Water Pipe System Pump

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A20EM4015

Table of Contents:

Introduction: **2**
Team Members: 2
Selection of plant process: **3**
Installation: 3
Delivery and Suction Pipes: 3
Pump Size: 4
OPPM/Gantt Chart: **4**
Proposed Schematic diagram: **5**
Design Calculations: **6**
Selection Process: 6
Theoretical performance analysis and comparison**:** 7
Motor Selection: **8**
Specification : 8
References: **9**
Appendix: **10**

Introduction:

MKE is a custom turbomachinery manufacturing company specialized in centrifugal pump installation and design. Our team of experts conduct a thorough in-depth analysis of the proposed project, focusing majorly on precisely calculated specifications to implement the best suited turbomachinery and innovative design practices for a cost efficient customer experience and quality consumer product.

Team Members:

Muhammad Arslan

Ahmed Mohammed

Mazen Omar

Farhan Wilson

Selection of plant process:

Chosen installation location is the client's residence, comprising a two story house. The client has installed a new water tank at the roof, however, due to the lack of an existing piping system,, the client requires a centrifugal pump to provide water from the ground to the tank for daily necessities, the roof is at an approximate height of 10 meters from the ground.

To choose the best possible centrifugal pump, a few steps must be followed. These steps pertain to the installation of the pump, the delivery and suction pipes used, the pump type chosen according to the working fluid and the pump size that must conform to flow rate, pressure, speed and suction conditions.

Installation:

The centrifugal pump must be installed in close vicinity to the local ground water supply line, ensuring the least amount of bend pipe fittings to reduce the overall delivery pressure drop. It is essential to provide enough working space around the pump fitting to allow for easy maintenance and repair.

Delivery and Suction Pipes:

Piping systems utilized in the pump design have special characteristics that can affect their pump performance. The valves and fittings contribute to the pressure loss in a piping system which can be calculated using the friction factor of the fittings. This analysis is carried out carefully using the proposed schematic diagram.

Pump Type:

The pump type chosen must correspond to the fluid used. As the client requested the pump to be installed for water supply, the working fluid used is water hence all standard properties such as viscosity, temperature and density can be used in calculations.

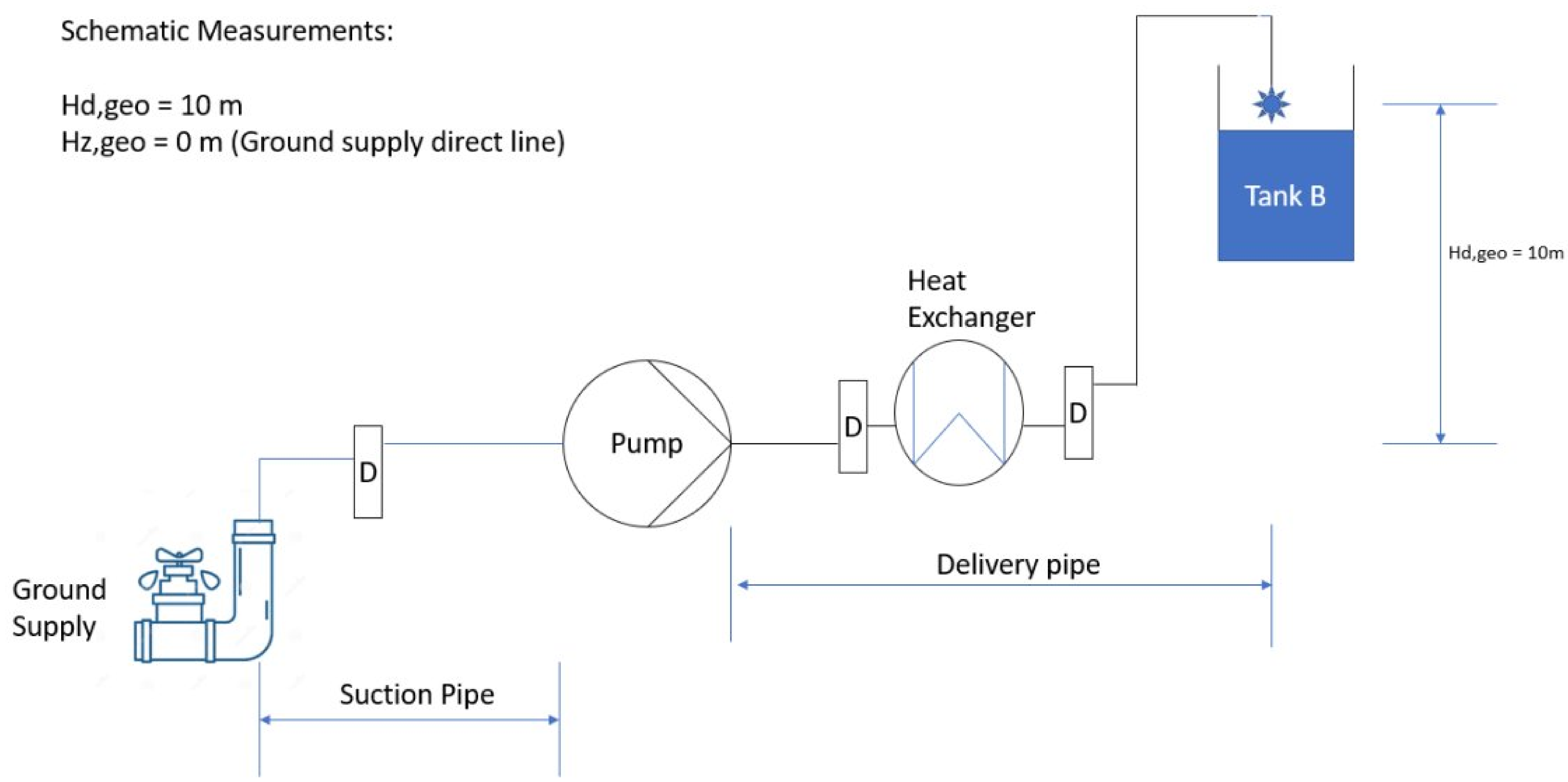
Pump Size:

