Experience in Application of XLPD Extra Low-Profile Robotic LHD for Narrow Bedded Vein Mining at Mine No.8 of ‘PIMCU’ PJSC

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Abstract

The paper presents the demonstration test results of the XLPD track low-profile LHD designed by DOK-ING for narrow bedded vein mining (m=1.6–1.8 m). These tests were performed in Mine No.8 of ‘PIMCU’ PJSC. The demonstration results proved the applicability of this equipment for the conditions of Mine No.8 due to reduced dilution, improved safety of mining operations, decreased volumes of both mined and processed ore keeping the metal production at the same level.

The main economic effect of utilizing this complex can be obtained by cutting the metallurgical conversion costs.

Key words: *load and haul equipment, low-profile LHD, track, underground, robotic, production capacity, bucket, crawler, diesel-engine drive*

General information on the testing ground

The Mine No.8 allotment includes the Malo-Tulukuevskoe and part of the Yubileynoe deposits. The mined bedded ore veins are limited by a low-angle inter-formational fault at the boundary between tuff / tuff sandstones and underlying conglomerates. They account for approximately 30% of the mine's balance reserves. In the plane view the ore bodies have the shape of narrow veins with the width from 20 up to 150 m and the length from the first hundreds up to 800-1400 m. They are limited with tectonic wedges. The deposits generally dip at 5–10° and less frequently at 15–20° The average thickness of the ore bodies within the deposit is 1.62 m.

As a rule, the ores are soft and require post-and-bar supports with the spacing of 1-1.5 m.

The need and objectives to demonstrate XLPD operational capabilities

Until recently all the ‘PIMCU’ PJSC mines were mostly developing steep dipping ore bodies of small and average thickness using descending mining in slices and consolidating stowing with top-down sequence. The share of other mining methods was insignificant due to unstable properties of ores and the surrounding rocks as well as the 4th Group of morphological complexity.
Upon commissioning of Mine No.8, extraction from narrow bedded ore bodies was started, which represents part of the mine’s reserves (Fig.1).

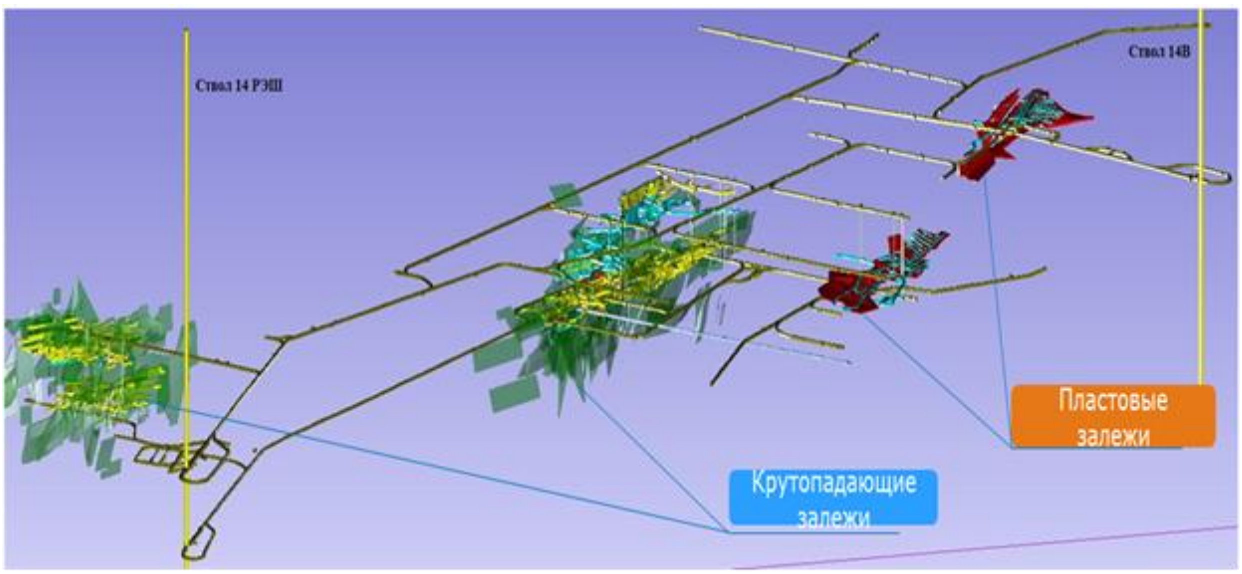

Figure 1. 3D model of mine workings and ore bodies at Levels 6 and 7 in Mine No.8 with indication of the steeply dipping and bedded ore bodies

The first stopes of this morphology with the thickness of 1.5-2 m were mined in *stopes with the cross-section of* 34 m using the hauling equipment available in the mine (PD-2E). A typical cross-section of the stopes used for mining bedded ore bodies with standard equipment is shown in Figure 2.

