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CURRENT ISSUES OF THE ROZNA I MINE DEWATERING DUE TO ITS FLOODING PROCESS, CZECH REPUBLIC

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Abstract -
This paper describes the current non mining state of the uranium mine Rozna I in the central part of the Czech Republic. The focus is the conception of dewatering 1 200 m deep mine by main pumping stations which are inset with centrifugal pumps and leveling sumps. Mine water is pumped by multi-staged pumping system through discharge lines towards the surface, where the water is further decontaminated. Cascade pumping system is fully automated thanks to programmable automatic machines by the company Siemens with subsequent visualization at the central control center at Rozna I. Current state will be changed depending on reconfiguration of the mine due to partial flooding of the mine. Partial flooding will be done from 12th to 24th level. Second part of this paper describes technical and conceptual proposal for a change of the pumping system and a new way of pumping. Reusing of the pumping units, automatic machines and other appliances from the dismantled main pumping stations is considered. A new submersible pumping station was devised for the R7S shaft, which will be critical for keeping the mine water in the retention space below level 12. Described issues are bound by corresponding legislative of the Czech Republic. To conclude, a situation, which will occur as soon as the mine is fully flooded and the mine complex is completely abandoned, is contemplated.

Keywords - Mine Water; Dewatering; Pumping; Flooding; Rozna; Uranium Mine

I. INTRODUCTION

Mining of the mineral raw materials by surface and underground methods would not be possible without proper dewatering [1]. Dewatering of the mine is carried out by pumping system, which with the increasing depth creates pumping cascades and so a system of pumping stations is created. During mining of the mineral raw material, it is necessary to keep the pumping system in an operational condition in order to eliminate the possibility of the mine water entering into the mining space and it is endangering miners at work.
Once the mining of the mineral raw material is terminated, in normal conditions the pumping system is shut down and the now unused mine is subjected to flooding. Examples of flooding of the German uranium mines are described by Jenk [2] and of the Czech mines by Lusk [3].

II. BRIEF CHARACTERISTIC OF THE AREA

Mine Rozna I is a part of the uranium deposit Rozna, which is located at the edge of Bohemian-Moravian Highlands, see Fig. 1. The spin-off GEAM Dolní Rozinka, which is part of the national enterprise DIAMO in Straz pod Ralskem, carries out permitted mining activities in working district of the area of 8,76 km^2. The main focus of the mining activities from 1957 to 2017 was underground exploitation of the uranium ore and its subsequent processing into uranium concentrate - ammonium diuranate $(NH_4)_2U_2O_7$.

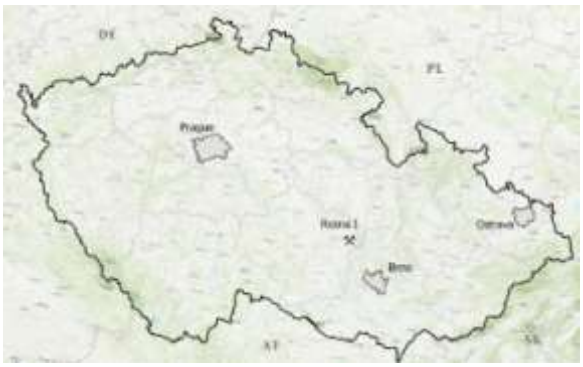

Figure 1. Localization of the Rozna I mine in the Czech Republic

Discovery of the deposit Rozna in 1950s began an extensive geological work with a purpose to map the ore-bearing structures and calculate the uranium stock. The mining itself was carried out in mining shafts R1, R2 and B1, which were up to 1963 sinked to level 12, corresponding with a depth of approximately 600 m. After the stock was verified, in 1973, the R3 shaft was deepened to level 24 and the blind shaft R7S from level 12 to 24 [4].
In 1990s a huge decrease in mining, especially mining of ores and uranium, took place in whole Czech Republic. Since 1997 the mine Rozna I was the single active uranium ore mine in the central Europe.
In 2014-2017 a generic laboratory for research of the radioactive waste storage was built at level 12 of the B1 shaft, which is in the depth of 600 m [5]. Since the termination of the uranium ore mining in 2017, the mine complex was used solely for scientific-research purposes [6].

