CHAPTER 2

EXPERIMENTAL SETUP

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2.1 Introduction

An experimental setup was designed and constructed to provide reliable experimental data, in order to obtain the pump and turbine performances. In addition, experimental data has been verified by computational one. The experimental setup, shown in Figures (2-1) and (2-2), was installed in the Fluid Mechanics Laboratory at the Faculty of Engineering, Alexandria University where tests had been performed.

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2.2 Experimental Setup

The setup consists of the following main components:

1. Inline centrifugal pump (or turbine)
2. DC motor with coupling or generator
3. Electrical circuit
4. One inch pipes
5. Overhead tank
6. Orifice meter
7. Ball valve
8. Globe valve
9. Ground Tank

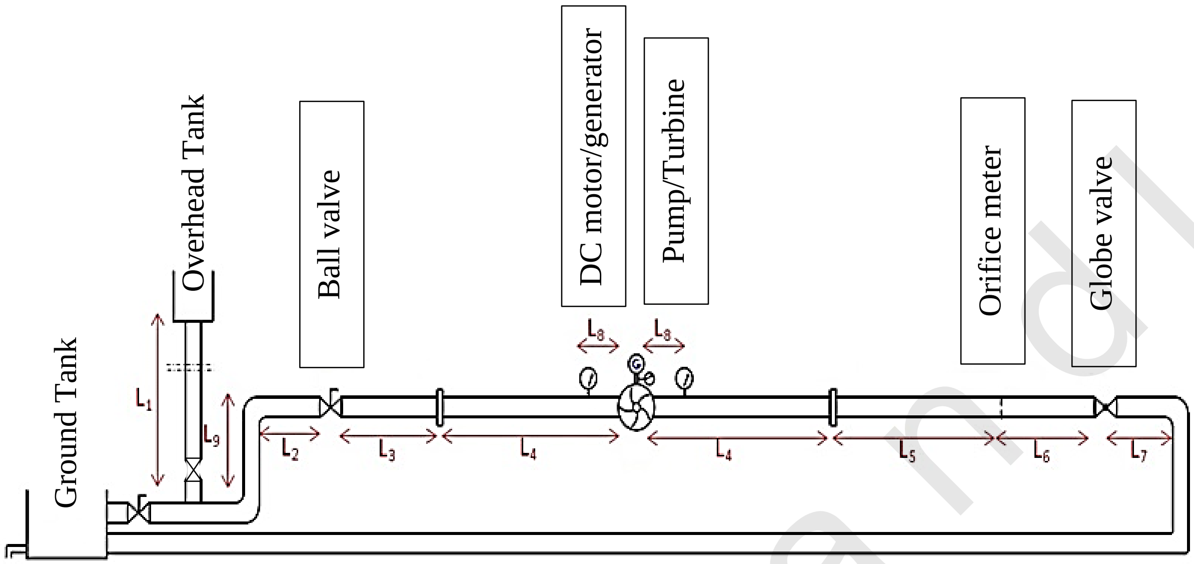
2.2.1 Pump

The experimental test rig comprises a pump of type "Grundfos" UPS 25-60-180 inline, canned rotor pump as shown in Figure (2-3) which was coupled directly with a single phase induction motor. The motor was replaced by a DC electric motor due to the difficulty of operating single phase induction motor as generator in the reverse mode. The pump maximum head was up to 6 m water. The pressure at the inlet and the outlet of the pump/turbine were measured using bourdon tube gauges.

2.2.2 DC Motor with Coupling

The pump was coupled directly with a DC electric motor as shown in Figure (2-4). The motor was used in one of two modes as follows:

1- A motor
2- A generator.



