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The study of fluid analysis on a new blowdown pump sealing line

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Abstract

The sealing system is used on the pump as a sealing medium between a stationary object (the pump casing) and a rotating object (shaft), maintains the shaft temperature, and keeps the fluid not in or out of the system. The blowdown pump in Priok Combined Cycle Power Plant (CCPP) used service water as a medium for the sealing system because potential seawater will contaminate the pumped water. In this case, the authors observe a blowdown pump, one of the pumps in the desalination system that pumps the seawater. There is no potential for contaminating fluid systems by sealing water because the fluid contains many salts and is thrown directly into the ocean. This project is to replace the water sealing using seawater as a sealing system on the blowdown pump will not harm the system because the fluid system is carried out. This research can reduce the use of water service by as much as 1142 liters per day for 2 desalination plants because the discharge water used sealing each desalination unit is 23,79 liters / hour / desalination.

Keywords*: Blowdown Pump; Desalination Plant; Fluid System*

1. INTRODUCTION

Using as little water as possible in the energy industry is the goal of the world's industry. Relation between power generation and water consumption has been gaining increasing attention from policymakers and scientists (1,2). Indonesia Power, as a subsidiary of PLN, has a Combined Cycle Power Plant (CCPP) with an installed power of 2723 megawatts in Tanjung Priok Jakarta (3). The water requirement for CCPP is obtained by distillation from the mouth of the Kalijapat river, which is important because water is used for working medium, cooler, pump seal system, and so on. The water to be used on the working medium must pass through the treatment plant resulting in the appropriate conductivity of water, namely 0.2 s/cm^2, called make-up water (4). Make-up water used as a working medium has several requirements that must have a maximum conductivity of 0.2 s/cm^2, water ph 6-7, and a silica (SiO_2) content of not more than 0.2%.

The various types of water requirements show that the need for adequate water by CCPP is urgently needed. Therefore, water use is essential so that it is more efficient and can meet all the needs of CCPP. It should be noted that some of the water used in the sealing system at the pump uses service water. Service water is fresh water with a relatively high conductivity of around 85us/cm^2. Even though service water is a raw material for make-up water, service water for sealing systems must be genuinely selective. The sealing system in a pump prevents liquid leakage from the pump or air into the pump, pump fluid flow, and there is a pressure difference between the atmosphere and pump body gap between fluid along the axis external leak (5). The sealing water used in the sealing system will not contaminate the water pumped. Service water is used as a sealing system for the pump if there is a concern that seawater as a sealing system will mix with the pumped water. An example of the Priok CCPP is the distillate pump, and this pump pumps service water. If the distillate pump uses seawater as a sealing system, there is a concern that it will contaminate the pumped water.

The author observes that there is a pump in CCPP that pumps seawater inside, so there is no potential for contamination by sealing water, namely the blowdown pump. The blowdown pump circulates water in the system, which does not evaporate in the evaporator. This water contains many salts and is discharged directly into the sea, so using seawater as a sealing system for the blowdown pump will not harm the system and reduce service water use. Using seawater as a sealing system for blowdown pumps requires a new path to distribute seawater into the sealing system, which is analyzed using fluid analysis. Some research related to fluid analysis in piping has been carried out by calculating head losses, major losses, and minor losses (6,7) This research shows that a line cannot flow fluid if all the existing paths are turned on simultaneously. Another research has conducted analysis related to the diameter, pipe material, and flow discharge using the Contrast test on poly Vinyl Chloride (PVC) and Polyethylene (PE) pipes. The conclusions from this research are that section diameter, pipe material, and fluid flow discharge have significant effects on head losses (8).

This research starts with making a new piping sealing line design based on the influence of the flow inlet desalination system, which will connect seawater to the sealing system of the blowdown pump. It then proceeds with calculating the amount of pressure entering the sealing system by fluid analysis to ascertain whether the pressure that arises is **capable** of working on the blowdown pump sealing.

2. Methods

This research was conducted at CCPP Tanjung Priok, North Jakarta, by analyzing pump sealing requirements, making a new seawater flow design from the existing pipe to the sealing system (9), and the impact of pressure drop from new pipe branches. This research method was carried out by directly observing companies and collecting primary and secondary data from the following companies. Primary data needed are seawater temperature data mode and data properties of seawater and existing Piping data, such as pipe length, diameter, number of turns, valves, strainers, and elevation. The secondary data which get from the calculation are pump performance data (pumps distributing seawater to the desalination plant) and piping material data. The collected primary and secondary data will be used to determine: 1. the flow type in the existing system, the friction factor with moody diagrams, 2. determine the head loss along the existing pipe to the new pipeline branching, and 3. calculate the pressure drop on the existing pipe and new pipe branching.

