retain its chemical composition and chemical properties within the limits ensuring adequate safety during storage and handling. Depends on the chemical nature, purity, and conditions of storage of the explosive. Some explosives are capable of self-accelerating chemical decomposition in the event that suitable circumstances converge. The decomposition of nitro ester explosives can occur, for example, when impurities of mineral acids or ammonium nitrate explosives enter their composition, and in the reaction of an ammonium nitrate solution with sulfur or certain other compounds. When charging akvatol into a flooded drillhole, the finely-disperse aluminum in the explosive composition can interact with the alkali if its impurities are present in water.

In normal conditions of storage in use, all commercial explosives produced in the USSR are quite chemically stable.

7. Brief Information on the Theory of Safety Explosives

Explosive operations have wide application in the mining of coal. Most coal mines contain methane and coal dust in the atmosphere of the workings and are classified in the category of mines that are dangerous as to methane or coal dust. Safety explosives are used in these mines and measures aimed at increasing the safety of explosive operations are carried out.

Mine gases released into the atmosphere of workings can contain methane and other combustible gases (mainly, hydrocarbons).

Methane-air mixtures containing 4-15 percent methane are the most hazardous; they are capable of fast-spreading reactions with the release of heat and a buildup in pressure.

The explosion of a methane-air mixture can be caused either by heating it, or by igniting it with flame or spark. The causes for the inflammation of a methane-air mixture in explosive operations can vary.

According to the theory of Malar and Le Chatelier, the explosion of a methane-air mixture can be caused by a thermal impulse, that is, by the action on the mixture of the heated gaseous explosion products of an explosive. The temperature of the explosion of safety explosives varies within the limits 1500-2000° C, while the flash point of a methane-air mixture is much lower -- 650° C.

At 650° C, the ignition of methane can occur with a delay of as much as 10 seconds, but as the temperature is increased the delay time becomes shorter. If the explosion temperature is very high, the delay time of the ignition of a methane-air mixture can become shorter than the detonation time of the explosive and the mixture can explode; but if the delay time of the ignition of the mixture is longer than the explosion period, methane does not ignite.

The flame of an explosive and its duration depend not only on the properties of the explosive, but also on the size of the charge; the larger the charge, the more dangerous it is.

According to the theory of Odiber gaseous explosion products, by mixing with air containing methane, react and in the process can oxidize methane by means of the oxygen of the explosion products, accelerating its spontaneous combustion. In this case the safety of the explosive depends not so much on the temperature of the explosion products, as much on the amount of heat released per unit volume of the gaseous products of the explosion. The heat of explosion can be reduced by introducing heat-absorbing flame inhibitors into the explosive composition.

L. V. Dubnov showed that in addition to the heat of gaseous explosion products, the delay time of methane ignition is affected by certain impurities that impede the oxidation of methane.

Chlorides of potassium and nitrogen that are part of the safety explosives are also anticatalysts, raising the flash point of the methane-air medium or prolonging the ignition delay time of the mixture.

Among the hypotheses accounting for the igniting of methane-air mixtures in explosive operations, interest is drawn to the work of Beyling, who showed that in the detonation of an explosive charge, solid heated explosive particles can form. To prevent the igniting of the methane-air mixture with these particles, safety explosives with good detonatability must be used, and compact tamping must be employed.

The principle of formulating safety explosives. In selecting safety explosives and in developing new compositions, the following principle is observed. Safety explosives must exhibit good detonatability, ensuring the nonfailure detonation of charges in blastholes if compact stemming is present, and if no large gaps exist between the explosive cartridges and the blasthole walls. Safety explosives must also exhibit high selectivity, that is, the ability to completely detonate only in an enclosed space. In the absence of stemming or if an exposed surface is present, for example, a crack in the blasthole, the detonation of the explosive charge either does not occur or, or else only the sensitizer present in the explosive composition in the amount of 10-15 percent detonates; this kind of partial detonation is not capable of igniting a methane-air mixture.

Among these safety explosives are the following four classes of explosives:

class III represents safety explosives intended for explosive operations in coal mines when overburden is present (ammonite AP-4ShV, AP-5ZhV, and pobedite VP-4);

class IV represents safety explosives intended for blasting for coal (ammonite PZhV-20, miporite No 1, and ammonite PZhV-20 in a resite-salt shell);

class V represents increased-safety explosives intended for especially dangerous mines; they differ from explosives in class IV by the fact that in an explosion in a test drift the maximum charge is up to 250 g (uglenite E-6, an explosive in solution-filled shells PVP-1-U selektite No 1, and uglenite No 5); and

class VI represents high-safety explosives intended for especially dangerous mines. The explosion of a freely suspended charge in a test drift does not explode a methane-air mixture when the charge weighs up to 1 kg (uglenite No 7).

Most class-V and class-VI safety explosives exhibit low efficiency, which limits their applications.

Characteristics of gas-air and dust-air mine atmospheres. Mine categories. Among gas- and dust-dangerous mines are those in which combustible gases or combustible dust in a mixture with air can form an atmosphere that ignites or explodes when a spark or fire is present.

When methane is continually released into the mine, its relative gas contamination is thus determined, which refers to the amount of methane released in the mine per day, per ton of daily extraction.

In terms of gas contamination, mines are divided into the following four categories:

Mine category	Amount of methane released per day per ton of average-daily coal extraction, m^3
I	Up to 5
II	From 5 to 10
III	From 10 to 15
Super-category mine or mines in which strata are exploited that are dangerous in terms of gas feeders and sudden eruptions of coal or gas	15 and higher

CHAPTER II
EXPLOSIVES

8. Classification of Commercial Explosives

Commercial explosives are divided into individual chemical compounds (trotyl, tetryl, hexogen, and so on) and mechanical mixtures, in which ammonium-nitrate explosives have gained the predominant acceptance.

Ammonium nitrate explosives refer to explosives in which the principal oxygen-containing component is ammonium nitrate -- a synthetic cheap salt that relatively easily decomposes in the explosive process into gaseous products, with the release of 20 percent of the excess oxygen and a small amount (370 kcal/kg) of heat. These advantages were the impetus for formulating various kinds of commercial explosives based on ammonium nitrate. Ammonium nitrate explosives are subdivided into ammonites, ammonals, slurry explosives (akvatols and akvanites), dynammons, and nitroglycerin and hexogen-containing compositions without a very sharp delineation between them.

Ammonites refer to ammonium-nitrate mixtures of powdered structure, in which trotyl or other nitro compounds are used as the explosive sensitizer and the fuel. In the grain-granulated state, ammonites are called zernogranulites.

Slurry ammonites of plastic consistency are called akvanites, while flowing slurry ammonites are called akvatols.

Ammonals refer to ammonites in which, in addition to other components, aluminum is present. In the granulate state they are called grammonals.

Dynammons refer to powdered mixtures of ammonium nitrate with nonexplosive combustibles, including possibly aluminum.

TABLE 9. CLASSIFICATION OF COMMERCIAL EXPLOSIVES BY SERVICE CONDITIONS

A Класс	B Группа	C ВВ
D 1. ВВ только для открытых работ	E 1. Гранулированные водоустойчивые ВВ для крепких и весьма крепких пород в обводненных забоях	F Алюмотол Гранулотол Зерногранулиты 30/70-В и 50/50-В Граммонал А-45
	G 2. Водонаполненные текучие ВВ для сухих и обводненных скважин в крепких и весьма крепких породах	H Акватол 65/35 Металлизованные акватолы М-15 и МГ (гелеобразный)
	I 3. Водоустойчивые литые ВВ в кусках и шашках для обводненных скважин в крепких породах	J Тротиловые шашки и куски
	K 4. Шнекованные ВВ в шашках для обводненных скважин в породах средней крепости	L Шнекованный аммонит В-3
	M 5. Порошкообразные водоустойчивые непатронированные ВВ для слабых и средней крепости пород в сухих и мокрых забоях	N Аммониты № 9-ЖВ и № 10-ЖВ
	O 6. Кумулятивные наружные заряды для вторичного взрывания	P Заряды типа ЗКП-ОР
	Q 7. Промежуточные детонаторы для инициирования гранулированных и водонаполненных ВВ	R Шашки Т-400, Ш-400, ТГ-500, Тет-150, ПТ-150
S II. ВВ для открытых и подзем-	T 1. Прессованные водоустойчивые высокомощ-	U Аммонит скальный № 1

[Continuation of Table 9]

A Класс	B Группа	C ВВ
S ных работ, кроме работ в шахтах, опасных по газу или пыли	T ные ВВ в патронах для весьма крепких пород	U Аммонит скальный №1
	V 2. Порошкообразные водоустойчивые ВВ повышенной мощности в набивных патронах стандартного и крупного диаметров для крепких пород	W Аммонал скальный № 3 Аммонал водоустойчивый Динамоны АМ-8 и АМ-10
	X 3. Порошкообразные водоустойчивые и неводоустойчивые средней мощности ВВ в патронах и россыпью для пород средней крепости	Y Аммонит № 6-ЖВ Динафталит Аммонит № 7-ЖВ
	Z 4. Порошкообразные водоустойчивые ВВ, содержащие нитроэфиры, в патронах стандартного и малых диаметров для крепких и весьма крепких пород	A' Детониты 6А, 10А, 15А-10 Детонит М
	B' 5. Пластичные водоустойчивые ВВ для крепких и весьма крепких пород	C' Динамит 62% Акваниты 3Л и 16
	D' 6. Гранулированные водоустойчивые ВВ для пород средней крепости и крепких в обводненных забоях	E' Граммонал А-8 Зерногранулит 79/21 (горячего смешения)
	F' 7. Гранулированные неводоустойчивые ВВ для пород средней крепости и крепких в сухих забоях	G' Зерногранулит 79/21 (холодного смешения) Гранулиты АС-4 и АС-8 Гранулиты М и С-2 Игданит

[Conclusion of Table 9]

Класс A	Группа B	ВВ C
H' II. ВВ для открытых и подземных работ, кроме работ в шахтах, опасных по газу или пыли	I' 8. Кумулятивные наружные заряды	J' Заряды типа ЗКП-ПР
	K' 9. Промежуточные детонаторы для инициирования малочувствительных ВВ	L' Шашки скального аммонита и патроны других аммонитов и детонитов
M' III. Предохранительные ВВ для породных забоев, опасных по метану, и специального назначения	N' 1. ВВ для работ в породных забоях	O' Победит ВП-4 Аммониты АП-4ЖВ АП-5ЖВ
	P' 2. ВВ для серных шахт	Q' Серный аммонит № 1-ЖВ
	R' 3. ВВ для шахт, опасных по нефтяным парам	S' Нефтяной аммонит № 3-ЖВ
T' IV. Предохранительные ВВ для угольных и смешанных забоев шахт, опасных по газу и пыли	U' ВВ типа аммонитов	V' Аммонит Т-19 Аммонит ПЖВ-20 Мипорит
W' V. ВВ повышенной предохранительности для угольных, смешанных забоев и специальных работ в шахтах всех категорий	X' 1. Нитроглицериновые ВВ в патронах	Y' Угленит Э-6 Угленит № 5
	Z' 2. Селективнодетонирующие гранулированные ВВ в патронах или шлангах	A'' Селектит № 1
	B'' 3. ВВ в жестких предохранительных оболочках	C'' Малогабаритные патроны МГПП-50
	D'' 4. ВВ в водонаполненных полиэтиленовых оболочках	E'' Патроны аммонита в оболочке ПВП-1-У
F'' VI. Высокопредохранительные ВВ для отбойки угля и специальных работ в шахтах, особо опасных по газу	G'' Нитроглицериновые маломощные ВВ	H'' Угленит № 7

KEY [to Table 9]:

A -- Class
B -- Group
C -- Explosive
D -- I. Explosive only for open-mine operations
E -- 1. Granulated water-resistant explosives for tough and extra tough rock in flooded faces
F -- Alyumotol; Granulotol; Zernogranulites 30/70-V and 50/50-V; Grammonal A-45
G -- 2. Slurry free-flowing explosives for dry and flooded drillholes in tough and extra tough rock
H -- Akvatol 65/35; metallized akvatols M-15 and MG (gel-like)
I -- 3. Water-resistant cast explosives and fragments and charges for flooded drillholes in tough rock
J -- Trotyl charges and fragments
K -- 4. Worm conveyor-packed explosives and charges for flooded drillholes in moderate-tough rock
L -- Worm conveyor-packed ammonite V-3
M -- 5. Powdered water-resistant noncartridged explosives for weak and moderate-tough rock in dry and wet faces
N -- Ammonites No 9-ZhV and No 10-ZhV
O -- 6. Shaped external charges for secondary blasting
P -- Type ZKP-OR charges
Q -- 7. Intermediate detonators for initiating granulated and slurry explosives
R -- Charges T-400, Sh-400, TG-500, Tet-150, and PT-150
S -- II. Explosives for open and underground operations, in addition to operations in mines that are dangerous as to gas or dust
T -- 1. Pressed water-resistant high-strength explosives in cartridges for extremely tough rock
U -- Ammonite No 1, rock-oriented
V -- 2. Powdered water-resistant increased-strength explosives in tamped cartridges of standard and large diameters for tough rock
W -- Amronite No 3, rock-oriented; water-resistant ammonal; dynammons AM-8 and AM-10
X -- 3. Powdered water-resistant and nonwater-resistant, moderate-strength explosives and cartridges and loose pack for moderate-tough rock
Y -- Ammonites No 6-ZhV; Dinaphthalite; ammonite No 7-ZhV
Z -- 4. Powdered water-resistant explosives containing nitro esters, in cartridges of standard and small diameters for tough and extra tough rock
A' -- Detonites 6A, 10A, and 15A-10; detonites M
B' -- 5. Plastic water-resistant explosives for tough and extra tough rock
C' -- Dynamite, 62 percent; akvanites 3L and 16
D' -- 6. Granulated water-resistant explosives for rock of moderate toughness and tough rock in flooded faces

KEY [continuation]:
E' -- Grammonal A-8; Zernogranulite 79/21 (flammable mixture)
F' -- 7. Granulated nonwater-resistant explosives for moderate-tough and tough rock in dry faces
G' -- Zernogranulite 79/21 (cold mixing); granulites AS-4 and AS-8; granulites M and S-2; igdanite
H' -- 11. Explosives for open and underground operations, except operations in mines that are dangerous as to gas or dust
I' -- 8. Shaped external charges
J' -- Type ZKP-PR charges
K' -- 9. Intermediate detonators for initiating low-sensitivity explosives
L' -- Charges of rock-oriented ammonite and cartridges of other ammonites and detonites
M' -- III. Safety explosives for rock faces dangerous as to methane, and for special purposes
N' -- 1. Explosives for operations in rock faces
O' -- Pobedite VP-4; ammonites AP-4 ZhV and AP-5 ZhV
P' -- 2. Explosives for sulfur mines
Q' -- Sulfur ammonite No 1-ZhV
R' -- 3. Explosives for mines dangerous as to petroleum vapor
S' -- Petroleum ammonite No 3-ZhV
T' -- IV. Safety explosives for coal and mixed faces of mines dangerous as to gas and dust
U' -- Ammonite type explosives
V' -- Ammonite T-19; ammonite PZhV-20; miporite
W' -- V. Explosives of increased safety for coal, mixed faces, and special operations in mines of all categories
X' -- 1. Nitroglycerin explosives in cartridges
Y' -- Uglenite E-6; uglenite No 5
Z' -- 2. Selective-detonating granulated explosives in cartridges or hoses
A" -- Selectite No 1
B" -- 3. Explosives in stiff safety shells
C" -- Small-size cartridges MGPP-50
D" -- 4. Explosives in slurry polyethylene shells
E" -- Cartridges of ammonite in PVP-1-U shell
F" -- VI. High-safety explosives for breaking down coal and special operations in mines especially gas-hazardous
G" -- Nitroglycerin low-strength explosives
H" -- Uglenite No 7

Mixtures of granulated ammonium nitrate with nonexplosive combustibles are referred to as *granulites*. The simplest ammonium nitrate granulated explosive in which the combustible is diesel oil is called igdanite.

Nitroglycerin ammonium nitrate explosives are explosives whose composition includes -- as the active sensitizer -- nitroglycerin, more properly, its mixture with nitrodiglycol. They are divided into plastic dynamites and weakly gelatinized powdered explosives. They include nonsafety detonites and safety uglenites, pobedite, selektite, and others.

Hexogen-containing explosives refer to explosives in which the sensitizer and the active combustible is hexogen, for example, rock-oriented ammonite No 1 and rock-oriented ammonal No 3.

Trotyl in granulated form is called granulotol, while its granulated melt with aluminum is referred to as alyumotol. A melt of trotyl with TEN used in casting detonator charges is referred to as pentolite.

Commercial explosives can be classified by various features: chemical composition of physical state, the most typical features of their properties and composition, or by their fields of use. In terms of field of use, all commercial explosives can be divided into two groups: nonsafety and safety. The first of these is subdivided into explosives suitable only for open work, since their composition is not completely balanced with respect to oxygen and therefore they can release large amounts of toxic gases during an explosion, and explosives intended for underground operations in mines where there are no explosive concentrations of combustible gases and dust.[1] Safety explosives comprise a special group of explosives intended for coal and other mines that are dangerous with respect to explosions of combustible gases (methane and hydrogen) and readily combustible dusts (coal, shale, and sulfur). In terms of safety (anti-firedamp status), they are subdivided into several classes in relation to the conditions of use in the mines.

Table 9 presents a classification of explosives by conditions of use. The classes of explosives correspond to that adopted in Yedinaya Klassifikatsiya Promyshlennykh Vzrychatykh Veshchestv.

A large part of the ammonium nitrate explosives listed in Table 9 are produced under GOST [State Standard] 9073-64, trotyl is produced according to GOST 4117-67, and alyumotol -- under GOST 12696-67. But most of the listed explosives are produced according to the appropriate inter-republican technical conditions (MRTU).

In addition to class-V and class-VI safety explosives, special nonigniting blast charges are intended for use in the same coal mine conditions.

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[1] Editor's remark. With increasing depth of open-pit workings, the requirement for the absence of noxious gas forming during the blasting of explosives takes on equally valid importance for all explosives, including also those intended for use in open-pit workings.

9. Explosives for Open-pit Operations (Class I)

Granulated water-resistant explosives

Granulotol and alyumotol. Granulotol is granulated trotyl. Alyumotol is the granulated melt of trotyl with 15 percent aluminum powder. They are both classified as coarse-granular explosives. The size of their spherical granules is 3-5 mm. Due to their large size, smooth surface, and relatively high density (Table 10), they readily sink in water, and also more dense liquids and slurries. They are free flowing when dry or wet. Their distinguishing characteristics include nonhygroscopicity, nonsolubility in water, and high stability. The granulotol and alyumotol do not become wet, do not cake, and do not become sintered in storage. In winter, granulotol and alyumotol can be frozen if more than 2 percent moistures present on the surfaces of the granules. To prevent the freezing of explosives and the rotting of containers, the moisture content of the product when released from the plant is regulated. Granulotol and alyumotol exhibit practically unlimited water resistance. Their charges can be in water for long periods, including flowing water without suffering losses or reduction in explosive characteristics. They are suitable for underwater blasting at great depths.

Granulotol and alyumotol are not adequately sensitive to the initiating impulse; an intermediate detonator is required to cause their detonation. In the water-filled [slurry] state they are also not very sensitive to mechanical forces as well. In conditions of laboratory tests, sensitivity to shock and to friction is high in alyumotol than in granulotol (Table 11). Owing to the large oxygen deficiency in their composition, much carbon monoxide is released in their explosion. Therefore, in massive blasts in deep pits, additional measures for ventilating faces are required.

Alyumotol is classified as a high-strength granulated explosive and is intended for breaking down extra tough, hard-blasting rock and ores. Granulotol is intended for tough rock. Two varieties are produced, differing by moisture content, freezing point, and density of granules.

Granulotol and alyumotol are recommended to be used in the slurry [water-filled] state. When the air gaps between charge granules are filled with water, the density of charging can rise to 1.3-1.35 g/cm^3, detonation conditions can improve, and the effect of the blast can be augmented. Saturation of water with ammonium nitrate in such charges even further raises the density of charging and the effectiveness of blasting due to the additional release of the explosion energy resulting from the reaction of the granule detonation products with the nitrate oxygen. Use of these explosives in drying of boreholes is ill-advised. They are economically used to advantage in combined charges with other, less expensive explosives for charging the flooded (lower) section of boreholes. In the slurry state, they are stable and detonate at high rates not only in borehole charges, but also in small-diameter blasthole charges.

TABLE 10. STANDARDIZED TECHNICAL INDICATORS

1 Показатели	2 Гранулотол*		5 Алюмотол	6 Граммонал А-45	7 Зерногранулиты	
	3 I сорт	4 II сорт			8 50/50-В	9 30/70-В
10 Размер гранул, не более *мм*	5	5	5	7	3	3
11 Влажность, не более %	1,0	2,0	1,5	1,5	0,7	0,5
12 Плотность гранул, не менее *г/см*³	1,5	1,48	1,5	1,45	—	—
13 Нерастворимые примеси, не более %	0,3	0,3	0,5	0,5	0,5	0,5
14 Водоустойчивость по методике выщелачивания селитры (время выдержки в воде 4 ч), не более %	—	—	—	10	10	5
15 Гранулометрический состав-остаток на сите с ячейками размером:						
16 4,0 *мм*, не более %	—	—	—	—	15	15
17 0,9 *мм*, не менее %	—	—	—	—	85	85
18 Гарантийный срок использования, месяц:						
19 в обычной упаковке	24	12	24	12	6	6
20 в полиэтиленовой	—	—	—	—	12	12

* For granulotol, the standardized indicators are these: freezing point (not below 77.5° C for grade I, and not below 76.5° C for grade II), content of residual acidity not more than 0.05 percent, and absence of tetranitromethane.

KEY:
1 -- Indicators
2 -- Granulotol*
3 -- grade I
4 -- grade II
5 -- Alyumotol
6 -- Grammonal A-45
7 -- Zernogranulites
8 -- 50/50-V
9 -- 30/70-V
10 -- Granule size, not more than, in mm
11 -- Moisture content, not more than, in percent
12 -- Density of granules, not less than, in g/cm³
13 -- Insoluble impurities, not more than, in percent
14 -- Water resistance based on the method of leaching nitrate (exposure time in water, 4 hours), not more than, in percent
15 -- Granulometric composition, residue on screen with mesh of the following sizes
16 -- 4.0 mm, not more than, in percent
17 -- 0.9 mm, not less than, in percent
18 -- Guarantee service period, in months
19 -- in ordinary packing
20 -- in polyethylene packing

TABLE 11. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

1 Характеристики	2 Гранулотол	3 Алюмотол	4 Граммонал А-45	5 Зерногранулиты	
				50/50-В 6	30/70-В 7
8 Расчетные					
Кислородный баланс, % 9	—74	—76,25	—38,65	—27,15	—45,9
Теплота взрыва, *ккал/кг* 10	1010*	1260	1490	880	911
Объем газов, *л/кг* 11	750**	875	752	810	800
Температура взрыва, *град* 12	3400	4510	4520	3000	3150
Полная идеальная работа взрыва, *ккал/кг* 13	710	1020	—	—	—
Экспериментальные 14					
Влажность, % 15	0,5—1,0	1,0—1,5	0,5—0,8	0,4—0,6	0,2—0,4
Насыпная плотность, *г/см³* 16	0,95—1,0	0,95—1,0	0,9—0,95	0,85—0,90	0,85—0,90
Плотность гранул, *г/см³* 17	1,48—1,54	1,52—1,68	1,4—1,54	1,35—1,45	1,35—1,45
Теплота взрыва, *ккал/кг* 18	810—995	1340	1320	980	990
Работоспособность, *см³* 19	285—295	420—440	440—460	340—350	330—340
Тротиловый эквивалент 20	1,0	1,3	1,35	1,05	1,1
Обжатие свинцового столбика, *мм*, зарядом в стальной оболочке: 21					
в безводном состоянии 22	24—26	28—30	30—32	23—25	24—27

[Continuation of Table 11]

⑤

①	②	③	④	⑥	⑦
2* 23 в водонаполненном	32—34	24 Полное разрушение		28—30	32—34
Скорость детонации, *км/сек*: 25					
в безводном состоянии 26	4,5—5,0	4,3—4,8	4,5—4,9	3,6—4,2	3,8—4,5
в водонаполненном 27	5,5—6,5	5,5—6,0	5,8—6,3	5,2—5,6	5,5—6,0
Критический диаметр, *мм*: 28					
открытого заряда без воды 29	60—80	70—80	60—80	40—50	40—60
водонаполненного в стальной оболочке 30	5—10	5—10	7—10	15—20	10—15
Чувствительность к КД № 8 (в безводном состоянии) 31	32 Не устойчиво			32 Не устойчиво	
Минимальный вес промежуточного детонатора-шашки тротила для водонаполненного заряда в стальной оболочке, *г* 33	30—50	25—30	50	30	30
Чувствительность измельченного сухого ВВ: 34					
к удару, % 35	4—12	24—48	24—36	12—24	12—16
к трению, *кГ/см²* 36	1930—2900	2300—2600	2200—2300	2500—3000	2200—2900
Гигроскопичность (прирост влаги за 6 *ч* при выдержке над водой), % 37	0,05	0,01	0,8	12,0	0,2
Водоустойчивость (количество растворившейся селитры при выдержке 6 *ч* в стоячей воде), % 38	—	—	8—11	8—10	3—5

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* At a density of 1.5 g/cm^3 of dry explosives; at a density of 1.0 g/cm^3, the heat of explosion is 880 kcal/kg; for slurry granulotol, it is 825 kcal/kg.

** With allowance for evaporation of surrounding water, the volume of the granulotol gases is 1045 l/kg, for alyumotol -- 875 l/kg, and for zernogranulites -- 1000-1070 l/kg.

KEY [to Table 11]:
1 -- Characteristics
2 -- Granulotol
3 -- Alyumotol
4 -- Grammonal A-45
5 -- Zernogranulites
6 -- 50/50-V
7 -- 30/70-V
8 -- Calculated
9 -- Oxygen balance
10 -- Heat of explosion, kcal/kg
11 -- Volume of gases, l/kg
12 -- Temperature of explosion, degrees
13 -- Total ideal work of explosion, kcal/kg
14 -- Experimental
15 -- Moisture content
16 -- Heaped density, g/cm^3
17 -- Density of granules, g/cm^3
18 -- Heat of explosion, kcal/kg
19 -- Efficiency, cm^3
20 -- Trotyl equivalent
21 -- Compression of lead column, mm, by a charge in a steel shell
22 -- in anhydrous state
23 -- in slurry state
24 -- Total disintegration
25 -- Rate of detonation, km/sec
26 -- in anhydrous state
27 -- in slurry state
28 -- Critical diameter
29 -- of exposed charge not containing water
30 -- of slurry charge in steel shell
31 -- Sensitivity to blasting cap No 8 (in anhydrous state)
32 -- Unstable
33 -- Minimum weight of intermediate detonator, trotyl load for slurry charge in steel shell, g
34 -- Sensitivity of pulverized dry explosive
35 -- to shock
36 -- to friction, kg/cm^2
37 -- Hygroscopicity (increment in moisture content in 6 hours after exposure over water)
38 -- Water resistance (amount of dissolved nitrate after exposure for 6 hours in standing water)

Granulotol and alyumotol may also be used for mechanical mixing in mines with 25-30 percent granulated nitrate, automatically added during the charging of boreholes with mixing-charging rigs. From the plant, these explosives are shipped in paper and exterior jute sacks in a set with detonator charges.

detonator charges. Extended guarantee periods of use are specified for them (cf. Table 10). The wholesale price of 1 ton of granulotol of grade 1 is 345 rubles, while that for alyumotol is 536 rubles.[1]

Grammonal A-45 is melted granulated ammonal with high trotyl and aluminum content. Its light gray granules are semispherical, 5-7 mm in size, and weigh 0.2-0.4 g each. Grammonal is marked by reduced hygroscopicity (cf. Table 11); during storage it acquires little moisture, does not cake, and does not become sintered. It exhibits good friability and immersibility in water and can reside in drillholes containing still water for up to 3 days. This explosive is not recommended to be used for drillholes with rapid flowing water. It is permitted for introduction into dry and restrictedly flooded faces.

In terms of sensitivity to initial impulse and mechanical forces, grammonal differs virtually not at all from alyumotol, but surpasses it in energy characteristics (cf. Table 11). Of the granulated explosives produced, it is the most powerful and relatively inexpensive. Its application in extremely tough, hard-blasting rock makes it possible to attain high technical-economic indicators of mineral extraction. Depending on the blasting conditions, grammonal is profitably employed separately or in combination charges with more water-resistant or less expensive explosives. An intermediate detonator is needed to initiate its charges.

The temporary wholesale cost of 1 ton of grammonal is 440 rubles.

Zernogranulites 50/50-V and 30/70-V[2] are noncaking and nondusting, readily flowing granulated ammonium nitrate explosives. Nitrate granules in these explosives are coated with a continuous protective layer of fused trotyl, and in this way the explosives are less hygroscopic and exhibit water resistance. Their hygroscopicity and water resistance depend on the thickness of the trotyl layer. Zernogranulite 30/70-V is water-resistant and zernogranulite 50/50-V then can be used along with granulite in faces heavily inundated with still water. Its charges withstand residence in drillhole water for more than 3 days. When a weak current of water is present, their residence time must be limited to 1-2 days. This explosive is not recommended for drillholes with fast-moving water.

Zernogranulite 50/50-V is suitable for flooded drillholes with still water, where the charge residence is limited to a few days. As to sensitivity to initial impulse and mechanical forces, these zernogranulites differ little from granulotol, to which they are equated in terms of conditions of storage and handling. They do not require additional hermetic

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[1] Here and below, the prices are given based on the price list of wholesale prices introduced as of 1 July 1967 and based on its supplements for products packed without polyethylene insert-bags on which a surcharge to intra-industry prices is set.

[2] The numerator of the fraction denotes the nitrate content, and the denominator -- the trotyl content.

packing for a six-month storage time. Intermediate detonators (T-400 loads) are required for initiation in drillhole charges. They are intended for blasting moderate-tough and tough rock. The wholesale price of 1 ton of zernogranulite 30/70-V[1] is 330 rubles, while zernogranulite 50/50-V costs 270 rubles wholesale.

Zernogranulite 30/70 is a mechanical mixture of granulated nitrate and granulotol, which is prepared either at the plant or in the field in a mixing-charging unit during charging. This explosive is suitable for charging drillholes containing still water. After certain amount of time following the loading of the explosive into the flooded drillhole, a suspension of granulotol forms in a nitrate solution, whose concentration depends on the amount of water and the time the charge has been in the drillhole. For complete utilization of nitrate (during the blast), there must be no more water present in the drillhole than is required to fill the gaps between the trotyl granules with the solution formed. The charging density of this suspension is 1.35-1.40 g/cm^3. It is 15-20 percent superior to straight granulotol as to blasting effectiveness. It is supplied by plants in the friable state in a set with detonator charges. The guarantee period of use is 6 months; and for deliveries to the Far North in hermetic packing it is 12 months. The wholesale price of 1 ton of the explosive is 330 rubles; when additional packing in polyethylene bags is provided, the wholesale price of 1 ton is 343 rubles. Experimental explosive characteristics of zernogranulite 30/70 differ little from those of zernogranulite 30/70-V listed in Table 11.

Slurry [Water-filled] friable explosives

Slurry ammonium nitrate explosive mixtures are a new type of commercial explosive developed and introduced in the early 1960's. They are explosive suspensions, in which the liquid phase is a saturated aqueous solution of ammonium nitrate (sometimes with other nitrates as well), thickened by adding special high-polymer agents to the desired consistency, and in which granules and grains of trotyl, aluminum, and other combustible nonexplosive materials (coal), as well as nondissolving crystals or granules of the indicator nitrates can be present as the solid phase. In consistency they resemble thick concrete mortars, but their mass is more coherent and ropy. Water in the composition of these explosives plays a very significant role: it converts the explosive into a mobile, free-flowing or plastic highly dense mass, which during charging of drillholes readily fills the entire charging volume and permits the charging density to approximate the suspension density. The water, in addition, strongly phlegmatizes the explosive, making it practically insensitive to mechanical influences and extremely weakly sensitive to the explosive impulse. In the transformation of the aqueous solution of the suspension with special thickening agents into the gel-like state, the explosive becomes water resistant.

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[1] [See footnote 2 on preceding page.]

Distinguishing features of slurry explosives are as follows: high density and volumetric concentration of energy (greater by a factor of 1.5-2.0 than for powdered explosives), and also a high rate of energy release, which provides — assuming that the blasting cavity is well filled — the requisite blasting effect; high water resistance, making it possible to charge drillholes of any degree of inundation for an extended period; high safety and convenience in charging, preventing mechanization of this process; and relatively low cost. Slurry explosives are accepted as being the most promising of all the presently known nonsafety explosives.

Among the slurry explosives used in the USSR are the free-flowing akvatols 65/35, M-15, and MG — of gel-like consistency, the last two of which are metallized; also included in this category are the plastic akvanites 3L and No 16.

Standardized technical indicators for dry akvatol mixtures delivered from the plant are as follows:

	Akvatol 65/35	Akvatol M-15
Moisture content, more than, in percent	0.8	0.5
Efficiency, not less than, in cm^3	350	450
Completeness of detonation using an intermediate detonator of a charge of a dry mixture in a paper shell of the following diameter, in mm	100	120
Granulometric composition — residue on sieve with meshes of the size:		
4 mm, not more than, in percent	15	15
0.9 mm, not less than, in percent	80	70
Guarantee peiod of use, in months:		
in paper packing	6	3
in polythylene packing	12	6

Granulated ammonium nitrate is incorporated as the oxidizer in akvatol compositions. The role of the combustible and sensitizer in akvatols 65/35 and M-15 is flaked trotyl, whose content in the first case varies within the limits 27-30 percent, and in the second — 21-22 percent with respect to the slurry composition. Slurry akvatol M-15 contains 12.5-13.2 percent coarse aluminum powder. The thickening agent in several grades of akvatols is the sodium salt of carboxymethylcellulose (CMC), although it can be replaced by more effective gel-forming agents — guar with the binding additive of borax, polyacrylamide powder, and so on. Technical grade CMC in the amount of 2.5-3.5 percent is allowed to be used in akvatol 65/35, and metallized akvatols make use of 1.0-1.5 percent CMC, purified alkali, chlorides, and other accompanying impurities.

Akvatols are usually prepared at plants and are shipped in the form of anhydrous friable mixtures, packed in paper bags, for water additions at the site of use, but they can be shipped also in ready-to-use water-filled [slurry] form in the appropriate packaging (for example, polyethylene bags laid in boxes) or in special trucks or charging trucks. In particular, high-strength akvatol MG (metallized, gel-like) based on alyumotol with increased aluminum content, is provided for deliveries from the plant.

In addition to plant manufacture, slurry explosives are manufactured directly at mining enterprises either on a stationary installation installed in the service warehouse of explosive materials, or else during charging of drillholes using mixer-charging trucks. Several types of these vehicles are designed for the use of pre-formulated hot solutions of ammonium nitrate to which CMC or polyacrylamide has been added.

The water content in akvatols after slurry preparation must not exceed 13-15 percent (by weight). When the water content is lower, it is difficult to give the mass the needed fluidity; a higher water content dilutes the explosive and thereby reduces its strength, water resistance, and sensitivity. To simplify slurry preparation of akvatols and to achieve good gel-like consistency of an explosive together with high water resistance and the requisite fluidity, it is recommended that the water be first heated to 85-95° C and that as far as possible the mass be heated in a mechanical mixture, since dissolving of ammonium nitrate occurs with much heat absorption (about 78.8 kcal/kg) and depends heavily on temperature. It is also recommended to use intense mechanical mixing, which makes it easier to produce a uniform and plastic consistency of the mass.

Physical characteristics of akvatols (turbidity, absence of layering, and water resistance) depend strongly on the amount and quality of thickening and binding additives introduced, the thickening procedures, and the temperature of the resulting slurry mass. Akvatols compared with 1.0-2.0 percent guar (resinous meal made from the pods of certain varieties of acacia and other gum-bearing plants and soluble in aqueous salt solutions) are more stable and exhibit greater water resistance than akvatols with the same amount of the sodium salt of CMC, especially if to their composition is added a small amount (0.02-0.05 percent) borax or other additives binding (crosslinking) the macromolecules of the thickening agent swelling in water. They do not segregate and are not diluted with water over a long period (up to 30 days) of residence in flooded boreholes. Slurry akvatols containing 1.5-3.0 percent CMC, but without binding additives, can be allowed to remain in flooded boreholes containing still water for 2-3 days, and for 5-10 hours in flooded boreholes containing running water. The fluidity of slurry akvatols drops off sharply with decrease in temperature. At 30-35° C, freshly prepared akvatols stream freely from a tipped vessel. As the temperature is lowered to 20-15° C, excess pressure of 2-3 atm is required for flow. At temperatures near zero, they thicken to such an extent that apart from mechanical agitation they are incapable of flowing along pipelines, while at -13 to -15° C -- they freeze.

Akvatols, especially metallized, exhibit high volumetric energy of explosion. The high volumetric concentration of energy in the drillhole and the high rate of its release leads to an abrupt rise in the parameters of the detonation wave, a modification in the pattern of shock wave propagation in the rock mass being broken up, and improvement in the fragmentation of the rock.

Calculated and experimental characteristics of slurry akvatols are as follows:

Calculated	Akvatol 65/35	Akvatol M-15
Oxygen balance, percent	-12.5	-21.0
Heat explosion, kcal/kg:		
gravimetric	920	1474
volumetric	1340	2030
Volume of gases, l/kg	925	990
Total ideal work of explosion, kcal/kg	775	1120
Experimental		
Freezing point, degrees	-15	-15
Density of explosive, g/cm^3	1.4-1.45	1.35-1.40
Efficiency, cm^3	330-350	465-480
Heat of explosion, kcal/kg	910	1398
Trotyl equivalent	1.15	1.4
Compression of lead column (mm) by a charge placed in a steel shell when initiated with a 10 gram trotyl load	25-28	30-34
Detonation rate, km/sec	4.8-5.5	4.8-5.8
Critical diameter of exposed charge:		
of dry mixture	50-70	60-70
in slurry state	100-150	100-150
Critical diameter of slurry explosive in steel shell, mm	35-40	30-36
Minimum weight of intermediate-detonator (for explosive charge in shell), grams of trotyl	15-20	20-25
Sensitivity of dry mixture to a No 8 blasting cap	Inadequate	
Optimal intermediate detonator for failure-free detonation	Charge TG-500, two Tet-150 charges, or one T-400 charge	
Sensitivity of ground dry explosive:		
to shock, percent	12-24	36-56
to friction, kg/cm^2	2330	1650

Experimental [Conclusion]	Akvatol 65/35	Akvatol M-15
Lower limit of sensitivity to shock, mm	500	300
Sensitivity of slurry explosive:		
to shock, percent	0-4	4-8
to friction, kg/cm^2	3000	3900
Lower limit of sensitivity to shock, mm	500	500

Gel-like akvatol MG has the following characteristics:

Heat of explosion, kcal/kg	1320
Efficiency, cm^3	520-560
Density, g/cm^3	1.35-1.40
Detonation rate, km/sec	5.0-5.5
Equivalent to akvatol M-15 in sensitivity to mechanical forces.	

The most rational field of use of akvatols is breaking up extremely tough hard-blasting rock in dry and flooded boreholes using borehole charges. Akvatols are not recommended to be used in dry or to be charged by pouring in a dry mixture into a flooded drillhole, since when this is done the high charging density and blasting efficiency are not achieved.

A powerful intermediate detonator is needed to initiate akvatol charges. In the slurry state, the charges are very weakly sensitive to mechanical forces, but dry akvatol mixtures differ little from ammonites in sensitivity to external forces.

Akvatols are permitted to be used in the slurry state in dry and flooded drillholes in open workings. Plants deliver them in a set with T-400 detonator-charges, or with TG-500 detonators (at a rate of four charges per ton of explosive). The wholesale cost of 1 ton of dry mixtures of akvatol 65/35 is 233 rubles, for akvatol M-15 -- 380 rubles, and for gel-like akvatol MG--- 480 rubles.

Water-resistant cast explosives in chunks and charges

Cast explosives refer to explosives prepared by melting and casting them into piecewise products. They include trotyl chunks and cylindrical charges. The chunks are rectangular or more often irregular in shape, 25-50 mm in thickness, and have a maximum transverse size of 100 mm. The charges are produced mainly in two kinds: solid bars 210-220 mm in diameter and weighing 20 kg under the name of cast LZ-20 charges, and LZ-2.6 cast charges (Fig. 1), with a 20 mm diameter central channel and containing a pressed 75-gram load of ground trotyl, which has a recess beneath the blasting cap or the electric detonator. These charges weigh 2.6 kg. They are used easily in exploratory seismic work, where they are initiated with an electric detonator whose leads pass through the channel of the small charges [75-gram ground trotyl charges]. However, if a bundle of 8 strands of a powerful detonating fuse is placed into this channel and wedged in such a way that they are in tight contact with the channel walls and with each other, and if the end of the blasting fuse is inserted into the recess of the small charge, this overall charge can be used as a powerful intermediate detonator in initiating the primary charges of akvatols and granulated explosives in flooded drillholes.

On customer order, all LZ-2.6 charges or some of them can be manufactured solid and not containing the pressed small charge, for use as a high-density booster drillhole charge in combination blasting using granulated explosives.

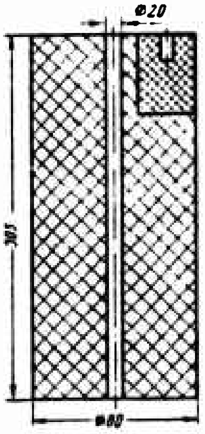

Fig. 1. Cast trotyl charge containing pressed load of intermediate detonator

Cast trotyl chunks and small charges exhibit high indicators of density (1.48-1.59 g/cm^3), brisance (30-34 mm), detonation rate (6.2-6.8 km/sec), and water-resistant. Suitably initiated, they are capable of detonating after long residence in standing and flowing water; after any suitable initiation they are capable of detonating after the water filling

TABLE 12. FORMULATION COMPOSITION AND STANDARDIZED TECHNICAL INDICATORS

1 Компоненты и показатели	2 Аммонит В-3 в порошке	3 Аммонит № 9-ЖВ	4 Аммонит № 10-ЖВ
5 Состав, %			
Селитра аммиачная: 6			
обычная 7	82,0+1,5	—	—
водоустойчивая 8	—	87+1,5	85+1,5
Тротил 9	16,5±1,0	$5^{+1,5}_{-0,5}$	$8^{+1,0}_{-0,5}$
Асфальтит 10	1,0±0,25		
Парафин 11	0,5±0,1	—	—
Мука древесная 12	—	8±1,0	8±1,0
Технические показатели 13			
Влажность, не более % 14	0,2	0,6	0,5
Бризантность, не менее *мм* 15	14	10	11
Работоспособность, не менее *см*³ 16	360	300	300
Водоустойчивость, не менее *см вод. ст.* 17	40	40	40
Гарантийный срок использования, месяцев 18	6	6	6

KEY: 1 -- Components and indicators
2 -- Ammonite V-3 in powder
3 -- Ammonite No 9-ZhV
4 -- Ammonite No 10-ZhV
5 -- Composition
6 -- Ammonium nitrate
7 -- ordinary
8 -- water-resistant
9 -- Trotyl
10 -- Asphaltite
11 -- Paraffin
12 -- Wood meal
13 -- Technical indicators
14 -- Moisture content, not more than
15 -- Brisance, not less than
16 -- Efficiency, not less than
17 -- Water-resistant, not less than cm of H_2O column
18 -- Guarantee period of use, months

the charge has frozen. One pressed T-400 charge is adequate for initiating primary charges of cast trotyl chunks and solid small charges.

Cast trotyl in chunks and small charges have the same calculated explosive characteristics and oxygen balance as found for granulotol (cf. Table 11). The critical diameter of cast trotyl, depending on density, is

30-40 mm. A 20-gram pressed trotyl small charge is adequate as a minimum impulse in initiating cast trotyl. In the fused state, trotyl shows very low sensitivity to shock (0-4 percent) and to friction (> 2900 kg/cm^2). It is not hygroscopic and it is chemically resistant and can be stored for long time in nonhermetic containers. Its chunks are supplied in paper or external jute sacks priced at 350 rubles, while the small charges are delivered in sacks or boxes priced at 551 and 622 rubles per ton, respectively. The guarantee period of use is 12 months.

Worm conveyor-packed explosives

Worm conveyor-packed [subsequently referred to as WCP] explosives include ammonite V-3, produced only in WCP large-diameter charges with a mean density of 1.3 g/cm^3, readily sinking in water in the charging of flooded drillholes; it is used in blasting rock and ore of moderate toughness. The water resistance of WCP charges prepared from V-3 ammonite powder with standardized technical indicators (Table 12) is higher than the water resistance of tamped cartridges prepared from this and other powdered explosives. Therefore they are suitable also for drillholes containing running water.

A waterproofing additive, consisting of asphaltite and paraffin, incorporated in V-3 ammonite gives it water resistance and is a cementing agent, making it possible to fabricate charges of required strength within the limits of the working density.

