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## Substantiation of Choice of Method of Manufacturing and Delivery of Emulsion Explosives in Modern Conditions of Functioning of Mining Enterprises

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# Substantiation of Choice of Method of Manufacturing and Delivery of Emulsion Explosives in Modern Conditions of Functioning of Mining Enterprises

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**Abstract.** The paper shows the mineral deposits of the southern Urals, which do open-pit mining with the use of emulsion explosives (EE). The classification of EE type “water in oil” is developed depending on the main components of the emulsion matrix at the final stage of its production. Possible variants of mobile technological complexes and their adaptation in the conditions of the market and modern conditions of functioning of the mining enterprises are presented. Technological chain is presented from point of fabrication emulsion on base mobile technological complexes to the loading downhole charges with emulsion explosives. The ways to improve the competitiveness by an example of famous mining enterprises with different production capacity, which use emulsion explosives of the type “water in oil”, are shown and worked over. Adaptation models are developed to improve the efficiency of mining enterprises in the conditions of modern market relations by transferring the preparation process to outsourcing or partial outsourcing to companies with special mobile technological complexes. The scheme of relations between mining companies and outsourcing companies and the efficiency of the outsourcing project is shown on the example of the organization LLC “Ural Sibirit” (Magnitogorsk), which manufactures emulsion explosives “Sibirit-1000 and 1200” on base of mobile technological complex.

## 1. Introduction

At the beginning of the XXI century on the territory of Russia and former Union republics, in particular Kazakhstan and Ukraine [1], at a rapid pace are in the production of explosive works at mining enterprises emulsion explosives (EE) based on disperse systems introduced, they are widely used and consist of two mutually insoluble liquids, one of which is distributed to the other in the form of tiny drops.

It is a class of industrial explosives (E) based on reverse (invert) emulsions “water in oil” [2, 3].

Currently, this class of EE is the fourth stage of development of water-containing explosives (WE), obtained on the basis of reverse type emulsion (droplets of aqueous solution of ammonium nitrate (AN) in oil) and has the following advantages relative to the standard E [4,5,6,7,8].

- safety in relation to mechanical and thermal effects (impact, friction, heat, fire);
- ability to control explosive characteristics in a wide range of operating densities from 0.5 to 1.5 kg / cm<sup>3</sup>;
- water resistance.



EE type "water in oil" are known since 1969, when in the patent USA [9]. Blum described its compositions, which include a water-discrete phase (aqueous solution of inorganic salts-oxidants), a continuous phase of liquid hydrocarbons, an emulsifier and dispersed gas bubbles.

This composition could detonate only in charges of a relatively large diameter and with the use of a powerful intermediate detonator.

In order to eliminate this drawback, various compositions and technologies of the production of EE have been developed.

At the same time the variety of EE compositions and accordingly the technologies of their production requires the justification of the choice of the method of their production and delivery, which must provide the maximum economic and quality indicators of drilling and blasting operations (DBO) in accordance with the mining and technical conditions of the developed fields.

## 2. The scope of application of emulsion explosives in the southern Urals

Currently, most of the fields of the southern Urals, presented in table 1 use for the preparation of rocks for excavation in quarries by DBO method with the use EE (Sibirit-1000, Sibirit-1200, AS-25P, Emulast AS-30, Nitronit, Fortis and other) [10].

**Table 1.** Deposits of minerals of the southern Urals and used in them EE.

Type of Deposit	Quarry (company)	Used EE
Iron ore deposits	Techensky	Sibirit-1200, Sibirit-2500 RZ, AS-25P
	Tukansky, Verkhne-Karadinsky	Emulast AS-30, Nitronit, Fortis
	Malyy Kuybas	Sibirit-1000, Sibirit-1200
	Sultanovsky	Nitronit, Fortis
Deposits of non-ferrous metals	Mikheevsky	Sibirit-1200, Sibirit-2500 RZ, AS-25P, Igdanit P, Granulit NP
	Ganeevsky	Emulast AS-30, Nitronit, Fortis
	Khudolazsky	AS-25P, Fortis
	Irkilinsky	AS-25P, Fortis advantage 100
Limestone, dolomite deposits	Severo-Kizilsky	Emulast AS-30, Emulsen I-90
	Agapovsky	Sibirit-1000, Sibirit-1200, Fortis
	Suysh	Emulast AS-30
	Yuzhno-Kandurovsky	AS-25P, Sibirit-1000, Sibirit-1200
	Lisegorsky	Sibirit-1000, Sibirit-1200, Fortis
	Gudronovsky	Emulast AS-30 FP, AS-25P, Fortis
	Novo-Petrovsky	Fortis 1, Emulsolit P-A- 20, Igdanit
	Abzakovsky	Emulast AS-30, Emulsen I-90
Deposits of building materials	Argayashsky	AS-25P, Sibirit-1000, Sibirit-1200
	Eleninsky	AS-25P, Sibirit-1000, Sibirit-1200
	Granitny (LTD "Prom-Aktiv")	AS-25P, Sibirit-1000, Sibirit-1200
	YuzhUralgips	AS-25P, Sibirit-1000, Sibirit-1200
	Mednogorsky	AS-25P, Fortis, Emulsolit P-A-20
	Magnitogorsky granitny	AS-25P, Sibirit-1000, Sibirit-1200
	Gumbeisky	AS-25P, Sibirit-1000, Sibirit-1200
	Verkhne-Yatvinsky	Emulast AS-30, Nitronit, Fortis

