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CENTRIFUGAL PUMP DESIGN WITH CAPACITY 50.6 L/MIN FOR WATER UTILIZATION FROM STEAM TRAP AS BOILER FEED WATER

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ABSTRACT

Condensate water is the result of condensing steam which has decreased in temperature and pressure due to losses from the environment. Steam trap used to separate water or dew from steam resulting from a decrease in temperature. This condensate water has a temperature of 50°C. Based on the results of condensate water testing from steam trap it has permissible criteria for boiler feed. In the existing conditions, the boiler feed water requirement is 500 liters/hour with a temperature of 25°C, while the water produced from steam trap of 230 liters/hour so that to be able to meet the needs of boiler feed water, a pump designed with a capacity of 50.6 liters/minute is needed. The purpose of this research is to design a pump to utilize steam trap water as boiler feed water. Materials are selected according to requirements and standards. Condensate water from the steam trap becomes the initial parameter for calculating Head, NPSH, Impeller Diameter, and Shaft Diameter. NPSH available must be greater than NPSH request to prevent pump cavitation, which can cause damage or loss. Based on the calculations, the NPSH req value is smaller than the NPSH available, which is 4.62 m < 11.48 m. The total head is 7.97 meters, and the number of blades is 7. The design dimensions obtained are the impeller inner diameter of 29.47 mm, outer diameter of 72.58 mm, shaft diameter of 6 mm, casing diameter of 76.215 mm.

Keyword: *Centrifugal Pump, Head, NPSH, Impeller, Shaft, Casing*

1. INTRODUCTION

Steam is produced by a steam boiler or boiler through a heating process with heat generated from fuel. In this study, the boilers used had a capacity of 3 tons/h and 2 tons/h. The need for boiler feed water per day is 12 m^3. Furthermore, the steam produced by the boiler is distributed through working pipes to the point where the heat energy is needed so that heat transfer occurs from the pipe to the environment in the process of distributing steam to the process point[1]. This is due to the radiation heat transfer from the distribution pipe [2].

An insulator is used to minimize the heat transfer process, but heat transfer still occurs which causes condensation in the steam [3]. Condensed steam must be removed from the pipe so that the pipe does not occur hammering or water enters the engine [4]. Steam trap separate the water or dew from the steam. Based on observations at the research location there is water from steam trap which are still discharged into the environment. Considering process efficiency and the environment, a closed system is generally used, namely the steam condensate is circulated back to the boiler to produce steam and so on [5]. Boiler feed water that does not meet boiler water requirements causes scale on the pipes in the boiler drum and water that is good to use as feed water is water that comes from the distillation process and water from the condensation process.

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Boiler feed water before entering the boiler undergoes a purification process and removes substances that can react and cause damage to the boiler. After passing through the filter in the water treatment, feed water then enters the deaerator. Water vapor is steam that arises due to changes in the water phase (liquid) to steam by boiling (boiling) [6]. Increasing the temperature of the feed water can shorten the boiling process of water so that the faster the process of boiling water into steam, the less fuel is used. The water requirements that are allowed to be used as boiler feed must meet several criteria such as PH 10.5-11.5, TDS max 3500 Ppm, Iron max 2 Ppm, Silica max 150 Ppm. If based on the results of laboratory tests, the condensate water from steam trap this has good results (according to the criteria) then it is allowed to be used as boiler feed water.

The purpose of this research is to design a centrifugal pump consisting of impeller, casing, and shaft dimensions. The function of the pump is to move one place to another that is far away and to move water from low pressure to high pressure [7]. This pump is necessary for water utilization steam trap as boiler feed water. So that the contents of this research discussion will answer the objectives and produce output in the form of calculation results and pump design drawings.

2. METHODOLOGY

To design a centrifugal pump requires initial parameters such as pressure, temperature, and the distance from the holding tank to the deaerator. In addition, this design has boundary conditions that must be met.