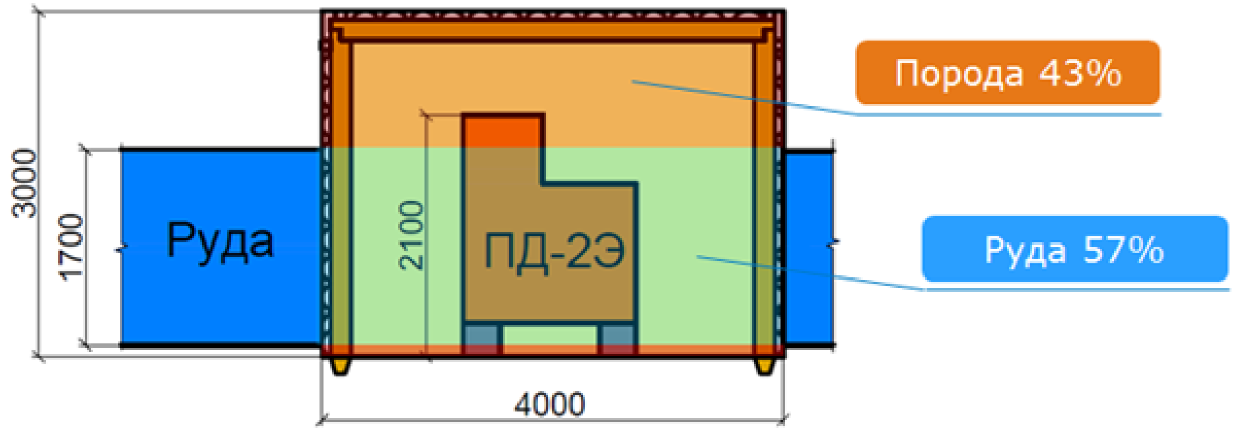

Figure 2. Typical cross-section of the stopes when the PD-2E unit is used for ore haulage

Experience gained during the vein extraction determined the specific features of the block development patterns, rational width of the stopes and their locations with relation to the ore bodies. However, high dilution (over 43%) required searching for new equipment that would meet the existing mining and geological conditions.

The diesel XLPD low-profile robotic LHD (Fig.3) manufactured by DOK-ING (Croatia) was selected as the best fit for the given conditions and the existing size of permanent workings.

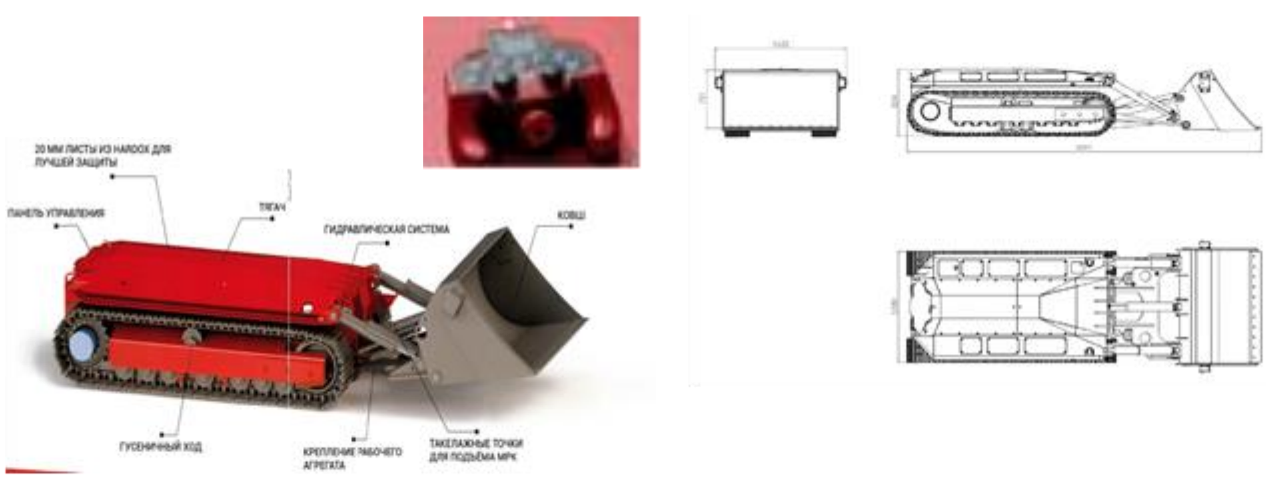

Figure 3. Exterior view of the XLPD low-profile robotic LHD:
a) Exterior view and remote controller; b) Outside dimensions

The main advantage of this model is its compact size that enables mining of bedded ore bodies with minimum vertical cutback of waste rock (Table 1).

