ТЕХНОЛОГИЧЕСКИЕ СХЕМЫ БЕСЦЕЛИКОВОЙ ОТРАБОТКИ КАЛИЙНЫХ ПЛАСТОВ В СЛОЖНЫХ ГОРНО-ГЕОЛОГИЧЕСКИХ И ГОРНОТЕХНИЧЕСКИХ УСЛОВИЯХ

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РЕЗЮМЕ. Представлены перспективные технологические схемы бесцеликовой отработки калийных пластов в сложных горно-геологических и горнотехнических условиях ведения подготовительных и очистных работ в условиях рудников РУП «ПО «Беларуськалий».

TECHNOLOGICAL SCHEMES OF POTASH SEAMS PILLARLESS MINING UNDER DIFFICULT GEOLOGICAL AND MINING CONDITIONS

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ABSTRACT. Presented perspective technological plans of pillarless mining of potash seams under difficult geological and mining conditions during development and longwall mining under conditions of ore mines of the JSC «Belaruskali».

Introduction

Maintenance of productive capacities of operating potash mines of the JSC "Belaruskali" is based, first of all, on the strict economic assessment of the remained potash ore field reserves, solution of questions concerning adjustment of qualitative characteristics of useful components' content in the ore during extraction and processing. The mines have free sections at their mine-field boundary. For the mines or separate sections of the levels having insignificant remaining life using slot system or generally pillar mining for reserve extraction including the reserves at their mine-field boundary is unique possibility of maintenance of their productive capacities, as well as by winning under difficult geological and mining conditions of Starobin potash salt deposit and under the conditions of the limited basis of mine construction [1, 2].

Extension of their mine life for account of the rational reserve extraction by minimum losses left in protective pillars between development workings is considered to be a special case of maintenance of operating potash mines' productive capacities. At the same time, the reserve extraction for account of free sections is often carried out without additional economic feasibility on the ratio of ore mining at maximum possible and economically feasible losses reduction in protective pillars between development workings. Preparation of such sections is carried out under provisional plans with deconcentration of mining. Mining at the deep levels (exceeding 750 m) complicates preparation and mining of new sections as well as completion of mining in connection with difficult geological and mining conditions of the development. Moreover depth factor not so much explains the reasons of technical and economic indexes degradation as shows non-conformance of existing panels' development plan and nor in respect of production engineering but in their suitability to mining of seams with complicated structure at the deep levels and decrease losses left in the pillars for protection of development workings. In the future there are no reasons to wait that full road heading and mining machine appear and will be able to settle the problem of existing mechanization of potash seams mining comprehensively.

The analysis of current situation shows that resources of technical upgrading are in many respects depleted, and primarily without re-engineering of extraction and as well as without essential decrease losses of mineral it is impossible to achieve considerable improvement of technical and economic indexes of domestic potash branch's performance. But even in this situation it is possible to maintain that existing equipment is able to raise extraction efficiency but the essential precondition is perfection of production engineering of potash ore extraction, reduction of mineral's operational losses by implementation of potash seams' pillarless mining [3, 4].

It should be pointed out that mining of the 2nd, 3rd and 4th layers of the third seam with its driving at the depth exceeding 750 m is defined by high mineral losses (more than 50%) in interstall protective pillars. It is determined that [5] reserves extraction volume and expenses for their winning are in direct dependence on the mining method chosen for specific mining and geological conditions. Selection of the most effective seam mining method becomes complicated at the depth of working exceeding 750 m. At such depth of the 3rd seam becomes problematic to use slice mining to support gate roads of the top face on the 4th sylvinite layer because of hazardous roof. For this reason this layer is left underground. Herewith only development workings driven in the bottom seam part with connection of roof to stable interlayer keep stable condition during panel working. At the seam depth of 900 m and more the development workings driven in the bottom seam part start to destroy in 5-6 months after their driving.

There are various alternatives for protection of section development mining located from worked out area's side by pillarless seams' mining and roof control by total roof caving. These alternatives are based upon use of packs and cast sections from fast-hardening materials, as well as engineering structures and camouflet cavities [6-9].

In addition gate protection methods by means of mineral pillars are wide-known and nowadays. The basic demands raised to pillars are maintenance of development mining stability in longwall work affected area as well as pillar's autodestruction in worked out area after taking some protective measures.