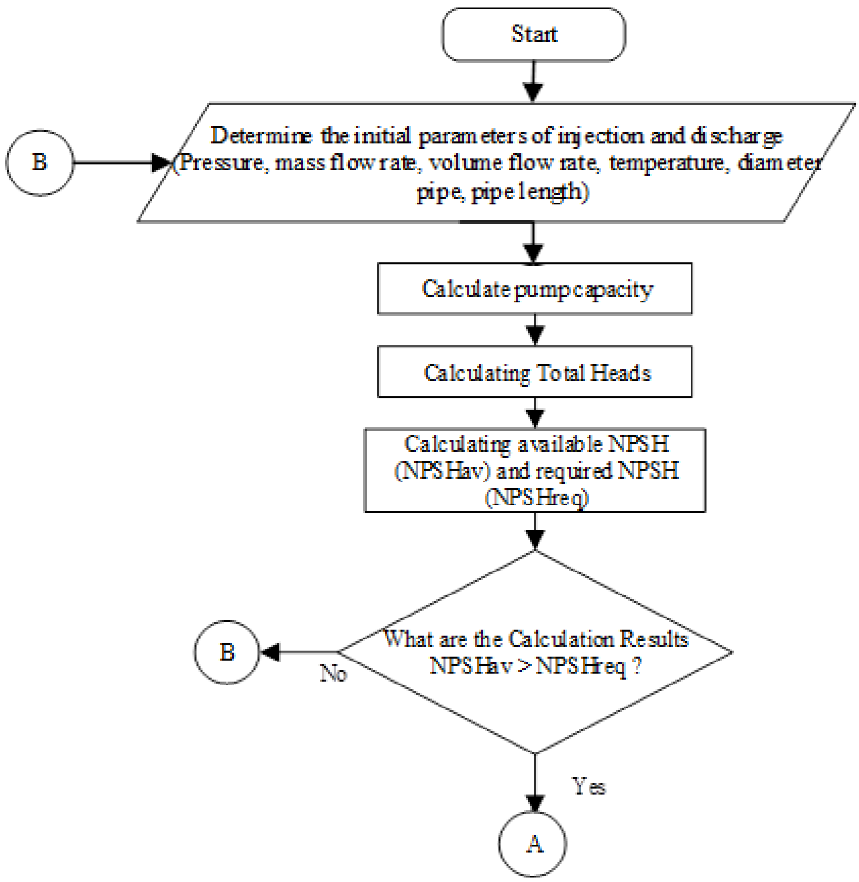

Figure 1. research methods flow 1

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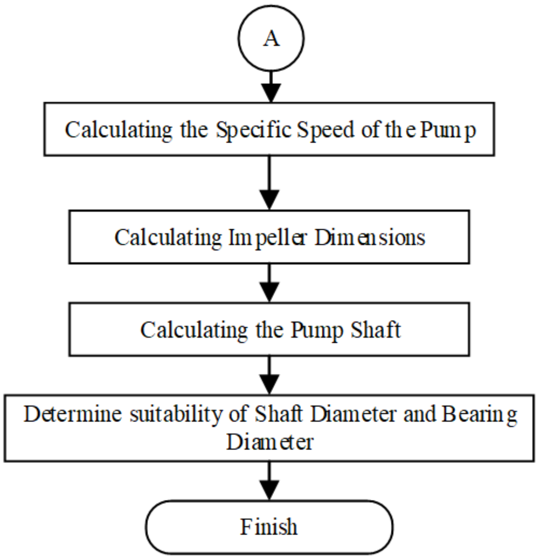

Figure 2. research methods flow 2

2.1. Research Metodhs

The initial design parameters were determined based on observations at the research location with the parameters and values shown in table 1 below:

Table 1. The amount of water produced Steam trap

No	Parameter	Value	Unit
1	Debit	1,25	liters/15 minutes
2	Steam trap Total	46	
3	Debit Total	230	liter/hour
3	Mass Flow Rate	0,8329	kg/s
4	Suction pressure	1,10	Atm
5	discharge pressure	2,03	Atm
6	Temperature Air	50	°C
7	Density of Water	987,68	kg/m³
8	Kinematic Viscosity	0,000000538	m²/s
9	Gravity	9,8	m/s²

Water volume of steam trap produced 230 L/hour with a temperature of 50 °C so that a pump is needed to move the water into the deaerator and feed it to the boiler. In this design, we get the result of designing a pump with a suction diameter of 1.5-inch and a discharge diameter of 1 inch. The pump to be designed has the following design characteristics:

Table 1. Planning Criteria

Parameter	Value	Unit
Viscosity	1-2	m/s
NPHS	NPSH soil > NPSH req	
%validation	<5	%

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2.2. Head

Head is the mechanical energy in the fluid per unit weight (kgf or newtons) [8].

