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# ME 316: Thermofluids Laboratory

## Experiment # 3

## PUMP PERFORMANCE MEASUREMENTS

### 1) OBJECTIVES

a) To introduce the operational principle and the main components of a centrifugal pump.
b) To carry out standard measurements for obtaining the pump characteristic curves.

### 2) INTRODUCTION

The pump is defined as a machine that utilizes mechanical work to increase the total energy content of a fluid. This energy increase may be in the form of velocity increase, pressure increase, or the combined effect of both. Pumps are used in many industries to move liquids from one place to another and for that they are called liquid movers. Different types of pumps are used in different applications depending on the flow rate, the head developed and the type of pumped fluid. The most common type is the centrifugal pump that has wide applications in petroleum and petrochemical industries, domestic water systems, sewage systems, and many others.

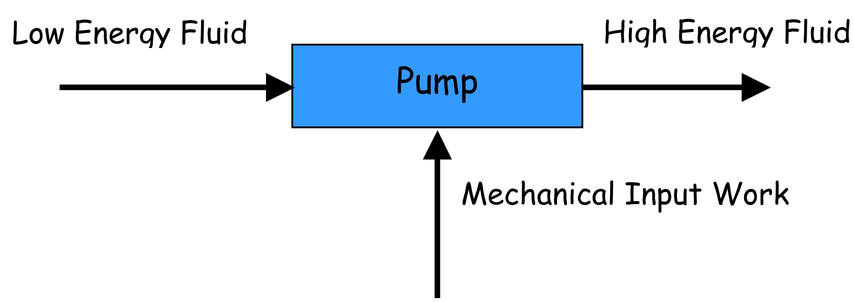


Figure 1 shows the main components of a typical centrifugal pump. The pump impeller is the main pump component that is responsible for energy transformation (mechanical input work $\rightarrow$ output fluid energy). The fluid enters the impeller axially at relatively low velocity and low pressure and leaves from the impeller periphery at higher velocity and higher pressure. The impeller vanes force the fluid to rotate and at the same time the fluid moves outward by centrifugal forces. Accordingly the fluid velocity inside the impeller has a tangential component and a radial component. The fluid leaves the impeller with high kinetic energy due to the high velocity. Further transformation from kinetic energy to pressure takes place in the volute casing and in the discharge nozzle that acts as a diffuser.

Every pump is equipped with one or more bearings for supporting the shaft and also equipped with a sealing system to prevent fluid leakage. Leakage may be hazardous especially if the liquid pumped is toxic or flammable. Centrifugal pumps are normally driven at speeds ranging from 1000 rpm to 4000 rpm but may be driven at higher speeds in special applications. Pumps are considered as the heart of most petroleum and petrochemical industries.

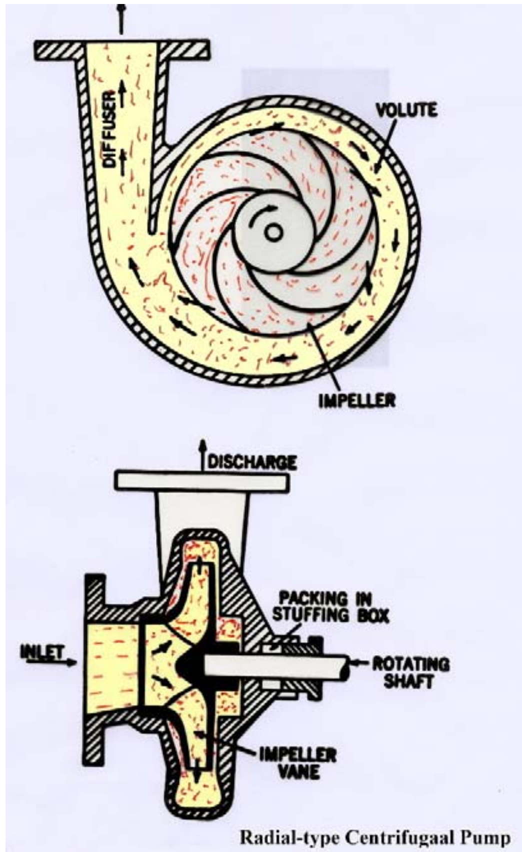


Figure 1. The main components of a radial-type centrifugal pump.