Figure(2-1) A schematic diagram of the experimental setup

Dimensions in cm			
L_1	1100	L_6	25
L_2	10	L_7	25
L_3	15	L_8	5
L_4	75	L_9	10
L_5	62.5		

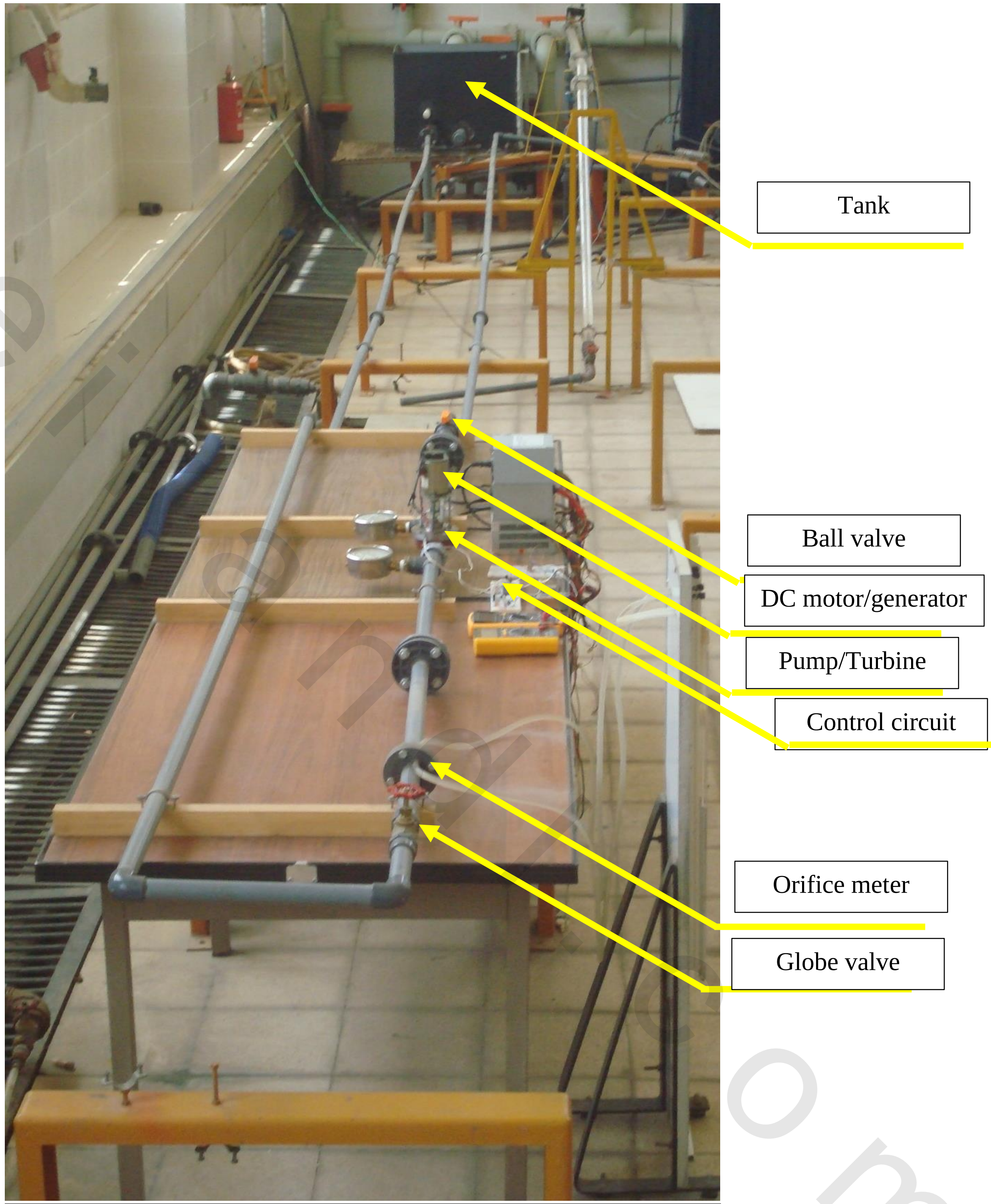


Figure (2-2) Experimental Setup

The motor was coupled with the pump by a flexible coupling in order to accommodate misalignment, if it exists, between the pump shaft and motor shaft.

