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THE MEASURE OF FLOW IN LARGE SIZE TURBOPUMPS

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Abstract: This work presents a procedure adopted to measure the flow in an installation with four large sized axial pumps. A twelve captors Pitot type special probe was used for the measurement of flow, specifically developed for this work, as well as, the data acquisition system. The experimental results are shown.
Keywords: Flow, Probe, Turbopump

1 INTRODUCTION

The measure of flow in large pumping facilities is a hard task, mainly in that cases where these measures are not covered by traditional and standardised methods. This work presents a methodology to measure the flows of an installation of pumping of large size.

The studied installation has four axial vertical pumps, whith 11,25 [m^3/s] of rated flow each one, that are used for pumping urban water from a stream called Águas Espraiadas to Pinheiros River at São Paulo city. This stream is drained in an 12 [km] length channel to the reservoir where the pumps are located. When the water level in the reservoir reaches a maximum value, the pumps start automatically, avoiding the overflow of the stream, pumping it to Pinheiros River.

This pumping system present some particularities: The layout of the pumping installation doesn't allow the measure of flow with a traditional and standardised method; the flow of the system is variable and the time of pumping is very small. These characteristics forced the development of a special probe with 12 pressure intakes. The probe was installed in a pipe with 1,5 [m] diameter.

For a pre-established set of levels of water in the reservoir, the measures of pressures were carried automatically, using pressure sensor linked in each captor and using a data acquisition system, controlled by a software especially configured for this work.

The obtained experimental results were satisfactory and received by the contracting.

2 THE PUMPING PLANT

Figure 1 shows the pumping plant. The maximum quote of water operation in the reservoir is 721,90 [m] and the minimum is 718 [m]. The rated operation conditions are 11,25 [m^3/s] at 6,2 [m].

3 THE PROBE

A specific project of a probe multi holes was developed for the special characteristics of the pumping plant. In this project, a pressure take was used to obtain the static pressure in the center of the pipe and other eleven pressure takes were used to obtain the stagnation pressure distributed in the whole diameter of pipe - five captors installed in each radius of the pipe and one in its center. This way, it was obtained the punctual speeds, that will provide the determination of the speed profile in the transverse section of the pipe and, consequently, the instantaneous flows.

