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Feasibility Analysis of the Electric Fire Pump for PT X Eye Clinic

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ABSTRACT

In a pumping system, one important parameter that needs to be analyzed is the hydraulic power needed to move the fluid. This hydraulic power reflects how much energy is needed to move the fluid through the piping system, and this is highly dependent on factors such as flow rate, head, and the characteristics of the pump itself. The purpose of this Pkn is to determine the hydraulic power of the pump. In pumping, it is necessary to pay attention to several factors so that the pump can work optimally, such as the height of the water to be sucked and the height of the building to be distributed and the design of the pipes as water channels. The method used to determine the hydraulic power of the pump is through data collection. From the results of data processing, we can find out the different flow rate values based on the discharge and pipe diameter, flow losses obtained at pipe joints such as major losses and minor losses, the power required to drive the pump is 55 KW and the hydraulic power is 45.53840 KW, and the pump efficiency is 82.79%.

Keywords: Hydraulic power, flow losses, efficiency

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1. Introduction

The construction of PT. X's 4-story Eye Clinic building is currently in the final completion stage. One of the prioritized projects is the installation of the building's fire protection system, which includes fire pump units and sprinklers on every floor. The contractor has already purchased an electric fire pump unit; however, the owner requires a calculation base to ensure that the pump meets the necessary requirements for use. Therefore, the owner has requested a calculation and feasibility analysis of the pump to ensure it is suitable for the specific conditions of the PT. X Eye Clinic building.

An electric pump is a type of mechanical device used to move fluids—both liquids and gases—using electrical power. In this type of pump, the power provided by an electric motor is used to move the fluid through pipes and piping systems. One specific type used is the electric centrifugal pump. This pump operates based on the principle of centrifugal force generated by a rotating impeller, which applies pressure to the fluid so it can flow more smoothly.

In a pumping system, a critical parameter that needs to be analyzed is the hydraulic power required to move the fluid. This hydraulic power reflects how much energy is needed to drive the fluid through the piping system and is highly dependent on factors such as flow rate, head, and the pump's own characteristics. In this scientific article, the pump feasibility analysis includes calculating the required hydraulic power while accounting for flow losses (head loss) incurred by the electric centrifugal pump, as well as determining the pump's efficiency value.

2. Methodology of Research

2.1 Field Method

This research employs a field data collection method to obtain actual conditions that influence hydraulic power. These data are used to calculate the major and minor losses occurring in the system, ultimately determining the total actual head. Furthermore, a comparison is made between the actual power requirements and the installed pump power. This process allows for an efficiency comparison and a feasibility analysis to determine whether the pump can remain in use or needs to be replaced.

2.2 Main Research Instrument

The following are the tools and materials used in the design:

2.2.1 GWT (Ground Water Tank)

A Ground Water Tank (GWT) is a water storage tank positioned either below ground level or at the surface. The GWT plays a vital role in water distribution and pumping systems

Figure 2.1 Ground Water Tank(GWT)

2.2.2 Pump and Building/Hydrant

Piping Installation Pump piping serves as a medium for fluid transportation from the water source (Ground Water Tank/GWT) to the pump. Building or hydrant piping is a primary component in a fire protection system, functioning to distribute water from the source to discharge points such as fire hydrants, sprinklers, and fire pumps

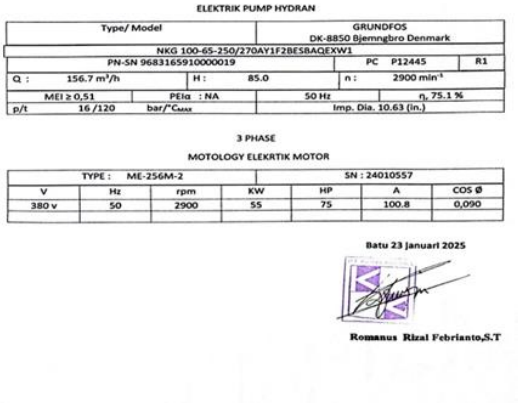
a b

Figure 2.2.a. Pump piping installation, b. Building/hydrant

2.2.3 Electric Pump An Electric

Pump is the primary pump that utilizes an electric motor as its power source to move water through the piping system.

