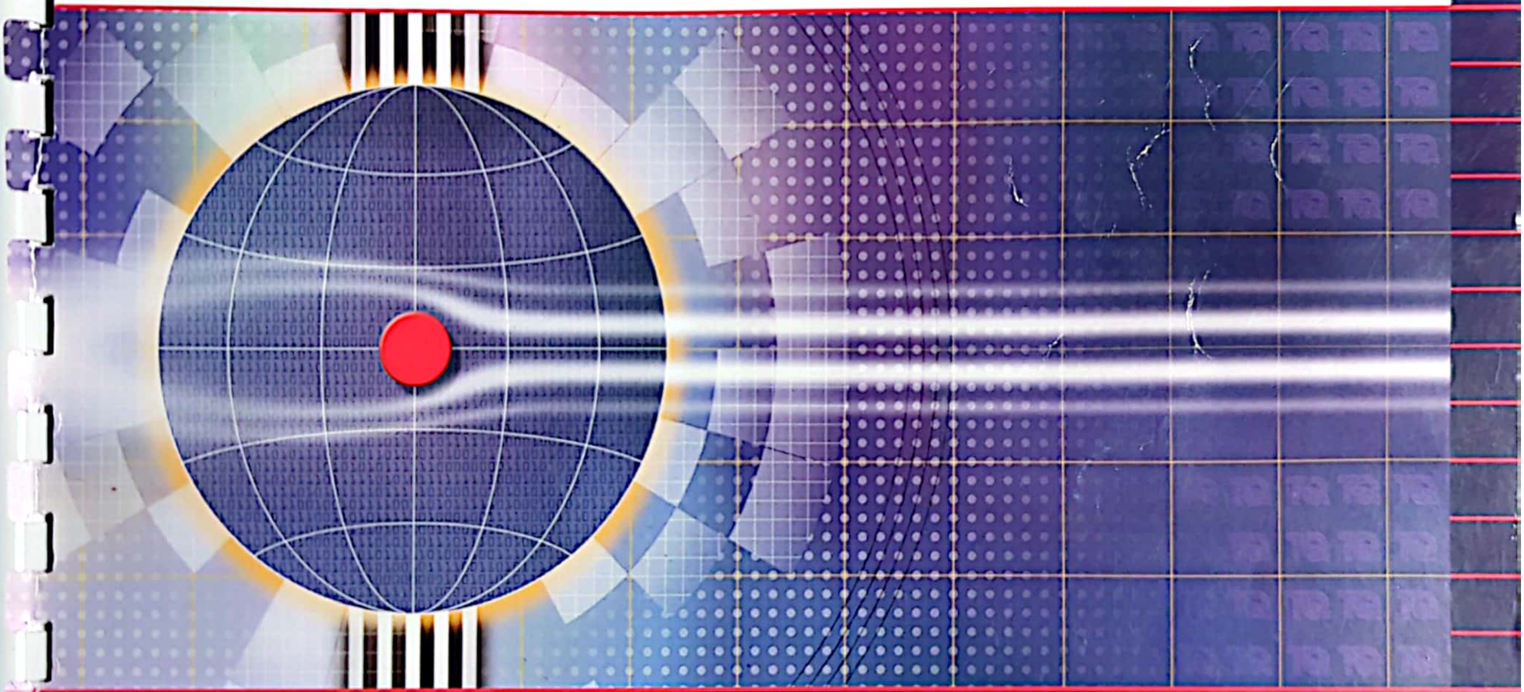
TecQuipment

H83

Two-stage Centrifugal Pump Test Set

User Guide



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TecQuipment has taken care to make the contents of this manual accurate and up to date. However, if you find any errors, please let us know so we can rectify the problem.

TecQuipment supplies a Packing Contents List (PCL) with the equipment. Carefully check the contents of the package(s) against the list. If any items are missing or damaged, contact TecQuipment or the local agent.

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TecQuipment

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Introduction

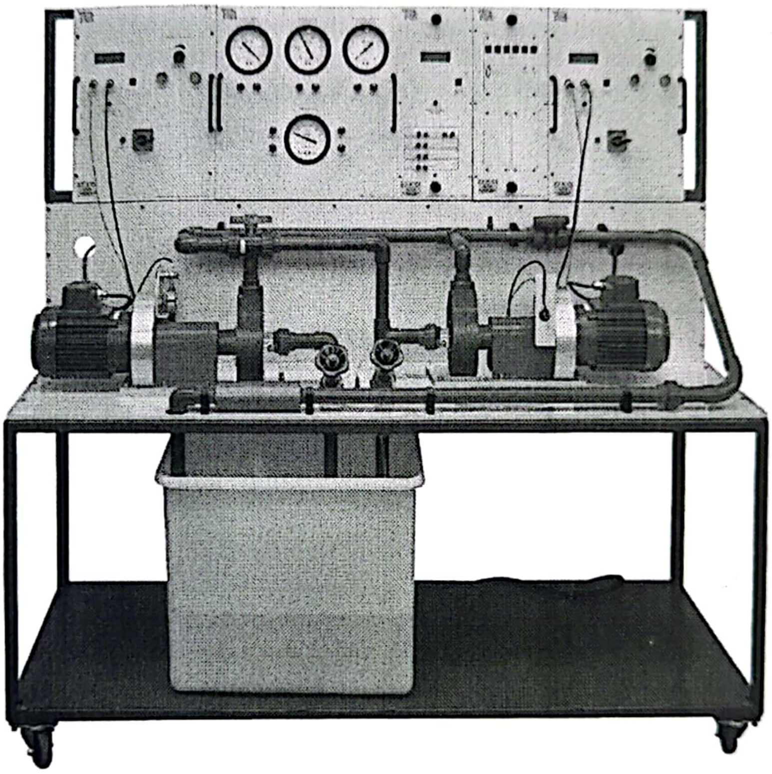


Figure 1 The H83 Two-stage Centrifugal Pump Test Set (shown with all optional instruments)

VDAS **This product works with VDAS®**

The Two-stage Centrifugal Pump Test Set is one of a range of different pump test sets made by TecQuipment Ltd. This Test Set is based on two simple, identical commercial pumps.

The compact and practical unit includes instruments, pipework and motor drives to allow students to do a range of single, parallel and series connected pump experiments and demonstrations.