2.1 Flow Type and Friction Factor

Determining the flow type in the existing pipe and knowing the friction factor in the flow can use the following equation and moody diagram (10) . The value of the flow type can be found using the Reynolds number with the following equation.

$$Re = \frac{\rho.V.d}{\mu} = \frac{\rho.4.\dot{m}.d}{\rho.\pi.d^2.\mu} = \frac{4.\dot{m}}{\pi.d.\mu} \quad (1)$$

Where Re is the Reynolds number. If the value Re > 4000, then it is called turbulent flow, Re < 2000 is called laminar flow, and Re between 2000 - 4000 is called transitional or critical flow, ρ is liquid density, V is velocity, μ is absolute viscosity, $\dot{m}$ is mass flow, and *d* is pipe internal diameter (m). For laminar flow, Reynolds number R < 2000, the Darcy friction factor f is calculated from the simple calculation (11).

$$f = \frac{64}{Re} \quad (2)$$

where f is friction factor. In addition to the above empirical equations, moody diagrams can be used to determine the friction factor for turbulent flow. Figure 1. shows the relationship of the friction factor (f) – Reynolds and its relationship to the relative roughness *ε/d* or *d/ε*.

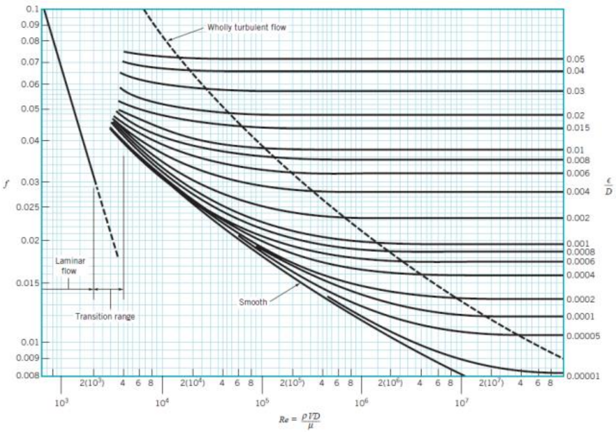


Figure 1. Moody Diagram
Source: Fundamental of Fluid Mechanics, Burce R. Munson D

2.2 Head Loss

Head losses are any energy loss caused by some localized flow disruption due to various flow appurtenances, such as valves, bends, elbows, inlets, exits, enlargement, and contractions in addition to the pipes (12). Calculating the total headloss is needed to determine the pressure at the new branch point. This calculation uses equations 5, 6, 7, and 8. Complete data regarding the major losses and minor losses in the Tanjung Priok CCPP are shown in table 1, based on condition in figure 2.

Figure 2. Head Loss Line Pipe Calculating
Source: CCPP Tanjung Priok

Table 1. Quantity of Major and Minor Losses

	Type	Quantity
1	elbow 90	21
2	elbow 45	7
3	thee	7
4	check valve	2
5	butterfly valve	6
6	Line	241.6 m
7	Δh	1.4 m

Source: CCPP Tanjung Priok

2.2.1 Bernoulli's Equation

Bernoulli's law explains the basic concept of fluid flow: an increase in velocity in a fluid will decrease pressure on the fluid. That is, there will be a decrease in potential energy in the fluid flow (10).

$$z_1 + \frac{{V_1}^2}{2g} + \frac{P_1}{\gamma} - h_l = z_2 + \frac{{V_2}^2}{2g} + \frac{P_2}{\gamma} \quad (3)$$

Where z is height above reference level (m), V is average velocity of fluid (m/sec), P is pressure of fluid (kg/cm^2), g is acceleration due to gravity (m/sec^2), h_l total head loss (m), and γ is spesific weight of barometric liquid.