Figure 2.3 Electric Pump



ELEKTRIK PUMP HYDRAN

Type/ Model		GRUNDFOS DK-8850 Bjemngbro Denmark	
NKG 100-65-250/270AY1F2BESBAQEXW1			
PN-SN 9683165910000019		PC P12445	R1
Q : 156.7 m^3/h	H : 85.0	n : 2900 min^{-1}	
MEI ≥ 0,51	PEIa : NA	50 Hz	η, 75.1 %
p/t 16 /120 bar/°C_{MAX}		Imp. Dia. 10.63 (in.)	

3 PHASE

MOTOLOGY ELEKRTIK MOTOR

TYPE : ME-256M-2			SN : 24010557			
V	Hz	rpm	KW	HP	A	COS Ø
380 v	50	2900	55	75	100.8	0,090

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Figure 2.4 Electric pump specifications

2.2.4 Pillar Hydrant

The function of a pillar hydrant is to provide high-pressure water necessary for discharging water onto fire hotspots during the firefighting process

Figure 2.5 Pillar hydrant

3. Result and Discussion

3.1. Water piping layout schema

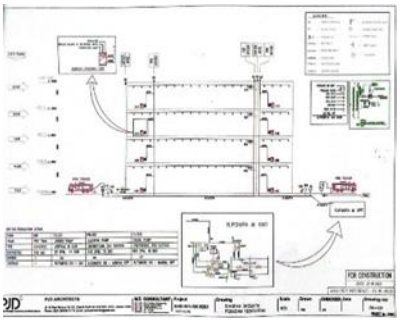


Figure 3.1 Water piping schematic diagram

3.2. Pump room piping installation

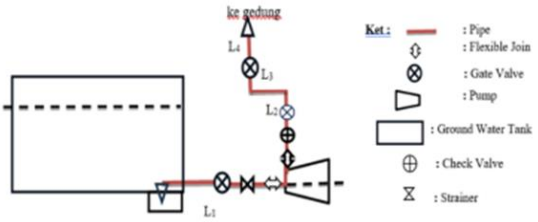
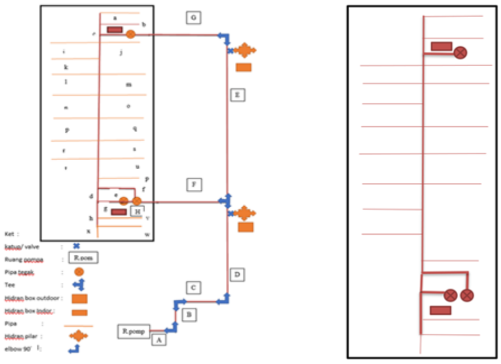


Figure 3.2 Pump room piping installation design

3.3 Plumbing installation for floors 1, 2, 3, and 4.



a. 1st floor b. 2nd, 3rd, and 4th floors

Figure 3.3 Piping installation design on each floor

3.4 Calculations

3.4.1 Water Flow Velocity

$$v = Q/A$$

Q : Water Flow Rate
A : Cross-sectional Area

a. Pipe diameter: 150 mm

$$A = \frac{\pi}{4} d^2 = \frac{3.14}{4} 0{,}15^2\ m^2 = 0{,}0176 \text{ m2}$$

$$v = \frac{0{,}04353\ m^3/dt}{0{,}0176 m^2} = 2{,}5\ m/dt$$

b. 150 mm diameter branch pipe 2

$$A = \frac{\pi}{4} d^2 = \frac{3{,}14}{4} 0{,}15^2\ m^2 = 0{,}0176 \text{ m2}$$

$$v = \frac{0{,}02176 m^3/dt}{0{,}0176 m^2} = 1{,}2\ m/dt$$

Following the same calculation procedure, the results for the remaining sections are summarized in Table 1:

Table 1. Results of water flow rate and velocity calculations

Dia. Pipa (mm)	Debit (m3)	v (m/det)	Keterangan
100	0,04353	5,5	pipa 1 (p1)
100	0,02177	2,75	p2 = p1 bercabang 2
100	0,01088	1,38	p3 = p2 bercabang 2
40	0,01088	8,71	karena tersambung dengan p3
40	0,0006046	0,48	lantai 1, bercabang 18
40	0,0005728	0,46	lantai 2, bercabang 19
40	0,0005441	0,44	lantai 3, bercabang 20
40	0,0004534	0,36	lantai 4, bercabang 24
25	0,0006046	1,23	tersambung dengan tiap dia 40 mm (lantai 1)
25	0,0005728	1,17	tersambung dengan tiap dia 40 mm (lantai 2)
25	0,0005441	1,11	tersambung dengan tiap dia 40 mm (lantai 3)
25	0,0004534	0,93	tersambung dengan tiap dia 40 mm (lantai 4)