Description

The pumps are mounted on a mobile frame that carries a water reservoir, pipework and instruments mounted on a rail. A variable speed motor drives each pump. Each of the two motor-to-pump assemblies include a force sensor (load cell) to measure motor torque, this forms a basic dynamometer. A tachometer sensor on each motor shaft measures angular velocity (pump speed). The cables from each motor and its sensors connect to each of two Motor Drives that locate in the Instrument Rail. Each Motor Drive includes stop, start and speed controls for the motor, and a display for the pump speed, torque and shaft power.

Water is drawn from the reservoir to each pump through strainers and one-way valves. The water then passes through pump inlet valves, through the pumps and out to an arrangement of pipework and valves until it finds its way back to the reservoir by means of a venturi meter. The arrangement of pipework and valves allows the pumps to be set for parallel or series flow conditions. Pressure tappings in the pipework and on the Venturi meter connect to the digital display and the optional analogue pressure display, mounted in the Instrument Rail. The Venturi meter is fitted to allow calculation of flow rate.

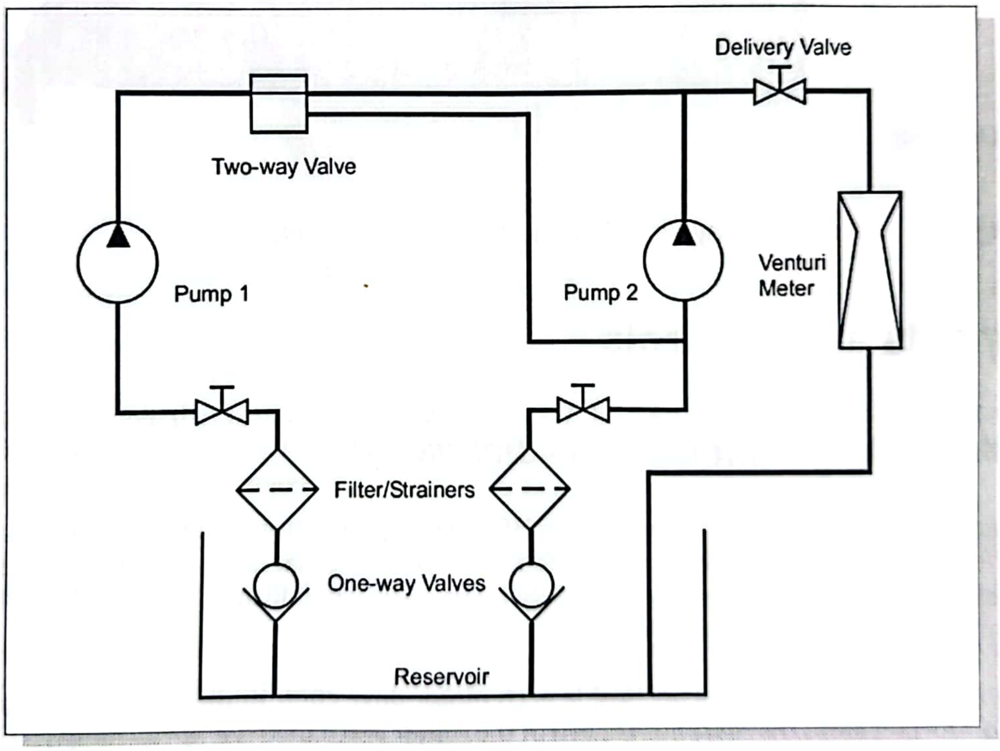


Figure 2 H83 Pipe Flow Layout

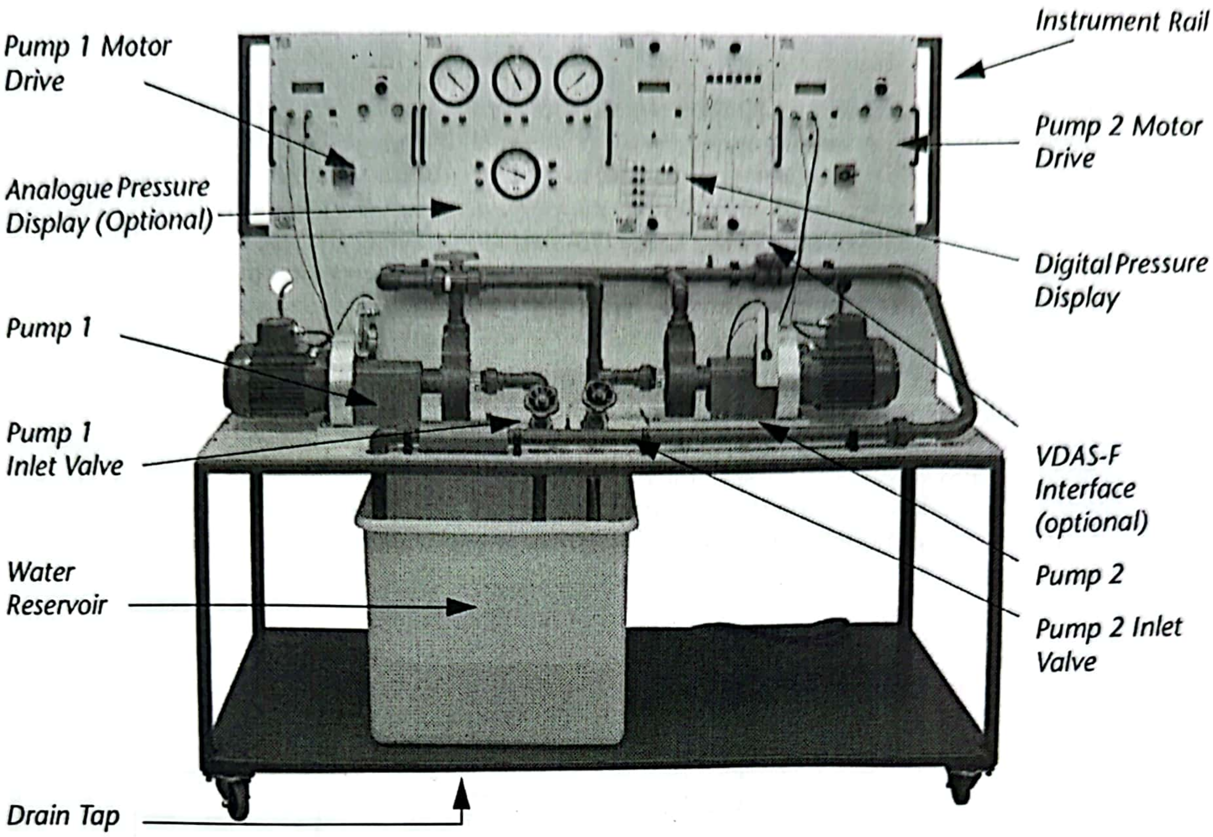


Figure 3 H83 General Layout - Shown with Optional Ancillaries

Instruments and Controls

Motor Drives (included as standard)

Each Motor Drive (there are two on the H83) has a stop button, a start button and a speed control for the pump drive motors. Each panel includes a display unit that displays speed, torque and automatically calculates power (power = torque x speed). The display unit includes a 'Digital Output' socket to link it to TecQuipment's optional VDAS®.

