

# Rescue complex for coal mines

D A Yungmeyster, R Yu Urazbakhtin

Saint-Petersburg Mining University, 21 Line, 2, St. Petersburg, 199106, Russia

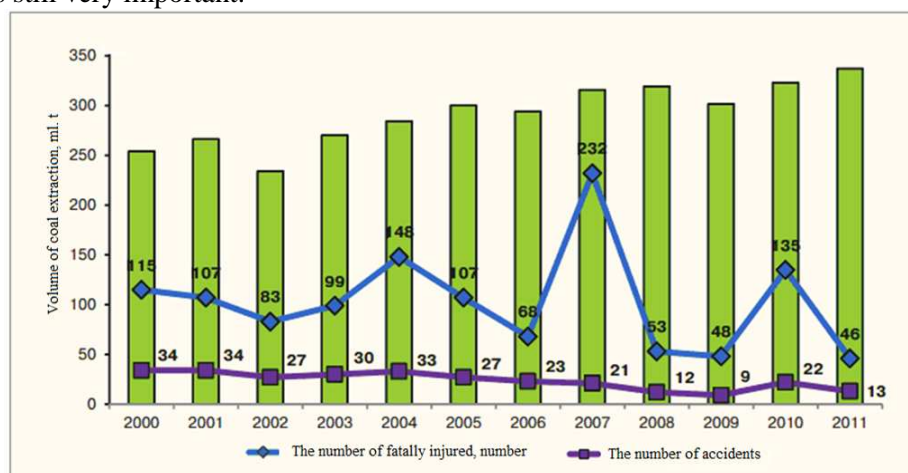
E-mail: [ruraz@mail.ru](mailto:ruraz@mail.ru)

**Abstract.** The mining industry was potentially dangerous at all times, even with the use of modern equipment in mines, accidents continue to occur, including catastrophic ones. Accidents in mines are due to the presence of specific features in the conduct of mining operations. These include the inconsistency of mining and geological conditions, the contamination of the mine atmosphere due to the release of gases from minerals, the presence of self-igniting coal strata, which creates the danger of underground fires, gas explosions. The main cause of accidents is the irresponsibility of both the manager and the personnel who violate the safety rules during mining operations.

## 1. Introduction

Currently, rescue operations in coal mines and other mines are carried out by mine rescuers using the minimum manual equipment set. Therefore, the urgent task is the development of a rescue complex for high-speed driving of a connection for emergency evacuation of the injured, which would significantly reduce the risk of traumatic situations for mine rescuers.

Figure 1 shows that every year [1,2], with the growth in production and mining operations, the number of accidents and deaths among workers in coal mines decreases, but the task of saving people from blockages is still very important.



**Figure 1.** Dynamics of production, fatal injuries and accidents in the coal industry.

As an example, let us consider the technogenic accident that occurred on October 23, 2003 in the

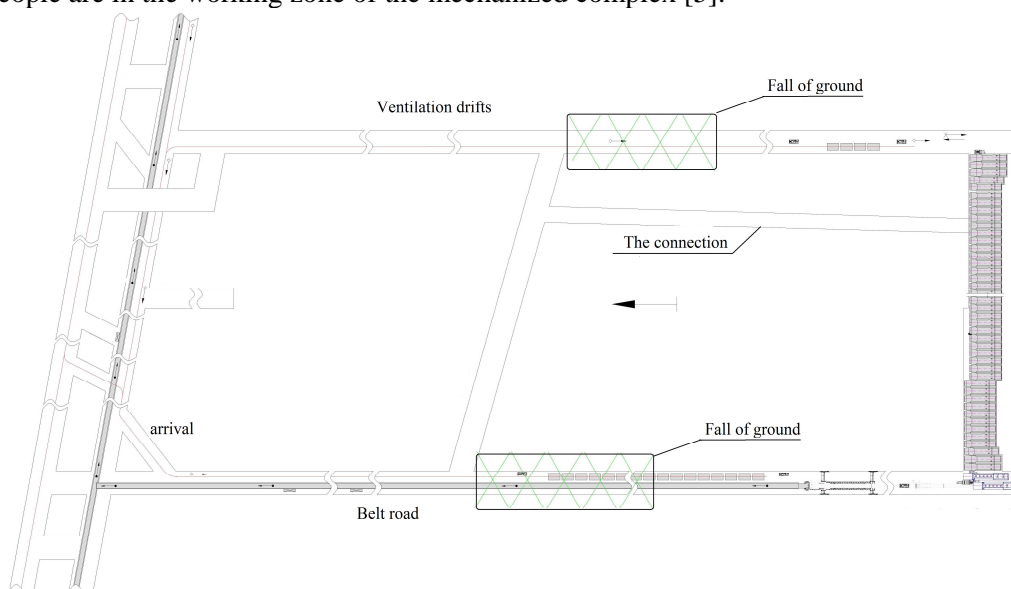
mine «Zapadnaya-Kapitalnaya». The accident cut off the way to the surface of the 46 workers of the mine, as a result of the breakthrough of water into the main skip shaft of the mine [3]. To rescue people, mine rescuers had to drive a 60-metre connection from the transport drift of the neighboring mine «Komsomolskaya Pravda» to the conveyor drift of the «Zapadnaya-Kapitalnaya» mine along which the workers were evacuated to the surface. The connection was driven using manual labor and fastening with wooden frames of trapezoidal shape. Obviously, in this case, the availability of special equipment providing high-speed driving of a connection such as a lightweight pass-through complex would substantially reduce the time spent by rescued workers under extreme conditions.