III. LEGISLATIVE DESIGNATION OF DEWATERING UNDER LAWS OF THE CZECH REPUBLIC

Mining law n. 44 [7] sets an obligation to the organization while preparing the documentation during planning, construction and reconstruction of the mines and quarries to ensure by general regulations in letter e) the security of the operations and safety and protection of health during working on pumping and draining the mine water.

The law further defines the term "mine water" in § 40 as all underground, surface and rainwater, which entered into the underground or surface mine areas no matter if it happened by percolation or gravity from the overburden, underlying rock or from the side, or by the rainwater simply flowing into the area, up to a point of if joining with other permanent surface or groundwater.

Act n. 61 [8] sets an obligation to the Czech mining institute to set a more elaborate generally binding regulation specifying the requirements to ensure safety and protection of health during working and security of operations of the mining activities and activities carried out in a mining way including security of used technical devices and fire protection underground. Thanks to this obligation Decree n. 22 was created [9].

Decree n. 22 [9] more elaborately describes pumping of mine water in § 205 – 211. These terms are defined there:

- pumping device,
- main pumping station,
- auxiliary pumping station,
- automated operation of the main pumping station,
- sumps,
- discharge pumps,
- operation and maintenance of the pumping station.

These generally binding legal regulations are stipulated in the current amendment and are enforced in the whole Czech Republic. Organizations can tighten up these regulations anytime and have an obligation to adjust them according to their specific conditions with the help of the operating regulations.

IV. CURRENT STATE OF PUMPING MINE WATER AT THE DEPOSIT ROZNA

To ensure the safety operations in the mine, because of its mine water tributaries, it is necessary to drain them. Dewatering is carried out with the help of cascade pumping system, which consists of main pumping stations at the respective levels. Mine water from a certain part of the mine is accumulated in the sumps and is subsequently pumped upwards by the pumps. A comprehensive diagram of the mine water tributaries is shown in the figure 2 [10].

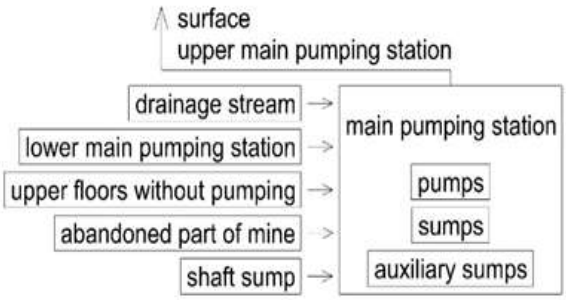

Figure 2: Block scheme of the tributaries of mine water of the main pumping station

4.1. Pumping systems and pumping stations

Pumping system at the deposit Rozna is divided into four drained mining areas, where the mine water is pumped by the cascade pumping system from the depth of 1 200 meters, see Fig. 3 [11].

4.1.1 Mining area of the R1 shaft

Dewatering of the mining area of the R1 shaft is carried out with the help of three main pumping stations at levels 12→9→3, from there the mine water is on the surface drained into an accumulation tank of the decontamination station R1.

4.1.2 Mining area of the R2, R3 shafts

Dewatering of the mining area of the R2, R3 shafts is carried out with the help of four main pumping stations, see Fig. 4, at levels 24→18→12→6, from there the mine water is on the surface drained into an accumulation tank of the decontamination station R1.

