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Application of hydrant piping system design in boiler plants for fire safety systems in paper making companies

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Abstract

As one of the important components, hydrants must be present in the boiler plant, whose function is to extinguish the fire in the event of a fire incident in the area. The working principle of hydrant system is that when an event of fire occurs, the suction pump will take water from the ground reservoir, later on the water will flow into the pipe leading to the pillar hydrant, and the fire hose will be disconnected from the pillar hydrant to extinguish the burning area. The issue needs to be solved in this research is to design a hydrant piping system in the boiler area of PT Mekabox Internasional that meets the standards used by the industries. The purpose of designing this hydrant piping system is to find out how much flow is in the hydrant if the boiler plant area has an area of 2016 m^2, how thick the pipe should be, and how many pillar hydrants are necessary. The scope of the research discussion includes: hydrant piping systems, hydrant piping calculations, and standards used in hydrant piping systems. The results of the calculation and data processing of this hydrant system design are; the number of pillar hydrants needed in an area of 2016 m^2 is 2 pillar hydrants, the required water discharge is 432 m^3 with the assumption that the blackout time is 2 hours, and the pipe diameter required is 6 inches and must have a pipe thickness of 6 mm. The results of the hydrant piping system design on the boiler plant can be applied directly to the company.

Keywords: Plant boiler unit; Pillar hydrant; Fire safety system

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1. Introduction

Technological advancements drove humans to be more active, creative, and innovative while following the developments of an increasingly modern era. Humans also take part in major roles in the development of manufacturing and industrial technology in the future. With that in mind, creating security systems for buildings should not be underestimated (Mareta & Hidayat, 2020; Rohmah, & Sufianto, 2018).

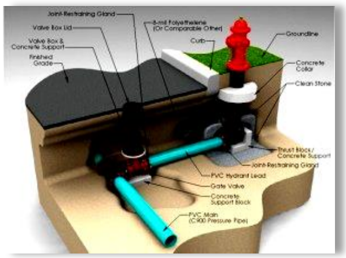
The risk that could be suffered might be very large if the security system is not installed. One such security system is a fire extinguishing system (Haramain et al., 2017). There are various fire extinguishing systems, ranging from using the classic method (water) to using foam. Nevertheless, a backup water is needed to prevent unwanted things from happening. This backup water provider is often called a hydrant (Fajrian et al., 2018; Putri, 2017).

The company where this research is conducted own a boiler generating unit plant which the fire safety system does not include in the plant area. In real conditions the plant is an area that is very prone to explosion or fire incidents. Based on these conditions, research was conducted on the design of the hydrant system in the boiler unit plant area at PT Mekabox Internasional.

Fire hydrant (Figure 1) is one of the fire safety systems which is organized, meaning the components are integrated with each other. Consequently, if one component is failing, it could affect the overall performance of the hydrant.

Gate valves (Figure 2) are the most frequently used valves in piping systems. Its function is to open and close the flow (on-off), but not to adjust the flow size (throttling). The advantage of the gate valve is that the valve resistance is minimal when fully opened, so that the flow can be maximized.

A pressure reducing valve (PRV) is a pressure reducing valve, sometimes also called a pressure regulating valve. One of the purposes of installing PRV in clean water installations is to save water, because the higher the pressure, the faster the flow and the more water is wasted in the same time of use. In addition, using high pressure may damage the installation pipe (Akiyoshi et al., 2017), and damage the installed sanitary equipment and can even endanger the people who use it (Figure 3).



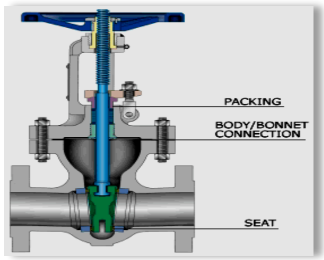


Figure 1. Hydrant networks installation (https://www.bromindo.com)
Figure 2. Gate valve (https://www.enggcyclopedia.com)
Figure 3. Pressure reducing valve (https://www.processindustryforum.com)

Pillar hydrant (Figure 4) is a fire extinguisher connected to a pressurized water source. This device is useful for extinguishing fires without making users worry about lack of water supply. There are two types of pillar hydrants, namely branch one and branch two. Pillar hydrant is used for outdoor use. The difference between branch one and branch two lies on how many sources of water can be flowed during use.

