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ESE – 40… ENERGY SYSTEMS LABORATORY -…
Serial and Parallel Pumps Experiment Report

Student ID Number :
Name-Surname :
Experiment Date :
Grade :

2.3 Serial and Parallel Pumps Experiment

2.3.1 Objective

1) To develop pump characteristic curves for a single pump, two pumps in series, and two pumps in parallel by measuring head (h) and flow rate (Q) using the experimental apparatus.
2) To develop theoretical pump characteristic curves for pumps in series and pumps in parallel experimentally derived single pump characteristic curve.
3) To compare the experimental and theoretical pump characteristic curves for pumps in series and pumps in parallel.

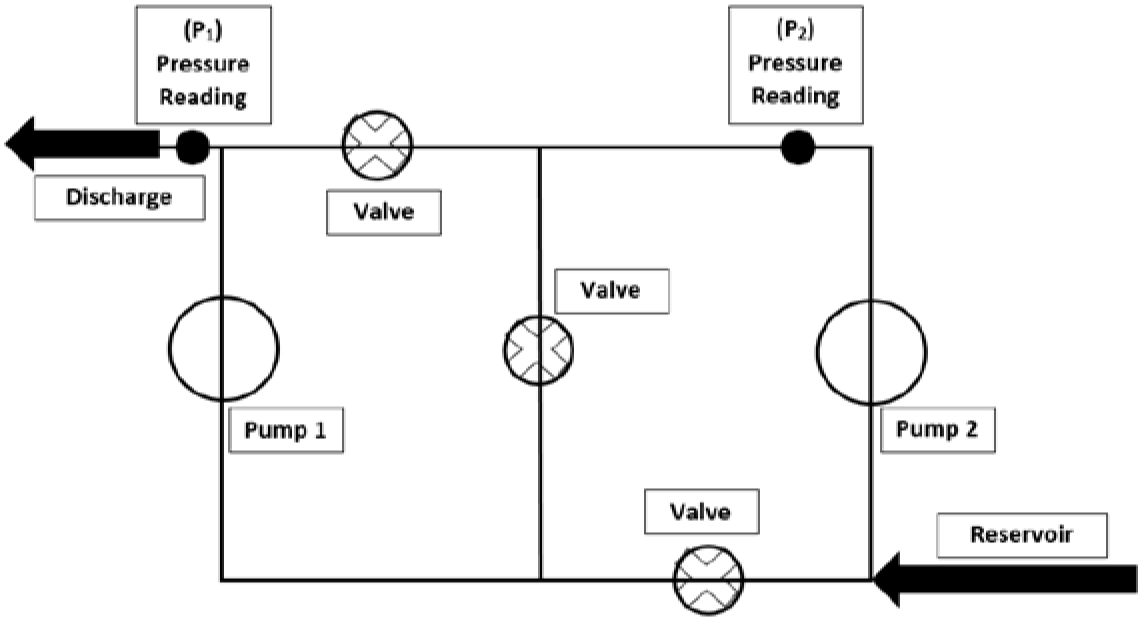


Figure 2.3.1. The schematic of the experimental setup

2.3.2 Introduction

Whereas turbines extract the energy from the fluid, pumps adds energy into fluid, increasing the energy possessed by the fluid. There are two main pump types: positive displacement pumps—pistons, plungers, diaphragms, vanes, screws, lobes, which have a fixed flow rate per stroke or revolution; and turbo-hydraulic or kinetic pumps / centrifugal pumps, which convert fluid kinetic energy into pressure [1].

Today, the design of a centrifugal pump has the water entering the low-pressure center of the impeller. The vanes then lead the water to the higher-pressure region to the casing. The casing is designed with a gradually expanding spiral shape so that minimum loss occurs in the transformation of kinetic energy to pressure. The pump receives the water at a low velocity on the interior edge of the set of moving impeller vanes and discharges it from the outer edge with kinetic energy sufficient to raise it to a desired height; and through the gradually expanding spiral passage transforms the kinetic energy into pressure [1].