The technical conditions provide for production of charges having the following parameters:

Charge diameter, mm	Explosive weight, kg
130	6.5
150	10
175	12
185	13.5
200	16
210	17.5

The permissible deviations from these values are ± 5 percent. Their length of charges of all sizes is 420 mm. The regulated mean working density of charges must not exceed the limits 1.25-1.35 g/cm^3. Several local compactions of explosives with respect to the height and diameter of a charge of not more than 1.45 g/cm^3 are allowed.

TABLE 13. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

1 Характеристики	2 Аммонит В-3 в порошке	3 Аммонит № 9-ЖВ	4 Аммонит № 10-ЖВ
Расчетные 5			
Кислородный баланс, % 6	—0,43	+2,74	+1,53
Теплота взрыва, ккал/кг 7	1000	857	908
Объем газов, л/кг 8	910	933	924
Температура взрыва, град 9	2870	2460	2610
Экспериментальные 10			
Насыпная плотность, г/см^3 11	0,85—0,90	0,72—0,78	0,75—0,80
Работоспособность, см^3 12	360—380	300—330	310—340
Бризантность, мм 13			
в пределах 14	14—16	10,0—12,5	11—13
в среднем 15	15,2	10,9	12,5
Передача детонации между патронами диаметром 32 мм, см 16	3—5	2—3	2—5
17 Скорость детонации, км/сек	3,6—4,0	3,0—3,5	3,2—3,6
Критический диаметр детонации, мм: 18			
открытого заряда 19	13—15	20—25	15—20
в прочной оболочке 20	5—8	10—15	8—10
Чувствительность к удару, % 21	24—36	12—24	12—24
Чувствительность к трению, кГ/см^2 22	1900	>3000	>3000
Водоустойчивость, см вод. ст. 23	40—60	35—45	40—60

KEY: 1 -- Characteristics
2 -- Ammonite V-3 in powder
3 -- Ammonite No 9-ZhV
4 -- Ammonite No 10-ZhV
5 -- Calculated
6 -- Oxygen balance
7 -- Heat of explosion, kcal/kg
8 -- Volume of gases, l/kg
9 -- Temperature of explosion, degrees
10 -- Experimental
11 -- Heat density, g/cm^3
12 -- Efficiency, cm^3
13 -- Brisance
14 -- within the limits
15 -- on the average
16 -- transmission of detonation between 32 mm diameter cartridges
17 -- Detonation rate, km/sec
18 -- Critical diameter of detonation
19 -- of exposed charge

[to be continued on following page]

KEY [to Table 13, continuation]:
20 -- In strong shell
21 -- Shock sensitivity
22 -- Friction sensitivity, kg/cm^2
23 -- Water resistance, cm of H_2O column

Charges are wrapped over their entire surface in paper sheaths waterproofed with bitumen with cementing of seams, which protects them against wetting during storage and to some extent raises their water resistance. For convenience in lowering into drillholes, charges have a loop formed of cord. The data on the brisance and detonation rates of explosives given in Table 13 were obtained for a density of 1 g/cm^3. The guarantee period of use of charges is 6 months. The wholesale cost of 1 ton of V-3 ammonite charges, 130-150 mm in diameter, is 325 rubles, for ammonite V-3 charges 175-185 mm in diameter -- 315, and for charges 200-210 mm in diameter -- 300 rubles.

Powdered noncartridged explosive

Powdered explosives permitted for use in noncartridged form in open-pit operations include the water-resistant ammonites No 9-ZhV and No 10-ZhV, which are uniform flow-flowing loose powder of moderate dispersion. Because their composition includes water-resistant nitrate and a large amount of loose water-holding wood meal (Table 12), they have only a low tendency to cake, do not become overcompacted, and retain detonatability when severely wet (up to 8-10 percent). They are marked by relatively high critical detonation density (1.35-1.40 g/cm^3). In terms of sensitivity to mechanical forces, they do not differ from other ordinary ammonites; they are more sensitive to flames than ammonite No 6-ZhV; when dry, they ignite more readily after prolonged exposure to flame and burn better than ammonites not containing wood meal. Their combustion in large quantities, just as other ammonium nitrate explosives, can end in an explosion. They are only slightly inferior to ammonite No 6-ZhV in water resistance.

Ammonites No 9-ZhV and No 10-ZhV are classified as moderate-strength explosives. Moreover, they differ somewhat in composition, strength characteristics (cf. Tables 12 and 13), and cost. With the incorporation of igdanite and granulites, the use of these ammonites has come to an end. They are employed in conditions when granulated explosives are not capable of stably detonating, for example, in secondary blasting with exterior and small blasthole charges.

Ammonites No 9-ZhV and No 10-ZhV are produced only in bulk form in paper packing. The wholesale price of 1 ton of the ammonites No 9-ZhV and No 10-ZhV is 138 and 145 rubles, respectively.

TABLE 14. STANDARDIZED TECHNICAL INDICATORS FOR POWDERED EXPLOSIVES AND TAMPED CARTRIDGES

Показатели 1	Аммонит скальный № 1 2	Аммонал скальный № 3 3	Аммонал водоустойчивый 4
Влажность, не более % 5	0,2	0,2	0,2
Плотность патронов, г/см^3 6	0,95—1,10	0,90—1,10	0,95—1,10
Работоспособность не менее, см^3 7	450	450	400
Бризантность при плотности 1 г/см^3, не менее мм 8	18	18	16
Передача детонации (см) между патронами диаметром, мм: 9			
24, не менее 10	—	3	—
28, не менее	—	5	—
32, не менее	7	7	4*
36, не менее	9	8	6*
Передача детонации (см) после выдержки в воде патронов диаметром, мм: 11			
24, не менее 10	—	2	—
28, не менее	—	3	—
32, не менее	5	5	3*
36, не менее	6	6	4*
Гарантийный срок использования, месяц: 12			
в бумажной упаковке 13	6	6	6
в полиэтиленовой упаковке 14	12	12	12

* When water-resistant ammonal is produced in non-cartridged form, its testing for transmission of detonation is not carried out. The water resistance, whose norm is set at not less than 40 cm H_2O column, is determined with the hydraulic instrument.

KEY:
1 -- Indicators
2 -- Ammonite, rock-oriented, No 1
3 -- Ammonal, rock-oriented, No 4
4 -- Ammonal, water-resistant
5 -- Moisture content, not more than
6 -- Density of cartridges, g/cm^3
7 -- Efficiency, not less than
8 -- Brisance at a density of 1 g/cm^3, not less than
9 -- Transmission of detonation (cm) between cartridges having the following diameters, mm
10 -- not less than
11 -- Transmission of detonation (cm) after exposure in water of cartridges having the following diameters, mm
12 -- Guarantee period of use, months
13 -- in paper packing
14 -- in polyethylene packing

10. Explosives for Open-Pit and Underground Operations, Except for Operations in Mines That Are Hazardous as to Gas or Dust (Class II)

Class II explosives are subdivided into seven groups (cf. Table 9). Their main purpose is application in underground mining operations, but many of them find use also in open-pit work in combination borehole and chamber charges (granulites, zernogranulites, igdanite, ammonites No 6-ZhV and No 7-ZhV in powdered form), while some are used as intermediate detonators in drillhole charges and for secondary blasting of oversize rock chunks.

Pressed water-stable explosives

Only rock-oriented ammonite No 1 is produced in pressed form; its composition includes a relatively large amount of the high-sensitivity sensitizer hexogen, through which it exhibits high detonatability. Tables 14 and 15 give the main technical indicators of nonpressed powdered rock-oriented ammonite No 1, from which it follows that it is a powerful explosive (it contains aluminum as well as hexogen) and detonates with high indicators of velocity and brisance. In tamped small-diameter cartridges (24-28 mm) it transmits detonation over long distances. Even higher characteristics are shown by this explosive when pressed; it is in this state that it is mainly used in cartridges (charges) 36 mm in diameter, less often 45 mm in diameter, and weighing 250 and 400 grams, respectively.

Standardized technical indicators for pressed cartridges of rock-oriented ammonite No 1 are as follows:

Density of cartridges, g/cm^3	1.43-1.58
Brisance for moderate cartridge density, not less than, in mm	22
Transmission of detonation, cm:	
after exposure in water, not less than	4
between dry cartridges, not less than	5

In pressed cartridges (density 1.45-1.50 g/cm^3), rock-oriented ammonite No 1 has even higher explosive characteristics: it detonates at the rate of 6.0-6.5 km/sec; when tested for brisance, it produces a compression of lead amounting to 28-32 mm and transmits detonation between cartridges 5-10 cm apart. Although pressing reduces somewhat its sensitivity to the initial impulse, it still is detonated with a No 8 blasting cap and detonating fuse. Pressed cartridges of this explosive exhibit high water resistance, withstanding many hours of soaking in flooded blastholes containing running water. They do not suffer loss of detonatability at

TABLE 15. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Аммонит скальный № 1 (в порошке) 2	Аммонал скальный № 3 3	Аммонал водоустойчивый 4
Расчетные 5			
Кислородный баланс, % 6	−0,79	−0,78	+0,18
Теплота взрыва, *ккал/кг* 7	1292	1360	1180
Объем газов, *л/кг* 8	830	810	845
Температура взрыва, *град.* 9	3520	3640	3210
Полная идеальная работа взрыва, *ккал/кг* 10	1055	1060	940
Экспериментальные 11			
Теплота взрыва, *ккал/кг* 12	1250	1343	—
Объем газов, *л/кг* 13	820	801	—
Работоспособность, *г/см*^{3} 14	450—480	450—470	410—430
Бризантность (*мм*) при плотности 1 *г/см*^{3}: 15			
в пределах 16	18,5—22,5	18—20	16,4—19,5
в среднем 17	20	19	17,5
Передача детонации (*см*) между набивными патронами диаметром, *мм*: 18			
24	4—6	3—5	—
28	6—10	6—9	—
32	10—14	8—12	5—8
36	15—18	10—14	8—12
Передача детонации (*см*) после выдержки в воде в течение 1 *ч* патронов диаметром, *мм*: 19			
24	3—4	2—3	—
28	4—6	5—8	—
32	10—12	8—10	4—5
36	12—16	10—12	6—8
20 Тротиловый эквивалент по баллистическому маятнику	1,1	1,12	1,08
21 Скорость детонации, *км/сек*	4,8—5,3	4,0—4,5	4,0—4,5
22 Критический диаметр детонации открытого заряда, *мм*	5—6	8—10	12—14
23 Восприимчивость к детонации от тротиловой шашки весом 50 *г* на расстоянии, *см*	15	18	10
24 Чувствительность к удару, %	40—60	40—44	24—36
25 Нижний предел чувствительности к удару, *мм*	106	150	200
26 Чувствительность к удару на большом копре, %	80	40	32
27 Чувствительность к трению, *кГ/см*^{2}	900—1200	1320	1936—2840
28 Водоустойчивость, *см вод. ст.*:			
29 в пределах	70—80	70—90	40—70
30 в среднем	75	85	55

KEY [to Table 15]:
1 -- Characteristics
2 -- Ammonite, rock-oriented, No 1 (in powder)
3 -- Ammonal, rock-oriented, No 3
4 -- Ammonal, water-resistant
5 -- Calculated
6 -- Oxygen balance
7 -- Heat of explosion, kcal/kg
8 -- Volume of gases, l/kg
9 -- Temperature of explosion, degrees
10 -- Total ideal work of explosion, kcal/kg
11 -- Experimental
12 -- Heat of explosion, kcal/kg
13 -- Volume of gases, l/kg
14 -- Efficiency, g/cm^3
15 -- Brisance (mm) for a density of 1 g/cm^3
16 -- within the limits
17 -- on the average
18 -- Transmission of detonation (cm) between tamped cartridges having the following diameters
19 -- Transmission of detonation (cm) after exposure in water for 1 hour of cartridges with the following diameters
20 -- Trotyl equivalent based on the ballistic pendulum tests
21 -- Rate of detonation, km/sec
22 -- Critical diameter of detonation of exposed charge
23 -- Susceptibility to detonation from a trotyl load weighing 50 g, at a distance indicated, in cm
24 -- Shock sensitivity
25 -- Lower limit of sensitivity to shock
26 -- Sensitivity to shock using a large pile driver
27 -- Sensitivity to friction, kg/cm^2
28 -- Water resistance, cm of H_2O column

29 -- within the limits
30 -- on the average

high rates even in intensely wetted state. Rock-oriented ammonite in explosive operations forms toxic gases to a smaller extent than do ordinary ammonites, especially nitrogen oxides.

Compared with ordinary ammonites, rock-oriented ammonite exhibits greater sensitivity to mechanical forces (Table 15) and naked flame. When the residues of cartridges that for some reason can remain in "bootlegs" of blastholes are drilled out, an explosion is possible by a strong blow of a steel instrument against rock in which this explosive can be present. When cartridges of this explosive are burned (for example, in bonfire), detonation is also possible. Therefore, in transporting, storing, using, and eliminating rock-oriented ammonite No 1, increased caution must be exercised, in spite of the fact that in handling conditions it is classified as a group-II explosive. In addition to pressed cartridges 36-45 mm in diameter and small-diameter tamped cartridges of this explosive, in some orders it can also be produced as large-diameter cartridges (60-120 mm) at heaped density (for charging of refractory drillholes). Transporting and using noncartridged rock-oriented ammonite is forbidden.

Pressed at rock-oriented ammonite No 1 is intended for driving operations in extremely tough hard-blasting rock in faces flooded to any extent, including also with running water. Cartridges 36 mm in diameter consist of two loads each weighing 125 g, while 45-mm diameter cartridges consist of two loads each weighing 200 g. A recess with a diameter of 8 ± 0.1 mm and a depth of 73 ± 0.5 mm is provided at one end of the pressed cartridges intended for making strikers, under the electric detonator or the blasting cap. Lots of the strikers are provided in sets on the basis of four packs of cartridge-strikers for ten packs of cartridges without recesses. The same ratio was observed also when packing in boxes. An arrow indicating the placement of the recess is printed on the shell of the cartridge-striker, and the word "strikers" is written on the packs of these cartridges.

The wholesale price of 1 ton of pressed rock-oriented ammonite No 1 for a cartridge diameter of 36-45 mm is 900 rubles, for tamped cartridges of the same diameter -- 713 rubles, and for 60-90 mm diameter cartridges -- 697 rubles, while for 100-120 mm diameter cartridges it is 689 rubles.

Powdered water-resistant explosives of increased strength and regular strength

This group includes high-strength rock-oriented ammonal No 3, containing -- in addition to hexogen -- 8 percent aluminum; water-resistant ammonal; and the dynammons AM-8 and AM-10, whose compositions also include aluminum.

Rock-oriented ammonal No 3 is a weakly-friable, homogeneous steel-gray powder. Compared with rock-oriented ammonal No 1, it has somewhat less sensitivity to mechanical forces and is marked by relatively lower stability, while it has a higher indicator of explosive energy (Table 15). This ammonal is the most powerful ammonium nitrate powdered type explosive, as to explosive characteristics, of the explosives used in tamped cartridges. Its good detonatability allows to be produced in standard and small-diameter cartridges (24-28 mm). In these cartridges, it exhibits high water resistance, does not become caked during storage, stably detonates in wet and soaking condition, and is suitable for charging severely flooded blastholes. It is intended for driving and clearing operations in rock and for certain specialized operations (contour blasting, and so on).

TABLE 16. FORMULATION COMPOSITION AND STANDARDIZED TECHNICAL INDICATORS

Компоненты и показатели 1	Аммонит № 6-ЖВ 2	Динафталит 3	Аммонит № 7-ЖВ 4	Динамоны 5	
				АМ-8	АМ-10
Состав, % 6					
Селитра аммиачная водоустойчивая 7	79±1,5	35±1,5	81,5±1,5	89±1,5	87,7±1,5
Селитра аммиачная 8	—	53±1,5	—	—	—
Тротил 9	21±1,5	—	16±1,0	—	—
Д[illegible]ин 10	—	11,6±1,0	—	—	—
[illegible] 11	—	—	2,5±0,5	—	—
[illegible] 12	—	—	—	8±1,0	10,0±1,0
[illegible] 13		0,4±0,1	—	—	—
Масло минеральное 14	—	—	—	3±0,5	2,3±0,5
Технические показатели 15					
Влажность, не более % 16	0,2	0,2	0,3	0,2	0,2
Плотность патронов, $г/см^3$ 17	1,0—1,2	1,0—1,15	0,95—1,10	0,90—1,1	0,90—1,1
Работоспособность, не менее $см^3$ 18	360	320	350	400	420

TABLE 16 [Continuation]

Компоненты и показатели 1	2 Аммонит № 6-ЖВ	3 Динафталит	4 Аммонит № 7-ЖВ	Динамоны 5	
				АМ-8	АМ-10
Бризантность, не менее *мм* 19	14	15	13	13	14
Передача детонации (*см*) между патронами диаметром: 20				27	
32 *мм*, не менее 21	5	3	4	Патроны ∅ 60—90 *мм* 4	5
36 *мм*, не менее 21	7	4	5	Патроны ∅ 100—120 *мм* 27 8	10
Передача детонации (*см*) после выдержки в воде* патронов диаметром: 23					
32 *мм*, не менее 21	3	2	2	—	—
36 *мм*, не менее 22	4	3	2	—	—
Водоустойчивость по гидроприбору, не менее *см вод. ст.* 24	40	40	40	28 Испытание факультативное	
Гарантийный срок использования в бумажной упаковке 25	3	3	3	3	3
в полиэтиленовой, месяц 26	12	12	12	8	8

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* Uncartridged explosives are not tested for transmission of detonation; instead, they are tested for water resistance based on use of the hydraulic instrument.

KEY [to Table 16]:
1 -- Component and indicators
2 -- Ammonite No 6-ZhV
3 -- Dinaphthalite
4 -- Ammonite No 7-ZhV
5 -- Dynammons
6 -- Compositions
7 -- Water-resistant ammonium nitrate
8 -- Ammonium nitrate
9 -- Trotyl
10 -- Dinitronaphthalene
11 -- Wood meal
12 -- Aluminum powder
13 -- Paraffin
14 -- Mineral oil
15 -- Technical indicators
16 -- Moisture content, not more than
17 -- Density of cartridges, g/cm^3
18 -- Efficiency, not less than
19 -- Brisance, not less than
20 -- Transmission of detonation (cm) between cartridges having the following diameters
21 -- not less than
22 -- not less than
23 -- Transmission of detonation (cm) after exposure in water* of cartridges having the following diameters
24 -- Water resistance based on use of the hydraulic instrument, not less than cm H_2O column
25 -- Guarantee period of use in paper packing
26 -- in polyethylene packing, months
27 -- Cartridges
28 -- Test is optional

Rock-oriented ammonal No 3 in long charges detonates more reliably than pressed rock-oriented ammonite No 1. Increased caution during handling is required, even though it is classed as a group-II explosive. Use of this explosive in noncartridged form is not permitted. The provisional wholesale price of 1 ton is 630 rubles.

Water-resistant ammonal is a steel-gray finely dispersed pulverulent powder of the following formulated composition: 80.5 ± 1.5 percent water-resistant ammonium nitrate, 15.0 ± 1.0 percent trotyl, and 4.5 ± 1.0 percent aluminum powder. It exhibits satisfactory water resistance and does not cake when normal storage conditions are observed. It is inferior to rock-oriented ammonal No 3 and ammonite No 1 (cf. Table 15) in its energy characteristics and detonatability, but exceeds ordinary ammonites in strength. A distinguishing feature of water-resistant ammonal is its relatively low sensitivity to mechanical forces. It is at the level of

TABLE 17. CLACULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Аммонит № 6-ЖВ 2	Динафталит 3	Аммонит № 7-ЖВ 4	Динамоны 5	
				АМ-8	АМ-10
Расчетные 6					
Кислородный баланс, % 7	−0,53	+0,3	+0,22	−0,3	+0,03
Теплота взрыва, *ккал/кг* 8	1030	975	995	1180	1285
Объем газов, *л/кг* 9	895	920	905	843	840
Температура взрыва, *град* 10	2960	2780	2850	3250	3380
Полная идеальная работа взрыва, *ккал/кг* 11	850	790	820	972	1015
Экспериментальные 12					
Насыпная плотность с утряской, *г/см³* 13	0,85—0,90	0,9—0,95	0,78—0,83	0,85—0,90	0,85—0,90
Работоспособность, *см³* 14	360—380	320—350	360—370	420—440	430—450
Бризантность, *мм* 15	15—18	15—16	14—16	14,3—17,6	14,5—17,7
в среднем 16	16,5	15,5	15,2	15,5	16,0
Передача детонации (*см*) между патронами диаметром: 17				18 Диаметром 60 *мм*	
32 *мм*	6—9	4—7	5—8	12—15	15—18

TABLE 17 [Continuation]

①	②	③	④	⑤	
				30 Диаметром 100 *мм*	
36 *мм*	8—12	4—9	6—10	20—25	25—30
Передача детонации (*см*) после выдержки в воде патронов диаметром: 19					
32 *мм*	3—6	2—5	3—4	—	—
				31 Диаметром 40 *мм* горизонтально	
36 *мм*	5—10	3—6	3—5	3—5	4—6
Водоустойчивость по гидроприбору, *см вод. ст.* в пределах 20	50—80	50—90	40—60	25—35	30—40
в среднем 21	75	80	52	30	35
Скорость детонации, *км/сек* 22	3,6—4,8	3,5—4,6	3,5—4,0	3,2—4,0	3,4—4,2
Критический диаметр детонации, *мм*: 23					
открытого заряда 24	10—13	13—14	11—13	15—20	15—18
в прочной оболочке 25	4—6	5—6	5—7	8—10	6—8
Критическая плотность, *г/см*³ 26	1,45—1,55	1,35—1,45	1,35—1,45	1,2—1,25	1,25—1,35
Чувствительность к удару, % 27	16—32	12—24	16—28	12—24	12—24
Нижний предел чувствительности к удару, *мм* 28	220	400	280	400	350
Чувствительность к трению, *кГ/см*² 29	2335	>3000	2850	>3000	>3000

KEY [to Table 17]:

1 -- Characteristics
2 -- Ammonite No 6-ZhV
3 -- Dinaphthalite
4 -- Ammonite No 7-ZhV
5 -- Dynammons
6 -- Calculated
7 -- Oxygen balance
8 -- Heat of explosion, kcal/kg
9 -- Volume of gases, l/kg
10 -- Temperature of explosion, degrees
11 -- Total ideal work of explosion, kcal/kg
12 -- Experimental
13 -- Heaped density after shaking, g/cm^3
14 -- Efficiency, cm^3
15 -- Brisance
16 -- on the average
17 -- Transmission of detonation (cm) between cartridges having the following diameters
18 -- Diameter of 60 mm
19 -- Transmission of detonation (cm) after exposure in water of cartridges having the following diameters
20 -- Water resistance based on use of the hydraulic instrument, cm H_2O column, within the limits
21 -- on the average
22 -- Detonation rate, km/sec
23 -- Critical diameter of detonation
24 -- of exposed charge
25 -- in strong shell
26 -- Critical density, g/cm^3
27 -- Sensitivity to shock
28 -- Lower limit of sensitivity to shock
29 -- Sensitivity to friction, kg/cm^2
30 -- Diameter of 100 mm
31 -- Diameter of 40 mm, horizontally

ammonite No 6-ZhV in terms of these characteristics. The permissible amount of toxic gases is released in blasting operations. It is stable, just as other waterproofed ammonites. It is manufactured in noncartridged form as well as standard and large-diameter cartridges. It is intended for blasting tough rock of any degree of flooding with standing water in underground and open-pit operations. The wholesale price of 1 ton of ammonal powder is 205 rubles, the cost of 1 ton of 32-36 mm diameter cartridges is 329 rubles, for 1 ton of 40-50 mm diameter cartridges -- 322 rubles, and for 1 ton of 60-100 mm diameter cartridges -- 314 rubles.

Dynammons AM-8 and AM-10 (Tables 16 and 17) are nonpulverulent oiled poorly-friable ammonium nitrate, powdered mixtures of moderate dispersion and steel-gray in color. They do not cake in cartridged form and are less water-resistant than ammonite No 6-ZhV. Dynammon AM-8 is at the level of water-resistant ammonal in its energy characteristics and efficiency, while dynammon AM-10 is close to detonite 10A in this respect. A distinguishing feature of these explosives is the low sensitivity to mechanical forces, permitting the charging of ascending drillholes with large-diameter cartridges, and another feature is their low cost compared to their strength. The presence of mineral oil in the dynammon composition renders them nonpulverulent and to some extent phlegmatizes them. They differ between each other mainly by strength and resistance.

When used in drillhole charges, dynammons in many cases are capable of replacing — owing to their efficiency — not only ammonal, but even the more expensive rock-oriented ammonite No 1 (in tamped cartridges) and detonites 6A and 10A. Dynammons are sensitive to No 8 blasting caps and detonating fuses, however when blasting is done in drillhole charges it is recommended that a small intermediate detonator (ammonite cartridge) be used to totally ensure that the detonation does not hand fire. They are produced in 60-120 mm diameter cartridges for charging of dry and wet remaining drillholes. The wholesale price of 1 ton of large-diameter cartridges of the dynammons AM-8 and AM-10 is 340 and 365 rubles, respectively.

Powdered water-resistant moderate-strength explosives

These include the water-resistant ammonites No 6-ZhV and No 7-ZhV and dinaphthalite (Table 16).

Ammonite No 6-ZhV is a finely disperse, poorly-friable, and pulverulent powder. As to explosive qualities and water resistance, it is suitable for blasting rock of moderate and extra-moderate toughness in flooded faces (cf. Table 17). It is not recommended to charge flooded drillholes with uncartridged ammonite in view of its poor immersibility.

When carefully manufactured and well-packed, ammonite No 6-ZhV does not cake in the cartridged state and does so very little — when in powdered form. In detonatability (critical values of diameter and density, and distance of the transmission of detonation between cartridges), it is close to the more powerful high-sensitivity explosives. In addition to being produced in moderate- and large-diameter cartridges, in some cases it can also be manufactured in 28 mm diameter cartridges. It is supplied for blasting operations also in noncartridged form in asphalted paper sacks priced at 180 rubles per ton, and in paper sacks with polyethylene sack-insert (for a guarantee period of use of 12 months) at the price of 193 rubles. The wholesale price of 1 ton of 32-36 mm diameter cartridges is 315 rubles, and for 120 mm diameter cartridges — 291 rubles. Owing to poor transportability, the capacity to become electrified, and intense dusting when dry, it is not suitable for pneumatic charging, just as all powdered explosives are not suitable. It is permitted for use in open-pit and underground operations in dry and flooded faces in cartridge as well as in powdered form. It can be used as intermediate detonators for granulites, zernogranulites, and igdanite. It is classified as a group-II explosive in terms of handling conditions.

Dinaphthalite is a friable low-dusting powder with grain content from 30 to 60 percent. The grains consist of compacted fine-disperse explosive powder; their permissible size is 4-5 mm and its density of explosive is 1.25-1.46 g/cm^3. Waterproofing and granulation of an explosive mixture renders dinaphthalite water-resistant and noncaking. In explosive qualities, it differs only slightly from ammonite No 6-ZhV (cf. Table 17), and is less sensitive to mechanical forces. In the noncartridged form, it is poorly suited for charging by the pneumatic method.

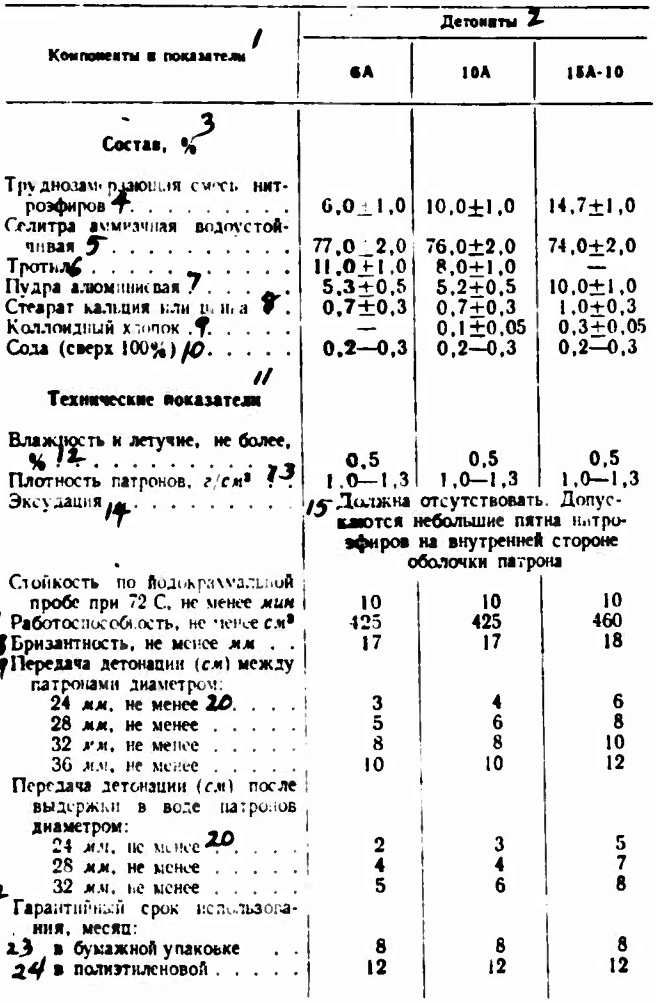
It is intended for blasting rock of moderate and increased toughness in flooded faces. It is manufactured in 32-36 mm diameter cartridges priced at 348 rubles per ton. When ordered, it can be delivered in large-diameter cartridges (90-120 mm) priced at 335 rubles per ton for charging ascending wet drillholes in underground operations. This explosive is classified in group II of explosives in terms of conditions of storage and handling.

Ammonite No 7-ZhV is a fine-disperse water-resistant powder, somewhat loosened by the addition of wood meal (Table 16), which guarantees it noncaking dependency along with a retention of water resistance. It is close to ammonite No 6-ZhV in explosive characteristics (cf. Table 17) and in several cases can replace it when blasting rock of moderate and increased toughness in flooded faces. It is suitable for drillhole and blasthole charges. In the case of noncartridge charging with pneumatic charges, it is not recommended for use owing to its dusting tendency. It is produced in noncartridge form at the price of 167 rubles per ton and in 32-36 mm diameter cartridges at the price of 290 rubles per ton. It is classified with group-II explosives.

Powdered water-resistant explosives

These include detonites 6A, 10A, 15A-10, and M, which are weakly-friable nondusting powders oily to the touch, whose composition includes a hard-to-freeze mixture of liquid nitro esters (Table 18). They are more coarsely dispersed than ammonites. Their friability decreases with increase in the nitro ester content. Greater friability is shown by detonite 6A containing 6 percent nitroesters and detonite M, which contains 10 percent each of aluminum powder and nitro esters.

TABLE 18. FORMULATION COMPOSITION AND STANDARDIZED TECHNICAL INDICATORS



Компоненты и показатели 1	Детониты 2		
	6А	10А	15А-10
Состав, % 3			
Труднозамерзающая смесь нитроэфиров 4	6,0±1,0	10,0±1,0	14,7±1,0
Селитра аммиачная водоустойчивая 5	77,0±2,0	76,0±2,0	74,0±2,0
Тротил 6	11,0±1,0	8,0±1,0	—
Пудра алюминиевая 7	5,3±0,5	5,2±0,5	10,0±1,0
Стеарат кальция или цинка 8	0,7±0,3	0,7±0,3	1,0±0,3
Коллоидный хлопок 9	—	0,1±0,05	0,3±0,05
Сода (сверх 100%) 10	0,2—0,3	0,2—0,3	0,2—0,3
Технические показатели 11			
Влажность и летучие, не более, % 12	0,5	0,5	0,5
Плотность патронов, *г/см*³ 13	1,0—1,3	1,0—1,3	1,0—1,3
Эксудация 14	15 Должна отсутствовать. Допускаются небольшие пятна нитроэфиров на внутренней стороне оболочки патрона		
16 Стойкость по йодокрахмальной пробе при 72 С, не менее *мин*	10	10	10
17 Работоспособность, не менее *см*³	425	425	460
18 Бризантность, не менее *мм*	17	17	18
19 Передача детонации (*см*) между патронами диаметром:			
24 *мм*, не менее 20	3	4	6
28 *мм*, не менее	5	6	8
32 *мм*, не менее	8	8	10
36 *мм*, не менее	10	10	12
21 Передача детонации (*см*) после выдержки в воде патронов диаметром:			
24 *мм*, не менее 20	2	3	5
28 *мм*, не менее	4	4	7
32 *мм*, не менее	5	6	8
22 Гарантийный срок использования, месяц:			
23 в бумажной упаковке	8	8	8
24 в полиэтиленовой	12	12	12

KEY: 1 — Components and indicators
2 — Detonites
3 — Composition
4 — Low-freezing mixture of nitro esters
5 -- Water-resistant ammonium nitrate
6 -- Trotyl
[Key continued on following page]

KEY [to Table 18, continuation]:
7 -- Aluminum power
8 -- Calcium or zinc stearate
9 -- Colloidal cotton
10 -- Soda (upwards of 100 percent)
11 -- Technical indicators
12 -- Moisture content and volatiles, not more than
13 -- Density of cartridges, g/cm^3
14 -- Exudation
15 -- Must be absent, small patches of nitro esters on the inner side of the cartridge shell are allowed.
16 -- Resistance based on the iodine-starch test at 72° C, not less than, in minutes
17 -- Efficiency, not less than, in cm^3
18 -- Brisance, not less than
19 -- Transmission of detonation (cm) between cartridges having the following diameters
20 -- not less than
21 -- Transmission of detonation (cm) after exposure in water of cartridges having the following diameters
22 -- Guarantee period of use, in months
23 -- in paper packing
24 -- in polyethylene packing

Detonite 10A is a heavily oiled, clumping powder, while detonite 15A-10 can be classified with the semiplastic explosives in its physical condition. When cartridged, detonites compact more readily than ordinary ammonites and are produced in cartridges of various diameters with higher densities. Their cartridges can be pressed upon in blastholes to achieve greater charging density.

Detonites cake only slightly and are quite water-resistant. They are notable for high detonatability when dry and when wet and stability of explosive characteristics in storage. They have very small critical diameters of detonation; they transmit detonation over large distances between the cartridges, which renders them suitable for use in small-diameter blasthole charges. They do not suffer from overcompaction, overwetting, and soaking in blastholes. They detonate stably in the most unfavorable blasting conditions, giving off less toxic gases, especially nitrogen oxides, can do the nonnitroglycerin ammonites. They also lack a major disadvantage of dynamites, ageing, which reduces or completely eliminates explosive qualities; they are less subject to exudation. Detonites 6A and M virtually do not exude at all, while detonites 10A and 15A-10 exude only when overwetted during manufacture or storage. In contrast to plastic dynamites, detonites do not suffer changes in their explosive characteristics at low temperatures when frozen. The freezing point of nitro esters in their composition is about -19.5° C. Short-term

TABLE 19. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

1 Характеристики	2 Детонит			
	6А	10А	15А-10	М
Расчетные 3				
4 Кислородный баланс, %	—1,0	+0,51	—0,75	+0,18
5 Теплота взрыва, *ккал/кг*	1218	1200	1407	1382
6 Объем газов, *л/кг* . . .	837	828	778	832
7 Температура взрыва, *град*	3270	3280	3570	3400
8 **Экспериментальные**				
9 Плотность патронов, *г/см*^{3}	1,1—1,2	1,15—1,25	1,2—1,3	1,1—1,3
10 Работоспособность, *см*^{3}	425—440	430—450	470—520	460—500
11 Бризантность, *мм*:				
12 в пределах	17—18,5	17—20	18—23	18—22
13 в среднем	17,6	18,0	19,5	19,0
14 Передача детонации (*см*) между патронами диаметром, *мм*:				
24	5—8	6—10	10—15	6—12
28	8—15	10—17	11—20	10—16
32	12—18	12—20	15—22	16—22
36	15—22	18—25	23—28	20—26
15 Передача детонации (*см*) после выдержки в воде в течение 1 *ч* патронов диаметром, *мм*:				
24	4—5	4—8	8—12	4—8
28	7—12	8—12	10—16	6—12
32	10—15	10—16	12—18	10—15
16 36	14—20	14—22	20—25	12—20
Тротиловый эквивалент по баллистическому маятнику	1,06	1,1	1,13	1,12
17 Скорость детонации (*км/сек*) в патронах диаметром, *мм*:				
24	4,0—4,3	4,2—4,5	4,3—5,0	3,9—4,3
28	4,2—4,5	4,4—4,8	4,7—5,0	4,2—4,8
32	4,5—4,8	4,8—5,0	4,9—5,3	4,8—5,0
18 40	4,8—5,1	5,0—5,3	5,4—5,8	5,0—5,3
Критический диаметр детонации, *мм*:				
19 открытого заряда . .	8—10	6—8	4—9	8—10
20 в прочной оболочке	5	5	5	5
21				
22 Критическая плотность, *г/см*^{3}	1,55	1,6	1,7	1,6
23 Чувствительность к удару, %	32—56	40—78	48—88	40—60
24 Чувствительность к удару на большом копре, %	20—36	36—40	80—100	32—36
Чувствительность к трению, *кГ/см*^{2}	1500—1930	1245—1330	980—1200	1525—1930

KEY [to Table 19]:
1 -- Characteristics
2 -- Detonite
3 -- Calculated
4 -- Oxygen balance
5 -- Heat of explosion, kcal/kg
6 -- Volume of gases, l/kg
7 -- Temperature of explosion, degrees
8 -- Experimental
9 -- Density of cartridges, g/cm^3
10 -- Efficiency, cm^3
11 -- Brisance
12 -- within the limits
13 -- on the average
14 -- Transmission of detonation (cm) between the cartridges having the following diameters
15 -- Transmission of detonation (cm) after exposure in water per hour of cartridges having the diameter diameters
16 -- Trotyl equivalent based on use of the ballistic pendulum
17 -- Detonation rate (km/sec) in cartridges having the following diameters
18 -- Critical diameter of detonation
19 -- of exposed charge
20 -- in strong shell
21 -- Critical density g/cm^3
22 -- Sensitivity to shock
23 -- Sensitivity to shock using a large pile driver
24 -- Sensitivity to friction, kg/cm^2

storage of their cylinders (for several hours) is permitted in blasting operations down to temperatures as low as -40° C. They are classified with the group-II explosives in terms of storage conditions, not requiring heated storage sites. They are suitable for use in all climatic regions of the USSR. They have extended guarantee periods of use.

Detonites are powerful explosives. The highest strength and a high level of water resistance are shown by the semiplastic detonite 15A-10 and by the powdered detonite of grade M, in whose manufacture technical conditions set approximately identical standardized quality indicators. In blasting efficiency, they are not inferior to high-percentage plastic dynamites and therefore are intended for hard-blasting and extremely tough rock in flooded faces of mine workings. Detonites 6A and 10A are intended for use in blasthole and drillhole charges (in underground operations, in 40-60 mm diameter cartridges) for tough, flooded rock. All the detonites listed are suitable for use in cartridges 24 and 28 mm in diameter. They detonate at high rates in cartridges of standard and small diameters (Table 19).

Detonites exhibit increased sensitivity to mechanical and thermal action, increasing with their increased content of nitro esters. More careful handling is required than for ordinary ammonites. According to the Yedinyye Pravily Bezopasnosti Pri Vzryvnykh Rabotakh [Unified Safety Rules in Blasting Work], their cartridges must be periodically inspected during storage and, before use, must be checked for exudation. A key disadvantage of detonites, just as for other explosives containing nitro esters, is the toxic action of nitro esters on the human organism. Therefore when working with them direct contact with open explosives and inhalation of explosive dust must be avoided, and so it is recommended that the operator use gloves and respirators in handling these explosives. In order not to pierce detonite cartridges, the strikers must be made of non-nitro ester water-resistant explosive.

Detonites are produced in cartridges of the following diameters: 24, 28, 32, 36, 60, and 90 mm; on customer order, they can also be produced in cartridges of other diameters. The production and use of these explosives in uncartridged form is forbidden. The following prices have been set (in rubes per ton), depending on the grade of detonite and cartridge diameter:

	24 mm	28 mm	32-36 mm	60-90 mm
Detonite 6A	--	--	485	--
Detonite 10A	546	532	506	485
Detonite 15A-10	608	594	585	580
Detonite M	578	564	545	--

In its service characteristics and fields of use, detonite M is more universal than other detonites. It was developed and recommended to replace them. In the future, with the aim of consolidation, a gradual reduction in the output of detonites 6A, 10A, and 15A-10 is projected, with a conversion to detonite M in cartridges having the diameter range 24-60 mm.

Technical conditions specify the following standards for detonite M:

Cartridge density, g/cm^3	1.0-1.3
Efficiency, not less than, in cm^3	450
Brisance, not less than, mm	17
Transmission of detonation between 32 mm diameter cartridges:	
before soaking in water, not less than, cm	8
after soaking, not less than, cm	6

TABLE 20. STANDARDIZED TECHNICAL INDICATORS

Показатели 1	Динамит 62%-ный 2	Акваниты 3		
		№ 2	№ 16	ЗЛ (льющийся) 4
5 Влажность, не более %	0,75	13 Не нормируется		
6 Плотность патронов, не менее $г/см^3$	1,4	1,4	1,3	1,4
7 Химическая стойкость по йодокрахмальной пробе, не менее, *мин*	10	13 Не нормируется		
8 Работоспособность, не менее $см^3$	360	390	360	450*
9 Бризантность при плотности патронов, не менее *мм*	18	14 Факультативно 20	18*	20*
10 Передача детонации (*см*) между патронами диаметром:				
28 *мм*, не менее 11	4	—	—	—
32 *мм*, не менее	8	2	—	—
12 36 *мм*, не менее	10	4	2**	—
Гарантийный срок использования, месяцев	8	6	4	6

* Charge is initiated with a trotyl load weighing 10 g.

** When prepared in large-diameter cartridges (60-120 mm), acceptance tests of lots for detonation transmission are carried out in 36 mm diameter cartridges.

KEY:
1 -- Indicators
2 -- 62 percent Dynamite
3 -- Akvanites
4 -- ZL (casting type)
5 -- Moisture content, not more than
6 -- Density of cartridges, not less than, g/cm^3
7 -- Chemical resistance based on the iodine-test, not less than, minutes
8 -- Efficiency, not less than
9 -- Brisance for a cartridge density not less than, in mm
10 -- Transmission of detonation (cm) between cartridges having the following diameters
11 -- not less than
12 -- Guarantee period of use, in months
13 -- Not standardized
14 -- Optional

Water-resistant plastic explosives

Plastic explosives include slurry [water-filled] akvanites No 2 and No 16 and 62 percent low-freezing dynamite (Table 20). Typical distinguishing features of these explosives include the plastic consistency of composition, high density, and water resistance. As to physical state, they are thick structure-bound paste-like suspensions, consisting of a gel-like base (gelled liquid phase) and solid fine-disperse constituents. In the normal state (at above-zero temperatures and undisturbed structure), these explosives readily lend themselves to the formation and retain the form imparted to them, which is of much practical importance, since it makes possible in cartridge and noncartridge charging to attain high density and high concentration of the explosive energy in the charge cavity. Such explosives are especially profitable for charging steeply ascending blastholes and drillholes in which the cartridges -- with limited compaction -- are held tightly, and also for charging descending flooded blastholes during driving and deepening of mine shafts. They can remain in water for up to several days in cartridged and uncartridged form. Uncartridged akvanites are suitable also for secondary blasting with external charges, which upon being compressed lie tightly against all irregularities of rock fragments to be blasted. Good contact between the charge and the surface of the rock fragment, and high density and detonation rate of the explosives make for good fragmentation. These charges are capable of being retained on an irregular inclined surface of rock after cleared of dust and wetting.

The group of slurry akvanites also includes akvanite 3L, which in contrast to the akvanites No 2 and 16 has a liquid-viscous consistency and therefore is suitable for charging descending blastholes and drillholes by the method of casting or by compression under water.

Common disadvantages of all plastic explosives include changes in their plasticity and rheology in relation to temperature and their ability to age with time. After prolonged storage, their plasticity gradually decreases and at minus temperatures they shrivel and harden (freeze). Heating, kneading, or remixing can restore the lost plasticity. A result of ageing of plastic 62 percent dynamite is a reduction in sensitivity to initiating impulse and a worsening of detonation qualities. Slurry explosives, with a reduction in plasticity, show practically no changes in their detonation qualities. They can dry out when not adequately sealed in packing.

Disadvantages of plastic explosives can also include the complex technology of their manufacture, adding to costs.

Akvanites. In contrast to dynamite, the plasticizing base of akvanites No 2 and No 16 is an aqueous solution of potassium nitrate, thickened to a gel-like consistency, in which ammonium nitrate and other constituents are also partially dissolved.

