UNIVERSITY OF MELBOURNE
FLUID MECHANICS
ENGR30002

Experiment: Elements and evaluation of a centrifugal pump

AIMS

- To take apart a centrifugal pump to determine the inner working of the equipment
- To determine the performance curve of a 100 W centrifugal pump
- To apply a theoretical system head and determine operation conditions of a similar 100W centrifugal pump

SAFETY AND STUDENT DRESS

Operation of experimental equipment should always be in accordance with local safety procedures. Dangers can occur if the equipment is misused or poorly maintained. The equipment is designed to operate safely.

It is a University requirement that student dress and behaviour in the lab must conform to the following safety standards:

- Safety glasses, long-sleeve and long-leg clothing are compulsory (otherwise lab coats must be worn)
- Do not take your safety glasses off while in the lab.
- Footwear must completely cover feet.
- No smoking, drinking, or eating in lab.
- No sitting on table or floor.
- Let the demonstrator know if you need to leave the lab.
- Keep table/work area tidy, notes and other items away from chemicals.
- Handle chemicals and equipment with care.
- Follow the lab supervisor's instruction in case of emergency evacuation.
- Ask question if you are unsure of anything during the practical session.

The laboratory demonstrator will determine whether students meet these requirements. Students not meeting these requirements will be asked to leave the laboratory and will receive zero for this part of the subject assessment.

Take 5 assessment of equipment and setup:

- *Electrical Safety* – pump is connected to the mains power (240V). Ensure water is not spilt onto electrical connections when transferring water into the equipment. Equipment must be drained before dismantling equipment. Spills should be cleaned as soon as possible.

- *Pinch Hazards* – when using barrel unions and pipe clamps. Ensure hair is tied back and no loose items of clothing.
- *Water borne hazards* – if water is left stagnant for long periods of time, bacteria can grow and cause respiratory harm if droplets are inhaled. System should be drained at the end of each day.
- *Hot surfaces* – when pump is running continually, the motor generates heat and the surface becomes hot. Appropriate gloves may be required to handle the pump if it is not given enough time to cool down.

THEORY

For fluid to flow in a horizontal pipe, a driving force is required. One way of providing this driving force is to use a centrifugal pump. The pump provides energy to the fluid in the pipe and drives the flow. We can perform energy conservation to the fluid in the pipe using the Bernoulli equation. At steady-state conditions, the equation is given by:

$$\frac{p_1}{\rho g} + \frac{u_1^2}{2g} + z_1 + h_p = \frac{p_2}{\rho g} + \frac{u_2^2}{2g} + z_2 + h_f \qquad (1)$$

Where p is the pressure in the fluid
u is the velocity of fluid in the pipe
z is the elevation of the fluid
h_p is the pump head
h_f is the friction head

Figure 1 shows a typical piping system which uses a centrifugal pump to drive water flow in a pipe. Points 1 and 2 are the free surface of water in the storage tank. The system head of the centrifugal pump can be determined by energy conservation between points 1 and 2.

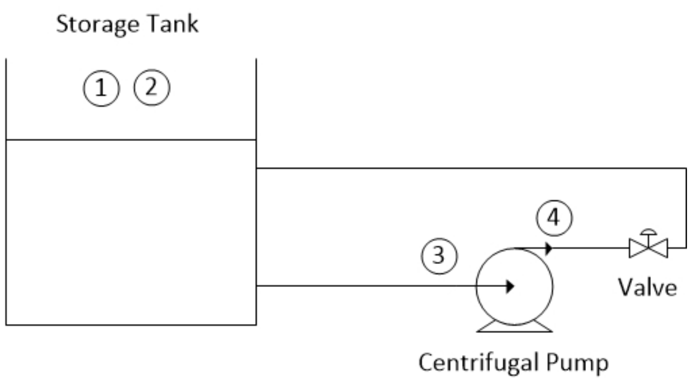


Figure 1: Schematic diagram of the pump experiment displaying energy levels for Bernoulli equation.