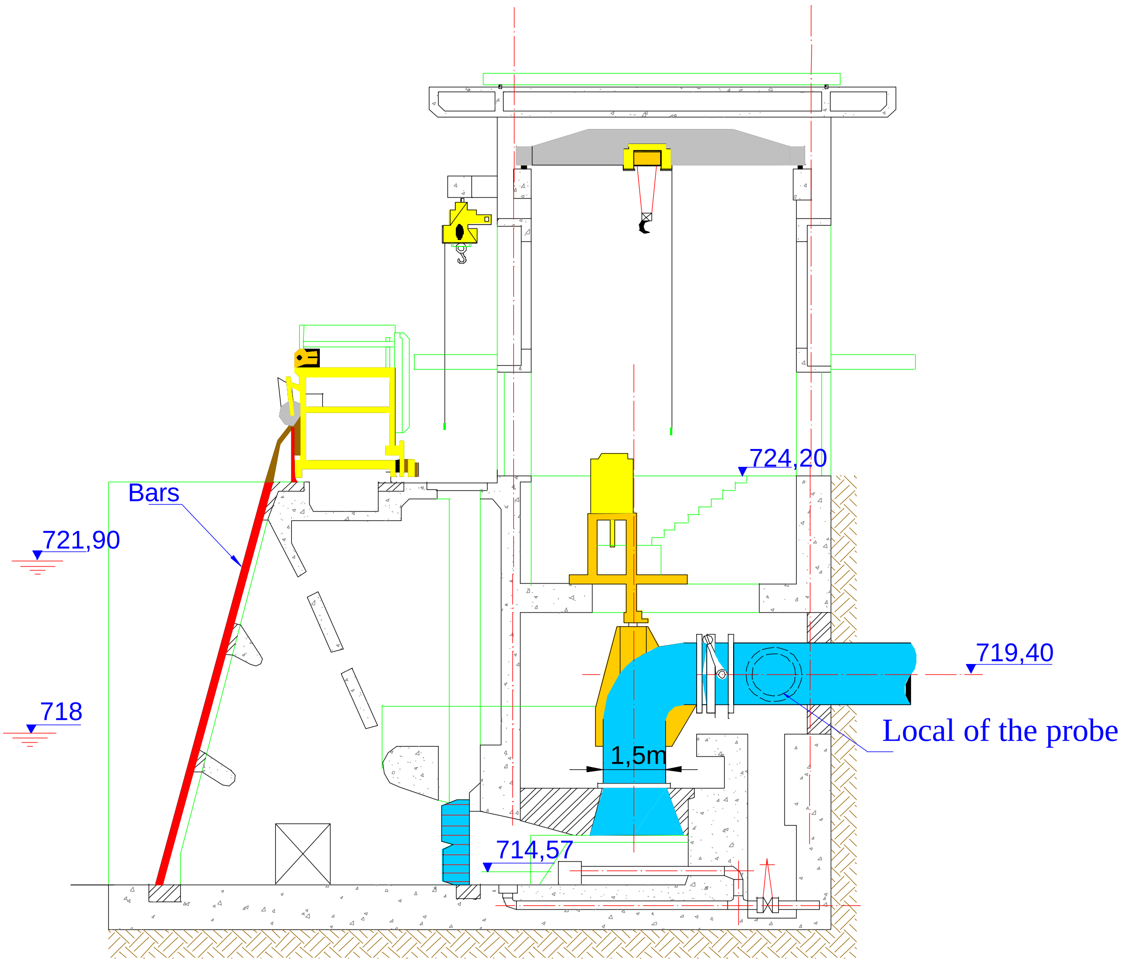


Figure 1 – The Pumping Plant

The pressure captors were traditional Pitot type with square border, distributed in the diameter of the pipe according to DIN-1944 standard [1]. This distribution is shown in the figure 2 and in the table 1.

Table 1 – Position of Pitot's tubes

Internal Ray R = 0.75[m					
Positions	0.316 R	0.548 R	0.706 R	0.836 R	0.948 R
	0.237[m]	0.411[m]	0.530[m]	0.627[m]	0.711[m]
Points	4 – 6	3 – 7	2 – 8	1 – 9	0 – 10

For high Reynolds numbers this type of captors presents coefficient near to one [2]. The number of Reynolds in a pipe is calculated using (1), where Re is the Reynolds number [1], Q [m^3/s] is the pumping flow, D [m] is the internal diameter of the pipe and n [m^2/s] is kinematics viscosity of the water.

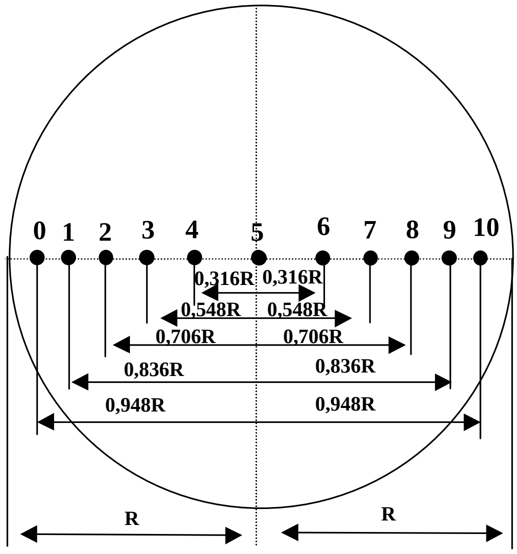


Figura 2 – The distribution of the captors in the pipe.

$$Re = \frac{4.Q}{\pi.D.\nu} \qquad (1)$$

For the case in study, the flow is characterised as highly turbulent type with Reynolds Number of about 10.2 10^6. It was determined considering the internal diameter of the pipe equal to 1,5 [m], the flow equal to 12 [m^3/s] and the cinematic viscosity of 10^{-6} [m^2/s]. For this, the calibration of the pressures captors of the probe was released and the coefficient of same (Cp) considered equal to one.

The place chosen for the fixation of the probe was the existent inspection window. It is placed in the pump discharge, after the butterfly valve, as shown in the figure 1.

For the extremal conditions of operation of the pumps, a special care was payed for the probe characteristic design, such as:

- mechanical resistance to the drag forces current with speeds of about 9 [m/s];
- The probe should rotate in its axis in order to be aligned; and
- The tubes of pressure transmission should be rigid to avoid any type of pressure reduction. This problem was solved with the employment of commercial ½" still tubes. These tubes improve the structural resistance of the probe and provide smaller resistance to the draining.