3.4.2 Pump Outlet Flow Type

The water temperature used is the standard temperature, which is: 20°C

Table 2. Water Viscosity

Temperatur (derajat Celcius)	Viskositas Kinematik ν (10^{-6} x m²/s)	Temperatur (derajat Celcius)	Viskositas Kinematik ν (10^{-6} x m²/s)
0	1.793	25	0.893
1	1.732	26	0.873
2	1.674	27	0.854
3	1.619	28	0.836
4	1.568	29	0.818
5	1.520	**30**	**0.802**
6	1.474	31	0.785
7	1.429	32	0.769
8	1.386	33	0.753
9	1.346	34	0.738
10	**1.307**	35	0.724
11	1.270	36	0.711
12	1.235	37	0.697
13	1.201	38	0.684
14	1.169	39	0.671
15	1.138	**40**	**0.658**
16	1.108	45	0.602
17	1.080	50	0.554
18	1.053	55	0.511
19	1.027	60	0.476
20	**1.002**	65	0.443
21	0.978	70	0.413
22	0.955	75	0.386
23	0.933	80	0.363
24	0.911	85	0.342

v : Water Flow Velocity
d : Pipe Diameter
υ : Water Viscosity (Kinematic Viscosity)

$$Re = \frac{vd}{\upsilon}$$

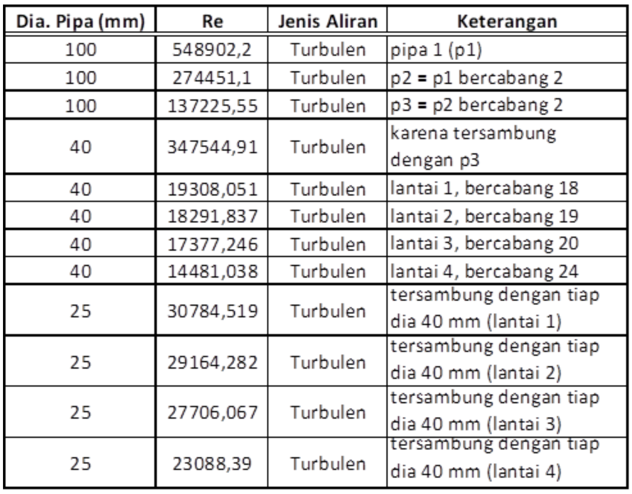
Main pipe (150 mm diameter)

$$\text{Re} = \frac{2{,}5 \frac{\text{m}}{\text{dt}} \,.\, 0{,}15 \text{ m}}{1{,}002.10^{-6}\text{m}^2/\text{dt}} = 374251{,}4 > 4000$$

(Turbulent Flow)

Using the same calculation method for the others, the results are obtained as shown in Table 3 below:

Table 3. Results of Reynolds Number (Re) and Flow Regime Calculations



Dia. Pipa (mm)	Re	Jenis Aliran	Keterangan
100	548902,2	Turbulen	pipa 1 (p1)
100	274451,1	Turbulen	p2 = p1 bercabang 2
100	137225,55	Turbulen	p3 = p2 bercabang 2
40	347544,91	Turbulen	karena tersambung dengan p3
40	19308,051	Turbulen	lantai 1, bercabang 18
40	18291,837	Turbulen	lantai 2, bercabang 19
40	17377,246	Turbulen	lantai 3, bercabang 20
40	14481,038	Turbulen	lantai 4, bercabang 24
25	30784,519	Turbulen	tersambung dengan tiap dia 40 mm (lantai 1)
25	29164,282	Turbulen	tersambung dengan tiap dia 40 mm (lantai 2)
25	27706,067	Turbulen	tersambung dengan tiap dia 40 mm (lantai 3)
25	23088,39	Turbulen	tersambung dengan tiap dia 40 mm (lantai 4)