2.3.3 Theory

Pumps are used to lift water up or to increase the energy so that the water can travel farther. This lab determines the head/flow characteristics of centrifugal pumps operating at a single speed: a single centrifugal pump, two similar centrifugal pumps operating in parallel and in series.

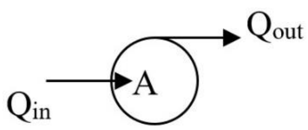
Recall the total head is the difference between the total energy head at the outlet and the total energy head at the inlet (neglecting the small differences in velocity heads). As shown be the following equation:

$$\left(\frac{p_2}{\rho g}+\frac{V_2^2}{2g}+z_2\right)-\left(\frac{p_1}{\rho g}+\frac{V_1^2}{2g}+z_1\right)=H_P-H_L \qquad (2.3.1)$$

where subscripts 1 and 2 refer to inlet and outlet sections. H_P is the pressure head produced by the pump and H_L is the energy loss due to friction and pipe fittings. By conservation of mass, $V_1=V_2$ if the pipe diameters are equal at the inlet and outlet sections.

Total Head: H_P = (pressure head increased by the pump)
Total Head Outlet: H_P = (pressure head at pump outlet - pressure head at pump inlet)
= (outlet pressure/γ) – (inlet pressure/γ)
Total Head Manifold: H_P = ({manifold pressure head + datum correction} - inlet pressure head})
= [{(manifold pressure/γ) + datum correction} - (inlet pressure/γ)]

Single pump:



$Q_{in} = Q_{out}$
$h_{pump} = \Delta h_{water}$

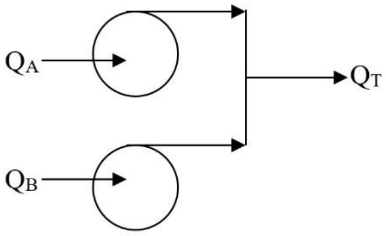
2.3.3.1 Pumps in Parallel

When two or more similar pumps are connected in parallel, the head across each pump is the same and the total flow rate is shared equally between the pumps, Q_P/n, where n is the number of pumps in parallel. For identical pumps in parallel, the pressures at the two inlets and outlets are identical and the maximum head the two pumps can deliver is no greater than for a single pump. Theoretically, the flow rate is doubled, although in practice, this will not occur, due to losses in the piping systems.

Total head (using *outlet*, not *manifold*) is determined the in the same manner as for the single pump. The theoretical curve for the parallel pump configuration is obtained from the single pump data by multiplying the flow rate by two.

For *theoretical* parallel pump curve, plot: H_p(single pump) vs. 2*Q(single pump)

Parallel Pumps:



$$n = 2 \text{ pumps}$$
$$h_{pumpA} = h_{pumpB} = \Delta h_{water}$$
$$Q_A + Q_B = Q_{Total}$$

Since the head loss across the parallel pumps is equal, the pump curve derived for each should be the same.

2.3.3.2 Pumps in Series

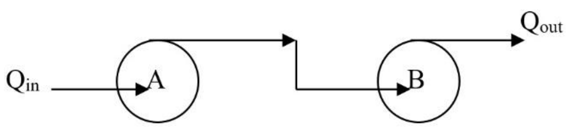
When two or more similar pumps are connected in series, the same flow rate passes through each pump and under goes a head boost of total head divided by number of pumps, H_P/n. Therefore, the series configuration of two identical pipes provides a pump characteristic of twice the head as for a single pump.

For series pumps, the total head can be computed as follows:

Total Head: H_P = (pressure head at pump 2 outlet - pressure head at pump 1 inlet)
= [(outlet 2 pressure/γ) – (inlet 1 pressure/γ)]

The theoretical curve for the series pump configuration is obtained from the single pump data by multiplying the head by two. This doubled head is plotted with the measured flow rate.

