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VERIFICATION OF A DEEP WELL PUMP FOR THE INDUSTRIAL WATER SUPPLY SYSTEM

Abstract

This paper gives a procedure of calculation verification the technical characteristics of the pump under given operating conditions in an example of the existing installation of a deep well pump for the technical water supply of the Nisal factory, The calculation was done analytically and graphically.

It also presents a scheme of industrial water supply, disposition of a deep well pump installation, as well as its technical characteristics.

***Key words**: deep well pump, calculation, disposition, technical characteristics*

1 INTRODUCTION

Deep well pumps are used in the water supply facilities, industry, construction and mining to reduce or maintain the water levels [1]. Three reservoirs R1, R2 and R3 are used for the needs of the technological process of the “Nisal” factory in Nis. The reservoirs are supplied with water from three artesian wells for the technical water B1, B2 and B3. The B1 well is Ø1600 mm in diameter, about 20 m in depth, and water is pumped from it by means of a deep well pump made by the ”Jastrebac“ Nis, with label BP-150-4. The B2 and B3 wells are Ø1200 mm in diameter, about 7 m in depth, and water is pumped from them by means of a deep well pump made by the “Jastrebac“ Nis, with label BP-100-2. All reservoirs are connected in the “ring” in case of failure of individual deep well pump by the buried steel pipelines A case of supply o the reservoirs R1, R2 and R3 from the B2 well will be analyzed in this paper. The scheme of industrial water supply from the B2 well with designated sections is shown in Figure 1.

2 TECHNICAL DESCRIPTION

Vertical deep well pump construction consists of the discharge head, fixed discharge pipe section, discharge pipe sections, hydraulic sections and suction bell [2]. The cross section drawing of the deep well pump is shown in Figure 2. A flanged electromotor with electrically driven pumps is assembled on a discharge head, while a discharge head itself contains the axial and radial bearing, shaft, elastic coupling, manometer, shaft sealing and discharge connection. Fixed discharge pipe section serves as a connection of discharge head with the discharge pipe sections. Discharge pipe sections make the necessary pump height. Hydraulic part of the pump consists of the suction and discharge cases, as well as a certain number of impellers with diffusers through which the shaft on rubber bearings passes. Suction bell consists of the suction strainer and check valve. Deep well pump BP-100-2 is a two-stage semi-axial vertical deep well pump driven by electromotor made by the “Jastrebac“ Nis the with following technical characteristics:

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- power: $P = 3\ [kW]$
- speed: $n = 2900 \left[\frac{1}{min}\right]$
- discharge connection: DN100 PN10

Disposition of deep well pump BP-100-2 in the B2 well is shown in Figure 3.

Performance curve of the pump is shown in Figures 4 and 5.