Effective application of pillarless mining of potash seams under difficult geological and mining conditions is restrained by some unsettled issues connected with calculation of minimum sizes of pillars, justification of protective means for skin-to-skin workings, especially at deep levels, as well as with adaptation of known technological schemes of slice mining to conditions of acting potash mines of the JSC "Belaruskali", and with development of new resource-saving technological schemes of room mining.

Technological schemes of potash seams pillarless mining and area of their application

Experience of existing technological schemes of pillarless seams mining (potash and coal seams) with long mining faces shows the following: pillarless mining of flat potash and coal seams at total thickness and with separation into layers is generally conducted abroad under the technological schemes providing reuse of the gate road for mining of the next panel by its maintenance in the various ways and means, and as well as mining temporarily left interstall pillar between double entries by shearer simultaneously with pillar mining in conventional face. By mining of interstall pillar either alternative is using a shearer cutting unsupported mining or dead-end face. At the coal mines abroad pillarless mining under technological schemes providing skin-to-skin mining (with pillar of 2-4 m) to worked out area is used at the seams 4-6 m thick with difficult mining and geological conditions.

At Starobin deposit mine fields sections allowing carrying out connection of skin-to-skin mining to stable layers of stone salt or sylvinite (to provide II or III roof type) could be considered as perspective for their pillarless mining using skin-to-skin mining. In addition in technological schemes is effectually to provide stagewise driving (by sections of 400-800 m) skin-to-skin minings by single advancing of the full face roadheader PK 8.

Technological schemes of slice mining of the 3rd seam developed and mastered at No. 1 PU' mine of the JSC "Belaruskali" provide wide opportunities for perfection of pillarless mining schemes of potash seams at Starobin deposit using double entries and cutting interstall pillars by a shearer of conventional face, as well as by location in the face of upgraded face conveyor's drive allowing cutting drum to advance to the face side with exception of face-end support with mining face for maintenance of the gate road from worked out area.

Mining methods used for the bottom layers of the 3rd seam (layer II, II-III, III) at No. 1 PU' mine with mining of the interstall pillar by the dummy road should be recognized as perspective for more difficult mining and geological conditions, but in these cases, the increased extraction of mineral deposit requires technical solutions for effective ventilation of blind parts of mining faces exceeding 10 m.

Pillarless options of pillar mining with maintenance of panel entries with packs from destroyed halite should be considered as perspective for Starobin potassium salt deposit. Longwall and pillar mining with in-stone development can be considered as basic for development of mine fields with difficult mining and geological conditions of mining works.

Development of potash seams pillarless mining under difficult geological and mining conditions is based on two main principles of development workings maintenance and driving at the boundary with the worked out area: reuse of the panel entries and their skin-to-skin mining to worked out area. Each of these methods for maintenance of the working has its advantages and disadvantages.

The advantage of skin-to-skin workings is their location outside a high underground pressure area, and the disadvantage is the need for stage-by-stage roadheading for the observance of set time-limit of their abutment to worked out area, as well as cutting service roadways in the face area and their maintenance in the area of intensive exposure of lateral back abutment pressure (behind unloading area). Therefore, by these technological schemes it is effectually to carry out panel development with a minimum number of service roadways or to fill these roadways with the ore from skin-to-skin entry while its stage-by-stage driving.

