

Rockburst From Floors

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Abstract. The purpose of this work is the calculation of the optimal parameters involved with advanced drilling of gas-draining holes. These holes are made to floor entryways and provide an efficiency test for floor degas extractions, like the AB bed at the Uralkali's Berizniki Ore Development Unit No 2 and Unit No 4 (Mine 2 and Mine 4). Current conditions and entry floor mechanisms affect the gassy outburst analysis of the potash mines. The optimal parameters of gas-draining holes at the Mine 2 and Mine 4 are calculated. The effectiveness test of advance drilling in a potash mine is made. Promising technologies for preparation and extraction, that help reduce the dangers associated with rockbursts from entry floors, have been proposed. Implementation of advance drilling in potash mines have significantly improved the safety of Mine 2's and Mine 4's AB bed preparation and extraction. A conclusion was made, based on the results of gassy outburst calculations of entry floors, that mitigation of hazards can be achieved by both degassing, and through the use of mining equipment that minimizes the size of floor cutting layers. The remaining ore, in the floor, helps eliminate the adverse effects of rockbursts.

Keywords: floor, gas-draining hole, gassy outburst, potash mines, rockburst, sylvinite bed, trapped gas pressure.

1. Introduction

It is understood that factors such as the pressure of trapped gas, gas found in the contact zone of lithological rock varieties (known as contact gas), the stress-strain placed upon rock salt mass, variations in physical and mechanical properties found in the rock, and the ore zone structure, will affect gas generation and subsequent gassy outbursts from the entry floor of potash mines (Proskuriakov *et al.*, 1974, 1988; Proskuriakov, 1980, 1991; Kovalev *et al.*, 1982; Duchrow, 1961; Ekkart, 1965).

A rockburst from the floor first occurred in France in 1959, during the development of the Alsatian potash deposit (Permyakov and Proskuryakov, 1972).

Since that time, effective techniques for anticipating gassy outburst hazards and mine control procedures for entry have been developed. Sudden roof breaks, often accompanied by gassing, can be avoided. These techniques have been implemented for Upper Kama mining districts (JSC «Uralkaliy», 2005; JSC «Sil'vinit», 2009).

The All-Russian Vedenev Hydraulic Engineering Research Institute (VNIIG), the Saint-Petersburg Mining University, the Perm National Research Polytechnic University, the Ural Branch of VNIIG and other organizations have contributed significant investigations on the mechanisms associated with rockburst generation and how to handle it.

Implementation of this research has resulted in the mining operations ability to significantly minimize gassy outburst related problems experienced during the extrac-

tions conducted at the sylvinite bed at the Upper Kama mining districts.

However, mining operations in the Uralkali's potash mines showed that the rockburst problem still is a topical problem.

Over the last few years, gassy outburst from entry floors has again become a relevant problem, during Mine 2's and Mine 4's AB bed extractions (Fig. 1).

Rockburst may lead to the sudden destruction of the rock floor, accompanied by gassing, which poses a threat to the life and well-being of miners, and may result in the need to shut down a mine for several months.

In this context, there was an urgent need to assess the effectiveness of advanced drilling techniques for gas-draining holes, which mitigate gassy outburst events, and the proper calculation of the optimal parameters related to degas drilling at Uralkali's Mine 2 and Mine 4.

2. Material and Methods

It is understood that the gassy outburst occurrence, as seen by sudden floor breakage, accompanied by gassing, is possible if the active force (pressure of the contact gas) exceeds the force supporting the floor.

Analysis of the conditions associated with rockburst occurrence has shown that the bottom base of the cavity is where contact gas is confined (contact zone of lithological rock varieties, clay seams, high-shale ore).

For the safety of miners during entries, the floor which contains contact gas needs to have an assessment of floor stability, with calculation of the minimal forces that

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Figure 1 - Rockburst in the sudden destruction of the rock floor, accompanied by gassing at Mine 4 AB bed.

could affect its balance (Kovalev *et al.*, 1982; Proskuriakov *et al.*, 1988; Proskuriakov, 1991; Obert, 1964; Obert & Duvall, 1967; Gasausbruch-richtlinien, 1981).

As already indicated, floor stability will vary, depending on the effects of the contact gas on or near the face zone position (face zone or a distance from face of 20 m (off-face zone)) (Fig. 2).