2.2.2 Friction Head Loss

In fluid analysis, the pressure drops in a given length of pipe, expressed in a meter of the liquid head (h), can be calculated using the following Darcy–Weis–Bach equation 4:

$$hl = f.\frac{l}{d}.\frac{v^2}{2.g} \quad (4)$$

Where l is pipe length (m), *d* is pipe internal diameter (m). V is average velocity of fluid (m/sec), and g is acceleration due to gravity (m/sec^2). Equation 4, known as the Darcy-Weisbach equation, can determine the energy loss due to friction along the pipe for both laminar and turbulent flow. In laminar flow, energy losses can be determined by the Hagen-Poiseuille equation 5.

$$hl = \frac{32.\mu.L.V}{\rho.g.d^2} \quad (5)$$

2.2.3 Minor Losses

Minor losses (h_{lm}) occur in pipelines due to bends, valves, changes in cross-sectional area, and so on. Generally used experimental data. The equation 6 or 7 can determine these minor losses (13).

$$h_{lm} = k.\frac{V^2}{2.g} \quad (6)$$

$$h_{lm} = f.\frac{Le}{d}.\frac{V^2}{2.g} \quad (7)$$

Where h_{lm} is value of minor losses (m), k is coefficient loss, Le/d is equivalent length. The value of the loss coefficient k and the equivalent length of Le/d for various fittings are shown in Table 2 below.

Table 2. Value of Equivalent Lengths

Fitting Type	Description	Equivalent Lengths (L_e/D)
Globe Valve	Fully Open	340
Angle Valve	Fully Open	145
Gate Valve	Fully Open	13
	¾ Open	35
	½ Open	160
	¼ Open	900
Check Valve	Swing Type	135
	Ball Type	150
Butterfly Valve	Fully Open	40
90^0 Standard elbow		30

45^0 Standard elbow		16
90^0 elbow	Long Radius	20
90^0 Street elbow		50
45^0 Street elbow		26
Tee	Flow through run	20
	Flow through branch	60
Return bend	Close Patern	50

Source*: Fundamental of Fluid Mechanics, Burce R. Munson D*

2.2.4 Major Losses

Major losses occur in the pipeline because of the length of the pipe itself, and the flow rubs against the pipe wall. The equation 8 can determine this major loss:

$$h_l = f.\frac{L}{d}.\frac{V^2}{2.g} \quad (8)$$

Where L is pipe length (m), *d* is pipe internal diameter (m). V is average velocity of fluid (m/sec), and g is acceleration due to gravity (m/sec^2).

2.3 Pressure Drop

Pressure drop is the difference in total pressure between two points in a fluid-carrying network. A pressure drop or loss will occur when a liquid material enters one end of a piping system and leaves the other. Due to different elevations, frictional losses while flowing through piping and losses due to fittings pressure drop or head loss are caused. The widely used methods used to calculate the head loss in the pipe are Manning, Hagen-Poiseuille, and Darcy-Weisbach equations 3, 4, and 5.

3. Result and Discussion

3.1 Flow Type and Friction Factor in Existing line

Fluid analysis with Reynold number has calculated flow type in the existing line with equation 1. The Reynold number in the existing line Re is 89.543,22 meaning the flow type is turbulent. The friction factor can be determined using the moody diagram. Based on the Reynolds value and Moody diagram in Figure 2, it can be determined that the friction factor f is 0.0204.

3.2 Piping Design

Designing a new pipeline with a function as a sealing system branched off from the existing pipeline must consider the pressure drop, head loss and aesthetics of the design. Therefore, the design is made using 3D software, which allows the user to do an overview before executing the design. Autodesk Inventor is used to design the new sealing system piping line, shown gray piping line in Figure 3.