## 3) <u>THEORETICAL BACKGROUND</u>

Considering the pump schematic sketch shown in Figure 2, section 1 represents the inlet of the pump suction nozzle and section 2 represents the outlet of the pump delivery nozzle. Applying the energy equation between 1 and 2, one can write

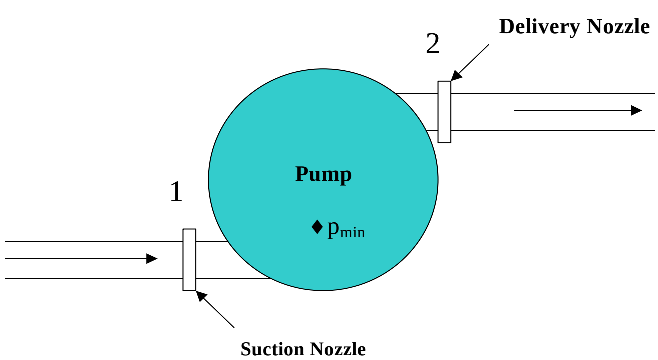


Figure 2. Schematic sketch of the pump showing the suction and discharge nozzles.

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+Z_1+h_p = \frac{p_2}{\gamma}+\frac{V_2^2}{2g}+Z_2+h_L \qquad (1)$$

where $h_p$ represents the net head added to the fluid by the pump (pump total head) and accordingly $h_L=0$. The above equation can be written in the form

$$h_p = \left(\frac{p_2-p_1}{\gamma}\right)+\left(\frac{V_2^2-V_1^2}{2g}\right)+\left(Z_2-Z_1\right) \qquad (2)$$

The first term on the right side represents the increase in the pressure head, the second term represents the increase in the velocity head and the third term represents the increase in the potential energy per unit weight of fluid. The second and third terms are very small in comparison with the first term and accordingly one can write

$$h_p \simeq \left(\frac{p_2-p_1}{\gamma}\right) \qquad (3)$$

The pump input power is normally referred to as the pump brake power *(B.P.)* while the pump output power is referred to as the pump fluid power *($P_{fluid}$)*. The pump overall efficiency *($\eta_o$)* can be expressed as

$$\eta_o = \frac{P_{fluid}}{B.P.} = \frac{\gamma Q h_p}{B.P.} \qquad (4)$$

where $Q$ is the pump capacity (flow rate delivered by the pump) and $\gamma$ is the fluid specific weight. The pump performance characteristics are normally presented in the form of three curves when operating at its rated speed (design speed). These curves differ from one pump to another and also depend on the pump speed. Typical performance curves for a centrifugal pump are shown in Figure 3.

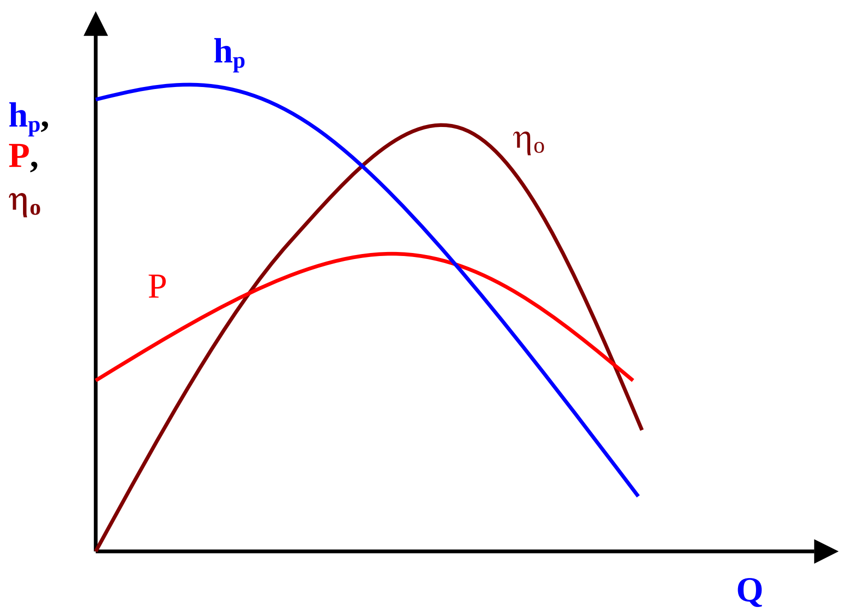


Figure 3. Typical performance curves for a centrifugal pump.