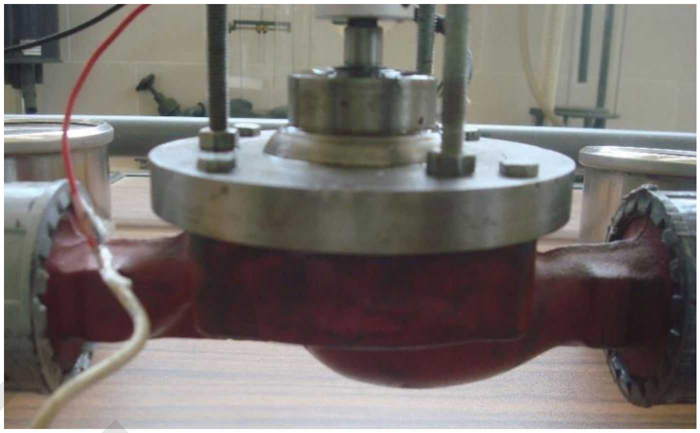


Figure (2-3) “Grundfos” UPS 25-60 180 Inline Centrifugal pump

Figure (2-4) DC motor and its coupling

2.2.3 Electrical Circuit:

In order to control the RPM in direct (pump) and in reverse (turbine), a control circuit was built to accommodate the RPM at different flow rates as shown in Figures (2-5), (2-6) and (2-7).

Concerning the turbine mode, the RPM of the motor as generator was changed according to the change of the flow rate which was adjusted by the delivery valve (gate valve). This make it difficult to plot the performance curve of the turbine as the speed was changed for each opening of the delivery valve.