2.2.1. Head Total Pompa

The total head is a representation of the increase in energy received by the liquid per kilogram flowing through the pump [1].

$$H = \left(\frac{P_2}{pg} + \frac{C_2^2}{2g} + Z_2\right) - \left(\frac{P_1}{pg} + \frac{C_1^2}{2g} + Z_1\right) + hl \quad (1)$$

Information:

H_s = Head pompa (m)

P_2 and P_1 = Pump inlet and outlet pressure (Pa)

Z_1 dan Z_2 = pump height (m)

C_2 andC_2 = velocity of fluid flow in and out of the pump (m/s)

ρ = density of liquid (kg/m^3)

D = inner diameter of pipe (m)

2.2.2. Head Total Mayor

The major head loss is the friction loss between the pipe wall and the fluid flow without changing the cross-sectional area inside the pipe.

$$hlp = f\frac{Lin^2}{d2g} \quad (2)$$

Information:

f = friction factor

L = pipe length (m)

in = fluid velocity (m/s)

d = inner pipe diameter (m)

(Source Sularso 1996)

2.2.3. Head Loss Minor

This loss can be caused by bends, valves, and pipe joints.

$$hlf = n\,.\,k\frac{in^2}{2g} \quad (3)$$

Information:

n = number of similar valve fittings

k = friction factor on fittings, valves for the same size and type

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in = fluid velocity (m/s)

(Source: Sularso 1996)

2.3. NPSH

2.3.1. Available NPSH

The available NPSH is the fluid level at the inlet side of the pump (equal to the absolute pressure at the inlet side of the pump) minus the saturated vapor pressure of the fluid at that location.

$$NPSH_{of} = \frac{P_1}{\rho} - \frac{P_{in}}{\rho} \pm With_1 - h_{ls} \quad (4)$$

Information:

P1 = suction side pressure (kgf/m2)

Pv = saturated vapor pressure (kgf/m2)

+ = if the pump is above the surface of the liquid

(-) = if the pump is below the liquid level

(Source: MSME & Tahara 2000)

2.3.2. Required NPSH

The NPSH requirement is needed to determine the head pressure on the liquid flowing through the pump.

$$NPSH_{req} = H_{sv} = \sigma\, x\, H \quad (5)$$

With:
σ = Thoma cavitation coefficient
(Source: Srinivasan 2008)

Calculating the thoma cavitation coefficient can use the specific suction speed number (S)[8]

$$\sigma = \frac{(n_s^{4/3})}{s} \quad (6)$$

2.4. Pump Efficiency

2.4.1. Hydrolysis efficiency

Hydraulic efficiency is a comparison between head actual pump with head theoretical pump with an infinite number of blades.

$$\eta_h = 1 - \frac{0,42}{(log\ log\ D_1 - 0,172)^{\ 2}} \quad (7)$$

Information:

theh = hydraulic efficiency (%)

D1= impeller inlet diameter(mm)

(Source: Srinivasan 2008)

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2.4.2. Volumetric Efficiency

Volumetric damage occurs due to leakage of fluid flow after passing through the impeller.

$$\eta_{in} = \frac{1}{1 + (0{,}68\ x\ n_s{}^{-2/3})} \tag{8}$$

Information:

ηs = Specific Speed

(Source: Srinivasan 2008)

2.4.3. Mechanical Efficiency

Friction on the bearings when rotating greatly affects the mechanical efficiency because it includes losses. The value of mechanical efficiency can be assumed with the ability to distribute power from the drive whose value ranges from 94% to 98%.

2.5. Power

2.5.1. Power Output

The output power is the energy effectively received by the fluid from the pump per unit time.

$$N_O = \frac{g\ x\ \rho\ x\ Q\ x\ H}{1000} \tag{9}$$

Information:

N0= output power/hydraulic (kW)

(Source: Srinivasan 2008)

2.5.2. Power Input

Pump input power is the power used to rotate the pump shaft which is supplied from the prime mover where in this design an electric motor is used as the initial mover.

$$N_i = \frac{N_O}{\eta} \tag{10}$$

Information:

N_i = input power / shaft (kW)

(Source: Srinivasan 2008)

3. RESULT AND DISCUSSION

The pump used to distribute the fluid is a diaphragm pump. When using a diaphragm pump, the load obtained by the pump becomes lower[9]. The design of this centrifugal type of pump is based on the requirements so that this type of centrifugal is suitable for the pump to be designed. Centrifugal force is caused by water meeting the rotating impeller blades so that the water flows outward to the pump

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following the pump casing[10]. This pump is designed considering the occurrence of cavitation so that cavitation can be prevented [11]. In addition, the number of blades designed is also included in the calculation.

