On the issue of defining safe distances and overpressure under impact of shock air blast wave (Magnesitovaya mine)

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Abstract. As the depth of mining increases, attention to the preservation of mine workings and mining blasting is steadily growing. Technological methods of effective mineral development are often limited by dynamic blasting impact causing short-period fluctuations in the rock mass. Therefore, correct explosion impact identification, to a great extent, determines effective mining trends. Some results of researches for minimum blasting impact on mining workings are given in the article. Calculation of safe distances and excess pressure at shock air impact of technological explosions on the Magnezitovaya mine personnel was made. The calculation was made for the 15.5 m mine working section, with two conditions of the total section of the mine workings adjacent to the face of 15.5 m and 31 m with distances of 50 m and 100 m. Overpressure was also calculated for a total cross-section of 15.5 m and distances of 150 and 200 m. It was determined that the safe distance for people under overpressure conditions at the shock air wave front, depending on breaking schemes, is in the range of 150-200 m. The urgency of this research is to ensure industrial safety of underground mining operations.
Keywords: blasting operations, technological explosion, blasting operations in underground mine workings, shock air wave, excessive pressure at the front of shock air wave (SAW)

1 Introduction

Urgency of the research of underground explosions impact is determined by the necessity to determine the safety of new and improve the existing systems for mineral development and their parameters, within the pilot industrial testing. The assessment of explosions consequences is necessary for subsequent selection of acceptable drilling and blasting options in specific areas, depending on the actual underground working space. Our task was to determine the safe distances and overpressure of technological explosions during cleaning operations in the Magnezitovaya mine under industrial conditions.

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2 Industrial explosive

Industrial granular grammonite TM explosive is used for blasting operations at the Magnezitovaya mine. Its purpose is manual and mechanized charging of dry and drained boreholes, wells and chambers on the earth's surface and in the faces of underground mines, non-hazardous for gas and dust in the temperature range from -50 to +50 ° C for medium hard and hard rocks, except for sulfide ores.

An intermediate detonator is necessary for grammonite TM initiation. For open working one intermediate charge T-400G or 2 ... 3 cartridges of ammonite 6ZhV (GOST - Russian National Standard 21984-76) with a cartridge weight of 200 ... 250 g are enough, and a cartridge-packed ammonite 6ZhV with weight not less than 200 g is used for underground operations.

Grammonite TM is the explosive, fire hazardous and toxic substance. It is sensitive to mechanical and thermal effects. It should be protected from strong mechanical action, any external fire and heating sources, soaking, atmospheric precipitation and direct sun rays.

The main physical-chemical and explosive characteristics of grammonite TM are presented in Table 1.

Table 1. Physical-chemical and explosive characteristics of grammonite TM [1]

Characteristics	Standard
Appearance	Mixture of ammonium nitrate granules and crystals with granulatole and petroleum product
Mass fraction of moisture and volatile substances, %	0.7
Explosive heat, kJ/kg	3938 (940)
Volume of gases, l/kg, toxic fumes including calculated on CO, l/kg, not more than	854 24
Oxygen balance, %	- 0.36
Trinitrotolul equivalent by explosion heat	0.94
Charging density, g/cm^3	1.0 … 1.15
Detonation velocity, m/s	2200 … 3500
Critical detonation diameter in steel pipe, mm	19
Brisance (GOST 5984-99), mm	23
Impact sensitivity (GOST 4545-88): Blast frequency in the device 1, % lower limit in the device 2, mm	24 … 40 200
Friction sensitivity to (GOST R50835-95), lower limit, mPa	490
Flash point, °C	346 … 349
Volume resistivity, Ohm*m	2.9 * 10^6

3 Theory and Calculation Results

The overpressure is determined at the shock air waves (SAW) front to specify the safe distances of the SAW impact to exclude the people injury, facilities and technological equipment damage during underground mine blasting [2-12] (expression (1)). The calculation was made for the mine section of 15.5 m, two variants of the total section of the mine workings adjacent to the face of 15.5 m and 31 m with the calculated distances of 50 m and 100 m. Overpressure was also calculated for a total cross-section of 15.5 m and distances of 150 m and 200 m.

$$\Delta P = \left(3410\frac{Q_e}{R\sum S} + 794\sqrt{\frac{Q_e}{R\sum S}}\right)\cdot e^{-\frac{\beta R}{d}},\ \text{kPa}, \qquad (1)$$

where $\sum S$ - the total cross-section area of the mine workings adjacent to the charge (two variants are taken into account 15.5 m and 31 m); R – distance; e - base of the natural logarithm = 2.71; *d* - equivalent diameter of mine working; β - surface roughness coefficient (accepted 0.07) ∑S = 31 m.

$$d = 1.12\sqrt{S} \text{ , m,} \tag{2}$$

Equivalent charge (Q_e) is defined as follows:

$$Q_e = 12PdK_sN \text{ , kg,} \tag{3}$$

where *d* - diameter of the blast chamber; K_s - coefficient taking into account the ratio of the length of stemming or the undercharged part of the blast chamber to the borehole diameter; N - number of charges in the group.

Calculation was made according to FRaR (Federal Rules and Regulations): Safety Regulations for Blasting Operation [13]. Results of calculations are presented in tables 2 - 6.