An electronic drive control unit inside each motor drive controls the speed of each pump motor. This control unit limits the maximum speed of the motor and includes a 'speed ramp', so that there is a short delay before the motor reaches the set speed. This prolongs the life of the motor and reduces the chances of damaging the dynamometer assembly. Additionally, to comply with european safety standards, the pump motors each have a thermal sensor (thermistor) to stop the drive in the unlikely event of the motor overheating.

NOTE *The pump motors will not run if you do not connect the thermistor cables (see installation details).*

On the back of each Motor Drive is a set of IEC outlets for connection to the instruments that fit into the Instrument Frame.

Pressure Displays

Determined by your order, the equipment may include the digital pressure display or the analogue display, but you may have both. The equipment includes 'T' pieces, so you can use both the Analogue and Digital Pressure Displays at the same time.

The Digital Pressure Display Module (DP1)

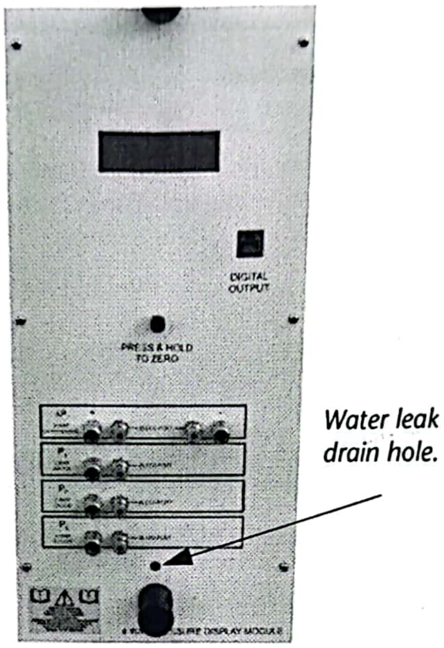


Figure 4 The Digital Pressure Display Module

This is a single module that locates in the Instrument Rail. It includes five tappings connected to four internal pressure transducers, the first transducer (ΔP_1) is a differential transducer and connects to the two tappings on the Venturi meter.

Pressure transducers P_2, P_3 and P_4 connect to the tappings in the pipework to give inlet and outlet pressures of the pumps as shown in Table 1.

Each pressure tapping includes a separate 'Bleed Port'. The bleed ports are needed to bleed trapped air from the pressure tapping pipework.

NOTE *Trapped air will give false pressure readings.*

The module includes a display for manual recording of results and a socket to link it to a VDAS® interface.

In the middle of the Pressure Display is a button marked 'Press and Hold to Zero Display'. Use this button to zero the pressure readings.

Pressure Transducer	Connects to
ΔP_1	Venturi Meter
P_2	Inlet of Pump 1
P_3	Inlet of Pump 2
P_4	Combined Pump Outlet (Delivery)

Table 1 Pressure Transducer Connections

CAUTION

As a safety feature, the Pressure Display includes a water leak 'witness' hole. If the transducer seals ever fail, the water will drain out of the drain hole at bottom of the module to indicate the fault.

If this happens, disconnect the module from the electrical supply. Do not use the module again unless a qualified engineer confirms that it is safe to use, or send the unit back to TecQuipment for repair.

The Optional Analogue Pressure Display (AP2)

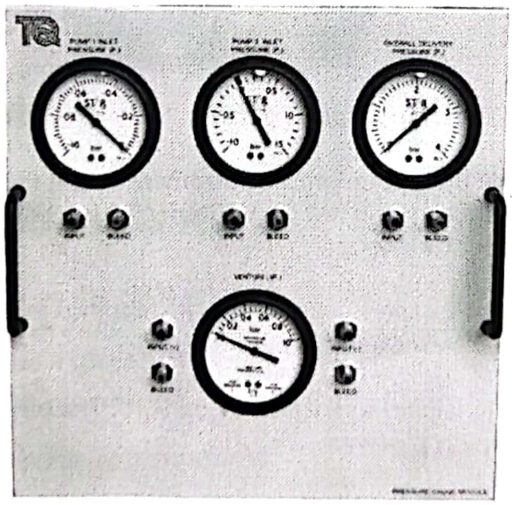


Figure 5 The Optional Analogue Pressure Display (AP2)

On this module, the three upper gauges measure the pump inlet (suction) and outlet (delivery) pressures. The inlet (suction) gauge for Pump 1 is a vacuum type gauge and operates in reverse to the delivery gauge. The inlet (suction) gauge for Pump 2 works as a suction and pressure gauge.

The lower gauge is a differential gauge, it shows the **pressure difference** between the two tappings on the Venturi Meter. Each gauge includes a bleed port to bleed out the trapped air at the beginning of each test.

The Bleed Line and Bleed Port Plugs

A bleed line is fitted to the apparatus, insert the end of the bleed line into a pressure port to bleed out any trapped air. The bleed line helps to stop water spillage. Trapped air and water is drained down to the reservoir (water moves up from the reservoir when a suction gauge is bled).

NOTE *Trapped air will give false pressure readings.*

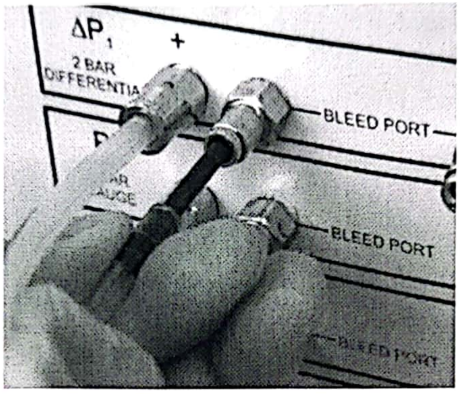


Figure 6 The Bleed Line Inserted into a Bleed Port (Shown inserted into the Digital Pressure Display)

You must keep the self-sealing bleed ports free from dust and dirt which may cause them to stop sealing correctly. To help prevent this, TecQuipment fit plastic plugs to the bleed ports of the Digital and Analogue Pressure Displays, which you must refit when you have completed your bleeding procedure. The plug also helps to reduce any chances of the pump suction pressure from drawing air through the bleed port and entering the pump, which would affect your results.

