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*Branislav Rajković[*1], Vladan Kamenović[*2], Zoran Ilić[*3], Ljubiša Obradović[*4], Goran Angelov[*]*

CONCEPTUAL DESIGN OF HYDROTECHNICAL INSTALLATION FOR SPRINKLING THE TAILING DUMP IN THE MINES AND FLOTATION PLANT KOPAONIK – LEPOSAVIĆ[**]

Orcid: 1) https://orcid.org/0000-0002-6646-0144 2) https://orcid.org/0000-0001-9476-5378
3) https://orcid.org/0000-0002-3174-9941 4) https://orcid.org/0000-0002-6715-4173
5) https://orcid.org/0000-0003-3841-8667

Abstract

This paper presents a description of operation and main elements of mechanical installation on an example of the conceptual design of the hydrotechnical installation for sprinkling the MFP Kopaonik tailing dump. Calculation for the pump selection is given at the level of conceptual design in the calculation part. Presentation of the PID of installation for sprinkling the tailing dump, as well as the technical characteristics of the main elements of installation, are also given.

***Keywords**: sprinkling of tailing dump, hydrotechnical installation, technical characteristics*

1 INTRODUCTION

For expanding the flotation tailing dump MFP Kopaonik, the Mining and Metallurgy Institute Bor has made the Basic Design for Expansion the Flotation Tailing Dump in 2018. In addition to this project, at the request of the investor Trepča AD RMHK Holding, the Conceptual Design for Sprinkling the Flotation Tailing Dump in the MFP Kopaonik in Leposavić [1] was made. At the time of the project, recultivation of the tailings area had not yet been done, so there was a problem of dust emission from a part of tailings area into the surroundings, especially in the summer. The conceptual design of sprinkling provides a technical solution for overcoming this problem in the technological, construction, electrical and mechanical parts. In this paper, the attention will be paid to the selection of a pump and detailed technical characteristics of both the pump itself and main elements of mechanical equipment specific to such sprinkler systems, namely the big volume guns and control valves.

2 TECHNICAL DESCRIPTIONS

The purpose of the installation for sprinkling the Leposavić flotation tailing dump is to keep the surfaces of the tailing dump emitting the airborne dust in a wet state in order to prevent dust from the landfill being blown into the environment. The installation is planned for operation only in the

[*] *Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia,
E-mail: branislav.rajkovic@irmbor.co.rs*
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summer period of the year, when the problem of dust emission is the greatest. The surfaces emitting the airborne dust practically represent the upper part of the slopes that extend from the bottom of the tailing dump to the top of the embankment along most of the perimeter of tailing dump (Figure 1).

Figure 1 *Slope of the Leposavić flotation tailing dump before recultivation*

The installation in question enables keeping these surfaces in a wet state by periodic watering with technical water. Technical water for watering the tailing dump will be provided from the Ibar river nearby (Figure 2), from which the water will come purified by filtering through a layer of soil to the well, which will house a deep well pump for technical water transport to the sprinklers-big volume guns.

Figure 2 *View from the top of the Leposavić flotation tailing dump on the Ibar river*

Sprinkling the tailing dump will be carried out by 18 big volume guns placed behind the crown of the embankment distributed at an appropriate distance from each other along the perimeter of tailing dump (Figure 3).