Features	Parameter
Prime mover dimensions (L x W x H), mm	2700 x 1380 x 834
Prime mover dimensions with bucket (L x W x H), mm	4391 x 1632 x 834
Prime mover weight, t	3.5
Prime mover weight with bucket, t	4.3
Bucket volume, m^3	0.65
Driving speed, km/h	Up to 5
Ground clearance, mm	130
Engine	DEUTZ diesel engine, 3100 cm^3
Power rating, hp	88
Fuel capacity, l	60
Power transmission	Hydraulic
Drive train	Track driven
Chassis	20 mm steel plate

Table 1. Technical Specifications of XLPD LHD

Some doubts in the XLPD applicability were raised due to its relatively low speed (up to 5 km/h), thus an agreement was reached between the 'PIMCU' PJSC and DOK-ING to perform a demonstration of the diesel XLPD low-profile robotic LHD at a 'PIMCU' PJSC site in order to achieve the following goals:

1. To verify conformity of the system's key parameters to the production process requirements, i.e. gradeability, permissible drift size, carbon oxide and nitrogen oxide content in exhaust gases;
2. To test the operating capability of the LHD, i.e. duration of continuous operation during the shift;
3. To measure the technical performance of the unit;
4. To define the machine's time of the failure (MTBF) and the time required to perform the scheduled maintenance operations.

The results of this demonstration test had to be used to assess the application efficiency of this LHD and its procurement.

Demonstration place and test progress

Stope No.8-708 was selected for capability demonstration of the XLPD LHD. By the demonstration test time, the development work had already been completed and production was started using standard equipment, i.e. PD-2E. Mineralisation in the selected site is represented with unstable bedded flat deposit with the dip angles of 10–12° and the thickness of 1.6–1.8 m. Mining was done in stopes No.5, 7, 9 (Fig.4). The mined rock was done from the stopes with the negative dip angle of 8–12° and further on along a slice crosscut at the grade of 20°. The ore was unloaded either into ore pass 8-707/1 or on the haulage roadway floor. Throughout the whole demonstration test the machine was controlled by a qualified DOK-ING operator-mechanic.

Figure 4. Layout of mine workings at the site for capability demonstration test of the tracked XLPD low-profile LHD

The first days of the XLPD operation in the stope demonstrated a mismatch of the bucket shape the mining conditions. The box-shaped bucket was designed for loose platinum ores mined in the South African Republic, Canadian diamond mines and copper mines of Chile. A new bucket shape was proposed for conditions of the 'PIMCU' PJSC, which had a lip that would facilitate its penetration into the pile. Upon a prompt approval by the manufacturer, the proposed design was implemented. Changes in the bucket configuration resulted in significantly improved bucket penetration into the mined rock and enhanced bucket.

Bucket loading with rocks was done from the first pass without any additional operations. However, it turned out impossible to achieve the same efficiency in cleaning up of the working face at negative grades as was achieved with the PD-2E LHD. This happened mostly due to the differences in bucket lifting kinematics between the XLPD and PD-2E units.

The possible solutions are to construct the stopes from the bottom upwards or to gain more operator experience in working face cleaning operations. Introduction of the lip structure also had an impact on unloading capabilities on flat. There appeared the need for putting a wooden prop below the tracks, i.e. to create a ramp, in the dump area to enable a complete bucket discharge onto the drift floor. This modification had no impact on the cycle time.

Movement of the loaded XLPD LHD along the drifts was stable and the motion trajectory was in conformance with the one set by the operator. Bucket loading was done in stopes with the negative grade of 8–10°. Reversing of the loaded unit along the cut and the slope upon completion of the loading cycle did not involve any difficulties.

Insignificant spillage of the mined rock was observed bucket-forward down a slope with the grade of 20–25°. Upon revealing this issue, movement was done with the rear part forward only. However, when moving with the rear part forward these issues were no longer present. The manufacturer announced that this issue can be resolved by using deep-profile tracks.