## 2. Methods and means of rescue operations of mines

The main method of rescuing people from localized zones after accidents at mines is to carry out high-speed workings of small cross-section for supplying air and livelihoods to the miners who fell into a blockage. The experience of such operations shows that in some cases it is advisable to conduct a well from the surface (mine San Jose, Chile) [4], which, after expansion, allows evacuating people from the dam zone. In the Russian Federation, where mines are located in difficult areas, evacuation of people through vertical workings is often impossible, so horizontal rescue workings are mostly used. Meanwhile, there is a large number of complexes and sets of equipment for performing such operations. However, still there is a very urgent task to create a complex for high-speed driving of small-section workings, consisting of machines and units that meet the basic requirements: small dimensions and weight, easy assembly and dismantling, high driving rate.

## 3. Development of design and parameters of the rescue complex

The main task, in our opinion, is the development of a set of mechanisms capable of driving rescue workings as soon as possible, in order to evacuate people from the dam. In this case, the length of the rescue connection must be minimal. Figure 2 shows a possible version of driving a rescue working in the case of the obstruction of belt road and ventilation drifts of the mining section of the coal mine when people are in the working zone of the mechanized complex [5].

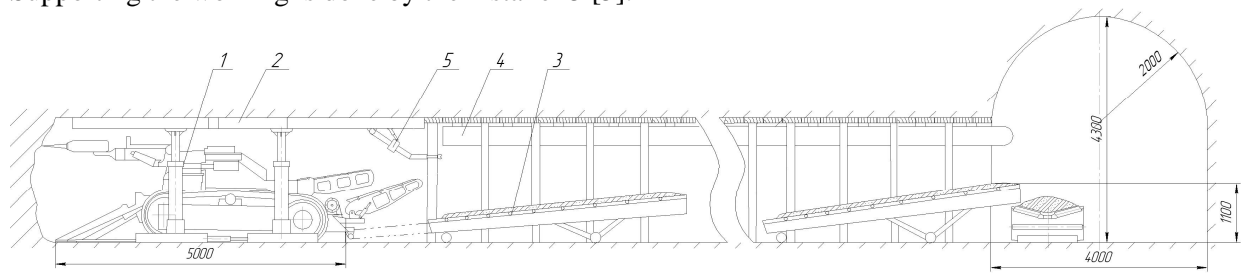


**Figure 2.** Variant of rescue work

### *The design of the rescue complex*

Figure 3 shows the possible layout of the complex with a medium-stable roof. Roadheader 1 produces rock cutting with a shock hammer executive unit. At the same time, the roof over the roadheader is retained by a powered walking support 2. The rock is transported, for example, by belt conveyors 3. Ventilation is provided by means of ventilation pipes 4 and a fan of local ventilation.

Supporting the working is done by the installer 5 [5].



**Figure 3.** The layout of the complex with a medium-stable roof.

Roadheader must have removable cutting attachments or executive units (EU): cutting heads for processing slaughtering or part of the face formed by brittle and soft rocks (charcoal); a shock hammer executive unit for the destruction of hard interlayers or rocks of increased hardness; the executive unit in the form of hydraulic (pneumatic) power shears; the executive unit in the form of a bucket. The design of replaceable cutting attachments must ensure the simplicity and speed of their replacement [5].

**Table 1.** Calculated values of the technical productivity  $Q_t$  for two values of rock hardness

Type of executive unit	$Q_t, \text{m}^3/\text{h}$	$Q_t, \text{m}^3/\text{h}$
	f=2	f=6
Rotational action	65	-
Shock action	54	4.3

Table 1 shows that the performance of the executive unit of the rotary action is higher than of the shock hammer executive unit, but since this type of executive unit is not applied to hard rocks, it is advisable to use the removable cutter heads of shock hammer action, providing the possibility of driving the working, but with a significant loss in productivity [5].