Therefore, the friction factor (f) is obtained from the Moody diagram

1. Relative Pipe Roughness = $\frac{\varepsilon}{d} = \frac{0{,}0005}{0{,}15m} = 0{,}003$

   Friction factor (f) = 0,028

2. Relative Pipe Roughness = $\frac{\varepsilon}{d} = \frac{0{,}0005}{0{,}1m} = 0{,}005$

   Friction factor (f) = 0,032

3. Relative Pipe Roughness = $\frac{\varepsilon}{d} = \frac{0{,}0005}{0{,}04m} = 0{,}0125$

   Friction factor (f)
   - Ground Floor = 0,037
   - 2nd Floor = 0,037
   - 3rd Floor = 0,038
   - 4th Floor = 0,039

4. Relative Pipe Roughness = $\frac{\varepsilon}{d} = \frac{0{,}0005}{0{,}025m} = 0{,}02$

   Friction factor (f)
   - Ground Floor = 0,048
   - 2nd Floor = 0,048
   - 3rd Floor = 0,049
   - 4th Floor = 0,049

3.4.3 Major Losses (Straight Pipes)

- l: Pipe Length
- d : Pipe Diameter
- v^2 : Water Flow Velocity
- g : Acceleration due to Gravity

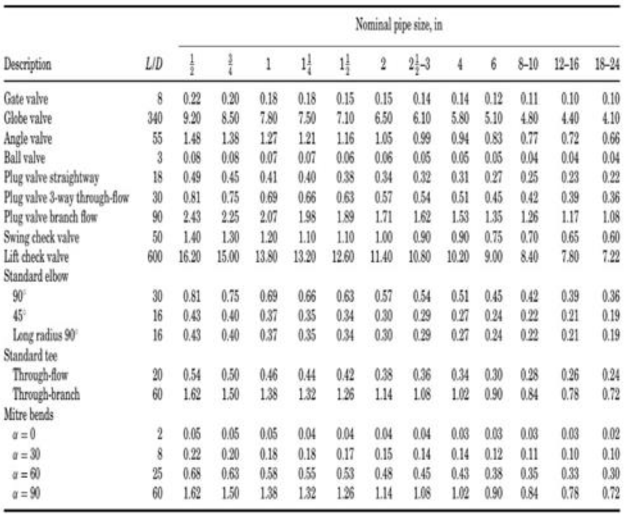
$$h_{mayor} = f\,\frac{l2}{d}\,\frac{v^2}{2g}$$

$$h_{mayor} = 0{,}032\,\frac{1{,}65m}{0{,}15\ m}.\frac{4{,}016^2m^2/dt^2}{2.9{,}81m/dt^2}$$

$$h_{mayor} = 0{,}28\ \mathrm{m}$$

3.4.4 Minor Losses (Bends, Fittings, Valves, and Strainers)

Table 4. Types of Fittings and Connections



		Nominal pipe size, in											
Description	L/D	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$–3	4	6	8–10	12–16	18–24
Gate valve	8	0.22	0.20	0.18	0.18	0.15	0.15	0.14	0.14	0.12	0.11	0.10	0.10
Globe valve	340	9.20	8.50	7.80	7.50	7.10	6.50	6.10	5.80	5.10	4.80	4.40	4.10
Angle valve	55	1.48	1.38	1.27	1.21	1.16	1.05	0.99	0.94	0.83	0.77	0.72	0.66
Ball valve	3	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04
Plug valve straightway	18	0.49	0.45	0.41	0.40	0.38	0.34	0.32	0.31	0.27	0.25	0.23	0.22
Plug valve 3-way through-flow	30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
Plug valve branch flow	90	2.43	2.25	2.07	1.98	1.89	1.71	1.62	1.53	1.35	1.26	1.17	1.08
Swing check valve	50	1.40	1.30	1.20	1.10	1.10	1.00	0.90	0.90	0.75	0.70	0.65	0.60
Lift check valve	600	16.20	15.00	13.80	13.20	12.60	11.40	10.80	10.20	9.00	8.40	7.80	7.22
Standard elbow													
90°	30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
45°	16	0.43	0.40	0.37	0.35	0.34	0.30	0.29	0.27	0.24	0.22	0.21	0.19
Long radius 90°	16	0.43	0.40	0.37	0.35	0.34	0.30	0.29	0.27	0.24	0.22	0.21	0.19
Standard tee													
Through-flow	20	0.54	0.50	0.46	0.44	0.42	0.38	0.36	0.34	0.30	0.28	0.26	0.24
Through-branch	60	1.62	1.50	1.38	1.32	1.26	1.14	1.08	1.02	0.90	0.84	0.78	0.72
Mitre bends													
$\alpha = 0$	2	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02
$\alpha = 30$	8	0.22	0.20	0.18	0.18	0.17	0.15	0.14	0.14	0.12	0.11	0.10	0.10
$\alpha = 60$	25	0.68	0.63	0.58	0.55	0.53	0.48	0.45	0.43	0.38	0.35	0.33	0.30
$\alpha = 90$	60	1.62	1.50	1.38	1.32	1.26	1.14	1.08	1.02	0.90	0.84	0.78	0.72