According to the data of factories are technical and economic indicators of the use of EE in the considered conditions in the following range provided:

- distance of emulsion transportation - up to 500 km;

- the production capacity of the enterprise on the mountain weight - from 500 thousand m<sup>3</sup> / year to 20 million m<sup>3</sup> / year;
- weight of EE on the blown up block-up to 100 tons.

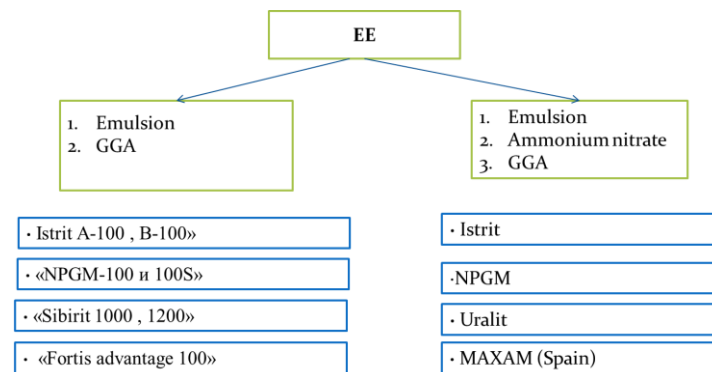
### 3. Classification of EE by the presence of dry phase

In modern conditions all mining enterprises average the physical and mechanical properties of rocks in order to use one type of EE and as a consequence to use the constant specific consumption of EE.

At the same time despite the deterioration of the qualitative indicators of the explosion (increase in the output of oversize, overgrinding, not qualitative study of the sole of the ledge) are acceptable technical and economic indicators provided [11, 12, 13].

In his turn the advantage of EE is practically not used, it consists the possibility of varying the range of its quality characteristics taking into account relation of the changing range of physical and mechanical properties of the explosive rocks of the developed deposit, both on the quarry site and within one the blown up block [14,15,16].

All currently used EE type "water in oil" depending on the main components at the final stage of production (it means directly before charging them into the hole or by the location in tanks of mixing and charging machines (MCM)) can we classify into two subclasses: with or without the addition of a dry phase AN to the matrix emulsion solution before mixing it with a gas-generating additive (GGA) to activate the gas generation process.



**Figure 1.** Classification of EE type "water in oil" on the main components at the final stage of their production (MCM).

In the table 2, 3 are shown the compositions as a percentage of the main components listed EE, according to the classification and technical conditions (TC) [17, 18, 19, 20], and possible range of variation of their explosive characteristics.

**Table 2.** The relation of the emulsion and GGA in percent for various types of emulsion explosives, according to the TC(1 subclass of classification) and the range of possible changes in their explosive characteristics.

Name	The structure of the component, %							
	Istrit A-100	Istrit B-100	NPGM-100	NPGM-100S	Fortis advantage 100	Fortis eclipse 100	Sibirit-1000	Sibirit-1200
Emulsion	98,5	98,5	98-99	98-99	100	100	100	100
GGA	1,5	1,5	0,5-2,0	0,5-2,0	0,3-1,0 (in excess of 100% of the emulsion)	0,3-1,0 (in excess of 100% of the emulsion)	1,0-2,0 (in excess of 100% of the emulsion)	1,0-2,0 (in excess of 100% of the emulsion)
Heat of explosion, Kcal/kg	750 (3135)	750 (3135)	558 (2336)	558 (2336)	778 (3260)	778 (3260)	729 (3050)	617 (2580)
Detonation speed, m / s	5400	5400	5400	5400	5100	5100	4800-5400	4900-5200

**Table 3.** The relation of the emulsion and GGA in percent for various types of emulsion explosives, according to the TC (2 subclass of conditional classification) and the range of possible changes in their explosive characteristics.

Name	The structure of the component, %					
	Istrit A-70	Istrit B-70	NPGM-75	NPGM-75S	Fortis advantage 80	Fortis eclipse 80
Emulsion	69	69	74-74,5	74-74,5	80	80
Ammonium nitrate	30	30	24-24,5	24-24,5	20	20
GGA	1,0	1,0	0,5-2,0	0,5-2,0	0,3-1,0 (in excess of 100% of the emulsion)	0,3-1,0 (in excess of 100% of the emulsion)
Heat of explosion, Kcal/kg	830 (3469)	830 (3469)	689 (2879)	689 (2879)	880 (3700)	880 (3700)
Detonation speed, m / s	5700	5700	5100	5100	4740	4740

Because the basis of all considered EE is matrix emulsion, the table 4 presents its compositions used in the fields of the southern Urals.