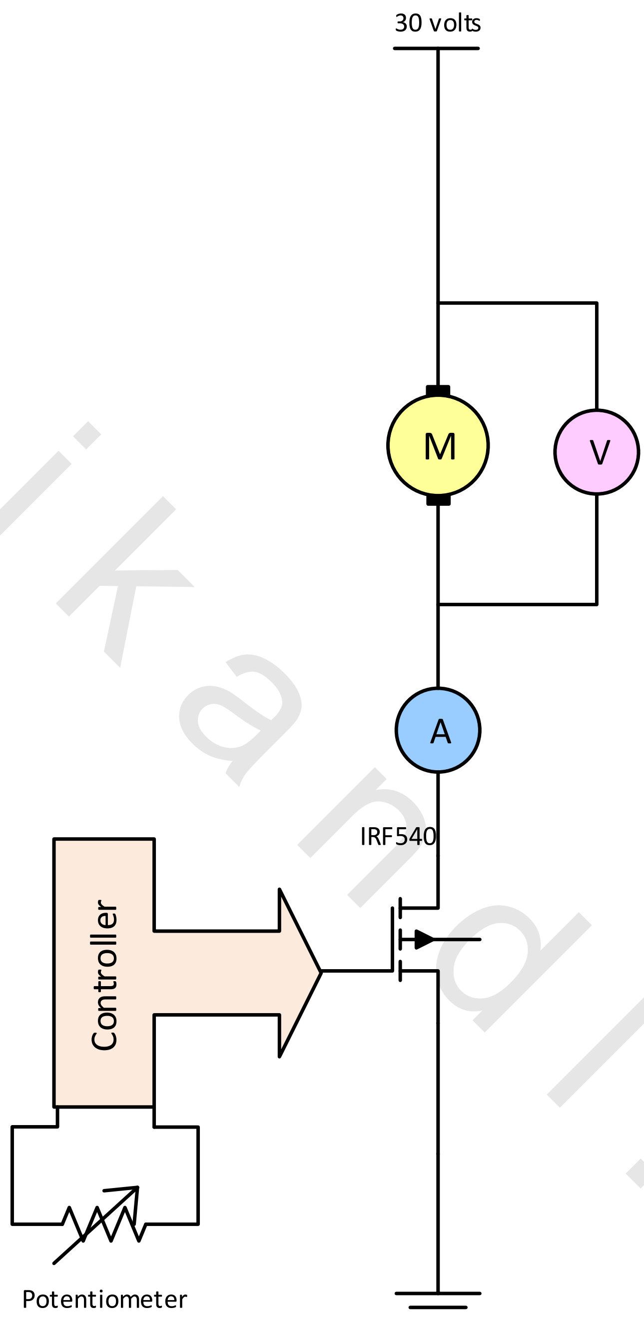


Figure (2-5) Electrical circuit for pump mode control

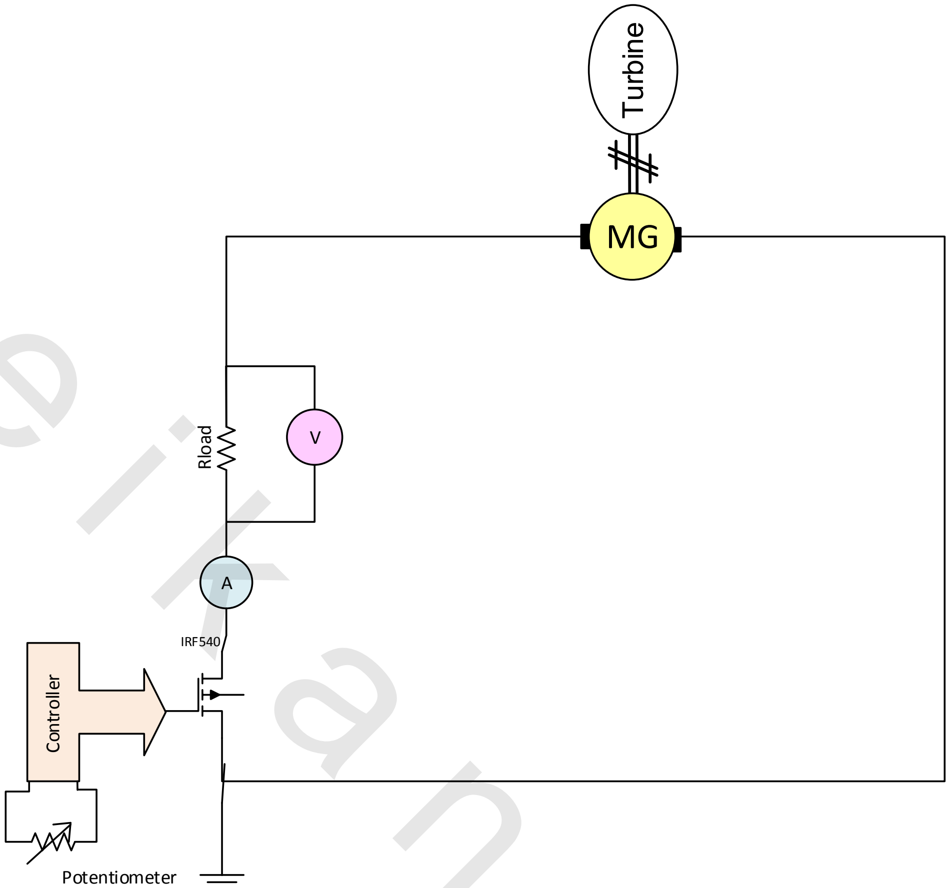


Figure (2-6) Electrical circuit for turbine mode control

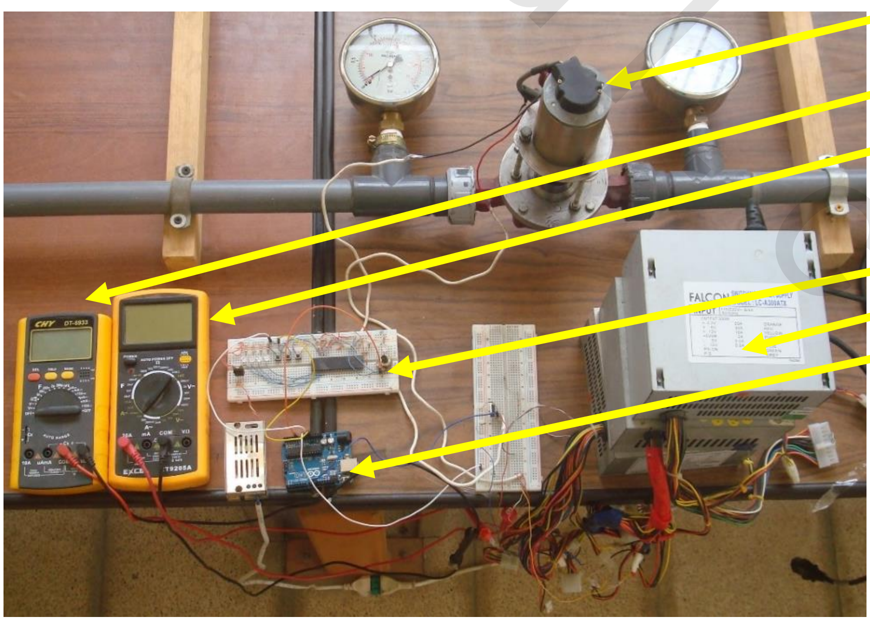


Figure (2-7) Electrical circuit and setup

An electrical circuit was built to control the RPM of the motor as a generator to be fixed at different flow rates in order to plot the turbine curve for a constant RPM. On the other hand, the electrical circuit was used to control the motor speed in direct mode (pump mode) as well.