*Calculation of the time of driving the connection for a different hardness of the bottomhole rocks*

1. For unstable roofing and increased hardness of rocks in the face:

Calculation of cycle time:

$$T_C = T_{\text{formation}} + T_{\text{cycle of walking}} + T_{\text{support}} + T_{\text{preparatory}}, \text{h}, \quad (1)$$

where  $T_{\text{formation}}$ ,  $T_{\text{cycle of walking}}$ ,  $T_{\text{support}}$ ,  $T_{\text{preparatory}}$  – the time of formation of the face, the cycle of walking, the support of the connection, the preparatory operations (the sum of the time for pulling up the conveyor and increasing the ventilation pipe).

$$T_{\text{formation}} = \frac{V}{Q_t} = \frac{S \cdot l}{Q_t}, \text{h}, \quad (2)$$

where  $V$  – the volume of the worked out space,  $\text{m}^3$ ;  $S$  – cross sectional area ( $S=3\text{m}^2$ );  $l$  – the depth of the worked out space ( $l=0.5\text{m}$ );  $Q_t$  – technical productivity (table 1),  $\text{m}^3/\text{h}$ .

$T_{\text{cycle of walking}} = 1.7 \text{ min}$ ;  $T_{\text{support}} = 12 \text{ min}$ ;  $T_{\text{preparatory}} = 5 \text{ min}$ .

Calculation of the rate of driving:

$$v = \frac{L_C}{T_C}, \text{m/h}, \quad (3)$$

where  $L_C$  – Cycle length ( $L_C=0.5 \text{ m}$ ).

Calculation of the driving time of the connection 50 m long connection (Table 2):

$$T_{\text{driving}} = \frac{L_{\text{connection}}}{v}, h, \quad (4)$$

where  $L_{\text{connection}}$  - length of the connection ( $L_{\text{connection}} = 50 \text{ m}$ ).

2. For a stable roof with a low rock hardness in the face when combining some operations:  
Calculation of cycle time:

$$T_C = T_{\text{cycle of walking}} + T_{\text{support}} + T_{\text{preparatory}}, h, \quad (5)$$

when combined  $T_{\text{formation}}$  and  $T_{\text{cycle of walking}}$  used the longest time  $T_{\text{cycle of walking}}$ .

Since there is no need for frequent fixing of a stable roof, the step of installing the arch support is 1m, thus  $l = L_C = 1$  in the formulas (2,3).

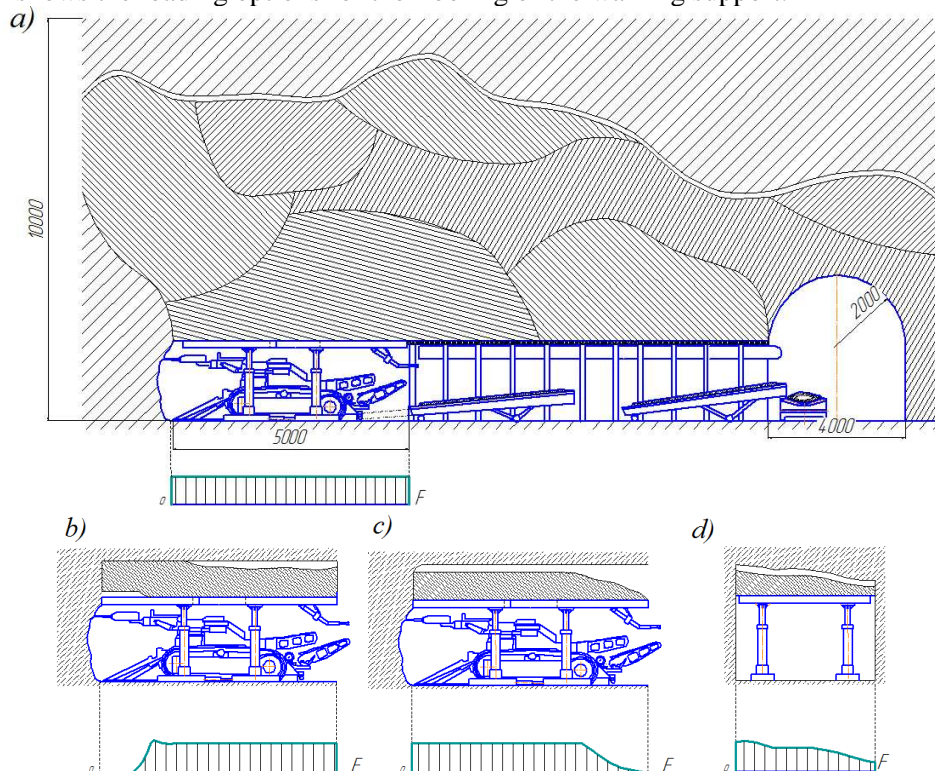
**Table 2.** The calculated values of the main parameters in the complex, depending on the type of stability of the roof