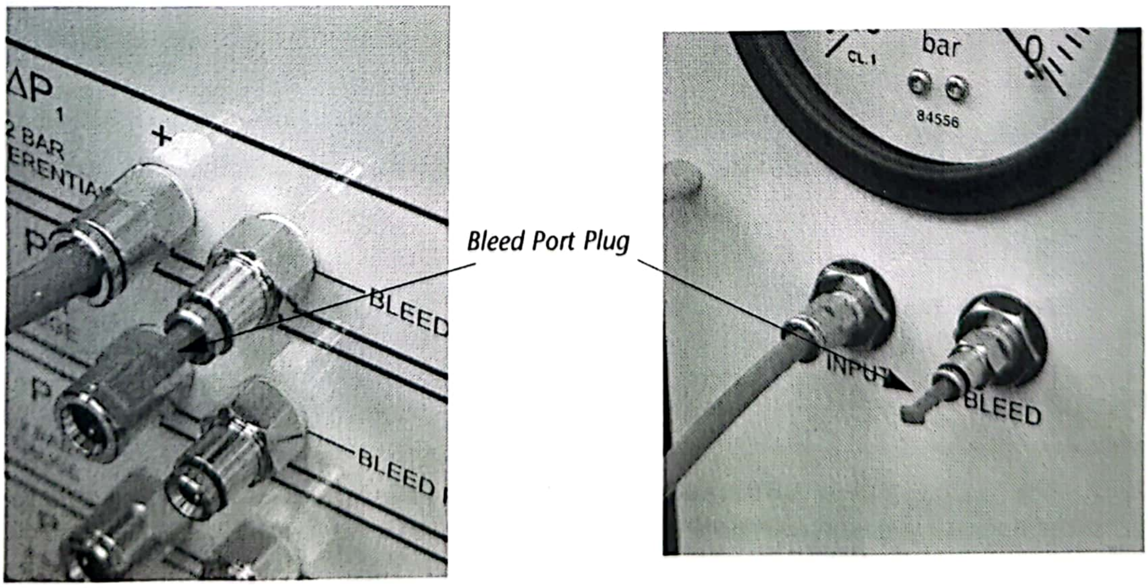


Figure 7 Bleed Port Plugs on Digital and Analogue Displays

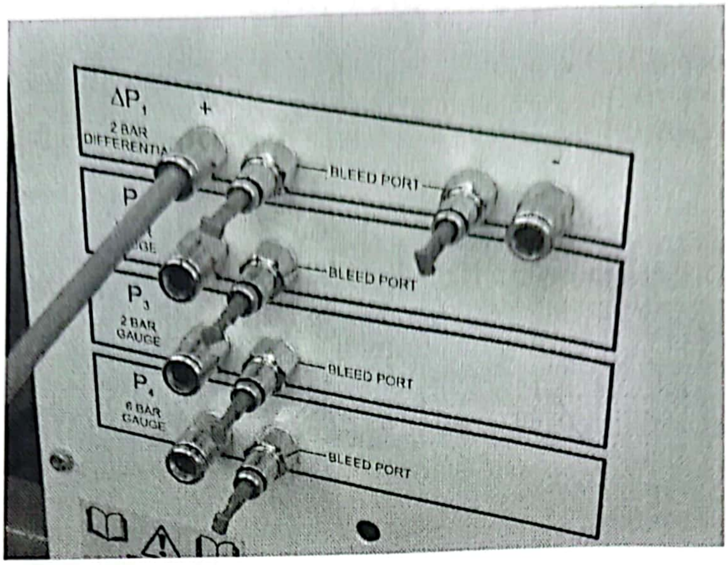


Figure 8 All Bleed Port Plugs Fitted

The Valves

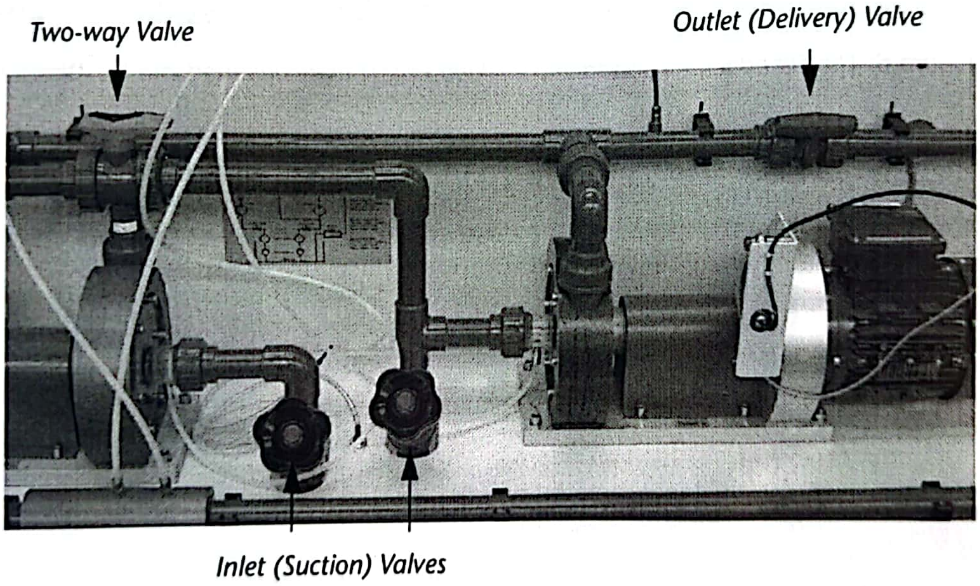


Figure 9 The Valves

CAUTION *When you use the valves, always turn them slowly. If you turn them quickly, you can create a 'water hammer' effect that may damage parts of the equipment.*

The Outlet (Delivery) Valve

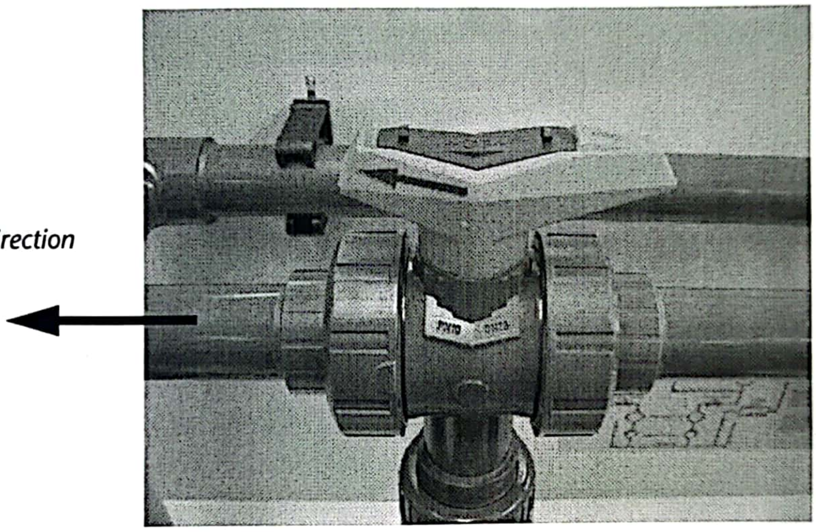
The Outlet Valve is manually controlled. When you shut it, the delivery pressure increases. When you open it, the delivery pressure decreases. It turns through 90°. It is open when it is in line with the pipe. It is shut when it is at 90° to the pipe.