The control circuit consists mainly of a microcontroller, DC supply and a potentiometer as shown in Figure (2-5) and (2-7). The load on the pump as a turbine was controlled via this circuit by accommodating the potentiometer location (i.e. the speed of the turbine was regulated to a single value each time flow rate is controlled by the delivery valve). Controlling the potentiometer was the main key to control the speed as the controller senses the change in the voltage and current. Each time the flow rate was changed the potentiometer location must be changed to regulate the speed of the motor as a generator.

On the other hand, the pump mode was controlled the same way as the turbine mode. The difference was that three power supplies in series were used to supply a voltage of 30 Volts to the DC motor to drive the pump as shown in Figure (2-6) and (2-7). The potentiometer was used as the same way of the turbine mode to regulate the motor speed.

For the code of the circuit see Appendix (C).

2.2.4 Pipes

The setup consists of 25.4 mm inside diameter horizontal PVC pipeline as illustrated in Figure (2-8), 4 mm thickness connecting the overhead tank and the ground tank. It consists of 11.5 m PVC pipes divided into number of segments coupled by special flange arrangement as shown in Figure (2-10). The pipeline was firmly fixed by rigid supports, as shown in Figure (2-9).

2.2.5 Overhead Tank

A constant head steel tank was comprised in the experimental test rig as shown in Figure (2-11). The tank capacity is 9 m^3. The tank was settled on the laboratory's roof of 11 m elevation above the pipe centerline.

An overflow vertical pipe was connected to the tank to ensure that the water head in the tank was maintained constant at 11 m. the overhead tank is the source of water for turbine mode operation. The water flows from the tank to the pump as a turbine inlet through a system of series pipes.

Figure (2-8) PVC pipeline

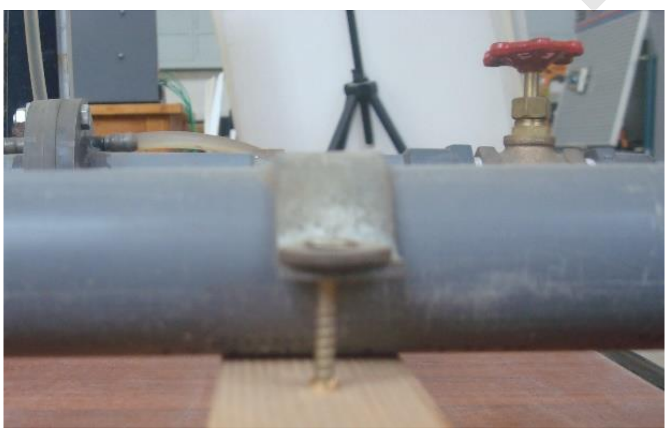


Figure (2-9) pipeline fixation

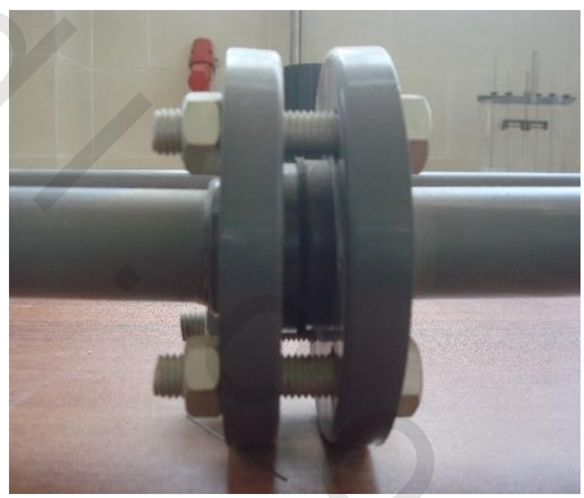


Figure (2-10) Flange arrangement of the PVC pipeline

Figure (2-11) Overhead tank

2.2.6 Orifice Meter

The orifice meter was made from PVC and connected with a U-tube manometer filled with mercury as a differential fluid between inlet and outlet of the orifice. The orifice shape and schematic diagram are illustrated in Figures (2.12), (2.13). The type of orifice used is the Foxboro Integral Orifice Flow Meter Assembly (IFOA) which is suitable for small pipe sizes (from ½ to 1 ½ in) with corner taps as shown in Figure (2.13).