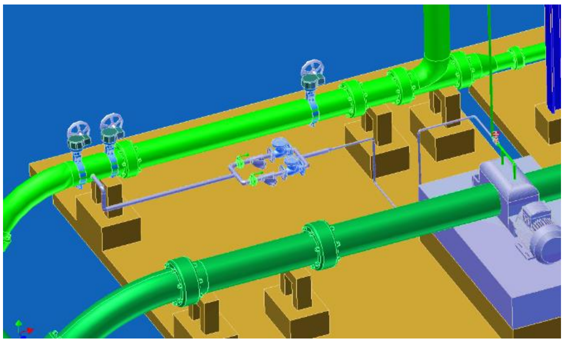


Figure 3. Design a New Sealing System Piping Line
Source: Personal Document

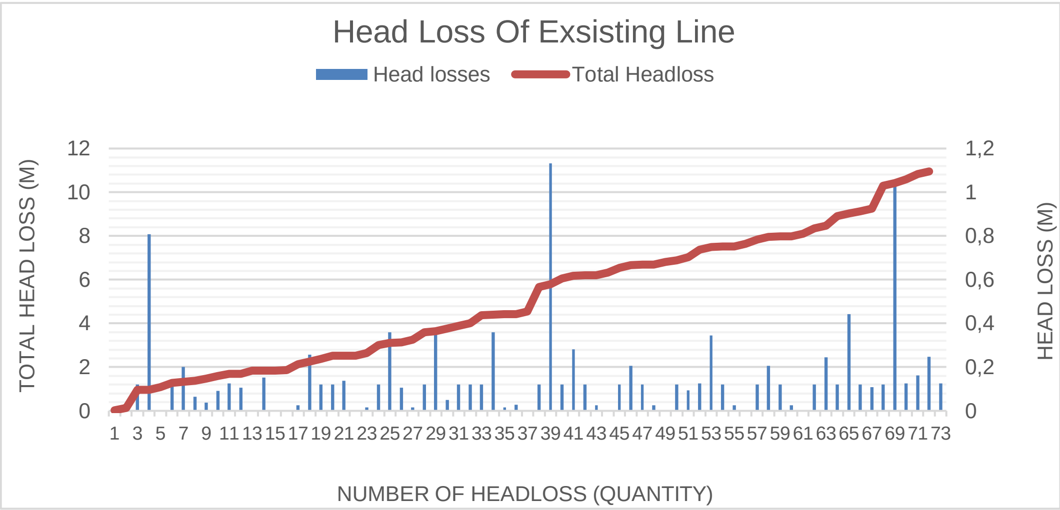
The addition of a new line has several major and minor losses as shown in table 3.

Table 3. Major and Minor Losses in New Piping Line

No.	Name	Quantity
1	elbow 90	4 – 2 in 5 – 1 in
2	Reducer 2'-1'	1
3	thee	2
4	Line 1 in	4.5 m
5	Line 2 in	3.2 m
6	∆h	0.53 m
7	Check Valve	2

3.3 Head Loss and Pressure Drop in the Existing Pipe

Head loss in existing pipes must be known to ensure sufficient pressure before branching into the new pipe sealing system. The existing seawater pipeline has a pump pressure of 7 bar (700,000 N/m^2). Based on the primary data table 1, there are 74 cases of losses, including fittings, elevations, bends, and the length of the pipe. Head loss is calculated in graph 1. (73 data shown due to numbering). Each case of loss is illustrated in this graph by a bar chart. A red line diagram depicts the total head loss for each case. The head loss along the existing pipe is 10.952 m. Thus, the pressure drop from the existing pipe is 1,247 bar (124,693.8804 N/m^2), and the pressure at the start of branching new sealing line is 5,75 bar (575,3 kN/m^2).



Graph 1. Head Loss of Existing Line

3.4 Head Loss and Pressure Drop in the New Sealing Pipe System

The pressure at the starting point of the pipe branching is known using equation 3. After that, use equation 3 again to find the pressure drop value so that the pressure at the end of the new line pipe can be determined. The number of major and minor losses must be known to get the pressure drop value. Figure 4 shows the new design of line sealing, and there are 15 cases of head loss (hl) which include: 6 elbows 1 in ($hl_{1.1\text{-}1.6}$), four elbows

2 in ($hl_{2.1\text{-}2.4}$), two pieces of Tee 2 in ($hl_{3.1,\ 3.2}$), Y-Strainer (hl_4), Gate Valve (hl_5), and Check Valve (hl_6).

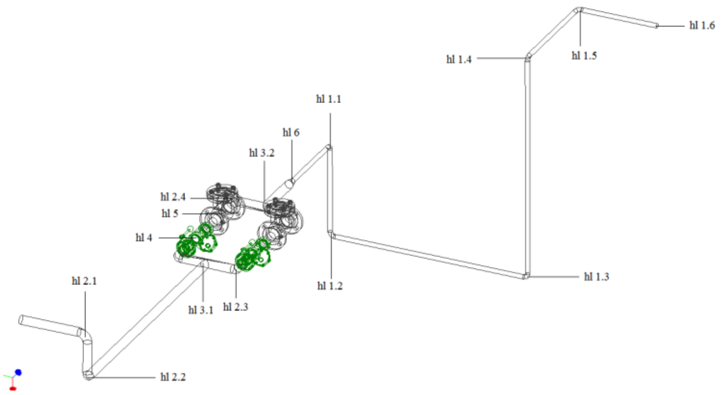


Figure 4 The Number of Major and Minor Losses in New Sealing Pipe

After knowing the cases of major and minor head loss, the head loss and pressure drop can be calculated with the following calculation,is known : Z_C = 20.918 in = 0,53 m, P_A= 575,3 kN/m2 = 5,75 bar, V_A = 2.485 m/s, Q_2 = 0.5 m3/s (water sealing needs), V_2 = Q/A = 0.28 m/s. γ = 10094,49 N/m3, g = 9.81 m/s2, μ = 8,5 x 10-4 N.s/m2, D_1 = 1 in, D_2 = 2 in