In akvanite 3L, this base is a thickened aqueous solution of ammonium nitrate. The liquid phase in akvanites No 2 and No 16, at normal temperatures, is about 20-25 percent, while in akvanite 3L it is about 45 percent which gives it fluidity. Though the water content in akvanites No 2 and No 16 does not exceed 5-7 percent, still this amount severely reduces the

TABLE 21. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	2 Динамит 62%-ный	3 Акваниты		
		№ 2	16	3Л
Расчетные 4				
5 Кислородный баланс, %	—0,96	0,0	—7,5	—0,47
6 Теплота взрыва, *ккал/кг*:				
7 весовая	1274	1095	1067	935
8 объемная	1850	1600	1410	1590
9 Объем газов, *л/кг*	586	853	—	680
10 Температура взрыва, *град*	4100	3500	—	—
11 **Экспериментальные**				
12 Температура замерзания, *град*.	—19,5	—15—20	—15—20	—15—20
13 Плотность ВВ в патроне, *г/см*³	1,45—1,5	1,45—1,5	1,30—1,35	1,45—1,50
14 Работоспособность, *см*³	380—420	380—400	320—340	470—520*
15 Бризантность при плотности 1,5 *г/см*³, *мм*	18—22	20—22	18—20	18—20*
16 Обжатие свинцового цилиндра зарядом в стальном кольце, *мм*	—	30—33	27—30	17 Полное разрушение
18 Передача детонации (*см*) между патронами диаметром *мм*:				
28	5—10	—	—	—
32	8—15	—	—	—
36	12—20	3—5	3—5	—
19 45	20—28	4—8	4—6	—
Передача детонации (*см*) после выдержки в воде в течение 1 *ч* патронов диаметром, *мм*:				
32	8—15	—	—	—
36	12—20	3—4	1—2	—
20 45	20—28	4—8	3—4	—
21 Скорость детонации, *км/сек*	5,5—6,8	5,8—6,3	5,0—5,4	5,0—5,5
Критический диаметр, *мм*:				
22 открытого заряда	1—20	20—25	28—30	40—45
23 в прочной оболочке	—	10—12	20—22	22—25
24 Чувствительность к удару, %	100	12—40**	0	0
25 Нижний предел чувствительности, *мм*	70***	450	>500	>500
26 Чувствительность к удару на большом копре, %	100	8—12	—	0
27 Чувствительность к трению, *кГ/см*²	650	2900	>3000	>3000
28 Минимальный инициальный импульс, *г* тротила (или КД № 8)	29 КД № 8	29 КД № 8	29 КД № 8	2 10—20

* Initiating a charge weighing 5 g.

** Anhydrous mixtures.

*** For a weight of 2 kg.

KEY [to Table 21]:

1 -- Characteristics
2 -- 62 percent dynamite
3 -- Akvanites
4 -- Calculated
5 -- Oxygen balance
6 -- Heat of explosion, kcal/kg
7 -- gravimetric
8 -- volumetric
9 -- Volume of gases, l/kg
10 -- Temperature of explosion, degrees
11 -- Experimental
12 -- Freezing point, degrees
13 -- Density of explosive in cartridge, g/cm^3
14 -- Efficiency
15 -- Brisance for a density of 1.5 g/cm^3
16 -- Compression of lead cylinder by the charging a steel ring
17 -- Total disintegration
18 -- Transmission of detonation (cm) between cartridges having the following diameters
19 -- Transmission of detonation (cm) after exposure in water for 1 hour of cartridges having the following diameters
20 -- Detonation rate, km/sec
21 -- Critical diameter
22 -- of exposed charge
23 -- in strong shell
24 -- Sensitivity to shock
25 -- Lower limit of sensitivity
26 -- Sensitivity to shock when using a large pile driver
27 -- Sensitivity to friction, kg/cm^2
28 -- Minimum initial impulse, grams of trotyl (or blasting cap No 8)
29 -- Blasting cap No 8

sensitivity to mechanical forces. Therefore the major advantages of akvanites over 62 percent dynamite, which they are not inferior to in density or water-resistance, but are slightly inferior in strength characteristics (Table 21), include very low sensitivity to mechanical forces, safety in handling permitting mechanization of the charging process, absence of toxicity, and relatively low cost. Particularly low sensitivity to mechanical forces distinguishes the akvanites 3L and 16 sensitized with trotyl. They do not produce explosions when tested for shock sensitivity and friction sensitivity by laboratory methods. But in the anhydrous state (after drying out), they do not differ from ordinary ammonites in terms of sensitivity.

High sensitivity in this state is shown by akvanite No 2, whose sensitizer is hexogen. However, in the slurry state it is suitable for mechanized charging with the breakdown (crushing) of cartridges.

Akvanites show reduced sensitivity to initiation by an air shock wave owing to the intense phlegmatizing action of water present in their composition. Therefore, the distance by which a detonation is transmitted between standard-diameter cartridges of akvanites No 2 and No 16 is relatively small.

By its consistency, akvanite 3L is not suitable for cartridge use: the transmission of detonation between its cartridges would be made difficult. It is intended for use in continuous blasthole or drillhole charges; it is recommended that they be initiated with a cartridge of pressed rock-oriented ammonite. Akvanites No 2 and No 16 in the normal state are sensitive to a No 8 blasting cap. They detonate at a high rate also in the solidified and frozen state when their charges are initiated by means of an intermediate detonator. Normally detonating akvanites form toxic gases in mines to no greater extent than other explosives that are permitted in underground work.

To achieve high charging density of blastholes, it is recommended that akvanite No 16 be charged in uncartridged form using a charging device. In the absence of a charging device, its cartridges must be slit and crushed for better filling of the charging cavity. Akvanites No 2 and No 16 are intended for production in standard-diameter cartridges (32-45 mm) for blasthole charges. By customer order, these akvanites can be delivered in uncartridged form, packed in packs or in polyethylene bags; hermetic packing is required, without which they dry and shrivel, as a result of which it may be necessary to knead the cartridges before charging. Akvanite 3L can be produced in fill-type polyethylene containers (canisters or cans) or in thickened polyethylene bags laid in boxes. Akvanite No 2 is intended for driving operations in rock in dry and flooded faces of underground workings. Akvanite No 16 is intended for blasting tough rock with blasthole and drillhole charges. Akvanite 3L is intended mainly for sinking shafts and breaking tough rock with charges placed in descending drillholes and blastholes.

Akvanites are in the commercial testing stage. The approximate wholesale price of 1 ton of akvanite No 2 is 500-550 rubles, for akvanite No 16 -- 380-400 rubles, and for akvanite 3L -- 490 rubles.

62 percent dynamite is an elasticoplastic, high-density mass prepared from a low-density mixture of liquid nitro esters. In addition to the common properties of plastic explosives, it is marked by its virtually unlimited water resistance; its cartridges do not lose their ability to detonate or their strength after prolonged residence in water, including flowing water. This explosive is classified as a nonhygroscopic low-melting explosive. Its melting point is -19.5° C, but owing to the ability of nitro esters to undergo some supercooling, it does not freeze after short-term (not more than 4 hours) residence in air at -30° C, though in these cases its cartridges require heating before being compacted. 62 percent dynamite has high energy characteristics, density, and detonation rate (cf. Table 21). It is used in very small amount in sinking shafts through rock in conditions of continuous flooding. Its key disadvantages include

the following: high sensitivity to mechanical forces, toxicity, inadequate physical stability (exudation and ageing), and also high costs. Exuding and freezing dynamite represents the same danger as pure nitroglycerin. In this condition, when its cartridges are punctured for placement of the blasting cap, or when they undergo fracture or are struck with a metal object, they can explode. This explosive is sensitive to flame. The burning of even a few of its cartridges (for example, in a bonfire) can lead to detonation. Therefore it is classified as a group-II explosive as to storage and handling conditions.

Ageing or freezing dynamite cartridges become hard, insensitive to a No 8 blasting cap, and suffer a sharp loss in detonation rate and other explosive characteristics. In these cases, to achieve a suitable explosion, they must be initiated with an intermediate cartridge detonator of good quality explosive. It can be produced in cartridges having the diameters 28, 32, 36, 40, and 45 mm. The wholesale cost of 1 ton of dynamite in 32-45 mm diameter cartridges is 850 rubles. Well manufactured dynamite, under normal conditions of storage, ages and exudes only slightly (within the limits of the permissible norms) during the specified eight-month storage time.

Granulated water-resistant explosives for underground work

These include zernogranulite 79/21 (hot-mixed) and grammonal A-8 (Tables 22 and 23), intended for noncartridge mechanized charging in underground operations chiefly of wet and flooded blastholes containing nonflowing water.

Zernogranulite 79/21[1] is a granulated, very friable and homogeneous light yellow product, whose nitrate granules are impregnated and partially coated with fused trotyl. In composition and explosive energy, it corresponds to ammonite No 6, differing from it by improved physical characteristics, somewhat reduced sensitivity and high stability. It does not cake when stored, exhibits some water resistance, that is adequate for use in damp and wet faces in which there is no running water[2]. It is readily transported along pneumatic-charging pipelines laid along horizontal and vertical mine workings, for example, when charging from a haulage horizon. It is suitable for hand charging of underground vertical and inclined drillholes by loading explosive into them from the top. It exhibits better detonation characteristics than granulites. It is sensitive to a No 8 blasting cap and to a detonation fuse assembly and detonates reliably in

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[1] The numerator of the fraction denotes the ammonium nitrate content and the denominator -- the trotyl content.

[2] Editor's note. The water resistance of this and other improved or new explosives can be judged from experience in using them under varied conditions.

TABLE 22. STANDARDIZED TECHNICAL INDICATORS

Показатели 1	2 Граммонал А-8	3 Зерногранулит 79/21	
		4 горячего смешения	5 холодного смешения
6 Внешний вид и размер гранул (зерен)	7 Гранулы 1—3 мм серого цвета	8 Гранулы 1—5 мм желтого цвета	9 Смесь гранул селитры и зерен тротила 1—5 мм
10 Влажность, не более %	0,5	0,5	0,8
11 Нерастворимые вещества, не более %	0,5	0,5	0,5
12 Работоспособность, не менее см³	410	360	350
13 Должен полностью детонировать в открытом заряде диаметром, не менее мм	80	80	100
14 Гранулометрический состав (%) — остатков на сите с ячейками размером:			
4 мм, не более 15	5	5	5
0,9 мм, не менее 16	85	95	60
17 Гарантийный срок использования, месяц:			
18 в бумажных мешках	6	6	6
19 в полиэтиленовых	12	12	12

KEY:
1 -- Indicators
2 -- Grammonal
3 -- Zernogranulite
4 -- Hot-mixed
5 -- Cold-mixed
6 -- External appearance and granule (grain) size
7 -- Granules 1-3 mm, gray in color
8 -- Granules 1-3 mm, yellow in color
9 -- Mixture of nitrate granules and trotyl grains 1.5 mm in size
10 -- Moisture content, not more than
11 -- Insoluble substances, not more than
12 -- Efficiency, not less than
13 -- Must detonate completely in an exposed charge with a diameter of not less than
14 -- Granulometric composition (percent) -- of residues on sieve with mesh of the following sizes
15 -- not more than
16 -- not less than
17 -- Guarantee period of use, in months
18 -- in paper bags
19 -- in polyethylene bags

TABLE 23. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Граммонал А-8 2	Зерногранулит 79/21 3	
		горячего смешения 4	холодного смешения 5
Расчетные 6			
Кислородный баланс, % 7	−0,24	+0,02	+0,02
Теплота взрыва, *ккал/кг* 8	1285	1030	1030
Объем газов, *л/кг* 9	860	895	895
Температура взрыва, *град* 10	3350	2960	2960
Полная идеальная работа взрыва, *ккал/кг* 11	1060	850	850
12 **Экспериментальные**			
Влажность, % 13	0,1—0,5	0,1—0,5	0,3—0,6
Насыпная плотность, *г/см³* 14	0,85—0,90	0,85—0,90	0,8—0,85
Работоспособность, *см³* 15	420—440	360—380	360—370
Теплота взрыва, *ккал/кг* 16	1264	967	967
Тротиловый эквивалент по баллистическому маятнику 17	1,1	1,05	1,05
Обжатие свинцового столбика зарядом в стальной оболочке от тротиловой шашки весом 5 *г*, *мм* 18	26—30	22—26	20—25
Скорость детонации, *км/сек* 19	3,8—4,0	3,5—4,2	3,0—3,6
Передача детонации (*см*) между патронами диаметром, *мм*: 20			
60	8—12	10—15	2—3
90	15—18	15—20	5—8
Критическая плотность, *г/см³* 21	1,4—1,45	1,5—1,6	1,5—1,55
Критический диаметр, *мм*: 22			
открытого заряда 23	30—40	25—35	50—60
в прочной оболочке 24	13—15	10—15	15—20
Чувствительность к КД № 8 25	Детонирует 26		Недостаточная 27
Рекомендуемый оптимальный промежуточный детонатор 28	29 200-граммовый патрон аммонита любой марки		
Чувствительность: 30			
к удару, % 31	24—36	12—24	12—24
к трению, *кГ/см²* 32	2200	2450	2500
34 Нижний предел чувствительности к удару, *мм* 33	120—170	180—200	200—220
на большом копре, *мм*	1400	1600	1800
35 Чувствительность к ударной волне — расстояние восприятия детонации через воздух от тротиловой шашки весом 200 *г*, *см*	30—40	35—45	25—30

[KEY on following page]

KEY [to Table 23]:

1 -- Characteristics
2 -- Grammonal A-8
3 -- Zernogranulite 79/21
4 -- hot-mixed
5 -- cold-mixed
6 -- Calculated
7 -- Oxygen balance
8 -- Heat of explosion, kcal/kg
9 -- Volume of gases, l/kg
10 -- Temperature of explosion, degrees
11 -- Total ideal work of explosion, kcal/kg
12 -- Experimental
13 -- Moisture content
14 -- Heaped density, g/cm^3
15 -- Efficiency
16 -- Heat of explosion, kcal/kg
17 -- Trotyl equivalent based on the ballistic pendulum test
18 -- Compression of lead column by a charge in a steel shell, using a trotyl load weighing 5 g
19 -- Rate of detonation, km/sec
20 -- Transmission of detonation (cm) between cartridges having the following diameters
21 -- Critical density, g/cm^3
22 -- Critical diameter
23 -- of exposed charge
24 -- in strong shell
25 -- Sensitivity to blasting cap No 8
26 -- Detonates
27 -- Inadequate
28 -- Recommended optimal intermediate detonator
29 -- 200-gram cartridge of ammonite of any grade
30 -- Sensitivity
31 -- to shock
32 -- to friction, kg/cm^2
33 -- Lower limit of sensitivity to shock
34 -- As above, using a large pile driver
35 -- Sensitivity to shock wave -- distance detonation is effective through air from a trotyl load weighing 200 g

blasthole charges of small diameters (25-30 mm). For a complete assurance of the blast not hanging fire, drillhole and blasthole charges of this explosive are recommended to be initiated with a standard cartridge of any grade of ammonite. When blastholes are charged without cartridges in rocks of moderate and increased toughness, it can replace ammonite No 6-ZhV and other, more expensive cartridged explosives. It can be used for secondary blasting, with blasthole charges, of oversize rock fragments. It is not suitable for external charges.

Hot-mixed zernogranulites, since it is a homogeneous explosive sensitized with trotyl, differs little in its toxic gas content from ammonites. Wetting of no more than 5 percent during pneumatic charging is permitted (when necessary to suppress dust with water), and up to 10-12 percent — in blasting. It is produced loose in paper bags priced at 186 rubles per ton. It is equated with ammonites as to handling conditions. It is permitted for permanent use in open and underground work.

Grammonal A-8 is granulated ammonal with an increased aluminum content (8 percent). Externally, it is a homogeneous friable silvery product with 0.5-2.5 mm granules. It is classified as among the most powerful granulated explosives intended for underground work and is only somewhat inferior in strength to cartridged rock-oriented ammonite and cartridged detonite 10A, but can replace them in noncartridged charging of blastholes and drillholes in tough flooded rock. Flooded blastholes and drillholes, before being charged with grammonal, must be swept with compressed air.

In storage, grammonal does not cake and is readily transported along charging hoses. To eliminate the dust in the pneumatic charging classes of this explosive, in its manufacture it is treated with a small amount of mineral oil, and at the field location it is wetted up to 2-3 percent in the pneumatic charging of blastholes, and up to 4-5 percent — in charging drillholes. It is sensitive to a No 8 blasting cap and detonating fuses. It is only slightly subject to wetting, has a satisfactory gas characteristic in normal blasting conditions, and detonates when severely wet (up to moisture content of 10-12 percent). It is intended for blasting tough and extremely tough rock in driving and clearing operations in flooded conditions. For total assurance that the detonation will not hang fire and to provide normal gas characteristics, its blasthole and drillhole charges (especially when wet) must be initiated with a cartridge of good quality ammonite.

In the pneumatic charging of grammonal and zernogranulite, safety measures as to static electricity specified by the appropriate instructions and regulations governing operations must be strictly adhered to. Grammonal is produced loose in paper bags. It is classified as a group-II explosive in terms of handling conditions. The wholesale price of 1 ton is 236 rubles.

Granulated nonwater-resistant explosives for open-pit and underground work

These explosives include zernogranulite 79/21 (cold-mixed) and the granulites AS-8, AS-4, S-2, and M, plant-manufactured, and also granulite prepared by users in the field.

Cold-mixed zernogranulite 79/21 (cf. Table 23) is a friable mechanical mixture of granulated nitrate with flaked trotyl, taken in a stoichiometric ratio during pneumatic charging, this explosive raises dust and when charged at a high rate is capable of segregating owing to the pulverization of trotyl flakes in the stream. Therefore, when blastholes undergo pneumatic charging in underground work, it is recommended that to the composition of this explosive be added up to 3 percent water, and when drillholes are charged -- up to 5 percent water. Wetting of zernogranulite, in addition, prevents electrification and increases charging density. When pneumatic charges are used in open-pit work, it is desirable to have dust-trapping devices for charging of dry zernogranulites. Charging by heaping into drillholes is not accompanied by much dusting. This zernogranulite permits damp blastholes and wet drillholes to be charged if they have a slight water content. In normal initiation, the gas characteristic of the detonation products is satisfactory. This explosive is not sensitive enough to detonating fuse and No 8 blasting caps; it requires a small intermediate detonator -- a standard ammonite cartridge. It stably detonates in blastholes when dry or wet (up to certain limits). The optimal limits of blasthole charging density is 1.0-1.2 g/cm^3, and the optimal limits of drillhole charging density is 1.0-1.3 g/cm^3. It is intended mainly for open-pit work. It can be recommended for underground work only for chamber charges and for charging of downward-directed drillholes by heaping. It is not recommended for secondary blasting with exterior charges. In terms of handling conditions, it is equated to ordinary ammonites. It is supplied in loose form in paper bags at the rate of 167 rubles per ton. When mixer-charging machines are available, it can be prepared on location.

Granulites. For blasting operations in rock of various toughness levels in open-pit and underground work, granulites AS-8, AS-4, S-2, and M are produced, differing by strength and cost (Tables 24-25).

Granulites AS-8 and AS-4 are outwardly homogeneous and granulated silver-gray explosives, whose granules are spherical in shape and 1.0-2.5 mm in size, uniformly coated with an oil film, and powdered as to formulation composition (cf. Table 24), they are metallized dynammons; here the finely disperse aluminum deposited on the granule surfaces acts as a sensitizer, by giving off large amounts of heat in combustion. The aluminum also prevents caking and promotes friability of the explosive. The mineral oil included in their composition bonds the aluminum particles in the nitrate granules, which means that the explosive raises little dust.

According to the instructions on using granulites in underground work, for complete prevention of dusting during pneumatic charging, eliminating the possibility of electrification, and increasing the charging density and reducing explosive losses due to entrainment, the explosives are wetted during charging of blastholes and drillholes using charging units equipped with water sprayers.

Granulite S-2 is a three-base mixture, in which the powdering component is fine-disperse, porous wood meal, partially absorbing oil and

TABLE 24. FORMULATION COMPOSITION AND STANDARDIZED TECHNICAL INDICATORS

Компоненты и показатели 1	Гранулиты 2				Игданит 6
	АС-8 3	АС-4 4	С-2 5	М	
7 Состав, %					
Селитра аммиачная гранулированная 8	89±1,5	91,8±1,5	92,8±1,5	94,5±1,0*	94,5+94,0
Пудра алюминиевая 9	8±1,0	4,0±0,5	—	—	—
Мука древесная 10	—	—	3,0±0,5	—	—
Масло минеральное 11	3±0,5	4,2±0,5	4,2±0,5	5,5±0,5	—
Дизельное топливо 12	—	—	—	—	5,5—6,0
Технические показатели 13					
Влажность, не более % 14	0,8	0,7	0,8	0,7	24 Технические показатели не нормированы 25 Изготовляется на месте применения
Нерастворимые вещества, не более % 15	0,5	0,5	—	—	
Должен детонировать* от промежуточного детонатора в открытом заряде диаметром, не менее, мм 16	120	120	150	—	
Работоспособность**, не менее $см^3$ 17	400	400	300	300	
Гранулометрический состав (%)—остаток на сите с ячейками размером 18					
4,0 мм, не более 19	5	5	5	5	
0,9 мм, не менее 20	70	65	65	65	
Гарантийный срок использования, месяц 21					
в бумажных мешках, покрытых полиэтиленом 22	6	6	6	4	
в полиэтиленовых мешках 23	12	12	12	6	

* Porous. ** Test is optional.

KEY:
1 -- Constituents and indicators
2 -- Granulites
3 -- AS-8
4 -- AS-4
5 -- S-2
6 -- Igdanite
7 -- Composition
8 -- Granulated ammonium nitrate
9 -- Aluminum powder
10 -- Wood meal
11 -- Mineral oil
12 -- Diesel oil
13 -- Technical indicators
14 -- Moisture content, not more than
15 -- Insolubles, not more than, percent
16 -- Must detonate from an intermediate detonator in an open charge with a diameter not less than, mm
17 -- Efficiency **, not less than, cm^3
18 -- Granulometric composition (percent) -- residue on sieve with mesh of the following sizes:
19 -- not more than
20 -- not less than
21 -- Guarantee period of use, months
22 -- in paper bags coated with polyethylene
23 -- in polyethylene bags
24 -- Technical indicators are not standardized
25 -- Is prepared at the site of use

TABLE 25. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Гранулиты 2				Игданит 6
	АС-8 3	АС-4 4	С-2 5	М*	
Расчетные 7					
Кислородный баланс, % 8	+0,34	+0,41	+0,06	+0,14	+0,12—1,65**
Теплота взрыва, *ккал/кг* 9	1242	1060	917	920	900—920
Объем газов, *л/кг* 10	847	907	935	980	980—990
Полная идеальная работа взрыва, *ккал/кг* 11	955	870	755	755	755
Экспериментальные 12					
Влажность, % 13	0,4—0,8	0,4—0,7	0,4—0,8	0,3—0,7	0,8—1,2
Насыпная плотность, *г/см*^{3} 14	0,87—0,92	0,8—0,85	0,8—0,85	0,9	0,8—0,9
Работоспособность, *см*^{3} 15	410—430	390—410	320—330	320—330	320—330
Тротиловый эквивалент 16	1,08	1,05	1,03	1,04	1,04
Теплота взрыва, *ккал/кг* 17	1260	1128	886	904	904
Обжатие свинцового столбика взрывом заряда в стальной оболочке от тротиловой шашки весом 5 *г, мм* 18	24—28	22—26	15—20	18—22	15—20
Скорость детонации, *км/сек* 19	3,0—3,6	2,6—3,2	2,4—3,2	2,5—3,6	2,2—2,7
Критическая плотность, *г/см*^{3} 20	1,3—1,4	1,3—1,4	1,3—1,4	1,25—1,3	1,25—1,3
Критический диаметр, *мм*: 21					
открытого заряда 22	80—100	100—120	120—150	70—100	120—160
в прочной оболочке (шпуре) 23	18—25	20—28	20—25	20—25	25—30
Чувствительность к КД № 8 и ДШ 24	25 В открытом заряде, скважине и шпуре недостаточно чувствительны, требуют промежуточного детонатора				
Минимальный вес промежуточного детонатора, *г* тротила 26	5—10	5—10	20—30	10—20	20—30
	27 Диаметр заряда гранулированного ВВ				
Чувствительность к ударной волне—расстояние восприятия детонации через воздух от тротиловой шашки весом 200 *г, см* 28	120 5—10	120 2—4	150 0—2	150 2—4	150 0—2
Чувствительность: ~~28~~ 29					
29 к удару, % 30	8—12	4—12	0—4	0	0
к трению с примесью песка, *кГ/см*^{2} 31	>3000	>3000	>3000	>3000	>3000
Нижний предел чувствительности, *мм*: 32					
к удару 30	420	450	500	500	—
к удару на большом копре (навеска в бумажном стаканчике) 33	>2000	>2000	>2000	>2000	—
Рекомендуемый оптимальный промежуточный детонатор 34	35 Шашка прессованного тротила или тетрила весом 150—200 *г*; патрон аммонита весом 200—400 *г*				

* For porous nitrate.

** Depending on the diesel fuel content

[KEY on following page]

KEY [to Table 25]:
1 -- Characteristics
2 -- Granulites
3 -- AS-8
4 -- AS-4
5 -- S-2
6 -- Igdanite
7 -- Calculated
8 -- Oxygen balance
9 -- Heat of explosion, kcal/kg
10 -- Volume of gas, l/kg
11 -- Total ideal work of explosion, kcal/kg
12 -- Experimental
13 -- Moisture content
14 -- Heaped density, g/cm^3
15 -- Efficiency, cm^3
16 -- Trotyl equivalent
17 -- Heat of explosion, kcal/kg
18 -- Compression of lead column by the blast of a charge in a steel shell from a trotyl weighing 5 grams, mm
19 -- Detonation rate, km/sec
20 -- Critical density, g/cm^3
21 -- Critical diameter, mm
22 -- of open charge
23 -- in strong shell (blasthole)
24 -- Sensitivity to No 8 blasting cap and detonating fuse
25 -- Not sensitive enough in open charge, drillhole, and blasthole, and requires intermediate detonator
26 -- Minimum weight of intermediate detonator, grams of trotyl
27 -- Diameter of charge of granulated explosive
28 -- Sensitivity to shock waves -- distance detonation is received through the air from a trotyl load weighing 200 grams, cm
29 -- Sensitivity
30 -- to shock
31 -- to friction with sand impurity, kg/cm^2
32 -- Lower limit of sensitivity
33 -- to shock using a large pile driver (weighed sample a small paper beaker)
34 -- Recommended optimal intermediate detonator
35 -- Charge of pressed trotyl or tetryl weighing 150-200 grams; ammonite cartridge weighing 200-400 grams

preventing its streaming. It is prepared with ordinary nonporous granulated grade B nitrate.

Granulite M is a double-base mixture of porous granulated nitrate and mineral oil. The good absorbability of the porous nitrate granules accounts for the stability of granulite during the guarantee period of storage.

Important distinguishing features of these granulites are the following: the absence of a caking tendency, good friability, low dusting when the appropriate pneumatic charging conditions are observed, and low sensitivity to mechanical forces and the initial impulse (cf. Table 25). They are in effect very slightly sensitive to shock and friction; in the absence of a strong shell, they detonate stably only in large-diameter charges; they are not adequately sensitive to a No 8 blasting cap or detonating fuse; they are reliably excited to detonation only with an intermediate detonator; here a single cartridge of good quality ammonite weighing 200 g is adequate as the intermediate detonator for blasthole charges of dry explosives, while for drillhole charges a large-diameter (weighing 1.5-3.0 kg) of ammonite No 6-ZhV must be used as the intermediate detonator. Mechanized use of granulites is quite safe when general safety rules, operational procedures, and instructions on automatic charging are observed.

Chamber charges of granulites are recommended to be initiated from several points. As for all dynammons, granulites are sensitive to wetting and when the moisture content is more than 1.5-2.0 percent they require a more intense impulse. Granulites containing aluminum show a more stable gas characteristic when wet.

A major disadvantage of all granulites is their lack of water resistance. Granulite AS-8 is the most powerful explosive in the granulite group. It is intended for blasting tough and extra tough rock in dry or wet (without water actually presents) faces, with drillhole or blasthole charges. It is sensitive to an air shock wave and has a smaller critical detonation diameter. The optimal limits of charging density in blastholes are 1.1-1.25 g/cm^3, and in drillholes -- 1.1-1.30 g/cm^3.

AS-4 granulite is intended for pneumatic charging of dry and slightly wet blastholes and drillholes in underground work. It is recommended for drillhole and chamber charges in open work. The optimal limits of charging density in blastholes are 1.0-1.20 g/cm^3, and 1.1-1.25 g/cm^3 -- in drillholes. It can be used in combination charges with a water-resistant explosive when charging flooded drillholes in open-pit operations.

The granulites S-2 and M are suitable for blasting moderate-tough rock in dry faces; when blastholes undergo noncartridge charging in these conditions, they can replace more powerful ammonites (No 6-ZhV and No 7-ZhV). They can be used in wet drillholes to charge their dry sections. The optimal limits of the charging density in blastholes are 1.0-1.2 g/cm^3 and in drillholes -- 1.1-1.25 g/cm^3.

The detonation characteristics of granulite M depend heavily on the porosity of the nitrate granules; when prepared with porous nitrate, it has greater sensitivity to detonation, smaller critical diameter, higher values of the optimal blasthole charging density (1.15-1.25 g/cm^3), and detonates at a higher rate than the same granulite prepared with ordinary grade B nitrate, though they are practically the same in explosive strength characteristics.

These granulites are unsuitable for secondary blasting with external and small blasthole charges. In terms of handling conditions,the granulites AS-8, AS-4, S-2, and M are classified as group-II explosives. They are produced in loose form in paper bags coated internally with polyethylene; the cost of 1 ton of granulite AS-8 is 185 rubles; 1 ton of granulite AS-4 costs 150 rubles, 1 ton of granulite S-2 -- 116 rubles; and 1 ton of granulite M -- 112 rubles.

Igdanite is an explosive mixture of ordinary granulated ammonium nitrate with diesel fuel (cf. Table 26); it is prepared in the field; it is intended for use in open-pit and underground work and is marked by low cost compared with plant-manufacture explosive. Abroad, these mixtures are prepared mainly on the basis of a specially produced porous granulated nitrate, exhibiting higher absorbing and retaining ability compared to liquid petroleum products.

Mixtures prepared with porous nitrate are marked by the requisite uniformity and stability of composition (prolonged storage is allowed), in most cases are sensitive to the blasting cap, and detonate at an increased rate (2.8-3.5 km/sec).

In the USSR, in mining enterprises igdanite is made with granulated nitrate (grade B according to GOST 12-65 and others); the production of a special grade of porous nitrate for igdanite and granulites is being developed. In some cases, grade ZhV granulated water-resistant nitrate is used in making igdanites, marked by superior retaining ability compared with diesel fuel.

To prepare an oxygen-balance explosive mixture, igdanite used in underground work contains 5.5 percent diesel fuel; for open-pit work, the proportion of fuel is raised to 6 percent on the basis of its partial loss from drillholes due to vaporization and absorption by the surrounding medium. For underground work, igdanite requires straight proportioning and more careful blending of the constituents. Its detonatability, just as that of granulites, depends heavily on nitrate granule (grain) size and porosity. Igdanite prepared with porous nitrate in blasthole charges detonates at an increased rate (3.0-3.5 km/sec). Grinding and compaction of igdanite, just as for other granulated explosives during pneumatic charging, increases the detonation rate of blasthole and drillhole charges and promotes their retention in ascending drillholes. Properly prepared igdanite using granulated nitrate with low moisture content (0.4-0.8 percent) exhibits good friability, does not form plugs, and does not dust in pneumatic charging. When using these explosives in poorly ventilated underground workings, personnel must be protected against breathing vapor and the mistlike droplets of diesel fuel formed during charging.

Igdanite is not water-resistant and is suitable only for dry faces and for charging the dry sections of drillholes when blasting with combination charges. It is not suitable for secondary blasting using external charges.

Its sensitivity and detonatability, just as for granulites, decrease with increasing wetness. When the moisture content is up to 8-10 percent, it completely loses its ability to be detonated in blastholes and detonates unstably in drillholes. With increasing wetness and reduction in detonatability, the content of nitrogen oxides in the explosion products can rise sharply. For underground conditions, in blasthole work it is recommended that igdanite be prepared with dry (with moisture content not more than 0.5 percent), preferably porous, nitrate. A small intermediate detonator is required for igdanite with a moisture content of 0.5-1.5 percent; for blasthole charges, an ammonite cartridge is sufficient; while for drillhole charges 0.5-1.0 kg of this explosive, or a 150-200 gram trotyl charge is adequate.

The optimal density for charging blastholes with igdanite is taken as 1.0-1.2 g/cm^3, and for charging drillholes -- 1.15-1.25 g/cm^3. At densities above 1.25 g/cm^3, the detonation of charges can die out. Igdanite is classified as a moderately powerful explosive and is intended for blasting moderate-tough rock. Noncartridge blasting with increased density of well-prepared igdanite makes it possible to effectively carry out blasting breakage of rock of even higher toughness in dry faces.

The use of igdanite is economically advantageous. When prepared with machines in the field, igdanite costs 80-95 rubles per ton. When it is used, there are no longer transportation and storage costs for supplying the explosives from plants and storerooms are not required. The use of this inexpensive explosive in large amounts has been held off by the lack of good quality granulated nitrate (with low moisture content, good friability, and good retaining capacity), and also by a shortage of mechanized facilities for preparing and charging it.

Igdanite is classified as a group-II explosive in terms of handling conditions.

11. Safety Explosives for Rock Faces That Are Dangerous as to Methane, and Special-Purpose Safety Explosives (Class III)

Safety ammonium-nitrate grade-III explosives, according to the classification adopted (cf. Table 9) are divided into three groups.

The first group is made up of safety explosives, whose field of use is limited to blasting country rock in mines that are dangerous as to gas and dust, given the condition that in the blasted rock faces there must be no coal dust and no more than 1 percent methane can accumulate. For blasting rock, fairly strong explosives are required; therefore, rock-oriented safety explosives contain small amounts of flame inhibitor and increased amounts of sensitizers and other active constituents, as a result of which they exhibit reduced anti-firedamp capacity.

TABLE 26. FORMULATION COMPOSITION AND STANDARDIZED TECHNICAL INDICATORS

Компоненты и показатели 1	Победит ВП-4 2	Аммониты 3	
		серный № 1 ЖВ 4	нефтяной № 3 ЖВ 5
Состав, % 6			
Труднозамерзающая смесь нитроэфиров 7	9,0±0,7	5,0±0,5	9,0±0,7
Селитра аммиачная водоустойчивая 8	65,5±1,5	52,0±2,0	52,5±1,5
Тротил 9	12,0±1,0	11,5±1,0	7,0±0,5
Пламегаситель 10	12,0±1,0	30,0±1,5	30,0±2,0
Древесная мука 11	1,5±0,5	1,5±0,5	—
Коллодионный хлопок (сверх 100%) 12	0,13—0,15	—	0,13—0,15
Стеарат кальция 13	—	—	1,5±0,3
Сода (сверх 100%) 14	0,1—0,3	0,2—0,3	0,2—0,3
Технические показатели 15			
Влажность, не более % 16	0,4	0,5	0,5
Химическая стойкость по йодокрахмальной пробе, не менее *мин* 17	10	10	10
Диаметр патронов, *мм* 18	36	32*	32*
Плотность патронов, *г/см³* 27	1,1—1,3	0,95—1,05	1,1—1,3
Работоспособность, не менее *см³* 19	320	200	230
Бризантность, не менее *мм* 20	14	11	12
Передача детонации, (*см*) между патронами диаметром: 21			
32 *мм*, не менее 22	—	5	3
36 *мм*, не менее 22	6	—	—
Передача детонации после выдержки в течение 1 ч патронов в воде в вертикальном положении, не менее, *см* 23	5	3**	2
Предельный заряд при подрыве в мортире в опытном штреке, *г*: 24			
по метану, не менее 25	600	—	400***
по угольной (серной) пыли, не менее 26	700	(400)	—

* Can also be produced in 36 mm diameter cartridges.

** Cartridges are exposed in water in the horizontal position.

*** For gasoline vapor in a mixture with methane, the standard is 350 grams.

[KEY on following page]

KEY [to Table 26]:
1 -- Constituents and indicators
2 -- Pobedite VP-4
3 -- Ammonites
4 -- Grade No 1 ZhV
5 -- petroleum- oriented No 3 ZhV
6 -- Composition
7 -- Low-melting mixture of nitro esters
8 -- Water-resistant ammonium nitrate
9 -- Trotyl
10 -- Flame inhibitor
11 -- Wood meal
12 -- Colloidal cotton (upward of 100 percent)
13 -- Calcium stearate
14 -- Soda (upwards of 100 percent)
15 -- Technical indicators
16 -- Moisture content, not more than
17 -- Chemical resistance based on the iodine-starch test, not less than, minutes
18 -- Cartridge diameter
19 -- Efficiency, not less than, cm^3
20 -- Brisance, not less than
21 -- Transmission of detonation (cm) between cartridges having the following diameters
22 -- not less than
23 -- Transmission of detonation after cartridges have been exposed for 1 hour in water in the vertical position, not less than, cm
24 -- Limiting charge for blasting in experimental drift, grams
25 -- With respect to methane, not less than
26 -- With respect to coal (sulfur) dust, not less than
27 -- Cartridge density, g/cm^3

This group includes pobedite VP-4 and the ammonites AP-4ZhV and AP-5ZhV. They are not permitted for blasting coal without being used without the explosives. In combination charges with less powerful, but safer explosives taken in a specific ratio, they can be used -- with permission of the mine superintendent -- in blasting tough coals in coal and mixed faces of mines that are classified in category I and II, with additional precautionary measures observed.

The second group includes grade ammonite No 1ZhV prepared for sulfur mines that are dangerous as to combustion and explosion of sulfur dust. Here the flame-inhibitor is ammonium chloride, marked by high heat-absorbing ability, as the result for which the temperature of the detonation products ejected into the explosive-dangerous medium at the time the explosive is blasted is sharply reduced.

TABLE 27. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Победит ВП-4 2	Аммониты 3	
		серный 4 № 1ЖВ	нефтяной 5 № 3ЖВ
Расчетные 6			
Кислородный баланс, % 7	−0,20	−1,4	−0,65
Теплота взрыва, *ккал/кг* 8	923	483	744
Объем газов, *л/кг* 9	780	878	635
Температура взрыва, *град* 10	2565	1570	2090
Экспериментальные 11			
Рабочая плотность патронов, *г/см*^{3} 12	1,13—1,20	0,98—1,03	1,12—1,26
Работоспособность, *г/см*^{3} 13	320—340	200—220	230—240
Бризантность при минимально допустимой плотности патрона, *мм* 14	15—18	10—12	13—14
Передача детонации (*см*) между патронами диаметром: 15			
32 *мм*	10—16	7—10	6—12
36 *мм*	15—25	—	—
Передача детонации (*см*) после выдержки патронов в воде в течение 1 *ч* 16	10—20	3—5*	2—5
17 Скорость детонации, *км/сек*	3,8—4,6	2,5—3,0	2,8—3,2
18 Критический диаметр, *мм*	5—7	8—10	6—8
19 Чувствительность к удару, %	40—60	36—40	36—56
Чувствительность к трению, *кГ/см*^{2} 20	1650	1535	1535
Критическое давление горения, *кГ/см*^{2} 21	8—10	—	—
Длина участка детонации в условиях канального эффекта, *м* 22	0,75**	—	—

* Cartridges are exposed in the horizontal position.

** Testing in a steel tube with a clearance of 10-15 mm.

KEY:
1 -- Characteristics
2 -- Pobedite VP-4
3 -- Ammonites
4 -- sulfur No 1 ZhV
5 -- petroleum-oriented No 3 ZhV
6 -- Calculated
7 -- Oxygen balance
8 -- Heat of explosion, kcal/kg
9 -- Volume of gases, l/kg
10 -- Explosion temperature, degrees
11 -- Experimental
12 -- Working density of cartridges, g/cm^3
[KEY continued on following page]

KEY [to Table 27, continuation]:
13 -- Efficiency, g/cm^3
14 -- Brisance for minimum allowable cartridge density, mm
15 -- Transmission of detonation (cm) between cartridges having the following diameters
16 -- Transmission of detonation (cm) after cartridges have been exposed for 1 hour in water
17 -- Detonation rate, km/sec
18 -- Critical diameter, mm
19 -- Sensitivity to shock
20 -- Sensitivity to friction, kg/cm^2
21 -- Critical pressure of combustion, kg/cm^2
22 -- Length of detonation section in channel-effect conditions

The third group includes the petroleum-oriented ammonite No 3ZhV, intended for mines that are dangerous with respect to vapors of petroleum hydrocarbons, characterized by broader limits of explosive-dangerous concentrations with air and by more ready combustibility than methane and coal dust. To ensure the necessary safety in blasting operations in these conditions, a large amount of an effective flame inhibitor is added to the petroleum-oriented ammonites -- potassium chloride. It is also allowed to use combination charges of cartridges of the ammonite AP-5ZhV and uglenites in mines where petroleum gases are liberated.

Explosives for working in rock faces

Pobedite VP-4 is a powdery, nondusting water-resistant explosive that is greasy to the touch, sensitized with liquid nitro esters; as a result of which, in cartridges it has increased density and exhibits high detonatability (Tables 26 and 27). Detonation is transmitted by greater distances between cartridges. Charges detonate stably (without dying out and burning up) for blasthole densities up to 1.65-1.7 g/cm^3.

Pobedite is suitable for faces of any degree of flooding and detonates without fail also when wet. The use of this explosive in flooded faces is more reliable and effective than ordinary water-resistant ammonites containing trotyl sensitizer, though the degree of water resistance of the latter may be even higher. The composition and properties of pobedite are quite stable for the entire guarantee period of fitness. It is suitable for use in various climatic conditions.

In terms of strength characteristics, VP-4 pobedite (Table 27) surpasses all now-used safety explosives and approaches in this respect nonsafety ammonite No 6-ZhV (cf. Table 17). The use of pobedite is allowed in combination charges containing low-strength uglenites for breakage with blasthole charges and shock blasting.

TABLE 28. FORMULATION COMPOSITION AND STANDARDIZED TECHNICAL INDICATORS

Компоненты и показатели 1	Аммониты 2		Мипорит 4	Аммониты 5	
	ПЖВ-20 3	Т-19		АП-4ЖВ 6	АП-5ЖВ 7
Состав, % 8					
Селитра аммиачная водоустойчивая фуксинированная* 9	64±1,5	61±1,5	65±1,5	68±1,5	70±1,5
Тротил 10	16±1,0	19±1,0	15±1,0	17±1,0	18±1,0
Пламегаситель 11	20±1,0	20±1,0	18±1,0	15±1,0	12±1,0
Мипора 12	—	—	2±0,3	—	—
Технические показатели 13					
Влажность ВВ, не более % 14	0,2	0,2	0,4	0,2	0,2
Плотность патронов, г/см^3 15	1,05—1,2	1,05—1,2	0,85—1,0	1,00—1,15	1,0—1,15
Работоспособность, не менее см^3 16	265	265	265	285	320
Бризантность при плотности 1 г/см^3, не менее мм 17	13	14	12	13	14
Передача детонации между патронами, не менее см 18	5	5	4	5	5
Передача детонации (см) после часовой выдержки патронов в воде в течение 1 ч 19					
вертикально, не менее 20	2	2	—	2	2
горизонтально, не менее 21	—	—	2	—	—
Предельный заряд (г) при подрыве в мортире в опытном штреке: 22					
по метану, не менее 23	600	600	600	600	600
по угольной пыли, не менее 24	700	700	700	700	700

* Nonfucsinated modification is also permitted.

KEY:
1 -- Constituents and indicators
2 -- Ammonites
3 -- PZhV-20
4 -- Miporite
5 -- Ammonites
6 -- AP-4ZhV
7 -- AP-5ZhV
8 -- Composition
9 -- Water-resistant, fucsinated ammonium nitrate*
10 -- Trotyl
11 -- Flame inhibitor
12 -- Mipora
13 -- Technical indicators
14 -- Moisture content of explosives, not more than
15 -- Cartridge density, g/cm^3
16 -- Efficiency, not less than, cm^3
17 -- Brisance at a density of 1 g/cm^3, not less than
18 -- Transmission of detonation between cartridges, not less than, cm
19 -- Transmission of detonation (cm) after 1-hour exposure of cartridges in water
20 -- vertically, not less than
21 -- horizontally, not less than
22 -- Limiting charge (grams) for blasting in a mortar in an experimental drift
23 -- with respect to methane, not less than
24 -- with respect to coal dust, not less than

TABLE 29. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Аммониты 2		Минорит 4	Аммониты 5	
	ПЖВ-20 3	Т-19		АП-4ЖВ 6	АП-5ЖВ 7
Расчетные 8					
Кислородный баланс, % 9	+0,32	−2,47	−0,15	+0,34	−0,02
Теплота взрыва, *ккал/кг* 10	813	814	836	864	907
Объем газов, *л/кг* 11	717	724	745	761	787
Температура взрыва, *град* 12	2220	2230	2280	2500	2520
Экспериментальные 13					
Рабочая плотность патронов, *г/см*^{3} 14	1,1—1,18	1,1—1,2	0,85—0,95	1,05—1,12	1,05—1,12
Работоспособность, *см*^{3} 15	265—280	270—280	265—280	285—300	320—330
Тротиловый эквивалент 16	0,68	0,7	0,67	0,71	0,74
Бризантность при минимально допустимой плотности патрона, *мм* 17	14—16	15—17	13—15,5	14,5—16,8	15—17
Передача детонации между патронами, *см* 18	7—10	8—12*	6—9	7--10	8—10
Передача детонации после выдержки патронов в воде в течение 1 *ч*, *см* 19	4—7	4—8*	2—4**	4—6	4—7
Скорость детонации, *км/сек* 20	3,5—4,0	3,6—4,3	3,5—3,8	3,6—4,2	3,6—4,6
Критический диаметр детонации (*мм*) при плотности: 21					
1,1 *г/см*^{3} 22	12—14	10—12	11—13	11—12	10—12
1,6 *г/см*^{3} 22	26—28	17—19	22—25	23—25	20—24
Критическая плотность детонации в шпурах, *г/см*^{3} 23	1,45—1,55	1,65+1,7	1,55—1,65	1,40--1,5	1,45--1,6
Чувствительность к удару, % 24	12—24	12—24	12—24	16—28	24—32
Чувствительность к трению, *кг/см*^{2} 25	1740—2250	2000—2300	2300—2700	2200—2500	1930—2200
Водоустойчивость на гидроприборе, *см вод. ст.* 26	60—80	60—90	30—40	50—70	70—80
Предохранительные свойства 27	28 Выдерживают испытание в опытном штреке по газу и пыли по методике ГОСТ 7140—54				

* Based on the three-cartridge method of testing, 4-8 cm between dry cartridges, and 2-4 cm between wet.