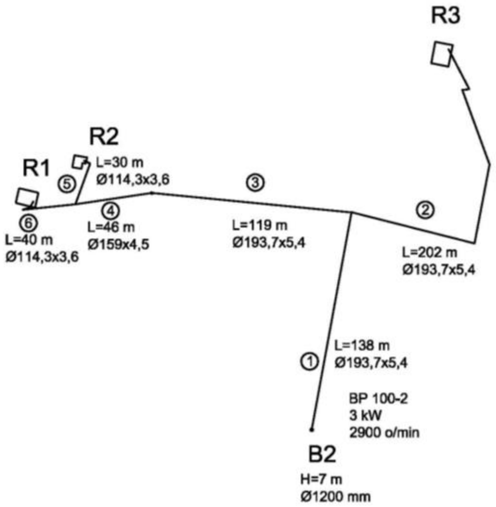

Figure 1 *Scheme of the industrial water supply from the B2 well*

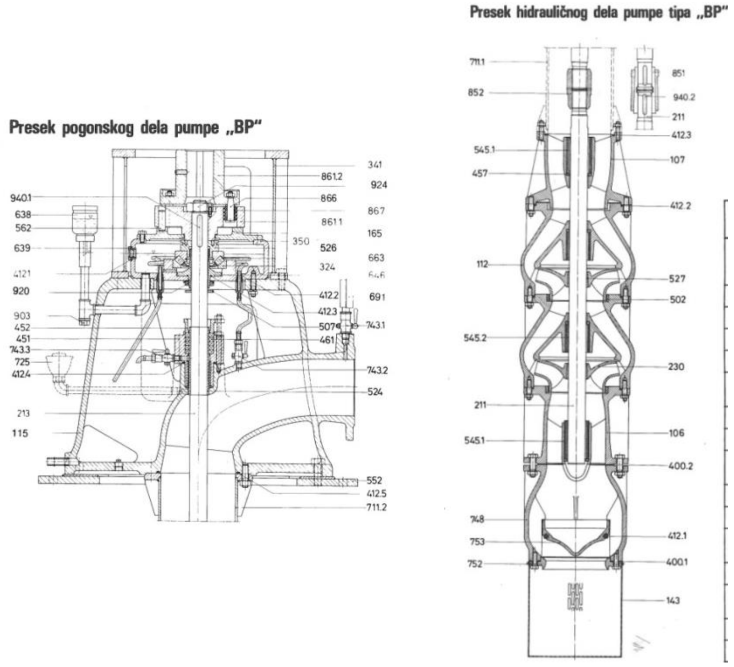

Figure 2 *Cross section of the BP deep well pump*

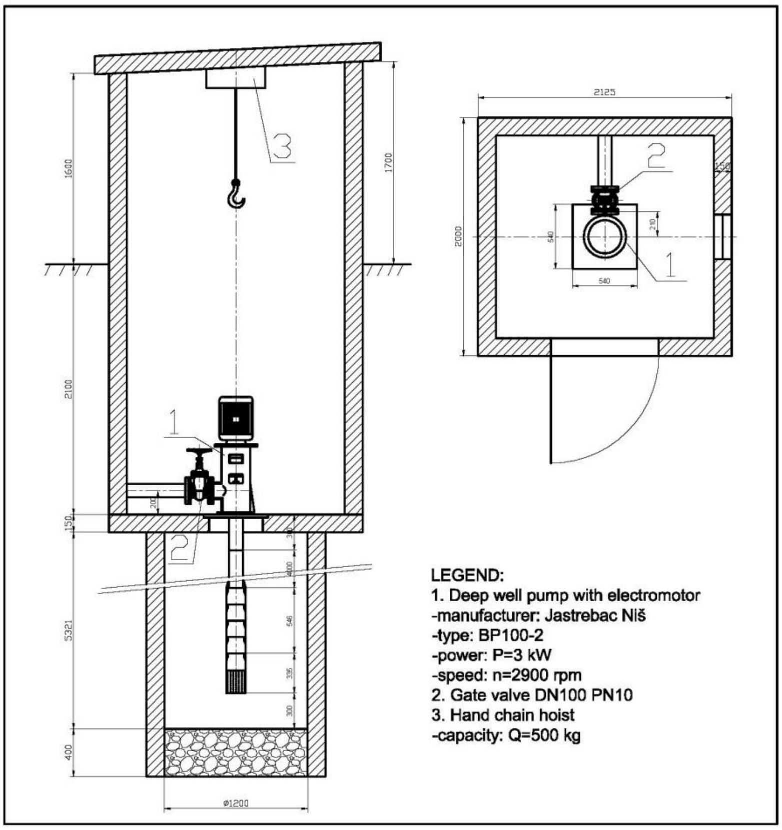

Figure 3 *Disposition of the deep well pump BP-100-2 in the B2 well*

3 CALCULATION

Hydraulic calculation of the industrial water system of Nisal was done for the purpose of verifying the BP-100-2 deep well pump that transports water from the well B2 into the reservoirs R1, R2 and R3 for the needs of the technological process, and it is given according to [3]. The calculation results are the flow rates for every section, and afterwards comparison with the required flow rates for each reservoir is done.