In the above system, pressure at points 1 and 2 is atmospheric as the storage tank is open to atmosphere. The velocity of water on the free surface can be approximated to be zero. The change in elevation between points 1 and 2 is also zero. Applying all the above conditions into (1), the Bernoulli equation becomes:

$$h_p = h_f = 2f\left(\frac{L}{D}\right)\left(\frac{u^2}{g}\right) + \sum K\left(\frac{u^2}{2g}\right) \tag{2}$$

Where f is Fanning friction factor
L is length of pipe

Note that, as the pipe diameter changes, the velocity and the velocity head term on the right hand side of (2) will be different in different sections of the pipe.

Point 3 is the suction side of the pump and point 4 is the discharge side of the pump. Points 3 and 4 can be used to determine the pump head using the Bernoulli equation. Assuming the suction and discharge pipe have the same diameter, then the velocity at points 3 and 4 will be the same. Also, the change in elevation between the suction and discharge side is negligible. The Bernoulli equation reduces to:

$$h_p = \frac{p_4 - p_3}{\rho g} \tag{3}$$

PART 1 – ELEMENTS OF A CENTRIFUGAL PUMP

EXPERIMENT NOTES

- Do not overtighten screws on equipment as this may damage the thread.
- If bolts do not screw in easily, it is likely that the bolt is not aligned properly. Undo screw and realign to prevent cross threading.
- The pumps used in this experiment are purely for dismantling and reassembly only. They should not be used for any other purpose.

EXPERIMENTAL APPARATUS

Figure 2 is the centrifugal pump setup. The setup consists of 2 sets of flanges, 1 centrifugal pump, 1 gate valve and PVC pipe fittings.

Figure 2: Evaluation of a centrifugal pump experiment setup.

EXPERMENTAL PROCEDURES

This practical exercise is to take apart a centrifugal pump and identify the components used to make up the piece of equipment.

Using the tools provided progress through the disassembly of the centrifugal pump and take photos of the various parts as they are disassembled.