The Inlet (Suction) Valves

The suction valves are manually controlled. When you shut them, the suction pressure increases. When you open them, the suction pressure decreases. Turn them clockwise to shut them and anticlockwise to open them.

The Two-way Valve

Flow direction



The two-way valve directs the flow from Pump 1 to the input of Pump 2 (for series flow), or directly to the delivery pipe (for single or parallel flow).

Turn the valve to position 1 (left) to direct flow straight to the delivery valve. Turn the valve to position 2 (right) to direct flow to the input of pump 2.

The Venturi Meter

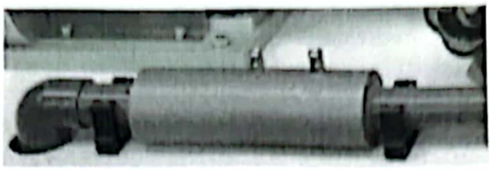


Figure 10 The Venturi Meter

The Venturi Meter is a flow measurement device. There are two pressure tappings on the Venturi, one at the inlet and the other at the throat. As the water passes along the Venturi, it causes a pressure difference between the two tappings. The pressure difference is related to the water flow rate, the greater the flow rate, the greater the pressure difference. You can calculate the water flow rate from the pressure difference. Refer to **'Flow Rate'** in **Useful Equations and Theory** for more details.

NOTE *If you use TecQuipment's VDAS®, the software will automatically calculate the flow rate for you.*

Versatile Data Acquisition System (VDAS®)

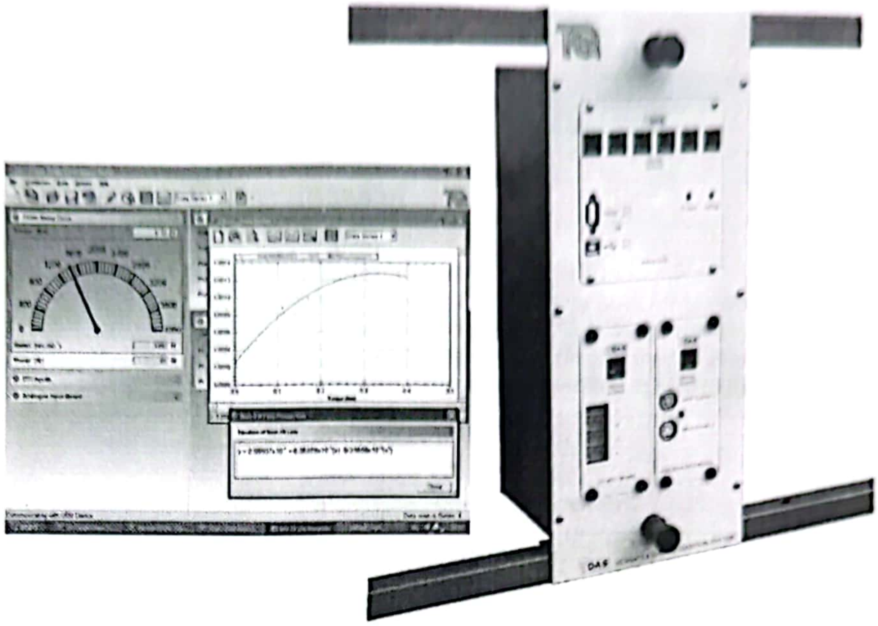


Figure 11 The VDAS® Hardware and Software

TecQuipment's VDAS® is a two-part product (hardware and software) that will:

- automatically log data from your experiments
- automatically calculate data for you
- save you time
- reduce errors
- create charts and tables of your data
- export your data for processing in other software

NOTE *You will need a suitable computer (not supplied) to use TecQuipment's VDAS®.*

Technical Details

Item	Details
Dimensions	Length 1670 mm, Depth 650 mm, Height 1590 mm
Weight (with both Motor Drives)	139.5 kg
Operating Environment	Altitude up to 2000 m Temperature range 5°C to 40°C Maximum relative humidity 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C Overvoltage category 2 (as specified in EN61010-1). Pollution degree 2 (as specified in EN61010-1).
Pumps	Centrifugal Total Head 120 $kN.m^{-2}$ Maximum Flow Approximately 2.2 $L.s^{-1}$
Pump Motors	3 Phase Induction Maximum Speed 3000 $rev.min^{-1}$
Electrical Supply (for each Motor Drive)	
Type	Single Phase with neutral and earth 220 VAC to 240 VAC 50/60 Hz Phase to phase with neutral and earth 220 VAC to 240 VAC 50/60 Hz
Maximum Current (with all instruments) Note: you only use one Motor Drive to supply power to the instruments.	12.5 A Supply must be rated at a minimum of 13 A.
Electrical Protection (each Motor Drive)	
Motor Drive	Double Pole Isolator and 16 A Double Pole MCB type B
Motor Drive Display Power Supply and IEC outlets for instruments	2 A Double Pole MCB type D ***Note: Maximum current output of IEC outlets for instruments is 2 A.***
External Electrical Connections (each Motor Drive)	Torque and speed input from motor: Extra Low Voltage (ELV) VDAS Socket: Extra Low Voltage (ELV) IEC outlets to rear: 4 way single phase with earth at incoming supply voltage

Digital Pressure Display (DP1)

Pressure Transducers	1 x Differential 2 bar 2 x 2 bar (gauge) 1 x 6 bar (gauge)
Electrical Supply and fuse	Input: 90 VAC to 250 VAC 50 Hz to 60 Hz 1 A (from Motor drive) 6.3 A Fuse type F
Weight	4 kg
External Electrical Connections	VDAS Socket: Extra Low Voltage (ELV)