Thereby, the conditions of gassy outburst occurrence from entry floors at the face zone or the off-face zone can be calculated using the following formula (Kovalev *et al.*, 1982; Proskuryakov *et al.*, 1988):

$$P_{critical} \geq (0.7925 \times \sigma_t \times h_c^2 \times a^{-2} + \gamma h_c) + \Delta_{c.s.} \quad (1)$$

$$P_{critical} \geq (0.5 \times \sigma_t \times h_c^2 \times a^{-2} + \gamma h_c) + \Delta_{c.s.} \quad (2)$$

When potential rockburst from entry floors at the face zone is assessed using Eq. 1 and consideration is given to the weight of mining machines, a reduction in the occurrence of gassy outbursts results.

At the face zone, two sub zones were located.

The first sub zone is characterized by the pressure caused by the weight of mining machines.

Mining machine weight distribution is made on the area, which is determined by the entry width and length, the undercarriage dimensions of the mining machine, and the stiffness of Krasnyy I-A rock-salt bed.

Thus, weight application area is 19.2 m² for ore excavating machines PC-8 or Ural-61; weight application area for Ural-10KSA is 32 m²; weight application areas are 44 m², 46.4 m² and 48.8 m² and depend on entry width for Ural-20, making Eq. 1 for the first sub zone:

$$P_{critical} \geq (0.7925 \times \sigma_t \times h_c^2 \times a^{-2} + \gamma h_c) + \Delta_{c.s.} + \Delta_{m.m.} \quad (3)$$

Equation 1 will be correct for the second face sub zone.

Gas is associated with the contact and clay seams, which results in a force to stability mass structure (apart from geological faults zone).

The condition of rockburst occurrence at the off-face zone is also overworking of a gas pocket of the contact zone. It is possible, when the gas has larger pressure or migrates to this area through the change of the stress environment.

When the face zone is distant from a gas-containing region, the change of floor stability near the contact gas may result in gassy outburst occurrence of this type even with constant physical and mechanical characteristics of the rocks and the mass (with the same tensile strength, at the same gas content, gas pressure, etc.).

Thus, rockburst from the floor at the off-face zone may occur at a contact gas pressure not enough for the occurrence near the face. Gassy outburst at the off-face zone is therefore particularly dangerous, since it occurs suddenly. This fact must be considered when developing measures for the elimination of rockburst of this type. The criteria of a loss in floor stability were assessed for operating panels and unmined areas at Uralkali's Mine 2 and Mine 4.

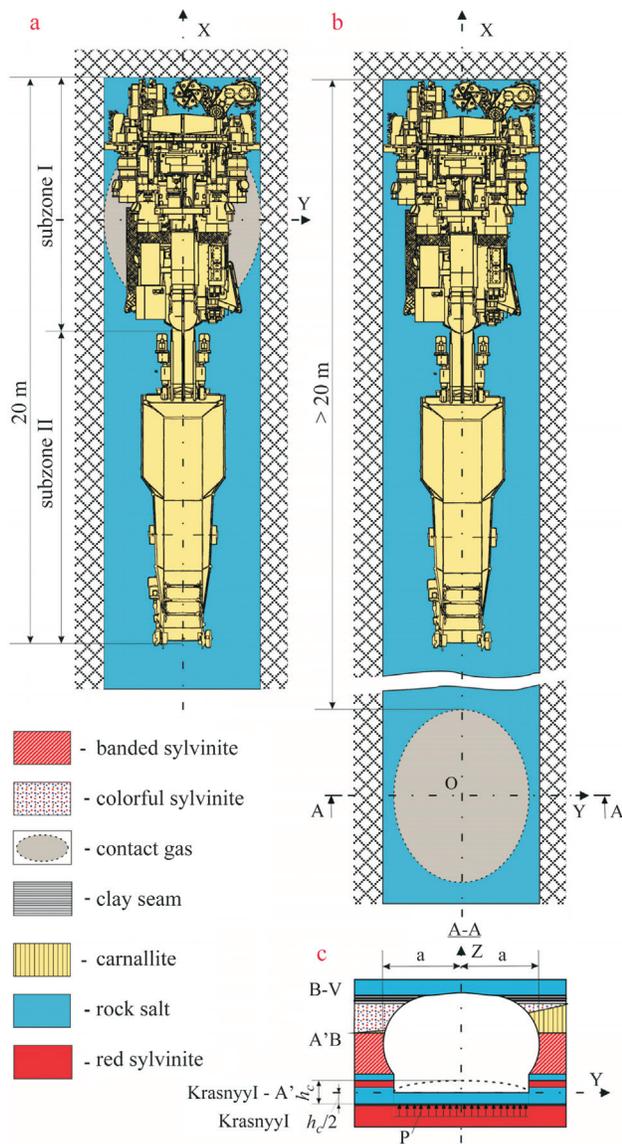


Figure 2 - Definition scheme of the contact gas critical pressure: a - at the face zone; b - at the off-face zone; c - for the rock floor.