The minimum distances required at the junctions between the support posts were defined as 2.6 m in the drift and 3.5 m in the stope. More effective operation of the XLPD LHD was observed at unsupported junctions with the operator safely located under the post-and-bar support in the haulage roadway. The operator was controlling the unit from the distance of 3-10 m from the LHD. This helped him to control the machine operation standing under the supported part of the working as well as to prevent unauthorized access of personnel into the production area (Fig.5).

Figure 5. Operation of the XLPD LHD in the block:
a, b, c – ore loading inside the stope;
d – exiting the primary stope towards the haulage roadway;
e – clearing a «dammed» junction at the haulage roadway

Stability of the XLPD LHD in transport of the mined ore along slopes in conditions of underground Mine No.8 was beyond criticism. Demonstration of the machine capabilities was performed on loose and clayey ground, and moving over such soils was done without sliding. Some challenges were faced when turning at the slope with the grade over 20°. This challenge was met by moving with the rear part forward.

Maintenance of the XLPD unit during the capability demonstration test caused no problems. As with any other diesel LHD, the unit was greased, the oil level was checked, the filters were purged with compressed air and the hose clamps were verified on the basis. The difference in maintenance as compared to the wheeled equipment was the need to perform tracks ‘tapping’ to check for the loss of bolts every shift. The time required for daily maintenance of the XLPD was around 30-40 minutes.

Results of capability demonstration test

The following parameters were obtained during the capability demonstration test:

Indicators	Result
Total haulage volumes, m^3	191
Achieved rate with L=80 m, m^3/h	5
Fuel consumption, l/h	6
Achieved minimum head room with the post-and-bar support, m	1.6
Decrease in the volume of mined ore due to reduced dilution, m^3	70
Increased content of useful minerals in the mines ore	by 1,8 times

Table 2. Results of capability demonstration test

During the demonstration test the height of a standard stope was lowered from 3 m to 1.8-2.0 m, which corresponded to the average thickness of the ore body (Fig. 6).

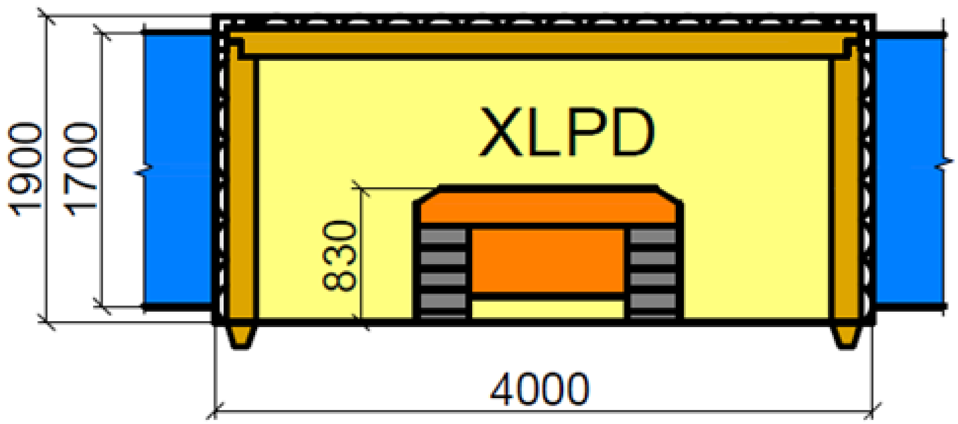

Figure 6. Mine working cross-section with the post-and-bar support with the tracked XLPD low-profile LHD used for ore haulage

Based on the demonstration results, block development and extraction plan were designed for further application with the use of the XLPD LHD with the post-and-bar support (Fig.7):

- Extraction of the bed is done from one flank to the other. The bed is divided along the strike by crosscuts into blocks with the length of 100-200 m depending on the availability of development drifts at the production level and the amount of reserves. Two adjacent crosscuts are inter-connected with a haulage roadway in the upper part of the deposit. Production stopes are driven down-dip from this roadway. The attempts to execute stopping up the dip and along the strike were not successful due to increasing formation pressure in the bottom part of the deposit following the work progress. The same reason explains why no delineating ore drift that would significantly facilitate block ventilation is constructed at the bottom of the deposit;

- Construction of development and access workings in the block using the PD-2E LHD. The XLPD is used to load and haul ore from the low-height stopes;

- Stopping is done in two stages: the block is divided into primary and secondary production stopes with the width of 4 m and the height of 1.8–2.0 m; the primary stopes are filled with consolidating stowing, while the secondary ones are backfilled with waste rock from the development operations or with sealing materials;

- The mined ore is delivered by the XLPD LHD to the short haul from the working face to the haulage roadway and is unloaded onto the roadway floor, (i.e. within the operator's line of sight without the need of additional relocation). The ore is then loaded from the floor of the haulage roadway by the PD-2E LHD and transported to the block's ore pass.

