**Equipment Description**

All numerical references in brackets relate to the diagram.

All numerical references in brackets relate to the diagrams.

Before using the unit for the first time attach the two sections of delivery pipework (12) between the discharge of the centrifugal pump (5) and the reservoir (11). Ensure that all unions are tight before filling with water. Connect the flexible tubing from sensor SPW1 (12) to the tappings on the orifice plate (15) with LOW P1 connected to the top tapping the HIGH P2 connected to the bottom tapping.

Place the Centrifugal Pump Demonstration Unit in a suitable location adjacent to a compatible computer.

Place the IFD Interface alongside the computer. Place the SWA1 Integrating Wattmeter (if available) alongside the IFD as convenient.

Ensure that all tappings in the pipework of the Pump Unit are connected to appropriate sensors or blanked.

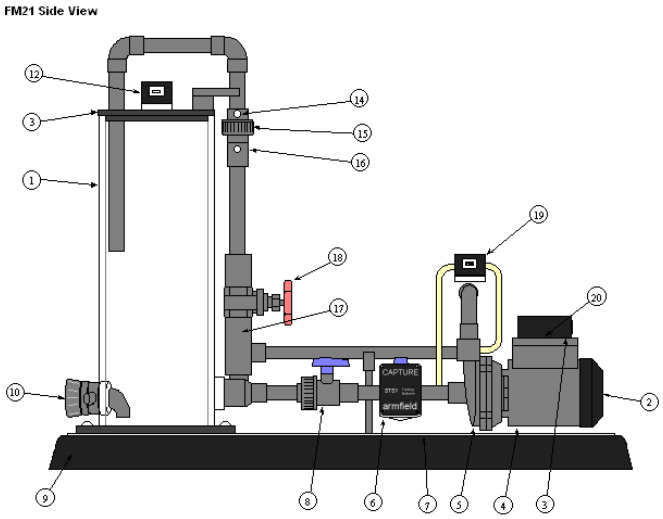


Figure 1: Side view of pump apparatus

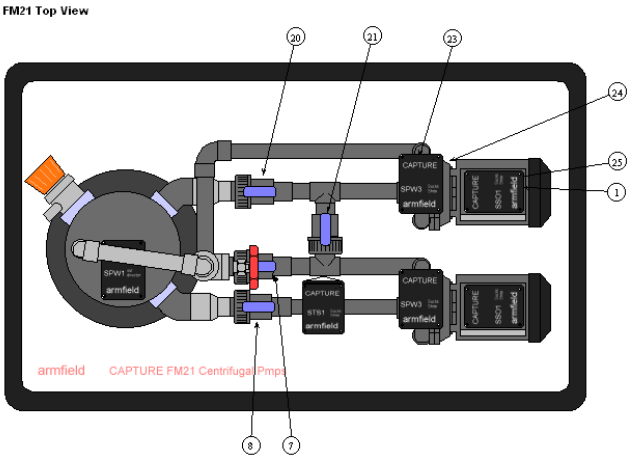


Figure 2: Top vew of pump apparatus

Open the inlet valve (8) and close the outlet control valve (7).

Ensure that the drain valve (10) at the base of the reservoir is fully closed then fill the reservoir with clean, cold water.

The pressure sensors on the unit require priming with water before initial operation (and whenever the tank has been emptied and refilled). A hypodermic syringe and micro-bore tubing are supplied for this purpose.

To prime the tubes with water remove the flexible tubing from the PVC pipe by removing the pipe clip and gently pulling the tube from the stainless steel tapping. Fill the syringe with water and gently insert the micro-bore tubing into the sensor's flexible tubing until it is a few millimetres away from the sensor. Hold the flexible tubing vertically.

Slowly inject water into the tube until it is completely filled, then remove the syringe and micro-bore tubing, and replace the flexible tubing on to the stainless steel tapping.