3. Results

3.1. Assessment of a potential gassy rockburst

Assessment is made of a potential rockburst from the entry floor, where contact gas is located in clay seam of 3-5 cm thickness, between the Krasnyy I and KrasnyyI-A' rock salt beds, at the Berizniki Ore Development Unit No. 2. Assessment of a potential breakage of the entry floor is made for north-western and south-eastern areas of Mine 2: 8, 10, 12, 14, 16, 18 and 20 western panels (W. P.); 11, 13, 15 and 17 eastern panels (E. P.). It was calculated using Eqs 1, 2 and 3. Calculations were made for the types of ore excavating machines being used at the mined panels. Results of the calculations are shown in Table 1 (h_c , floor distance from the contact gas).

At the 8 W.P., the floor distance from the contact gas for “Ural-61” varies two fold, between 1.5-2.9 m as shown in Table. The distance of the floor from the contact gas is between 1.0-2.4 m, when using “Ural-20R”, which is also a very important factor. At 16 W. P., h_c was predicted to be at 2.0 m, due to insufficient data on the AB bed structure and the surrounding rock, when using “Ural-61”.

Table 2 shows the results of the calculation of the safe gas pressure at the floor entries, driven by Mine 2’s AB bed.

At the 14 W.P. the minimum gas safety pressure P_s on the floor, is 0.47 MPa (subzone II) and 0.49 MPa (subzone I) in extraction AB bed in Mine 2 north-western area when using “Ural-10A” as shown in Table 2. At the 14 W.P. P_s is 0.26 MPa (sub-zone II) and 0.28 MPa (subzone I) when using “Ural-61”. At 14 W.P. P_s is 0.02 MPa (subzone II) and 0.04 MPa (subzone I) when using “Ural-20R”. At the other panels in the north-western area, pressure is also minimum when using “Ural-20R” compared to the other types of mining machines.

Table 3 shows the results of an assessment of a potential gassy outburst from the entry floor at the off-face zone at Mine 2, as seen by sudden breakage of the entry floor.

In a similar manner, the criterium for loss in floor stability was assessed for Mine 4.

3.2. Justification for drilling optimal gas-draining holes in the entry floor at Mine-2, using advanced drilling techniques

There was a total of eighteen gassy outbursts with sudden breakage of the entry floor, that were accompanied by gassing at Mine 2. The histogram of distribution of the value h_c is shown in Fig. 3. On the horizontal axis, the floor distance h_c is set with a 0.3 m interval between values - with an interval of 0.3 m between them. The vertical axis displays the number of rockburst accidents having this distance.

The distribution is verified by checking the conformity with the normal probability law, and it was confirmed that it follows the rule (Ryzhov, 1973; Kalosha *et al.*, 1982). The next step was to determine the confidence interval for the value h_c .

The confidence interval for a normal distribution of value h_c at Mine-2 with a probability of 94% is:

$$3 \text{ m} < h_c < 1.7 \text{ m} \quad (4)$$

4. Discussion

The analysis of the extract from the Mine 2 north-western area subsequently showed that the distance of the floor from the contact gas is minimal at 10 and 14 W. P. when using “Ural-20R” and at 14 W.P. when using “Ural-61”, with h_c between 0.8-3.7 m.

As a result, the analysis of the extract from Mine 2 south-eastern area subsequently showed that 13, 15 and 17

Table 1 - Floor distances from the contact gas at Mine 2.