Optional Analogue Pressure Display

Pressure Gauges	1 x Differential 0 to 1 bar 1 x -1 to 0 bar (gauge) 1 x -1 to 1.5 bar (gauge) 1 x 0 to 4 bar (gauge)
Weight	5.5 kg

The Pump Impeller

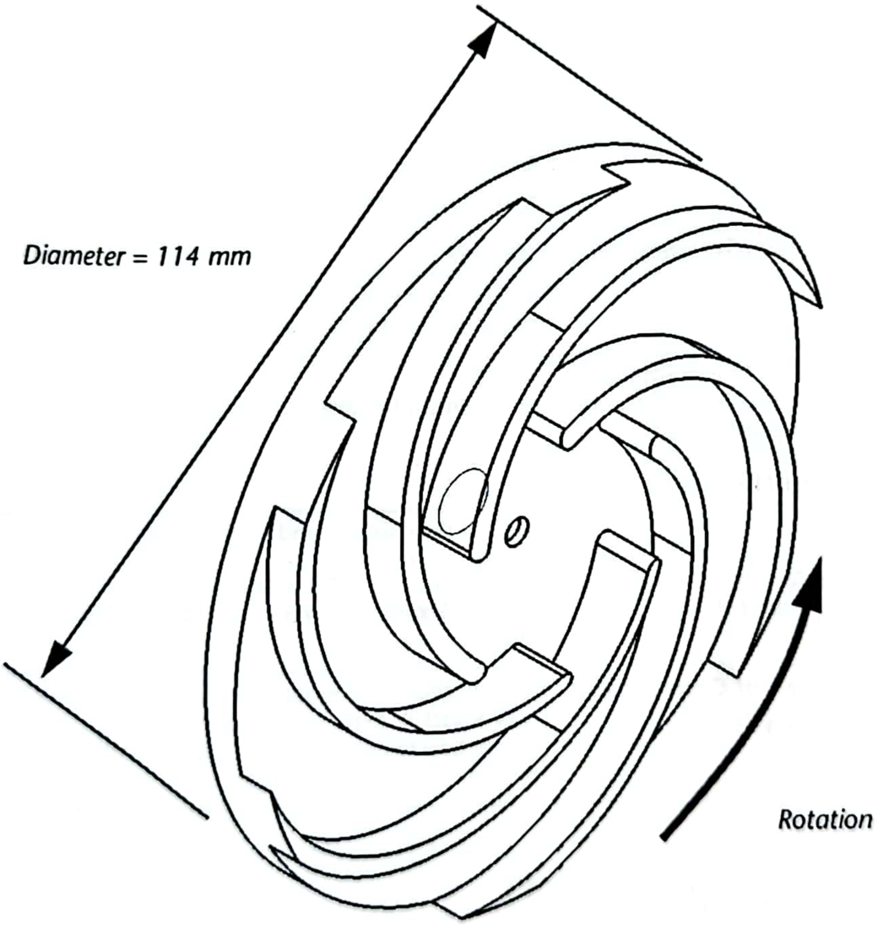


Figure 12 The Pump Impeller

Figure 12 shows a diagram of a typical impeller used in the pump body. The impeller has backward curved blades to give a reasonable delivery pressure with good flow and efficiency.

The Venturi

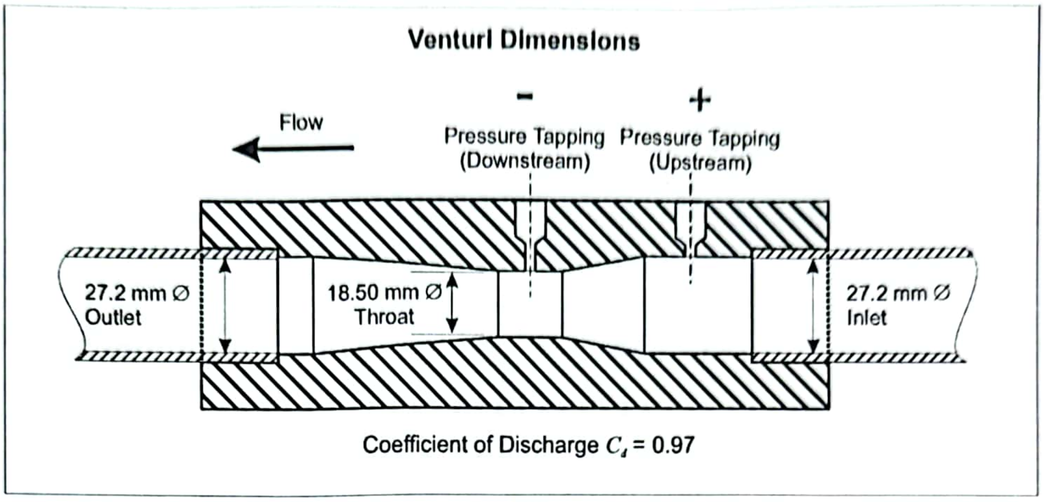


Figure 13 The Dimensions of the Venturi

Noise Levels

The noise levels recorded at this apparatus are lower than 70 dB (A).

Installation and Assembly

The terms **left, right, front** and **rear** of the apparatus refer to the operators' position, facing the unit.

NOTE

- *A wax coating may have been applied to parts of this apparatus to prevent corrosion during transport. Remove the wax coating by using paraffin or white spirit, applied with either a soft brush or a cloth.*
- *Follow any regulations that affect the installation, operation and maintenance of this apparatus in the country where it is to be used.*

Handling Instructions

WARNING ***Follow the correct handling procedures when moving this apparatus.***

Location

Use the H83 Test Set in a clean, well lit laboratory or classroom type area, on a solid level floor, preferably made of concrete.

WARNING ***Install and use this apparatus at least 2 m away from any electrical sockets or supplies.***

The apparatus occupies a floor area of 650 mm x 1670 mm. It is 1590 mm high. Allow at least 1 m of free space around each side of the apparatus for access.

Installation

1. Wheel the Test Set into position. Two of its wheels have brakes. Use them.
2. The instruments are stored for transport on the Instrument Rail at the back of the frame. Bands secure the instruments and the Water Reservoir for transport.
3. Cut the transport bands and carefully remove the instruments (see Figure 14) - you must lift them up and out of the rail. Place the instruments on a clean, flat surface.