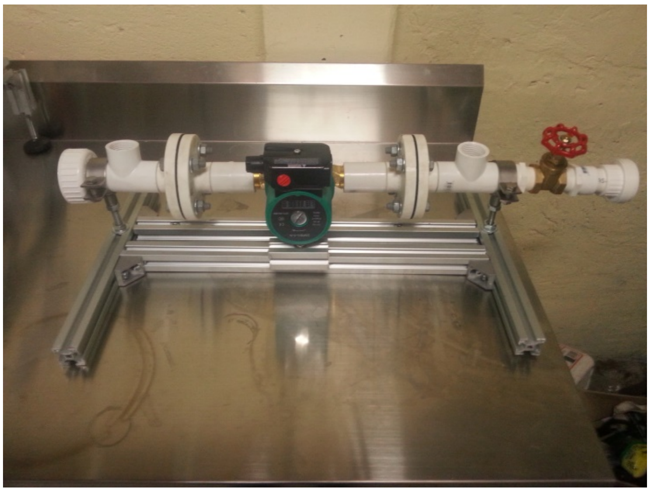
Tools Required

Tools required for this exercise are

- 1x Allen Key
- 1x Shifter
- 1x 10mm Spanner

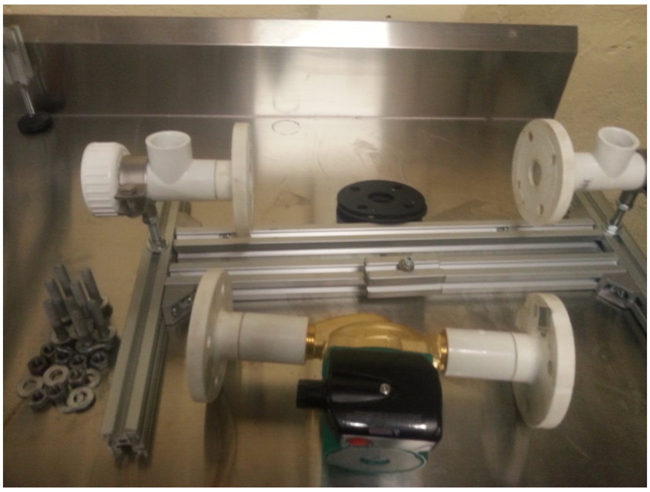
Disassembly of centrifugal pump

1. Ensure equipment and tools are acceptable for use.



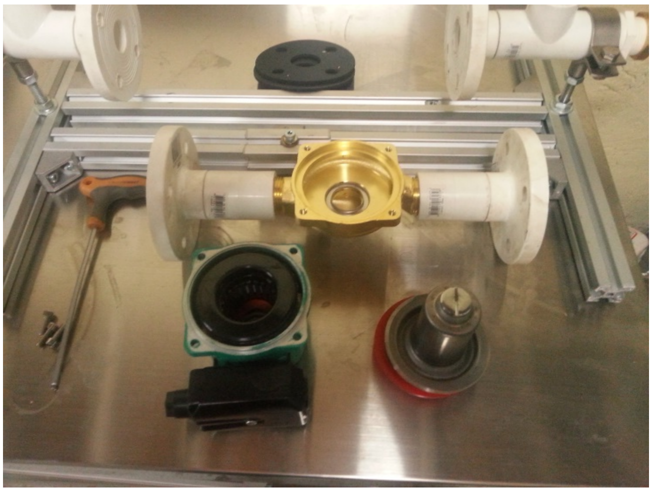
2. Remove flange bolts nuts from each side, keeping bolts in position. When all nuts are removed, remove all but 1 bolt from each side. Hold the pump steady and remove the remaining bolts.

3. Remove pump from setup and use the Allen key to remove the 4 bolts connecting the motor to the pump housing.

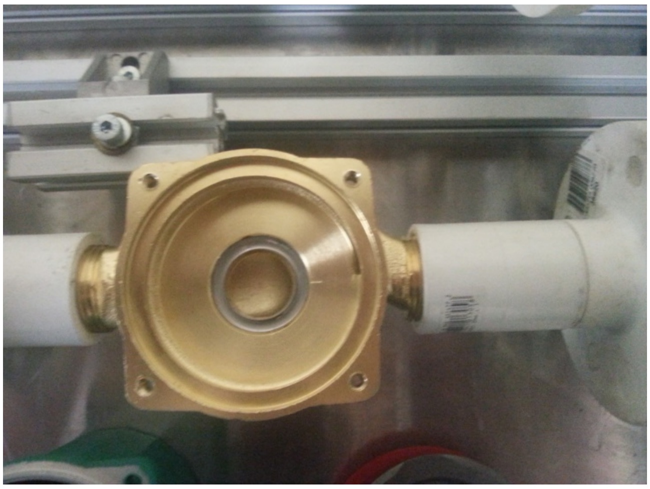


4. The demonstrator will then remove the rotor from the motor and take photos of each piece.

   Important Note: This step is done only by the demonstrator. The impeller blade is very sharp and you risk cutting your fingers if you disassemble the pump.



5. Discuss the water flow path on the pump housing with the demonstrator. Why does water move in this direction?



PART 2 – EVALUATION OF A CENTRIFUGAL PUMP

EXPERIMENT NOTES

Pump must not be connected to power point unless the system has been filled with water and the pump primed. Running pump dry can cause premature equipment failure.

Barrel unions should screw easily and not be over tightened. If they are not aligned correctly, the thread can be damaged and it will cause the equipment to leak.

All threaded PVC fittings (excluding barrel unions) require Teflon tape to be applied before installation. Teflon tape is used to seal gaps between the solid fittings to stop leaks.