No.	Panel	Thickness of bed A'B, m		Thickness of bed Krasnyy I - A', m		h_c , floor distance from the contact gas, m					
						Ural 10A		Ural 61		Ural 20R	
		from	to	from	to	from	to	from	to	from	to
1.	8 western	2.65	3.41	1.8	2.44	-	-	1.5	2.9	1.0	2.4
2.	10 western	2.5	4.08	1.66	2.58	1.8	4.3	1.2	3.7	0.7	3.2
3.	12 western	2.50	3.18	1.84	2.21	2.0	3.0	1.4	2.4	-	-
4.	14 western	2.30	4.15	1.45	2.50	1.4	4.3	0.8	3.7	0.3	3.2
5.	16 western	2.78	2.78	2.15	2.15	-*	-	2.0	2.0	-	-
6.	18 western	2.70	4.37	2.00	3.30	-	-	1.8	4.7	1.3	4.2
7.	20 western	2.45	3.40	2.00	2.40	2.1	3.5	1.5	2.9	1.0	2.4
8.	11 eastern	2.30	2.60	1.62	2.18	-	-	1.0	1.8	-	-
9.	13 eastern	1.73	2.55	1.29	1.67	-	-	0.1	1.3	-	-
10.	15 eastern	1.98	2.54	1.30	1.82	-	-	0.3	1.4	-	-
11.	17 eastern	1.69	2.63	1.62	3.25	-	-	0.4	2.9	-	-

*- A line in the table means that the mining machine is not used at this panel.

Table 2 - Calculation results of gas safety pressure in Mine 2 entries floor (subzones I and II of the face).

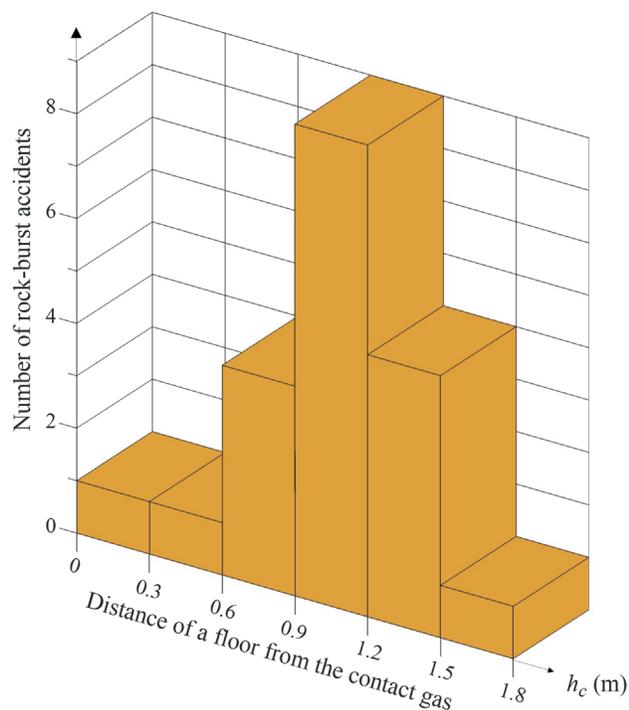
Panel	Ural 10A				Ural 61				Ural 20R			
	Gas safety pressure P_g , MPa				Gas safety pressure P_g , MPa				Gas safety pressure P_g , MPa			
	(subzone I)		(subzone II)		(subzone I)		(subzone II)		(subzone I)		(subzone II)	
	from	to	from	to	from	to	from	to	from	to	from	to
8 W.P.	-	-	-	-	0.90	3.22	0.87	3.19	0.19	0.92	0.17	0.89
10 W.P.	0.80	4.32	0.78	4.30	0.60	5.22	0.57	5.19	0.11	1.60	0.09	1.58
12 W.P.	0.96	2.18	0.94	2.16	0.78	2.29	0.75	2.26	-	-	-	-
14 W.P.	0.49	4.30	0.47	4.28	0.28	5.19	0.26	5.17	0.04	1.59	0.02	1.57
16 W.P.	-	-	-	-	1.53	1.53	1.50	1.50	-	-	-	-
18 W.P.	-	-	-	-	1.20	8.41	1.18	8.38	0.28	2.72	0.26	2.70
20 W.P.	1.06	2.79	1.04	2.77	0.90	3.11	0.87	3.08	0.19	0.88	0.17	0.86
11 E.P.	-	-	-	-	0.40	1.31	0.37	1.28	-	-	-	-
13 E.P.	-	-	-	-	0.03	0.66	0.00	0.63	-	-	-	-
15 E.P.	-	-	-	-	0.08	0.80	0.05	0.77	-	-	-	-
17 E.P.	-	-	-	-	0.09	3.28	0.06	3.25	-	-	-	-

Table 3 - Assessment results of a potential rockburst at Mine 2.