Hydrant box (Figure 5) is a place to store equipment for extinguishing fires, such as fire hoses, nozzles and hydrant valves. This will certainly make it easier for firefighters to find the tools they need. For instance, if there is no hydrant box, these tools will be difficult to find, especially in an emergency and panic situation. In a fire condition, time is very valuable, losing one second can result in very high material losses, and therefore, another function of the existence of a hydrant box is time efficiency.

A centrifugal pump (Figure 6) is a pump that consists of a driving motor with an impeller blade that rotates at high speed. The working principle is to change the mechanical energy of the propulsion device into fluid kinetic energy (velocity) then the

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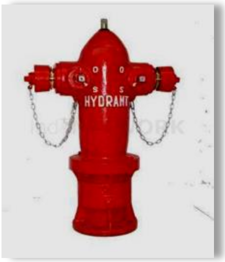
fluid is directed to the exhaust channel using pressure (the kinetic energy of some of the fluid is converted into pressure energy) by using an impeller that rotates in the casing (Munson et al., 2002; Eswanto & Syahputra, 2017). The casing is connected to a suction line and a discharge line, to keep the casing filled with liquid, so the suction line must be equipped with a foot valve.

The jockey pump is a small pump in fire hydrant and fire sprinkler installations that work together with an electric hydrant pump and a diesel hydrant pump as a regulator of water pressure from the reservoir to the pipeline. The function of the jockey pump is to maintain the water pressure in the fire hydrant system installation and the sprinkler system remains stable, so that if there is a slight leak in the pump, valve and other equipment in the installation, the jockey pump will return to the pressure that has been set or determined (Putri, 2017). With the jockey pump in the fire hydrant system to avoid installation components from being damaged quickly, usually which can damage damaged components due to high water pressure, when the main pump flows high pressure water (Lingireddy et al., 2022). To adjust the pressure so that the main pump is not running all the time.



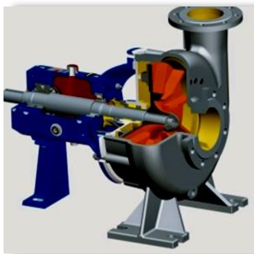



Figure 4. Pillar hydrant (https://vincifire.com)
Figure 5. Hydrant box (https://vincifire.com)
Figure 6. Centrifugal pump (https://www.insinyoer.com)
Figure 7. Jockey pump (https://www.indotrading.com)

The main topic of this research is how to design a hydrant piping system in the boiler area at PT Mekabox International according to the standards used by industry. In this research, the author limits the problems discussed, including: hydrant piping system, calculating hydrant pipes, and standards used in hydrant piping systems.

2. Method, Data, and Analysis

The research carried out in the boiler plant area at the paper-making company PT Mekabox Internasional consists of two stages, namely: (1) Field survey including Interviewing field supervisor Take a look at hydrant pipe installation arrangement plan. (2) Image analysis including checking the location of the hydrant pipe installation on the isometric drawing and measuring the length of the hydrant pipe on the isometric drawing.

The research variables here are factors that play an important role in this study, which are (1) Independent variable the total area of the boiler plant. (2) Control variables: pipe length, pipe material, pipe diameter, and available water debit. (3) Dependent variables: head losses and available water debit.

The design calculations in the hydrant piping system in the boiler plant area are as follows: (1) Calculate the water flow that will be needed by the hydrant system (Q_t); (2) Calculating the flow rate (v); (3) Calculating major losses (H_l); (4) Calculating minor losses

(H_{ml}), includes: losses due to tee connection (h_t), losses due to bend or elbow (h_e), losses due to valve gate (h_g), losses due to valve check (h_c), and losses due to loss at the inlet (h_{in}).

The tools used for this research are: (1) Motorcycle odometer, used to measure the length of hydrant pipelines and (2) Meter gauge used to measure data in the field.

The results of research conducted in the boiler plant area obtained the following data: (1) The area of the boiler plant is 56 m x 36 m; (2) Boiler plant total area is 2016 m^2; (3) The length of the hydrant pipeline network is 114 m

The place for research and data collection was carried out in the boiler plant area of the PT Mekabox International Paper Factory, Ngoro, Mojokerto. Implementation of research and data collection began in early January 2016.