** After soaking in the horizontal position.

[KEY on following page]

KEY [to Table 29]:
1 -- Characteristics
2 -- Ammonites
3 -- PZhV-20
4 -- Miporite
5 -- Ammonites
6 -- AP-4ZhV
7 -- AP-5ZhV
8 -- Calculated
9 -- Oxygen balance
10 -- Heat of explosion, kcal/kg
11 -- Volume of gases, l/kg
12 -- Temperature of explosion, degrees
13 -- Experimental
14 -- Working density of cartridges, g/cm^3
15 -- Efficiency, cm^3
16 -- Trotyl equivalent
17 -- Brisance for minimum allowable cartridge density, mm
18 -- Transmission of detonation between cartridges, cm
19 -- Transmission of detonation after cartridges have been exposed in water for 1 hour, cm
20 -- Detonation rate, km/sec
21 -- Critical diameter of detonation (mm) for the following densities
22 -- g/cm^3
23 -- Critical density of detonation in blastholes, g/cm^3
24 -- Sensitivity to shock
25 -- Sensitivity to friction, kg/cm^2
26 -- Water resistance using a hydraulic instrument, cm H_2O
27 -- Safety properties
28 -- Passes a test in an experimental drift for gas and dust, based on the method given in GOST 7140-54

Disadvantages of pobedite include toxicity, increased sensitivity to mechanical forces, and high cost.

Pobedite is produced in 36 mm diameter cartridges weighing 250 or 300 g in hermetic polyethylene packing. By customer order, it can be produced in 32 mm diameter cartridges weighing less. The wholesale price of 1 ton is 394 rubles. It is classified as a group-II explosive, but requires more cautious handling than ammonites. In view of the fact that nitro esters included in its composition freeze at low temperatures, it is recommended that pobedite cartridges (after they have been at -20° C for more than 2 hours) be kept in a room at a temperature not below 10° C.

The guarantee period of use of pobedite is 4 months, and for users in the Far North -- 12 months. It is permitted for permanent use in clean-rock dry and flooded faces in preparatory working in mines and coal mines of all categories of gas or dust danger. When pobedite is used, measures precluding coal dust entering the face from other workings or excavated strata must be adopted. In the event that more than 1 percent of methane appears in a face, before blasting pobedite charges, water-sprayed curtains must be used.

Ammonites AP-4ZhV and AP-5ZhV are fine-disperse, low-caking water-resistant explosives. The first of these has potassium chloride as the flame inhibitor, and in the second -- sodium chloride (Table 28). The second has higher indicators of efficiency and brisance (Table 29). In water resistance, sensitivity to mechanical forces, and critical conditions of detonation, these explosives differ little from nonsafety ammonites sensitized with trotyl. They are inferior in strength to pobedite. The guarantee period of their use is 12 months when delivered to the Far North, and 4 months -- when delivered to other parts of the country. They are permitted for permanent use in dry and flooded rock faces of mines and shafts of all categories of gas or dust hazard, assuming that the same blasting conditions are observed as in the use of pobedite VP-4. They are produced in 36 mm diameter cartridges weighing 250 or 300 g, with a hermetic polyethylene packing. The wholesale price of 1 ton of ammonite AP-4ZhV is 313 rubles, while 1 ton of the ammonite AP-5ZhV costs 312 rubles in polyethylene packing. The surcharge for fucsination of the explosives is 10 rubles.

Explosives for sulfur mines and mines dangerous with respect to petroleum vapor

Sulfur and petroleum-oriented ammonites are nondusting, poorly friable powdered explosives, greasy to the touch and sensitized with nitro esters. The first of these exhibits less water resistance, less ability to be consolidated and less caking owing to the presence in its composition of wood meal and the loosening ability of ammonium chloride.

Cartridges of sulfur and petroleum-oriented ammonites exhibit good detonatability. These explosives are permitted for permanent use. They are produced in cartridges 32 mm in diameter and weighing 200-250 grams. The guarantee period of use is 6 months. The wholesale cost of 1 ton of sulfur ammonite is 445 rubles, while 1 ton of petroleum-oriented ammonite costs 457 rubles. In view of the high cost and low strength, these explosives find limited use.

12. Safety Explosives for Coal and Mixed Faces of Mines That Are Gas or Dust Hazardous (Class IV)

Safety ammonium nitrate explosives of class IV are the most widespread of the safety explosives. They are intended for preparatory and cleaning operations in coal faces (with or without rock interlayers) for grouped short-delay blasting.

TABLE 30. COMPARATIVE EXPERIMENTAL DATA CHARACTERIZING THE DETONATABILITY OF EXPLOSIVES

Марка ВВ 1	Показатели 2	Плотность патронов, г/см³ 3					
		1,1	1,2	1,4	1,5	1,6	1,7
Аммонит Т-19 4	Бризантность, мм 7	16,8	18,0	17,1	15,3	13,8	12,0
Аммонит ПЖВ-20 5		16,3	17,7	14,8	6,4	2,8	—
Победит ВП-4 6		14,6	15,3	14,2	14,3	13,7	13,2
Аммонит Т-19 4	Скорость детонации в стальной трубе диаметром 40 мм, км/сек 8	4,3	4,8	5,5	5,7	5,1	4,8
Аммонит ПЖВ-20 5		4,1	4,25	4,5	4,6	Отказ 10	
Победит ВП-4 6		—	4,1	4,4	4,7	4,3	4,1
Аммонит Т-19 4	Критический диаметр открытого заряда, мм 9	8	10	13	15	17	19
Аммонит ПЖВ-20 5		10	13	18	20	26	30
Победит ВП-4 6		8	6	13	17	21	22
Аммонит Т-19 4	Передача детонации между патронами 11 диаметром 36 мм, см	9—10	7—8	3—4	0—1	Впритык 12	
Аммонит ПЖВ-20 5		7—9	5—7	1—2	0	Отказ 10	

KEY:
1 -- Explosive grade
2 -- Indicators
3 -- Cartridge density, g/cm^3
4 -- Ammonite T-19
5 -- Ammonite PZhV-20
6 -- Pobedite VP-4
7 -- Brisance
8 -- Detonation rate in 40 mm diameter steel tube, km/sec
9 -- Critical diameter of open charge, mm
10 -- Failure
11 -- Transmission of detonation between 36 mm diameter cartridges
12 -- Abutting

Ammonite PZhV-20 is a trotyl-sensitized moderate-strength powdered explosive. It is prepared based on water-resistant grade ZhV nitrate, usually with the addition of fucsin (cf. Table 28). Because of this, and also due to the mandatory cooling of the powder before cartridging down to below 32° C and hermetic packing in polyethylene film, cartridges of ammonite PZhV-20 show practically no caking and retain their initial blasting characteristics for the guarantee period of fitness. It is water-resistant. Its cartridges are capable of detonating after being exposed in flooded blastholes

TABLE 31. CONSOLIDATABILITY, FLAMMABILITY, AND DETONATABILITY CHARACTERIZING SAFETY OF USING SAFETY EXPLOSIVES IN COAL MINES

Условия испытания 1	Аммонит Т-19 2	Аммонит ПЖВ-20 3	Мипорит 4
Уплотнение ВВ в патронах, г/см³: 5			
при статическом обжатии 6	1,60—1,65	1,6—1,64	1,4
при динамическом обжатии 7	1,5—1,6	1,5—1,55	Не обжимается 11
Критическое давление горения, атм 8	—	10—13	7—10
Длина участка детонации в условиях канального эффекта (при зазоре 10 мм), м 9	—	0,77	0,60
Приведенное расстояние устойчивой детонации*, см 10	9,3	12,9—13,4**	—

* When the coal-cement block is used according to the method of the **MakNII** [Makeyevka Scientific Research Institute for Work Safety in the Mining Industry]

** High quality ammonite gives the value of 9.8-10.4 cm.

KEY:
1 -- Test conditions
2 -- Ammonite T-19
3 -- Ammonite PZhV-20
4 -- Miporite
5 -- Consolidation of explosive in cartridges, g/cm³
6 -- in static compression
7 -- in dynamic compression
8 -- Critical pressure of combustion, atmospheres
9 -- Length of section of detonation in conditions of channel effect (with a clearance of 10 mm)
10 -- Reduced distance of stable detonation*, cm

for several hours. When released from the plant, its explosive and main physicochemical characteristics as a rule markedly exceed the established technical norms.

The detonatability of ammonite PZhV-20, after increased density, is characterized by the data given in Table 30, from which it is clear that its sensitivity to detonation drops off sharply with increase in density. When the consolidation is upwards of 1.6-1.65 g/cm³, ammonite PZhV-20 produces detonation failures in 36 mm diameter cartridges. The detonation properties of this explosive are also characterized by experimental data (Table 31) obtained from testing for completeness of detonation in conditions of each channel effect (when the gap between the cartridge and the blastholes is 10 mm) and from determinations of the reduced distance between neighboring blasthole charges in a coal mass, where they have not yet been overconsolidated and detonate completely (cf. Table 29). A comparison of data relating to the ammonite PZhV-20 with similar data for ammonite T-19 shows that the detonatability of the latter is much higher. It can burn when the pressure of the surrounding medium is above 10 atmospheres.

Ammonite PZhV-20 is produced in 36 mm diameter cartridges weighing 250-300 grams with mandatory hermetic packing of the packs in polyethylene bags placed in boxes. On customer order, it can also be produced in 32 mm diameter cartridges weighing 200-250 grams. The guarantee period of its use in this kind of container is 12 months for users in the Far North and 6 months for all the rest. The wholesale cost of 1 ton of fucsinated ammonite in polyethylene packing is 306 rubles, and for nonfucsinated -- 294 rubles.

Ammonite T-19 is a moderate-strength fine-dispersed explosive. Compared with ammonite PZhV-20, it includes somewhat more trotyl and receives better manufacturing, which gives it enhanced explosive characteristics, superior water resistance (cf. Table 29), and better detonatability; when compacted, it has a smaller probability of burning up in blasthole charges and greater safety in use.

Ammonite T-19 is permitted for the same blasting conditions in which ammonite PZhV-20 is used; it is produced in cartridges of the same diameters and weights and in the same packing. The provisional wholesale price of 1 ton when packed in polyethylene is 330 rubles.

Miporite is a loosened, noncaking ammonite, exhibiting elasticity owing to its inclusion of an additive of foamed urea-formaldehyde resin -- mipora. The addition of mipora strongly predetermines the properties of miporite. Its cartridges do not become overcompacted (they suffer little compression) in short-delay blasting of near-placed blasthole charges in coal; it gives fewer failures and burnout in mines and therefore is safer to use than ammonite PZhV-20.

The porous structure of miporite favors the normal course of the detonation process even in severely pressed charges of this explosive. In blasting effectiveness when used in coal and moderate-tough rock, miporite is not inferior to ammonite PZhV-20. Owing to its reduced density and porosity, it is more hygroscopic and is approximately half as water-resistant as ammonite PZhV-20. Therefore for dry and slightly flooded faces, cartridges must not reside in wet blastholes for more than 2 hours. Miporite cartridges in faces with heavy flooding must be insulated from the water, for example, by being placed in polyethylene hoses.

TABLE 32. STANDARDIZED TECHNICAL INDICATORS OF UGLENITES

Показатели 1	Углениты 2			3 Селектит № 1
	15 Э-6	№ 5	№ 7	
Влажность, не более % 4	0,5	0,5	0,5	1,0
Химическая стойкость по йодокрахмальной пробе, не менее, мин. 5	10	10	10	10
Плотность патронов, г/см^3 6	1,1—1,25	1,1—1,35	1,1—1,3	0,95—1,1
Работоспособность, не менее см^3 7	130	50—90*	80	200
Бризантность при плотности 1,1 г/см^3, не менее мм 8	7	4	3	—
Передача детонации между патронами диаметром 36 мм, не менее см 9	5	3	3	5
Передача детонации (см) после выдержки в течение 0,5 ч в воде патронов: 10				
вертикально 11	3	—	—	—
горизонтально 12	—	2	—	3
Предохранительные свойства: не должен воспламенять метано-воздушную смесь при взрыве открытого свободноподвешенного заряда, г не менее 13	200	500	1000	200
Гарантийный срок использования в полиэтиленовой упаковке, месяц 14	6	6	6	6

* Restricted by limits.

KEY: 1 -- Indicators
2 -- Uglenites
3 -- Selektite No 4
4 -- Moisture content, not more than
5 -- Chemical resistance based on the iodine-starch test, not less than, minutes
6 -- Cartridge density, g/cm^3
7 -- Efficiency, not less than, cm^3
8 -- Brisance for a density of 1.1 g/cm^3, not less than, mm
9 -- Transmission of detonation between 36 mm diameter cartridges, not less than, cm
10 -- Transmission of detonation (cm) after cartridges have been kept for 0.5 hour in water in the following positions
11 -- vertical
12 -- horizontal
[KEY continued on following page]

KEY [to Table 32, continued]:
13 -- Safety qualities: must not ignite methane-air mixture in the explosion of an open freely suspended charge, grams, not less than
14 -- Guarantee period of use in polyethylene packing, months
15 -- E-6

Miporite is produced in 36 mm diameter cartridges weighing 250 grams in polyethylene or double paper packing. In the first case, the guarantee period of use is 12 months and the wholesale price of 1 ton is 359 rubles, and in the second -- 8 months and 341 rubles.

13. Higher-Safety Explosives (Class V)

Class-V explosives are suitable, based on their safety properties, for blasting in category-III coal mines and extra-category mines, and in certain metal and non-ore mines using blasthole, drillhole, and open charges. However, in strength they can be effective only in blasting soft coals mainly in clearing faces and for carrying out some specialized operations. In driving faces, these explosives are preferably used in combination charges with more powerful safety explosives.

In the USSR and abroad, three fundamentally different types of class-V explosives have gained acceptance. The first type includes ion-exchange explosives. Their composition has no ammonium nitrate or sodium chloride; they are produced in the finely-dispersed state in a ready form or as individual components during the blasting process resulting from an exchange reaction between sodium nitrate and ammonium chloride that are incorporated into the explosive composition. The increased safety properties of these explosives are accounted for by the high dispersion of the sodium chloride formed, since the inhibiting action with respect to the oxidation of methane depends not so much on the amount of this constituent, as on the specific surface area of its particles.

The second type of explosives in this class includes equivalent explosives, that is, those in whose composition the content of the flame inhibitor is equivalent to its overall content in the core and the sheath of sheathed safety explosives, which are also marked by increased safety properties.

A common feature of ion-exchange and equivalent safety explosives is the fact that in certain conditions (in a small-diameter open charge, for a small sensitizer content), they are capable of detonating selectively. For example, in exposed blasthole charges of these explosives, only their sensitizer detonates, ejecting other reacted constituents, as the result of which relatively little energy is released into the surrounding medium, inadequate to ignite coal dust or methane. Charges of these explosives in

TABLE 33. CALCULATED AND EXPERIMENTAL CHARACTERISTICS

Характеристики 1	Угления 2			3 Селектит № 1
	23 Э-6	№ 5	№ 7	
Расчетные 4				
Кислородный баланс, % 5	+0,53	—0,18	+4,94	—0,02
Теплота взрыва, *ккал/кг* 6	640	311	375	810
Объем газов, *л/кг* 7	560	215	527	760
Температура взрыва, *град* 8	1790	920	1500	2280
Экспериментальные 9				
Рабочая плотность патронов, *г/см*^{3} 10	1,15—1,2	1,2—1,3	1,15—1,25	0,95—1,05
Работоспособность, *см*^{3} 11	130—170	60—90	100—120	220—240
Тротиловый эквивалент 12	0,58	—	—	0,82
Бризантность при плотности 1,1 *г/см*^{3}, *мм* 13	7,5—11,0	5—8	5—7	6—10*
Передача детонации между патронами диаметром 36 *мм*, *см* 14	7—12	5—10	5—10	5—12
Передача детонации (*см*) после выдержки в течение 0,5 *ч* патронов в воде: 15				
вертикально 16	3—10	—	—	—
18 горизонтально 17	—	2—4	—	3—7
Скорость детонации, *км/сек*	1,9—2,2	1,75—1,9	1,6—1,8	1,8—2,0
Критический диаметр, *мм* 19	7—9	8—10	7—10	8—10
20 Чувствительность к удару, %	40—70	40—60	80—100	24—36
Чувствительность к трению,** *кГ/см*^{2} 21	2300	2300	2300	2900
Предохранительные свойства: 22 не воспламеняет метано-воздушную смесь свободно подвешенным зарядом максимальным весом, *г*	300	1000	1500	300

* For a charge density of 1.0 g/cm^3.

** Without sand impurity; with impurity, the produced indicators are decreased by more than a factor of 2.

KEY:
1 -- Characteristics
2 -- Uglenites
3 -- Selektite No 1
4 -- Calculated
5 -- Oxygen balance
6 -- Heat of explosion, kcal/kg
7 -- Volume of gases, l/kg
8 -- Temperature of explosion, degrees
9 -- Experimental
10 -- Working density of cartridges, g/cm^3

[KEY continued on following page]

KEY [to Table 33, continued]:
11 -- Efficiency
12 -- Trotyl equivalent
13 -- Brisance for a density of 1.1 g/cm^3, mm
14 -- Transmission of detonation between 36 mm diameter cartridges
15 -- Transmission of detonation (cm) after cartridges have been kept in water for 0.5 hour in the following positions
16 -- vertical
17 -- horizontal
18 -- Detonation rate, km/sec
19 -- Critical diameter, mm
20 -- Sensitivity to shock
21 -- Sensitivity to friction,** kg/cm^2
22 -- Safety properties: must not ignite methane-air mixture with a freely suspended charge having the maximum weight as indicated, grams
23 -- E-6

blastholes cannot burn when a detonation misfires. This increases the safety of using selectively detonating safety explosives. In normal blasting conditions (in a closed volume, with adequate initiation), these explosives detonate completely with the maximum possible release of energy.

The third type of class-V explosive consists of explosives that are composed of an active core of safety explosive and a passive sheath, whose composition includes the flame inhibitor.

Safety explosives of this class include uglenites E-6 and No 5, selektite No 1, and the PVP-1-U and MGPP-50 cartridges in safety shells.

Ion-exchange and equivalent selectively detonating explosives

Uglenite E-6 is a nondusting, poorly friable powder that is oily to the touch. It is classified as an ion-exchange safety explosive. Its composition includes an exchange salt pair ($NaNO_3$ and NH_4Cl) and the small amount of potassium chloride, as the supplementary flame inhibitor. It is sensitized with a low-melting mixture of nitro esters (14 percent) and is waterproofed with calcium stearate. It is less hygroscopic and less prone to caking than other safety explosives whose compositions include ammonium nitrate. It shows practically no caking in cartridges. It is inferior in water resistance to the ammonite PZhV-20. The technical standard for exposure of its cartridges in water when tested for water resistance has been reduced to 0.5 hour (Table 32), but since it has a high-sensitivity sensitizer, it is capable of detonating without failure and transmitting a detonation from cartridge to cartridge in the soaked state. Cases of the detonation failure of blasthole charges of this explosive in flooded faces owing to soaking occur seldom. It does not freeze when the temperature is lowered to -19.5° C. It is roughly 1.5 times weaker than ammonite PZhV-20 and exceeds it in detonatability and safety properties (Table 33). In the normal state and when consolidated in blastholes, its cartridges are excited to detonation with a No 8 blasting cap without failure.

With the ability to detonate in the consolidated state, and also due to its high safety status in comparison with ammonite PZhV-20, uglenite E-6 is less prone to burn out and, therefore, is safer in use in category-III and extra-category coal mines. It does not ignite methane in an experimental drift when a freely suspended charge weighing up to 300 grams is exploded.

Owing to its low strength, E-6 is intended for blasting coal in clearing and preparatory workings when two outcropping planes are present (longwalls and preparatory faces with machine cut) in mines of all categories of gas or dust hazard, and also for special blasting work (artificial caving in of roofs, dislodgement, and so on) in mines of categories I and II. It can be used in driving operations when blasting weak coals and when exploiting workings with small coal cross-sections. In mines with increased gas hazard, it is recommended to use combination blasthole charges made of cartridges of E-6 uglenite and the ammonites T-19 or PZhV-20 in driving operations in weak rock and tough coals.

Uglenite E-6 is permitted for permanent use in mines of all categories, and also in strata that are hazardous as to sudden gas eruption. The distance between blasthole charges must not be less than 30 cm. This explosive is produced in 36 mm diameter cartridges weighing 200-250 grams in which the packs are filled in boxes with polyethylene film. In terms of handling in storage conditions, this explosive is equated to a group-II explosive, however since it is a nitro ester explosive it requires more cautious handling than ammonites do. The wholesale cost of 1 ton of uglenite is 490 rubles (without the surcharge for polyethylene packing).

Uglenite No 5 is a nondusting, poorly friable powder oily to the touch, sensitized with a 10 percent low-melting mixture of nitro esters; it is classified as an equivalent-type ammonium nitrate safety explosive. It contains a large amount (75 percent) of a flame inhibitor, therefore it has increased safety properties, low energy characteristics, and low strength; it is marked by good detonatability; it detonates without failure in open charges 32-36 mm in diameter and transmits detonation between cartridges over long distances (cf. Table 33). It shows virtually no caking in cartridges. It has moderate water resistance; when tested for water resistance, it withstands only half an hour soaking of cartridges in the horizontal position.

Uglenite No 5 is permitted for blasting work in coal in category-III and extra-category mines, and also for special operations with open charges in category-I and category-II coal mines (elimination of obstructions in coal chutes and headings, fragmentation of oversize chunks of coal and rock using external charges, rebreaking of supports in the artificial caving of roofs, and so on). It can be used in combination charges for blasting coal in driving and cleaning operations in mines with increased methane hazard. It is produced in 36 mm diameter cartridges in the weights of 150, 200, 250, and 300 g, depending on order. Packs containing cartridges are hermetically sealed in polyethylene. It is equated to group-II explosives in conditions of transportation and storage, but it requires more cautious handling. The wholesale price of 1 ton of uglenite No 5 is 350 rubles.

Selektite No 1 is a granulated friable ammonite nitrate explosive, sensitized with a 10 percent low-melting mixture of nitro esters. It is classified with the selectively detonating safety explosives. Due to its granulated state and large amount of carbonaceous loosening material, it does not cake during storage and is not overconsolidated in blasthole charges. Sensitizing with nitro esters gives its charges high detonation indicators. The ability to withstand compacting loads in short-delay blasting in coal, to reliably detonate (without burnouts) in closed blasthole charges, and to detonate selectively with small release of energy made it possible to classify selektite No 1 in degree of safety with the class-V explosives, in spite of its relatively small flame inhibitor content. However, in experimental strength characteristics (cf. Table 33) and its actual explosive deficiency, it can be equated to a class-IV explosive. Selektite No 1 is not water-resistant. When flooded blastholes are charged with it, its cartridges must be placed in polyethylene hoses. It is produced in 36 mm diameter paper cartridges weighing 250-300 g. It is equated to the uglenites in handling conditions. It is intended for use in driving and clearing work in coal using blasthole charges in mines or categories when the use of other class-V explosives is permitted. The approximate wholesale price of 1 ton in gross output is about 350 rubles. The cost of experimental batches when packed in polyethylene is 420 rubles.

Explosives in safety shells

Charging explosives in rigid strong pressed shells made of nonexplosive material increases the detonatability of the core and the safety qualities of the entire charge. The strong shell promotes a more complete explosion occurring at a higher rate, reduces the critical diameter of stable detonation, and improves the conditions of detonation transmission between cartridges. In addition, the presence of a shell reduces the size of the charge in a blasthole by about 35 percent. Safety properties of explosives in shells are determined by the composition and thickness of the core, and also by the anti-firedamp ability of the shell.

In the USSR, safety cartridges of the ammonites TZhV-20, T-19, or AP-4ZhV have been developed and produced in soft polyethylene shells with double walls (PVP-1-U cartridges); the interwall space is filled with a water-salt solution; and the safety cartridges of these ammonites are also produced in rigid closed type resite-salt safety shells (MGPP-50 cartridges).

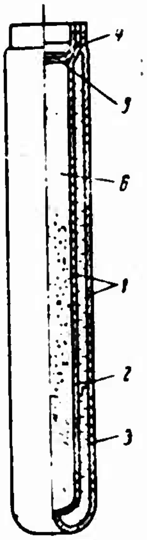

Fig. 2. PVP-1-U cartridge in polyethylene safety shell filled with nitrate solution:
1 -- inner and outer walls of shell
2 -- centering boss
3 -- nitrate solution
4 -- cover
5 -- recess for electric detonator after puncturing
6 -- ammonite

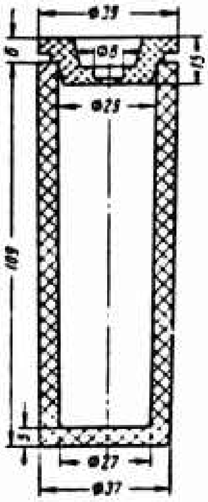

Fig. 3. Resite-salt shell for MGPP-50 cartridges

PVP-1-U slurry safety cartridges

PVP-1-U consists of a double-wall polyethylene shell (ampule) with a false bottom and a removable cover (Fig. 2). The core of the shell is filled with ammonite PZhV-20 or T-19, while the space between the walls is filled with a 56-65 percent aqueous solution of ammonium nitrate. The space between the shell walls has a round centering polyethylene insert, which ensures an identical thickness of the solution layer in the entire interwall space of 4-5 mm. The center of the shell cover has a recess with a thin bottom, which is pierced for insertion of the electric detonator in the manufacture of the striker cartridge. Into the interwall space of the shell is placed 130-135 grams of solution, and into its center -- 120-125 grams of the explosive. The open ends of both of its walls are welded with a hermetic seam, while the side of the contact side of the cover with the body is hermetized over its entire circumference with bakelite varnish or

TABLE 34. CHARACTERISTICS OF EXPLOSIVES IN SAFETY SHELLS

Характеристики 1	Патроны 2	
	МГПП-50 3	ПВП-1-У 4
Тип оболочки 5	6 Жесткая резитосолевая	7 Мягкая полиэтиленовая, наполненная раствором селитры
Размер оболочки, *мм*: 8		
наружный диаметр 9	37—39±0,2	38—39
внутренний диаметр 10	27—29±0,2	30±0,5
длина 11	116±0,3	242±2
Вес, *г* 12	110±5	165±10*
Тип ВВ в оболочке 13	Аммониты Т-19, ПЖВ-20 22 или АП-4ЖВ	
Плотность ВВ, *г/см³* 14	1,05—1,20	0,95—1,15
Вес ВВ, *г* 15	50±4	120±6
Общий вес патрона в оболочке, *г* 16	160±9	285±15
Передача детонации между патронами в оболочках, *см*: 17		
до замочки в воде 18	—	5—10
после замочки в течение 1 *ч* 19	—	5—10
Скорость детонации, *км/сек* 20	3,2—3,6	4,2—4,5
Тротиловый эквивалент 21	0,44	0,58

* Including 130 grams of nitrate solution.

KEY:
1 -- Characteristics
2 -- Cartridges
3 -- MGPP-50
4 -- PVP-1-U
5 -- Shell types
6 -- Rigid resite-salts
7 -- Soft polyethylene, filled with nitrate solution
8 -- Shell size
9 -- outer diameter
10 -- inner diameter
11 -- length
12 -- Weight, grams
13 -- Explosive type in shell
14 -- Density of explosive, g/cm^3
15 -- Weight of explosive, g
16 -- Total weight of cartridge in shell, grams
17 -- Transmission of detonation between cartridges in shells, cm
18 -- before soaking in water
19 -- after soaking for 1 hour
20 -- Detonation rate, km/sec

[KEY continued on following page]

KEY [to Table 34, continued]:
21 -- Trotyl equivalent
22 -- Ammonites T-19, PZhV-20, or AP-4ZhV

a special mastic. Hermetic welding of the walls prevents leaking and drying of the solution and the formation of air bubbles above the solution more than 15 mm in diameter, while hermetizing of the cover protects the explosive against wetting during storage and against soaking after charging of flooded blastholes.

Charged cartridges exhibit low water resistance and are strong, convenient, and reliable in use. When they are inserted into a blasthole with a rammer, the hermeticity is not violated. As to efficiency, they are only slightly inferior to ordinary cartridges of PZhV-20 ammonite (Table 34). They are packed in boxes piece by piece in the vertical position. A box contains 100-120 pieces, and the number of cartridges in a lot is 5000-30,000. In production, each batch of cartridges is tested for detonation transmission (a standard based on the technical conditions is not less than 5 cm) and for safety qualities. PVP-1-U cartridges are supplied with a guarantee period of 6 and 12 months, depending on the conditions of transportation and the remoteness of the user. The wholesale price is 300 rubles for 1000 cartridges.

PVP-1-U cartridges are permitted for driving and clearing operations in coal in mines that are dangerous as to gas, of all categories, and in mines that are dust-dangerous, as well as for shock blasting in strata that are dangerous with respect to sudden eruptions of coal, as well as for spraying of water from polyethylene bags when setting up water curtains in workings.

Through improvements in the PVP-1-U cartridge, the MakNII [Makeyevka Scientific Research Institute for Work Safety in the Mining Industry] proposed filling the core with class-V safety explosive uglenite E-6, and the interwall space of the shell -- with a sodium perchlorate solution. The grade designation of the new cartridge is SP-1.

Small-sized MGPP-50 safety cartridges (Fig. 3) consist of a plastic resite-salt shell with a false bottom and a removable cover. Within the shell is placed a small cartridge or else powder of safety ammonite PZhV-20 or AP-4ZhV. The body and the cover of the shell have circular notches in which cartridges are hermetically coupled together with water-resistant cement or paraffin mastic. The center of the cover has a recess with a 2 mm thick bottom; after puncturing it, the electric detonator is introduced, and its wires are fastened in a circular slot formed between the body and the cover as they are being assembled. The body of the shell has a small taper facilitating its fabrication by pressing, and also insertion into an opening drilled into the mine support when artificially caving roofs in longwalls.

MGPP-50 cartridges are permitted for permanent use for auxiliary blasting work using open charges (caving of roofs, water spraying, and so on) in coal mines of all categories of gas or dust danger. They are supplied to users in lots in wooden boxes. The number of cartridges per box is 200-220, and per lot — from 5000 to 20,000. The guarantee period of use is 6 months and the wholesale price is 133 rubles per 1000 cartridges.

In manufacturing release, each cartridge lot is tested for safety properties in a test drift by blasting cartridges in the freely suspended state.

14. High-Safety Explosives (Class VI)

Class VI of explosives, whose limiting charge in the freely suspended state must not be less than 1000 g, include uglenite No 7, which is a low-strength, but quite detonatable, nonwater-resistant powdered explosive mixture of the ion-exchange type, sensitized with nitro esters (Table 33). When uglenite undergoes explosive transformation, as the result of the exchange reaction a large amount of flame inhibitor in the fine-disperse state is formed, as the result of which it has the highest safety properties. In blasting, little energy is given off and no high temperature is produced, therefore the methane-air mixture is not ignited in blasting of an open charge weighing up to 1.5 kg. When a detonation is extinguished, its charges cannot burn owing to the inclusion in its composition of large amount of inert salts.

Uglenite No 7 is permitted for blasting coal with blasthole charges in mines of all gas and dust danger categories, and for special operations with open charges: rebreaking wooden supports in the blast caving in of roofs in developed workings using charges weighing not more than 150 grams, fragmenting oversize pieces of rock and coal, dislodging coal headings and coal chutes with charges weighing not more than 500 grams, and so on. It can be used in large-diameter cartridges for shock blasting of coal in mines with feeder release of methane. It is produced in 36 mm diameter cartridges weighing 250-300 grams. The provisional wholesale price is 400 rubles per ton. It is equated to group-II explosives as to handling and storage conditions. Compared with ammonites, it is more sensitive to mechanical forces and therefore requires more cautious handling.

CHAPTER IV
EXPLOSIVE PRODUCTS FOR AUXILIARY BLASTING WORK AND FLAMELESS BLASTING

15. Shaped External Charges and Intermediate Detonators

Shaped charges

For secondary fragmentation of oversize rock and ore chunks with external charges, special high-density charges (Fig. 4) with shaped recess intensifying their penetrating action are used, in addition to powdered and plastic explosives.

Several types of shaped charges are produced for open-pit work: they differ in size, weight, and sometimes in the kind of explosive use (Table 35). Charges are usually prepared from trotyl by casting or pressing, and less often from tetryl, phlegmatized hexogen, or pentolite. The density of explosives in these charges is within the limits 1.52-1.68 g/cm^3. An intermediate detonator is provided for initiating the detonation of shaped charges with a detonating fuse in their design: a pressed load of tetryl or pentolite. One or several coils of the detonating fuse are wrapped tightly in the lateral position against the faces of the load and are held on it with an aluminum staple. A steel sheet 0.8 mm thick is used for lining the shaped and end surfaces of charges. Steel-lined shaped charges are somewhat more effective than ordinary external charges made of powdered or plastic explosives. Employing them permits a reduction of several times in the powder factor of explosives in secondary fragmentation of large pieces of rock.

The external surfaces of charges are coated with a protective layer of varnish or paraffin mastic to increase safety in handling them and prevent soaking of the explosive when charges are used in water. To the index ЗКП is added the letters OP or ПР in marking shaped charges, indicating that they are permitted only for open-pit or underground work [respectively].

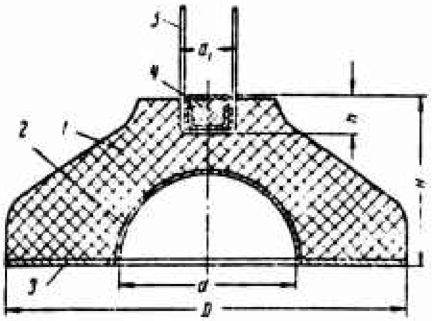

Fig. 4. External charge of the ZKP [ЗКП] type (weighing up to 400 grams) with a spherical shaped recess for secondary blasting:

1 -- explosive charge
2 and 3 -- steel lining
4 -- load of intermediate detonator in shell
5 -- aluminum staple

Intermediate detonators

Several kinds of loads are used in intermediate detonators (Table 36) for reliable initiation of the detonation of charges of explosives that are not sensitive enough to a No 8 blasting cap or detonating fuse.

A pressed T-400 load for a cast TG-500 load has a continuous central channel intended for tight placement in it of a bundle of four blasting fuse strands (Fig. 5); more sensitive loads have a channel under one blasting fuse strand (Fig. 6), from which they are reliably initiated. Cast PT-150 loads have two parallel continuous openings for rapid connection with the blasting fuse in the form of a loop (Fig. 7). The most inexpensive pressed Sh-200 and Sh-400 loads are produced in oblong form without openings or nonblasting cap initiation, or on customer request, with a recess under a No 8 blasting cap for cap initiation. The reliability of initiating loads without openings depends on the number of blasting fuse strands and the density of their attachments to the load surface. Fig. 8 shows one of the recommended procedures of connecting an oblong load with a blasting fuse.

All types of loads, in manufacturing, are coated with a layer of varnish or paraffin-petrolatum mastic protecting them against soaking when they are immersed in water and increasing safety in handling. When packed in wooden boxes, the loads are wrapped item by item in paper, on which the appropriate marking is made.

TABLE 35. CHARACTERISTICS OF SHAPED EXTERNAL CHARGES

1 Тип заряда	2 Средний вес ВВ, г		3 Размеры, мм					13 Максимально допускаемый объем негабаритного камня, м³	14 Цена за штуку, руб—коп.
			4 Заряда			5 Детонатора			
	6 основного заряда	7 промежуточного детонатора	8 Диаметр D	9 Диаметр выемки d	10 Номинальная высота H	11 Диаметр d_1	12 Высота h		
ЗКП-50 15	52	5—10	50	25	30	10	14	0,18	0—48
ЗКП-100 16	125	5—10	80	30	38	10	14	0,45	0—64
ЗКП-200 17	225	10—12	100	45	43	15	14	0,80	0—73
ЗКП-400 18	400—450	10—12	125	54—60	55—58	12	8—10	1,6	1—48
ЗКП-1000 19	1000	1+40*	172	77	68	40	20	2,0	1—11
ЗКП-2000 20	2000	1+40*	200	90	80	40	20	3,0	0—97
ЗКП-4000 21	4000	1+40*	251	113	100	40	20	6,9	0—94

* Detonation assembly consists of a 40-gram load of tetryl and extra DP-1 detonator weighing 1 gram with a recess under the detonating fuse and a securing staple.

KEY:
1 -- Charge type
2 -- Average weight of explosive, g
3 -- Dimensions
4 -- Of charge
5 -- Of detonator
6 -- of main charge
7 -- of intermediate detonator
8 -- Diameter
9 -- Diameter of recess
10 -- Nominal height
11 -- Diameter
12 -- Height
13 -- Maximum allowable volume of oversize rock
14 -- Cost per unit, rubles-kopecks
15 -- ZKP-50
16 -- ZKP-100
17 -- ZKP-200
18 -- ZKP-400
19 -- ZKP-1000
20 -- ZKP-2000
21 -- ZKP-4000

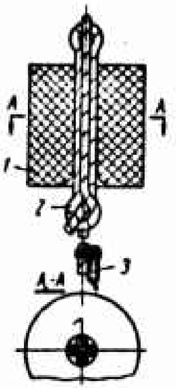

Fig. 5. Connection of T-400 and TG-500 charges with detonating fuse:
1 -- charge
2 -- detonating fuse
3 -- blasting cap

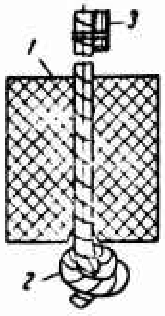

Fig. 6. Connection of Tet-150 charge with detonating fuse:
1 -- charge
2 -- detonating fuse
3 -- blasting cap

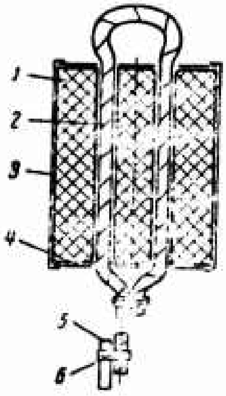

Fig. 7. Connection of PT-150 charge with detonating fuse loop:
1 -- charge
2 -- detonating fuse
3 and 4 -- paper shell
5 -- blasting cap
6 -- cord

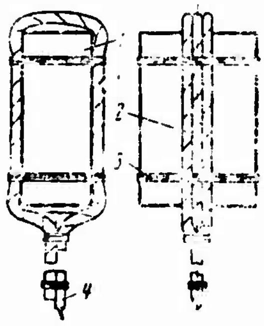

Fig. 8. Binding of straight charge Sh-400 with coils of detonating fuse:
1 -- charge
2 -- detonating fuse
3 -- cord
4 -- blasting cap

TABLE 36. CHARACTERISTICS OF DETONATOR-LOADS

1 Индекс шашки	2 Тип ВВ	3 Вес шашки, г	4 Плотность, $г/см^3$	5 Удельная энергия, ккал/кг	6 Скорость детонации, км/сек	7 Давление детонационной волны, 10^3 $кГ/см^2$	8 Номинальные размеры шашки, мм			12 Диаметр отверстия, мм	13 Цена за штуку, коп.
							9 диаметр (ширина)	10 длина	11 высота		
14 Т-400	20 Тротил	400±20	1,50—1,59	1030	6,4—7,0	159—199	70	70	—	14,5±0,5	39,5
15 Ш-200	21 То же	200±10	1,47—1,59	1028	6,2—6,8	143—189	51	101	26	7,7—8,2*	12,5
16 Ш-400	»	400±20	1,48—1,59	1028	6,2—6,8	143—189	51	101	51	7,8—8,2*	23,5
17 ТГ-500	22 Тротил-гексоген	500±30	1,58—1,64	1200	7,2—7,8	209—225	70	83	—	14,5—0,5	80,0**
18 Тет-150	23 Тетрил	150±7	1,53—1,62	1090	7,0—7,5	192—231	50	50	—	6,0—6,1	42,0**
19 ПТ-150	24 Пентолит	150±7	1,58—1,64	1280	7,8—8,2	230—243	50	50	—	6,0—6,1	75,0**

* Depths of opening (recess) 34-38 mm (can be as much as 60 mm);

** Provisional prices.

KEY: 1 -- Load
2 -- Explosive type
3 -- Load weight, grams
4 -- Density, g/cm^3
5 -- Specific energy, kcal/kg
6 -- Detonation rate, km/sec
7 -- Pressure of detonation wave, 10^3, kg/cm^2
8 -- Nominal load dimensions
9 -- diameter (width)
10 -- length
11 -- height
12 -- Diameter of opening
13 -- Price per load, kopecks
14 -- T-400
15 -- Sh-200
16 -- Sh-400
17 -- TG-500
18 -- Tet-150
19 -- PT-150
20 -- Trotyl
21 -- As above
22 -- Trotyl-hexogen
23 -- Tetryl
24 -- Pentolite

Detonator loads require cautious handling; they are not allowed to be fragmented with strong blows of metal objects, or have holes drilled into them, or be burned. A short manual on their use is sent to the user with each lot of detonator loads.

Detonator loads permitted for open-pit work (cf. Table 36), with the permission of mine superintendent agencies, can be used also in underground work in the event (for example, in chamber or drillhole charges of large diameter) the intermediate detonator will represent a negligible weight compared to the weight of the main charge and the amount of toxic gases formed will not threaten the safety of mine personnel.

For most commercial explosives in use, it is sufficient to have one detonator load per charge of any weight. Trotyl charges are recommended for initiating dry and moist drillhole and chamber charges of igdanite, granulites, zernogranulites, and other explosives. Charges with high initiating ability (TG-500, Tet-150, and PT-150) are intended for initiation of flooded charges of granulotol, alyumotol, zernogranulites, and slurry akvatols. In specific blasting conditions, the size of the intermediate detonator must be selected by trial and error.

16. Methods and Means of Flameless Blasting

Flameless blasting is used in extra-category coal mines in especially dangerous conditions when the use of explosives, including high-safety explosives, is prohibited.

Essentially, flameless blasting consists in transforming the potential energy of the compressed gas into kinetic energy, performing work in breaking up coal without forming flames.

The energy accumulator is a metal cartridge placed in a blasthole, consisting of a charge head, discharge head with exhaust openings (for gas exiting), and the tube (case) made of high-strength alloy steel. A metal shear diaphragm is positioned in the discharge head. The reserve of potential energy in metal cartridges can be produced by various methods and means, and depending on these flameless blasting is divided into the Hydrox, Aerodox, Cardox, and other methods.

The Hydrox and Aerodox methods have gained the widest use in the USSR.

Hydrox method. In this method the reserve of potential energy is produced by the chemical gasification of a powdered charge in a hermetically sealed vessel (Fig. 9). The gas pressure in the metal cartridge rises until it perforates the diaphragm, after which the gases escape into the blasthole. Water vapor (60-70 percent) represents most of the gaseous products formed in the transition of the charge from the condensed state into the gaseous.

Fig. 9. "Hydrox" cartridge containing BV-48 flameless blasting charge:

1 -- charge head
2 -- discharge head
3 -- tube
4 -- replaceable shearing diaphragm
5 -- charge sheath
6 -- electrothermic element
7 -- initiating composition
8 -- main composition

The reaction of the charge in the cartridges initiated with a heating element, due to which the initiating (internal) composition of the charge is ignited. As a result, in the charge pressure and temperature are built up that cause the main charge composition to react, and as a result the working pressure of gases in the cartridge rises to 1600 kg/cm^2. Exposed to the high pressure, the calibrated metal disk is sheared and gases are liberated through the openings of the discharge head into the blasthole, performing work in breaking up the coal or rock.

Metal cartridges for Hydrox charges are produced in two type classes: V-1, 40 mm in diameter and 1210 mm in length, and V-2, 53 mm in diameter and 1320 mm in length. BV-48 charges weighing 190 grams are used for V-1 cartridges, and for V-2 cartridges -- charges weighing 270 grams and 2.0 mm thick shear disks.

When the cartridge diameter is 48 mm, 51 mm diameter cutters and 48 mm diameter drilling rods are used in drilling blastholes; for a 53 mm diameter cartridge -- 60 mm diameter cutters and 57 mm diameter rods.