## 4) APPARATUS

The apparatus to be used is the Gilkes GH61 centrifugal pump test set. Figure 4 represents a general view of the apparatus and Figure 5 shows schematic diagram of various components. The setup consists of the following:

i) Fiberglass Tank: The tank is subdivided into two portions. The first is the upper tank and is called the flow-measuring tank and the second is the lower tank and is called the suction tank. The pump discharges water to the flow measuring tank which forms an open channel equipped with a V-notch weir used as a flow meter. The water then flows into the lower tank that is directly connected to the pump suction [see Fig. (5)]. The flow rate is measured by means of a calibrated water level gage on the upper tank.

ii) A Motor Driven Centrifugal Pump: A centrifugal pump of radial shrouded impeller type is used to suck water from the suction tank and deliver to the flow measuring tank through a throttle valve. Figure (6) shows an exploded view of the pump and motor components. The variable speed motor is equipped with a dynamometer used to measure the driving torque.

iii) A Pressure Gage: A dual scale Bourdon-tube pressure gage is used for measuring the pump discharge pressure

iv) A Motor Speed Controller: The electric motor speed is adjusted by using a transformer/rectifier speed control unit.

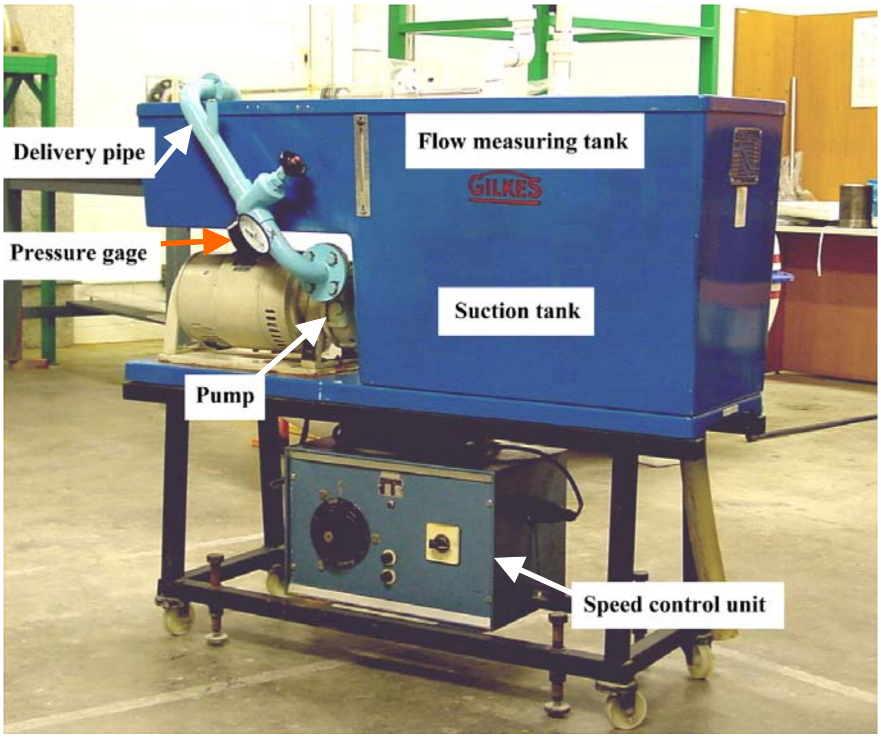


Figure 4. General view of the Gilkes GH61 centrifugal pump apparatus.