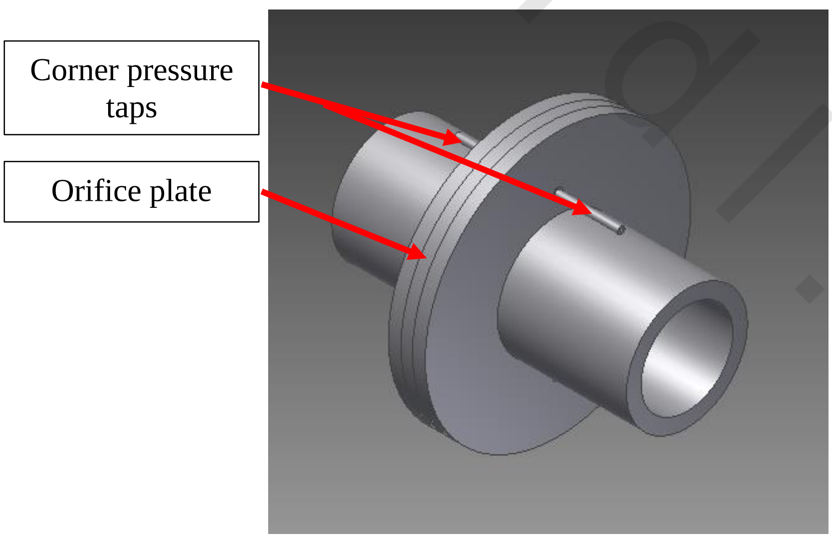


Figure (2-12) Orifice meter three-dimensional

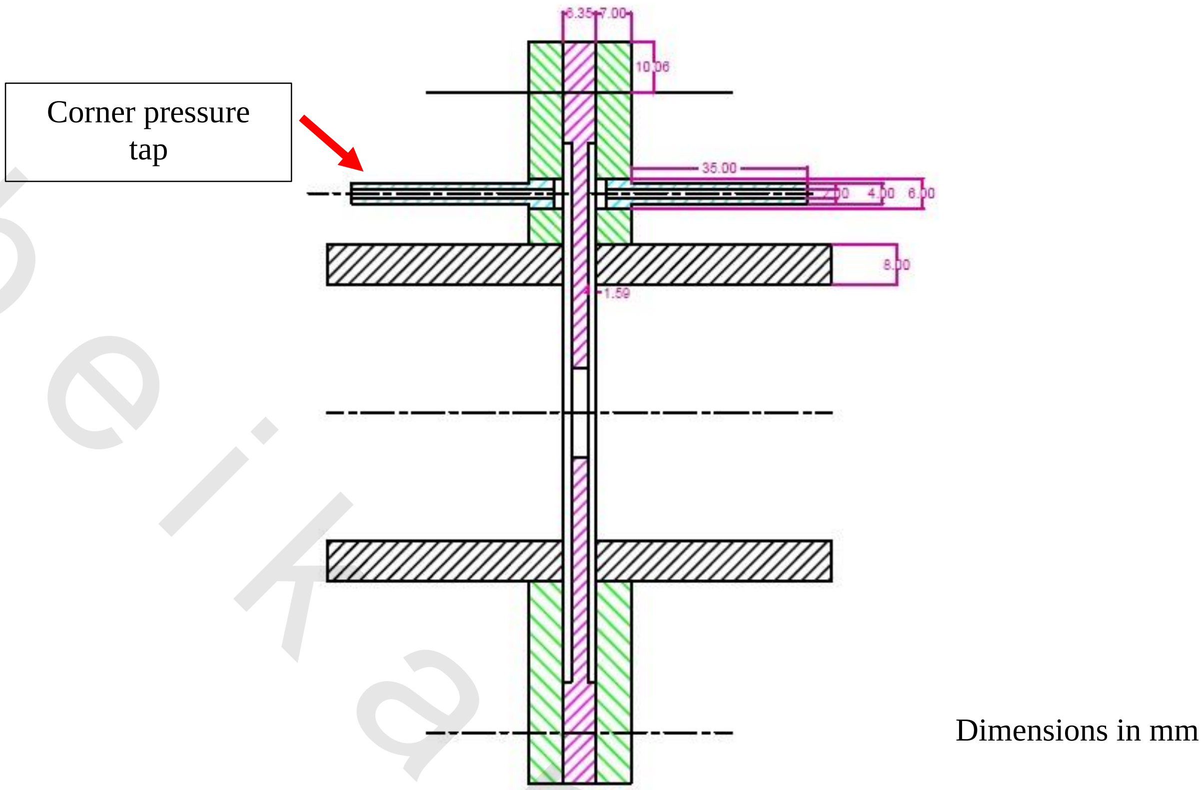


Figure (2-13) Orifice schematic diagram

The orifice taps are often used as 0.5D and 1.5D from orifice center line but in the case of smaller line sizes, the effects of plate eccentricity, pipe roughness, and pressure tap geometry are magnified and meters are specially designed to minimize these effects [20].

The Foxboro Integral Orifice Flow Meter Assembly which is used in the experimental setup has corner taps, since flange or D and D/2 taps would be located in regions where pipe friction would influence the differential.

The Beta ratio (β) of the orifice was selected to be 0.7. The bore diameter was 1.778 cm which was corresponded to Beta ratio. The orifice was calibrated using a tank of volume 27 liters as illustrated in details in Appendix (A) and the coefficient of discharge "C_D" was found to be 0.754.

2.2.7 Ball Valve

There are three ball valves of type "Cumer" as shown in Figure (2-14) which were used as On/Off valves to control the fluid route in both a pump or a turbines mode.

Figure (2-14) Ball valve for On/Off control

2.2.8 Globe Valve

A globe valve of type "Cumer" was used to assure fine adjustment of the flow rate as shown in Figure (2-15). It is used to provide fine flow control in one way.

Figure (2-15) Globe valve for flow control

2.2.9 Ground Tank

The tank, shown in Figure (2-16), is an open PVC rectangular tank of 0.29 m^3 capacity. The water level in the tank can be kept nearly constant at a height of about 100 cm from tank bottom using an overflow pipe connected to the side of the tank.

Figure (2-16) Ground tank

2.3 Pump Mode

The pump mode is selected by controlling the ball valves to close the turbine route. The pump is tested at different speeds of rotation. The speed of the pump is controlled by a control circuit connected to the motor. In addition, an AVO (Ampere-Volt) meter is used to measure the voltage and another AVO meter is used to measure the ampere via a control circuit. In addition the RPM is measured using a stroboscope. The pump-mode schematic diagram is shown in Figure (2-17).