Serial Pumps:



$$n = 2 \text{ pumps}$$
$$Q_{in} = Q_{out} = Q_{total}$$
$$h_{pumpA} + h_{pumpB} = \Delta h_{water}$$

2.3.3.3 Pump Efficiency

For a pump, the efficiency is defined as

$$\eta = P_o/P_i$$

where P_o = power out from the pump = power imparted to the fluid
$= \gamma * Q * H_p = [N/m^3]*[m^3/s]*[m] = [N\text{-}m/s] = [J/s] = [W]$
P_i = power input to the pump shaft = power output from the motor = [W]

Output power is determined experimentally. Input power should be given in the manufacturer's specifications for the pump.

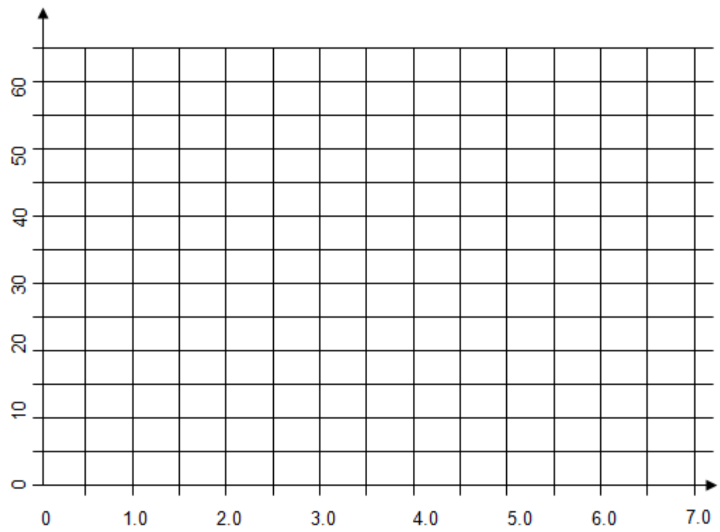
An important objective when selecting a pump for an engineering system is maximizing the efficiency for the desired flow conditions.

A) EXPERIMENT NO: **01**

B) EXPERIMENT NAME: **Single pump characteristic curve**

C) THE AIM OF THE EXPERIMENT: Total pressure height provided by the pump. In practice the differences in pump in and out, potential and speed, pressure, are negligible. So, the total pressure height can be considered pressure height.

Number of measurements	Flowmeter $\dot{V}$ [m^3/h]	Discharge Head H [mWc]
1	2,8	
2	3,7	
3	4,6	
4	5,2	
5	5,9	
6	6,7	



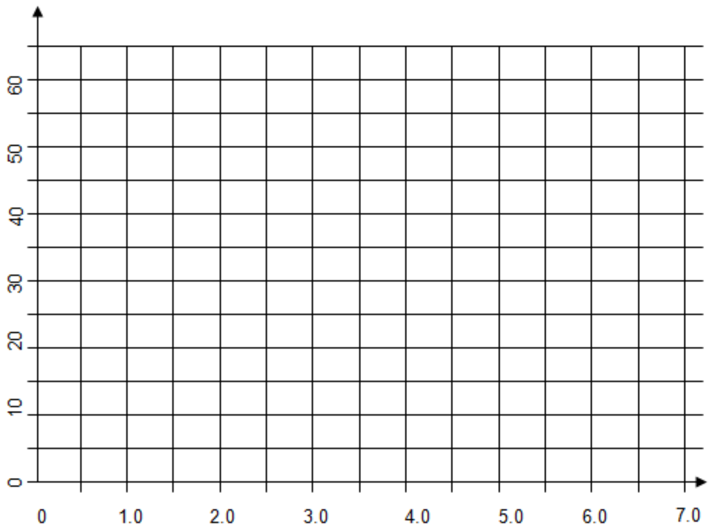
***** X axis flowmeter ([m^3/h]), Y axis Discharge head [mWc]**

A) EXPERIMENT NO: **02**
B) EXPERIMENT NAME: **Finding pump specific speed**
C) THE AIM OF THE EXPERIMENT: The pump's specific velocity allows it to compare different pumps to similarities, but also to be a function of the type of wheel. Pump wheel types are classified according to their specific speed at maximum efficiency. The experimental availability of pump specific speed will enable this information to be reinforced.