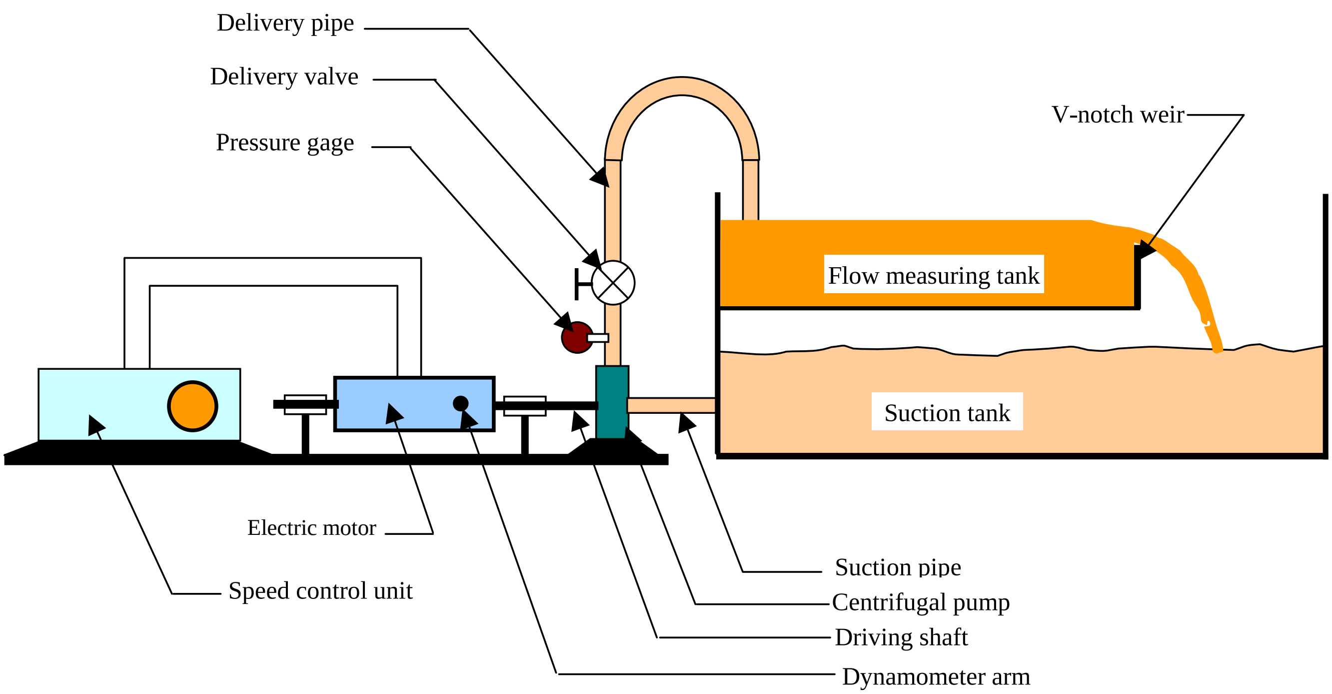


Figure 5. Schematic diagram of the experimental setup

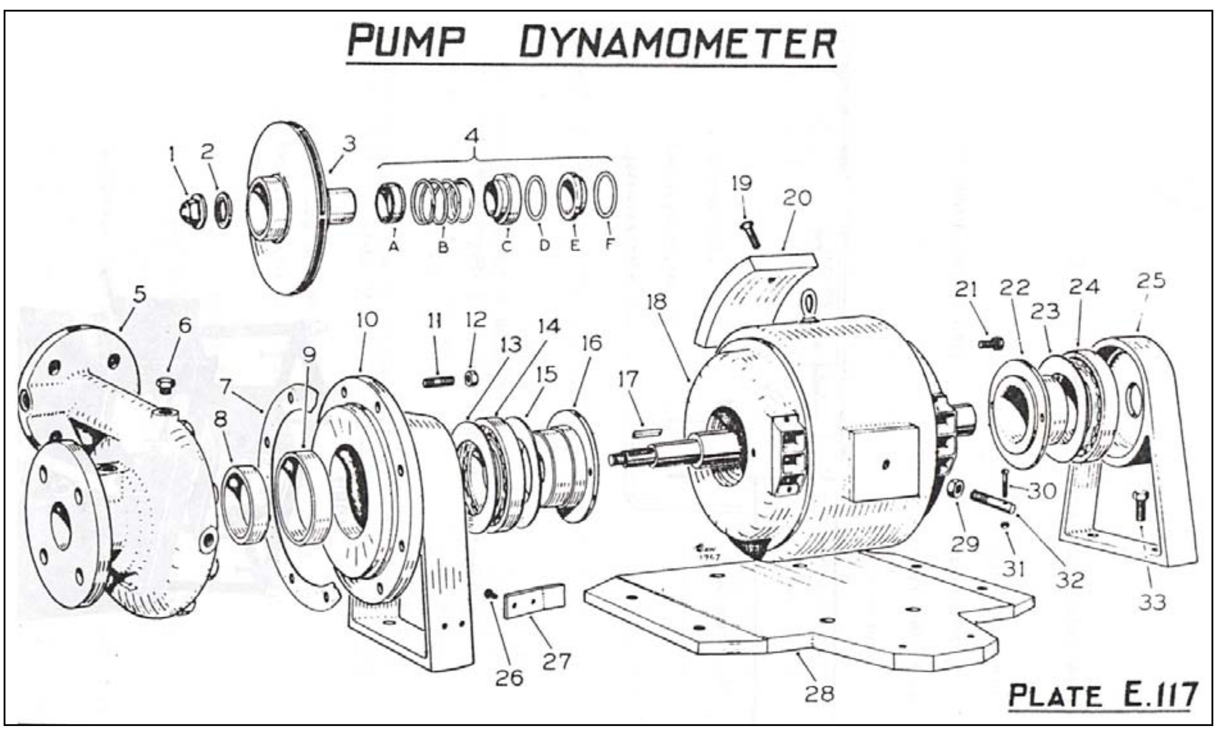


Figure 6. Exploded view of pump and dynamometer components.

## 5) TEST PROCEDURE AND CALCULATIONS

### a) Test Procedure

1. Ensure that the apparatus is leveled in both directions before starting the experiments.
2. Ensure that the delivery valve is fully closed to reduce the motor start-up current.
3. Start the driving motor and use the speed controller to adjust the rotational speed at 1700 rpm. Speed is measured by using a hand tachometer.
4. Record the delivery pressure, $p_2$, the flow rate, Q, and the dynamometer load, F.
5. Open the delivery valve slightly allowing water to flow.
6. Check the driving-motor speed and use the speed controller to readjust it, if necessary. Take the three readings $p_2$, Q, and F as in step (4).
7. Increase the delivery valve opening and repeat step (6) until the delivery valve is fully open. Try to take as many readings as possible in the available range of flow rate.

### b) Calculations

1. The total head delivered by the pump, H, is given by

$$h_p = \left( h_d + \frac{V_d^2}{2g} + z_d \right) - \left( h_s + \frac{V_s^2}{2g} + z_s \right) \quad (5)$$

where the subscripts s and d denote the pump suction and delivery sections respectively. But since the pump is approximately at the same level as the water in the suction tank, then the term $\left( h_s + \frac{V_s^2}{2g} + z_s \right)$ is approximately equal zero. Also, the term $\left( \frac{V_d^2}{2g} + z_d \right)$ is considered very small in comparison with $h_d$ and therefore,

$$h_p \approx h_d \quad (6)$$

2. The output fluid power or the fluid horsepower $P_{fluid}$ is given by

$$P_{fluid} = \frac{\gamma\, Q\, H}{550} \quad horse\ power \quad (7)$$