There are two stainless steel tappings at each tapping point. One is connected to the sensor, whilst the other is used to connect a manometer for calibration. It should be noted that there is a difference between the two points. The sensor tapping is fitted with a nylon restrictor to dampen pressure fluctuations. The calibration tapping has no restrictor. Ensure the sensor is connected to the correct tapping point.

Connect the mains lead (20) from the motor of the centrifugal pump to the Integrating Wattmeter SWA1. Connect the Wattmeter to the POWER OUTPUT of IFD.

Connect the mains supply lead from an appropriate electrical supply to the MAINS INPUT socket on IFD ensuring that the voltage of the electrical supply is compatible with the console (indicated on the rear of the console).

Switch on the mains supply. Switch on the IFD. Check that the pump operates. Open the outlet flow control valve fully and allow water to circulate until all air bubbles are expelled. Switch off IFD.

Connect each of the sensor conditioning boxes to the appropriate SENSOR SOCKETS on the front of IFD, using the numbered connecting leads, as follows:-

- Channel 1 to sensor SPW1 (12)
- Channel 2 to sensor STS1 (6)
- Channel 3 to sensor SPW3 (19) Pump 1
- Channel 4 to sensor SSO1 (3) Pump 1
- Channel 5 to sensor SWA1 Pump 1
- Channel 6 to sensor SPW3 (22) Pump 2
- Channel 7 to sensor SSO1 (24) Pump 2
- Channel 8 to sensor SWA1 Pump 2

Load the FM21 Software from the Windows start menu. The equipment is ready for use..

The following sensors are used to monitor the performance of the centrifugal water pump:-

**Differential pressure sensor SPW1 connected to Channel 1 on IFD:**
This comprises of a pressure sensitive piezoresistive device with appropriate signal conditioning all contained in a protective case (12) and is used to measure pressure developed across the orifice plate (15) installed in the discharge pipework of the pump. The volume flow rate of water through the pump can be calculated using this measurement. The sensor is connected to the appropriate tappings in the pipework using flexible tubing.

**Temperature sensor STS1 connected to Channel 2 on IFD:**
This comprises of a temperature sensitive semiconductor device on a remote lead with appropriate signal conditioning in a protective case (6) and is used to measure the temperature of the water entering the centrifugal pump.

The sensor is inserted through the wall of the pipe using a waterproof gland. The sensor may be removed from the gland for the purpose of calibration using appropriate equipment (not supplied).

**Differential pressure sensor SPW3 connected to Channel 3 for pump 1 and channel 6 for pump 2 on IFD:**

This comprises of a pressure sensitive piezoresistive device with appropriate signal conditioning all contained in a protective case (3 & 19) and is used to measure the difference in pressure between the inlet and outlet of the centrifugal pump. The head developed by the pump can be calculated from this measurement.

The sensor is connected to the appropriate tappings in the pipework using flexible tubing. Additional tappings are provided for the connection of appropriate instrumentation (not supplied) to facilitate calibration of the differential pressure sensor.

**Rotational speed sensor SSO1 connected to Channel 4 for pump 1 and Channel 7 for pump 2 on IFD:**

This comprises of a reflective infra-red opto switch (2) on a remote lead with appropriate signal conditioning in a protective case (3) and is used to measure the rotational speed of the motor/pump impeller.

The opto switch is mounted on a support bracket adjacent to the end of the motor shaft which incorporates a reflective strip to facilitate measurement of the rotational speed. An appropriate non-contacting optical tachometer (not supplied) may be used to calibrate the rotational speed sensor.

**Power Supplied to the Pump, Channel 5 for pump 1 and channel 8 for pump 2 to the Integrating Wattmeter SWA1**

The Armfield SWA1 Integrating Wattmeter provides power of between 0 and 500W, continuously variable using the Variac Dial. The meter signal is available on a ‘phone’ connector, giving a 0 to 5V output.

The Wattmeter is connected between the mains lead from the pump and a suitable power supply to facilitate measurement of the electrical power supplied to the motor. The Integrating Wattmeter may be calibrated using a suitable twin trace oscilloscope (not supplied).