Number of measurements	Flowmeter $\dot{V}$ [m³/h]	Discharge Head H [mWc] (Measured above)	Calculate Ns (Specific Speed)
1	2,8		
2	3,7		
3	4,6		
4	5,2		
5	5,9		
6	6,7		

$$N_s = \frac{N\sqrt{\dot{V}}}{H^{0,75}}$$

N = The speed at which the wheel rotates (rpm) (2900 rpm)
$\dot{V}$ = Flowmeter (m^3/h)
H = Pressing pressure at all levels (mWc)



***** X axis flowmeter ([m³/h]), Y axis N_s**

EXPERIMENT NO: **03**

A) EXPERIMENT NAME: **Finding pump efficiency**

B) THE AIM OF THE EXPERIMENT: Pump efficiency is described as the ratio of hydraulic power to pump engine electrical input power. Pumps operate at different yields in different working conditions. These yield zones are shown as islets on the characteristic curve. It is important to choose from the right side of the maximum yield curves in the pump selection. Because pressure losses will increase as the system is contaminated, the point of operation shifts to the left and works with higher efficiency.

Number of measurements	Flowmeter $\dot{V}$ [m³/h]	Voltage [Vm]	Engine Current Im [A]	cosφ	Efficiency (η)
1	2,8	220	2,76	1	
2	3,7	220	2,88	1	
3	4,6	220	3,06	1	
4	5,2	220	3,16	1	
5	5,9	220	3,27	1	
6	6,7	220	3,37	1	

Efficiency (η): The efficiency of a pump is the ratio of fluid power generated to pump input power. This is defined by the following formula.

$$\eta = \frac{\dot{m} g H}{V_m I_m \cos\varphi}$$

$\dot{m}$ (kg/s)= $\rho * \dot{V}/3600$

$\dot{m}$: [kg/s]

H : Discharge Head [mWc]

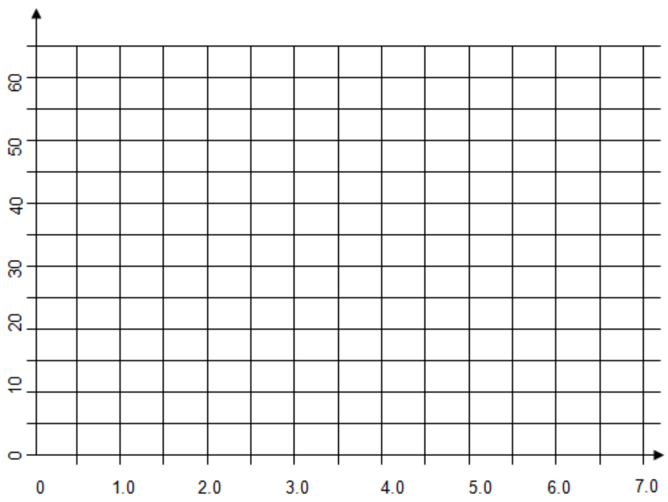
I_m : Current [A]

ρ_{water}: 998,2 kg/m³ at 20°C

g : Gravitational acceleration 9,81[m/s²]