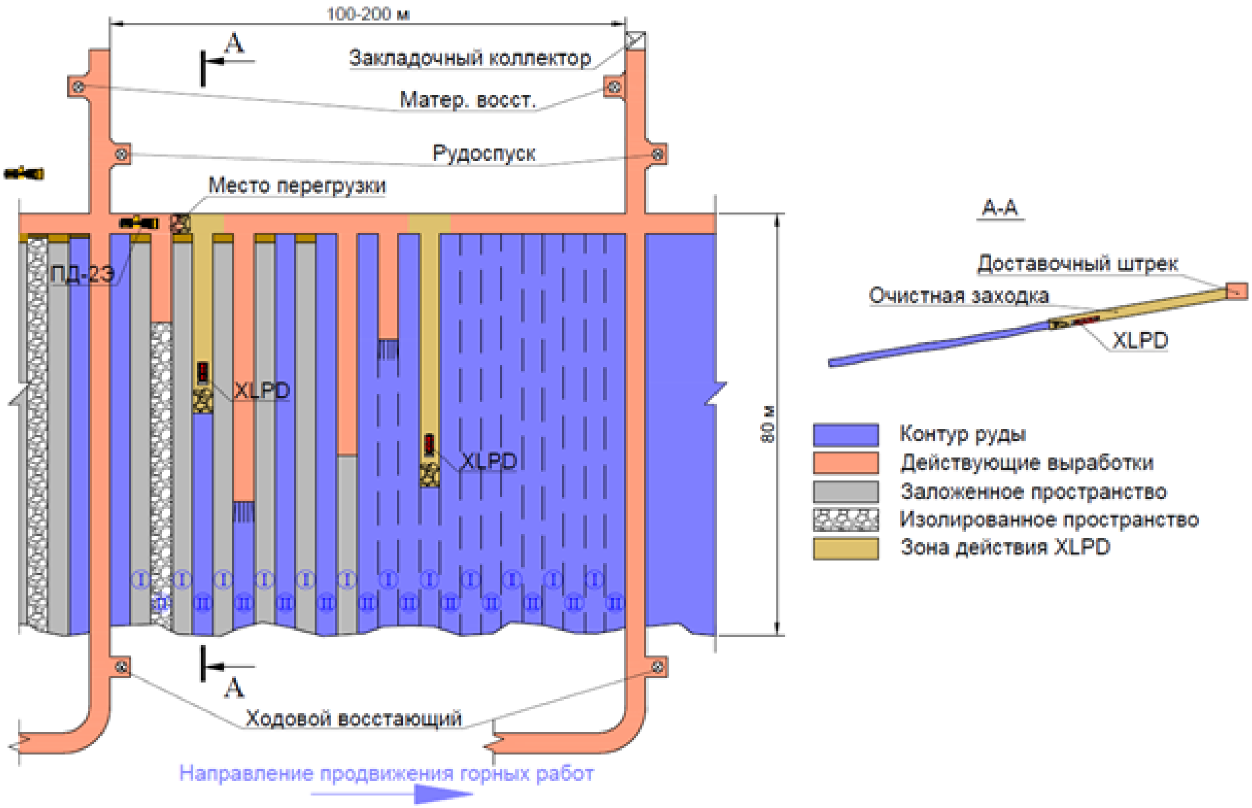

Figure 7. Recommended block development and extraction plan using the XLPD LHD

The recommended mining plan will facilitate to:

- use the XLPD capabilities with the maximum efficiency;
- ensure a significant excavation front to permanently keep the robotic complex in operation;
- facilitate operator's work;
- carry out work in the safest conditions possible.

Main advantages and disadvantages of XLPD, economic effect of operation performed during capability demonstration

The XLPD advantages and disadvantages revealed during the capability demonstration are presented in Table 3.