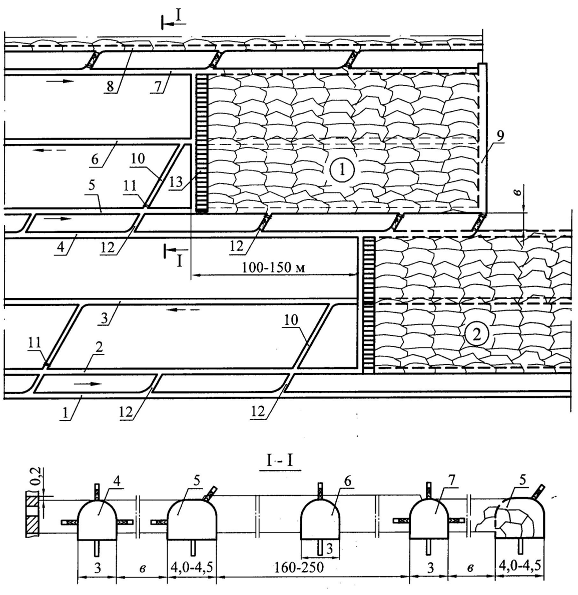
At the reuse of panel entries it is unnecessary to drive service roadways in the area of intensive exposure of lateral back abutment pressure, and length and quantity of service roadways are essentially reduced by panel mining using one group from three or four workings. Such panel development with driving of workings out of intensive exposure zone of longwall work enhances stability of development workings, reduces their road life and accordingly the time for mining panel development. However expenses for maintenance of workings reused can essentially increase in some alternative technological schemes. The most essential decrease in expenses for maintenance of reusable workings under conditions of Starobin deposit is achieved by their use only for air supply (output) into the face (from the face).

Further we present some examples of pillarless mining of the second and third seams.

Figure 1 provides the technological scheme of complete mining of the 2nd potash seam with reuse of adjoining panel's haulage roadway only for ventilation of conventional face.

Each panel is developed by group of three gates using service roadways for driving air roadways in the central part of the panel out of intensive exposure zone of longwall work from the adjoining face. This allows simultaneous mining of few mining panels (2, 3 or more) with longwall works advancing from 100-150 m to 500 m and more. Necessary protection and support of reusable haulage roadways in the conventional face is provided depending on advancing longwall works in adjoining panels. Thus for sealing of worked out area from penetration of combustible gases into working zone of conventional face, the panel entry 1 is driven with leaving banded interstall pillar of width *в*, determined depending upon mining and geological working conditions, according to researches [4, 10]. Conveyor crosscut s 12 between panel haulage roadway 4 and face belt road 5 in front of working face of advanced face are filled with the rock between isolating dams. The rock for filling is obtained, for example, from cutting 4 compensation slots in the roadway. Thus, reliable sealing of worked out area from penetration of combustible gases into conventional adjoining face it is carried out.

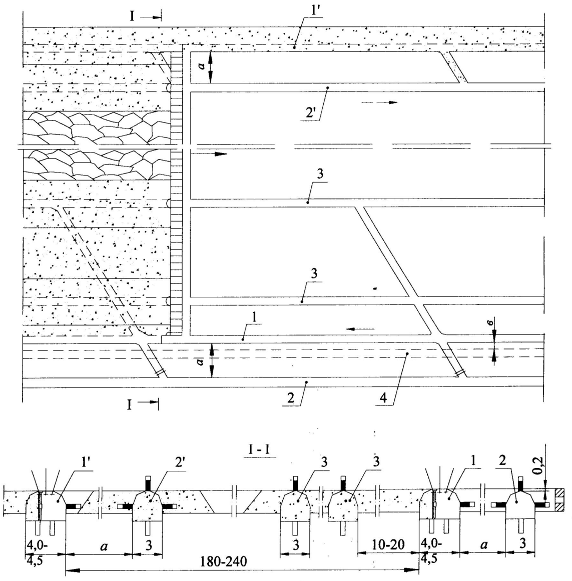
Nowadays there is a tendency of selective mining of the 2nd seam using complete mining at full capacity. For example, at No. 3 PU' mine selective face was driven using two three-roadway groups: from the solid's using panel belt road, face belt road and panel air roadway, and from the interstall pillar's side using air roadway with unloading and stowing entries. Panel air entry and stowing entry were driven using development workings cutting the field of the face. Three rotary throwing machines were installed (at each junction of the development working with the face), that allows stowing all broken rock in the worked out area.



1 – advanced mining pillar; 2 – conventional mining pillar; 1, 4 – panel haulage roadways; 2, 5 – belt face roadways; 3, 6 – air face roadways; 7 – reused haulage roadway without maintenance (only for ventilation); 8 – belt road of the interstall pillar; 9 – mother entries; 10 – access break-through; 11 – air stopping; 12 – conveyor break-through; 13 – face support; *в* – width of the banded interstall pillar

Fig. 1. Technological scheme of the second potash seam mining with reuse of panel entry at the boundary with the working without maintenance

Using previous experience a new technological scheme of selective seam mining was designed with application of development group scheme with workings' reuse. In the group of workings the panel air roadway 2 (Fig. 2) is driven from the solid and is protected by temporary pillar *a* from bearing pressure effects of adjoining face. Two to three stowing entries are driven In the field of the panel plotted against the accepted length of the face (Fig. 2).