Therefore, the K-value is taken from the table above based on the pipe diameter

k : Friction factor

v^2 : Water Flow Velocity

g : Acceleration due to Gravity

$$\Delta h = k\frac{v^{\ 2}}{2g}$$

$$\Delta h = 0{,}51\,\frac{1{,}791^2m^2/dt^2}{2.9{,}81m/dt^2} = 0{,}083\ m$$

The calculations using the major and minor loss equations mentioned above are tabulated as follows:

Table 5. Calculation of Major Head Loss from Pump Room to Building

Pipe	Diameter	Length	Friction factor (f)	Hl mayor
Pump Room Piping				
L_1	150 mm	1,5 m	0,028	0,089
L_2	100 mm	1,65 m	0,032	0,43
L_3	150 mm	3 m	0,028	0,17
L4	150 mm	2,45 m	0,028	0,14
Building Service Pipe				
A	150 mm	1 m	0,028	0,059
B	150 mm	2 m	0,028	0,11
C	150 mm	4 m	0,028	0,23
D	150 mm	35 m	0,028	2,08
E	150 mm	35 m	0,028	2,08
F	150 mm	6 m	0,028	0,082
G	150 mm	6 m	0,028	0,082
$H_{pipa\ tegak}$	100 mm	17,6 m	0,032	2
$H_{pipa\ tegak}$	100 mm	2 x 17,6 m	0,032	0,97
Hi total mayor = 8,52 m				

Table 6. Calculation of Minor Head Loss from Pump Room to Building

fitting	Diameter	Quantity	Friction factor (f)	Hl minor
Gate Valve	100 mm	1	0,14	0,052
Flexible Joint	100 mm	1	0,14	0,052
Check Valve	100 mm	1	0,90	0,33
Strainer	100 mm	1	0,14	0,052
Elbow 90°	100 mm	1	0,51	0,18
Gate Valve	150 mm	3	0,36	0,11
Elbow 90°	150 mm	4	1,8	0,57
tee	150 mm	2	0,6	0,19
Hl (minor) Total: Pump Room to Building = 1,53 m				

Table 7. Major Head Loss Calculation for Ground Floor

Pipa	Diameter	Panjang	Friction factor (f)	Hl mayor
Ground Floor				
a	25 mm	7 m	0,048	1,036
b	25 mm	7 m	0,048	1,036
c	40 mm	3 m	0,037	0,032
d	40 mm	42 m	0,037	0,45
e	40 mm	4 m	0,037	0,043
f	40 mm	1 m	0,037	0,010
g	40 mm	2 m	0,037	0,011
h	40 mm	3 m	0,037	0,021
i	25 mm	7 m	0,048	1,036
j	25 mm	7 m	0,048	1,036
k	25 mm	7 m	0,048	1,036
l	25 mm	7 m	0,048	1,036
m	25 mm	7 m	0,048	1,036
n	25 mm	7 m	0,048	1,036
o	25 mm	7 m	0,048	1,036
P	25 mm	7 m	0,048	1,036
q	25 mm	7 m	0,048	1,036
r	25 mm	7 m	0,048	1,036
s	25 mm	7 m	0,048	1,036
t	25 mm	7 m	0,048	1,036
u	25 mm	7 m	0,048	1,036
v	25 mm	7 m	0,048	1,036
w	25 mm	7 m	0,048	1,036
x	25 mm	7 m	0,048	1,036
Hl mayor Ground Floor = 19,21 m				

Table 8. Major Head Loss Calculation for Floors 2, 3, and 4

Floor	Diameter	Quantity	Length	Friction factor(f)	Hl mayor
2nd Floor	40 mm	6	55 m	0,037	0,47
	25 mm	19	133	0,048	17,51
3rd Floor	40 mm	6	55 m	0,038	0,49
	25 mm	20	140	0,049	17,72
4th Floor	40 mm	6	55 m	0,039	0,35
	25 mm	24	168	0,049	14,20
Hl (major) Total: 2nd–4th Floors= 50,74 m					