Head loss (h_{lc}) :

$$h_{lc} = f_1.\frac{l_1}{D_1}.\frac{{V_1}^2}{2.g} + f_2.\frac{l_2}{D_2}.\frac{{V_2}^2}{2.g} + \sum k_1.\frac{{V_1}^2}{2.g} + \sum k_2.\frac{{V_2}^2}{2.g}$$

Substitusion to equation 3 :

$$z_A + \frac{{V_A}^2}{2g} + \frac{P_A}{\gamma} = z_2 + \frac{{V_2}^2}{2g} + \frac{Pv_2}{\gamma} + \frac{32.\mu.V_2}{\rho.g}.\left(\frac{l_1}{4.{D_1}^2} + \frac{l_2}{{D_2}^2}\right) + \sum k_1.\frac{{V_2}^2}{4.2.g} + \sum k_2.\frac{{V_2}^2}{2.g}$$

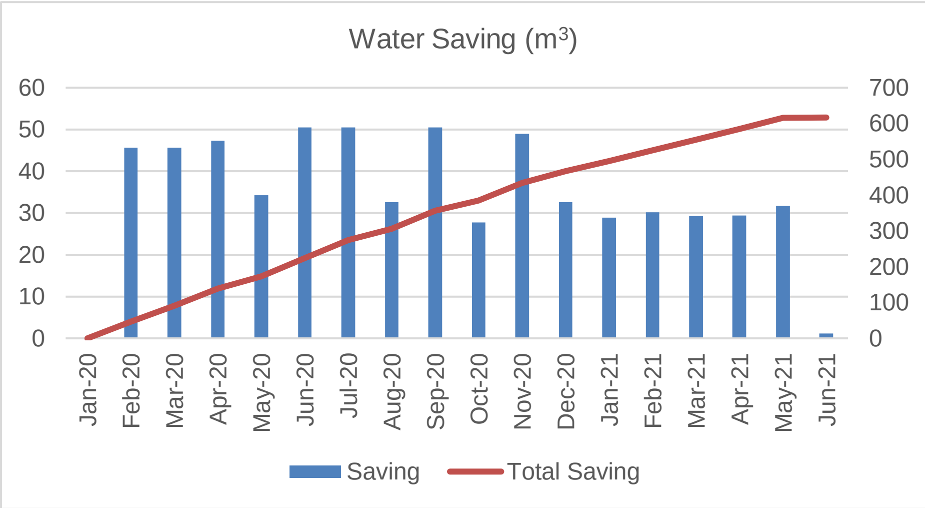
$$(0 - 0.53)m + \frac{(2{,}485\ m/s)^2}{2\ .9{,}81 m/s^2} + \frac{575{,}3\ kN/m^2}{10{,}09449\ KN/m^2} = \frac{0.28^{\,2}}{2\ .\ 9{,}81 m/s^2}(1 + 0.25(1{,}257) + (15.82)) +$$

$$\frac{32\ .8{,}5\ x\ 10^{-4} N.s/m^2.0.28 m/s}{1030\ kg/m^3\ .9{,}81 m/s^2}.\left(\frac{3{,}2m}{4.(5{,}08\ x\ 10^{-2}\ m)^2} + \frac{4{,}5\ m}{(2{,}54\ x\ 10^{-2}\ m)^2}\right) + \frac{Pv_2}{\gamma}$$

$$\boldsymbol{P_{v2} = 5,7\ bar}$$

4. CONCLUSION

The pressure at the endpoint in this new branch is P_{v2} = 5.7 bar. This pressure capable to provide sealing the blowdown pump because the sealing pressure required is at least 3 – 3.2 bar. This research started in early 2020 and continued to operate until June 2021. Finally, the desalination plant at CCPP Priok changed its status to standby (regulation of company efficiency) so that water-saving data can be seen in graphic 2. Based On The Graphic, the total saving water from this research is 616,78 m3 or 1142 liters per day and 23,79 liters per hour per desalination. Replacing sealing water with seawater for cooling sealing systems such as blowdown pumps can be applied to all pumps in the generation unit as long as the fluid being pumped is not potentially contaminated.



Graph 2. Water Saving

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