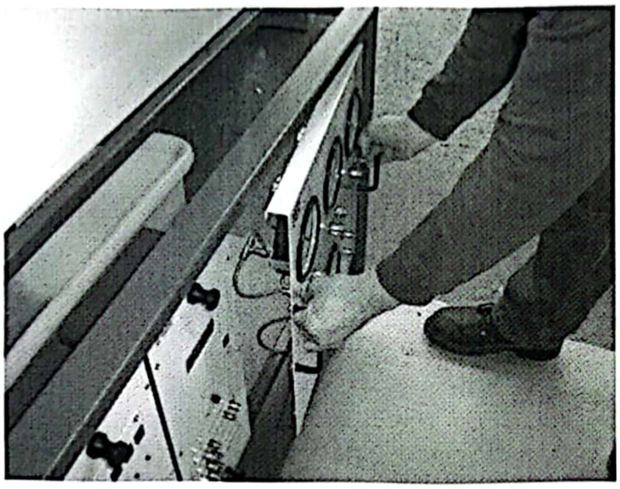


Figure 14 Remove the Instruments from the Instrument Rail

4. Undo the fixings of the red brackets that secure the Instrument Rail (see Figure 15) and remove the Instrument Rail from its storage hooks.

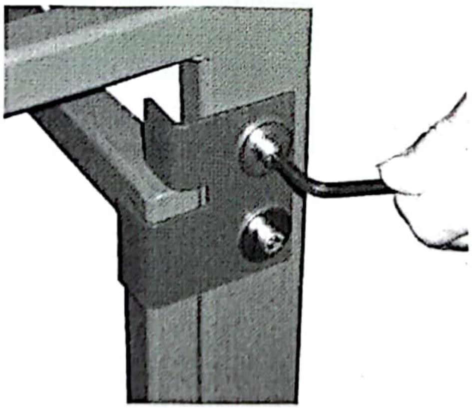


Figure 15 Undo the Red Brackets that Hold the Instrument Rail

5. Use the fixings (supplied) to fix the Instrument Rail to the top of the back panel (see Figure 16).

Figure 16 Fix the Instrument Rail to the Top of the Back Panel

6. Put the two Pump Motor Drives and the other Instrument Modules into the Instrument Rail. Figure 20 shows the recommended arrangement.

7. Fit the one-way valves to the pump inlet pipes, then connect the pump inlet pipes, including the connection to the two-way valve (see Figure 17). Tywrap the bleed pipe to the nearest inlet pipe.

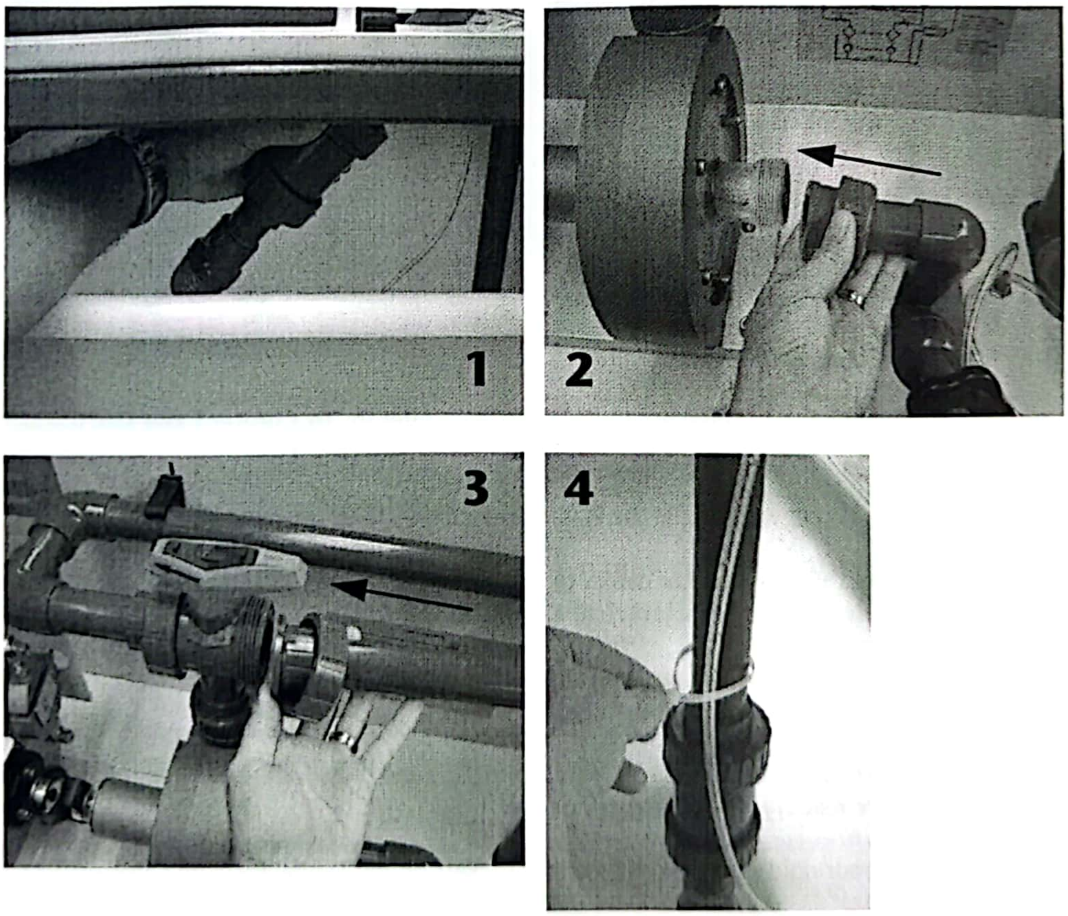


Figure 17 Fit the One-way Valve and Inlet Pipes

8. Cut the rigid pipe (supplied) to suitable lengths for connection of the pressure tappings on the pipework to the instruments as shown in Figure 19. Note that Figure 19 shows the connections for both the analogue and the digital pressure displays. **Do not insert the ends of the pipes into the Digital Pressure Display yet.**

9. The load cells on each pump dynamometer are fitted with a transit plate to prevent damage to the load cell when the H83 is transported. Loosen and remove the bottom and then the top screws of the transit plate from each load cell (see Figure 18). Store the transit plates safely, in case you need to transport the H83 again.