The input data:

1. Minimum height difference between the water level in the B2 well and the reservoirs R1, R2 and R3 amounts H=7 m at the equal water level in all reservoirs

2. Maximum height difference between the water level in the B2 well and the reservoirs R1, R2 and R3 amounts H=14 m at the equal water level in all reservoirs

3. $\delta = 0.2\ [mm]$ - absolute roughness of the steel pipe

4. $\upsilon = 1.306 \cdot 10^{-6}\ \left[\frac{m^2}{s}\right]$ - kinematic viscosity of water

5. Local losses amounts 20% from friction losses

6. $L\ [m]$ - length of section

7. $D\ [m]$ - internal diameter of section

8. $v\ \left[\frac{m}{s}\right]$ - water velocity in section

9. $\varsigma\ [-]$ - coefficient of local losses

The following calculation formulae are used in the calculation:

1. $Re = \frac{v \cdot D}{\nu}$ - Reynolds number

2. $\lambda = 0.11 \cdot \left(\frac{\delta}{D} + \frac{68}{Re}\right)^{0.25}$ - friction coefficient of a section according to the Altsule

3. $m = \frac{8}{\pi^2 \cdot D^4}\left(\lambda \cdot \frac{L}{D} + \sum \varsigma\right) \left[\frac{J/kg}{m^3/s}\right]$ - resistance coefficient of a section

4. $Y_g = g \cdot H + m \cdot Q^2 \left[\frac{J}{kg}\right]$ - pressure loss curve of a section

where

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

$Q \left[\frac{m^3}{s}\right]$ - flow rate in section

5. $Y_p \left[\frac{J}{kg}\right]$ - pump performance curve given by a pump supplier

On the basis of resistance coefficients of each section and the scheme of pipe network (see Fig. 1) by appropriate addition of the pressure loss curves of sections, taking into account whether the sections are connected in series or parallel the cumulative pipeline pressure loss curve is determined. At the intersection of this curve and pump performance curve in Y-Q diagram, the operating point of pump is placed which simultaneously determines the flow rate through the section 1. Then the flow rates for all other sections are determined based on the known pressure loss curves. The calculation is carried out iteratively which means that at first the velocities in sections are assumed, and the calculation is repeated until the calculated velocities match the ones in the previous iteration. The results of the calculation are tabulated in Tables 1 and 2, while the operating points of the pump are shown in Figures 4 and 5 for both cases of adopted height differences between the water level in the well B2 and the reservoirs R1, R2 and R3.

Table 1 *Flow rates and velocities at height difference of* $H_{min}=7[m]$

SECTION NUMBER	SECTION LENGTH	INTERNAL PIPE DIAMETER	VELOCITY	REYNOLDS NUMBER	FRICTION COEFFICIENT	RESISTANCE COEFFICIENT	ACTUAL FLOW RATE	ACTUAL VELOCITY
-	L	D	v	Re	λ	m	Q	v
-	m	mm	m/s	-	-	(J/kg)/(m^3/s)	l/s	m/s
1	138	182.9	0.61	85428	0.023	15040	16.00	0.61
2	202	182.9	0.36	50417	0.024	23474	9.34	0.36
3	119	182.9	0.25	35011	0.026	14602	6.66	0.25
4	46	150	0.38	43645	0.026	15029	6.66	0.38
5	30	107.1	0.4	32802	0.028	57072	3.59	0.40
6	40	107.1	0.34	27882	0.028	77804	3.07	0.34

Table 2 *Flow rates and velocities at height difference of Hmax=14[m]*

SECTION NUMBER	SECTION LENGTH	INTERNAL PIPE DIAMETER	VELOCITY	REYNOLDS NUMBER	FRICTION COEFFICIENT	RESISTANCE COEFFICIENT	ACTUAL FLOW RATE	ACTUAL VELOCITY
-	L	D	v	Re	λ	m	Q	v
-	m	mm	m/s	-	-	(J/kg)/(m^3/s)	l/s	m/s
1	138	182.9	0.45	62365	0.024	15595	11.60	0.44
2	202	182.9	0.26	36582	0.026	24614	6.87	0.26
3	119	182.9	0.19	26249	0.027	15326	4.90	0.19
4	46	150	0.28	32006	0.027	15717	4.90	0.28
5	30	107.1	0.29	24022	0.029	59637	2.64	0.29
6	40	107.1	0.25	20804	0.029	81308	2.26	0.25