Roof type	$l, \text{ m}$	$L_C, \text{ m}$	$T_C, \text{ min}$	$v, \text{ m/h}$	$T_{\text{penetration}}, \text{ h}$
Unsustainable	0.5	0.5	40	0.75	67
Sustainable	1	1	20	3	17

Calculations show that the time of driving of a fifty-meter-long the connection with a stable roof will be approximately 20 hours, and with an unstable one - about 70 hours [5].

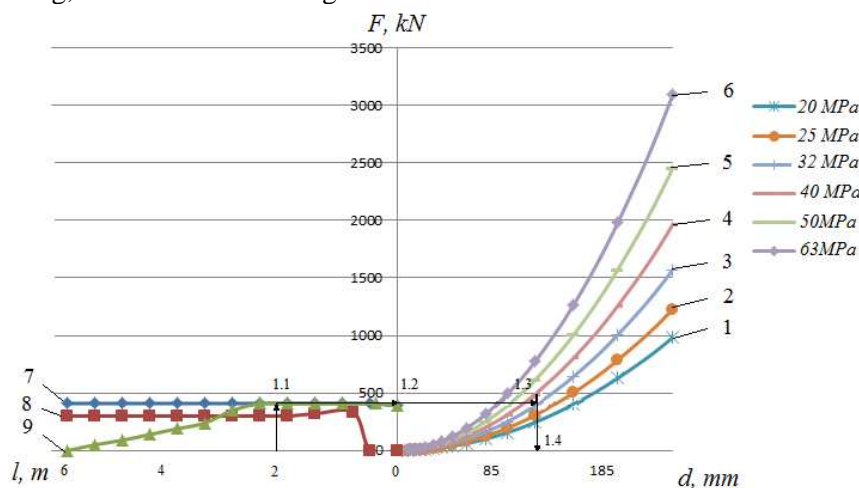
#### *Choice of the hydraulic cylinder of the walking support depending on the load*

Figure 4 shows the loading options for the flooring of the walking support.



**Figure 4.** Variants of loading of the beam of the walking support: a) the support is loaded with a monolithic piece of rock; b) the beam of the support in the front part is not loaded; c) the load on the walking support is reduced due to the flowability of rocks; d) uneven load on the support along the width of the face (view from the face).

Figure 4a shows the most unfavorable case where the beam of the walking support is subjected to the maximum load from the action of a monolithic piece of rock, provided that the support retains a rock block 8 m long, 2 m wide and 8 m high.



**Figure 5.** Nomogram of determining the hydraulic cylinder of the walking support in relation to the load acting on the roof side: 1 - load graph from the piston diameter at the working fluid pressure ( $p$ ) in the hydraulic cylinder 20 MPa; 2 - at  $p = 25$  MPa; 3 - at  $p = 32$  MPa; 4 - at  $p = 40$  MPa; 5 - at  $p = 50$  MPa; 6 - at  $p = 63$  MPa; 7 - a graph of the dependence of the load on the length of the output for a distributed load; 8 is a graph of the dependence of the load on the production length for a medium-stable roof; 9 is a graph of the dependence of the load on the production length in the presence of free-flowing rock [8-10].

So, for example, when loaded with a monolithic piece of rock (Fig. 4, a), the walking support experiences the maximum load ( $F = 400$  kN) per one pillar of the beam (point 1.1 - 1.2 in Figure 5). The optimal choice is a hydraulic cylinder with a piston diameter of 125 mm with a working fluid pressure of 40 MPa, which allows it to withstand the load on the roof side (point 1.3 - 1.4 in Figure 5), taking into account the force reserve for a small diameter.

#### 4. Conclusion

After the final selection of the layout schemes of all nodes of the patented universal complex and their technological processing, tests can be performed in industrial conditions to clarify the possibility of transporting the components of the complex, ensuring quality and speed of assembly and dismantling. This complex can provide effective rescue of people at blockages in coal, shale mines and potash mines, as well as for driving minor workings of small cross-section, including for household needs in the construction of subways.

#### 5. Acknowledgments

This research was supported by the St. Petersburg Mining University in 2017, St. Petersburg, Russia.

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