Aerodox. In this method high-pressure compressed air is the source of potential energy. The layout for blasting by the Aerodox method is shown in Fig. 10.

Compressed air is generated with a high-pressure (800 kg/cm^2) compressor with a capacity of 3 m^3/min and is fed into a main pipeline laid along the mine workings, from whence it is supplied through flexible armored hoses into a pneumatic cartridge accumulator of compressed air energy. Regulation of air supply into the main pipeline network, into the face, and into the pneumatic cartridges is carried out with main line, faces, and breakage valves.

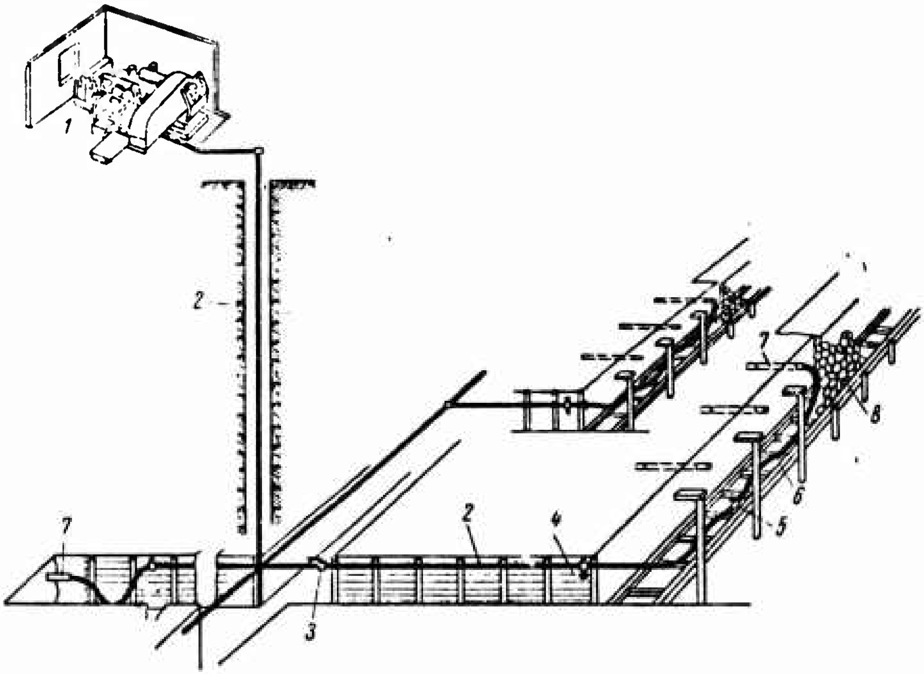

Fig. 10. Breakage with high-pressure compressed air:
1 -- KVD 3/800 high-pressure compressor
2 -- main 25 mm outside diameter (16 mm inside diameter) steel pipeline at a working pressure of 700 kg/cm^2
3 -- main valve
4 -- face valve
5 -- breakage valve
6 -- armored hose, 17 mm outer diameter and 4.5 mm inside diameter
7 -- pneumatic cartridge
8 -- coal broken by pneumatic blasting

The operation of the pneumatic cartridges based on the principle of shearing a calibrated metal disk (on analogy with the Hydrox cartridge), a strip, or a pin. Accordingly, a distinction is made between disk type, slide gate type, and piston type pneumatic cartridges.

Depending on the gauge of the shearing devices, it is possible to regulate the working pressure of compressed air in the pneumatic cartridge within the limits 300-700 kg/cm^2.

Pneumatic cartridges are produced in three diameters: 42, 54, and 63 mm, and in lengths from 1100 to 2300 mm. For a 42 mm diameter cartridge cutters 47 mm in diameter and drill rods 43 mm in diameter are used. With 54 mm diameter cartridges the cutters are 60 mm and the drill rods are 57 mm. With 63 mm cartridges the cutters are 70 mm and the rods 67 mm.

When flameless blasting agents are employed, cartridge size type is chosen in accordance with the mining geological and technical conditions of the working (stratum thickness, coal strength, presence of outcropping planes, etc.).

Flameless blasting agents provide safety in the conduct of blasting operations in mines that are dangerous because of gas, dust, or outbursts, a lowering of coal mining labor consumption as compared with the use of mechanical picks, a bringing into line of the times for performing coal mining technological processes, an improvement in the wholesomeness of working conditions, and an improvement in the quality of the coal (anthracite) extracted.

Flameless blasting methods and agents are recommended for use

a) for cutting coal with a strength coefficient of f = 1 to 2 on Prof. M. M. Protod'yakonov's scale when stratum thickness is more than 0.8 to 0.9 meters; with gently sloping or tilted layer bedding;

b) in mines that are supercategory or III category in gas and that are dangerous because of dust or outbursts, for carrying out coal mining operations in stopes, either with or without preliminary cutting in the conditions enumerated in paragraph a;

c) in anthracite mines in the conditions enumerated in paragraphs a and b;

d) for blasting soft rock of the clay shales type in the conditions enumerated in paragraphs a and b.

CHAPTER IV

BAGGING, PACKING, TRANSPORTING, AND STORING OF COMMERCIAL EXPLOSIVES

17. Bagging, Packing, and Labeling.

The types of bagging and packing of explosives depend on the properties, purpose, storage conditions, and use of the explosives. The uncartridged (loose) form can be used for low sensitivity explosives, which include all granulated and pelleted explosives, the majority of ammonites, dynammons, ammonals, and others. They are bagged and packed in bags weighing 40 to 44 kg. All nitroester and hexogen containing explosives (detonites, dynamite, ammonites Nos.1 and 3 on the scale), which have increased sensitivity, and also all permitted explosives can be used only in the cartridged form.

For non-permitted explosives (except for pressed scale ammonite) cartridges 32 mm in diameter weighing 200 g are considered standard; for permitted explosives these same parameters are 36 mm and 250 to 300 g, respectively. Non-permitted explosives with increased detonation capability (detonite, scale ammonite, and scale ammonal) can also be issued in small diameter cartridges (24 to 28 mm). Pressed scale ammonite No.1 cannot be issued in cartridges less than 36 mm in diameter. All non-permitted explosives of the powder type, irrespective of their sensitivity, besides being issued in cartridges of the standard diameter can, according to the request of the consumer, be issued in cartridges 60 mm in diameter or larger. Permitted explosives for mines that are not coal mines can be issued in cartridges 32 mm in diameter. Deviations from these technical conditions on cartridge diameters are permitted only with the agreement of the State Committee for Supervision of Industrial Safety and for Mining Inspection (Gosgortekhnadzor).

The weight of explosives in a cartridge is mainly determined by its diameter. Rarely it is determined by the dimensions of the external container in which they are packed. Cartridge length depends on its weight and on the density of explosive packing. Cartridges up to 45 mm in diameter have the following allowances in diameter, weight, and length when their density varies within the limits of 0.95 to 1.20 g/cm^3:

Diameter mm	Weight of explosive, g	Length, mm (approximately)
23—24	100±5	210—250
27—28	150±7	220—260
31—32	200±10	220—265
36—37	250±12	210—255
36—37	300±15	240—300
39—40	400±20	270—320
44—45	500±25	270—320

For 50-210 mm diameter cartridges, the following rational weights of their constituent explosives have been set, based on producing a cartridge length corresponding to the length of a standard box (500-510 mm):

Diameter, mm	Weight of explosive, kg	Diameter, mm	Weight of explosive, kg
50	1,0±0,050	100	4,0±0,20
60	1,5±0,075	120	5,0±0,25
70	0,0±0,100	130	6,5±0,30
80	2,5±2,125	150	10,0±0,50
90	3,0±0,150	210	17,6±0,80

The diameters of these cartridges are allowed to deviate by up to -5 percent. The density of cartridges prepared by heaping explosives along with shaking or tamping usually does not exceed the limits 0.95-1.10 g/cm^3. The density of worm conveyor-packed cartridges of ammonite V-3 is allowed to be within the limits 1.25-1.35 g/cm^3, and their length can be within the limits 290-420 mm.

Cartridges up to 32-45 mm in diameter are packed in wooden bundles or stacks of 8-12 each, while smaller diameter cartridges are packaged in paper bags containing 18-24 cartridges each. Cartridges of large diameters are packed in boxes without bagging.

Explosives not containing nitro esters or liquid constituents of other kinds are cartridged in cases made of ordinary paper 35-50 g/cm^2 in density. Nitro ester explosives, and also slurry akvanites are cartridged in parchment-like paper or in pre-waxed cartridge paper 40 g/cm^2 in diameter. Dynamite is cartridged only in plant-origin parchment. Cartridges (except for nonhygroscopic dynamite cartridges) are coated over the entire surface in a continuous thin film of a water-insulating mixture of paraffin containing 20-30 percent petroletum, imparting to the layer the necessary elasticity and adhesion to paper. For cartridge explosives intended for underground work, the weight of the paper case

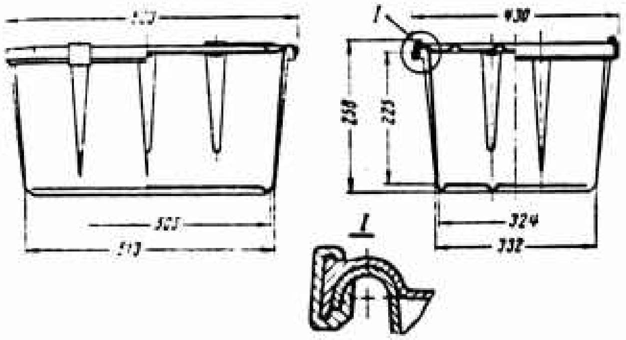

Fig. 11. Polyethylene box

and the moisture-insulating coating are standardized by technical conditions. For cartridges up to 32 mm in diameter, the weight of the paper case must not be more than 2 g per 100 g of explosive, while it must not be more than 3 g per 100 g of explosives in cartridges 36 mm or higher in diameter. The weight of the moisture-insulating coating in both cases must be not less than 1.3 g and not more than 2.5 g per 100 g of explosive. For detonites and several other explosives in parchment-like shells, the weight of the paper and the weight of the coating are increased, respectively, by 2.5 and 3 g per 100 g of explosive. These indicators are not standardized for cartridged explosives used in open-pit work.

Bundles of cartridges are also well proved with a paraffin mixture.

Water-insulated cartridges not bagged in bundles are packed in boxes after they have been continuously interlain with strips of water-insulating paper.

All safety ammonium nitrate explosives, regardless of their period of use, undergo hermetic packing that ensures retention of their initial properties. To do this, either bags made of polyethylene film 100 ± 20 microns thick lined in wooden boxes with a capacity of 28-36 kg of explosive are used, with internal dimensions 505x324x270 mm and a weight of 10 kg (GOST 4450-51), or else polyethylene boxes with a cover closed with locks (Fig. 11) are used, with a capacity of 28-32 kg of explosives, whose internal dimensions are 505x320x225 mm, weighing 3 kg.

The open neck of a polyethylene bag-insert, after water-insulated bundles of cartridges have been placed in it, must be hermetically sealed. Nonsafety explosives are packed in this way only on customer request or when hygroscopic products are shipped with a guarantee period 12 months, in particular, to the Far North. When hermetic packing is used, the price of 1 ton of explosives is raised by 18 rubles.

All noncartridged friable explosives are packed in multilayer paper bags, asphalt-treated, or else bags coated internally with a thin layer of polyethylene. Hygroscopic ammonium nitrate explosives are packed in two such bags with the total number of paper layers being not less than eight, while nonhygroscopic explosives (granulotol, alyumotol, trotyl chunks, and so on) are packed in a single six-layer asphalt-treated paper bag, whose upper surface is lined with a jute bag to provide packing strength.

Hygroscopic explosives with a guarantee period of use up to 4 months are packed in asphalt-treated doubled bags, while explosives with a period of use of 6 months are packed in bags coated with polyethylene. The paper layers of the open neck of bags are alternately turned under with a cover — for better hermetization, leaving three layers of the outer bag for sewing or joining with a length of jute twine. The bottom seams of both bags are insulated against moisture by immersing them in a paraffin-petrolatum mixture. When the guarantee period of the explosive is 12 months or longer, packing is done in doubled four to six-layer paper sacks, between which is placed an insert-bag coated with a 100 ± 20 microns thick film. The neck of this bag is sealed hermetically after the explosive has been loaded. When noncartridged explosives are hermetically sealed in polyethylene, the wholesale price is raised by 13 rubles per ton of explosive. When products are shipped to the Far North and in movements to other remote regions by sea, paper bags containing explosives in polyethylene inserts are additionally packed in wooden boxes or jute sacks. The cost of the wooden container is paid as a surcharge.

All kinds of explosives have markings and distinguishing symbols. The name and weight of the explosive, number of the lot, and the date of its manufacture are placed on the paper case of a cartridge, along with the trademark of the manufacturing plant. The paper cartridge case or its waterproofing coating must in addition be of a specific color or have a distinguishing color band. A red distinguishing color is specified for all explosives intended for use in mines that are not dangerous in terms of gas or dust; a blue color — for explosives used in rock faces of mines that are dangerous as to gas or dust; a yellow color — for explosives used in coal faces of mines that are gas or dust hazardous; and green -- for explosives used in sulfur mines. The name of the explosive, the trademark of the manufacturing plant, and the corresponding distinguishing diagonal band are marked on bundles of cartridges, if paper of a different color is used in making up the bundles.

The external container (bags and boxes) of all explosives has the following marking: the name of the products, number of the GOST or TU under which it was manufactured, number of the location and batch, month and year of manufacture, trademark of the manufacturing plant, net weight and gross weight of the individual location, railroad mark, explosive function group, colored distinguishing band applied along a diagonal over all of the remaining marks, and the red warning legend "Do not load with detonators!"

In addition to marking, a control label gives the name of the packer and the controller is inserted into each packing unit. The external container, after being packed and marked, as a rule is sealed with lead.

18. Hauling, Storing, Control Tests, and Disposing of Explosives

The movement of explosives from plants to users along main routes of transportation is carried out in accordance with the prevailing Pravily Perevozki Gruzov [Regulations on Fleet Movement], issued by the ministries of transportation, maritime fleet, and river fleet.

The movement of explosives by the customers' own means, their storage at base and service warehouses, and delivery to the location of blasting are carried out according to the appropriate instructions of the existing Yedinyye Pravily Bezopasnosti pri Vzryvnikh Rabotakh (YePB) [Unified Safety Rules in Blasting Work]. The instructions contain specific requirements and safety rules, whose compliance prevents the possibility of spoilage and explosion of explosives during transportation and storage.

All commercial explosives are subdivided into two groups by a degree of risk in transportation and storage, according to the YePB. Group I includes explosives in which the nitro ester content is more than 15 percent. Group II includes all ammonium nitrate explosives containing trotyl, hexogen, dinitronaphthalene, and nitro esters not more than 15 percent, and also trotyl in pure form and in melts with aluminum (alyumotol), aluminum and nitrate (ammonals), and hexogen (detonator-loads with the index TГ). Explosives of both groups must be transported and stored separately, as a rule. The possibility of their combined shipment is permitted only when specific conditions provided by Section 41 of the YePB are complied with.

Combined storage of group-I and group-II explosives is permitted only in above-surface dispensing warehouses made of fire-resistant materials, with permission of the responsible agency and given the condition that each group must be stored in a separate insulated room.

All explosives when released from a plant undergo control tests to see that they measure up to the formulation composition and the quality indicators, meeting the requirements of the appropriate technical conditions or GOST. During shipment and storage, explosives can deteriorate in their properties, therefore regardless of the plant tests — whose results are sent to the user in shipping the explosives, each explosive batch when arriving from a plant undergoes external inspection and control tests to determine its suitability for warehouse storage and use.

According to the YePB, all nitro ester explosives must undergo periodic examination and control tests for exudation, caking tendency, and ability to transmit detonation between cartridges, while all other ammonium nitrate explosives must be inspected and undergo tests for moisture content, caking tendency, and ability to transmit detonation. Water-resistant explosives are tested for their ability to transmit detonation between dry cartridges also after the cartridges have been soaked in water.

Batches of all explosives undergo internal inspection for the condition of packing and to see that the marking corresponds to the given type of product.

Nitro ester and all safety explosives undergo these control tests and inspection at the end of the guarantee period and every month during its coverage, while all other explosives receive this scrutiny at the end of the guarantee period, and every three months during its coverage.

Besides the mandatory control checks at the specified times, explosive batches must be tested also for other quality indicators, regardless of the periods of storage, if there is a doubt that they are in good condition or in the event of hangfires, or incomplete blasts in their use.

If upon inspection and tests shortcomings are found in the explosives, the question of their possible use is resolved by the superintendent of the blasting work at the enterprise. Exuding nitro ester explosives in all cases undergo immediate disposal. Other explosives which chemical stability is detected must also be disposed of.

All explosives becoming unsuitable for some reason are to be disposed of.

Explosives that are capable of being exploded are usually disposed of by blasting. For this purpose, measures preventing the possibility of shock and seismic waves striking personnel and also building and structures being damaged must be adopted. If owing to local conditions blasting cannot be carried out, other methods are used. In disposal by burning, measures are taken to guard against the possible transition of the burning of an explosive into detonation, the amount of explosive burned at one time is limited, it is cut up and spread around over the burning location, and blasting caps and detonating fuses are not allowed to be present in the fire.

The safest methods of disposal include dissolving or immersing in water. All explosives capable of dissolving in water can be disposed of by being so dissolved. When water-resistant explosives of the powdered type are to be dissolved, intensive agitation must be used to better wet them with water. Undissolved residues of explosives are done away with by burning.

Disposal by immersion is permitted to be done in the high seas at deep locations. Here measures must be taken against surfacing of the explosives.

CHAPTER V
METHODS OF TESTING EXPLOSIVES

Methods of testing commercial explosives are divided into mandatory control and nonmandatory optional tests. Mandatory methods are used to monitor each lot of explosive product as it comes from the plant to see that its formulation composition and its service indicators correspond to the technical norms set by the appropriate GOST or TU [Technical Condition]. These methods are also used in testing lots with elapsed guarantee service periods and in other cases when the need rises.

The monitoring organizations (MakNII and VostNII [Eastern Scientific Research Institute for Work Safety in Mining]) make periodic mandatory tests of samples of lots that arrive for control checking from plants on specified schedules or in a nonplanned fashion from coal mines and ore mines.

New explosives, when developed and introduced, must undergo -- besides mandatory control tests -- additional optional tests in the developing and monitoring organizations or the comprehensive study and evaluation of their properties and the determination of their conditions of use.

19. Methods of Testing for Indicators Covered by the GOST or the TU

Determination of brisance

The simplest method of testing for brisance is the test for compression of lead cylinders, still known as the Hess test. Test for brisance, under GOST 5984-51, is carried out as follows.

A 50 ± 0.1 g weighed sample of the test explosive is placed in a paper case, with an inner diameter of 40 mm, and is covered on top with a 1.3-2.0 mm thick round cardboard disk, with an outside diameter of 38-39 mm and a 7.5 mm diameter central opening. The charge is hand-pressed

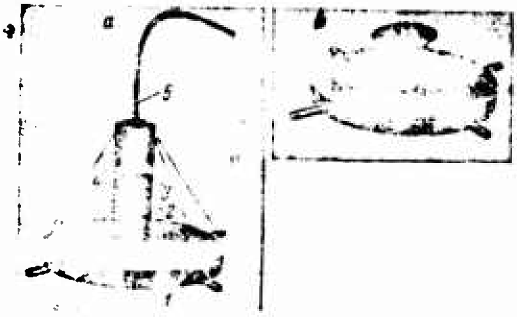

Fig. 12. Determination of brisance:
a -- general view of charge before blasting
b -- view of small lead cylinder after blasting
1 -- steel plate
2 -- lead cylinder
3 -- steel disk
4 -- weighed explosive sample in paper cartridge case
5 -- blasting cap with length of safety fuse

in a special die to a density of 1.0 g/cm^3 or to any other density given by the test conditions, using a plunger that has at one end a nipple for making a recess for the blasting cap (7.5 mm in diameter and 25 mm deep). In the recess formed, a wooden plug of suitable size is temporarily inserted, and then over the cardboard disk are bent the free edges of the paper case.

The charge case is made of a sheet of thick paper, 150x65 mm in size, by cementing it onto a cylindrical template. To the case is cemented its bottom made of the same paper, and here a 60 mm diameter disk is cut out, its edges are trimmed with a star wheel to a diameter of 40 mm, and the resulting serrations are bent over and cemented to the outer section of the case.

A prepared charge (Fig. 12 a) is transferred to a blasting platform and is positioned on a zinc cylinder, which in turn must rest on a smooth steel plate not less than 20 mm thick, placed horizontal on a strong base. It is recommended that the plate be provided with four forks for reliable fastening of the charge with cord. A steel disk is placed between the charge and the cylinder for uniform compression of the cylinder in the explosion. The disk must have a diameter of 41 ± 0.2 mm, a thickness of 10 ± 0.2 mm, a Brinell hardness within the limits 150-200, and a total surface finish of ∇6. The charge is pressed tightly against the steel disk with turns of the cord. The lead cylinder must have a diameter of 40 ± 0.2 mm, a height of 60 ± 0.5 mm, and a machining finish of the end surfaces ∇4.

After placement, centering, and securing of the charge, the wooden plug is removed from its recess and in its place is inserted an electric detonator or a blasting cap connected with a 300-350 mm length of safety fuse and the explosion is performed. After the blast, as a result of the sudden impact of detonation products over the steel disk the cylinder takes on a characteristic mushroom shape (Fig. 12 b).

Before and after the blast, the height of the lead cylinder is measured in four mutually perpendicular directions. The measure of brisance is the combustion of the cylinder, expressed in millimeters, that is, the difference between its mean heights before and after the blast. Two parallel tests are performed; the deviation between these must not be more than 1 mm. When a greater deviation is found between parallel experiments, the number of tests is doubled.

Lead cylinders are cast at 400° C of refined lead (GOST 3778-65) in metal molds with ground inner surface. After casting, the end faces are turned on a lathe.

Lead cylinders are made in lots from the same lead melt. From each lot, 2 percent of the cylinders, but not less than 4, are tested for compression by blasting, following the above procedure, of a reference standard sample of crystalline trotyl at a density of 1 g/cm^3. Trotyl with a melting point not below 80.2° C is used as the reference standard; the trotyl is recrystallized from alcohol, with crystals that pass through a 0.16 mm mesh sieve and remain on a 0.08 mm mesh sieve (GOST 4403-67).

A lot of cylinders is regarded as acceptable if after testing the reference standard trotyl the compression is 16.5 ± 0.5 mm. In addition to observing the quality of the lead used in the columns, test results are strongly affected by the absence of a gap between the bottom of the paper case of the charge and the steel disk.

The Hess test is used as the main standard method of evaluating the quality of fine-disperse commercial explosives sensitive to a No 8 blasting cap, in which the critical diameter of the open charges is less than 40 mm. This test is not suitable for coarse-grain (granulated) commercial explosives that have a critical charge diameter of more than 40 mm and do not completely explode in these conditions. In these cases, to ensure detonation completeness, the charge is placed in a steel ring and the detonation is initiated with an intermediate detonator -- a 5 g trotyl charge. These test conditions characterize brisance to a lesser extent (since it is not only the head but also much of the total impulse that acts on the steel cylinder), since the steel ring confinesthe lateral scattering of detonation products.

Determination of efficiency

The most common laboratory method is lead bomb blasting (the so-called Trauzl test), which consists in exploding a small explosive charge in the

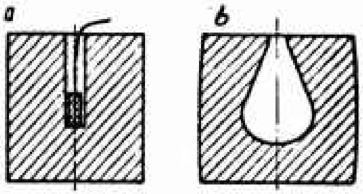

Fig. 13. Determination of efficiency:
a -- lead bomb in cross-section, containing charge and sand stemming before explosion
b -- view of bomb after explosion

channel of lead bomb with sand stemming and estimating the efficiency of the explosive by the size of the dilation in the bomb channel formed after the blast.

Under GOST 4546-48, the efficiency test is carried out as follows. A 10 ± 0.01 g weighed sample of the explosive is placed in a 24 mm diameter case, made of parchment-like paper, which is cut to a template corresponding to a rectangular trapezium with the dimensions 150x120x70 mm.

The case bottom is formed by bending the paper on four sides to a height of 15-20 mm over the cylindrical section of the case. A cardboard wad 1.0-1.5 mm thick is inserted over the explosive into the case; the wad has an outer diameter of 24 mm and a 7.5 mm diameter central opening. Then the case is placed in a special die with an inner diameter of 24.5 ± 0.1 mm, and using a 24 ± 0.2 mm diameter plunger that has a nipple at one end to form recess for the blasting cap (7 mm in diameter and 12 mm in depth), the weighed sample is manually pressed to the specified density, which is usually 1 g/cm^3 for powdered explosives. An electric detonator or a blasting cap connected with a 300-350 mm length of safety fuse (Fig. 13 a) is inserted into the recess of the miniature cartridge through the opening in the cardboard wad.

The charge prepared in this way is cautiously lowered to the bottom of the channel of the lead bomb, 200 mm in diameter and 200 mm in height. The diameter of the bomb channel is 25 mm and its depth is 125 mm. The free volume of the channel is heaped up to its mouth with dry sand screened on sieves No 07 and No 042 according to GOST 3584-53 and the explosion is carried out.

After the explosion, the bomb channel takes on the characteristic pear shape (Fig. 13 b). The cavity formed is cleaned with a hair brush; the contents are removed by turning over the bomb, and the volume of the cavity is measured by filling it with water from a graduated vessel.

The difference in volumes before and after the blast, expressed in cm^3, is the numerical value of the efficiency of the test explosive.

Two parallel tests are made, and the deviation between these must not be more than 10 cm^3. The result is calculated as the arithmetic mean of these tests.

The tests must be conducted at a bomb temperature of 15° C to comply with the standard conditions. If the tests are conducted at another temperature, then the following corrections are introduced into the result.

Bomb temperature, degrees	Correction, percent of measured dilation	Bomb temperature, degrees	Correction, percent of measured dilation
−30	+18	0	+5
−25	+16	+5	+3,5
−20	+14	+10	+2,0
−15	+12	+15	0,0
−10	+10	+20	−2
−5	+7	+25	−4
		+30	−6

In addition, all bombs intended for testing a given series of explosives must be cast from the same lead batch (GOST 3778-56) simultaneously and uniformly. The casting is done at 390-400° C. The bombs are presented for testing not earlier than 40 hours after testing.

The quality of lead bomb lots is tested for its effect on the efficiency of crystalline trotyl, obtained by recrystallization of flaked commercial product from alcohol. The reference standard trotyl prepared in this way must have a freezing point not below 80.2° C. Two bombs from each lot are sampled for testing.

When a 10 g weight trotyl sample is exploded, the dilation of the bomb channel must be 285 ± 7 cm^3. The bombs are accepted for remelting not more than 10 times with the addition to each melt of not more than 50 percent of fresh lead.

Any deviations from the test conditions outlined, in particular, deviations in the hardness of lead, can distort the results of explosive efficiency and are therefore inacceptable.

Using this method to test for the efficiency of coarse-grained (granulated) explosives capable of detonating completely only in large-diameter charges is carried after the explosives have been ground to pass entirely through a 0.05 mm mesh sieve. Slurry explosives are tested with an additional detonator -- a 5 g tetryl charge, with later correction of the results by the dilation of the bomb channel that this charge produces.

Since the results of testing for efficiency are predetermined mainly by the formulation of the explosive and depend little on the possible deviations in the technology of its manufacture within the limits of plant regulations, not every batch of product produced by the plant is permitted to undergo this test. In continuous production, the efficiency test is conducted once a month or even once a quarter.

Tests for detonation transmission

This test amounts to determining the ability of transmitting detonation from cartridge to explosive cartridge through an air gap between their faces. The test method is based on initiating the detonation of one cartridge by the explosion of another placed in the same line, at some distance from the former. The maximum distance to which detonation is transmitted between the cartridges is determined; this value is one of the major characteristics of the detonatability of a test explosive and characterizes the quality of its manufacture.

According to the procedures in GOST 14839.15-69, an electric detonator or blasting cap with a length of safety fuse not less than 0.4 m is inserted into the face of one of the cartridges sampled from the explosive lot. The cartridge-striker prepared thusly is placed on hard smooth ground of the test platform or the proving ground. Then at some distance a second cartridge is placed in the same lines so that its axis is a projection of the axis of the striker-cartridge. A template (distance gauge) with a length equal to the standardized distance to which detonation is transmitted for a given explosive is placed between the cartridges; to the template is tightly pressed the inner faces of the cartridges and then it is carefully removed without displacing the cartridges. Then, all personnel selected for the test retreat to cover or to a safe distance (not less than 50 m) and the cartridge-striker is exploded; from it the detonation of the second (passive) cartridge must occur. The transmission of detonation is evaluated by the absence of explosive remains and the shell of the passive cartridge and the presence of depressions or traces of the blast in the ground at the cartridge locations. If no depression is found at the location of the second cartridge, this means that the detonation was not transmitted and the ejected remains of the explosive and its shell must be looked for some distance from the explosion site.

Depending on the result of the first blast, subsequent pairs of cartridges are exploded in similar fashion; the distance between their inner faces is gradually increased or reduced by 1-2 cm until the maximum distance at which in three parallel experiments total detonation of the passive cartridge is recorded has been established. This distance measured in centimeters is then taken as the distance to which detonation of the test explosive is transmitted.

All lots of explosive produced in cartridged form are tested by this method at the plant. Usually cartridges of the same diameter, weight, and density with which they are supplied for blasting work undergo testing. When cartridges are produced with diameters greater than 45 mm, it is permitted to conduct acceptance tests for detonation transmission of the explosive lot in cartridges of 32-36 mm diameter and weighing 200-300 grams. For each cartridge diameter and weight, the technical conditions specify the detonation transmission norms. Explosive lots sent from plants in noncartridged form do not undergo testing for detonation transmission. They are tested by the user for ability to transmit detonation before blasting work; for this purpose they are cartridged in paper cases of the same diameter with which it is proposed to use the explosive, or more often in 31-32 mm diameter cases at a density of 0.95-1.5 g/cm^3. The weight of the cartridges must be 200 ± 10 g.

In several cases, for example, when it is necessary to test a lot of cartridged explosive before use or when the guarantee period of its storage has elapsed, the method of testing for detonation transmission is somewhat simplified. Instead of looking for the maximum distance of detonation transmission, three cartridge pairs are alternately blasted with the distance between their faces corresponding to the specified norm for the given explosive. The explosive lot is held to pass the test if in all three experiments total detonation of the passive cartridge is established. In the event that detonation fails in even one of the experiments, the test is repeated in a doubled number. If even after the repeat testing incomplete detonation of the passive cartridge is recorded, the explosive lot is rejected and is not permitted in blasting work in cartridged form.

The process of detonation transmission from cartridge to cartridge depends on numerous factors, therefore the tests must be conducted with extra care. The cartridges must be placed on even ground strictly along the same axis, the corners of the paper at the inner cartridge faces must be carefully bent over, and streams of paraffin from under the paper must be removed. Caked cartridges are manually kneaded before being tested.

MakNII developed and proposed for introduction a three-cartridge method of testing for detonation transmission, which has been standardized at the present time (GOST 11131-65) and is in the stage of mastery. By this method, three cartridges with identical distance between their inner faces are placed on the ground; a No 8 blasting cap displaces one of them. The maximum distance between the cartridges at which both passive cartridges are completely detonated is found by the above-described technique. The three-cartridge method of testing is more rigorous, requiring a higher quality of manufacture of cartridged explosives at plants.

Test for water resistance

There are several methods of testing commercial explosives for water resistance in relation to their kind and physical state. Water-resistant explosives produced and used in cartridges with diameters up to 45 mm and weight up to 300-400 g in most cases are tested for water resistance by determining the transmission of detonation between cartridges after they have been soaked in water. Noncartridged explosives of the powdered type, as well as powders intended for the manufacture of cartridges with diameters greater than 45 mm and greater weight than that indicated above are tested on a hydrodynamic instrument. Granulated water-resistant and slurry cartridges of gel-like consistency used in noncartridged form are tested by exposure of their weighed samples in water and subsequent determining of the amount of nitrate and other water-soluble constituents that have dissolved.

Determination of the ability to transmit detonation from cartridge to cartridge after they have been exposed in water. By the procedure in GOST 14839.15-69, paraffin-treated cartridges are placed, in aluminum cases with inner diameter and height somewhat exceeding the cartridge dimensions, and provided with a sufficient number of holes along the bottom and side surfaces for free access of water. Each pair of cartridge-containing cases is immersed on twine for equal time intervals (3-5 minutes) in a bath containing water to depth of 1 m, measured from the lower end of the cartridge. The water must be at room temperature and not contain impurities (for example, soap) which would reduce its surface tension and thus increase the wetting ability and penetration into the cartridge. After exposure for the time period that is actually required for blasting work, alternately two cases at a time are removed from the water and placed on the blasting platform for the detonation transmission test. In testing, cartridges are removed from the cases and placed on the ground in such a way that the lower (with respect to the position in which they were placed in the case) end of the striker-cartridge faces the upper end of the passive cartridge. A blasting cap or electric detonator is inserted into the upper end of the active cartridge. Drops of water from beneath the paper shell at the inner faces of both cartridges are squeezed out by cautious compression with the fingers.

Soaking of cartridges occurs to the greatest extent from their lower end in accordance with the hydrostatic pressure of water, whose value increases with the depth of immersion.

Cartridges of highly water-resistant cartridges after being soaked for 1 hour remain completely dry and transmit detonation to the same distance or even in greater distance than do cartridges of these explosives that have not been soaked. Cartridges that are not adequately water-resistant are soaked from the lower end to a depth of 1.2 cm and reduce the detonation transmission down to 4-2 cm. With more prolonged soaking, they can cause detonation hangfires for low water-resistant explosives; when tested for water resistance, less stringent soaking conditions are set up. Their cartridges are exposed in water in the horizontal position to depth of 1 m or 5 cm for 1 hour or 30 minutes. The soaking conditions are regulated by technical conditions for each type of explosive.

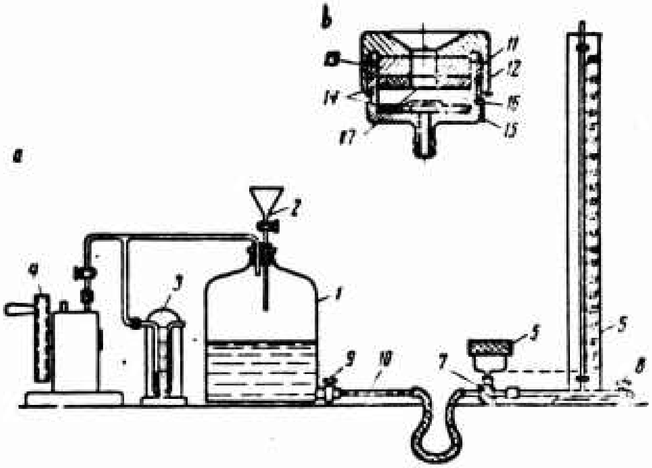

Fig. 14. Testing for water resistance:
a -- layout of hydrodynamic instrument
b -- instrument assembly in cross-section

After soaking, cartridges are tested for detonation transmission. If this test is difficult, then the water resistance can be evaluated by the depth to which explosives are soaked in cartridges, which is readily discernible by the change in the color of the soaked layers of the material. For this purpose, the shell is stripped from cartridges immersed in water, a longitudinal cut is made in the explosive, and a rule is used to measure the depth of soaking from the lower end and the lateral surface of the cartridge. If the explosive is soaked from the lower end of the cartridge by more than 2 cm, and from the lateral surface to a depth of more than 0.5 cm, then it must be regarded as not adequately water-resistant.

Determining water resistance with the hydrodynamic instrument. This method is based on determining the hydrostatic pressure of a column of water, increasing at a constant rate that is necessary to force water within the explosive. The criterion of estimating water resistance is the maximum height of the column of water in the gauge tube of the instrument, corresponding to the moment when the first drop soaking through the layer of tested explosive of a given thickness and density appears. The instrument and test method are standardized (GOST 14839.13-69).

The hydrodynamic instrument (Fig. 14 a) consists of a 5-10-liter bottle 1, filled through funnel 2 to the mark with distilled water, a mercury manometer 3, a hand pump 4, and assembly of the instrument 5 containing the test explosive, a gauge tube 6 1000 mm in length and with inside diameter of 2-3 mm, a three-position cock 7, auxiliary cocks 8 and 9, capillary tubing 10, and rubber connecting hoses. The bottle, assembly, and gauge tubing are connected with each other according to the principle of communicating vessels.

The instrument layout described can be simplified if in order to produce the required pressure head the bottom containing the water is placed at a height of not less than 2 m from the zero mark of the guage tubing of the instrument. In this case there is no need for the pump and the manometer.

The assembly to the hydrodynamic instrument (Fig. 14 b) consists of a case 11 with an inner diameter of 40 mm, height 30 mm, and a screw-in cover 12 made of stainless steel and provided with a 10 mm central opening, a aluminum lock ring 13 10 mm thick and with an outer diameter of 39 mm, and two gasket rings 14 made of 6-8 mm thick soft microporous rubber. The inner diameter of all three rings is 10 mm. The housing of the assembly has a connecting piece for connecting to the water line rubber hose. Its lateral surface is provided with a movable limiter 15, which delimits the course of the screw-in cover and the compression of the gasket ring to form a layer 16 of the test explosive 10 mm thick and 1 g/cm^3 in density between the rubber rings. The gasket rings prevent water being soaked up between the explosive layer and the housing walls, and the rings 17 made of filter paper prevent the spilling of powder.

Before the tests begin, an excess pressure of 150 mm Hg required to form the hydrostatic column of water in the gauge tube is produced in the bottle over the water, using the hand pump.

During the entire operation, the pressure in the bottle is kept at this level, by being monitored with the manometer. Then the instrument constant is checked — it is the constant rate at which the water rises in the gauge tube, 20 cm/min. For this purpose, the instrument assembly is disconnected by rotating the three-position cock 180°, the control cock is turned on, and the water is observed to enter the gauge tube. At the moment it passes the tube zero mark, the rise rate is recorded with a timer. If it is not possible to achieve a rate of 20 cm/min with the control cock, the capillary tube is replaced with another, of greater or smaller diameter.

The instrument constant is measured not less than twice for the height of measuring tube 0-60 cm. After the instrument constant is determined by rotating the three-position cock clockwise 135°, the bottle, assembly, and gauge tube are disconnected from each other and charging of the assembly unit is begun.

A 100 g explosive weight is sampled and sieved through a No 15 sieve (GOST 4403-67). The remaining crumbs and large grains of the product are forced through and rubbed until they have passed completely through the sieve, and then the sample is carefully mixed and a 10 g weight amount is taken. Then a rubber ring is placed tightly against the bottom of the assembly housing; the opening in the rubber ring is covered with a disk of filter paper and above it is heaped the weighed sample, leveling it with a rubber plug or by lightly rapping the assembly against the table to form a uniform layer 10 mm thick. Over the layer is placed another disk of filter paper 38 mm in diameter, followed by a rubber and a lock ring, and the cover is screwed on until it reaches the stop in the limiter, whose position on the housing is determined in advance in such a way that the explosive layer is compressed with the rubber ring to a density of 1 g/cm^3, or to another density value that is required based on test conditions.

The completed assembly is connected to the instrument; in the gauge tube of the instrument the water column is lowered down to the zero mark, by discharging the excess water through cock 8.

In the test, the three-position cock is rotated clockwise 45°, communicating now between the assembly and the gauge tube with the bottle that serves as the source of the constant water head. Then, continual observation is made of the ascent of the water in the tube through the opening in the assembly cover and of the surface of the paper ring on the explosive layer, awaiting the appearance of the spreading patch of water on the filter paper. At the moment the patch appears, by a reverse turn of the three-position cock by 45°, the admission of water into the assembly and the gauge tube is halted, with the level of the water column in the tube being led off from the scale. The height of the water column in the tube (in cm) noted at the moment the patch appears on the paper due to the liquid soaking in through the explosive layer is the indicator of its water resistance. Thus, the explosive is tested under the pressure of the uniformly rising water column. When the hydrostatic pressure exceeds the capillary back pressure of the waterproof pores of the explosive powder, the impregnation of its layer begins, from which water displaces the air. From this moment, the water ascent in the gauge tube slows down abruply and when the water impregnates the entire layer, halts altogether. The more waterproof is the explosive particle surface and the finer the capillary in its explosive layer, the higher the water resistance and thus, the greater hydrostatic pressure of the water column is needed to impregnate the layer.

Three to five parallel determinations are made for each explosive with the instrument, and the deviation between these readings must not exceed 3 cm. The arithmetic mean of the readings of all determination is taken as the end result.

This method is quite sensitive. When the test condition is carefully observed, it reveals a strict quantitative estimate of the water resistance for waterproof powders (explosive, water-resistant nitrate, and so on). From a fairly large number of experiments it was found that if the explosive in the hydrodynamic instrument shows a water resistance not less than 40 cm H_2O, it is capable -- in standard-length cartridges (24-26 cm) at a density not less than 1.0 g/cm^3 -- of withstanding soaking in flooded blastholes for not less than 1 hour and subsequently detonates without failure. Therefore many water-resistant explosives, the hydrodynamic instrument reading of 40 cm H_2O was set as the technical norm for many water-resistant explosives. When the instrument readings are 60-70 cm, standard cartridges of this explosive can reside in water for upwards of 2 hours, and when the readings are 80-90 cm, they withstand soaking for many hours.

Testing explosive powders soaked with nitro esters (detonites, uglenites, pobedite, and so on) or with mineral oil (dynammons AM) on the hydrodynamic instrument gives understated results. The estimate of the water resistance for these explosives must be made by soaking and firing off to transmit the detonation of their cartridges.

Determination of water resistance of granulated and slurry explosives. The tests for water resistance of ammonium nitrate granulated and slurry gel-like explosives is based on leaching from them the nitrate and other water-soluble components by exposing the weighed sample for a specific period of time in standing or running water. No generally accepted standardized method for these tests yet exists. Usually, in the standing water test, a 50-100 g weighed explosive sample is kept in 250-500 g water at room temperature. The exposure time for each explosive is standardized by technical conditions. For example, it is 2 hours for zernogranulite 50/50-V, while it is 5 hours for zernogranulite 30/70-V. After exposure, the amount of dissolving constituents of the explosive is determined by titrating averaged samples of the solution or by weighing the dry residue obtained after filtering the solution and drying the undissolved substance.

When making the test in running water, a 100 g weighed explosive sample, or a large amount, is placed in a water-filled cylindrical vessel, for example, a glass cylinder with an upper overflow cock, and down to its bottom is brought a rubber tube through which water is admitted from the main water line at a rate of 0.02 l/sec. At this water turnover rate, the weighed sample is kept in the cylinder for several hours or days, and then the weight losses determined by drying and weighing the residue of the weighed explosive sample. For granulated explosives, the exposure time in running water is taken as 2 hours, while for slurry explosives it can be as long as 3 days, depending on the conditions of their use.

Test for completeness of detonation

The test for detonation completeness is the simplest method of verifying the detonatability of an explosive. Cartridges or charges (loads) are tested in paper shells of suitable diameter, placed in the ground with ends abutting each other. In one of the outermost cartridges a No 8 blasting cap is inserted into one end and the explosion is performed. All the cartridges must detonate completely. The detonation completeness is evaluated by the absence of explosive residues and the presence of impressions or a funnel in the ground. No less than three such determinations are made with each test explosive. The length of the cartridge prepared for testing must be 6-10 times greater than its diameter. It was found that if a charge of a given explosive of this length is completely detonated in the open air, then the failure-free detonation of its charges of any length can be guaranteed in the same diameter both in the open form as well as in a drillhole or blasthole. If the conditions do not permit testing of long charges (owing to the large weight of the simultaneously blasted explosive, for example, of the granulated type), then the tester limits himself to a single charge (cartridge) not less than 250 mm in length and the test is conducted under GOST 14839.19-69.

Determination of moisture content

The moisture content of ammonites together with volatile impurities is determined under GOST 14839.12-69. Here a 5 g weighed explosive sample is placed in an even layer into a tared dry glass or aluminum beaker, 65 mm in diameter and 30 mm tall, and is dried at 60-70° C either in a thermostat for 4 hours, or using infrared rays in a special apparatus for 30-40 minutes. On completion of drying, the beakers are covered, cooled in a dessicator for not less than 30 minutes, and weighed. The content of moisture and volatiles (in percentages) is calculated by the formula

$$W = \frac{(G_1 - G_2)\,100}{G},\ \%, \qquad (9)$$

where G_1 and G_2 are weights of the small beaker containing the explosive before drying and after drying, respectively, grams; and
G is the weight of the explosive sample, grams.

If the explosive contains much volatiles or it is necessary to find the true amount of moisture, the determination can be made by the familiar Dean-Stark extraction method given the condition that the test explosive can be boiled in the extracting liquid.

The moisture content of nitro ester explosives is determined by drying over freshly calcined calcium chloride in a desiccator under vacuum at room temperature (GOST 5132-68). The test is conducted in the following order. Approximately 10 g of explosive is placed in a uniform layer in small tared dried beakers and weighed to a precision of up to 0.0002 g. The beakers are placed in the desiccator, and then with a water-jet pump a rarefaction of 50-60 mm Hg is produced in it and the beakers are kept at room temperature for 6 hours.