The process and instrumentation diagram for this experiment is shown **Error! Reference source not found.**.

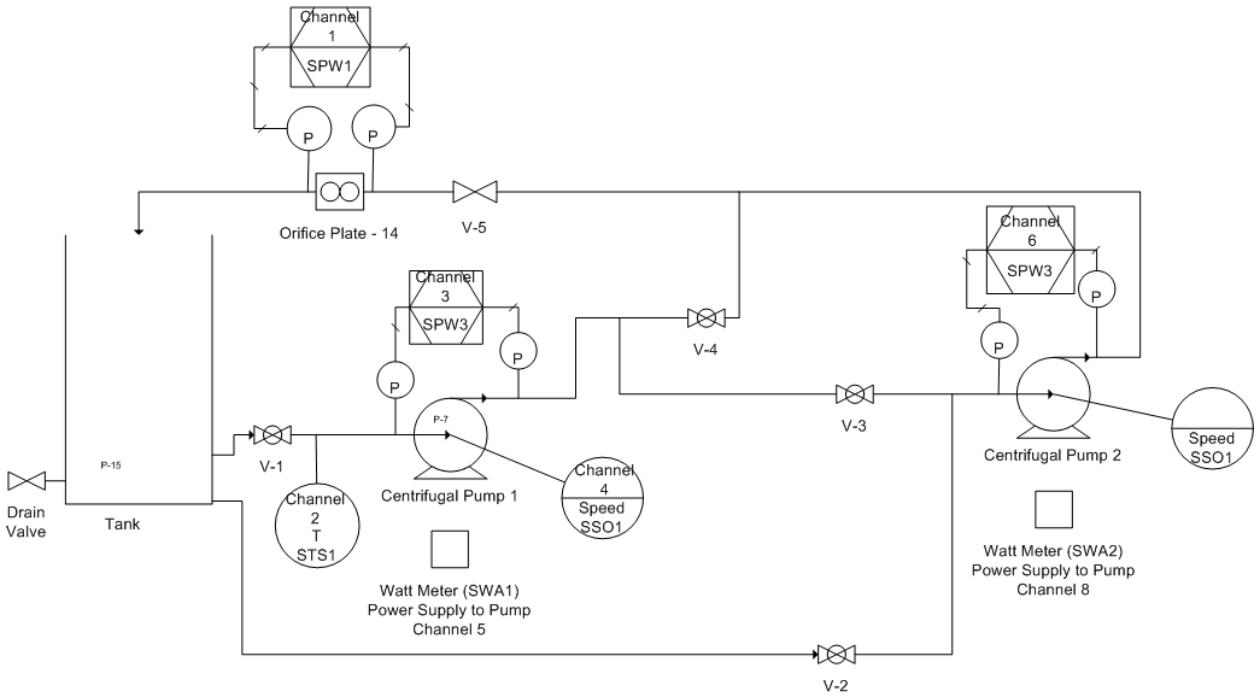


**Figure 3: Process and Instrumentation Diagram (P&ID) for Armfield Centrifugal Pump Experiment FM21 Series Operation**

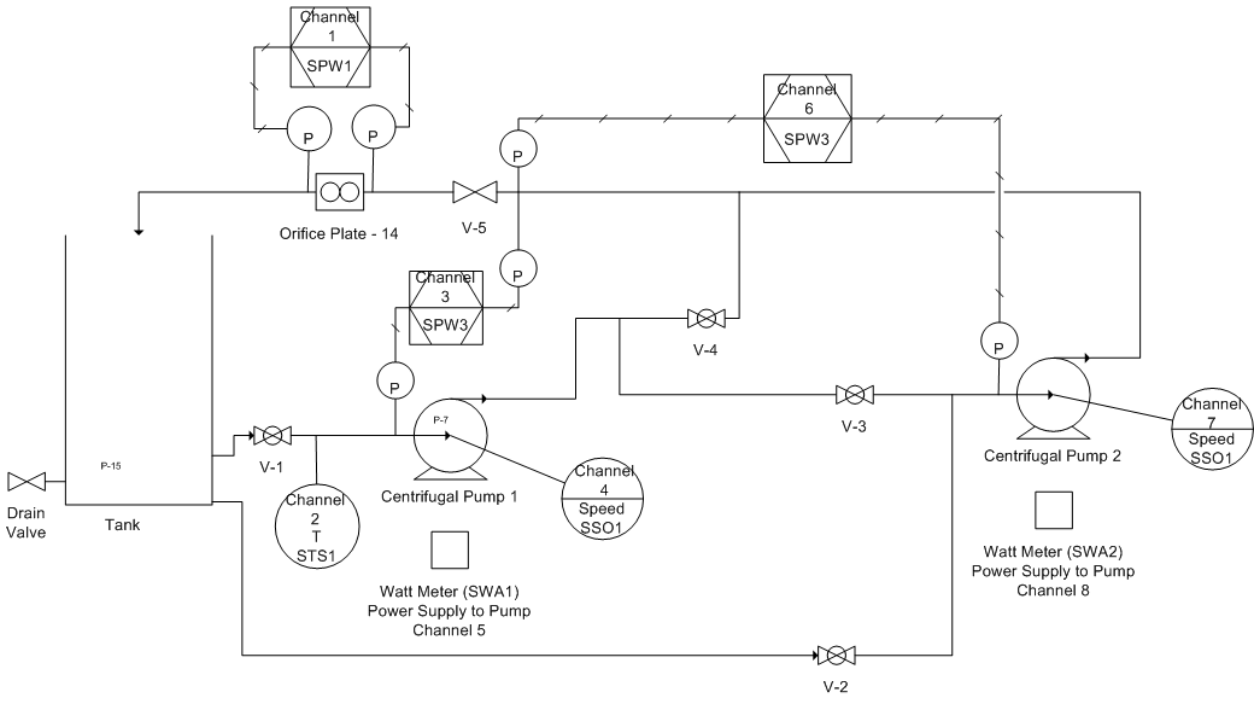


**Figure 4: Parallel Setup for Armfield FM21 (Valve Positions Not Shown)**

**Characteristic Pump Curve Experiments:**

Each team will conduct

- Single Pump Curve
- Series Pump Curve
- Parallel Pump Curve

**Procedure for Single Pump Curve: Maximum Power**

1. Using the Series Pump setup shown in Figure 3, close the appropriate valves so that the fluid is only flowing through Pump 1.
2. Select maximum pump speed N by adjusting the power controller to 100%.
3. Open inlet valve V1 fully. Close discharge valve V5 then start the pump (pump motor started under minimum load). Open discharge valve V5 fully and allow the water to circulate until all air bubbles have dispersed.
4. View the diagram screen and note the value of the volume flow indicated on the screen. Decide on suitable increments in flow to give adequate sample points (typically 15 points between zero and maximum flow.)
5. Close Valve V5, to correspond to the condition of no flow ie. Qv = 0. When the measured readings indicated in the boxes on the schematic diagram are sufficiently steady, click 'GO' to take a sample. This represents the first point on the characteristic curve. DO NOT leave the pumps in this condition of a closed outlet valve V5 as the water will heat up and change in viscosity which will invalidate the results. Go on to the next point as soon as possible:
6. Open valve V5 slightly, to give the first increment in volume flow at the bottom of the screen. When readings are steady enough, click 'GO'.
7. Repeat step 6above for a gradually increasing set of valve V5 openings, ie. increasing values of flow Qv. The final sample point will correspond to valve V5 being fully open.

**Procedure for Single Pump Curve: Variable Speed Centrifugal Pump Curve**

8. Repeat the procedure given in step 3, using the impeller speed assigned to your team given in Table 1. To obtain this impeller speed you will need to adjust the power controller setting for each new sample point. In this manner you will be able to plot a curve of constant impeller or pump speed. Remember to take the series of sample points in ascending steps of increased flow. This is done to minimize the time required to obtain steady state conditions for each point.