No.	Panel	Gas safety pressure P_g , MPa					
		Ural 10A		Ural-61		Ural 20R	
		from	to	from	to	from	to
1.	8 western	-	-	0.56	2.03	0.11	0.58
2.	10 western	0.51	2.75	0.37	3.31	0.06	1.02
3.	12 western	0.61	1.39	0.48	1.45	-	-
4.	14 western	0.31	2.73	0.17	3.29	0.01	1.01

Table 3 (cont.)

No.	Panel	Gas safety pressure P_s , MPa					
		Ural 10A		Ural-61		Ural 20R	
		from	to	from	to	from	to
5.	16 western	-	-	0.96	0.96	-	-
6.	18 western	-	-	0.76	5.32	0.17	1.73
7.	20 western	0.68	1.77	0.56	1.97	0.11	0.56
8.	11 eastern	-	-	0.24	0.82	-	-
9.	13 eastern	-	-	0	0.41	-	-
10.	15 eastern	-	-	0.03	0.5	-	-
11.	17 eastern	-	-	0.04	2.08	-	-

**Figure 3** - Histogram of floor distance from the contact gas at Mine 2.

E.P. are the areas with the greatest the possibility of a rockburst, as seen by an entry floor sudden breakage.

The possible occurrence of a potential gassy outburst is significant, as seen by an entry floor sudden breakage, during extraction of the AB bed in the north-western area using “Ural-20R”.

Based on the calculated pressures of the mining operations, there are dangers found at the East Panels when using “Ural-61”. It would appear to be useful to use a machine with a lower cutting height, or to use a drum miner, which would increase h_c and P_s .

Similar results for gas safety pressure calculations at the off-face zone were obtained, using face zone calculations. At the south-eastern area, rockburst, as seen by entry floor sudden breakage, at the off-face zone, is most proba-

ble at 14 W.P. when using “Ural-61” and at 8, 10, 14, 18, 20 W.P. when using “Ural-20R”.

For security reasons, the lower limit of 0.3 m for the confidence interval of the h_c value is not a preferred practice for mining operations at a bed with gassy outburst hazards.

Conclusions

The calculated results of contact gas safe pressure suggest that a technological solution is possible through the use of a mining machine that allows for minimized floor cutting (rock salt KrasnyyI-A’ bed). This approach, with rockburst problems from entries floor through advance drilling of gas-draining holes, differs from the traditional approach. Using a drum miner may be most appropriate in this mining engineering situation.

The upper limit of the confidence interval of value h_c reveals important practical findings:

- sudden breakage of the entry floor, accompanied by gassing, has a probability of 94% when cutting of 1.7 m thickness at Mine-2;
- it can be argued, that by drilling gas-draining holes in entries floor at AB bed of 1.7 m in depth, contact gas with a probability of 94%, will be degassed and the sudden breakage of the entry floor will be eliminated at Mine-2;
- it can be argued, that in the floor layers (ore leaved on the floor, in order to eliminate gassy outburst - value h_c) of more than 1.7 m thickness, rockburst of the entry floor, accompanied by gassing, will not occur when gas-draining holes are drilled.

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List of Symbols

- X, Y, Z: coordinate axis
 Ural 10A, Ural 61, Ural 20R: mining machine name
 E. P.: eastern panel
 P_s : safe gas pressure, MPa
 A'B, Krasnyy I - A': bed name
 W. P.: western panel
 for Eq. 1:
 $P_{critical}$: gas critical pressure, MPa
 σ_f : tensile strength of rock floor, MPa
 h_c : distance of a floor from the contact gas, m
 a : half entry width, m
 γ : unit weight of rock floor, H/m³
 $\Delta_{c.s.}$: shear strength of clay seams in floor, MPa
 for Eq. 2:
 $P_{critical}$: gas critical pressure, MPa
 σ_f : tensile strength of rock floor, MPa
 h_c : distance of a floor from the contact gas, m
 a : half entry width, m
 γ : unit weight of rock floor, H/m³
 $\Delta_{c.s.}$: shear strength of clay seams in floor, MPa
 for Eq. 3:
 $P_{critical}$: gas critical pressure, MPa
 σ_f : tensile strength of rock floor, MPa
 h_c : distance of a floor from the contact gas, m
 a : half entry width, m
 γ : unit weight of rock floor, H/m³
 $\Delta_{c.s.}$: shear strength of clay seams in floor, MPa
 $\Delta_{m.m.}$: pressure of the mining machine weight, MPa
 for Eq. 4:
 h_c : distance of a floor from the contact gas, m