The moisture content in percentages is calculated by Eq. (9).

Determination of density of cartridges, loads, grains, and granules

<u>Determination of cartridge density</u>. By GOST 14839.18-69, the cartridge density is determined gravimetrically using a sand volumeter (Fig. 15), which is a 60 mm diameter cylindrical vessel equipped with a funnel provided with a slide gate. Depending on the cartridge length, a volumeter is selected whose height exceeds the cartridge length by 5-6 cm. In testing, no less than four cartridges are sampled from the explosive lot.

Fig. 15. Sand volumeter:
1 -- volumeter
2 -- funnel
3 -- slide valve

Each cartridge is weighed on balances to a precision of 1 g and placed in the volumeter. On the bottom of the volumeter a 1 cm thick sand layer is placed in advance. Then a stream of sand flowing from a funnel placed 5 cm from the top of the volumeter is directed at the upper end of the cartridge.

The volumeter is filled with sand in one step; the excess sand is carefully removed with a roller (flush with the edges of the volumeter) and is weighed. Then, sand is poured out, the cartridge is removed, the volumeter is again filled with sand by the above-described methods, and then it is weighed.

In testing, the same sand is used, which must be reflection passing through a No 11 silk sieve and remaining on a No 32 * sieve (GOST 4403-67).

The density of the explosive cartridge is called by the formula

$$\rho = \frac{G_1}{V} \text{ g/cm}^3, \qquad (10)$$

where G_1 is the weight of the cartridge, g; and

V is the volume occupied by the cartridge in the volumeter, cm^3.

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* The sieve number denotes the number of openings per cm.

The volume occupied by the cartridge is calculated by the formula

$$V = \frac{G}{\Delta}, \quad \text{cm}^3, \tag{11}$$

where G is the weight of the sand in the volume occupied by the cartridge, g; and

Δ is the gravimetric density of the sand, g/cm^3.

The weight of the sand in the volume of the explosive cartridge is calculated by the formula

$$G = G_1 + G_2 - G_3, \quad g, \tag{12}$$

where G_2 is the weight of the volumeter containing sand, g; and

G_3 is the weight of the volumeter containing sand and the cartridge, g.

This method gives the mean density of the explosive in the cartridge determined as a ratio of the sum of the weights of the cartridge and the waterproofed shell to the overall volume occupied by the explosive, shell, and the air space between the explosive and the shell. More exact results can be obtained by replacing the sand with water. The density of cartridges of water-resistant ammonites can be determined with water. In this case the determination is simplified. The cartridge is weighed to a precision of 1 g, then immersed in a water-containing cylinder, and the volume of water displaced by it is determined to a precision of 1 cm^3. When determining the density of cartridges containing highly water-resistant explosives, several punctures are made at their ends to remove air from beneath the shell and to allow exposure in water for 5 minutes.

When determining the density of large-diameter cartridges (60 mm and more), in the event that there is no appropriate volumeter, their volume is determined by calculation.

Determining the density of pressed, worm conveyor-packed, and cast cartridges, loads, and chunks of explosives. The true density of an explosive in pressed and worm conveyor-packed cartridges, loads, and cast chunks is determined, after the paper shell has been removed from them, by the volumetric method, using water or mercury to measure the volume (when testing nonwater-resistant products). When water is used, the density of the product is calculated by dividing its weight by the volume of displaced water. When mercury is used, the volume of the product is determined by the method presented above for the sand volumeter.

Determination of grain and granule density. The true density of grains of grained explosives and the granules of granulated explosives is determined with a mercury volumeter based on GOST 8066-56 (Fig. 16). The lower

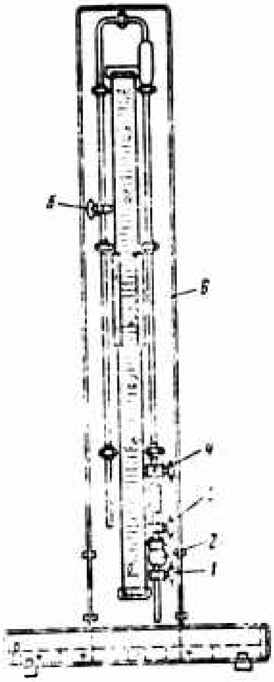

Fig. 16. Mercury volumeter for determining density of grains and granules

tube of a ball-shaped vessel 2 is immersed into a mercury-containing bowl. After closing cock 1, one opens cocks 3 and 4, cock 5 is connected to a vacuum pump, and air is sucked from the curved tubing and the spherical vessel. Then cock 2 is opened and the spherical vessel 1 and tube 6 are filled with mercury until the mercury rises to the height of 500-600 mm, read off from the scale, and its level ceases to change. Then cocks 2, 3, and 4 are closed, the spherical vessel is disconnected from tube 6, avoiding warming it with the hands, mercury is removed completely from the tubes by lightly wrapping with the hand and is then weighed; then the mercury from the spherical vessel and the curved tube of the instrument are poured into a wooden bowl.

After preparing the instrument, about 5-8 grams of explosive grains or granules is weighed in a 25 cm^3 miniature beaker to a precision of 0.01 g and the weighed sample is transferred to the cylindrical vessel of the instrument. Then just as in the first case, the instrument is assembled by connecting the vessel with a rubber union to glass tube 6 so that the

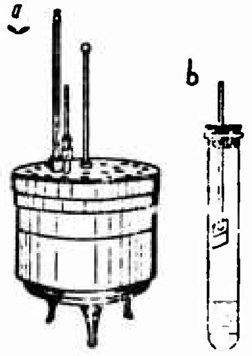

Fig. 17. Instrument for determining chemical resistance based on the iodine-starch test:
a -- general view of instrument
b -- test tube containing explosive and iodine-starch paper strip

midline of the cock 2 is aligned with the zero division of the scale, the air is evacuated from the instrument, and the instrument is filled with mercury, while attention is directed to see that the mercury level and the curved tube in the first and second cases is at the same height. After filling, the spherical vessel containing the weighed sample and the mercury are disconnected, the mercury is removed from the tube, and it is again weighed. Then the temperature of the mercury in the bowl is measured.

The density of grains (granules) is calculated by the formula

$$D = \frac{GD_1}{G_1 - G_2 + G}, \quad g/cm^3, \qquad (13)$$

where G is the weight of explosive sample, g;
D_1 is the density of the mercury at the temperature of determination, which is found from the table in a handbook of physical constants;
G_1 is the weight of the spherical vessel containing the mercury, g; and
G_2 is the weight of the spherical vessel containing the weighed sample and the mercury, g.

The density (specific gravity) of crystals or grains of individual constituents of a mixture explosive is determined by the familiar method using a pycnometer, selecting the liquid most suitable for this purpose.

Determining chemical resistance

The chemical resistance of ammonium nitrate explosives can be changed by breakdown of molecules of chemically unstable mixture constituents or through chemical reaction between constituents as well as their impurities, forming new unstable explosive or nonexplosive compounds.

The method described below pertains to determining chemical stability associated with the decomposition of the explosive.

Iodine-starch test (Abel test). The very simple and rapid, semiquantitative standardized test (GOST 5772-51) is used mainly for checking chemical stability in manufacturing and storing ammonium nitrate explosives whose composition includes nitro esters (detonites, uglenites, pobedite, and so on).

The test is based on the reaction between nitrogen oxides formed in the decomposition of nitro esters and potassium iodide, with which together with starch the indicator, so-called iodine-starch paper strip, is impregnated. When nitrogen oxides react with potassium iodide, free iodine is released, which yields the characteristic brown color with starch.

According to GOST 5772-51, the tests are conducted on an instrument (Fig. 17 a) as follows. The weighed sample of the test explosive, 3.24 g, is placed in a test tube (Fig. 17 b) 16-18 mm in diameter and 130-140 mm in height. The test tube is sealed with a rubber plug through which a 4-5 mm diameter glass rod is passed, with a curved hook at one end. The total length of the tube and the hook must be 85-95 mm. On the hook is vertically suspended a strip (15x20 mm) of standard iodine-starch paper, which after being introduced into the test tube is wetted halfway up with an aqueous solution of glycerin (1:1 ratio by volume) for a more distinct detection of the color change of the paper strip. The lower edge of the paper strip must be 76 mm from the bottom of the test tube. The test tube is placed in a preheated water bath (cf. Fig. 17 a) in which it is kept at 75 ± 0.4° C until a brown band appears at the border between the dry and wet sections of the iodine-starch paper strip. The color is compared with a reference standard paper strip placed in a free recess of the bath.

To check the temperature during the experiment, a test tube fitted with a thermometer is placed in one of the bath recesses.

The measure of resistance in this test is the time elapsing from the moment the test tube is immersed in the bath until a brown band appears on a paper strip, recorded with a timer. A period of not less than 15 minutes is the specified norm for the resistance of nitro esters going into the production of commercial explosives; this norm is 10 minutes for dynamites and other explosives containing nitro esters.

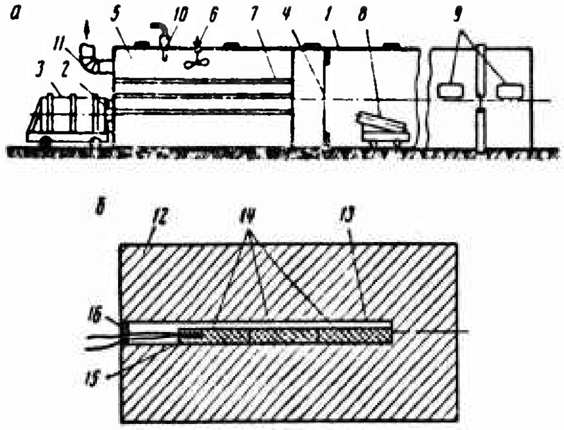

Fig. 18. Testing for safety properties of explosive:
a -- experimental drift
b -- drift discharger in cross-section

In testing dynamites, a 3 g weighed sample is ground with 6 g medicinal talc to impart a powdered structure to it, which facilitates removal of the nitrogen oxides from the explosive. When testing powdered explosives, talc is not added. The iodine-starch test is highly sensitive; its results depend on the volatility and moisture content of the explosive, on the impurities, and several additives introduced into the explosive for specific purpose.

Testing for safety properties

Depending on the conditions in which the explosive is employed, various methods of testing their safety properties are used. All safety explosives used in the coal industry are tested for blasting safety in an explosive-hazardous methane atmosphere or in suspended anthracite coal dust according to GOST 7140-54. Here, class-IV safety explosives intended for driving work in coal are additionally tested for detonatability in the consolidated state in a compressed medium. The more stringent testing conditions for safety of use in a methane-air atmosphere are imposed on class-V and class-VI safety explosives. Special-purpose safety explosives are tested in conditions for which they are intended. Thus, sulfur ammonite is tested in an atmosphere of sulfur dust, and petroleum-oriented ammonite -- in an atmosphere of the vapor of volatile petroleum hydrocarbons.

The most common method of testing safety explosives for safety properties is the method of exploding charges in a test drift in artificially produced gas-air and dust-air media of specific concentrations. There are various methods of exploding charges in a drift in accordance with the conditions of the actual use of the test explosive: blasting in a mortar with a channel, and blasting outside of mortar, and when a charge is freely suspended in the blast chamber of the drift.

To determine the limiting charge in the control testing of an explosive, a test drift is used; class-III and class-IV explosives are exploded in a mortar with a central channel, while class-V and class-VI explosives are exploded in a freely suspended state.

Layout of the drift. The test drifts used in the USSR (Fig. 18 a) consist of a steel tube 1 of elliptical or round cross-section, 1.65-2.0 m in diameter and 10-30 m in length, closed on one side with a thick bottom and secured to a concrete base. A 0.3-0.4 m diameter hatch 2 is made in the bottom, that is, somewhat less than the outside diameter of the mortar 3 installed on a rail trolley and rolled right up to the hatch during the test period. At some distance from the bottom there is a frame 2 in the tube, covered with a paper diaphragm or automatically opened before the blast with a blind to form blast chamber 5, 10 m^3 in volume. To mix gases, the chamber is provided with a propeller mixer 6, and to mix the dust -- longitudinal shells 7. In some drifts the dust is distributed with a special auxiliary mortar 8, 500-700 m in length and 150-200 mm in diameter, installed in front of the chamber of the tube and oriented at an angle of 20° toward the bottom of the drift. For this purpose, a small charge (weighing 20-50 g) of the safety explosive is placed in the mortar channel, over it is heaped the required amount of dust, and several seconds before the blast of the test explosive it is fired off. Beyond the limits of the gas chamber, ports 9 for visual observation of the ignition of gas or dust are made in the tube on opposite sides. Gas from cylinders is fed into the tube chamber through gas line 10. The gaseous products of the explosion are sucked after each test through ventilation duct 11. The blast chamber is also equipped with a connecting piece for sampling gas for analysis and with a thermocouple for recording the temperature rise in the chamber in the ignition of the gas or dust.

The mortar (Fig. 18 b) is a 550 mm diameter thick-walled, strong cylinder 12, 1140 mm long, made of high-alloy chrome-nickel steel in the form of a continuous rod, or of two joint cylinders (core and casing) for added strength. The mortar is provided with an axial channel 13, 55 mm in diameter and 900 mm deep for housing the explosive charge.

Preparation of the experiment and carrying out the test. Norms of limiting charges are official for each class of safety explosive; the explosives are permitted to be used in mines with these norms, and they must be tested against these norms. For class-III and class-IV safety explosives, these norms include 600-gram charge for gas and 700-gram charge for dust, exploded in the mortar. Norms of limiting charges exploded in a methane-air atmosphere in the freely suspended state are set for safety explosives in class-V shells and other types of safety explosives of classes V and VI. Gas and dust tests differ in their execution.

Gas test. When testing class-III and class-IV safety explosives, a 600 g amount of charge, comprised of standard cartridges 14 (31-32 or 36-37 mm in diameter and weighing 200-300 g) is heaped into it all the way up to its bottom; in the last of these cartridges (in the outer end) an instantaneous-action electric detonator 15 is inserted in a copper or paper case. The electric detonator must be completely embedded in the cartridge and directed with its bottom section toward the bottom of the mortar channel. The end of the charge must be not less than 5 cm from the mouth of the mortar. A stemming 16 10 mm long made of four parts dry clay and one part water is placed into the mouth of the channel, flush with its end. The loaded mortar is rolled right up to the hatch of the bottom of the drift and the ends of the electric detonator leads are connected to the electric blast network, reliably de-energized before the time of the explosion. Then, onto the frame of the blast chamber is cemented a diaphragm (or else the blind is lowered) and one begins filling the chamber with methane to a 8-10 percent concentration. The supply of methane is monitored with a gas meter. During the chamber filling time, the mixer is turned on to mix the gas with the air, and it is turned off in 5-10 minutes as the methane supply is completed. The concentration is checked with a Zeiger pipet or a gas analyzer. Before sampling of the gas in the pipet, it is filled with water, connected to the connecting piece of the drift, and the cocks are opened. Due to flowing of the water into the pipet, the gas is sucked from the chamber. As soon as the last drops of water have streamed from the pipet, the lower cock is closed and then the upper. The gas-filled pipet is connected through the contacts of its spark gap to the ends of the blasting machine leads, and by rotating the handle of the machine a spark discharge is produced in it, igniting the methane. To determine the volume of the consumed methane, the pipet is immersed by one of the cocks into a vessel containing a 15-20 percent solution of sodium chloride and the cock is opened in the solution for a certain period of time, and then the inner walls of the pipet are splashed with the accumulated solution and the cock is again immersed in the solution to a depth such that with the open cock the levels of the liquid in the vessel and the cock are made equal. Then, the cock is closed, the pipet is removed from the solution, and the volume of the accumulated liquid is measured with a graduated cylinder.

The methane content is calculated by the formula

$$X = \frac{V \cdot 100}{2V_1}, \%. \qquad (14)$$

where V is the volume of the solution in the pipet, cm^3; and
V_1 is the volume of the pipet; cm^3.

After placing the required concentration of the methane-air mixture in the drift chamber, the charge in the mortar is blasted with a blasting machine and the appearance of flame in the ports and in the open end of the drift tube is observed. Ignition of the gas can also be recorded by the deflection of the needle of a galvanometer connected to the thermocouple, whose contact head is located in the blast chamber.

In the order set forth, the experiments are repeated the required number of times with the same amount of charge. All produced plant lots of explosive undergo control testing for gas and dust safety. Three parallel experiments in a drift are conducted with each product lot for gas safety. In doubtful cases or when experimental lots of new safety explosives are produced, the number of parallel tests is brought to 10. Ten-fold testing is carried out in the MakNII or VostNII of control samples of all safety explosives produced by plants that are obligated to supply them to the MakNII or the VostNII not less often than once a year.

When establishing the maximum limiting charge (which does not yet ignite the gas) for new safety explosives, tests begin with a 350 g weight of charge, and in the case of nonignition, the amount is increased in each subsequent experiment until ignition occurs. The required number of experiments is repeated with the maximum charge found, and in none of these must there be ignition.

When testing class-V and class-VI safety explosives for their gas safety, an empty mortar is rolled drived up to the hatch in the drift, and cartridges containing the limiting amount of charge to be tested are suspended in the center of the blast chamber along the drift line in a single line one after the other, or with specific gaps, depending on the test conditions. All remaining operations are carried out just as described above.

Dust test. For this dust, coal dust of standard composition is used: the volatiles content is within the limits 29-35 percent, the ash content is not more than 9 percent, and the moisture content is not more than 2 percent; the residue on a No 15 sieve (GOST 4403-67) is not more than 10 percent, and not less than 50 percent passes through a No 76 sieve. The coal dust is obtained by drying and comminuting coal of the appropriate variety. The amount of coal dust per test must be 6 ± 0.1 kg on the basis of producing about 300 g per m^3 of air in the suspended state. Some of the dust (about 5 kg) is placed in the channel of an auxiliary mortar containing a charge weighing 50 ± 5 g, initiated with an instantaneous-action electric detonator in a paper or copper shell, while the other part is placed on the shells of the blast chamber in the drift. The explosive charge in the main mortar must be 700 g comprised of standard-size cartridges.

When testing for dust, half of the experiments are conducted with additional heaping into the channel of the main mortar of 100 g coal dust in such a way that most of it is in the free space in front of the charge. In none of the experiments is stemming used. The blast chamber is not blocked off with a blind and a diaphragm.

After preparing the charges, the mortars are put in place and the blast is conducted with a delay of 3-5 seconds of charge initiation in the auxiliary mortar, observing or recording the ignition of the dust with a galvanometer and a thermocouple.

To test currently produced safety explosive lots, according to GOST 7140-54, in plant drifts only two blasts are conducted with dust, while in plant testing of experimental lots and control tests in the MakNII or the VostNII samples of all safety explosives undergo ten parallel experiments for each type of explosive.

When testing freely suspended safety explosive charges of classes V and VI for dust safety, the drift hatch is covered with an empty mortar or a slide gate, and the cartridges are placed in the center of the chamber along the axis of the drift at specific distances from each other.

If during the testing, in even one of the experiments gas or dust is ignited, then a doubled number of cartridges is selected from the test explosive lot and a doubled number of blasts is carried out. Even if a single ignition is detected, the lot is rejected. An explosive lot is rejected also if the ignition of gas and dust does not take place, but residues of the explosive are detected in the mortar channel or in the blast chamber.

Testing for sulfur dust. Thus far only sulfur-oriented ammonite No 1ZhV used in mines containing finely disperse sulfur in workings is subjected to this test. The tests are conducted in a standard test drift, described above, in the same sequence as tests for coal dust safety. The limiting weight of the charge of the test explosive placed in the main mortar is 400 g. To disperse the sulfur dust in the blast chamber (at the rate of 200 g of dust per m^3 of chamber volume), a 50-100 g cartridge of the same explosive is used; it is placed along with the dust either in the auxiliary mortar or is suspended in the center of the drift chamber surrounded by dust. The dispersion is carried out 2 seconds before the explosion of the test charge. The tests are repeated five times. In none of them must dust ignite. If dust is ignited due to the blast of the auxiliary charge (which is suspended freely in the chamber), then this does not count in the test.

Dust obtained by drying and grinding sulfur dust from the Gaudrak or Changyr-Tash mines is used in the tests. It is dried to a moisture content of not more than 0.1 percent and is ground until not less than 40-50 percent passes through a No 58 sieve (GOST 4403-67).

Testing for the vapor of gasoline in a mixture with methane. The petroleum-oriented ammonite No 3-ZhV undergoes this test by the explosion of its limiting charge weighing 350 g in a mortar containing stemming in a test drift. Grade B-70 aviation gasoline covered by GOST 1012-54 and natural gas are used in the test. The concentration of the mixture of gasoline with methane in the blast chamber of the drift must be within the limits 2-4 percent for their volumetric ratio 1:1 to 1:3. To produce the gasoline-methane-air mixture, liquid gasoline is fed into the chamber of the drift through a funnel mounted in the bottom of the tube. The chamber is first heated with steam to 50-60° C with a heating coil lining its inner walls. Five minutes after dispersion of a portion (1.5-2 liters) of gasoline, its vapor is mixed with air with a mechanical mixer and the vapor concentration is determined with a Zeiger pipet. The gasoline content on a heptane basis is calculated by the formula

$$X_1 = \frac{V_1 100}{V_0 8},\ \%. \qquad (15)$$

where V_1 is the volume of solution collected with the pipet, cm^3; and
V_0 is the pipet volume, cm^3.

After establishing the required gasoline concentration in the chamber, the methane is admitted through a gas meter and its concentration is determined with the same Zeiger pipet. The methane content is determined by the formula

$$X_2 = \frac{(V_2 - V_1) 100}{2V_0},\ \%. \qquad (16)$$

where V_1 is the volume of the solution collected with the pipet in the analysis of the gasoline-air mixture, cm^3;
V_2 is the volume of the solution collected with the pipet in the analysis of the gasoline-methane-air mixture, cm^3; and
V_3 is the pipet volume, cm^3.

Five repeated experiments are conducted, and in none of these must the mixture ignite.

Test in a coal-cement block. Class-IV safety explosives intended for short-delay blasting in group charges for coal in mines, must undergo — in addition to the mandatory drift tests — also laboratory tests (optionally) for resistance to detonation in the intensely compact state (up to a density of 1.55-1.67 g/cm^3). In natural conditions of service, they can be in this condition in blastholes in a coal mass exposed to dynamic loads of the delay blast of neighboring charges and when the explosives exhibit

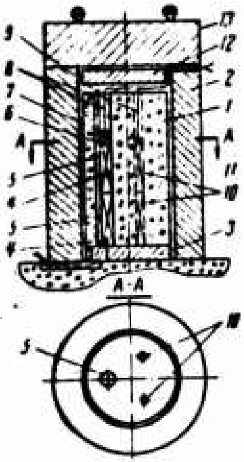

Fig. 19. Coal-cement block containing charge in steel casing

inadequate detonatability they can produce deflagration, which is dangerous in the methane-air atmosphere of mines. The tests are conducted in coal-cement blocks based on a method developed by the MakNII, which to a greater extent than other methods models the conditions of short-delay blasting of coal in driving faces. Essentially, it consists of exploding pressed and test charges located at some unknown distance from each other and determining the failure-free detonation of the latter in a coal-cement block which in its physicomechanical properties is close to the coal mass. The smaller the distance between the charge and the block, the more the charge of test explosive is compacted and, therefore, it must exhibit greater detonatability in order not to produce deflagrations in these blast conditions. The criterion of the estimate of detonatability is the minimum distance between charges in the block for which stable detonation of the test explosive is still observed. This distance, given in terms of the effective radius [1] of the pressed charges, and called the reduced distance, serves a measure of the estimate of the test explosive compared with any standard explosives adopted as the reference standard in this test method.

A block 250 mm in diameter and 500 mm in height is prepared in advance from a mixture of coal, cement, and water taken in the ratio 13:9:6, in special molds consisting of a split cylinder and a false bottom with

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[1] The effective radius is smaller than the actual radius by the lateral scattering of undetonated explosive, determined by calculation.

recesses in which pins are inserted to form continuous openings (blastholes) in the castings. The different recess layout in the false bottom makes it possible to modify the distance between blastholds, as desired.

Three blastholes are cast in each block; one of the blastholes, 44 mm in diameter, is intended for placement of a charge of the test explosive, and the other two -- 25 mm in diameter -- serve to house the pressed charges. All blastholes are located at equal distances from the center of the block and from each other. In casting of the blocks, initially molds are filled with coal, and then a cement mortar is poured over and exposed for 8-10 hours. The blocks free from the molds are exposed an additional period not less than '4 days, after which they acquire the requisite physicomechanical properties and become suitable for testing.

In testing, block 1 (Fig. 19) is placed in a thick-walled steel cylinder-housing 2, whose inner diameter corresponds to the block diameter. From the bottom, into the housing is inserted in advance a metal insert 3 provided with an opening for extending out leads of ionization sensor 4 inserted in the charge to measure the detonation rate of the test explosive. Then into a 44 mm diameter opening is placed charge 5, consisting of one or two 36 mm diameter cartridges in such a way that the charge length is 300-310 mm. An electric detonator 6 with a 15 msec delay is inserted into the charge from the top, and then the small clay wad 7 is put into place, and the remaining free space is heaped with sand 8. Along the entire charge a metal rod or tube 9 is placed into the block hole, serving as an additional marker of the detonation completeness of the explosive. Pressed charges 10 of the same length prepared from the test or other explosive fitted with an instantaneous electric detonator 11 are inserted into the two other block openings. The free spaces heaped with sand, with limited additional heaping of the sand to the face of the block to form a soft cushion in which the electric detonator leads are protected against crushing and short-circuiting. Coarse-grain sand is used in the stemming. A second metal insert 12 is placed over the block, with limited embedding in the housing, and a massive cover 13 weighing about 1 ton is lowered cautiously onto the block with a hoist; the cover is intended to block the rapid outflow of detonation products of the pressed charges, which compress and retain the charge of the test explosive in a stressed state before the explosion. After this block preparation, the leads of the electric detonators are connected to a current source, the instrument is adjusted to measure the detonation rate, and the blast is carried out. The nature of the detonation of the test explosive is estimated from the measured detonation rate and the deformation of the marker-tube. By repeating this experiment with the blasthole layout in the block modified, the unknown reduced distance is found that characterizes the safety of using the given explosive compared with others. This method reproduces as well the actual pattern of compaction of the explosive in blastholes of a coal mass and, by using it, the quality of standard explosives can be verified, and one can also test the detonatability of new safety explosives.

20. Methods of Testing for Indicators Not Governed by GOST or TU

Determining the heat of explosion

In addition to theoretical calculation, the heat of explosion is determined in a calorimetric bomb that is similar in design to the bomb used to determine the composition of explosion products. Bombs with a capacity of 20-26 l are used in testing commercial explosives, capable of exploding charges weighing 50-100 g.

The method is based on the precise measurement of the temperature of the bomb or the water temperature in a calorimeter, which are heated due to the heat released in the explosion of a charge of test explosive, and subsequent calculation of the unknown heat by multiplying the resulting temperature rise by the heat capacity of the calorimetric stand. Precise recording of the temperature is carried out with special thermometers (Beckman thermometer, and so on). Blasting of the charge in a bomb is carried out in a lead or other shell of high mass in order to ensure its most complete detonation.

Arrangement of the calorimetric bomb. The bomb (Fig. 20) has a capacity of 20 liters and consists of a thick-walled steel housing 1, with an outer diameter of 350 mm, and inner diameter of 200 mm, and height of 650 mm, a cover 2 hermetically closed via a lead gasket 3 with eight thick bolts. The underside of the cover is provided with hooks on which to hang the charge 4. The cover is provided with a bushing through to lead out the electric detonator leads 5 and to secure a pressure valve 6 used in evacuating the bomb and in collecting or releasing gases after the explosion.

In its assembled form, the bomb is loaded into a calorimetric steel vessel 7 filled with and equipped externally with heat insulation 8. The vessel dimensions are as follows: diameter 415 mm, height 1000 mm, and wall thickness 1.4 mm. The vessel is provided with mixer 9 to stir water, and thermometer 10 with a 0.01° scale division.

Preparation and carrying out of the tests. A 100 g weighed explosive sample, with appropriate density, is placed in a glass beaker 11 36-40 mm in diameter, and onto the beaker is fitted a lead shell 12 of appropriate diameter with wall and bottom thickness of 4.0-4.5 mm. The weight of the shell is about 500 g. Over the lead is placed the second glass beaker 13 in order to prevent the lead from sticking to the walls of the bomb after the blast, When an explosive with positive oxygen balance is tested, in place of the lead shell a sand or water shell is used, which is poured into the outer beaker. An electric detonator in a copper case is used as the initiator.

The emplaced charge is suspended in the center of the bomb at a distance of 150-200 mm from the cover, which is screwed in tightly and the air is

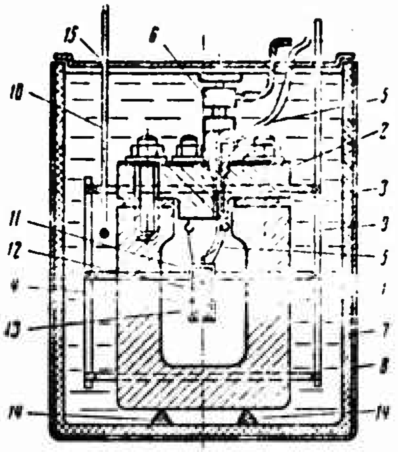


Fig. 20. Calorimetric bomb, 20 l capacity, for determining heat of explosion

evacuated from the bomb with a pump to a residual pressure of 3-5 mm Hg. Then with a hoist the bomb is lowered into the calorimetric vessel containing water onto the support 14, and is closed with cover 15.

Enough water is poured into the calorimetric vessel in order to cover all metal parts of the bomb. The water is weighed to a precision of 1 g. To conduct the blast, the bomb and the calorimeter are moved into a constant-temperature room, where the temperature fluctuations must not be more than ± 2°. Before the blast, the water in the calorimeter is stirred for 0.5 hour with a mixer, the water temperature in the calorimeter is recorded, along with the temperature and barometric pressure of the air in the room. During the experiment the temperature is recorded in three periods. Five readings are made before the blast, and then from the instant of the blast a reading is taken from the thermometer at equal time intervals until the end of heat release, when the temperature rise ceases. From the moment of temperature decline five more readings are taken. By the end of the temperature recording time, the mixer is turned off, the water is poured out, the bomb is lifted out of the calorimeter, and the bomb is dismantled for the next experiment.

By the time the temperature is measured, virtually all the water formed in the blast is in the liquid state. Therefore the first calculation of the heat of explosion is made using the formula

$$Q = \frac{C\Delta t - q}{a}, \quad \text{kcal/kg}, \qquad (17)$$

where C is the heat capacity of the calorimetric stand, which is determined by a special blast in a bomb of an explosive whose heat of explosion is known exactly, cal/deg;

q is the heat of explosion of the electric detonator, 1190 cal;

Δt is the temperature rise of the calorimeter, corrected for heat exchange and for the thermometer degree value (based on its rating certificate), deg; and

a is the weight of the weighed explosive sample, g.

The heat of explosion when the water is in the vapor state is a more correct characteristic of the explosive. Therefore a second calculation is made; the result obtained in the first calculation is recalculated for water in the vapor state using the formula

$$Q_v = Q - 584 q_1, \quad \text{kcal/kg}, \tag{18}$$

where q_1 is the amount of water in the explosion products determined by purging the bomb after the blast with dry air or by trapping the entrained moisture in calcium chloride tubes, kg/kg of explosive; and

584 is the difference between the heat of water formation in the liquid and in the vapor state.

Two parallel determinations are made and the arithmetic mean of these determinations is taken as the result. Simultaneously with the heat of explosion, when necessary the volume of the gaseous products of explosion can be determined and samples can be taken for analysis of gas composition.

Determination of detonation rate

There are methods for determining the detonation rate with a high precision. Optical instruments have been developed -- photographic recorders fixing the detonation process as a photographic image on luminescent film, where the detonation process accompanies the propagation of the detonation waves through the charge. The recording can be made either continuously over the entire area of the charge being measured, or else in separate frames following each other at a frequency up to 2 million/sec. With the photographic recorders, the detonation rate can be measured over small areas of the charge length (5-10 cm) to a precision of up to 1 percent, however these instruments are suitable only for nonshell charges or charges in transparent shells transmitting the luminescence of the detonation process.

There are even more precise instruments -- oscillographs that are capable of continuously measuring the detonation rate for extremely small (less than 2 cm) charge areas. With these instruments measurements can be made at large distances of open as well as opaque shell-enclosed charges of any size, for example, blasthole and drillhole charges.

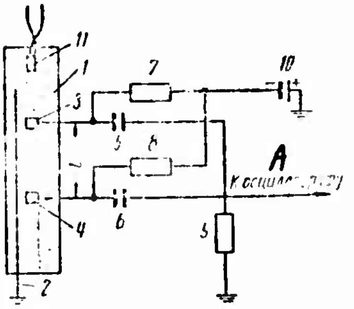


Fig. 21. Oscillographic method of determining detonation rate
KEY: A — To oscillograph

Oscillographic method. Essentially, the method consists in the following (Fig. 21). Along charge 1 of the test explosive is placed a grounded electric wire 2. Two sensors 3 and 4 are placed in the transverse position in the charge at a precisely measured distance between them. The sensors must not touch the ground electric wire, forming with it spark gaps through which prior to the moment of blasting an electric current does not reach the explosive, because all explosives when dry (excluding slurry explosives) have very low conductivity. The ends of the sensor wires are connected to an electric unit consisting of low capacity condensers 5 and 6, and resistors 7, 8, and 9. Voltage is fed to the unit from a direct current source 10 that charges the condensers.

Before testing, the oscillograph is connected to the unit. The charge is blasted with an electric detonator 11 or another impulse. When a detonation wave passes along the charge, the explosion products become sufficiently ionized that the gaps between the grounded wire and the sensors become current-conductive. The sensors are closed alternately. When sensor 3 is closed, capacitor 5 is discharged and produces the first current pulse to the oscillograph; when sensor 4 is closed, condenser 6 is discharged and produces the second impulse. Both successive impulses produce the corresponding voltage surges, which in the form of flashes of a glowing curve are recorded with high precision on a photographic film from the screen of the cathode ray tube of the oscillograph. With the oscillogram prepared in this way, the time of passage of the detonation wave between the sensors is determined, by comparing the distance between these two jumps (peaks) of the voltage curve and the time markers on the film.

The detonation range in the interval measured is calculated by the formula

$$D = \frac{L}{t}, \quad \text{m/sec}, \qquad (19)$$

where L is the distance between the sensors, m; and
t is time, sec.

The rate can be measured over several areas of the charge if the appropriate number of sensors is introduced into it. Depending on the state of aggregation of the test explosive (friable, solid, or liquid), in actual practice sensors of various designs are used (foil type, needle type, and so on). There are specialized sensors capable of continuous measurement of the detonation rate. The precision of measurement depends on the minimum sweep time of the oscillograph. An OK-17 oscillograph has a sweep time of 3 microseconds and can measure the detonation rate to a precision of up to 1 percent over a charge area up to 2 cm in length. The detonation rate is measured with a still greater precision with the OK-15 oscillograph, which produces a spiral sweep on the oscillogram, and with other modern oscillographs.

Dotrish method. To verify the quality of commercial explosives, usually a simple and accessible method of measuring the detonation rate with a detonating fuse is used (Dotrish method). Essentially, this method consists in the unknown detonation rate of the test explosive being compared with the known detonation rate of the detonating fuse. The fuse must exhibit high constancy of detonation rate along its length.

According to GOST 3250-58, a steel tube 1 (Fig. 22) with inner diameter 30 or 40 mm, wall thickness 3-4 mm, and length 450 mm is required for the test; the tube is closed on both ends with screw-in cover 2, in one of which a 7.5 mm diameter opening is drilled to accommodate blasting cap 3. On the surface of the tube there must be two openings of the same size, at the distance of 350 mm from each other, and 60 mm from the end of the tube on the side of the cover that has the opening to admit into the charge the ends of two lengths 4 and 5 of the blasting fuse. To record the collision of the detonation waves of the blasting fuse length, a plastic marking device 6 made of 0.7 mm thick galvanized iron, 15 mm wide and 600 mm long is used. Two transverse marks A and B are scribed on the plate 500 mm from each other for placing the blasting fuse ends. A 10 mm thick steel insert 7 is placed under the plate; the insert is 20 mm wide and 620 mm long. The plate wound spirally with the turns and containing the insert and the blasting fuse ends is placed in a metal tube 8 protecting the marking device against fragments in the detonation of the charge. The tube must have a wall thickness not less than 5 mm, inner diameter 50 mm, and length 630 mm. The detonation rate of the blasting fuse used in testing must be not less than 6.5 km/sec. Its measurement (taring of the blasting fuse) is made in advance by some precise enough method. The dispersion of the readings of parallel determinations from the mean measured value is allowed to be within the limits ± 1.5 percent.

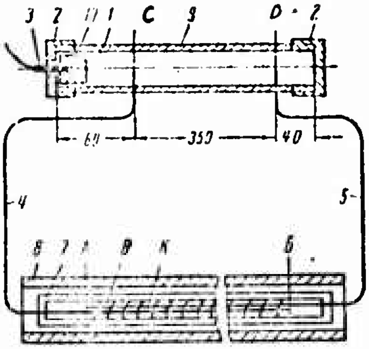


Fig. 22. Dotrish method of determining the detonation rate

For reliable initiation of a detonation, an intermediate detonator 10 is used in the test charge 9 of the explosive: the intermediate detonator is a pressed load of tetryl or trotyl weighing 30 g, and its diameter must be 1 mm smaller than the inner diameter of the charge tube. The load must have a density of 1.5-1.6 g/cm^3 and a 7.5 mm diameter recess, 15 mm deep, for the blasting cap. In the absence of loads, powdered or plastic explosive whose detonation rate must be one order greater than the detonation rate of the test explosive is allowed to be used as the intermediate detonator. The weight of this detonator must be 50-100 g.

Two uneven lengths of blasting fuse are used to assemble the recording system; the lengths are determined in relation to the anticipated detonation rate of the test explosive. If the detonation rate is expected to be more than 2.5 cm/sec, the first segment is 1.5 m in length, and the second -- 1.0 m long. But if the detonation rate must be below 2.5 km/sec, the first fragment is increased to 2.2 m. In addition, the base CD along which the velocity is measured is reduced from 350 to 200 mm. When the segments are assembled with the marker-plate, their ends are made to coincide precisely with the marks A and B.

A charge of the test explosive in a steel tube must have over its entire length the uniform specified density, which is usually 1 g/cm^3 in standard tests of powder type explosives, and fits tightly against the intermediate detonator.

The charge prepared for the test according to the scheme (Fig. 22) is blasted in a shelter (armored pit), then the remaining marker-plate 6 is extracted from the protective tube 7, the mark K formed on it from the collision of the two colliding detonation waves propagating from the charge along the blasting fuse length is looked for, and measurements are made from this mark to the marks A and B.

During initiation, the detonation wave propagating along the charge, on arriving at point B, causes the blasting fuse length 4 to detonate, and then reaching point D, initiates length 5. The detonation waves propagating along these lengths meet at some point K and, producing an instantaenous pressure rise, forms a characteristic dent on the plate, which then is used in measurements when calculating the detonation rate of the test explosive. The measurements between the mark K and the marks A and B on the plate, as well as between the points CD (between the centers of the openings on the tube) must be made with the highest possible precision, since the end result of the detonation rate depends on the precision of these measurements.

The detonation rate is calculated according to the formula

$$D_{\text{[illegible]}} = \frac{D_{ш} L}{L_1 - L_2}, \quad \text{m/sec}, \qquad (20)$$

where L is the distance between the centers of the side openings -- base CD of the tube, m;

L_1 is the distance from the center of the mark K to a point A, plus the length of the fuse segment AB, m;

L_2 is the distance from the center of the mark K to the point B, plus the length of the fuse segment BD, m; and

D is the detonation rate of the blasting fuse, m/sec.

Two parallel determinations are made for each test explosive; the deviation between these must not exceed 1.5 percent, and the mean result is derived. The precision of the detonation rate determination based on the above method, assuming that all conditions of the test are strictly observed, does not exceed the limits ± 3 percent, which is quite sufficient in evaluating the quality of commercial explosives.

Determination of critical diameter

Thus far there is no standard method for this test. Usually, a series of cylindrical charges of different diameters are exploded in sequence to determine detonation completeness. The length of each explosive charge must be 5 times greater than its diameter, and the density of the explosive must be uniform over its entire length. Charges prepared of powdered type explosives are usually tested at a density of 1 g/cm^3, while other explosives are tested at their working density if no specific charge density is specified by the test conditions.

Dependable initiation must be provided for the charges to be exploded. If the test explosive has insufficient sensitivity to a No 8 blasting cap, its charges are initiated via an intermediate detonator, which is recommended to be pressed loads of trotyl, tetryl, or in an extreme case, powdered ammonite weighing 50 g and detonating at a rate that is greater than the detonation rate of the test explosive. If the diameter of the test charge is smaller than the diameter of the initiator (for example, a blasting cap), then a conical or cylindrical dilation of the appropriate diameter and length is made at the charge end, and into it the detonator is emplaced.

The completeness of detonation of the exploded charge is judged by the absence of remains of the explosive and its shell, and also by the presence of explosion traces at the site over a funnel in the ground. A more reliable result can be obtained from the findings of a detonation of a blasting fuse length inserted into the tail end of a charge and buried in the ground.

Based on the results of exploding the preceding charge, the next charge is exploded with a greater or smaller diameter, and in this way the minimum diameter is found for which no less than three parallel experiments show failure-free detonation. This diameter then is taken as the critical diameter. In determining the critical diameter of commercial explosives, charges are tested in paper cases. For some kinds of explosives (granulated and slurry), the critical diameter is also determined in a steel tube with walls not less than 1.5-2.0 mm thick.

If there is no opportunity to carry out a large number of blasts of cylindrical charges to find the critical diameter, the tests are begun with charges of tapered form, in which the diameter of the base must be deliberately larger than the desired critical diameter for the given explosive. The length of the tapered charge must be such that the taper angle of the cone generatrix to its axis is 4-5°; the diameter for which the tapered charge dies out is found from a mark on the residue of a wooden rack placed beneath the charge. This result is regarded as an approximate value of the critical diameter, which is then revised with cylindrical charges.

Determination of critical density

In laboratory conditions, the critical density of many explosives can be determined by testing for brisance using the Hess test of chargers having various densities (Fig. 12). The result of compression of lead cylinders then is plotted on a graph of brisance versus density and the critical density is found from the maximum of the resulting curve. If the test explosive becomes insensitive to a No 8 blasting cap with increase in density, or if the 40 mm charge diameter used exceeds the critical diameter of stable detonation, then in the former case a load of trotyl or tetryl weighing 5-10 g is used in initiation, and in the second -- the charges are placed in a steel shell (ring) with walls 3-4 mm thick. The strong shell extends the upper limit of the critical density. It is recommended that critical density tests be conducted with charges weighing 100 g, by placing two steel disks between them and the lead columns in each case to reduce the overintense deformation of the lead.

Test for shock sensitivity

This test is based on the effect of the impact of a definite weight freely falling from some height onto an explosive layer of specific dimensions, placed between steel surfaces. The measure of sensitivity is the energy of the impact required to initiate the explosion. Pile drivers differing in their dimensions and design of the instrument in which the weighed sample of the test explosive is placed are used in the tests.

In laboratory conditions, tests for sensitivity are carried out on a Kast pile driver with small weighed samples of the explosive (0.05 g), after placing them on a roller instrument and striking a blow against it with a load weighing up to 10 g falling from a height up to 100 cm. This method is standardized (GOST 4545-48). In stand conditions, larger pile drivers are used, with which a load weighing 20-24 kg is dropped from a height of 1.5-2.0 m. They make it possible to raise the weight of the explosive sample to 5-10 g, but owing to the intense blow of the weight, the roller instruments are not used. The explosive placed in a small paper beaker is positioned directly on the anvil and is covered over with a steel plate onto which the load is allowed to drop.

Design of the Kast pile driver. The pile driver (Fig. 23) consists of a massive anvil 1 mounted on a foundation on which a roller instrument 2 containing the weighed sample of the test explosive is placed. The falling weight 3 of the pile driver, by means of a special holder 4, can be secured at the required height between two guide racks 5, measured with rack 6. By pressing against the cable lever, the load slides from the holder and, freely falling along the guides, strikes a blow against the explosive in the roller instrument. To trap the load as it rebounds, a gear rack is provided on the pile driver, and on the load -- a tooth with which it is meshed in the rack.

The roller instrument (Fig. 24) consists of a guide clutch 1 with smooth inner walls, false bottom 2, and two rollers 3 with removed bevels, differing by a high degree of constancy of their mechanical properties and dimensional precision. The rollers slide freely within the clutch. The weighed explosive sample 4 is placed between the rollers. All parts of the instrument are made of high quality steel. The rollers, which serve as a striker and an anvil, after heat-treatment must meet requirements imposed on roller bearings. The cylindrical and face surfaces of the rollers are carefully ground. The roller instrument on the pile driver anvil is centered precisely with respect to the weight by means of the special collar.