The pump size must correspond to the design calculations, this is to ensure that the machine can withstand the operating conditions such as the flow rate of the water, the pressure and speed in the suction and delivery pipes.

OPPM/Gantt Chart:

The proposed project requires apt scheduling and management, all tasks have been delegated and completed as indicated in the OPPM chart attached in the appendix.

Proposed Schematic diagram:



Design Calculations:

Selection Process:

Following all previous guidelines, and utilizing the proposed schematic diagram, the head pressure loss for the pump can be calculated. This allows us to determine the required pump head the centrifugal pump must contribute. Furthermore, the NPSH (Net Positive Suction Head) can be calculated to determine the pressure required for the suction pipe to function. Additionally, the pump flow rate must be chosen by the client. For this particular case study the flowrate was chosen to be **(8 m^3/hr)**.Once all the required values have been calculated, by utilizing the Q-H characteristic chart as attached in the Appendix, the required motor power and the impeller diameter can be obtained.

As shown below, with all considerations the chosen pump type is noted to be TP1020, 2 poles 50 Hz model.

$Q = 8\ m^3/hr$ Ref: Date:

$H_A = H_{geo} + \Sigma H_v$ $H_{geo} = H_{d\,geo} - H_{z\,geo}$

$= 10 - 0 = 10m$

$H_{v,s}$

1 d valve DN 50 = 18.41 m

3 90° bends DN 50 = 3 × 0.6 = 1.8m

1m pipe DN 50 = **1** m

$\Sigma = 21.21$

$H_{v,d}$

2 d valve DN 50 = 36.81 m

7 90° bends DN50 = 7 × 0.6 = 4.2m

10m pipe DN 50 = 10m

$\Sigma = 51.01$

Pressure drop H_v at 8m³/hr DN 50 $= 21.21 \times \frac{3}{100} = 0.6363$

$51.01 \times \frac{3}{100} = 1.5303$

Heat exchanger = 4m at 8 m³/hr

$H_A = 10 + 0.6363 + 1.5303 + 4 = 16.1666$

$\approx 16.17m$

TP 1020 2 poles 50Hz

Assuming water T = 20°C
and 2 open tanks

$NPSH_{avi} = 10 - H_{v,s} + H_{z\,geo}$

$= 10 - 0.6363 + 10$

$= 19.3637 \approx 19.36m$

Ref: Date:

[illegible] $\eta = 44\%$ approx

$NPSH_{req}$ @ Ø80 = 1.7m

$NPSH_{req}$ @ Ø130 = 1.3m

Power @ 80Ø = 0.52 kW

@ 130Ø = 1.01 kW

Theoretical performance analysis and comparison:

To compare the theoretical performance with the calculated values, it is necessary to assume the blade angle , as it is required to calculate the theoretical pressure head using the equation:

$$Ht = \omega T/\gamma Q$$

This equation can further be simplified to:

$$Ht = u2V2Cos(\alpha 2) - u1V1Cos(\alpha 1)/\, g$$

Assuming the best pump design for this case, the angular momentum entering impeller is zero, hence it can be assumed that angle α1= 90’, hence the equation further simplifies to:

$$Ht = u2V2Cos(\alpha 2)/\, g$$

As such, assuming the blade angle β2= 60’, α2 =30’. The theoretical pressure head is calculated.

Mechanics of Fluids - 2

Radial - Flow pumps

Comparison of theoretical pump head H_T

$$H_t = \frac{\omega T}{\gamma Q} \qquad Q = 8\ m^3/hr$$

$$H_t = \frac{U_2 V_2 \cos\alpha_2 - U_1 V_1 \cos\alpha_1}{g}$$

- Assuming best pump design ; angular momentum entering impeller is zero, maximum pressure rise. Set $\alpha_1 = 90^\circ$

$$H_t = \frac{U_2 V_2 \cos\alpha_2 - \cancel{U_1 V_1 \cos\alpha_1}^{\,0}}{g} = \frac{U_2 V_2 \cos\alpha_2}{g}$$

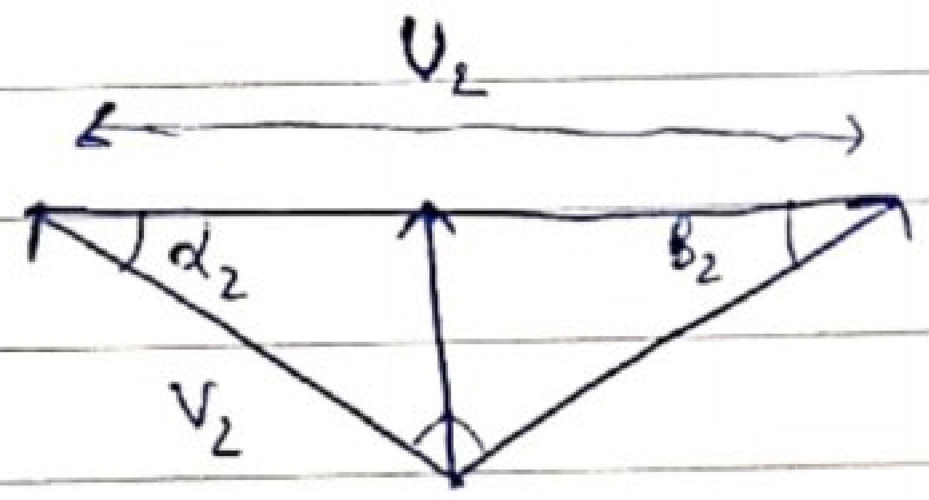
- Assuming ideal conditions ⇒ frictionless, negligible vane thickness, perfect guidance and no pre-rotation.

- Assuming $\alpha_2 = 30^\circ$

$$V_2 = \frac{Q}{A} = \frac{2.22 \times 10^{-3}}{\frac{\pi \times 0.13^2}{4}} = 0.167\ m/s$$

$\cancel{V_2 = V_2 \cos\alpha_2}$

$$\frac{V_2}{\sin(60)} = \frac{U_2}{\sin(90)}$$



output velocity triangle

$$U_2 = 0.193\ m/s$$

$$H_t = \frac{0.193 \times 0.167 \times \cos 30}{9.81} = 2.84 \times 10^{-3}\ m$$

As seen above, the theoretical pump head is drastically lower than the calculated pump head. This discrepancy can be attributed to the assumptions made in order to calculate the pressure loss. Furthermore, the chosen flow-rate can negatively impact the theoretical answer. Lastly, considering the assumptions regarding the blade angle, the theoretical pump head does not align with the calculated value.

Analyzing the obtained value, it can be seen that the error percentage far exceeds the acceptable limit of accuracy.

The large difference in value denotes that theoretically if the design angles are chosen to be similar to the ones as shown above, the centrifugal pump cannot achieve the pump head required to combat the pressure loss. As such, different assumptions need to be made in order to re-calculate the theoretical pressure head with different blade angle assumptions to ensure the pump can make up for the required pressure loss.