3. Results

Number of Pillar Hydrant

Based on the provisions of the main structure of the building against fire, the building must be fire resistant for at least 2 hours. The number of fire hydrants used is 1 per 1000 m2 area. It is known that the area of the boiler plant unit is 56 m x 36 m, so the number of pillar hydrants can be calculated by the following formula:

$$\Sigma\, Hydrant = \frac{Luasan}{1000\, m^2} = \frac{56\, m\, x\, 36\, m}{1000\, m^2} = 2.16 \qquad \text{(Eq. 1)}$$

Ground Reservoir Fire Hydrant Capacity

Pillar hydrant specifications: (1) Water debit: 1000 liter/menit; Maximum water pressure: 4.5 kg/cm^2; (3) Hose diameter: 2.5 inch; Hose length: 30 m; Minimum diameter: 4 inch; Ground clearance: 50 cm. One pillar hydrant has 2 fire hose reels, while two fire hose reels require a water discharge of 800 liter/minute.The maximum standard of handling when a fire occurs is 2 hours, assuming after 2 hours the firefighters have arrived at the location.Then the water requirement calculated by the followings: (1) Water flow rate = 4 fire hose reel + 2 pillar hydrant = 1,600 liter/minute + 2,000 liter/minute = 3,600 liter/minute; (2) Water demand for 2 hours = kebutuhan air x 120 menit= 3600 liter/menit x 120 menit = 432,000 liter = 432 m^3. Thus, the capacity of the Ground Reservoir Fire Hydrant required in that area is 432 m^3.

Flow debit on hydrant

Known that the formula for debit (Q):

$$Q = \frac{V}{t} = \frac{432000\, liter}{120\, menit} = 3600\, \frac{liter}{menit} = 0{,}06\, \frac{m^3}{s} \qquad \text{(Eq. 2)}$$

Pipe diameter

The formula for calculating pipe diameter is:

$$D^2 = \frac{4.Q}{\pi.v} \qquad \text{(Eq. 3)}$$

$$D = \sqrt{\frac{4\, x\, 0{,}06}{3{,}14\, x\, 3}} = 0{,}159\, m$$

Recalculated for the assumed (v) check:

$$v = \frac{4.Q}{\pi.D^2} = \frac{4\, x\, 0{,}06}{3{,}14\, x\, (0{,}159)^2} = 3{,}02\, \frac{m}{s}$$

Which: D = diameter (m); Q = Flow debit (m^3/s); v = flow speed (minimum speed) = 3 m/s, based on NFPA 13)

Calculation of total pump head

In determining the pump head, we assume that the pump must be able to supply water to the furthest point with adequate pressure. To get the total head, use the Bernoulli equation from the water surface (Munson et al., 2002).

$$H_{pompa} = \frac{P_2 - P_1}{\rho g} + \frac{v_2^2}{2g} + (Z_2 - Z_1) + (hl_2 - hl_1) \quad \text{(Eq. 4)}$$

The pump head required by the hydrant:
Δh_p= head pressure
P_2 = 4,43x10^5 N/m^2 (general pressure on hydrant)
P_1 = 10^5 N/m^2 (atmosphere pressure = 1 atm)
ρ = 998.2 Kg/m^3 (at temperature 20^{0}c)

$$\Delta h_p = \frac{P_2 - P_1}{\rho g} = \frac{4{,}43 - 1}{998{,}2\ x\ 9{,}81} = 35{,}03$$

v = 3 m/s (NFPA)
h_a = *head statis* (m) = $Z_2 - Z_1$ = 8.5-7.5 = 1 m
h_l = *head losses* (m) = $H_{t1} + H_{t2}$ = 1.74 + 13.32 = 15.06 m

$$H_{pompa} = h_a + \Delta h_p + h_l + \frac{v_2^2}{2g}$$

$$H_{pompa} = 1 + 35{,}03 + 15{,}06 + 0{,}46 = 52{,}9\ m$$

Pressure Calculations

The basic concept of pressure

In this pressure calculation, an example of calculating the pressure that occurs in each hydrant box will be given, so that it can be seen how much pressure occurs and whether it is still possible to use a fire extinguisher or must use a PRV (Pressure Reducing Valve).