4 THE FLOW CALCULATION

The method for the flow calculation consider the distribution of speeds in the rays of the tube, v, at any position of ray r of pipe. The flow of the draining in an area A is calculated by equation 2.

$$Q = \int_A v \cdot dA = 2\pi \cdot \int_0^R v \cdot r \cdot dr \qquad (2)$$

(a)

(b)

Figure 3 – (a) The pre-assembly of probe with the set of pressure sensors. (b) The concluded probe

Figure 4 – The preparation of the probe to the its installation

For the calculation of the flow and presentation of the profile of speeds in almost real time, the integral of a continuous profile was approached by an area summation. These areas were distributed carefully for supply the smallest possible error. This is shown in the figure 5.

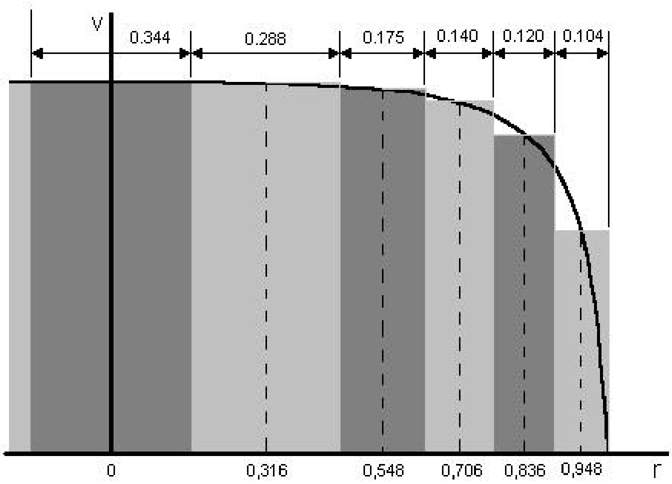


Figure 5 - Standardised distribution of the measure points

Using this approach, the equation 3 simplify the flow calculation.

$$Q = \frac{\pi D^2}{4}(0.098592\,V_0 + 0.100680\,V_1 + 0.098840\,V_2 + 0.096448\,V_3 + 0.091008\,V_4$$
$$0.091008\,V_6 + 0.096448\,V_7 + 0.098840\,V_8 + 0.100680\,V_9 + 0.098592\,V_{10}) \quad (3)$$

For the determination of the flow along the time, the pressure measures were made by a data acquisition system controlled by a software specifically programmed (DASYlab) [4].

The data acquisition system has as main component a data acquisition board (PCL818 by Advantech) that is connect in one of the PCs slots. This data acquisition card has an analogical-digital conversor that it transforms until 16 signs of voltage of 0 to 10 Volts into digital signals, intelligible for the computer, simultaneously.

As the output signal of the transducers is electric current, there was the need of the employment of a treatment signal module to convert this current in electric voltage, with appropriated level for the data acquisition card.

The flowchart of the acquisition software and data analysis is shown in the figure 6.

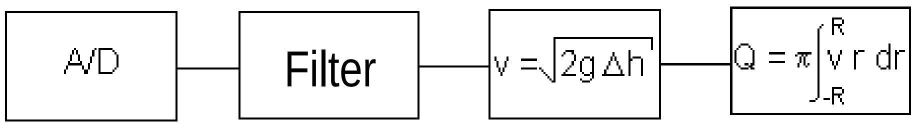


Figure 6 – The flow chart of software.