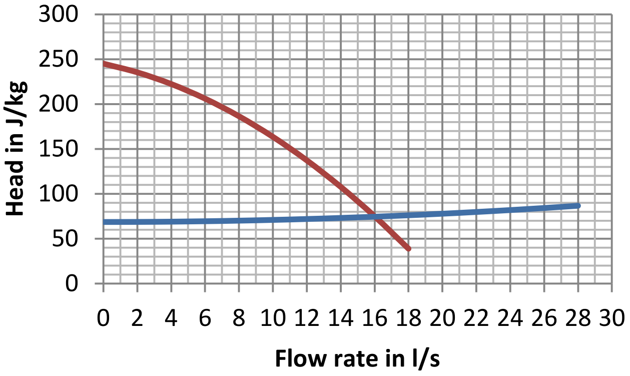

Figure 4 *Operating point of the pump at height difference of* H_{min}=7 [*m*]

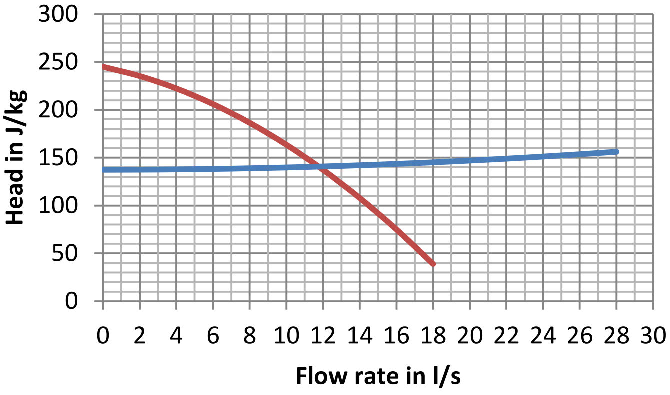

Figure 5 *Operating point of the pump at height difference of* H_{max}=14 [*m*]

4 DISCUSSION OF CALCULATION

As it can be seen from the calculation, when operating the pump in the most unfavorable variant, which means that the deep well pump B2 itself supplies all three reservoirs at the maximum height difference between the water level in the well and the reservoirs, the flow rate in each of the reservoirs will be greater than the required minimum flow rate. Corresponding values are given in Tables 3 and 4. The problem that has been solved here is to determine the flow rates through the sections for the given geometry of the complex pipeline consisting of 6 sections when the pump operates in section 1 with a given performance characteristic. Alternatively, it is possible to solve the problem of pump verification in such a way that, based on the values of the required inflows in the reservoirs, the values of the required flow rates in all sections are determined and for them the value of the total pressure drop for the most unfavorable circuit is calculated. This value represents the required pump head. If the available pump head is greater than the required pump head for the given total flow rate the pump may be verified.

Table 3 *Flow rates at height difference of* H_{min}=7 [*m*]

TECHNICAL WATER SUPPLY OF RESERVOIRS R1, R2 AND R3 FROM WELL B2 AT H_{min}=7m		
Pump operating point: head Y=74,57 J/kg; flow rate Q=16 l/s		
Reservoir	Calculated inflow in l/s	Required inflow in l/s
R1	3.07	2.15
R2	3.59	0.116
R3	9.34	5.56

Table 4 *Flow rates at height difference of* H_{max}=14[*m*]

TECHNICAL WATER SUPPLY OF RESERVOIRS R1, R2 AND R3 FROM WELL B2 AT H_{max}=14m		
Pump operating point: head Y=140,6 J/kg; flow rate Q=11,6 l/s		
Reservoir	Calculated inflow in l/s	Required inflow in l/s
R1	2.26	2.15
R2	2.64	0.116
R3	6.87	5.56

CONCLUSION

The exposed methodology of the hydraulic calculation of the complex pipeline is a grapho-analytical method for determining the operating point of the pump which, as can be seen, is not simple even when it comes to the complex pipelines with only a few sections, and when certain simplifications are used. Although it can be implemented for simpler cases of complex pipelines, a perspective is certainly in the application of specialized software.

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