V_m : Engine voltage [V],

$\cos\varphi$: Engine power coefficient



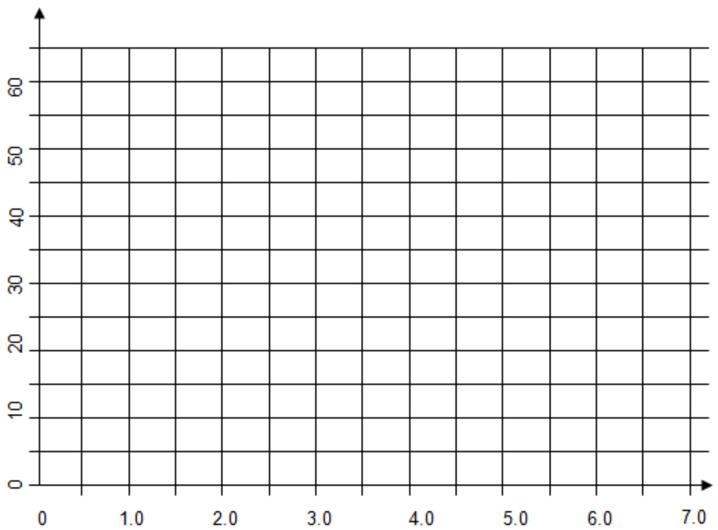
***** X axis flowmeter ([m³/h]), Y Efficiency (η)**

A) EXPERIMENT NO: **04**

B) EXPERIMENT NAME: **Drawing the characteristic curve of the serial pump**

C) THE AIM OF THE EXPERIMENT: Although there is a significant increase in pressure with the serial attachment of the pumps, the debit does not increase to that extent. The new characteristic curve can be theoretically drawn as well as experimentally found by the serial binding of two identical parallel pumps. This experiment can reveal the relationship between theoretical and experimental graphics.

Number of measurements	Flowmeter $\dot{V}$ [m^3/h]	Discharge Head H [mWc]
1	2,8	
2	3,7	
3	4,6	
4	5,2	
5	5,9	
6	6,7	



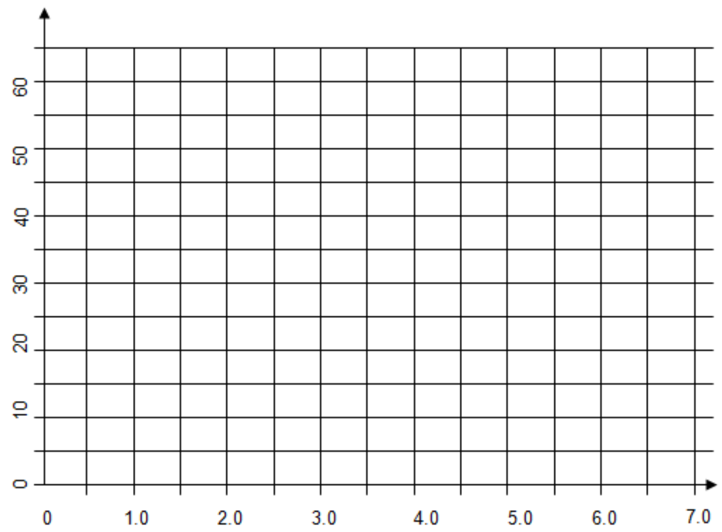
***** X axis flowmeter ([m^3/h]), Y axis Discharge head [mWc]**

A) EXPERIMENT NO: **06**

B) EXPERIMENT NAME: **Drawing the characteristic curve of the parallel pump**

C) THE AIM OF THE EXPERIMENT: Pressure does not increase to such an extent, although there is a significant increase in debates with parallel attachment of pumps. The new curve can be found experimentally with the serial attachment of two identical parallel pumps.

Number of measurements	Flowmeter $\dot{V}$ [m^3/h]	Discharge Head H [mWc]
1	2,8	
2	3,7	
3	4,6	
4	5,2	
5	5,9	
6	6,7	



***** X axis flowmeter ([m^3/h]), Y axis Discharge head [mWc]**

2.3.5 Report

In your laboratory, reports must have the followings;

a) Cover page

b) All the necessary calculations using measured data.

c) Discussion of your results and a conclusion.