Advantages	Disadvantages
Possibility of safe operation if the mine support is damaged	The need to use two LHDs in the same block
Operator location outside the formation pressure impact zone	Working at distance >40 m during the shift is a challenge for the operator
The average height of the production stope is decreased by over 1 meter	Mined ore haulage is hampered in confined areas
Interchangeability of the main assemblies with the other LHDs available in the mines	
Managing grades of up to 30 degrees	

Table 3. Revealed advantages and disadvantages

This creates additional direct costs for the company as the waste rock does not contain the commercial mineral value and any additional volume to be processed significantly increases the expenses. As the main share of the mine expenses is semi-fixed at a certain level of activities and it does not depend on decreasing or increasing ore output, the main benefit (70%) of the XLPD utilization is concerned with the decreased ore processing costs.

Figure 8 shows relative share of each process stage in the overall cost savings.

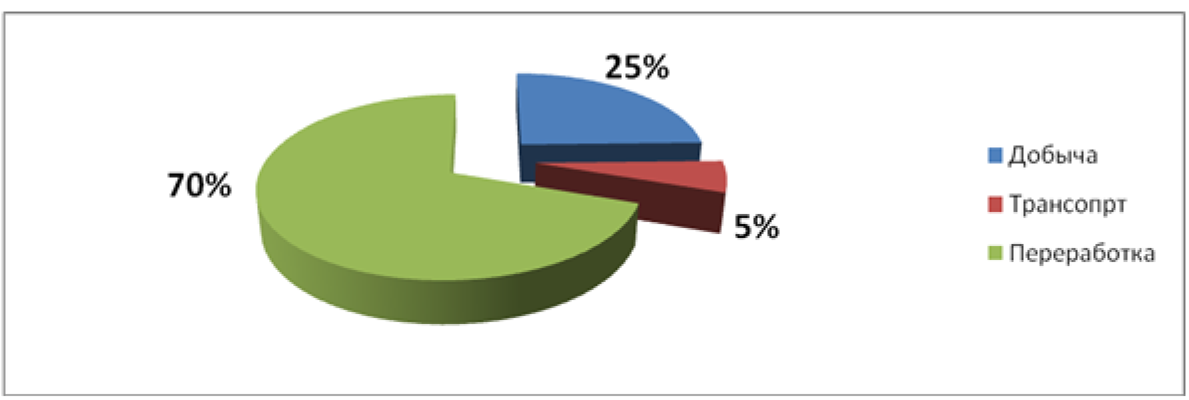

Figure 8. Distribution of economic effect due to XLPD utilization

The cost estimates demonstrate that in the current conditions the investment made in purchasing the XLPD LHD will be returned in 1.5 years.

Conclusion

Based on the demonstration test results the XLPD multi-purpose robotic complex proved its efficiency in mining of flat-dipping ore bodies. Its actual capability matches the stated technical specifications, the effective performance is comparable to the capacity of the LHDs currently used in the mine, the ore dilution in the stopes was decreased by 33% while the operational safety was substantially improved. The 'PIMCU' PJSC commission that was responsible to the capability demonstration test recommended application of the XLPD LHD at the company's mines.

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Extract from a review of article 'Experience in Application of XLPD Extra Low-Profile Robotic LHD for Narrow Bedded Vein Mining at Mine No.8 of 'PIMCU' PJSC' by O.A. Isyanov, A.S. Marchev, A.N. Rabolt, I.V. Mereskin

Involvement of narrow (1.62 m) bedded ore bodies (up to 30% of the mine reserves) into production in Mine No.8 of 'PIMCU' PJSC resulted in a significantly increased dilution (up to 43%) when extracting from production stopes as compared to mining of steeply dipping ore bodies due to utilization of loading and hauling equipment that did not match the new mining and geological factors. In this connection, there emerged a need to test a new remotely-controlled XLPD low-profile mobile loading and hauling (LHD) unit, which compact design enables mining of bedded ore bodies with the minimum vertical cutback of waste rock. Thus, the topicality of this test is beyond any doubts.

The purpose of field testing of this low-profile remote-controlled LHD was to verify if its operating capability was matching the existing mining and geological features and mining conditions as well as to reveal its capacities and shortcomings; the main task being to develop organizational, technical and process-oriented measures (solutions) that would secure efficient and safe mining of flat narrow veins during the stopping phase.

The performed test of the XLPD remotely-controlled LHD proved that the efficiency of its

application is mostly achieved due to a significant reduction in dilution and improved safety of extraction from production stopes within a block.
The paper contains tangible results and will be interesting to a wide range of specialists. The article is recommended for publishing with due account for the proposed comments and suggestions.

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