Table 2. Equivalent weight of explosives depending on blasting conditions

Borehole diameter, m	Charging density, kg/m^3	Equivalent weight Q_e, kg						
		Number of charges in group						
		6 charges	9 charges	11 charges	12 charges	13 charges	15 charges	16 charges
0.089	1000	0.6	1.4	1.6	1.8	2.2	2.5	3.4
	1100	0.7	1.6	1.8	2.0	2.4	2.7	3.7
	1150	0.7	1.6	1.8	2.1	2.5	2.9	3.9
0.076	1000	0.2	0.6	0.6	0.6	0.6	0.7	1.0
	1100	0.3	0.6	0.7	0.7	0.7	0.8	1.1
	1150	0.3	0.6	0.7	0.7	0.7	0.9	1.1

Table 3. Overpressure according to conditions at a distance of 50 m

∑S, m	Borehole diameter, m	Charging density, kg/m^3	Overpressure at 50 m distance, kPa						
			Number of charges in group						
			6 charges	9 charges	11 charges	12 charges	13 charges	15 charges	16 charges
15.5	0.089	1000	17.4	27.5	29.4	31.7	34.9	38.0	45.9
		1100	18.3	29.1	31.1	33.6	37.0	40.3	48.7
		1150	18.8	29.8	31.9	34.5	38.0	41.4	50.0
	0.076	1000	10.4	16.2	17.4	17.5	17.5	19.0	22.3
		1100	10.9	17.0	18.3	18.5	18.5	20.0	23.5
		1150	11.2	17.5	18.8	18.9	18.9	20.5	24.1
31	0.089	1000	15.0	23.4	24.9	26.9	29.5	32.0	38.3
		1100	15.8	24.7	26.3	28.3	31.1	33.8	40.5
		1150	16.2	25.3	27.0	29.1	31.9	34.7	41.6
	0.076	1000	9.1	14.0	15.0	15.1	15.1	16.3	19.1
		1100	9.5	14.7	15.8	15.9	15.9	17.2	20.1
		1150	9.8	15.1	16.2	16.3	16.3	17.6	20.6

Table 4. Overpressure according to conditions at a distance of 100 m

∑S, m	Borehole diameter, m	Charging density, kg/m³	Overpressure at100 m distance, kPa						
			Number of charges in group						
			6 charges	9 charges	11 charges	12 charges	13 charges	15 charges	16 charges
15.5	0.089	1000	5.4	8.4	9.0	9.7	10.6	11.5	13.8
		1100	5.7	8.9	9.5	10.2	11.2	12.1	14.6
		1150	5.8	9.1	9.7	10.5	11.5	12.5	14.9
	0.076	1000	3.3	5.0	5.4	5.4	5.4	5.9	6.9
		1100	3.4	5.3	5.7	5.7	5.7	6.2	7.2
		1150	3.5	5.4	5.8	5.9	5.9	6.3	7.4
31	0.089	1000	5.2	8.0	8.6	9.2	10.1	10.9	12.9
		1100	5.5	8.5	9.0	9.7	10.6	11.5	13.7
		1150	5.6	8.7	9.2	9.9	10.9	11.8	14.0
	0.076	1000	3.2	4.9	5.2	5.2	5.2	5.7	6.6
		1100	3.3	5.1	5.5	5.5	5.5	6.0	6.9
		1150	3.4	5.2	5.6	5.6	5.6	6.1	7.1

Table 5. Overpressure according to conditions at a distance of 150 m

∑S, m	Borehole diameter, m	Charging density, kg/m³	Overpressure at150 m distance, kPa						
			Number of charges in group						
			6 charges	9 charges	11 charges	12 charges	13 charges	15 charges	16 charges
15.5	0.089	1000	2.0	3.0	3.2	3.5	3.8	4.1	4.9
		1100	2.1	3.2	3.4	3.7	4.0	4.4	5.2
		1150	2.1	3.3	3.5	3.8	4.1	4.5	5.3
	0.076	1000	1.2	1.8	2.0	2.0	2.0	2.1	2.5
		1100	1.3	1.9	2.1	2.1	2.1	2.2	2.6
		1150	1.3	2.0	2.1	2.1	2.1	2.3	2.7

Table 6. Overpressure according to conditions at a distance of 200 m

∑S, m	Borehole diameter, m	Charging density, kg/m³	Overpressure at 200 m distance, kPa						
			Number of charges in group						
			6 charges	9 charges	11 charges	12 charges	13 charges	15 charges	16 charges
15.5	0.089	1000	0.8	1.2	1.3	1.3	1.5	1.6	1.9
		1100	0.8	1.2	1.3	1.4	1.6	1.7	2.0
		1150	0.8	1.3	1.4	1.5	1.6	1.7	2.1
	0.076	1000	0.5	0.7	0.8	0.8	0.8	0.8	1.0
		1100	0.5	0.8	0.8	0.8	0.8	0.9	1.0
		1150	0.5	0.8	0.8	0.8	0.8	0.9	1.0

The data in Tables 3 - 6, according to the selected conditions, indicate the following:

- up to 50 m from the explosion, the overpressure exceeds the maximum permissible pressure for a person (10 kPa) [13] almost in all cases and it is dangerous to be at this distance (dark grey);
- at a distance of 100 m from the explosion, the pressure is less, but in some conditions its value is also dangerous and exceeds 10 kPa;
- at a distance of 150 m all values are less than the maximum permissible, but the lower limit of damage for a person is present (5 kPa) [14];
- at a distance of 200 m the calculated pressure values are less than 2.2 kPa.

Therefore, according to the calculated data in Table 6, at a distance of 200 m, injury of a person is unlikely.

4 Conclusions

Thus, in the course of drilling and blasting operations with the accepted parameters specified above, the safe distance for overpressure at the SAW front for people, depending on the breakout scheme, is in the range of 150 - 200 m. This distance refers to the personnel forced to be close to the place of blasting operations. In other cases, the safety distance for people should be increased according to the FNiP "Safety regulations for blasting operations" [13].

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