**Table 4.** The content of the components of the emulsion (100 %) in percent for various types of emulsion explosives according to the TC.

Name of component	The structure of the component, %		
	Fortis advantage 100	Sibirit-1000	Sibirit-1200
Emulsion	100	100	100
Ammonium nitrate	75,2	58-69	73-79
Sodium nitrate (calcium)	-	10-18	-
Water	18,8	15-16	15-19
Industrial oil	4,5	4,5-7,5	4,5-7,5
Emulsifier	1,5	0,5-2,5	0,5-2,5

Thus the use of opportunities of changes in the characteristics of emulsion explosives in a wide range together with the data obtained in the process of drilling of the explosive block by the drilling rigs, which have axial pressure sensors, provides the optimal composition of emulsion explosives in the process of direct loading of a borehole, in accordance with the previously obtained physical-mechanical properties of the blasted rocks [21].

#### 4. Methods of manufacture, delivery and charging of emulsion explosives

Based on the analysis of the world and domestic experience in the manufacture of emulsion compositions on technological complexes [22] it is proposed their division based on the availability of energy and raw materials for the following types:

- stationary (factory);
- semi-stationary (containers);
- mobile (machine-factory).

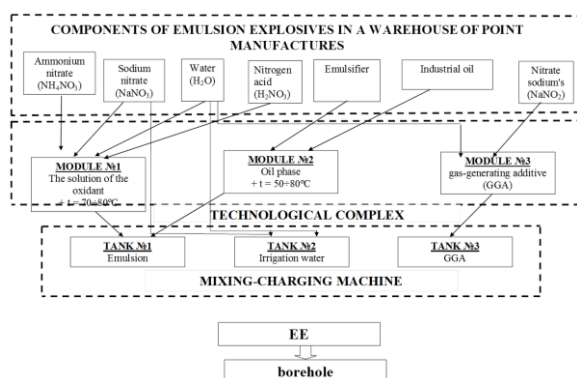
Stationary technological complexes should be installed in close proximity to energy resources and railway stations to supply the factory with the main components.

The main advantage of this complex is the minimum cost of production of EE and service of more than one field and the practical absence of restrictions on production capacity [23, 24].

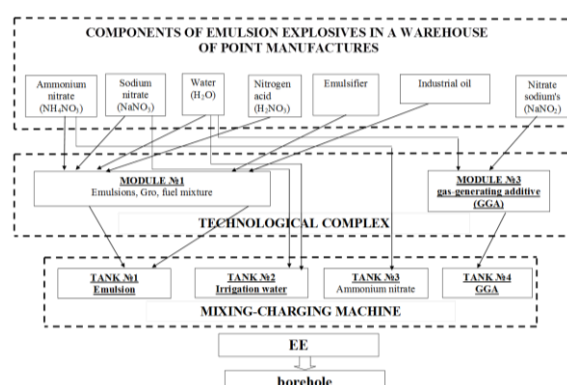
Semi-stationary technological complexes of container type it is advisable to install at the service of one's career and a significant remoteness from transport infrastructure and the chemical factory manufacturer of AN.

Mobile technological complexes such as "machine-factory" (Kemerovo) should be used by the location of the quarry in the immediate vicinity from the chemical factory or warehouse of AN.

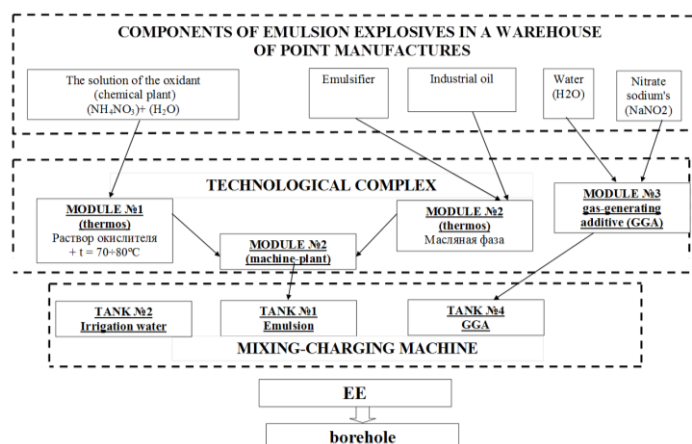
Schemes of technological complexes for the production of EE type stationary, semi-stationary and mobile are shown in 'fig. 2, 3 and 4'.