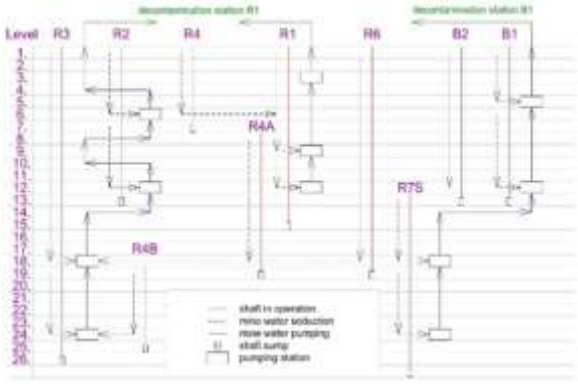

Figure 3: Current state of the cascade pumping system

4.1.3 Mining area of the R7S, B1 shafts

Dewatering of the mining area of the R7S, B1 shafts is carried out with the help of four main pumping stations at levels 24→18→12→5, from there the mine water is on the surface drained into an accumulation tank of the decontamination station Bukov.

4.1.4 Mining area of the R4, R4A, R4B, R6, B2 shafts

Dewatering of the mining area of these shafts is solved by draining the mine water underground towards the main pumping stations of R1, R3 and R7S shafts.

Figure 4: Main pumping station at level 18 in the R3 shaft

4.2. Monitoring of the pumping system

Dewatering of the mine water at the Rozna I mine is carried out in R1, R3, B1 shafts and blind shaft R7S. Main pumping stations are located at corresponding levels, where the main drain pits (sumps) are, from them the collected water is pumped into higher levels, alternatively from the top level to the surface [12].

If there are two drain pits at a certain level, one serves as the operational one and one as a backup. Furthermore, there are under-level auxiliary pits at some levels, which function as auxiliary pumping stations. At the bottom of each pit is a shaft sump, from which the water is pumped into the main drain pits of the lowest level.

Automation system for pumping mine water was designed in a form of a three-level management system [13]. The first level comprises of programmable automatic machines B&R Compact, each one of them serves as an autonomous controller of one pumping unit of the main drain pit. Second level comprises of programmable automatic machine B&R 2005, which is located in each main pumping station and is connected to the first level of the programmable automatic machines B&R Compact. Third level comprises of a personal computer located at the control center Rozna I, which enables a complete visualization and management of the whole pumping system based on data, which it obtains from second level programmable automatic machine B&R 2005. Their communication is achieved by cable connections at pits R1 and R7S, whereas data from pits R3 and B1 are transferred thanks to radio waves [11].

4.2.1 Description of the function of the management system

Level 1 management system – B&R Compact

The purpose of the level 1 management system is to directly control given pumping units of a main drain pit [11]. Commands for switch on or off come either from the superior management system via data communication line or from a hand operated control box placed near given pump. It also has to report state of the pump to a superior management system. In its report is included, if the pump is or is not operating, if there is a failure and also data from analogue measuring (such as temperature of the deposit, pressure under valve etc.).

Level 2 management system – B&R 2005

The purpose of the level 2 management system is to evaluate, based on the measured data, the state of the pumping system and thus manage the subordinate systems while also reporting to the superior systems about its activities. Management system controls, monitors, and carries out following measurements [10]:

- Measurement of the surface level in main drain pits – there are at least two main drain pits in the main pumping station – operational and a backup. Management system controls, monitors, and carries out following measurements:
  - Division of pumps and their order – division of pumps into operational and backups, specific order is determined by working hours of the pumps, in order to achieve uniform wear,
  - Automated switching of the pumps based on surface level – which is divided like this:
    - H_{min} – minimal surface level for pumping,
    - H_1 – surface level for switching on the operational pump,
    - H_2 – surface level for switching on the 1. backup pump,
    - H_3 – surface level for switching on the 2. backup pump,
    - H_{max} – maximum level, which signals a state of emergency and stops all of the pumping into this pit,
- Controlling of the pumps in auxiliary pit,
- Measuring the consumption of the pumps,
- Measuring of the amount of the pumped water,
- Measuring of the working hours of the pumps and the number of their switch-ons,
- Controlling of the pumps in the shaft pump [11].

Level 3 management system – PC

Level 3 management system serves for visualization of the mine´s pumping system thanks to the appropriate software. The software acquires information from appropriate drivers enabling communication connection with subordinate systems.

Figure 5: Monitoring program SP Power at the main control center Rozna I

4.2.2 Visualization of the pumping system

Visualization must allow display the whole pumping system, meaning all the components needed for pumping mine water, all measurements taken, all error reports and subsequent archiving of the state of the system, errors that occurred, control interventions and measurements taken.