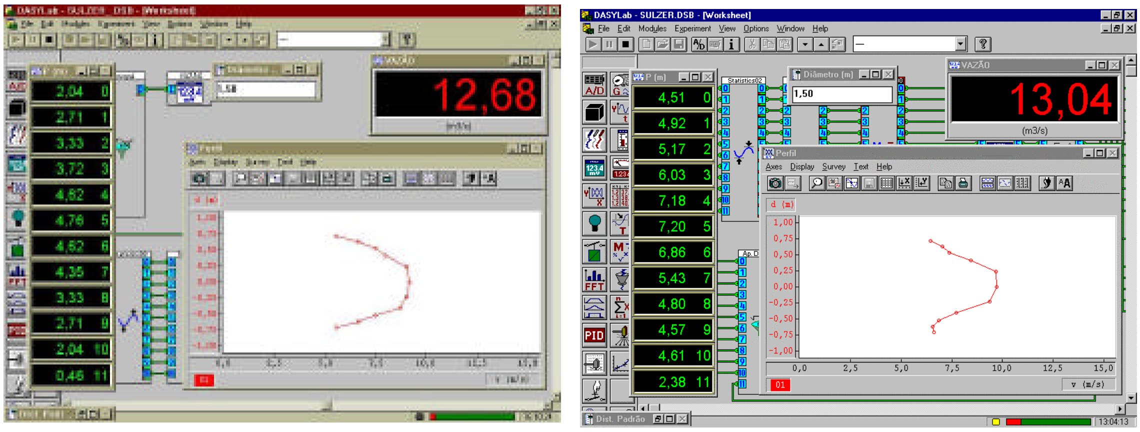
The twelve pressure sensors were calibrated in the Hidromechanic Laboratory for Small Power Plants of the Federal Scholl of Engineering of Itajuba, with a digital pressure standard, Z10 model, strip of -1 [bar] for 20[bar], piezoresistive capsule of precision 0,1 [%].

5 THE OBTAINED RESULTS

After the assembly of the probe in the pipe of the pump 1, it was defined the levels of the water in the reservoir to register the pressures, the speeds and, consequently, the flow. The levels of 719,50[m], 719,00[m], 718,50[m] and 718,00[m] were stipulated. This procedure was repeated for the pumps 2, 3 and 4.

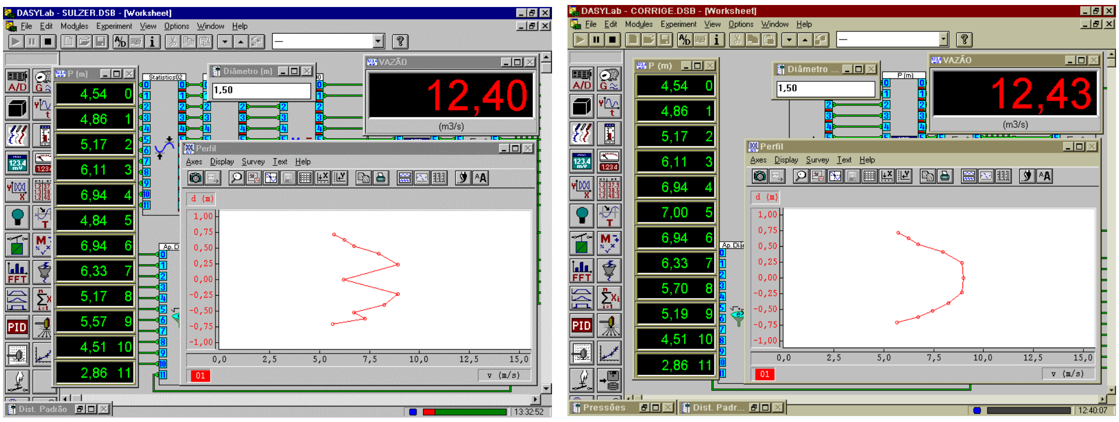
Some results are shown in the figures 7 and 8. The figure 7a shows the flow of 12,68 [m^3/s] obtained with the pump 1 in the level of 719 [m]. The figure 7b shows the flow of 13,04 [m^3/s] in the pump 3 in the even level.

Figure 8 shows the results of the pump 2 in the level of 718,5 [m]. By figure 8a one can see that there were problems in the profile of speeds due to blockage in some pressure captors caused by dirt of the water. Thus, the correction of the speed was adopted, as shown in the figure 8b. There were other problems of this nature which, too, are corrected. For the showed case, the accept flow is 12,43 [m^3/s] and not 12,40 [m^3/s].



(a) (b)

Figure 7 – Dates of the draining of the pump 1 (a) and of the pump 3 (b) in the level 719,50 [m]



(a) (b)

Figure 8 – The correction of the value of flow of the pump 2 to the level 718,50 [m]

6 CONCLUSIONS

In spite of the problems that happened the probe shown itself to be quite efficient for this case, specifically.

The success of the measures is due to the efficient of the data acquisition system utilised in the work, considering that the flow presented fast variations due to the differences between the suction levels.

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