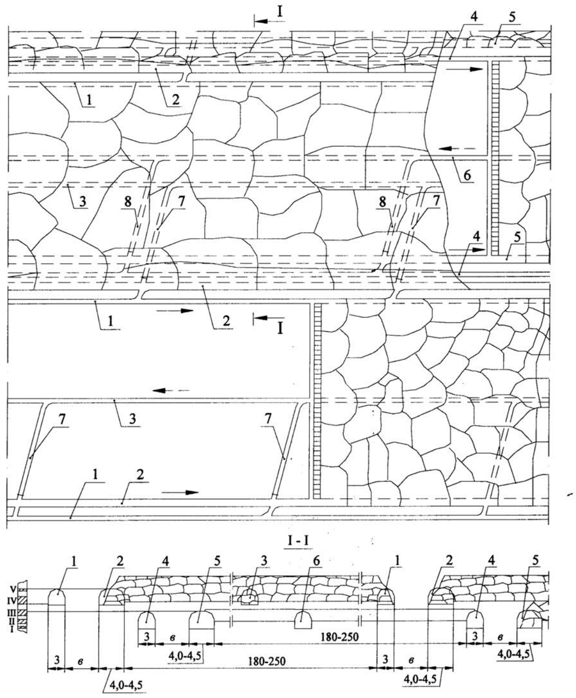
1 – belt roadway; 2 - panel air entry; 3 – stowing entry;
1 ' - belt roadway of the completed panel; 2 ' – face air entry;
4 – skin-to-skin (service) roadway (driven if necessary);
A - width of the temporary pillar; в - minimum width of the pillar

Fig. 2. Technological scheme of the second seam selective mining with reuse of adjoining panel workings

Technological scheme foresees reuse of panel air roadway 2 and belt roadway 1 with shearer cutting the conventional adjoining face to partly stowed and unsupported in the worked out area belt roadway 1 without installation of the face conveyor's drive and powered face-end support at its junction. Skin-to-skin service roadway 4 can be driven if it is necessary to use boundary working for transport of goods and people walking close to worked out area with a minimal pillar *в*.

Technological scheme of successive working of the upper layer (IV sylvinite layer) and the bottom part of the seam (layers II, II-III and III) with a group three-roads development of panels (Fig. 3) is designed for mine fields' sections of the 3rd potash seam with stable immediate mine roof of the seam (presence of V and VI sylvinite layers). Mining of both layers is conducted with leaving the pillars with the width *в* between panels. Development of each panel taking into account the upper layer starts with driving panel haulage roadway 1, belt roadway 2 and air face roadway 3 and is being driven with use of service roadways 7 for cutting air roadway 3 in the central field part of the face [11].

When the panel is developed the mother entries are joined with haulage roadway 1 of adjoining panel. Then mechanized complex is assembled and longwall works start without installation of the powered support at the junction of the face with reused haulage roadway of adjoining panel. Development and working is effectually to carry out in two or three panels simultaneously with longwall works advancing in adjoining panels using experimental way. Obviously, the closer to each other will be the mining faces, the less destructed will be the reused haulage roadway. As in the technological scheme of the 2nd seam mining (Fig. 1) in the given scheme the sealing of the panel haulage roadway from the worked out area can be carried out by means of sealing salt and concrete dams and by filling break-through by fine refuse, and as well as by combination of these two methods.



1, 4 - panel haulage roadways; 2, 3 – belt and air roadways of the top face; 5, 6 - belt and air roadways of the bottom face; 7, 8 – multislice service minings; в - minimum width of the pillar

Fig. 3. Technological scheme of successive pillarless mining of the third seam with complete mining of layers II, II-III and III

Development of the panel for each bottom face starts after working of the upper layer and is carried out also by three roadways (4, 5, 6) using service roadways 8. When development is finished and mother entries are joined with haulage roadway 4 of advanced face, installation of face equipment is carried out. Complete mining of the bottom layer's seams is driven using haulage roadway 4, which is cut with the pillar of 5-10 m between them and main gate 2 of the upper face. The reusable roadway is sealed in the above described way.

