Calculation and Application of Minimum Sump Volume

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1. Introduction

Most pumping systems that transfer liquid utilize some form of a pump sump including Kijang Research Reactor [1]. It is important to calculate the required minimum sump volume for estimation of the volume of the sump room or entire voulme of a reactor building. From the applicable Standard, it can be calculated but it is important to know the methods for diverse pump operation. In this study, the equations of minimum sump volume are derived and will be applied to other operation.

2. Methods and Results

Figure 1 shows operational sequences with descriptions for multi-pump stations.

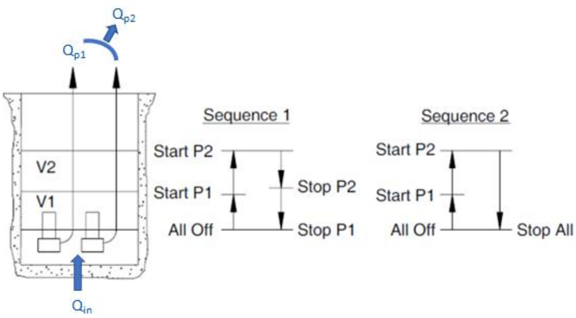

Fig. 1. Operational sequences [1] with descriptions

T = The pump cycle time in minutes, i.e., the time between two consecutive starts
Vol_x = The effective sump volume for pump x, i.e., the volume between the start level and the stop level in liters
Q_{in} = The inflow into the pump station in l/min
Q_{p1} = The flow rate of pump 1 in l/min
Q_{p2} = The combined flow rate with 2 pumps in l/min

2.1 Minimum Sump Volume Sequence 1

2.1.1 For Vol_1 (Stop P_1)

$$T = \frac{Vol_1}{Q_{in}} + \frac{Vol_1}{Q_{p1} - Q_{in}} \tag{1}$$

$$\Rightarrow Vol_1 = T(\frac{Q_{in}}{Q_{p1}})(Q_{p1} - Q_{in}) \tag{2}$$

For minimum sump volume Vol_1, partially differentiate Vol_1 from Q_{in}.

$$\text{When } \frac{\partial Vol_1}{\partial Q_{in}} = \frac{-(2Q_{in} - Q_{p1})T}{Q_{p1}} = 0 \tag{3}$$

$$\text{then } Q_{in} = \frac{Q_{p1}}{2} \tag{4}$$

Substituting Eq. (4) in (2) gives

$$Vol_1 = \frac{Q_{p1}}{4}T \tag{5}$$

2.1.2 For Vol_2 (Stop P_2)

$$T = \frac{Vol_2}{Q_{in} - Q_{p1}} + \frac{Vol_2}{Q_{p2} - Q_{in}} \tag{6}$$

$$\Rightarrow Vol_2 = T(Q_{in} - Q_{p1})(\frac{Q_{p2} - Q_{in}}{Q_{p2} - Q_{p1}}) \tag{7}$$

For minimum sump volume Vol_2, partially differentiate Vol_2 from Q_{in}.

$$\text{When } \frac{\partial Vol_2}{\partial Q_{in}} = \frac{(2Q_{in} - Q_{p1} - Q_{p2})T}{Q_{p1} - Q_{p2}} = 0 \tag{8}$$

$$\text{then } Q_{in} = \frac{Q_{p1} + Q_{p2}}{2} \tag{9}$$

Substituting Eq. (9) in (7) gives

$$Vol_2 = \frac{(Q_{p2} - Q_{p1})}{4}T \tag{10}$$

2.2 Minimum Sump Volume Sequence 2

2.2.1 For Vol_1 (Stop P_1)

It is the same as Sequence 1.

2.2.2 For Vol_2 (Stop All)

$$T = (\frac{Vol_1}{Q_{in}} + \frac{Vol_2}{Q_{in} - Q_{p1}} + \frac{Vol_1 + Vol_2}{Q_{p2} - Q_{in}}) \tag{11}$$

$$\Rightarrow Vol_2 = \frac{T(Q_{in} - Q_{p1})(Q_{p2} - Q_{in})}{Q_{p2} - Q_{p1}} - \frac{Vol_1 Q_{p2}(Q_{in} - Q_{p1})}{Q_{in}(Q_{p2} - Q_{p1})} \quad (12)$$

For minimum sump volume Vol_2, partially differentiate Vol_2 from Q_{in}.

$$\frac{\partial Vol_2}{\partial Q_{in}} = \frac{2Q_{in}^{3}T - Q_{in}^{2}T(Q_{p1} + Q_{p2}) + Q_{p1}Q_{p2}Vol_1}{Q_{in}^{2}(Q_{p1} - Q_{p2})} = 0 \quad (13)$$

2.3 Comparison for Validation

Comparison of calculated results of Standard examples [1] and derived equations can be used to verify that the equations are correct. Table I shows the calculated results of the examples and equations.

Table I: Calculated Results of Examples and Equations

Sequence	Variable	Example	Equation
1	Q_{in} of Vol_1	75	75
	Q_{in} of Vol_2	200	200
2	Q_{in} of Vol_2	180	177.74

As shown in Table I, the results of Sequence 1 are exactly the same. In the case of sequence 2, there is a slight difference, but it is the result of an iteration or trial error process as it appears in the Standard [1].

3. Conclusions

In this study, the equations of minimum sump volume are derived from the Standard [1] and validated from the calculated results. From the results, we can understand the meaning and methodology of volume calculation. By knowing the process and methodology, rather than simply substituting values for the Standard, it can be applied to other operational sequences that are not in the Standard.

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REFERENCES

[1] American National Standard for Pump Intake Design, ANSI/HI 9.8, Hydraulic Institute, 1998.