Motor Selection:

Specification :

The Standard IEC motor, rated at 3-phase 400V/±5%, with an IE3 efficiency classification, is an ideal choice for a fluid handling project, particularly for home use. This motor will be used to drive the pump power for the house, providing reliable and efficient fluid handling capabilities. With its 3-phase power supply, the motor ensures stable and consistent performance, while its IE3 efficiency rating reduces energy consumption and operating costs. The 400V voltage rating and ±5% tolerance are in line with industry standards, making it a suitable option for use in most residential facilities. The use of this motor for the pump power in a house represents a cost-effective solution for efficient and reliable fluid handling.

References:

1.GEA Mechanical Equipment. (2013). *Manual for the Design of Pipe Systems and Pumps*.

2.GEA Mechanical Equipment. (2014). *GEA Tuchenhagen Hygienic Centrifugal Pumps Business Line Hygienic Pump Technology*.

3.OMEC MOTORS AND THE PEJA GROUP. (2017). *ELECTRIC MOTORS CATALOGUE*.

4.VEMAT MOTORS. (2014). *General Purpose 3-phase Induction Motors, Product Catalogue*.

Appendix:

GRO	LEADER	PROJECT ACTIVITY PLANNING	FOCUS AREA	DURATION
	Arslan		Installation of a centrifugal pump	2 Weeks
	OBJECTIVE	To design a pump system for a two story client residence	SPECIFIC FOCUS AREA	TARGET
			Centrifugal pump design	

SUB-OBJECTIVE: 1. Project brainstorm and planning; 2. Pump project design; 3. Costing; 4. Report & presentation

SUB-OBJ 1	SUB-OBJ 2	SUB-OBJ 3	SUB-OBJ 4	No.	ACTIVITIES	20/1	21/1	22/1	23/1	24/1	25/1	26/1	27/1	8/2	9/2	10/2	Date	Date	Date	Date	Date	Date	Date	Arslan	Ahmed	Mazen	Farhan
●				1	Company setup, profile and task	●																		●	●	●	●
o				2	Project case study and planning	●	●																	●		●	
	o			3	Project preliminary design		●	●																●	●	o	o
	o			4	Project detail design & calculation sheet				●	●														●	o		●
	o			5	Pump selection and specification					●	●	●	●													●	●
		o		6	Project report								●	●										●	●	●	●
			o	7	Project presentation to client								o	o	o	o	o							●	●	●	●

PROGRESS AND ACHIEVEMENT — PERSON-IN-CHARGE (PIC)