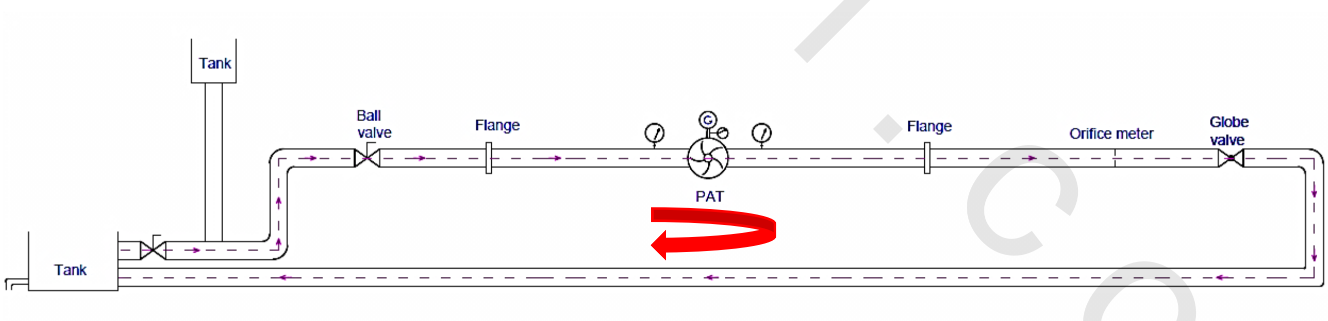


Figure (2-17) Schematic diagram of pump mode

2.3.1. Experimental Procedure:

1- Close ball valve which blocks the flow coming from the overhead tank.
2- The globe valve is completely closed before starting the pump.
3- Connect the DC motor to the power supply to start the pump.
4- Open the globe valve precisely to control the flow rate.

5- The flow rate is measured using the Orifice meter and the pressure is measured using the pressure gauges upstream and downstream the pump.
6- The voltage and current is measured by AVO meters in order to measure the power.
7- In each opening of the globe valve the flow rate, downstream pressure, upstream pressure, voltage, current and motor speed are monitored.
8- The control circuit was used to increase or decrease the motor speed of rotation according to the required value of the RPM.

2.4 Turbine Mode

The turbine mode is activated by closing the ball valve supplying water from the ground tank. The turbine is tested in the same speeds as the pump mode to get correlations between both modes. The DC motor is working as generator when the pump is used as turbine. The speed of the turbine is controlled by a control circuit connected with the motor working as generator. The frequency of the generator is kept constant using this circuit. The turbine-mode schematic diagram is shown in Figure (2-18).

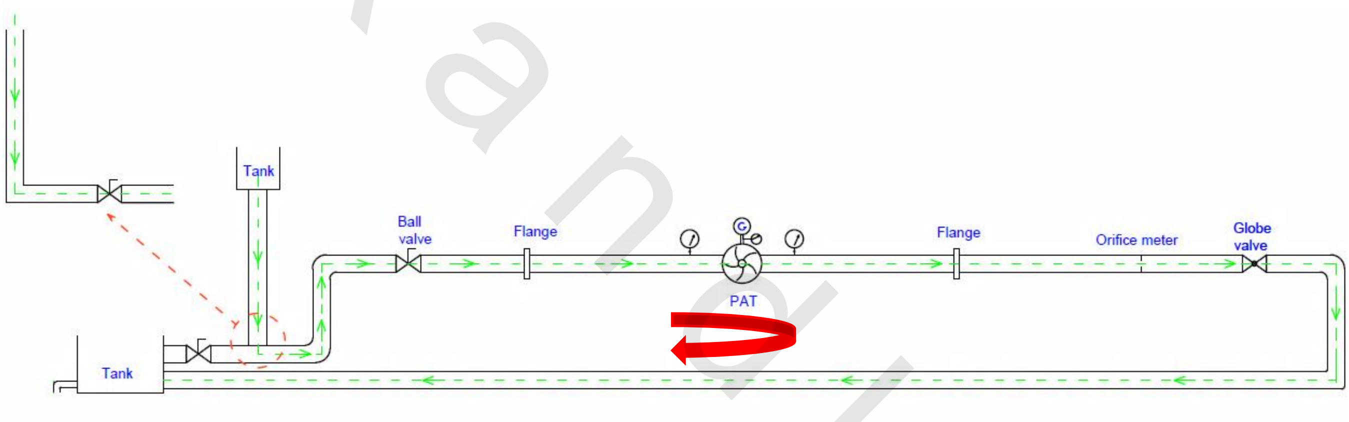


Figure (2-18) Schematic diagram of turbine mode

2.4.1. Experimental procedure:

1- Reverse the direction of the pump to operate as turbine.
2- Close the ball valve which supplies water from the tank.
3- The globe valve is completely closed before operating the turbine.
4- Open the globe valve precisely to control the flow rate.
5- The flow rate is measured using the Orifice meter and the pressure is measured using the pressure gauges upstream and downstream the turbine.
6- The voltage and current is measured by an AVO meters like the pump mode in order to measure the power.
7- In each opening of the globe valve the flow rate, downstream pressure, upstream pressure, voltage, current and motor as generator speed are monitored.
8- The speed of rotation of the generator is controlled using the potentiometer in the control circuit in order to fix the value of the speed of rotation for each valve opening.