For continuous displaying of the pumping system there is a summarizing scheme, where all pumping stations are plotted in a symbolic way and all-important information is shown, such as surface level in individual pits, state of operation of the pumps and all breakdowns [11]. It is possible to access summarizing schemes of the pumping stations from the main summarizing scheme, where everything is shown in more details (such as information about given pump).

V. FLOODING OF THE MINE AND DRAFT OF A NEW PUMPING SYSTEM

At the moment of abandoning the mine complex, it´s flooding is started by turning of the pumping system [14]. In normal circumstances the deposit is flooded up to a previously set level. A rare situation of partial flooding will be realized at the Rozna I mine.

Since 2017 an underground research generic laboratory for the research of deep storing of the radioactive waste is run at level 12 of the B1 shaft by a state organization Radioactive Waste Repository Authority. This organization carried out research in the whole area of the deposit Rozna, from the surface to level 24. Because of that, the organization could not carry out the flooding of the mine. By termination of the research under level 12 in 2019 it was possible to decrease the financial costs of running all 24 levels of the deposit Rozna and in 2021 the mine will be partially flooded. Partial flooding will be carried out withing the range of 13^{th} to 24^{th} level. In the retention space between 12^{th} and 13^{th} level the pumping of the mine water will be renewed thanks to an already modified pumping system [15].

5.1. Technical works connected to flooding of the mine

For purposes of mine water pumping withing the modification of conception of pumping, machines and devices at R3 and R7S shafts will be removed. During the removing process individual supply cable lines will be connected in a way to ensure charging of the remaining operating levels and pumping stations. Simultaneously the pumps, electrical engines and local managing systems from the main pumping stations from R3 and R7S shafts will be removed. In the R3 and R7S shafts holes in the isolation walls and ventilation objects will be created so that the mine water can flow into up to now closed spaces. Connected to these activities is a temporary increase of power of the main or as the case may be the backup ventilator type VCD 31,5M in accordance to the safety regulations requirements. Minimal number of pumps will continue to work and gradually a small mining device 2K6008 and 1B3212 will be put out of operation in the R3 shaft.

After the removal of mining devices at the R3 shaft is finished and the remaining devices of the main pumping stations at levels 18 and 24 in the R7S shaft are removed, the mining device 2B3216 2M/1 will be transferred to a transport apparatus and the unloading moved to level 18. Individual supply cable lines will be gradually disconnected as the work progresses. Then will come a modification of the current management system of pumping mine water and the pumping cascade R3 and R7S will be shut down. This will be a start of flooding the mine up to level 13. During the flooding process a surface level sensor will be installed in the R7S shaft to monitor the mine water. The principle of monitoring is based on water column pressure monitoring, which is recorded by piezoresistive or capacity sensor.

After the change of unloading the transport apparatus at R6 shaft a second change of unloading the mining device 2B3216 2M/1will happen at R7S shaft, specifically to level 13.

During the flooding process two pieces of horizontal discharge system will be removed from the already shut down pumping system between R7S and B1 and will be replaced with one piece of horizontal discharge system DN150 with total length 1 260 m. Subsequently one piece of horizontal discharge system of the new pumping system between R7S and R1 in total length of 2 400 m will be installed.

Construction of a new pumping place, which means submersible pumping station at R7S shaft, see Fig. 6, will begin by plundering the gear of the R7S shaft up to approximately level 14. Subsequently the transport container will be removed and the mining device 2B3216 2M/1 will be put out of operation.

The device of the pit bank 2B3216 2M/1R7S will be removed and a working platform with solid anchors for two pieces of discharge systems will be built over the pit. The pit bank will be modified for assembling a hoisting device for manipulation with pumps and submersible pumping station gear. A vertical ladder will be left at the pit and a system of probes to measure the surface level will be installed in its vicinity at the pit bank. With the help of the hoisting device, the pumps will be anchored at the pit bank. Supply power and signaling cable lines for the pumps will be anchored to the discharge systems. Simultaneously with building the machine part of the pumping place, the local management system and frequency transformer will be built, the three-way valve and electroinstalation for the new pumping place managed.