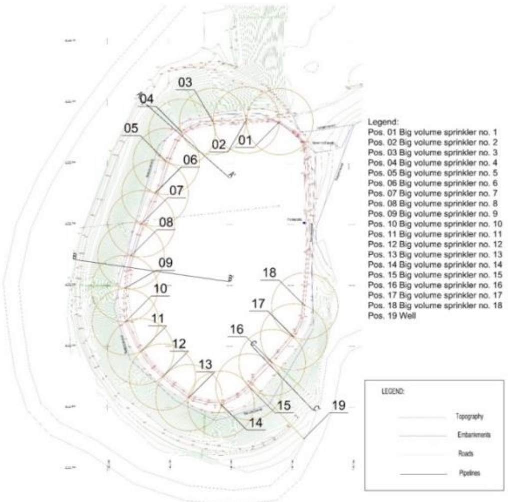


Figure 3 *Layout of the installation for sprinkling the Leposavić tailing dump*

Deep well pump will supply water to one big volume gun at one time, while the others will be turned off. Turning the big volume guns on and off will be controlled by the control unit, located next to the deep well pump via automatic valves mounted upstream of the big volume guns. The big volume guns have the ability to rotate around the vertical axis within adjustable limits so that one big volume gun sprinkles a certain area or zone. Sprinkling zones from individual big volume guns are shown in Figure 4, so that each big volume gun has its corresponding sprinkling zone.

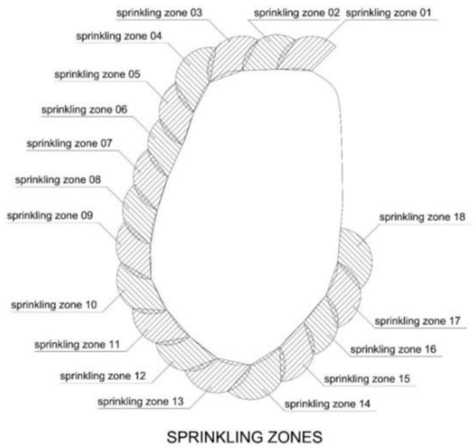
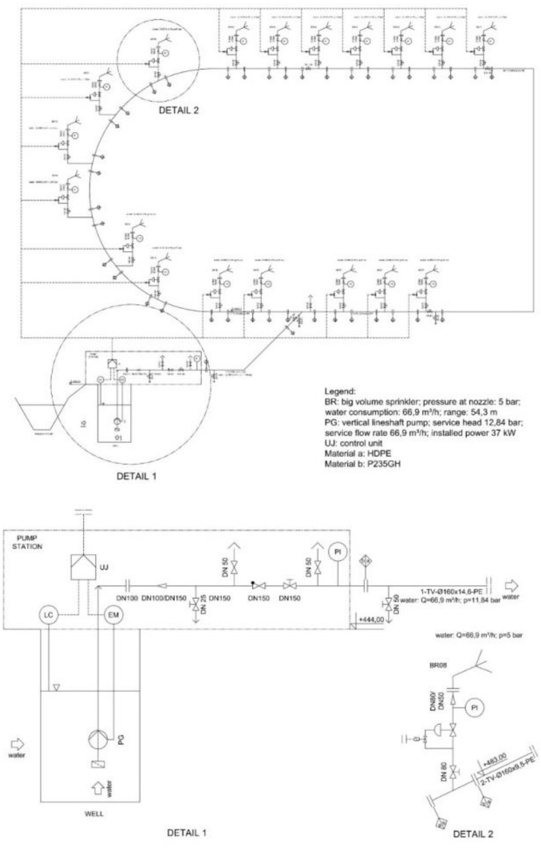


Figure 4 *Sprinkling zones of the Leposavić tailing dump*

The time of switching on and off the big volume guns will depend on condition of the surfaces to be wetted, climatic conditions and other technological requirements. An electric motor-driven deep well pump located in the pump station pumps water from the well. A suction strainer is provided on the suction port of the pump, and air relief and vacuum valve, check valve and manual gate valve are provided on the discharge port. Pump electric motor operation will be controlled via the control unit by turning the pump off when the level sensor registers the switch off water level limit in the well thus protecting the pump from running dry. A pressure gauge is provided for reading the pressure at the exit from the pump station. The main pipeline will be in the lower part with dimensions of Ø160x14.6 nominal pressure PN16 made of HDPE and it will transport technical water from the well to the top of the embankment in a length of 130 m with a height difference of 39 m. In the upper part, the main pipeline will be Ø160x9.5 with a nominal pressure of PN10 made of HDPE and will be laid along the entire perimeter of the embankment in a length of 1260 m. The pipelines will be laid on the ground freely. Depending on the terrain profile, the air release valves will be provided in the pipeline at the highest points, and drain valves at the lowest points. The big volume guns connections will be made of seamless steel pipes. Every connection is provided with a manual gate valve and automatic valve without auxiliary energy for turning sprinkler on and off, which is controlled via a solenoid valve that receives a control signal from the control unit in the pump station. A pressure gauge is provided for reading the pressure upstream from each big volume gun. The PID of the installation for sprinkling the tailing dump Leposavić is shown in Figure 5.