Depending on explosive sensitivity, loads of different weights are used with the Kast pile driver and the height from which they fall is varied from 25 to 100 cm. For high-sensitivity explosives (dynamites and so on), a load weighing 2 kg is used; for low- and moderate-sensitivity explosives, the weight of the load is 10 g.

Fig. 23. Pile driver for determining shock sensitivity of explosive

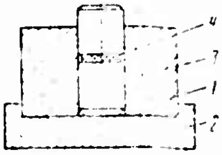


Fig. 24. Roller instrument

There are several methods of estimating the sensitivity of an explosive to an impact with the pile driver. The most common method is one by which the percentage of explosions is determined out of 20, 50, or 100 tests when a load weighing 10 g is dropped from a height of 25 cm. This method, however, hampers the estimation of the sensitivity in those cases when the percentage of explosions is equal to 0 or 100. Therefore, for a more full estimation of the sensitivity, the lower sensitivity limit is additionally determined; beyond this limit the minimum drop height of a load weighing 10 kg is taken as the one for which an explosion occurs in even one of the parallel experiments.

Shock sensitivity depends heavily on numerous factors, in particular, on the condition of the roller surface and the presence of chamfers along the edges, and on the quality of steel from which they are made, as well as the degree of hardening. Of major importance is protection of the explosive against wetting and contamination by foreign impurities during the test period. The test results with the pile driver are usually difficult to reproduce. Therefore they are extremely provisional in nature and serve as a comparative estimate of the sensitivity of a test explosive with the sensitivity of a standard well-known explosive taken as the reference standard. Usually tetryl of a specified dispersion is adopted as the reference standard in laboratory practice. For a more reliable estimation of sensitivity, it is recommended that in parallel with the test explosive tetryl or another well-studied explosive be tested with the same lot of rollers, by alternating the experiments on these explosives. After each experiment the roller surface is cleaned free of explosive residues and soot, and they are carefully wiped with gauze soaked in acetone. During the test, special attention is given to the preparation of the rollers and the condition of their face surfaces.

Under GOST 4545-48, a 0.05 g weighed sample of the test explosive, measured to a precision of up to 0.005 g, is evenly distributed between the rollers of the instrument, which is placed in the centering collar on the pile driver anvil. A 10 g weight is placed at a height of 25 cm and by pressing the release mechanism a blow is struck at the upper roller of the instrument. This determination is repeated 25 times, each time varying the roller instrument, and the percentage of explosions out of the entire number of tests is calculated. The result of the loads striking the explosive is determined by the sound effect, flash, and smoke formation, or by inspecting the remains of the substance in carbonization. If the impact is not accompanied by these features, then it is assumed that a "failure" has occurred. If the percentage of explosions is 100, the pile driver weight is reduced down to 5 kg, and if it is zero, the height of its fall is increased to 50 cm and the tests are repeated in the same order.

The quality of treatment of each lot of rollers is tested by checking the reference standard tetryl explosive for shock sensitivity. It is twice recrystallized from acetone and is sieved through a No 25 silk sieve (mesh opening 0.28 mm). The dust is sieved on a No 32 sieve (mesh opening 0.2 mm). This kind of tetryl must yield 44-56 percent of explosions on a pile driver in given test conditions.

When an explosive is tested with a 5 kg load, hexogen treated by the above-indicated method is taken as the reference standard. When all test conditions are complied with, the hexogen must yield 48 ± 4 percent explosions. When the explosive is tested with a 2 kg weight, sometimes trotyl is taken as the reference standard; when this done, the height from which the weight is dropped must be 100 cm.

The liquid explosive is tested; the weighed sample (two drops) is placed first in a German silver drop cup with the following dimensions: diameter 5.95 mm, height 3.75 mm, and wall thickness 0.15-0.20 mm, which is then inserted in the roller instrument between the striker and the anvil. Then the test is carried out by the usual procedure.

Shock sensitivity tests of explosives are regarded as effective if the results of testing a reference standard explosive can be placed within specified limits.

According to the adopted nonstandard method, shock sensitivity testing of low-sensitivity explosives in a large pile driver is carried out as follows.

A 3 g weighed explosive sample is placed on the anvil of a pile driver in a beaker underneath parchment paper without a bottom, 15 mm in diameter and with a height equal to the height of the explosive layer. The small beaker is covered with a 30 mm diameter hardened steel disk 5 mm thick. Then the blow is struck, by dropping a 24 kg weight from a height of 2 m. From 6 to 25 parallel experiments are carried out, and from these the percentage of explosions is derived.

Testing for sensitivity to friction

Thus far there is no standard test method. Most often, a method based on rubbing the test substance in a special assembly unit (Fig. 25 a) with steel surfaces under a specific load for a moderate period of time is used. The test is carried out in the instrument shown in Fig. 25 b. The criterion of sensitivity is the maximum pressure on the weighed sample of the explosive for which there is no decomposition of the explosive during the rubbing time (decrepitation, deflagration, or explosion).

The test is carried out as follows. A 0.05 g weighed explosive sample is placed in a die 1 (Fig. 25 a) on a false bottom 2 and the entire unit is inserted along guides into the mandrel 3 of an instrument which is secured on its base. Then plunger 4 is lowered into the die up to the stop in the weighed explosive sample using lever 5 hinge-connected with shaft 6 of the instrument. The plunger is connected with the shaft by means of chuck 7. The lever is provided with notches over a certain length of the arm on which load 8 with the required weight is suspended. A set of these weights weighing 5, 10, and 20 kg is provided with the instrument. To perform the test, an electric motor 9 is turned on, which activates shaft 10 of the instrument under load into rotational motion together with the plunger at the speed of 150 rpm and the timer is turned on. The test is continued for 10 seconds. If here no decomposition of the explosive follows, a new weighed sample is taken and the test is repeated under a larger load produced either by increasing the length L of the arm of load application on the lever (maximum length of the lever is 1000 mm, and its left end with counter weight is 200 mm long), or else if this procedure proves inadequate, a heavier weight is used. Thus, the rubbing pressure is increased until an explosion occurs. Then the pressure is gradually reduced until out of six parallel experiments there was not one sign of the decomposition of the explosive. This pressure then is taken as the criterion of friction sensitivity. The pressure is calculated by the formula

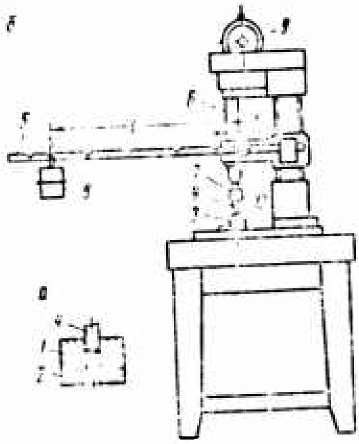


Fig. 25. Instrument for testing explosive for sensitivity to friction:
a — instrument assembly
b — general view of instrument

$$P = \frac{QL}{lS}, \quad \text{kg/cm}^2, \qquad (21)$$

where Q is the weight of the suspended load, kg;
L is the length of the arm of load application (distance from the center of the hinged point of the lever support to the point of load application), cm;
l is the distance from the center of the hinge to the axis of the vertical shaft, cm; and
S is the area of the plunger, cm^2.

To maintain constancy of test conditions in each new experiment, the die, false bottom, and plunger are carefully cleaned free of scale and explosive residue.

Most commercial explosives do not produce explosions when tested by this method even at a maximum pressure of 3000 kg/cm^2. Therefore, when testing all explosives, to their weighed samples is added approximately one-third as much fine sand (screened through a No 40 sieve) which greatly increases sensitivity. This method produces only a relative estimate of the friction sensitivity of various explosives in given test conditions. For a comparison, usually tetryl is taken as the reference standard; with this instrument, when sand is added tetryl produces explosions for a load of 540 kg/cm^2.

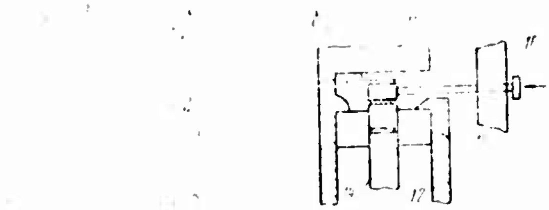


Fig. 26. K-44-111 pile driver for testing explosive for sensitivity to sliding shock:
a -- general view of pile driver
b -- working assembly pile driver
1 -- hydraulic press
2 -- oil pump
3 and 4 -- low- and high-pressure piston handles
5 -- port for placement of instrument
6 -- pendulum with load
7 -- instrument ejector
8 -- handle for rolling instrument casing
9 -- handle
10 -- sliding roller
11 -- stop
12 -- fixed roller
13 — explosive
14 — hydraulic press plunger
15 -- clutch
16 -- rod with head transmitting impact

In the manufacture and use of explosives, often a sliding blow is used, producing friction between particles of the explosive or between them and the surface of colliding bodies. To determine the sensitivity to this kind of action, a K-44-III pendulum pile driver is used (Fig. 26 a). The layout of the main assembly of this pile driver is shown schematically in Fig. 26 b. An 0.05 g weighed explosive sample in this assembly is compressed between two rollers 10 mm in diameter to a specified pressure by means of a hydraulic press. When the falling weight of the pendulum strikes a lateral blow against the striker in the direction of the arrow, the upper roller is shifted relative

Fig. 27. Dolgov bomb. Test of freely suspended charge:

1 -- body of steel bomb
2 -- electric detonator
3 -- charge

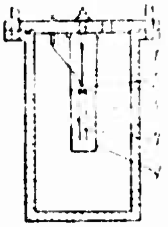


Fig. 28. Dolgov bomb. Testing in sand:

1 -- body of steel bomb
2 -- electric detonator
3 -- charge
4 -- paper case
5 -- sand

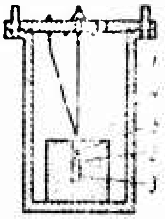


Fig. 29. Dolgov bomb. Testing in lead or rock block

1 -- body of steel bomb
2 -- electric detonator
3 -- charge
4 -- lead or rock block
5 -- sand stemming

to the lower roller, subjecting the explosive sample to the action of rubbing shear. The probability of the explosion depends on the pressure with which the weighed explosive sample is squeezed between the rollers. By varying this amount, one finds the lower, middle, and upper limits of sensitivity of the test explosive, that is, those pressure values for which the frequency of explosions is 0, 50, and 100 percent.

Determination of gas hazard (amount of toxic gases)

The composition and amount of toxic gases formed in blasting work is determined by laboratory and production methods.

Laboratory methods are used when explosives are used in small charges. The blasts are conducted in Dolgov or Bichel bombs in which the charges are placed in blocks made of various materials or rock, in sand, or in a lead block (Trauzl bomb) to simulate production conditions (Fig. 27).

Blasting in box of rock or other materials placed in a 50 liter capacity Dolgov bomb or in a 15 liter capacity Bichel bomb is illustrated above (Figs. 28 and 29).

A 20 g explosive charge is placed in a special blasthole 25-36 mm in diameter and 100-120 mm in depth, made in a rock block. The test block containing the explosive charge is placed in the channel of a bomb, hermetically sealed with a cover, and is blasted at atmosphere pressure. Eight minutes after the explosion the gas pressure in the bomb is determined and the gaseous products are sampled. Nitrogen oxides are collected in 500 cm^3 burette in which 0.05 N (normal) alkali solution had been poured in advance. Before sampling, air is evacuated from the burette to a residual pressure of 5-10 mm Hg. Samples for carbon monoxide taken in rubber bladders. Sulfur gases are collected in evacuated glass bottles in which either a 5 percent solution of Bertholet salt (for sulfur dioxide) or a 0.2 percent solution of sodium arsenate in a 0.5 N sodium carbonate solution (for hydrogen sulfide) had been placed in advance.

Carbon monoxide is analyzed by one of the following methods: on a gas analyzer designed by the Institute of Hygiene imeni Erisman, by the Reberg method, or else by a conductometric method.

The gas analyzer designed by the Institute imeni Erisman consists of a column intended for catalytic combustion of CO to CO_2, absorption of the resulting carbon dioxide with barium hydroxide, and an aspirator for sucking an air sample into the instrument and measuring its amount.

The carbon monoxide content is determined on a Reberg apparatus based on the principle that air containing CO is passed through a reaction tube containing iodine pentoxide heated to 130-150° C. The reaction can be described as follows:

$$I_2O_5 + 5CO \rightarrow 5CO_2 + I_2 \qquad ([illegible])$$

The CO_2 gas formed is absorbed by a titrated barium hydroxide solution, forming barium carbonate. The carbon monoxide level is found by the $Ba(OH)_2$ titer drop.

Underlying the conductometric method is the measurement of the electroconductivity of the absorber solution, which by passing continuously over the droplet pump sucks in the air to be examined. Since at constant temperature change in the electroconductivity of the solution depends only on its concentration of a specific compound, the electroconductivity readings alternately serve as a measure of the concentration of this substance.

In conducting the experiments, a conductometric stand is used; in it, CO is oxidized to CO_2 in advance with iodine pentoxide; the CO_2 is absorbed by a NaOH solution. All changes in the electroconductivity of CO_2 are measured.

The nitrogen oxides are analyzed using a Griss-Ilosvay reagent by the calorimetric method using a special scale.

The amount of sulfur gases is determined overall for sulfur dioxide and hydrogen sulfide using hyposulfite and iodine solution.

Blasting in a sand shell. By this method (proposed by B. Ya. Svetlov), the test charge is placed in a glass or lead vessel containing sand in such a way that the charge is completely surrounded by sand. The vessel is placed in a Bichel bomb and is exploded in vacuum. The test method is the same as above, with the exception of the determination of nitrogen oxides, using a saturated solution of nitrogen sulfite.

Method of exploding an explosive in a lead block (P. A. Paramonov method). The test explosive is placed in charges weighing 10 g and 20 g in the channel of a 25 mm diameter ead block, 125 mm in depth. The block size is 100x100 mm; it is placed in a Dolgov bomb and the charge is exploded in a nitrogen atmosphere at an excess pressure of 150-200 mm Hg. The sampling technique and the methods of analysis are the same as above.

The amount of toxic gases is determined by production methods directly in mine workings during the carrying out of blasting operations. The toxic gases formed in an explosion are determined in field conditions by a unified method adopted by all laboratories of the VGSCh [militarized mine rescue units], referred to as the chamber method.

It is based on determining the concentration of toxic gases in an isolated chamber, which is a segregated part of an underground dead-end working. The isolation of the chamber is achieved by dividing part of the mine working using a curtain made of gas-tight cloth (canvas or rubberized cloth).

A set of blastholes is drilled into the blind end of the working; they are charged and exploded by the electrical method. Immediately after the blast, the curtain is lowered, gases are mixed in the insolated chamber, and then samples are taken for analysis.

The dead-end working for the chamber must be horizontal or inclined by an angle not greater than 30°, with a cross-section of 4-10 m^2; the length of the chamber is within the limits 15-40 m, and its volume 60-450 m^3. The distance from the curtain to the ventilation working is not less than 50 m.

The sampling of the noxious gases for CO is carried out in 2-3 l football bladders or rubber bags 0.5 l in capacity; for the nitrogen oxides -- in evacuated 0.25 l or 0.5 l bottles containing a solution of 0.1 N KOH or NaOH in the amount of 10 or 20 ml; and for sulfur gases -- in doubled Petri dishes.

Carbon monoxide is analyzed by a conductometric method or by the Reberg method, hydrogen oxides -- by the Griss-Ilosvay method, and sulfur gases are determined as a total (SO_2 and H_2S) using the same method as in the laboratory.

The calculation of the content of toxic gases obtained in laboratories as well as in field conditions is based on the following formulas.

In laboratory conditions, we have

$$X_{CO} = \frac{a \cdot 10 \cdot 0.0\text{[illegible]} \cdot V_{a}}{P \cdot 100}, \quad \text{l/kg}, \tag{23}$$

where a is the concentration of carbon monoxide, mg/l;
0.08 is the conversion factor for recalculating the gravimetric amount of CO into a volumetric amount, percent;
V is the volume of the bomb channel after subtracting the volume occupied by the rock block, liters;
w is the pressure of the gases in the bomb after the explosion, atmospheres; and
P is the weight of the charge, grams.

$$X_{NO_2} = \frac{b\cdot 1000\cdot 0.053\cdot Vw}{P\cdot 100}, \quad 1/\text{kg}, \qquad (24)$$

where b is the concentration of the nitrogen oxides, mg/l; and
0.053 is the conversion factor for recalculating the gravimetric amount of NO_2 into a volumetric amount, percent.

$$X_{SO_2+H_2S} = \frac{c\cdot 1000\cdot 0.035\cdot Vw}{P\cdot 100}, \quad 1/\text{kg}, \qquad (25)$$

where c is the concentration of the sulfur gases, mg/l; and
0.035 is the conversion factor for recalculating the gravimetric amount of sulfur gases into a volumetric amount, percent.

In field conditions, the same formulas are used in calculating the gases, with the only difference that w is omitted in these formulas, and the letter V denotes the volume of the isolated chamber in which the blast is carried out.

Thus
$$X_{CO} = \frac{a\cdot 1000\cdot 0.08\cdot V}{P\cdot 100}, \quad 1/\text{kg}, \qquad (26)$$

The overall amount of toxic gases formed in exploding 1 kg of explosive when calculated to standard carbon monoxide is found by the formula

$$S = X_{CO} + 6.5X_{NO_2} + 2.5X_{SO_2+H_2S}, \quad 1/\text{kg}, \qquad (27)$$

6.5 and 2.5 are the toxicity factors of nitrogen oxides and sulfur gases with respect to carbon monoxide; and
S is the overall amount of toxic gases when recalculated for standard carbon monoxide.

Chamberless method. The chamberless method developed by the MakNII makes it unnecessary to build a hermeticized chamber and reduces to determining the dependence of the concentration of the test gas on the amount of air supplied into the ventilated working. If the amount of supplied air per unit time is constant, the gas concentration depends on the ventilation time. This function is determined by measurements in the dead-end working ventilated by delivery at a distance of from 50 to 100 m from the face.

The amount of air supplied to the working to dilute the explosion gases is calculated by the formula

$$Q = U_{cp} S, \ m^3, \qquad (28)$$

where U_{cp} [cp = average] is the air velocity, m^3/sec.

Simultaneously with calculating the amount of air supplied into the working, air samples are taken over the cross-section of the working at the required time intervals. Carbon monoxide is determined by a rapid linear-calorimetric method from the time the explosion gases arrive up to their disappearance. The method of analysis based on preparing a colored column of an indicator tube, whose length is proportional to the concentration of carbon monoxide sucked through the given tube. The method is based on the color reaction of carbon monoxide with iodine pentoxide dissolved in sulfur trioxide. Calorimetry is carried out based on the precipitated iodine, which in the presence of sulfur trioxide is colored bluish-green.

Nitrogen oxide samples are analyzed by the Griss-Ilosvay method.

Based on data of the analysis and measurement of air, a plot is made of the dependence of the carbon monoxide concentration on the amount of air supplied into the working; from this plot the volume of the carbon monoxide formed is calculated by determining the area of the figure bounded by the curve (Fig. 30).

Nitrogen oxide samples are taken during the first 10 minutes from the moment the leading front of the gas wave reaches the measurement site. In the analysis, the mean concentration of nitrogen oxides is determined when recalculated on the basis of carbon monoxide, and from this value the mean concentration of carbon monoxide is found; the concentration ratio NO/CO is determined for this same amount of supplied air.

Based on this method and the earlier found volume of CO, the volume of NO formed in the explosion is determined. By dividing the volume of carbon monoxide and the volume of the nitrogen oxides by the weight of the exploded explosive, one determines the amount of noxious gases.

The gases contained in underground workings, including carbon monoxide, have been analyzed in recent years by means of chromatographs of various designs.

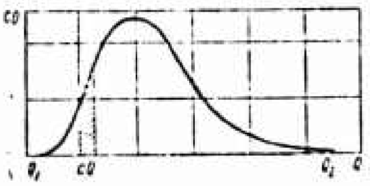


Fig. 30. Plot of the dependence of CO concentration on absolute amount of gas supplied into working

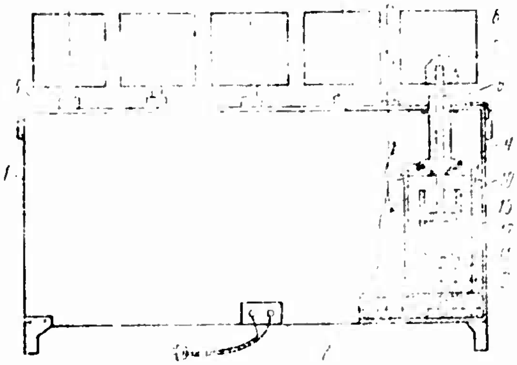


Fig. 31. Instrument for testing explosive for caking when exposed to variable humidity, temperature, and compressive load

Test for caking tendency

The caking tendency of commercial explosives depends on the moisture content, temperature, dispersion of the explosive, compressive load, and other factors that must be taken into account when estimating this effect. These factors are allowed for more fully by the following laboratory method that is instrument-based (Fig. 31). Weighed samples of the test explosive heated in advance and moistened to the required temperature and moisture content are subjected to simultaneous crushing and slow cooling in a special instrument assembly, followed by drying for certain period, that is, they are tested in conditions that are most common in the practice of storing explosives.

The instrument consists of a heat-insulated case 1 fitted in its bottom with an electric spiral heating element 2. The case has five pairs of recesses in which the assembly units containing the weighed samples of the test explosives

Fig. 32. Pestov instrument for caking explosive at room temperature.

Assembly details:

1 -- pan
2 -- split die
3 -- collar for blocking die
4 -- miniature piston under load-bearing rod

are placed. The instrument is capable of testing simultaneously five different explosives with two parallel samples of each. Calcium chloride 3 is placed on the bottom of the recesses under the false bottom to dry the explosives during the experiment. After an assembly unit containing the weighed explosive sample is put into place, the recess is covered tightly with cover 4, provided in its center with an opening fitted with a stuffing box seal. The instrument is covered with a general cover 5 provided with ten guide bushings 6, through which rods 7 are lowered, passing also through the openings in the recess covers, up to the stop in the explosive being compressed in the assembly unit. A load 8 weighing 5 or 10 kg is fitted onto each rod. The center of the instrument cover has a recess to accommodate the thermometer 9.

The assembly consists of a cylindrical die 10, whose diameter from top to bottom increases from 30 to 30.5 mm, and the entire internal surface is polished to facilitate releasing the sample without damage after caking. The die is 60 mm high and its walls are 6 mm thick. The matrix is placed tightly against the false bottom 11, that has three legs and 1 mm diameter openings over its entire bottom section through which calcium chloride absorbs moisture from the explosives. Over the explosive sample 12 a miniature piston 13 with 1 mm diameter openings is placed into the die. The center of the ministure piston has a depression in which the rod bearing the weight rests during the experiment.

The weighed sample of powdered or granulated explosive, 30 g, moistened in the dessicator over water or artificially to the required moisture content, is heaped into the die of the assembly placed on the false bottom, on which a disk of filter paper is placed. The explosive layer in the die is levelled, and then it is covered over with disks of 29 mm diameter filter paper. All ten assembly units are prepared in the same manner and they are placed in the corresponding recesses of the instrument, which has been heated in advance to 60° C. Then covers are placed on the recesses, the instrument cover is fitted and tightened on the loops, and through the guide bushings are inserted rods on which weights of the required amounts are fitted. In this condition, a temperature monitored with the thermometer is maintained in the instrument for 2 hours using a laboratory autotransformer. Then, the electric heating unit of the instrument is turned off and the test specimens are allowed to cool slowly (owing to the good heating insulation of the instrument case) and to dry while being exposed to the compressing load. The test explosives are kept in the instrument for 2 days, then the instrument is dismantled, the caked explosive samples are carefully expelled from the dies, the height of the loads formed is measured, and are either directly subject to crushing on a sensitive laboratory press, or (when there is high initial moisture content in the explosive) they are dried in a dessicator over calcium chloride. A measure of the caking tendency is the maximum crushing pressure of the load (kg/cm^2),

Explosives which cake strongly in actual conditions cake to a crushing pressure of 10-20 kg/cm^2 in the conditions of a given instrument, while low-caking explosives cake to a crushing pressure of 0.5-2.0 kg/cm^2.

To simplify determining the caking tendency, a Pestov instrument can be used (Fig. 32); however, in this instrument is not possible to allow for the effect on the caking tendency of variation in the explosive temperature during the crushing time. The arrangement of the assembly of this instrument is similar to the layout described above, but the test method differs somewhat. Friable samples of test explosives are moistened in advance outside the instrument, or else in the instrument assembly units. In the latter case weighed samples of explosive are kept for some time in the assembly units (12-24 hours) in the instrument under a hood over a cell containing water, and then the water is replaced with concentrated sulfuric acid, the samples are loaded with weights, and they are again exposed for 2 to 3 days for drying and caking. Caked specimens are removed from the instrument, dried in the dessicator, and crushed on the press.

From the crushing force in the press it can also be found how strongly an explosive cakes during storage. To do this, several caking cartridges are sampled from a lot, the paper cases are removed from them, and from two ends and the middle of each specimen small columns of explosive 25-30 mm high are sawed off. These small columns can also be drilled when a suitable probe is available also from caking crumbs of uncartridged explosive.

In the absence of suitable tools, the cartridge caking tendency can be estimated roughly by the ability to be kneaded in the hand and from the results of firing off to transmit detonation. The cartridges are regarded as being heavily caked if they cannot be crushed manually with a single hand after the cases have been removed, or if they show a transmission of detonation by a distance smaller than the rated data. Noncartridged explosive in field conditions can be tested for caking tendency by dropping bags of explosive from a height of 1.5 m onto a solid base followed by a count of large crumps and screening of fines through a sieve with 10 mm mesh openings. Caking tendency can also be estimated from the work required in manual fragmenting of bags of caked explosive that must be done before charging.

Determination of friability

A true characteristic of friability of ammonium nitrate mixed explosives is quite difficult to obtain, since the friability of these mixtures is inconstant and depends on numerous factors. Thus far there is no unified method of determining friability. Usually, the friability characteristic of a test explosive is found based on the total test results using a number of methods. Fairly readily friable coarse-grain and granulated explosives are tested for friability based on the time required for a 0.5-1.0 kg weighed sample to fall from a funnel (Fig. 33), that has a taper angle of the smooth interior surface of 60° and an opening 20 mm diameter with round edges. The funnel can be glass or aluminum with polished surface. To test poorly friable explosives, the funnel is placed on a vibratory table which has a specific vibratory rate adopted as the constant.

Other method of testing friability is to determine the angle of inclination of a smooth or rough surface on which an explosive begins to pile up when placed in a layer of specific thickness onto this surface. This test can be carried out with an uncomplicated instrument, shown in Fig. 34. A layer of explosive 10 mm thick is placed on a horizontal area and then with a uniform rotation of the flywheel the area is gradually raised until the explosive begins to pile up. The angle by which the area is rotated about its axis is determined on a scale with instrument mounted on this axis. The value of this angle then characterizes the friability of the explosive. A third indicator of the friability of an explosive can be the angle natural repose, which is determined simply without special instruments by heaping an explosive from a specific height and by measuring the angle of repose of the pile (cone) formed with a goniometer or by calculation (based on the height and diameter of the cone base). This can be done simultaneously with the determination of friability with a funnel. Finally, the friability of the explosive can be characterized by its ability to be pneumatically conveyed through charging hoses during mechanized charging.

Fig. 33. Funnel on stand for determining the friability of an explosive

Fig. 34. Platform area with adjustable angle of inclination for testing an explosive for friability

Determination of stability

There are no satisfactory rapid methods of estimating the ability of the properties of commercial explosives.

Stability is checked during the guarantee periods of use of an explosive or in order to establish these periods (for newly developed explosives) most often by storing the product in conditions approximating the actual conditions of its storage by the user, that is, in the corresponding packing and with the required temperature and humidity of the air in the storage site being maintained. After the storage, a test is made of the explosive and physicochemical properties, and the test results are compared with results obtained from similar tests before the explosive was stored. The stability of the explosive is evaluated by the reduction in the initial characteristics.

A fuller estimate of the stability of an explosive can be found from the result of its storage by usersfor the required period of time.

To verify the persistence of the main standardized indicators of plant lots of explosive, the corresponding standards provide for repeat tests for the main technical indicators of arbitrary samples from these explosive lots stored for the guarantee period at the plant warehouse. Here no reduction in the property indicators is allowed (compared to the established technical norms).

From existing rules, in all cases when there are any doubts about an explosive, it must be checked for moisture content and detonation transmission prior to use.

Determination of heaped density

Heaped density is defined as the ratio of the weight of an explosive freely heaped into a cylinder to the cylinder volume it occupies. A special instrument (cf. Fig. 15) is provided for this purpose, and in its absence an ordinary glass cylinder with 100 or 200 cm^3 divisions can be used. The heaped density, in addition to everything else, depends on the height of the column of explosive, therefore its values found in laboratory conditions will deviate somewhat from the values obtained in actual conditions, for example, for heaping into a deep drillhole.

More constant density values of a test explosive are obtained if after heaping of the weighed sample into a graduated cylinder it is compacted by rapping until the volume occupied by the explosive in the cylinders ceases to decrease. For this purpose, by grasping the upper face of the cylinder with the palm of the hand, sharp, quite vigorous blows are made with its bottom against a rubber gasket on a solid base. In this way the rapping density is determined, which in addition to the heaped density characterizes the volumetric properties of the explosive.

Determination of dispersion and granulometric composition

The dispersion of fine-ground ammonium nitrate explosives can be determined with available special instruments by measuring the specific surface area. Less precisely, but on the other hand much more simply, the dispersion characteristic can be obtained by sieve analysis on a set of sieves with small intervals of mesh size between adjoining sieves. The sieving of a weighed explosive sample of 100 g is usually done mechanically in identical conditions. To do this, the set of sieves used for this purpose is secured on a jostling instrument and it is switched on for a certain amount of time that provides for total sieving of the corresponding fractions. Then, the residues on each sieve are weighed and the percentage content of the fractions whose particle size corresponds to the mesh size of the above-lying sieve is found. The set of sieves used in analyzing fine-disperse explosives usually includes silk or metal sieves with mesh openings of the size 0.5, 0.22, 0.104, and 0.077 mm (sieves Nos 15, 29, 49, and 61). Sieves with mesh openings of 4, 0.9, and 0.5 mm are used for granulated explosives.

The granulometric composition of grained or granulated explosives is determined by GOST 14839.17-69 by sieve analysis using the appropriate set of sieves, to a fairly good precision. The result of analysis is either expressed by the percent of individual fractions obtained on each sieve, or else a complete particle distribution curve is plotted with size as the x coordinates.

Fig. 35. Penetrometer for
determining plasticity

Determination of plasticity and fluidity

The plasticity of an explosive of appropriate consistency is checked with several nonstandard laboratory methods. The plasticity of akvanites and dynamites can be determined with some precision on a penetiometer (Fig. 35) by measuring the depth of penetration of a loaded rod with a ball at its end into a mass of the test explosive in a specific period of time, or by measuring the degree of compaction of a column of this explosive having a diameter and height in the range 10–20 mm when a given load is applied on it for a specific time interval. In the latter case, in place of the ball at the end of the rod, a platform is secured with a diameter somewhat larger than the diameter of the explosive column. The load and the time during which it is applied on the test specimen are found ahead of time by trial and error, in relation to the consistency of the explosive. With the penetrometer, the plasticity of explosive samples is determined at room temperature or else after exposure in a thermostat.

In field conditions the plasticity of an explosive is estimated subjectively by the ability of cartridges to be manually kneaded and to be molded into a blasthole or a drillhole by being pressed with a stemmer.

The fluidity of slurry akvatols is determined in laboratory conditions by measuring their flow rate from glass calibrated test tubes inclined at a specific angle to the horizon. The fluidity of an explosive is measured at room temperature, or lower.

Test for exudation

Exudation can occur due to several factors: migration owing to capillary forces, displacing by moisture during moistening, flow due to gravity, compression on exposure to external loads, and so on. No all the factors listed are accounted for by currently used methods of determining exudation.

The exudation of nitro ester explosives is checked by several methods. In the laboratory determination, a small cylinder 30 mm high is cut from the cartridge, placed on a sheet of parchment paper and kept in a thermostat at 30-33° C for 6 days. The explosive is assumed to have passed the test if no drops of the nitro ester are visible on the paper beneath the cylinder. A barely detectable patch at the site of the cylinder is acceptable. If plastic dynamite undergoes testing, then in addition the height of the small cylinder must not be reduced by more than 25 percent of its initial value. When an explosive with a low nitro ester content is tested (uglenites or detonites), to determine the amount of segregated liquid, tared disks of filter paper are placed on the parchment paper under the small cylinder, and the liquid is soaked into this paper.

When nitro ester explosives are stored in users' storerooms and before use, exudation in cartridges is determined from patches or droplets of nitro esters on the inner surface of a unrolled paper case of a cartridge, especially at the place where the paper layers are joined. An explosive is regarded as not exuding if no clear signs of the presence of nitro esters are detected on the shell. Only a glistening band along the cartridge not more than 5 mm wide at the joining line of the edge of the paper case with the next overlying paper layer is permitted.

The same method is often used in laboratory studies as well when testing freshly prepared nitro ester explosives for exudation. Here, to cause exudation cartridges are frozen several times and then are kept at elevated temperatures.

The exudation of granulites and other explosives containing liquid petroleum products is checked by exposing a layer (column) of these explosives 200-500 mm in height in a glass cylinder or a polyethylene tube at room temperature for 10-15 days, followed by chemical analyses of samples taken from the top, from the middle, and from the bottom of the layer, to find the content of the liquid component.

In field conditions, exudation of oil-containing noncartridged explosives is estimated by visual inspection of the oiliness of various layers of the explosives contained in the layers.

CHAPTER VI
INITIATORS

21. Classification of Initiators

Initiators are designed to provide for the detonation of commercial explosives.

The following groups of initiators are produced:

1. Blasting caps (GOST 6254-62).
2. Electric detonators.
3. Detonating fuses (GOST 6169-54).
4. Safety fuses (GOST 3470-55).
5. Devices for ingiting safety fuses.

Electric detonators are subdivided into the following groups: instantaneous-action (GOST 9089-63), short-delay action, and delay action.

Initiators include the following: electric igniting tubes; safety fuse electric igniters; electric igniting cartridges; and igniting cartridges.

The delay relay of a KZDSh detonating fuse designed for short-delay blasting with a detonating fuse is considered together with detonating fuses.

22. Explosive Used in Making Initiators

Initiating explosives -- mercury fulminate, lead azide, and lead trinitroresorcinate -- are used in blasting caps and electric detonators as primary charges, while brisant explosives -- tetryl and sometimes hexogen -- are used as secondary charges.

The core of a blasting fuse consists of a TEN, and the core of a safety fuse consists of black powder.

TABLE 37. CHARACTERISTICS OF EXPLOSIVES USED IN INITIATORS

Показатели 1	Взрывчатые вещества 2					
	Гремучая ртуть 3	Азид свинца 4	Тенерес 5	Тетрил 6	ТЭН 7	Гексоген 8
Теплота взрыва, *ккал/кг* 9	405	381	418	1078	1410	1310
Объем газов, *л/кГ* 10	316	308	448	412	780	890
Температура взрыва, *град* 11	4450	4300	3030	3810	4000	3850
Давление при взрыве, *кГ/см*^{2} 12	8800	7000	17900	25900	43480	40000
Работа, *кгм* 13	176600	164000	191800	492700	610000	565000
Плотность, *г/см*^{3} 14	3,5	4,6	2,9	1,0	1,0	1,05
Кислородный баланс, % 15	—11,8	—	—56,0	—47,4	—10,1	—20,1
Скорость детонации, *м/сек* 16	5400	5300	5200	7200	3200	8300
Работоспособность, *см*^{3} 17	110	115	110	350	500	520
Температура вспышки, *град* 18	165	327	270	195	220	203,5
Чувствительность к удару (высота падения груза) 2 *кг* 19	2	4	11	30	30	30
Чувствительность к огню и повышенной температуре 20	22 Очень чувствителен			23 Чувствителен		
Чувствительность к пониженной температуре 21	23 Чувствителен	24 Не чувствителен				

KEY:
1 -- Indicators
2 -- Explosives
3 -- Mercury fulminate
4 -- Lead azide
5 -- Teneres
6 -- Tetryl
7 -- TEN
8 -- Hexogen
9 -- Heat of explosion, kcal/kg
10 -- Volume of gases, l/kg
11 -- Explosion temperature, deg
12 -- Pressure during explosion, kg/cm^2
13 -- Work performed, kgm
14 -- Density, g/cm^3
15 -- Oxygen balance
16 -- Detonation rate, m/sec
17 -- Efficiency, cm^3
18 -- Ignition point, deg
19 -- Sensitivity to shock (fall height of 2 kg load)
20 -- Sensitivity to flame and elevated temperature
21 -- Sensitivity to reduced temperature
22 -- Highly sensitive
23 -- Sensitive
24 -- Not sensitive

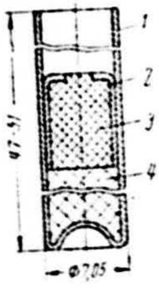


Fig. 36. No 8-M blasting cap:
1 -- case
2 -- small cup
3 -- mercury fulminate
4 -- tetryl (sometimes hexogen)

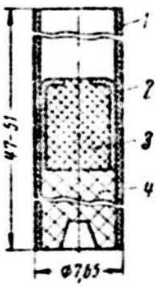


Fig. 37. No 8-B blasting cap:
1 -- case
2 -- small cup
3 -- mercury fulminate
4 -- tetryl

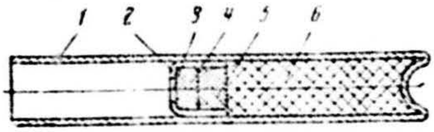


Fig. 38. No 8-A blasting cap:
1 -- case
2 -- small cup
3 -- silk screen
4 -- teneres
5 -- lead azide
6 -- tetryl

Characteristics of initiating and other explosives used in various kinds of initiators are given in Table 37.

Initiating explosives in the powdered state are highly sensitive: they are easily exploded upon impact, friction, jarring, explosure to flame, or to sparks. In the pressed state their sensitivity to external forces is somewhat reduced.

Initiating explosives are not hygroscopic, but they can become dampened. Moistened mercury does not detonate, but deflagrates; lead azide detonates without failure for a moisture content up to 30 percent.

Initiating explosives used in initiators as primary charges detonate directly upon being subject to impact, friction, or heating. Explosives used in secondary charges detonate from the explosion of primary explosive charges.

23. Blasting Caps

A blasting cap is a device for initiating the detonation of an explosive, consisting of a metal or paper case loaded with initiating explosive (Figs. 36, 37, and 38).

The case is filled with explosive roughly to two-thirds of its length; tetryl (sometimes hexogen) is in its lower section (considered from the bottom), and its upper section is filled with mercury fulminate or lead azide charge tegether with lead trinitroresorcinate, which is pressed down all over the lead azide in order to ensure failure-free detonation of the charge from the sparks of the safety fuse.

The primary charge in the case is covered with a metal cup provided with a center opening. It reduces the danger of an explosion from friction when the safety fuse is inserted and provides a strong chamber for maximum gas pressure during detonation.

A free space 17-23 mm long is left between the bore of the case and the cup, intended to accommodate the safety fuse.

Blasting caps are extremely sensitive to shock, friction, and flame; they must be guarded against becoming wet. Wet mercury fulminate pressed into a copper case or a cup forms extremely sensitive copper fulminate, while wet lead azide in an aluminum cup or case forms hazardous aluminum azide. On exposure to sunlight, the sensitivity of blasting caps to external forces rises.

Blasting cap parameters are given in Table 38.

Packing. Blasting caps are packed vertically, 100 at a time in metal or cardboard boxes, or in turn are placed 10 at a time in metal boxes; the boxes are packed in wooden crates. The capacity of a crate is 5000 blasting caps.

They withstand testing by jarring for 5 minutes.

The guarantee period of storage is 2 years.

The wholesale price of 1000 blasting caps in paper cases is 21 rubles, and in metal cases -- 32 rubles.

TABLE 38. CHARACTERISTICS OF BLASTING CAPS

Вид капсюль-детонатора 1	Состав, г 2				Материал гильзы 7	Размеры гильзы, мм 8	
	3 Тетрил	4 Гремучая ртуть	5 Азид свинца	6 Тенерес		—	Внешний диаметр 9
Гремучертутно-тетриловый № 8М . . 10	1	0,5	—	—	Медь 14	47	6,9
Гремучертутно-тетриловый № 8Б 11 . .	1	0,5	—	—	Бумага 15	49	7,5
Азидотетриловый № 8А 12	1	—	0,2	0,1	16 Алюминий	47	6,9
Азидотетриловый № 8Б 13	1	—	0,2	0,1	Бумага 15	49	7,5

KEY:	
1	Kind of blasting cap
2	Composition, g
3	Tetryl
4	Mercury fulminate
5	Lead azide
6	Teneres
7	Case material
8	Case dimensions, mm
9	External diameter
10	No 8M mercury fulminate-tetryl
11	No 8B mercury fulminate-tetryl
12	No 8A lead azide-tetryl
13	No 8B lead azide-tetryl
14	Copper
15	Paper
16	Aluminum

24. Electric Detonators

An electric detonator is a device for igniting the detonation of an explosive, consisting of a blasting cap and an electric igniter. They are manufactured in the instantaneous, short-delay, and delay action modifications.

An instantaneous-action electric detonator consists of a blasting cap in whose case is mounted an electric igniter.

An electric igniter consists of an incandescence bridge, an igniting head, a relieving bridge, a plastic plug, and lead wires. The incandescence bridge is made of 30-35 micron diameter nichrome wire. The fastening of the bridge to the lead wires can be elastic or rigid.

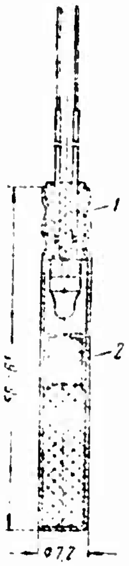


Fig. 39. ED-8PS Nonwater-resistant electric detonator:
1 -- electric igniter
2 -- blasting cap

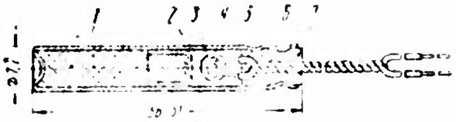


Fig. 40. ED-8-E electric detonator (with elastic mounting of incandescence bridge):
1 -- blasting cap
2 -- nitro varnish
3 -- incendiary composition
4 -- igniting composition
5 -- incandescence bridge
6 -- wire
7 -- plastic plug

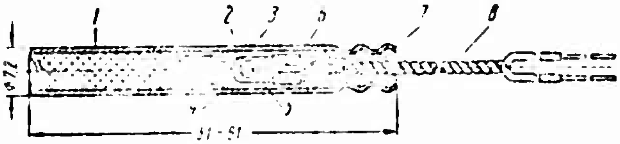


Fig. 41. ED-8-Zh electric detonator (with rigid mounting of incandescence bridge):
1 -- blasting cap
2 -- nitro varnish
3 -- incendiary composition
4 -- igniting composition
5 -- incandescence bridge
6 -- body
7 -- plastic plug
8 -- wire

The igniting head of the electric igniter is of the double-layer type; the inner layer is made of a readily flammable composition, and the outer layer is made of a composition that produces a strong shaft of fire.

The lead wires of electric detonators are made of copper or steel tinned strands. Electric detonator is used in mines that are dangerous in terms of gas or dust must have single-strand copper lead wires.

Copper wires have a strand diameter of 0.5 mm and a resistance of 0.09 ohms/m, while steel wires have values of 0.6 mm and 0.4-0.5 ohms/m, respectively.

The lead wires must have a plastic insulation (polychlorovinyl or polyethylene) or cotton.

The lead wires are 1-4 m in length. Their free ends are stripped of insulation, joined, and then the wires are turned into a small coil.

The electric igniter in the case of the blasting cap is fastened by gripping the case with a plastic plug pressed onto the lead wires when hot. The length of the plastic plug is 11-20 mm.

Instantaneous-action electric detonators are made in the following grades: ED-8-3PS -- nonwater-resistant (Fig. 39); ED-8-E and ED-8-Zh are water-resistant (Figs. 40 and 41); EDS -- seismic (Fig. 42); ED-8-P-59 and ED-8P -- safety (Figs. 43 and 44); and ED-8-PM — safety, high-strength (Fig. 45).

The main characteristics of these electric detonators are as follows: resistance -- 2-4.2 ohms (with copper strand) and 2.9-9.5 ohms (with steel frame); trigger time 2-10 msec; ignition impulses -- 0.6-2.5 (a^2·msec); safe current strength 0.18 a; detonates failure-free in series-connected groups of 20 from a 1 a dc after being exposed in water to a depth of 2 m for 3 hours, and in groups of 4 from condenser type blasting machines.

Lead plates 5 mm thick are perforated; high-strength electric detonators penetrate 6 mm lead strips; they are safe to handle and to transport; they withstand shaking in the adopted packing for 10 minutes; they are not triggered when suspended to wires of an electric detonator when struck by a 3 kg weight from a height of 0.5 m. The guarantee period of storage is 1.5 years.

Characteristics of individual electric detonator grades. ED-8-3PS (nonwater-resistant) is used with a copper wire in a cotton insulation impregnated with paraffin (sounding wire).