Finally, a partial reconstruction of the main pumping stations of the R1 and B1 shafts will take place, see Fig. 6. An appropriate number of pumps will be added to the main pumping stations.

In the end the new management system for pumping mine water will be installed, put into operation and tested.

Independently to the process of reconfiguration of the mine in the R1 shaft, removal of old and installing of two pieces of new vertical discharge systems will be carried out in a three-shift operation.

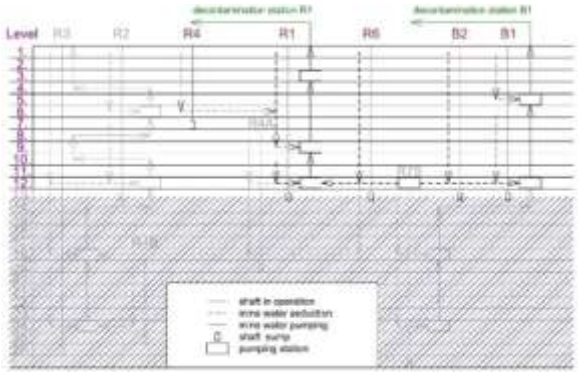

Figure 6: Cascade pumping system at the state of a partially flooded mine

5.2. Pumping system at the state of a partially flooded mine

The modified pumping system will be implemented with the use of the current cascade pumping system in the R1 and B1 shafts. A new submersible pumping station will be built in the R7S shaft. A distributor will be connected to the station, the mine water will be divided to horizontal piping, that will carry the mine water to the R1 and B1 shafts, see Table 1. Cascade pumping system at the R2, R3 and R7S shafts will be shut down.

	Average 2008-2018	Assumption after reconfiguration	Extent of pumping
Shaft R7S	12	31	24 → 12
Shafts R2, R3	19	-	24 → surface
Shaft R1	7	26	12 → surface
Shaft B1	10	22	12 → surface
Whole mine	48	48	

Table 1: Average amount of the pumped mine water in $l.s^{-1}$

5.2.1 Mining area of the R7S shaft

Mining area of the R7S shaft will be put through a full reconfiguration of the pumping system. Because the whole blind shaft will be flooded, the entire cascade pumping system will be shut down. The main pumping stations will be removed and the pumping device will be used to renovate other main pumping stations or stored for spare parts.

A new submersible pumping station at the pit bank of R7S will be build. It will be fitted with two pieces of submersible sludge pumps type KSB UPZ with the power of 2x 50 $l.s^{-1}$. Retention space between levels 12 and 13 with the capacity of about 318 000 m^3 will serve as retention space. With the daily average inflow of mine water of 2 678 m^3, the space will fill up in 118 days.

5.2.2 Mining area of the R1 shaft

Cascade pumping system in the R1 shaft will be kept in an unchanged state.

- Three centrifugal pumps type 100-CVN-305/7-OU-OO-F/2E with the power of 3x 20 $l.s^{-1}$ will be kept at the main pumping station of level 12.
- Three centrifugal pumps type 125-CDB-350-20/8-OU-OO-F/2E with the power of 3x 26 $l.s^{-1}$ will be kept at the main pumping station of level 9.
- Three centrifugal pumps type 125-CDB-350-20/6-OU-OO-F/2E with the power of 3x 40 $l.s^{-1}$ will be kept at the main pumping station of level 3.

5.2.3 Mining area of the B1 shaft

Cascade pumping system in the B1 shaft will be kept in an unchanged state.

- Four centrifugal pumps type 125-CDA-350-18/8-OU-OO-F/2E with the power of 4x 26,7 $l.s^{-1}$ will be kept at the main pumping station of level 12.
- Four centrifugal pumps type 125-CDA-350-18/8-OU-OO-F/2E with the power of 4x 26,7 $l.s^{-1}$ will be kept at the main pumping station of level 5.