EXPERIMENTAL APPARATUS

The experimental apparatus consists of a water tank, centrifugal pump, pressure gauges, flow meter and a throttling valve as shown in Figure 3. Once you have checked that the setup is complete, the experiment can be run according to the experimental method below.

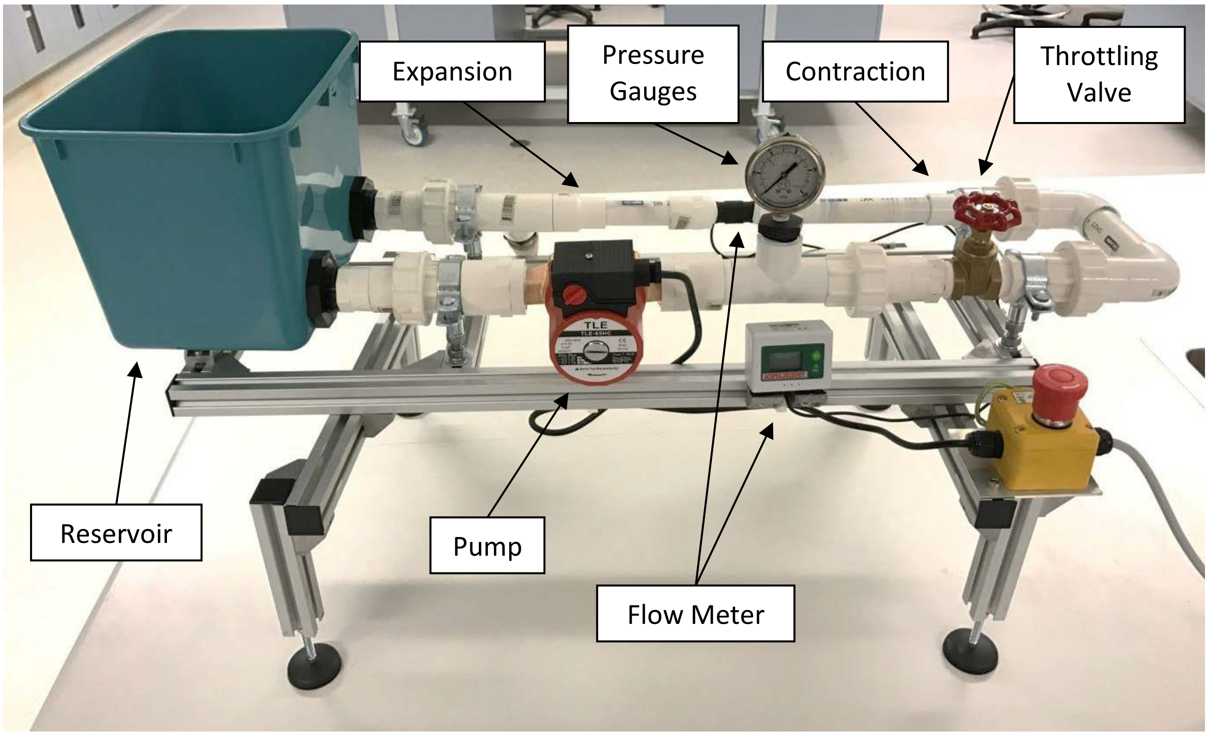


Figure 3: Evaluation of a centrifugal pump experiment setup.

Water in the reservoir enters the DN25 PVC pipe with an internal diameter of 25mm. It is then passed through a centrifugal pump, a valve and two 90-degrees elbows before moving to the DN20 PVC pipe with an internal diameter of 20mm through a contraction. The total length of the DN25 pipe from pipe entrance to the contraction is 108cm. The length of the DN20 pipe between the contraction and expansion is 39cm. After the expansion, the internal diameter of the pipe increases back to 25mm for a length of 22cm before water exits into the storage tank.