The formula used is the Bernoulli equation formula:

$$P_2 = \frac{P_1}{\rho g} - \frac{v_2^2}{2g} + (Z_1 - Z_2) + H_{pompa} - (hl_2 + hl_1)(\rho g) \quad \text{(Eq. 5)}$$

Pressure at the furthest hydrant:

H_{pompa}	= 55 m		
v_1	= 0 (could be ignored)		
ρ	= 998.2 kg/m^3	; v_2	= 3 m/s
P_1	= 10^5 N/m^2	; Z_1	= 7.5 m
g	= 9.81 m/s^2	; Z_2	= 8.5 m
$H_{losses1}$	= 13.32 m	; $H_{losses2}$	= 1.74 m

Bernoulli equation

$$P_2 = 10{,}21 - 0{,}45 - 1 + 55 - 11{,}58\ x\ (9792{,}34) = 5{,}10964 \text{ x } 105 \text{ N/m}^2$$

Calculation of hydrant pump power

The capacity of the pump to be used is: 1250 Gpm. According to (NFPA 20, 1999). The pump power used is:

$$P = \frac{\rho x g x H x Q}{\eta \rho} \quad \text{(Eq. 6)}$$

Thus the pump power:

$$P = \frac{\rho\ x\ g\ x\ H\ x\ Q}{\eta \rho} = \frac{998{,}2\ x\ 9{,}81\ x\ 55\ x\ 0{,}06}{0{,}84} = 38469{,}92 \frac{\text{Nm}}{\text{s}} = 38{,}469\ \text{kW}$$

Pump power calculation for jockey pump

$$P = \frac{\rho\ x\ g\ x\ H\ x\ Q}{\eta \rho} = \frac{998{,}2\ x\ 9{,}81\ x\ 55\ x\ 0{,}016}{0{,}79} = 10907{,}93 \frac{\text{Nm}}{\text{s}} = 10{,}907\ \text{kW}$$

The final result of all provisions and calculations from existing pump data, it can be determined which type of pump should be used. The pump head used is 55 m and the pump capacity used is 1250 Gpm, by using the pump type selection diagram below we can determine that the pump used is a centrifugal pump by using the pump type selection chart.

From the graph (figure , it can be seen that if the pump head is 55 m and the pump rotation speed is 2950 rpm, the amount of power that must be possessed by a centrifugal pump is ± 40 kw.

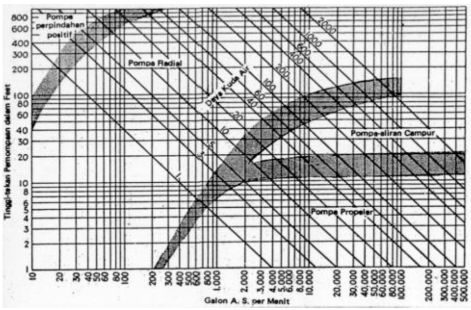


Figure 8. Pump selection diagram (Munson et al., 2002)

4. Discussion

In determining the capacity or need for water to be distributed to the hydrant system in the boiler unit area of PT Mekabox Internasional, it is necessary to know the area where the hydrant pipe line will be installed because this will affect how much water flow must be needed. From the data it is known that the area of the boiler unit at PT Mekabox International is 2016 m2 so that through the above calculations, the area requires 2 pillar hydrants. Assuming maximum handling for 2 hours, the overall flow rate of the hydrant is 0.06 m3/s. So that the ground fire hydrant reservoir capacity that must be owned in the area is 432 m3.

To determine how large the diameter and thickness of the pipe to be used in the hydrant piping system, it is necessary to first know how much flow rate, flow velocity, pressure in the pipe, tensile stress of pipe material, and the safety of the pipe itself (Margariyan, 2021; Pamungkas & Sufiyanto, 2014). Based on the calculation results, the diameter of the pipe to be used is 6” and the thickness of the pipe used is 6 mm.

5. Conclusion

In the design of the hydrant piping system, it will not be separated from the calculation of losses that occur due to connections to pipes, valves, entries, contraction of pipe cross sections, elbows, and branching of pipes. The thing that needs to be considered for the installation of these items is so that head losses can be minimized. From the calculation of the total losses obtained in the system design is 15.06 m, in order to obtain a pump head of 55 m. And seen from the graph if the pump head is 55 m and the pump rotation is 2950 rpm, the pump power is 40 kW.

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