5.3 Monitoring of the new pumping system

The principle of the management system for pumping mine water will be kept. By shutting down the cascade pumping stations at the R7S shaft and R2, R3 shafts, the current monitoring system will be left only at the R1 and B1 shafts. The operation of the mine water pumping will be kept in automated regime [16]. To manage the operation of pumps in the main pumping stations in the R1 and B1 shafts the current system SIMATIC will be used. System will be expanded with new components from the pumping stations removed from R7S, R2 and R3 shafts.

The newly build submersible pumping station at the R7S shaft will work in an automated regime. Management system SIMATIC will direct the power of pump in the pumping station based on the current inflow of mine water and so a stable operating surface level will be kept in the R7S shaft. With the help of the directed distributor of mine water, the system will divide the volume of mine water based on the surface levels in the sumps, the operating state of the main pumping stations and the volume of mine water pumped by the individual cascades, so that the workload of the cascade pumping stations in the R1 and B1 shafts is adequate to their designed capacity. In case of short-term increase of inflow and maximum flow rate in the individual cascades, automatic increase of the operating surface level in the R7S shaft will take place and the sufficient retention capacity at level 13 will be utilized. In case

of breakdown at one of the cascades the system will automatically through the distributor utilize the other cascade to the maximum. In case of a breakdown at both cascades the management system of pumping in the R7S shaft will shut itself down for the necessary period of time. After the inflow decreases or after the breakdowns are fixed, the mine water will be gradually drain to the operating levels.

Superior management system in cooperation with local management systems in the main pumping stations and the submersible pumping station in the R7S shaft will inform the operator through visualization at the central center Rozna I. The principle of visualization and possibilities for the control operator will be the same. Summarizing scheme will be modified according to the new regime of the mine configuration.

VI. CONCEPTION OF THE MINE WATER MANAGEMENT AFTER THE COMPLETE MINE FLOODING

During the state of partial flooding of the mine up to level 12, gradually based on availability, the liquidation processes of the unused main workings with surface openings will be carried out. Liquidation will be done by filling the pit shaft completely with unconsolidated backfill material and securing the pit bank with reinforced lockable platform [6].

Once it is decided to terminate all activities in the underground areas, the pumping system will be shut down and the complete flooding of the mine up to level 2 will be started. During the flooding process the remaining main workings with surface openings will be liquidated by a complete backfill. Only one mine working will not be liquidated with backfill, shaft R3, which will become water shaft.

Adapted water shaft R3 will serve for observing the advancement of the mine flooding. An adit for draining is connected into the shaft, it will serve for controlled removal of mine water from the deposit Rozna. After the mine water rises to level 2, the pumping system will be renewed and the water will be kept in the retention space between level 2 and 3 [6]. Mine water will be pumped through the adit for draining towards purifying technologies, where the mine water will be decontaminated and then let out into the watercourse [17]. Once the ecological limits of contaminants content in the released water are fulfilled, the pumping system will be shut down and the mine water will flow out into the watercourse spontaneously.

VII. CONCLUSION

The proposal describes a correctly set pumping system, which is an integral part of correct and above all safe functioning of a mine. Cascade pumping system at the deposit Rozna is set for mining in the depth of 1 200 m thanks to a cascade of mine pumping stations in the R1, B1, R2, R3 and R7S shafts. With the decision to partially flooding the situation changes and it is necessary to change the cascade pumping system with regards to the reconfiguration of the mine. A system of two cascade pumping stations at R1 and B1 shafts was designed. A new submersible pumping station will be built, it will be placed at the pit bank of R7S and will be the main regulation part for keeping the mine water in the retention space. Mine water will be pumped through a distributor at the R7S shaft, which will separate it proportionally to the pumping systems of R1 and B1 shafts.

The system represents a case study, how it is possible to solve technical aspects and the complete adjustments to the conception of the mine operations in a time of a partial flooding. Partial flooding is a rare state, because normally the mine is flooded in its entirety.

ACKNOWLEDGMENTS

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