Technological scheme presented in fig. 4 foresees advanced mining of IV sylvinite layer by pillar system as advancing mining to the development workings driven in the bottom part of the seam, and the subsequent mining of layers II, II-III and III also by pillar system as retreat mining with driving new workings. By design of production scheme the following was taken into account: necessity of service life decrease for mining roadways at the boundary with worked out area; providing high speed (3-4 m/days), advancing of mining face in the upper IV layer; fail-safe mining the upper IV layer of the development workings, which cut the panel of the bottom face.

It should be noted that based on the experience of the 3rd seam mining at the No. 4 PU's mine, all development workings are driven in the lower part of the seam with leaving in the roof a protective rock unit of the III sylvinite layer of a thickness 0.3 m. Panel development starts with a group of three workings: panel belt road 1, panel air roadway 2 and belt road 3 of the face, and is driven to the middle or to the one-third of the panel's technological crosscuts 5, which later will be used for air roadway 4 skin-to-skin cutting with sections acceptable for mining and geological conditions (on the length). In this case, at the first section of the mother entry is effectually to drive skin-to-skin roadway with a length equal to two distances between technological crosscuts 5.

For development of panel without crossings during stage-by-stage cutting of skin-to-skin air roadway 4, panel air roadway 2 is driven in the face field with leaving banded pillar of a width *в* between it and belt road 3 and is sealed from fresh air by air stoppings 6. In order to provide fail-safe extraction (without intermediate rock failure III-IV) of technological workings 5, after their development they are filled with the ore from driving skin-to-skin roadway.

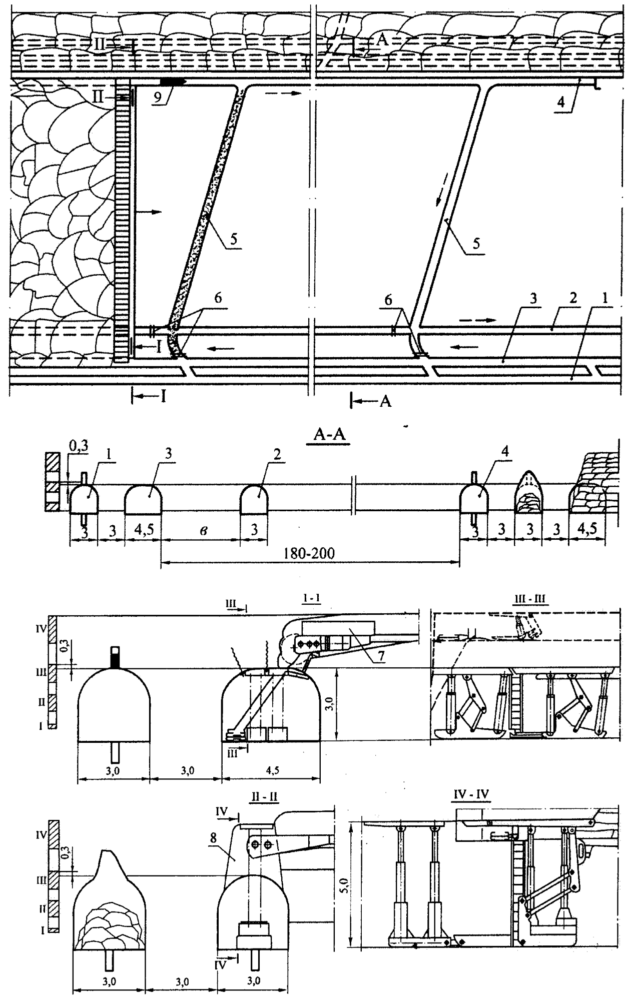
Longwall works taking into account the IV layer begin after installation of longwall equipment and cutting cavity 8 in the roof of skin-to-skin air roadway 4, for example, using the shearer KSP-22S with mining face advancing according to an experimentally determined length. Crosscutting of the main gate with mining face is performed during each technological cycle when shearer or face end machine ESA-150 reach the drive of the face conveyor. An inclined compensation slot is cut in the main gate from the face side with a "canopy" in the roof. It is used as secondary operation for driving crosscutting between face and main gate.