Sprinkler installation PID

Figure 5 *PID of the installation for sprinkling the Leposavić tailing dump*

3 CALCULATIONS

The hydraulic calculation of the system for sprinkling the Leposavić tailing dump was carried out in order to select a deep well pump for technical water transport from the well to the big volume guns. Since only one big volume gun is in operation at one time, the calculation was made for the most unfavorable section from the well to the big volume gun no. 01 for a flow rate value of 66.9 m^3/h.

Input data:

1. The total pressure loss in the pump station amounts Δp_1=1 bar.

2. The height difference from the exit from the pump station to the connection of the big volume gun no. 1 is H=39 m.

3. The total pressure loss at the connection of a big volume gun is Δp_2=1 bar.

4. Pressure at nozzle of a big volume gun is p_k=5 bar.

3. $\delta = 0.01[mm]$ –absolute roughness of HDPE pipe for diameters below 200 mm [2].

4. $\upsilon = 1.006 \cdot 10^{-6} \left[\frac{m^2}{s}\right]$ - kinematic viscosity of water for temperature of 20°C.

5. Local losses amount 10% of line losses.

The following calculation formulas were used in the calculation:

$$v = \frac{4 \cdot Q}{d^2 \cdot \pi}$$

$$Re = \frac{v \cdot d}{\nu}$$

$$\Delta p = \rho \cdot g \cdot H + 1.1 \cdot L \cdot \frac{\lambda}{d} \cdot \rho \cdot \frac{v^2}{2}$$

The individual symbols have the following meanings:

$L[m]$-length of the pipeline section

$\rho = 1000 \left[\frac{kg}{m^3}\right]$-water density

$g = 9.81 \left[\frac{m}{s^2}\right]$- gravitational constant

$Q \left[\frac{m^3}{s}\right]$- volumetric flow rate of water in the pipeline section

$H[m]$- height difference of the pipeline section

$d[m]$- internal diameter of the pipeline section

$v \left[\frac{m}{s}\right]$- actual water velocity in the pipeline section

$\nu \left[\frac{m^2}{s}\right]$- kinematic viscosity of water

Re–Reynolds number

$\delta[mm]$- absolute roughness of the pipe

$k = \delta \cdot 10^{-3}/d$- relative roughness of the pipe

$\lambda = \frac{1,325}{\left(\ln\left(\frac{k}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right)^2}$ – friction coefficient according to Russo and Smith

$\Delta p[Pa]$- pressure loss of the pipeline section

The pump head required amounts:

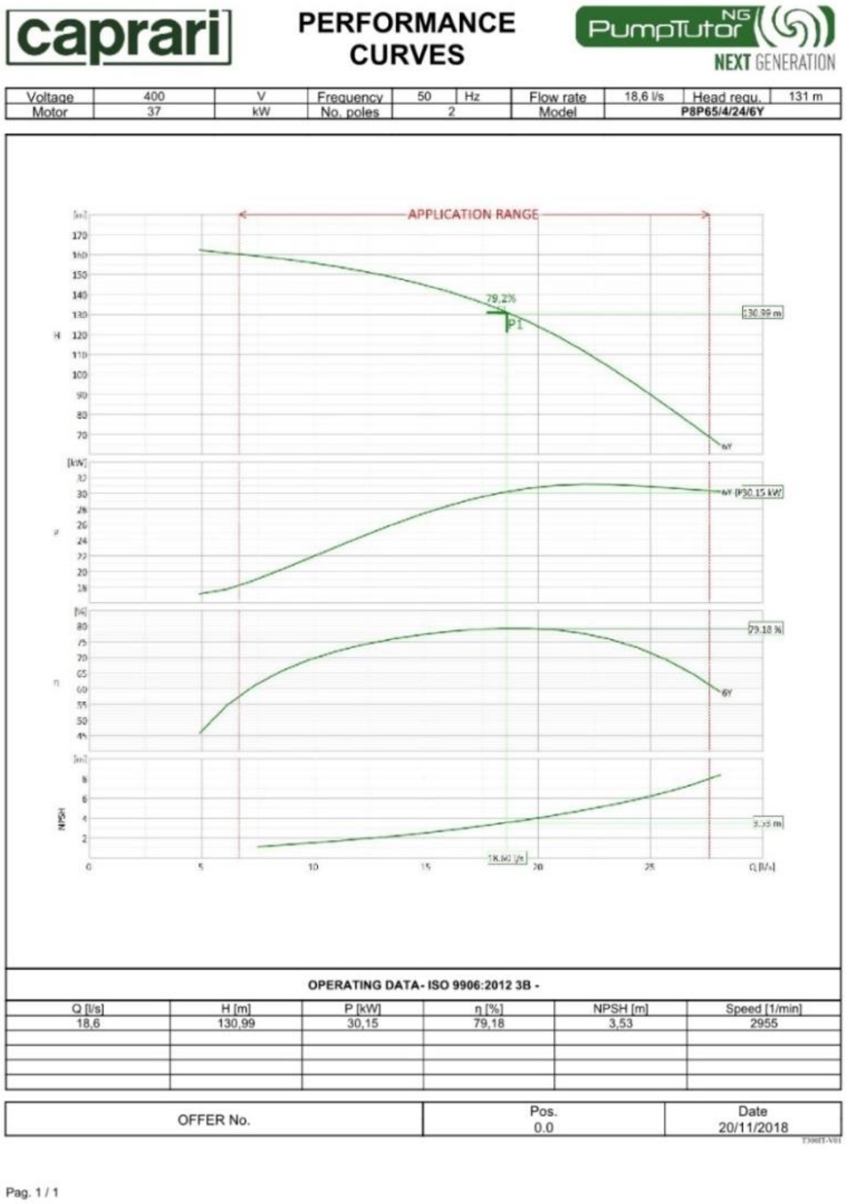
$$\Delta p_p = 1.1 \cdot (\Delta p_1 + \Delta p + \Delta p_2 + p_k) = 12.8\ [bar]$$

The calculation results of the pressure loss in the main pipeline of the HDPE pipes are shown in Table 1, and the pump performance curves in Figure 6.

The technical data of the selected pump are given in Table 2.

Table 1 *Calculation results of the pressure loss in sections 1 and 2*

Pressure loss in sections 1 and 2												
Section number	Volumetric flow rate through the section	Volumetric flow rate through the section	Section length	Height difference of the section	Internal diameter of the section	Velocity	Absolute roughness	Relative roughness	Reynolds number	Friction coefficient	Pressure loss in the section	Pressure loss in bar
-	Q*	Q	L	H	d	v	δ	k	Re	λ	Δp*	Δp
-	l/s	m^3/s	m	m	m	m/s	mm	-	-	-	Pa	bar
1	18.6	0.0186	130	39	0.1308	1.385	0.01	7.65E-05	180068	0.016	399868	4.0
2	18.6	0.0186	780	0	0.141	1.192	0.01	7.09E-05	167042	0.017	71951	0.7
Total			910	39							471819	4.7



caprari **PERFORMANCE CURVES** PumpTutor NG NEXT GENERATION

Voltage	400	V	Frequency	50	Hz	Flow rate	18,6 l/s	Head requ.	131 m
Motor	37	kW	No. poles	2		Model	P8P65/4/24/6Y		

OPERATING DATA- ISO 9906:2012 3B -

Q [l/s]	H [m]	P [kW]	η [%]	NPSH [m]	Speed [1/min]
18,6	130,99	30,15	79,18	3,53	2955