It is intended for working dry faces in underground and open-pit operations.

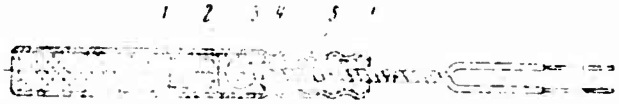


Fig. 42. EDS electric detonator:
1 -- blasting cap
2 -- nitro varnish
3 -- igniting composition
4 -- incandescence bridge
5 -- wire
6 -- plastic plug

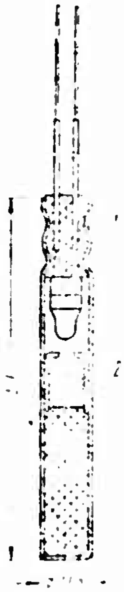


Fig. 43. ED-8P-59 water-resistant, safety electric detonator:
1 -- electric igniter
2 -- blasting cap

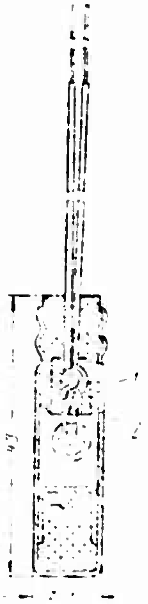


Fig. 44. ED-8P (armored) electric detonator:
1 -- blasting cap
2 -- electric igniter

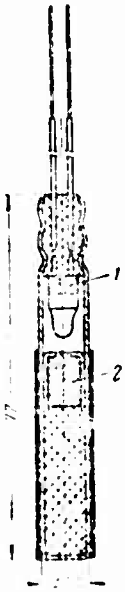


Fig. 45. ED-8PM water-resistant, high-strength, safety electric detonator:
1 -- electric igniter
2 -- blasting cap

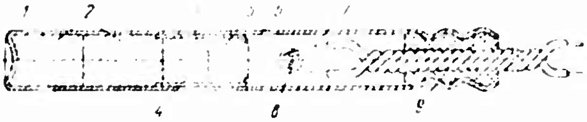


Fig. 46. EDKZ short-delay electric detonator:
1 -- case
2 -- tetryl
3 -- cap
4 -- lead azide
5 -- delay composition
6 -- silk screen
7 -- electric igniter
8 -- incendiary composition
9 -- plastic plug

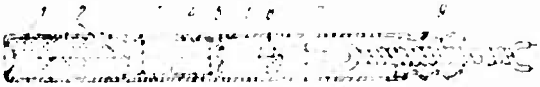


Fig. 47. EDZD delay electric detonator:
1 -- case
2 -- tetryl
3 -- cap
4 -- lead azide
5 -- delay composition
6 -- silk screen
7 -- electric igniter
8 -- incendiary composition
9 -- plastic plug

EDS -- (seismic) -- electric detonators have a nichrome 35 micron diameter wire as their incandescence bridge, with a resistance of 1.5-3 ohms. The safe current strength is 0.15 a.

These detonators are exploded failure-free with a 0.7 a direct current after being exposed in water under a pressure of 5 atm for 5 hours.

They are intended for operations in water.

The ED-8P (safety) electric detonator has a casing with 0.45-0.5 mm thick walls. It is intended for mines that are dangerous as to gas or dust.

TABLE 39. WHOLESALE PRICES OF ELECTRIC DETONATORS

Марка A	Краткая характеристика B	Оптовая цена за тысячу штук, руб. C
1	2	3
ЭД-8-ЗНС D	E Мгновенного действия неводостойкий, в биметаллической гильзе в таре со звонковыми проводами длиной 1—4 *м*	101—138
ЭД-8 F	G Мгновенного действия, водостойкий, в таре, провода с медной жилой и пластмассовой изоляцией длиной 2—4 *м*	120—144
ЭД-С H	I Мгновенного действия, сейсмический, в таре, провода с медной жилой, в пластмассовой изоляции	78
ЭД-8-ПМ J	K Мгновенного действия, предохранительный повышенной мощности, водостойкий в таре, провода с медной жилой в пластмассовой изоляции длиной 1—4 *м*	89—131
ЭД-8П-59 L	M Мгновенного действия, предохранительный, в таре, провода с медной жилой длиной 1,5—4,0 *м*	85—115
ЭД-8П N	O Мгновенного действия, предохранительный в таре, провода с медной жилой марки ЭП длиной 1—4 *м*	93—129
ЭД-8-Ж P	Q Мгновенного действия, в таре, электровоспламенитель каркасного типа, капсюль-детонатор № 8-С, провода со стальной жилой и водостойкой изоляцией марки ЭПЖ или ЭВЖ длиной 2—4 *м*	99—123
ЭД-КЗ R	S Короткозамедленного действия с интервалом от 25 до 250 *мсек* в таре, провода с медной жилой в пластмассовой изоляции длиной 1—4 *м*	89—131
ЭД-КЗ-ПМ T	U Короткозамедленного действия, предохранительный, повышенной мощности, с замедлением от 15 до 120 *мсек*, в тари, провода с медной жилой в пластмассовой изоляции длиной 1,5—4,0 *м*	107—142
ЭД-КЗ-15 V	W Короткозамедленного действия, в таре, провода с медной жилой длиной 2,0—2,5 *м*	133—139
ЭД-ЗД X	Y Замедленного действия, с интервалом замедлением от 0,5 до 10 *сек*, в таре провода с медной жилой в пластмассовой изоляции длиной 2—4 *м*	138—162

[KEY on following page]

KEY [to Table 39]:
A -- Grade
B -- Short characterization
C -- Wholesale price per 1000, rubles
D -- ED-8-3PS
E -- Instantaneous-action, nonwater-resistant, in bimetallic case in pack with 1-4 m long resounding wires
F -- ED-8
G -- Instantaneous-action, water-resistant, in container, wires with copper strand and plastic insulation, 2-4 m long
H -- ED-S
I -- Instantaneous-action, seismic, in container, wires containing copper strand, in plastic insulation
J -- ED-8-PM
K -- Instantaneous-action, increased-strength, safety, water-resistant in container, wires containing copper strand in plastic insulation, 1-4 m long
L -- ED-8P-59
M -- Instantaneous-action, safety, in container, wires containing copper strand 1.5-4.0 m long
N -- ED-8P
O -- Instantaneous-action, safety, in container, wires containing grade EP copper strand, 1-4 m long
P -- ED-8-Zh
Q -- Instantaneous-action, in container, body type electric igniter, No 8-S blasting cap, wires containing steel strand and grade EPZh for EVZh wire-resistant insulation, 2-4 m in length
R -- ED-KZ
S -- Short-delay action with interval in the range 25-250 msec, in container, wire containing copper strand in plastic insulation, 1-4 m long
T -- ED-KZ-PM
U -- Short-delay action, safety, increased-strength, with delay in the range 15-120 msec, in container, wires containing copper strand in plastic insulation, 1.5-4.0 m long
V -- ED-KZ-15
W -- Short-delay action, in container, wires containing copper strand, 2.0-2.5 m long
X -- ED-ZD
Y -- Delay action, with delay interval in the range 0.5-10 sec, in container, wire containing copper strand in plastic insulation, 2-4 m in length

The ED-8PM (safety, high-strength) electric detonator has an increased secondary charge weighing 1.6 g.

A layer of flame inhibitor 0.1 mm thick is applied on the outer surface of the casing. The trigger in time is 2-6 msec. The ignition impulse is

0.6-2 a^2/msec. A lead strip 6 mm is perforated. This detonator causes the stable detonation of ammonites with density up to 1.61 g/cm^3. It yields not less than 4 percent ignitions of methane-air mixtures.

It is intended for blasting work in mines that are dangerous as to gas and dust, of all categories.

Instead of the primary charge (initiating explosive), an igniting composition and TEN are pressed into a thick-walled steel cap.

It is intended for blasting operations at ground level.

Electric detonators with delay action are manufactured in following grades: ED-KZ -- short-delay action (Fig. 46); ED-KZ-PM -- short-delay action, high-strength, safety; ED-KZ -- moderate-delay action; and ED-ZD -- delay action (Fig. 47).

The delay intervals (msec) are as follows for the various grades of electric detonators:

ED-KZ-15	15		30	45	60	75	90	105	120
ED-KZ-25	25		50	75	100		150	250	
ED-KZ-PM-25	25		50	75	100				
ED-KZ-PM-15	15		30	45	60	75	90	105	120
ED-Z-N	15		30	45	60	75	90	105	120
ED-ZD (sec)	0,5	0,75	1	1,5	2	4	6	8	10

Electric detonators are packed in cardboard boxes, 40-70 at a time, depending on the length of the wires. Ten boxes are put in a metal box, which in turn is placed in a wooden crate.

Table 39 gives the wholesale prices for several types of electric detonators.

25. Detonating Fuses

A detonating fuse (Fig. 48) has a core of TEN, enclosed in a triple woven braiding coated with a waterproof mastic or plasticate. It is intended to ignite the detonation of a charge of explosive; it is used in all blasting operations except mines that are dangerous as to gas or dust. Characteristics of detonating fuses are given in Table 40.

The color of the blasting fuse varies from white to reddish, with two red filaments or with two bands on the outer braiding.

The guarantee period of use is 1.5 years.

TABLE 40. CHARACTERISTICS OF DETONATING FUSES

1 Марка шнура	2 Диаметр, мм	3 Длина шнура в бухте, м	4 Вес ВВ в 1 м шнура, г	5 Скорость детонации, м/сек	6 Материал оплетки
7 ДША (ГОСТ 6196—68)	4,8—5,8	50	12	9 Не менее 6500	10 Первая и вторая оплетка — нить льняная; третья — (наружная) — нитка хлопчатобумажная
8 ДШВ (водоустойчивый) (ГОСТ 6196—68)	4,8—5,8	50	13	6500	11 То же, но третья оболочка пластикатная

KEY:
1 -- Fuse grade
2 -- Diameter
3 -- Length of fuse in coil
4 -- Weight of explosive in 1 m of fuse, grams
5 -- Detonation rate, m/sec
6 -- Material of braiding
7 -- DShA (GOST 6196-68)
8 -- DShV (water-resistant) (GOST 6196-68)
9 -- Not less than 6500
10 -- First and second braidings -- linen strand; third braiding -- (external) -- cotton strand
11 -- As above, but third braiding is plastic

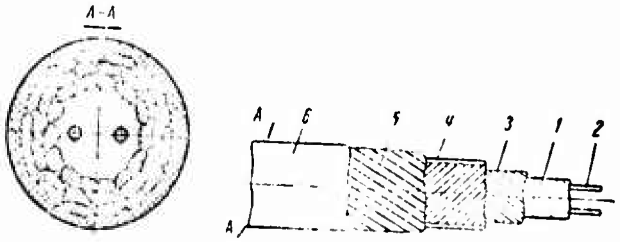


Fig. 48. Detonating fuse:
1 -- explosive core of TEN
2 -- guide stands
3 -- polyethylene film
4 -- linen braidings
5 -- cotton braidings
6 -- polychlorovinyl casing

Fuses detonate, failure-free, when heated for 6 hours; the DShA detonates at a temperature of +50° ± 3° C, and the DShV fuse **detonates** at +55 ± 3° C;

when cooled for 2 hours:
the DShA fuse detonates at a temperature of 28 ± 3° C, and the DShV fuse -- 35 ± 3° C.

Fuses can produce hangfires when used improperly, namely, when bent at a sharp angle or when a length is joined to the main line in a direction that is opposite to the direction of the detonation wave.

The fuse is packed in wooden boxes in 10 or 20 bundles per box, that is, 500 or 1000 m in length.

The wholesale price for 1000 m DSh-A fuse packed is 118 rubles, and for DSh-V -- 143 rubles.

The KZDSh delay relay is used for short-delay blasting of charges using a detonating fuse.

Detonation relays of two types are employed:
The KZSh-58, one-sided action (Fig. 49), and the KZDSh-62-2, two-sided action (Fig. 50).

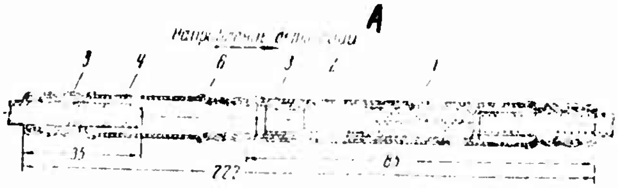


Fig. 49. KZDSh-58 pyrotechnic relay:
1 -- blasting cap
2 -- inhibitor
3 -- paper tube
4 -- detonating fuse
5 -- end piece
6 -- bushing
KEY: A -- Direction of detonation

The KZDSh-58 consists of a plastic or paper tube in which a blasting cap and a pyrotechnic inhibitor is inserted. At the ends of the tubes blasting fuses are fastened (manually).

The impact of the explosion by the left branch of the detonating fuse initially causes the inhibitor to burn, and then the explosion of the blasting cap and the right branch of the detonating fuse.

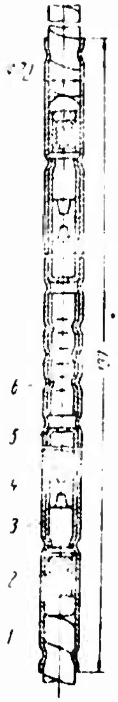


Fig. 50. KZDSh-62 pyrotechnic relay:
1 -- detonating fuse
2 -- blasting cap
3 -- metal tube
4 -- inhibitor
5 -- intermediate cap
6 -- connecting bushing

The characteristics of the KZDSh-58 are as follows:
triggering time 10, 20, 35, and 50 msec;
detonates without failure after exposure for 2 hours in 100 percent relative humidity and at temperatures from -30 to +50° C;
detonating fuse lengths are not pulled out of the tube when a weight of 2 kg is suspended from them for 3 minutes; and
withstands the jostling test for 10 minutes.

The KZDSh-62-2 detonating relay consists of a metal tube, which is fitted with a diaphragm and an inhibitor in the middle at the two gripping locations and in the tube up to the support from both ends; the inhibitor

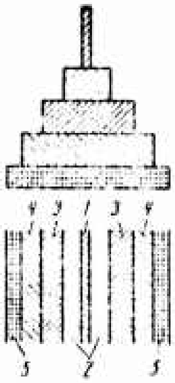
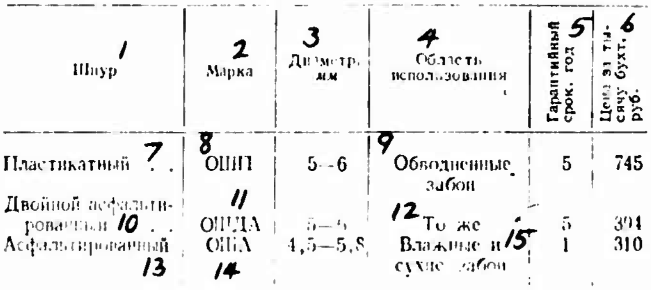


Fig. 51. Safety fuse:
1 -- guide strand
2 -- fuse powder
3 -- first linen braiding
4 -- second linen braiding
5 -- plastic

TABLE 41. CHARACTERISTICS OF SAFETY FUSES



Шнур 1	Марка 2	Диаметр, мм 3	Область использования 4	Гарантийный срок, год 5	Цена за тысячу бухт, руб. 6
Пластикатный 7 . .	8 ОШП	5—6	9 Обводненные забои	5	745
Двойной асфальтированный 10 . .	11 ОШДА	5—6	12 То же	5	394
Асфальтированный 13	ОША 14	4,5—5,8	Влажные и 15 сухие забои	1	310

KEY: 1 -- Fuse
2 -- Grade
3 -- Diameter
4 -- Field of use
5 -- Guarantee period, years
6 -- Cost per 1000 of bundles, rubles
7 -- Plasticized
8 -- OShP
9 -- Flooded faces
10 -- Double asphalt-treated
11 -- OShDA
12 -- As above
13 -- Asphalt-treated
14 -- OShA
15 -- Moist and dry faces

is gripped along the bore of the cup in the tube, and then into the tube is inserted the blasting cap; the 265 mm lengths of detonating fuse are secured by squeezing on the tube.

The KZDSh-62-2 inhibitor is similar to the KZDSh-58 inhibitor. Their difference is that the KZDSh-62-2 transmits detonation into the network of the detonating fuse regardless of which end it is connected to.

The detonating fuse relay is used in open pits, ore mines, and mines that are not dangerous as to gas or dust, and in place of electric detonators if there is a danger of stray currents in the same conditions.

The wholesale price of 1000 KZDSh-58 relay is 245 rubles, and 1000 KZDSh-62-2 relays cost 120 rubles.

26. Safety Fuses

A safety fuse (GOST 3470-55) is a device for igniting blasting caps (Fig. 51). It has a core made of black powder with a central guide thread and braidings covered or impregnated with airtight or watertight compound. A safety fuse is used in all kinds of work, except in mines that are dangerous in terms of gas or dust. A 60 cm length of fuse burns 60-70 sec. It retains its air and water impermeability at temperatures down to -30° C, while the outer case shows no tackiness at +45° C.

The fuse is coiled into turns of various diameters in such a way that the coils can lie one on the other. Each bundle must consist of 25 coils. A box is loaded with eight bundles of the same kind of fuse. Fuse characteristics are given in Table 41.

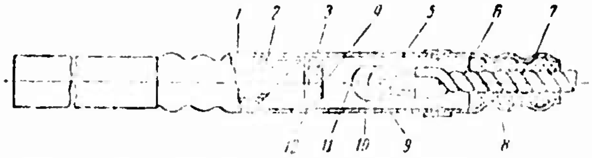


Fig. 52. EZT-2 electric incendiary tube:
1 -- case
2 -- safety fuse
3 -- cup
4 -- ring
5 -- incandescence bridge
6 -- EV wire
7 -- plug
8 -- tracing cloth
9 -- igniting composition
10 -- incendiary composition
11 -- nitro varnish
12 -- transmission composition

27. Safety Fuse Incendiary Devices

EZT-2 electric incendiary tubes consist of devices composed of an electric igniter and a safety fuse (Fig. 52). They are designed to initiate blasting caps in flame blasting; they have a 30 micron diameter nichrome incandescence bridge; when joined in series in groups of 20 they function reliably when supplied with 1 a direct current and with 2.5 a alternating current.

The price of 1000 EZT-2 tubes when packaged is 182 rubles when the safety fuse length is 230 mm, and 238 rubles -- when the safety fuse length is 630 mm.

Safety fuse incendiary devices are divided into three groups: safety fuse electric incendiary devices, electric incendiary cartridges, and incendiary cartridges (Table 42).

EZ-OSh-B safety fuse electric incendiary devices (Fig. 53) are designed to ignite the ends of the safety fuse length in dry and wet locations when blasting isolated charges and when blasting a small number of unconnected charges. They are used for cases when there is a large number of series-blasted charges, when electric incendiary devices are used to ignite various lengths of safety fuse, regulating the sequence in which incendiary cartridges are triggered.

The EZ-OSh-B electric incendiary device consists of a paper case, electric igniter with a plastic plug, sounding wire leads, and incandescence bridge, and an igniting head. It is triggered with 1 a of direct current and 2.5 a of alternating current. It is used everywhere except in mines that are gas- or dust-hazardous.

It is packed 20-40 devices in each cardboard box, which are then placed in wooden crates.

EZP-B electric incendiary cartridges are designed to ignite a cluster of safety fuse ends in dry and wet locations in group ignition, when the number of incendiary tubes does not exceed 40-50 and when the charges in faces (usually driving faces) are not too widely separated. These cartridges are permitted for mines that are not gas- or dust-hazardous.

This type of cartridge consists of a paper case (Fig. 54), on the bottom of which is placed a press cake of igniting composition, that provides for the failure-free ignition of all safety fuse lengths inserted into the case. The press cake is ignited by the incandescence of a wire caused by electric current.

EP-B incendiary cartridges (Fig. 55) are designed to ignite by means of a safety fuse length a cluster of safety fuse ends in dry and wet locations in flame blasting. They are also used in conjunction with EZ-OSh-B for series blasting of an unlimited number of charges, beginning with 30-40 in narrow chambers and longwalls.

TABLE 42. CHARACTERISTICS OF ELECTRIC INCENDIARY AND INCENDIARY CARTRIDGES

1 Число размещающихся отрезков огнепроводного шнура	2 Внутренний диаметр, мм	3 Высота, мм	4 Состав пороховой лепешки, %	5 Цена за 1000 штук в таре, руб.	
				6 Электрозажигательные патроны	7 Зажигательные патроны
1—7	16	50—60	8 Канифоль 9—9,5	136	42
8—12	24	—	—	141	43
13—19	30	70—80	9 Парафин 10 4,5—5,0	150	48
20—27	35	80—90	Дымный порох	154	51
28—38	43	90—100	85—86	160	55

KEY:
1 -- Number of accommodated safety fuse length
2 -- Inner diameter
3 -- Height
4 -- Composition of powder press cake
5 -- Price per 1000 cartridges when packed, rubles
6 -- Electric incendiary cartridges
7 -- Incendiary cartridges
8 -- Rosin
9 -- Paraffin
10 -- Black powder

Fig. 53. EZ-OSh-B electric incendiary device for safety fuse

1 -- case
2 -- plug
3 -- sounding wire
4 -- bushing
5 -- incandescence bridge
6 -- igniting composition
7 -- incendiary composition
8 -- OShDA safety fuse
9 -- bushing

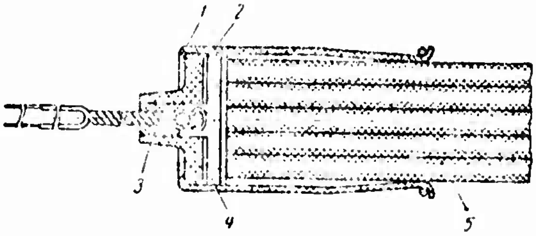


Fig. 54. EZP-B electric incendiary cartridge

1 -- case
2 -- bushing
3 -- electric igniter
4 -- incendiary composition
5 -- safety fuse

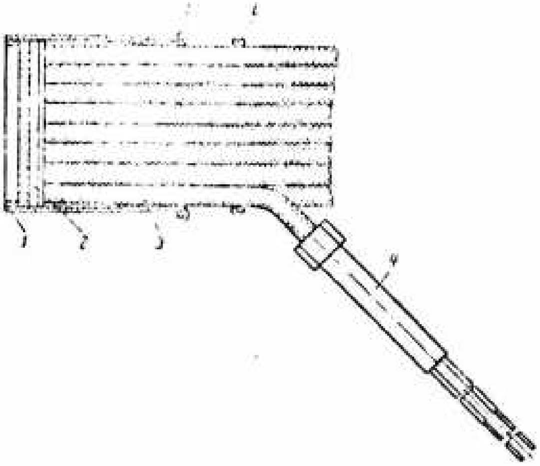


Fig. 55. EP-B incendiary cartridge:

1 -- case
2 -- incendiary composition
3 -- OShDA safety fuse
4 -- EZ-OSh-B electric incendiary unit for safety fuse
5 -- cord
6 -- rubber tube

They are distinguished from electric incendiary cartridges only by the method of igniting the press cake in the case; in this type of cartridge the press cake is ignited by setting fire to a short safety fuse length inserted into the case.

This type of cartridges permitted for use in mines that are not gas- or dust-hazardous.

28. Testing Initiators

Initiators arriving at mining enterprises undergo tests in accordance with Yedinyye Pravily Bezopasnosti pri Vzryvnykh Rabotakh [Unified Rules for Safety in Blasting Operations].

Testing of blasting caps

External inspection. **No fewer** than two crates are opened out of each lot of blasting caps arriving at the base warehouse and **no fewer** than 200 blasting caps are sampled for external inspection. It is found by the inspection whether or not there are cracks or pits in the metal cases, whether in the paper cases there is layering of the paper at the bore, which will prevent the insertion of the safety fuse.

The inner surface of metal and paper cases must be free of obstructions; chips of tetryl are not allowed at the bottom of a blasting cap in the paper case.

When these defects are found, the entire lot is rejected; a complaint is filled out and sent to the plant. The question of the further use of the lot is decided by a commission of representatives of users and the suppliers.

Blasting caps sampled and found to have defects are disposed of by being exploded.

Testing of electric detonators

External inspection. From each arriving lot of 20 boxes reaching the base warehouse, 200 electric detonators are sampled and undergo external inspection.

There must be no oxidation, contamination, cracks, dents, or pits on the metal cases of electric detonators, and there must be no layering of paper at the locations of cementing and fraying, nor must be there any chips of tetryl at the case bottom.

Weak gripping of the blasting cap case is not allowed, nor is a breakdown in the insulation of wires, contamination, and oxidation of the scraped wire ends.

When defects are found, a complaint is filled out, and then it is sent to the plant and to the Institute on Blasting Safety (MakNII or VostNII);

TABLE 43. ELECTRIC RESISTANCE OF VARIOUS GRADES OF ELECTRIC DETONATORS

1 Тип ЭД	2 Длины выводных проводов, м		5 Электрическое сопротивление, ом
	3 с медной жилой	4 со стальной жилой	
ЭД-8-Э 6	2—4	—	2,0—4,2
	2—3	—	1,6—3,6
	3,5—4	—	1,6—3,8
ЭД-8-Ж 7	—	2,0	2,9—5,6
		2,5	3,3—6,5
		3,0	3,7—7,5
		3,5	4,1—8,5
		4,0	4,5—9,5
ЭДС 8			1,5—3,0

KEY: 1 -- Type of electric detonator
2 -- Length of lead wires
3 -- Containing copper strand
4 -- Containing steel strand
5 -- Electric resistance, ohms
6 -- ED-8-E
7 -- ED-8-Zh
8 -- EDS

the entire lot is rejected. The problem of the further possible use of the lot is decided by a commission in which representatives of the users and suppliers participate. Rejected electric detonators are disposed of.

Checking electrical resistance. To check electrical resistance (in service warehouses), an electric detonator is placed in a specially equipped device that affords protection in the event that the electric detonator being tested explodes. This protective device (a length of steel tube lined internally with rubber or felt) is tested in advance in a proving ground for strength and reliability of protection by blasting a new electric detonator in it. The electric resistance check is carried out with direct current. Table 43 presents data on the electrical resistance of electric detonators.

Resistance is measured using instruments with a permanent precision rating not below 2.5 for a current strength not greater than 50 ma.

There must be no breaks, short-circuits, and "wondering" resistances (of an interrupted circuit) in electric detonators.

When deviations are found in the resistance indicators from the values given in the product labels, the electric detonators are rejected; a claim is filed on them, and it is sent to the manufacturing plant and to the Institute on Operational Safety in the Mining Industry.

Testing of detonating fuses

External inspection. One box is opened of each lot arriving at the warehouse; in the box all coils of detonating fuse are inspected. It is established whether or not there are any defects present: breakdown of casing integrity; bends; or thinned or thickened areas. If the number of coils found to have defects exceeds 10 percent of the total number of those examined. the entire lot of detonating fuses is rejected.

Testing for blasting safety based on established schemes. In the test three coils are selected, from each of which five 1 m long segments are cut, and the remaining 45-meter coils are arranged in the form of main lines. To each of these are connected, at some distance, the detonating fuse length, arranging them along the detonation path. The lengths are connected to the main line following the practice in blasting operations for which the fuse is intended. When the lengths are connected with overlapping joints, the fuse end must lie tightly along the main line to the extent of 10 cm. Insulation tape or cord is used for fastening.

If the coil consists of individual pieces, the ends of the main lines are connected with each other in series using overlapping joints. To one of the ends of the main line is connected an electric detonator or an incendiary tube and the blast is carried out at a distance not less than 50 m.

A detonating fuse that produces more than one failure in blasting with respect to detonation in the main line, or more than two failures in five connected lengths is rejected.

Testing for water resistance. When a detonating fuse is used in flooded conditions, it is tested for failure-free blasting after being soaked in water. The fuse is soaked to a depth of 1 m. If the fuse is used in wet faces, it is soaked for 1 hour, and when the operations are kept in water — it is soaked for 4 hours. A 5 m length of detonating fuse is used in testing for waterproof quality. The ends of the fuse length, after being immersed in water, are sealed with an insulating mastic. After being exposed in water, the fuse lengths are divided into five equal parts and they are connected one with the other in a single line using sailors' knots. The fuse joined in this way is tested for failure-free blasting; here it must detonate completely.

If the fuse ends do not pass the test for waterproof quality, they are tested additionally for failure-free blasting without wetting; when positive results are forthcoming, the lot is used in blasting work in dry faces.

Testing for the effect of elevated and reduced temperatures. Fuses used at temperatures up to 60° C are tested for failure-free blasting, and for water resistance after lengths are heated in a thermostat at 60° C for 4 hours.

A fuse intended for operations at temperatures below -15° C is tested for failure-free blasting in networks laid out after a two-hour exposure of the blasting fuse at its service temperature. Fuses not passing the test at elevated and reduced temperatures cannot be permitted for work in these conditions.

Testing of safety fuse

External inspection. No fewer than one crate is opened out of each lot; in the crate all coils of safety fuse undergoing inspection. Here it is established whether or not the following defects are found: bends, cracks in casing, fraying of ends, traces of damp, and so on.

When defects are found, the lot is rejected; a claim is filled out and sent to the manufacturing plant and to the Institute on Operational Safety in the Mining Industry. Coils of fuse found to have defects are disposed of by burning.

Of coils passing inspection, 2 percent are sampled for other tests.

Testing for water resistance. A safety fuse is tested for all indicators only after being exposed in water: 1 hour for the OShA fuse; 4 hours to a depth of 1 m for the OShDA and OShP fuses; the ends of grade OShP coils are insulated with water-resistant mastic.

A fuse that yields even a single sputtering out after being soaked is permitted only for work in dry faces.

Testing for rate, completeness, and uniformity of burning. Fuse coils selected for testing are uncoiled and from each coil a 5 cm piece is cut off from one end, and then a 60 cm piece. The prepared fuse lengths are ignited and the burning rate of each length is found. The burning time for a 60 cm length must be not less than 60 sec and not more than 70 sec. A safety fuse that is found to have a single case of sputtering out, and also a longer or shorter burning time is rejected.

The fuse coils remaining after the burning rate test are uncoiled on the test area and are ignited. The fuse must burn uniformly, without flocs and eruptions of spark through the casing; there must be no dying out of the combustion of the powder core and ignition of the casing. When there is even one dying out or other kind of defect, the lot undergoes the second test with a doubled number of fuses. When the defect is found again, the lot is rejected, and a complaint sent to the manufacturing plant and to the Institute on Operational Safety in the Mining Industry. The question as to the further use of the lot is decided by a commission of user and manufacture representatives.

The results of the inspection and tests of blasting machines are entered into a special log on Form No 1 (Appendix 2). When unsatisfactory results are obtained from the tests, in addition to the log entry, a report is made on Form No 2 (Appendix 2).

APPENDIX 1. TABLE OF CERTAIN CONSTANTS OF STARTING COMPONENTS AND EXPLOSION PRODUCTS OF COMMERCIAL EXPLOSIVES

Вещество A	Формула B	C Атомный или молекулярный вес	D Кислородный баланс, %	E Теплота образования, ккал/моль	
				Q_V	Q_p
1	2	3	4	5	6
F Исходные компоненты ВВ					
Нитрат аммония G	NH_4NO_3	80	+ 20	84,75	87,36
Нитрат натрия H	$NaNO_3$	85	+ 47,1	110,59	111,72
Нитрат калия I	KNO_3	101	+ 39,6	116,93	118,09
Нитрат кальция J	$Ca(NO_3)_2$	164	+ 48,8	221,70	224,04
Перхлорат аммония K	NH_4ClO_4	117,5	+ 34,0	67,30	70,20
Перхлорат натрия L	$NaClO_4$	122,5	+ 52,2	—	93,00
Аммиачная селитра техническая M					
N водоустойчивая, содержит 0,35% парафинов	—	—	+ 19,0	84,50	87,00
O гранулированная, содержит 98,5% нитрата	—	—	+ 19,7	83,48	86,05
Тротил P	$C_7H_5O_6N_3$	227	— 74,0	13,50	17,50
Тетрил Q	$C_7H_5O_8N_5$	287	— 47,4	—9,91	—4,70
Тэн R	$C_5H_8O_{12}N_4$	316	— 10,1	122,41	129,37
Гексоген S	$C_3H_6O_6N_6$	222	— 21,6	—20,86	—15,64
Динитротолуол T	$C_7H_6O_4N_2$	182	—114,2	15,35	18,80
Динитронафталин U	$C_{10}H_6O_4N_2$	218	—139,3	—7,60	—5,00
Нитроглицерин (НГЦ) V	$C_3H_5O_9N_3$	227	+ 3,5	83,71	88,63
Нитродикликоль (НДГ) W	$C_4H_8O_7N_2$	196	— 40,8	99,30	104,20
Смесь НГЦ/НДГ 60/40 X	—	214,6	— 14,2	—	—
Коллодионный хлопок (12,2% азота) Y	$C_{22.5}H_{28.8}O_{36.1}N_{8.7}$	998,2	— 36,9	649,7	—
Алюминий Z	Al	27	— 89,0	—	—
A'					
Древесная мука	$C_{15}H_{22}O_{10}$	362	—137,0	479	—
Бумага B'	—	—	—130,0	—	—
Целлюлоза C'	$C_6H_{10}O_5$	162	—118,5	—	230,3
Парафин D'	$C_{24}H_{50}$	338	—346,0	11190*	—
Минеральные масла E'	$C_{12}H_{26}$	168	—336,0	—	—
Асфальтит F'	$C_{6.92}H_8S_{1.87}O_{1.4}$	1000	—189,0	7640*	—
Уголь (сажа) G'	C	12	—266,7	7810*	—
Стеарат кальция H'	$C_{36}H_{70}O_4Ca$	607	—274,0	641,1	662,6
Полиэтилен I'	$(C_2H_4)_n$	28	—312,0	—	14,0
Мипора J'	—	—	— 70,0	—	78,5
Продукты взрыва K'					
Вода (жидкая) L'	H_2O	18	0	67,50	68,37
Вода (пар) M'	H_2O	18	0	57,49	57,78
Углекислый газ N'	CO_2	44	0	94,51	94,51
Окись углерода O'	CO	28	− 57,2	27,17	26,88
Окись азота P'	NO	30	+ 53,3	—21,60	—21,60
Двуокись азота (газ) Q'	N_2O_4	92	+ 69,6	—3,10	—
Хлористый водород (газ) R'	HCl	36,5	0	21,90	21,90
Метан S'	CH_4	16	—399,0	17,70	18,30
Окись алюминия T'	Al_2O_3	102	0	398,1	399,0
Окись кальция U'	CaO	56	0	150,8	151,70
Углекислый кальций V'	$CaCO_3$	100	0	288,6	289,5
Углекислый натрий W'	Na_2CO_3	106	0	269,0	269,9
Хлористый калий X'	KCl	74,5	0	104,07	104,36
Хлористый натрий Y'	NaCl	58,5	0	98,0	98,33

* Heat of combustion in kcal/kg/
[cf. KEY on following page]

KEY [to Appendix 1]:
A -- Substance
B -- Formula
C -- Atomic or molecular weight
D -- Oxygen balance
E -- Heat of formation, kcal/mole
F -- Starting components of explosive
G -- Ammonium nitrate
H -- Sodium nitrate
I -- Potassium nitrate
J -- Calcium nitrate
K -- Ammonium perchlorate
L -- Sodium perchlorate
M -- Technical ammonium nitrate
N -- water-resistant, contains 0.35 percent paraffins
O -- granulated, contains 98.5 percent nitrate
P -- Trotyl
Q -- Tetryl
R -- TEN
S -- Hexogen
T -- Dinitrotoluene
U -- Dinitronaphthalene
V -- Nitroglycerin
W -- Nitrodiglycol
X -- Nitroglycerin/nitrodiglycol mixture 60/40
Y -- Colloidal cotton (12.2 percent nitrogen)
Z -- Aluminum
A' -- Wood meal
B' -- Paper
C' -- Cellulose
D' -- Paraffin
E' -- Mineral oils
F' -- Asphaltite
G' -- Coal (carbon black)
H' -- Calcium stearate
I' -- Polyethylene
J' -- Mipore
K' -- Explosion products
L' -- Water (liquid)
M' -- Water (vapor)
N' -- Carbon dioxide gas
O' -- Carbon monoxide
P' -- Nitrogen oxide
Q' -- Nitrogen dioxide (gas)
R' -- Hydrogen chloride (gas)
S' -- Methane
T' -- Aluminum oxide
U' -- Calcium oxide
V' -- Calcium carbonate
W' -- Sodium carbonate
X' -- Potassium chloride
Y' -- Sodium chloride

APPENDIX 2 FORM No 1

1

Журнал учета испытаний ВМ на складе

(наименование предприятия) 2

а) Учет испытаний взрывчатых веществ 3

4 Дата испытаний	5 Наименование ВМ	6 Завод-изготовитель	7 № партии ВВ	8 Дата изготовления ВВ	9 Дата прибытия ВВ на склад	10 Выдержало или не выдержало испытание на		
						11 передачу детонации	12 влажность	13 эксудацию

б) Учет испытаний огнепроводного и детонирующего шнура 14.

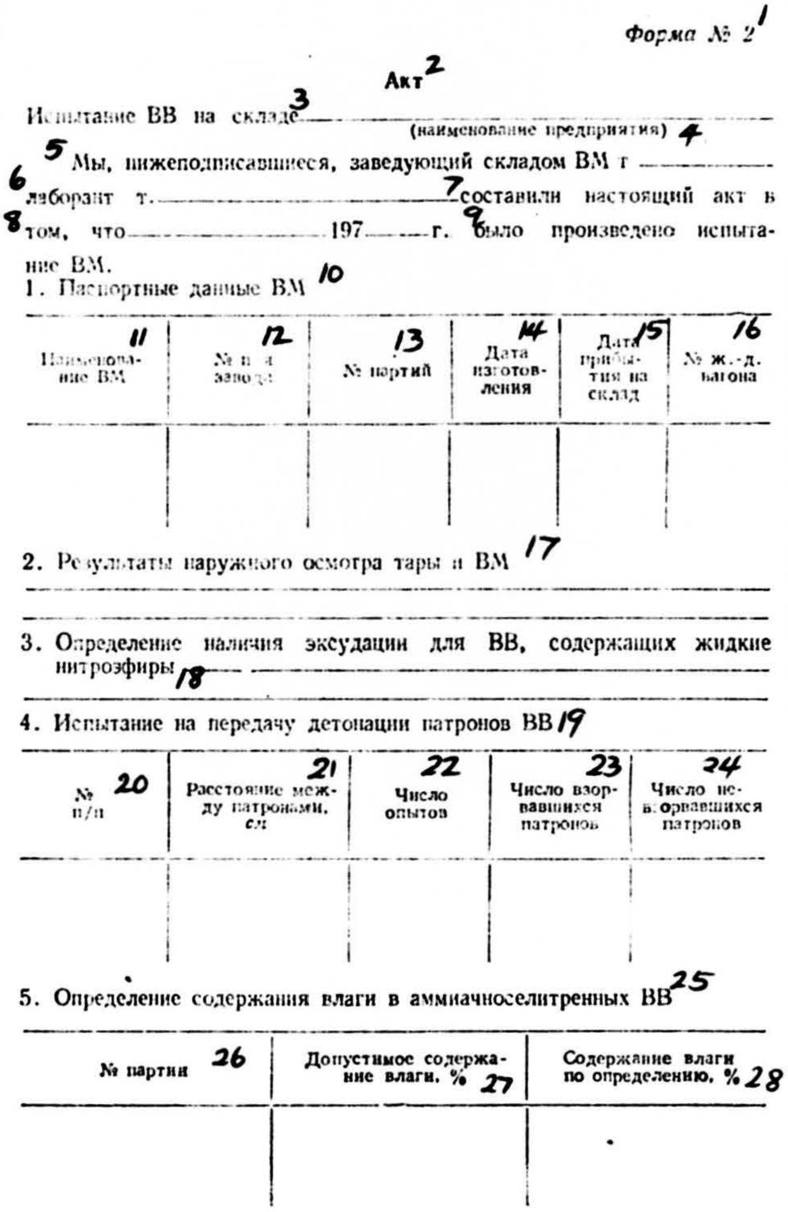
4 Дата испытаний	15 Сорт огнепроводного (детонирующего) шнура	6 Завод-изготовитель	7 № партий	8 Дата изготовления	16 Дата прибытия на склад	Выдержал или не выдержал испытание 17				
						18 Огнепроводный шнур		19 Детонирующий шнур		
						20 на				
						скорость горения отрезка 60 см 21	характер и полноту горения целой бухты 22	время выдержки в воде 23	безотказность взрывания 24	время выдержки в воде 25

KEY:
1 -- Log of tests made of blasting machines at warehouse
2 -- (name of enterprise)
3 -- Record of tests of explosives
4 -- Date of test
5 -- Name of blasting machine
6 -- Manufacturing plant
7 -- Explosive lot number
8 -- Date of explosive manufacture
9 -- Date of arrival of explosive at warehouse
10 -- Pass or not pass test for [indicator given below]
11 -- Transmission of detonation
12 -- Moisture content
13 -- Exudation
14 -- Record of tests of safety and detonating fuses
15 -- Kind of safety (detonating) fuse
16 -- Date of arrival at warehouse
17 -- Pass or not pass test
18 -- Safety fuse
19 -- Detonating fuse
20 -- for
21 -- Burning rate of 60 cm length

[KEY continued on following page]

KEY [to Appendix 2, Form 1, continued]:
22 -- Nature and completeness of burning of entire coil
23 -- Exposure time in water
24 -- Failure-blasting
25 -- Exposure time in water

APPENDIX 2



Форма № 2 1

Акт 2

Испытание ВВ на складе 3 ______________________
(наименование предприятия) 4

5 Мы, нижеподписавшиеся, заведующий складом ВМ т ________ 6 лаборант т. ________________ 7 составили настоящий акт в 8 том, что ______________ 197___ г. 9 было произведено испытание ВМ.

1. Паспортные данные ВМ 10

11 Наименование ВМ	12 № п/п завода	13 № партий	14 Дата изготовления	15 Дата прибытия на склад	16 № ж.-д. вагона

2. Результаты наружного осмотра тары и ВМ 17

3. Определение наличия эксудации для ВВ, содержащих жидкие нитроэфиры 18

4. Испытание на передачу детонации патронов ВВ 19

№ п/п 20	21 Расстояние между патронами, *см*	22 Число опытов	23 Число взорвавшихся патронов	24 Число невзорвавшихся патронов

5. Определение содержания влаги в аммиачноселитренных ВВ 25

№ партии 26	Допустимое содержание влаги, % 27	Содержание влаги по определению, % 28

[Continued on following page]

CONTINUATION [of APPENDIX 2, FORM No 2]

6. Наружный осмотр электродетонаторов 29

7. Наружный осмотр капсюль-детонаторов 30

8. Наружный осмотр огнепроводного шнура 31

9. Испытание на скорость, полноту и равномерность горения огнепроводного шнура 32

33 № партии огнепроводного шнура	34 Число отрезков шнура по 60 см	35 Время горения отрезка 60 см шнура, сек	36 Полнота и характер горения огнепроводного шнура (целых бухт)

10. Испытание огнепроводного шнура на водостойкость 37

38 № партии огнепроводного шнура	39 Глубина погружения шнура в воду, м	40 Время выдержки в воде, ч	41 Скорость горения отрезка шнура, см/сек	42 Полнота и характер горения целых бухт шнура

11. Заключение о годности или непригодности испытуемых ВВ 43

44

Подписи:

KEY:
1 -- Form No 2
2 -- Report
3 -- Test explosive at the warehouse
4 -- (name of enterprise)
5 -- We, the undersigned, director of the blasting machine warehouse, Comrade ....

[Key continued on following page]

KEY [to Appendix 2, Form No 2, continuation]:
6 -- Laboratory assistant, Comrade ....
7 -- Have prepared this report
8 -- Stating that on .... 197...
9 -- A test was made of blasting machines
10 -- Rated data of blasting machine
11 -- Name of blasting machine
12 -- Post office of plant
13 -- Lot number
14 -- Date of manufacture
15 -- Date of arrival at warehouse
16 -- Number of railway car
17 -- Results of internal inspection of packing and blasting machines
18 -- Determination of presence of exudation for explosive containing liquid nitro ester
19 -- Test for transmission of detonation for explosive cartridges
20 -- Number
21 -- Distance between cartridges, cm
22 -- Number of experiments
23 -- Number of exploded cartridges
24 -- Number of nonexploded cartridges
25 -- Determination of moisture content in ammonium nitrate explosives
26 -- Lots number
27 -- Permissible moisture content
28 -- Moisture content based on determination
29 -- External inspection of electric detonators
30 -- External inspection of blasting caps
31 -- External inspection of safety fuse
32 -- Test for rate, completeness, and completeness of burning of safety fuse
33 -- Number of safety fuse lots
34 -- Number of 60 cm fuse length
35 -- Burning time of 60 cm fuse length, sec
36 -- Completeness and nature of combustion of safety fuse (entire coals)
37 -- Test of safety fuse for water resistance
38 -- Number of safety fuse lot
39 -- Depth of fuse immersion in water
40 -- Exposure time in water, hours
41 -- Burning rate of fuse length, cm/sec
42 -- Completeness and nature of burning of entire fuse coils
43 -- Conclusion on the suitability or nonsuitability of the explosives tested
44 -- Signatures

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