Furthermore, with the data and parameters specified in table 1, the design can be calculated to obtain the design diameter of the pump as follows:

Table 3. Pump Design Results

Parameter	Value	Unit
Head	7,957	meter
Impeller inside diameter	29,48	mm
Impeller outer diameter	`72,586	mm
Diameter Poros	6	mm
bearing diameter	8	mm
Amount of blade	7	
Parameter	Value	Unit
diameter casing	76,215	mm
Motor Power	500	Watt

Based on the design calculation, the impeller inner diameter is 29.48 mm, and the impeller outer diameter is 72.586 mm. The material used in this impeller is Stainless Steel 316. The selection of impeller, shaft and casing materials is based on the temperature of the water used so that the material does not corrode easily so it can affect the age of the technology. The following is the result of a pump design drawing, namely:

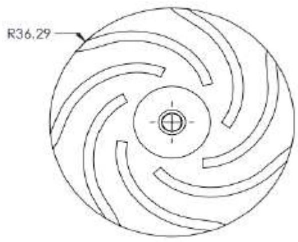

Figure 3. Impeller

Figure 1 above is a drawing of the pump impeller design. The type of impeller used is a semi-closed impeller with 7 blades.

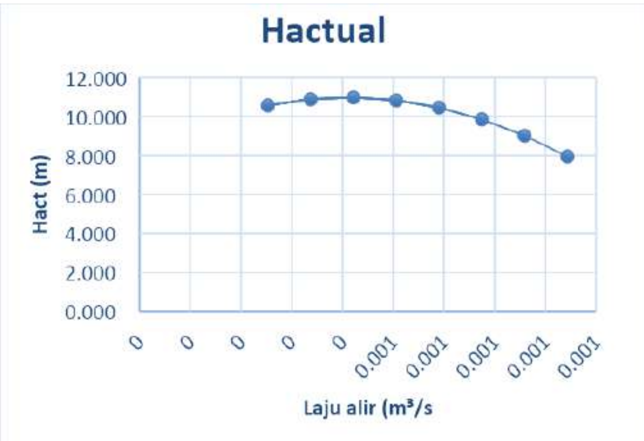

Figure 4. Graph of Flow Rate vs. Head

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Figure 2 above shows the relationship between the volume flow rate inversely proportional to the head, that is, the greater the incoming volume flow rate, the lower the head, according to the hydrolytic power formula theory. Hydrolysis power is needed to lift liquid to a certain height, the formula for hydrolysis power is as follows: N = ρ g H Q where N, ρ, and g are constant so that the equation Q=1/H is obtained. The overall pump design results are shown in Figure 3 below:

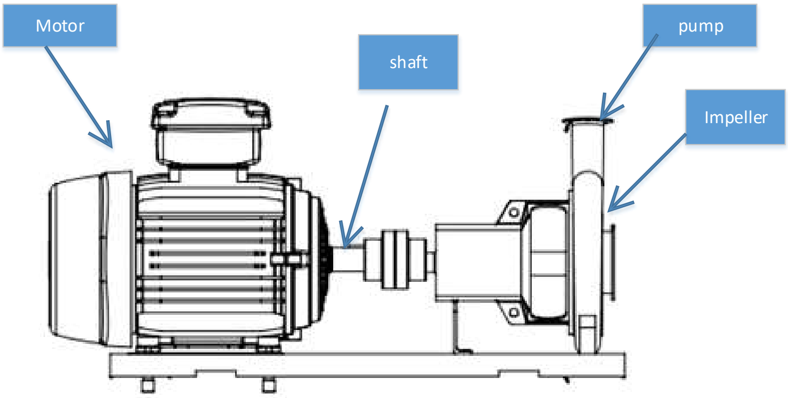

Figure 5. Pump parts

Based on graph 4, namely the volume flow rate to efficiency, it shows that the greater the value of the volume flow rate, the efficiency value continues to increase. The increase in pump capacity is in accordance with the specifications. Furthermore, after passing the pump capacity, the pump efficiency decreases.

4. CONCLUSION

Based on the resulting condensate water data steam trap namely 230 liters/hour, the design capacity of the pump that is suitable for returning the boiler feed water is 50.6 liters/minute, the pump suction pressure is 1.09 atm and the pump discharge pressure is 1.29 atm. The calculated parameters are the natural impeller diameter of 29.48 mm, the outer diameter of the impeller is 72.586 mm, the shaft diameter is 6 mm and the casing diameter is 76.215 mm. The material used in the impeller and casing is stainless steel 316.

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