Table 1: Impeller Speed for Each Team

| Team | Pump Setup | Power (%) | Speed (Hz) |
|---|---|---|---|
| 1 | Pump 1 | 100% | |
| 2 | | | 10 |
| 3 | | | 20 |
| 4 | | | 30 |
| 5 | | | 40 |
| 6 | | | 50 |
| 7 | | | 60 |
| 8 | | | ? |

**Series Pump Operation**

Ensure that all tappings in the pipework of the FM21 are connected to the appropriate sensors or blanked. The differential pressure sensor SPW1 (12) should be connected directly across the orifice plate assembly (15), the differential pressure sensor (19) should be connected between the inlet and the outlet of Pump 1 (5), and the differential pressure sensor SPW3 (22) should be connected across the outlet of pump 1 (5) and the outlet of pump 2 (23).

Open the inlet valve (8) and close the outlet control valve (18). Ensure that the unit configuration valves (7 and 20) are closed and (21) is open.

Ensure the drain valve (10) at the base of the reservoir is fully closed then fill the reservoir with clean, cold water.

Connect the mains leads from the Pumps to the two Integrating Wattmeters SWA1. Connect the Wattmeters to the MAINS OUTPUTS on IFD.

Switch on mains supply. Check that the two pumps operate. Open the outlet flow control valve fully and allow water to circulate until all the air bubbles are expelled. Switch off the pumps. Then repeat the procedure given in Step 1 to obtain data points for your series pump condition. Make sure your data matches either the 100% power or the constant speed operation.

**Parallel Pump Operation**

Ensure that all tappings in the pipework of the FM21 are connected to the appropriate sensors or blanked. The differential pressure sensor SPW1 (12) should be connected directly across the orifice plate assembly (15), the differential pressure sensor SPW3 (19) should be connected between the inlet of Pump 1 (5) and the tapping on the discharge pipework (17). The differential pressure sensor SPW3 (22) should be connected between the inlet of Pump 2 (23) and the discharge pipework tapping (17).

Open the inlet valve (8) and close the outlet control valve (18). Ensure that the unit configuration valves (7 and 20) are open and (21) is closed.

Ensure the drain valve (10) at the base of the reservoir is fully closed then fill the reservoir with clean, cold water.

Connect the main leads from the pump motors to the two Integrating Wattmeters. Connect the Wattmeters to the MAINS OUTPUTS on IFD

Switch on the power supply. Check that the two pumps operate. Open the outlet flow control valve fully and allow water to circulate until all the air bubbles are expelled. Switch off the pumps. Then repeat the procedure given in Step 1 to obtain data points for your series pump condition. Make sure your data matches either the 100% power or the constant speed operation.

**Laboratory Report:**

9. At the end of all teams experiments you will be sent an excel spreadsheet with all the data. Each team will construct several characteristic pump curves:
    a. Constant power input pump curve showing pressure drop across the pump as a function of flowrate. On the second y-axis you should show efficiency as a separate line.
    b. Constant power input pump curve showing pressure drop across the pump as a function of flowrate. On the second y-axis you should show power delivered to the pump as a separate line.
    c. Variable Speed Centrifugal pump curve showing pressure drop across the pump as a function of flowrate. On the second y-axis you should show efficiency as a separate line.
    d. Variable Speed Centrifugal pump curve showing pressure drop across the pump as a function of flowrate. On the second y-axis you should show power as a separate line.
10. Make a composite pump curve showing all of the data from the class. This graph should have lines showing the pump curve (delP vs flowrate) and efficiency vs. flowrate for each pump speed. To do this plot you will need the data from the class that was sent to you.
11. Make a set of pump curves for the series operation. On this plot show a comparison between single pump and series pump operation
12. Make a set of pump curves for the parallel operation. On this plot show a comparison between single pump and parallel pump operation
13. In your laboratory writeup you should give
    a. Your recorded tables
    b. Sample (hand) calculations of each calculated value
    c. Suggestion for optimum operating conditions for this pump.