Table 9. Minor Head Loss Calculation per Floor

Floor	fittingan	Diameter	Quantity	Friction factor (f)	Hl minor
Ground Floor	Elbow 90°	40 mm	1	0,63	0,0073
	Tee	40 mm	3	1,26	0,014
	Elbow 90°	25 mm	36	24,84	1,9
	Tee	25 mm	36	16,56	1,2
2nd Floor	Elbow 90°	40 mm	1	0,63	0,0065
	Tee	40 mm	3	1,26	0,013
	Elbow 90°	25 mm	37	25,53	1,7
	Tee	25 mm	38	17,48	1,1
3rd Floor	Elbow 90°	40 mm	1	0,63	0,0059
	Tee	40 mm	3	1,26	0,011
	Elbow 90°	25 mm	40	27,6	1
	Tee	25 mm	40	18,4	1,1
4th Floor	Elbow 90°	40 mm	1	0,63	0,0041
	Tee	40 mm	3	1,26	0,0083
	Elbow 90°	25 mm	48	33,12	1,4
	Tee	25 mm	48	22,08	0,95
Total Hl (minor): Floors 1–4 = 10,42 m					

Summary of Energy Losses

There are two types of energy losses in the system: major losses and minor losses. The calculated values are as follows:

- Major Losses: The total loss obtained from straight pipes is 78.47 m.
- Minor Losses: The total loss obtained from fittings (bends, valves, etc.) is 10.42 m

E. Hydraulic Power and Efficiency

ρ : Water Density

g : Acceleration due to Gravity

Q : Flow Rate

H_t: Total Dynamic Head

H_s : Static Suction Head

H_p : Discharge Head

$$WHP = \rho . g . Q . \mathrm{Ht}$$

$$H_t = h_s + h_p + \Sigma h_{mayor} + \Sigma h_{minor}$$

$$H_t = (-1{,}5m) + 19{,}25 + 78{,}47 \text{ m} + 10{,}42 \text{ m}$$

$$H_t = 106{,}64\ m$$

$$WHP = \rho . g . Q . H_t$$

$$WHP = 1000\ kg/m^3 . 9{,}81 \frac{m^2}{dt} . 0{,}04353\ m^3/dt . 106{,}64\ m$$

$$WHP = 45538{,}40 \frac{J}{dt} = 45{,}5384\ kW$$

$$\eta = \frac{daya\ hidrolis}{daya\ pompa} x100$$

$$\eta = \frac{45{,}5384}{55} x100$$

$$\eta = 82{,}79\ \%$$

Dari hasil perhitungan di atas dapat diketahui

- Pump Head= 85 m
- Total Head = 106,64 m
- Pump Power = 55 Kw
- Hydraulic Power = 45,53840 KW

System Performance Analysis

Based on the calculated data, the following observations can be made:

- Pump Head : 85 m (The pressure-generating capacity of the pump).
- Total Head : 106.64 m (The total head required by the system).
- (Head pompa / Head total) × 100% = (85m/106,64 m) × 100% = 79,70%

This indicates that the pump head only reaches 79.70% of the required total head. In ideal conditions, the pump head should be equal to or greater than the total head to ensure optimal system performance.

The difference between the pump head (85 m) and the total head (106.64 m) shows a gap of 21.64 m. This shortfall implies that the pump may not generate sufficient pressure for the fire extinguishing system during an emergency.Recommended Solutions: Adding a booster pump or modifying the system to reduce total head (e.g., by minimizing friction losses) is necessary.

An efficiency of 82.79% indicates that the pump is operating very effectively. This means that 82.79% of the electrical energy input is successfully converted into useful hydraulic energy, while approximately 17.21% is lost during the conversion process (due to heat, vibration, or mechanical friction)

4. Conclusions

1. Head Ratio: The actual pump head ratio is only 79.70% of the required total head.
2. Power Analysis: The calculated hydraulic power is 45.54 kW, while the actual pump power is 55 kW.
3. Pump Efficiency: The pump efficiency reaches 82.79%, which falls into the category of excellent pump performance.
4. System Requirements: To achieve the required total head, it is necessary to either add a booster pump or modify the current pump configuration

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