Except two technological schemes for the 3rd seam mining presented above, the other three are developed: simultaneous pillarless mining of the 3rd seam layers with selective mining of layers II, II-III and III; pillarless selective mining of the 3rd seam with mining bottom face workings; pillarless selective mining of the 3rd seam with reuse of an adjoining panel [12-14].

Selection of technological production scheme for the specific section of the 2nd or 3rd seam is made mainly taking into account thickness the seam layers, depth of working and stability of immediate seam roof.

It is recommended to use complete mining for sections of the second seam where the halite interlayer thickness is less than 0,6 m. The panel is driven using one three roadway group driven out of bearing pressure zone of adjoining face with reuse of haulage roadway of adjoining panel only for ventilation of adjoining part of mining face of conventional adjoining face (for example, according to the technological scheme presented in fig. 1).

Sections of the 2nd seam with halite interlayer thickness of 0,6 m and more, and of the upper sylvinite layer thickness less than 0,8 m are recommended for selective mining with stowing bands from the broken halite interlayer after roof support. These stowing bands are made using rotor throwers.



1, 2 - panel belt and air entries; 3 – belt entry of the face; 4 - air entry of the face driven skin-to-skin to the worked out area; 5 - technological workings; 6 - air stoppings; 7 - machine ESA-150 or shearer; 8 - cavity in the roof (cut by the shearer KSP-22S); 9 - shearer KSP-22S

Fig. 4. Technological scheme of the third seam extraction with subsequent mining of layers and driving panel entry of the upper face skin-to-skin to the worked out area

The application area of these pillarless mining schemes for the 3rd seam mining is defined by possibility of maintenance of face panel entries at the boundary with worked out area under conditions of their connection to the roof above IV sylvinite layer (presence or absence of V and VI sylvinite layers in the roof) and by the depth of the working.

For example, the technological scheme, presented in Fig. 3, is recommended for application at depths up to 800 m when the roof of the seam contains V and VI sylvinite layers, and the technological scheme, presented in Fig. 4, is recommended for application at depths exceeding 800 m by absence of V and VI sylvinite layers in the roof.

Width of pillars between skin-to-skin working and workings of the worked off adjoining face is determined depending on depth of working, for example, using the graph plotted in fig. 5.

Conclusions

Scientific researches and pilot and industrial tests carried out allowed developing seven the most perspective technological schemes of potash seams pillarless mining. Decrease of sizes or total absence of interstall pillars in developed technological schemes is attained for the account of: workings driven at the boundary with worked out area behind extraction front of the advancing adjoining face; reuse of working by its maintenance behind mining face of the working being worked or clearing out for working of adjoining panel of conventional face; leaving a temporary pillar between mining panels. This pillar is mined out by a shearer of the conventional adjoining face simultaneously with longwall mining in the face.

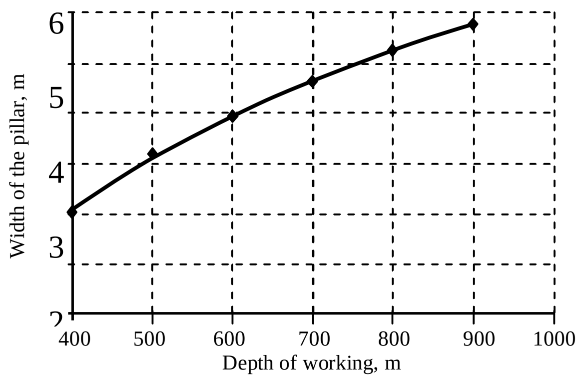


Fig. 5. Graph for determination of width of the pillar between skin-to-skin working and workings of the worked off adjoining face

Perfection of pillarless technological schemes of potash seams mining at the mines of the JSC "Belaruskali" under difficult mining and geological conditions issues perspective challenges. Their solution promotes more complete extraction of potash ore reserves by maximum possible and economically feasible losses reduction in the pillars. In modern production conditions development of scientific knowledge in the area of pillarless mining of potash seams has wide perspectives for maintenance of production capacities of operating potash mines.

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