where $\gamma$ is the specific weight of the fluid (lb/ft$^3$),
Q is the flow rate in ft$^3$/s, and
H is the total head in ft.

3. The driving torque can be obtained from $T = F \times R$, where *T* is the torque, *F* is the dynamometer load and *R* is the radius of dynamometer arm (*R= 6.3125 inches*).
4. The input power or brake power is obtained from the equation, $B.P. = \frac{T \times \omega}{550}$, where *T* is the driving torque in lb. ft and $\omega$ is the angular velocity in rad/s.

5. The overall efficiency $\eta_o$ can be obtained from the equation $\eta_o = P_{fluid} / B.P.$.

## 6) PRESENTATION OF RESULTS

1. It is required to plot the three curves representing the pump performance characteristics (H–Q curve, B.P. –Q curve and $\eta_o$ –Q curve) at the pump speed of 1700 rpm.
2. Determine the head and flow rate at the best efficiency point.
3. Conduct an error analysis for the obtained results.

## 7) IDEAS FOR FURTHER DISCUSSIONS

1. What is the percentage error involved in neglecting the term $V_d^2 / 2g$ when calculating the total head $h_p$?
2. What type of losses exists inside the pump?
3. Will it be more accurate to use a venturi meter or an orifice meter for flow rate measurements?
4. Conduct an energy balance and estimate the temperature rise through the pump when operating at its best efficiency point.
5. What can be done to improve the apparatus or the test procedure?

## 8) Possible Additional Work (20% extra credit)

The accuracy of the obtained results depends on the accuracy of the measuring devices used in this experiment. Suppose that you wish to test the accuracy of the pressure gage used for measuring the delivery pressure. Suggest an experiment for calibrating the pressure gage used in the centrifugal pump apparatus (or a similar one).