**Figure 2.** Technological scheme №1 of production of EE "Sibirit-1000 and 1200" on the example of LTD "Uralsky Sibirit".



**Figure 3.** Technological scheme №2 of production of EE "NPGM" on the example of JSC "NPIGORMASH".



**Figure 4.** Technological scheme №3 of production of EE on the example of "machine-factory" Kemerovo.

The main characteristics of technological complexes of preparation of EE and their comparison are presented in table 5.

**Table 5.** Characteristics of technological complexes for preparation of emulsion explosives and their comparison

Type of technological complex	Performance, tons / year	Raw material base (chemical factory)	Formulation, during the shift	Application	Region of the the location of the mobile technological complex EE (Example)
Stationary (Technological complex № 1)	More than 30 000	Any chemical factory	Variable (depending on career)	Quarries with different mining-geological and climatic conditions within a radius of 1000 km. Any temperature conditions	RF, LTD "Uralsky Sibirit", Magnitogorsk. (Sibirit-1000, Sibirit-1200)
Semi-stationary (Technological complex № 2)	No more than 17 000	Any chemical factory	Conditionally constant (without adaptation to external conditions, usually one quarry)	A quarry or quarries with constant mining, geological and climatic conditions within a radius of 1,000 km. The impact of low temperature (crystallization)	RF, JSC "NIPIGORMASH" Ekaterinburg. (NPGM)
Mobile (Technological complex № 3)	More than 20 000	Any chemical factory within a radius of 100 km	Constant (without adaptation to external conditions, usually one quarry)	Quarry with constant mountain-geological and climatic conditions in a radius of 300 km	Kemerovo

It should be noted that the construction of stationary and semi-stationary technological complexes provides the following:

- joint venture (royalty);
- capital construction or prepared place.

## 5. Substantiation of the choice of method of manufacture and delivery of Explosives on the example of Masalsky GOK

Possible variants of the application of technological schemes of production and delivery of EE are considered the example of the quarry Masalsky GOK.

*Option 1.* Stationary or semi-stationary technological complex for the manufacture of emulsion explosives. Masalsky GOK is located 16 km to the West of the railway station, which allows the construction and installation of its own stationary or semi-stationary technological complexes.

In this option the cost of production and delivery of 1 ton of Explosives is influenced by the following factors:

- Joint venture (royalty).
- Capital construction (schemes №1 and №2).
- Commissioning period (more than 1 year).
- Capital expenditures (more than 300 mln rubles).
- Equipment rental.

*Option 2.* Stationary technological complex on the basis of the existing factory LTD "Uralsky Sibirit" in Magnitogorsk on the basis of the outsourcing agreement. Masalsky GOK is 700 km from LTD "Uralsky Sibirit" factory located [23, 24]. To provide EE in volume of 10 000 tons / year it is planned to use MCM and suppliers of EE components (tractor, Tonar and tank container) by the outsourcing company. In this case the pricing of 1 t EE is regulated only by the outsourcing company.

The cost of 1 ton of Explosives is influenced by the following factors:

- The cost of the components of emulsion explosives at the factory.
- Transportation of components (matrix) EE by suppliers (10-12 cars).
- Use of MCM at the deposit (1-2 cars) for the manufacture and charging of Explosives.

Interest rate on the lease of delivery trucks, because it is necessary to buy them for the factory and its production capacity.

*Option 3.* Mobile technological complex on the example of partial outsourcing with the participation of the existing factory LTD "Uralsky Sibirit", Magnitogorsk. To provide EE in volume of 10000 tons / year, it is planned to lease the MCM and the tank container of the company-outsourcing and to purchase suppliers of the EE components to the factory (only the tractor and tonar).

Due to the fact that the deposit in question is located on the territory of the Republic of Kazakhstan, an export license (Russian Federation, LTD "Uralsky Sibirit") and an import license (Republic of Kazakhstan, Masalsky GOK) are required. In this case the pricing of 1 ton of EE is regulated not only by the outsourcing company, but also by the mining company (Masalsky GOK).

The cost of 1 ton of Explosives is influenced by the following factors:

- The cost of the components of emulsion explosives at the factory.
- Depreciation of suppliers of the components of emulsion explosives (10-12 cars).
- Operating costs by work of the suppliers.
- Rent of MCM (1-2 cars) for the manufacture and charging of EE.

After covering capital costs (1-1.5 years) the cost of EE is reduced to 20% of the second option (outsourcing).

## 6. Conclusion

Modern EE and methods of their production allow on the same components to provide qualitative explosive characteristics of EE in a wide range.

In aggregate with the presented specifications of prepared for the explosion block can we get a high quality of DBO by minimum costs for their implementation.

On example of quarry Masalsky GOK preferred is the use of mobile technological complexes, where the transport of all the components of emulsion explosives is by tank-container to the industrial site of the quarry, and then to a rechargeable block of MCM.

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