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Figure 6 *Pump performance curves*

Table 2 *Technical data of the selected pump*

Designation	**Six stages deep well (vertical lineshaft) pump for clear or slightly muddy water**
Manufacturer	Caprari
Model	P8P65/4/24/6Y
Lineshaft column type	LA4/24
Number of lineshaft columns	1
Drive head type	E20/55/4/24
Electric motor size	200
Nominal electric motor power	37 kW
Rated voltage	400 V
Rated frequency	50 Hz
Speed	2955 min^{-1}
Flow rate at operating point	18.6 l/s
Head at operating point	130.99 m
Power at operating point	30.15 kW
Pump efficiency	79.18%
Overall efficiency	74.2%
NPSH at operating point	3.53 m
Maximum temperature of water	60 °C
Maximum solid content (silt)	80 gr/m^3
Discharge connection size	DN100
Immersion depth	4.3 m
Overall dimensions of package LxWxH	590x434x5648,5 mm
Mass of package	354.8 kg

The pump consists of the following main parts:

1. hydraulic part – 6 pump stages with semi-axial impellers, type P8P65/4/24/6Y
2. lineshaft column, type LA4/24
3. drive head, type E20/55/4/24
4. electric motor 50 Hz 37 kW V1 2P IE3 400V, type P303702T2V12001
5. suction strainer, type SUP8

In this paragraph, a brief description of the pump will be given according to [3]. In the hydraulic part of the pump in each stage, there are the semi-axial impellers statically and dynamically balanced to ensure the vibration free operation. The impellers are mounted on a common shaft. At the housing ends of each stage, the shaft is supported by the rubber bearings resistant to wear by the abrasive action of the solid particles in water. The shaft passing through the lineshaft column transmits the power from the drive head to the impellers, while water flows up through the column. The lineshaft column consists of one or more pipes joined by flanges and its length depends on the required immersion depth of the pump. The shaft is supported by rubber bearings in the riser, which are lubricated by the lifting liquid. The drive head supports the assembly weight and provides the connection of discharge pipe to the discharge port. An electric motor is mounted on the drive head. All drive units are fitted with a device to prevent the pump from rotating in reverse. The strainer prevents foreign bodies from entering the suction port.

Valves at the discharge side of the pump belong to the usual equipment for this type of installation. Layout of the pump station and well is shown in Figure 7.

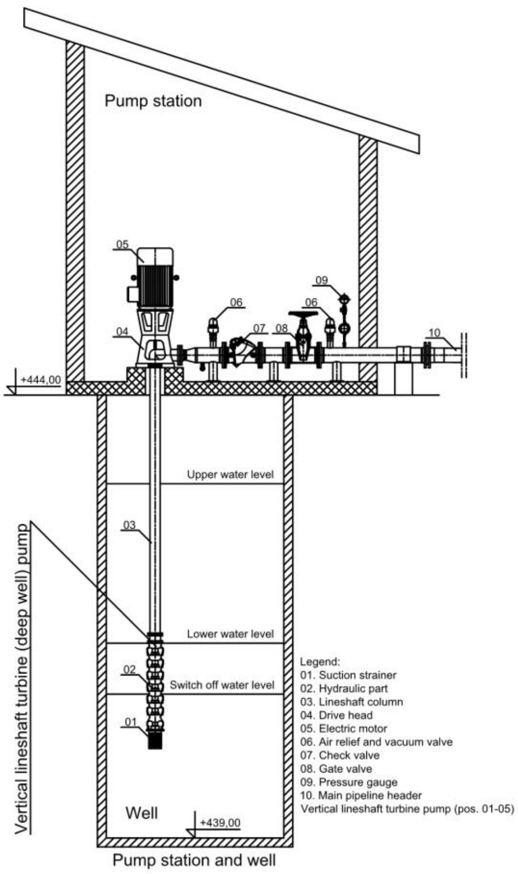

Figure 7 *Pump station and well of the sprinkling installation for sprinkling the Leposavić tailing dump*

4 DISCUSSION

Selection of the pump in this case was done based on the calculation of the pressure loss in a simple pipeline, considering that only one big volume gun works at one time. A somewhat more complicated case of selecting a deep well pump can be found, for example, in [5].