EXPERMENTAL PROCEDURES

Pre-start-up Checks

1. Check flow direction arrow on pump and flow meter to ensure they are installed correctly

2. Electrical outlet is switched off and pump power chord is not connected

3. Ensure drain valve is closed

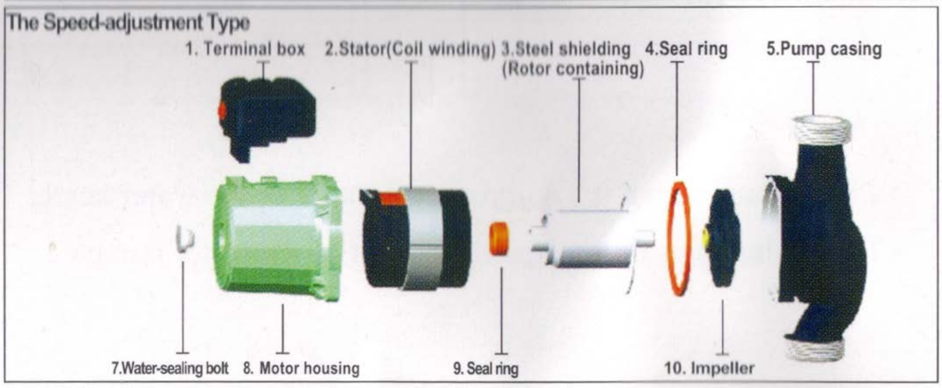
4. Open throttling valve by turning it anti-clockwise (do not over tighten)

5. Fill reservoir with approximately 5L - 8L of water

6. Ensure there are no leaks in the system

7. Prime pump by unscrewing the water-sealing bolt (see figure below) and retightening when water is flowing through.

N.	Description	N.	Description
1	Terminal box	6	Water-sealing bolt
2	stator(Coil winding)	7	Motor housing
3	Steel shielding(Rotor containing)	8	Seal ring
4	Automatic switch	9	Seal ring
5	Pump casing	10	Impeller



Turning on pump and experiment initiation

1. Ensure all pre-start-up check have been completed

2. Plug pump into electrical socket and turn on switch

3. Set pump to setting III and leave running to remove air from the system

4. When pump outlet pressure and flow become stable, progress to the next step

5. Cycle through each of the pump settings (I, II & III) and record the maximum flow rate and minimum pressure reading (Please take extra care when switching between different speed settings and do not break the plastic dial)

6. Close the valve completely by turning it clockwise (do not over tighten) and ensure the flow meter is reading 0 L/min

7. Cycle through the settings again and note the maximum pressure of each setting at a flow of 0 L/min

8. Turn off power to the pump from the electrical power switch

Experimental Run

1. Determine at least 10 pressure measurements for setting I, II and III between the maximum and minimum pressures recorded in the previous section

2. Open valve completely

3. Turn on pump

4. Manipulate the pressure and flow using the valve and record data for settings I, II and III

5. When all data is recorded, turn off pump from the GSO

Shutting down equipment

1. Open valve completely

2. Turn off pump from power switch

3. Remove pump plug from GSO

4. If required – Dismantle equipment.

QUESTIONS

1. Make a sketch of the system, showing all system elements, pipe lengths, diameters and regions where minor losses will be considered.

2. What is priming a pump? Why is it important before initial start-up?

3. For each setting, plot the experimental data (h_p versus Q) for the centrifugal pump (where h_p is in m and Q is in L/min).

4. Construct the pump curves for the 3 pump settings by generating an equation of best fit to the experimental data in the form of
$$h_p = a + bQ^c$$
Where h_p is in m and Q is in L/min. Report the values of a, b and c.

5. What is the purpose of a throttling valve? What are the implications of having a throttling valve prior to the pump inlet? Explain in terms of NPSH.

6. Using reasonable estimates of friction factors and minor loss coefficients, construct a curve of theoretical system head for the case of the valve being fully open.

7. For the 3 experimental runs with the valve fully open, how do your estimates of system head loss compare to the experimentally-obtained values? What might be the cause of any discrepancy?