ACTIVITY PLANNING — SUB-OBJECTIVE — DURATION — COST — SUCCESS CRITERIA

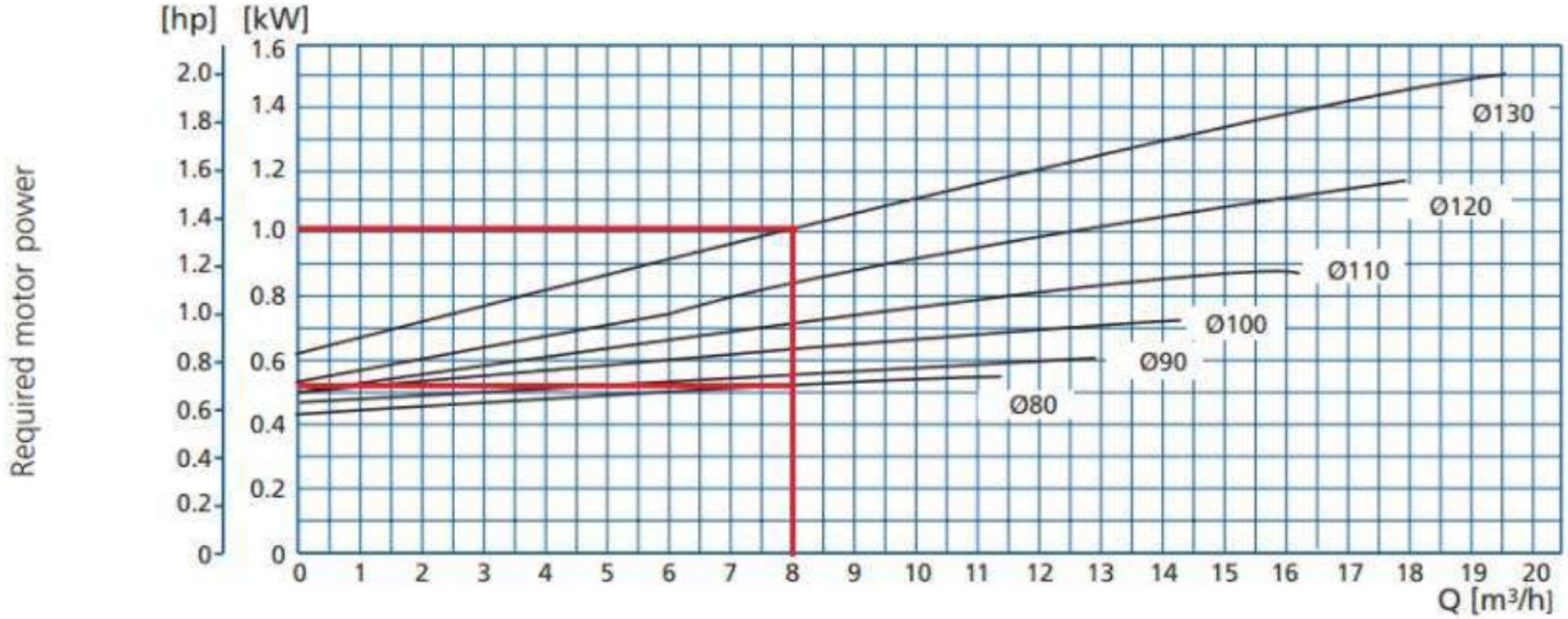
DURATION

	ESTIMATED BUDGET	RM

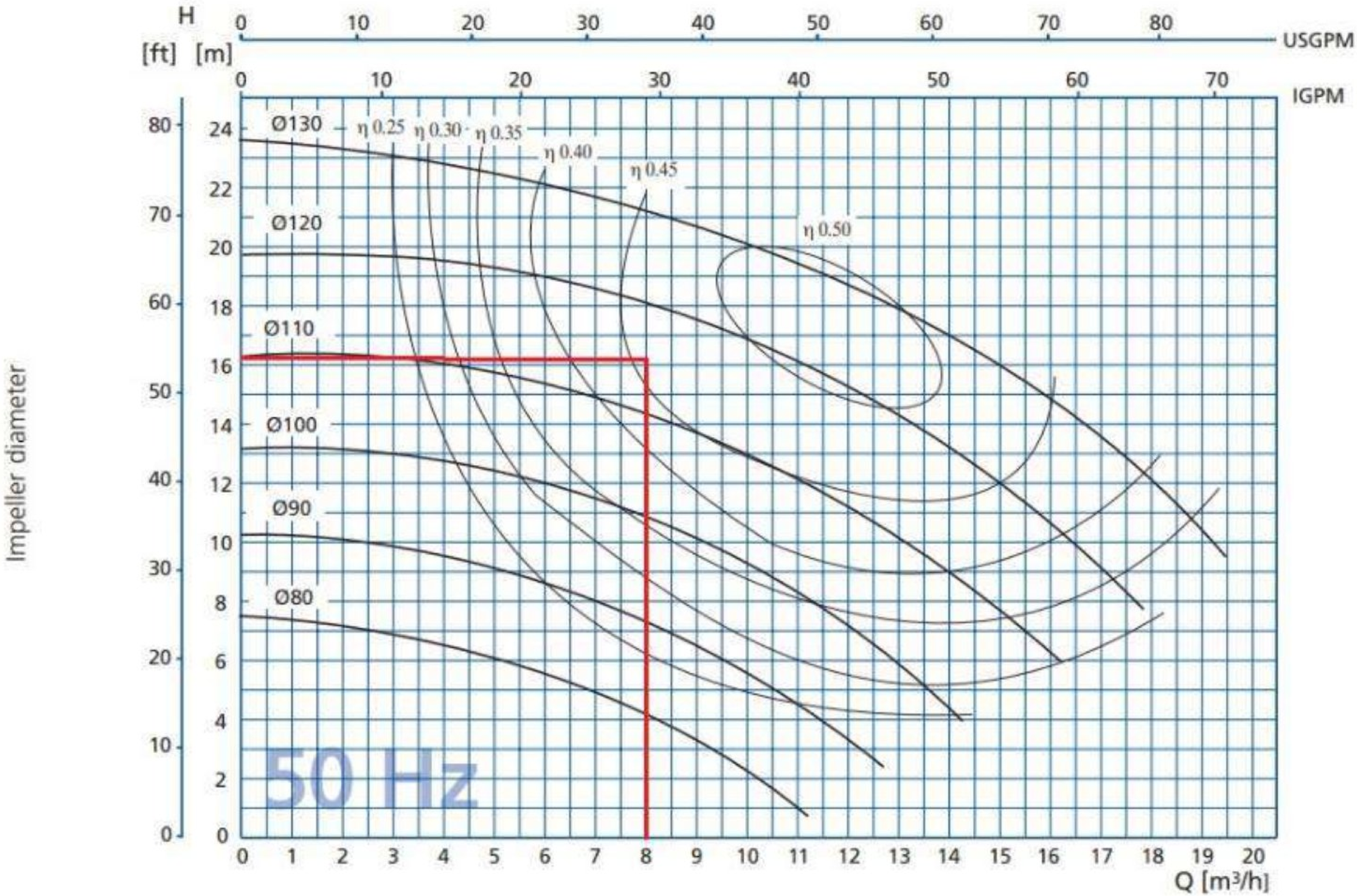
COMMENT OF ACTIVITY ACHIEVEMENT

The pump design project promotes creative problem solving skills and requries all team members to work together cohesively.

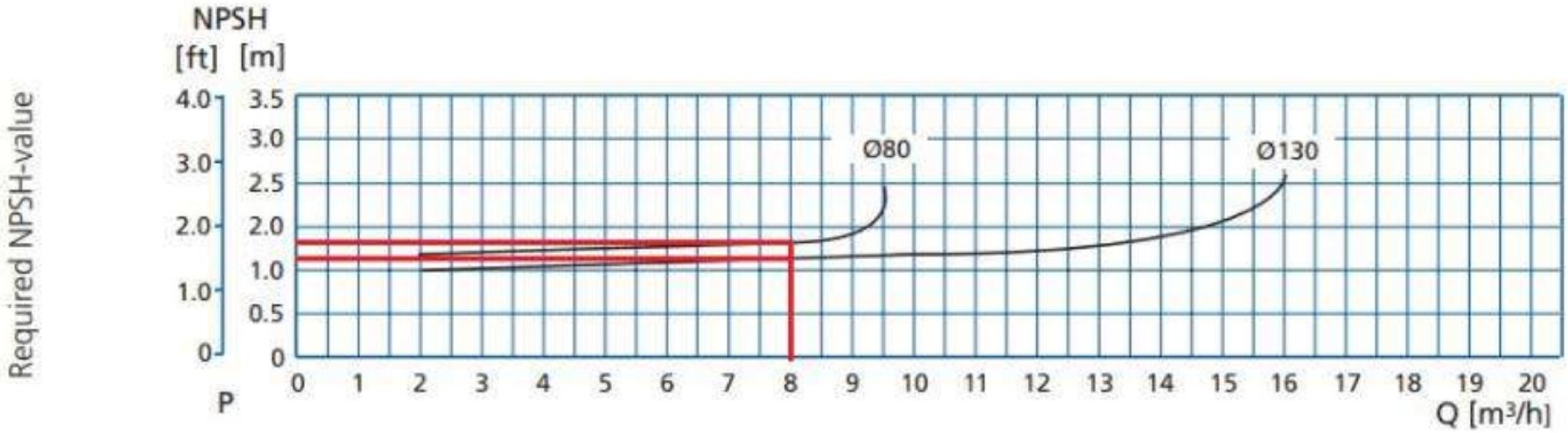
SUCCESS CRITERIA



Required motor power
[hp]
[kW]
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Q [m3/h]
Ø130
Ø120
Ø110
Ø100
Ø90
Ø80



H
[ft] [m]
USGPM
IGPM
Ø130
Ø120
Ø110
Ø100
Ø90
Ø80
η 0.25
η 0.30
η 0.35
η 0.40
η 0.45
η 0.50
Impeller diameter
50 Hz
Q [m³/h]



Required NPSH-value
NPSH
[ft] [m]
4.0
3.0
2.0
1.0
0
3.5
3.0
2.5
2.0
1.0
0.5
0
P
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Q [m3/h]
Ø80
Ø130