In this paragraph, a brief description of a big volume gun will be given according to [6]. The big volume gun is connected to the pipeline via a flange. The big volume gun may be with adjustable part circle rotating angle as in our case, or full circle rotating angle. The Komet automatic brake allows the big volume gun to maintain a constant rotation speed in all operating conditions regardless the pressure or flow. Komet deflector allows water to distribute uniformly starting from the gun over its entire throw range. The selected big volume gun is with a fixed trajectory angle but there are advanced options with adjustable trajectory angle, as well as with a dynamic jet-breaker.

The technical data of the big volume gun are given in Table 3, according to [6].

Table 3 *Technical data of the big volume gun*

Designation	Big volume gun with fixed trajectory angle and part circle rotating angle
Manufacturer	Komet
Model	TWIN 101 ULTRA
Pressure at nozzle	5 bars
Flow	66,9 m^3/h
Nozzle diameter	28 mm
Range	54.3 m
Trajectory angle	24°
Connection dimensions	DN50
Mass	9.48 kg

The water control valve serves for on/off regulation, i.e. to turn the big volume gun on and off. The valve is without auxiliary energy and is activated via a solenoid valve that receives a signal from the control unit. The valve, in addition to on/off regulation, can also be delivered with various other control functions [7].

The technical data of the control valve are given in Table 4, according to [8].

Table 4 *Technical data of the control valve*

Designation	Diaphragm control cast iron valve for water with on/off regulation, series 400
Manufacturer	Bermad
Model	410-KX
Nominal size	DN80 PN16
Specifications	Basic valve + 3 ways solenoid 24V AC
Valve position	Basic valve normally closed
Working fluid	Water with temperature up to 60°C
Body and cover material	Cast iron, polyester or epoxy coated
Diaphragm material	Nylon fabric, reinforced natural rubber
Diaphragm retainer and spring material	Stainless steel
Connections	Flanges DN80 PN16
Dimensions LxH	250x210 mm
Mass	19 kg

Proposal for installation the big volume gun with associated fittings at the big volume gun connection is given in Figure 8. As it can be seen from figure, a gate valve, strainer, control valve and pressure gauge are provided at the connection of each big volume gun.

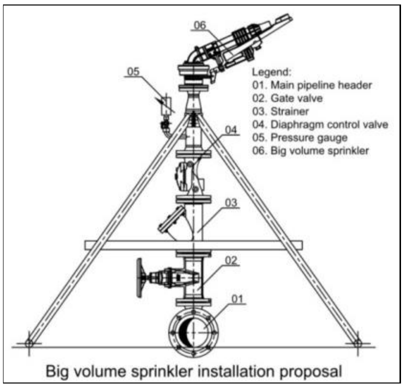

Figure 8 *Proposal for installation the big volume gun*

5 CONCLUSION

This work came out from the conceptual solution of sprinkling the Leposavić tailing dump as one variation. This conceptual solution was dictated by certain restrictions and requirements set by the investor. Before making a detail design of this type, it is necessary to prepare a detail technological design using a series of data obtained through measurements and tests, such as data related to the physical characteristics of surfaces to be wetted, then data on capacity the water supply sources, as well as data on physical and chemical characteristics of water which is used for sprinkling, etc. These data would allow determining the most favorable way of sprinkling the tailing dump as well as the most favorable way of water supply, including the preparation, transport and distribution of water. The equipment selection always depends on technological requirements, and in this paper, the attention is paid to the main hydrotechnical equipment specific to this particular installation. Adequate equipment will suit some other working conditions, which may deviate more or less from the one described in this paper [9]. Depending on the set requirements, more advanced solutions of such installations are also possible, for example for work in winter conditions or with a higher level of automation. The authors hope that this work will be useful to the designers and users of the tailing dump sprinkling installations.

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