CAUTION *Undo the bottom screw first. This stops you accidently over-stressing the load cell.*

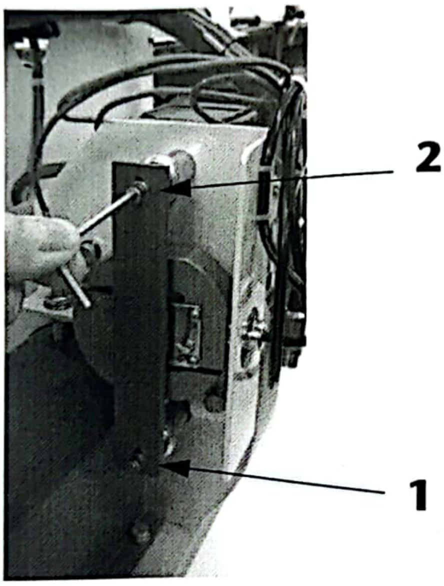


Figure 18 Remove the Transit Plate

10. If you have the optional modules and VDAS®, refer to: **To Connect the Optional VDAS®** on page 24.

11. Use clean cold water to fill the water reservoir to the fill level marker.

12. Connect the pump motor cables to the Motor Drives and connect the apparatus to the electrical supply as described in '**Electrical Connections**'.

13. Switch on the Motor Drives and check that the displays in the Digital Pressure Display and on the Motor Drives show some readings.

14. On the Digital Pressure Display, press and hold the button marked 'Press to Zero'. This has set the pressure readings to zero, ready for use.

15. Insert your rigid pipes into the correct sockets on the Digital Pressure Display.

CAUTION *Make sure the pipe connections are correct. Incorrect connections may cause damage to the gauges when pressure is applied.*

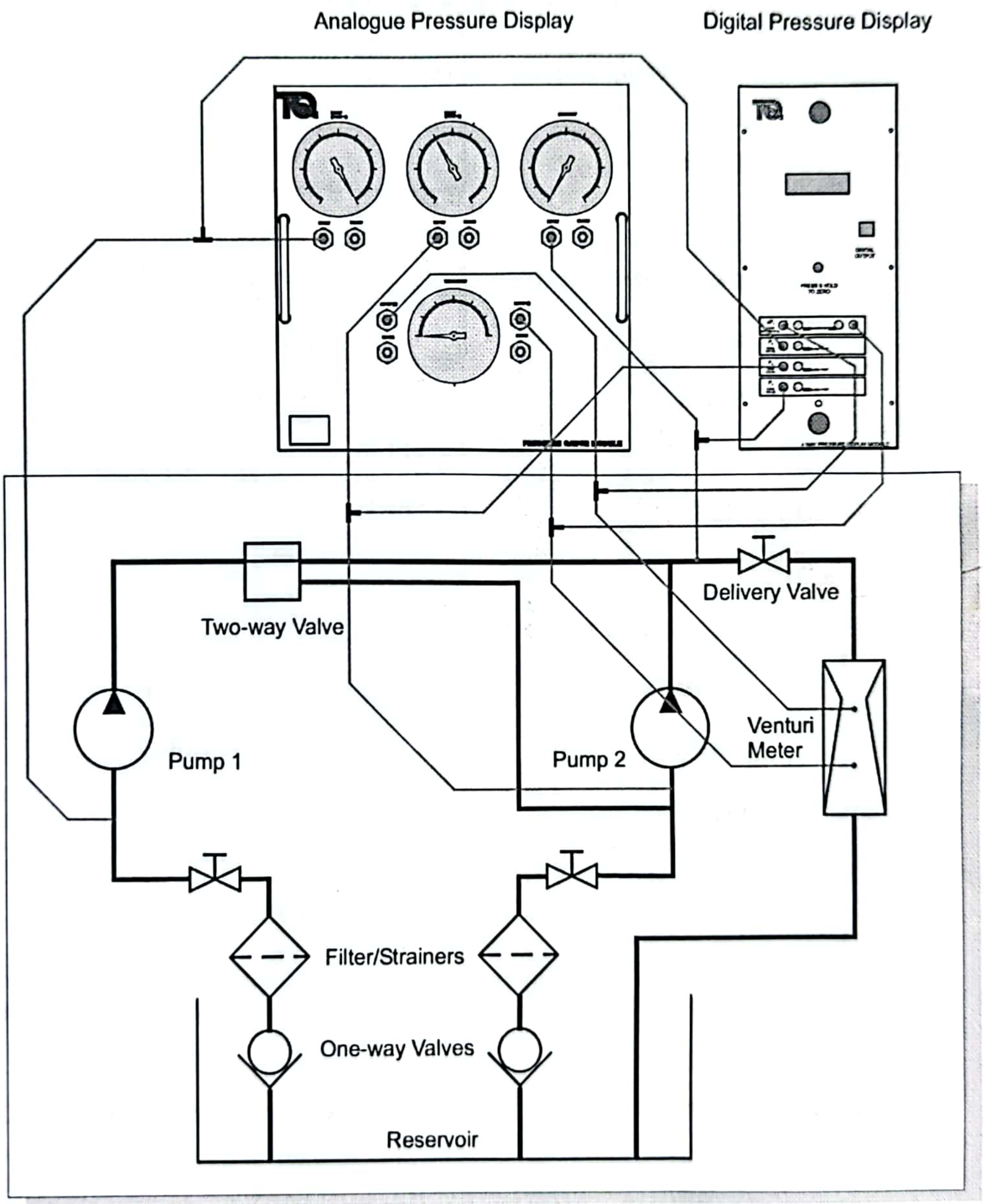


Figure 19 Pressure Pipe Connections (includes connections for both pressure displays)

Electrical Connections

Connect the two Motor Drives to an electrical supply using the cable(s) provided.

WARNING

Connect the apparatus to the supply through plugs and sockets.

The plugs and sockets are the mains disconnect devices. Make sure they are easily accessible.

The apparatus must be connected to earth.

Use this colour code to identify the individual conductors:

Phase to Neutral

GREEN AND YELLOW:	**EARTH E OR ⏚**
BROWN:	**LIVE**
BLUE:	**NEUTRAL**

Phase to Phase

GREEN AND YELLOW:	**EARTH E OR ⏚**
BROWN:	**LIVE 1 or Hot 1**
GREY:	**LIVE 2 or Hot 2**
BLACK:	**NEUTRAL**

Extra IEC Leads for the Instrument Modules

The instrument modules of the H83 are powered from the IEC sockets at the back of Pump 1 Motor Drive. Refer to Figure 20. TecQuipment supply male-to-female IEC leads with the equipment.

NOTE

Only use the IEC outlets from Pump 1 Motor Drive. Pump 2 Motor Drive is not switched on for some experiments.

CAUTION

The IEC outlets are only for use with the H83 modules. Do not use them for any other equipment.

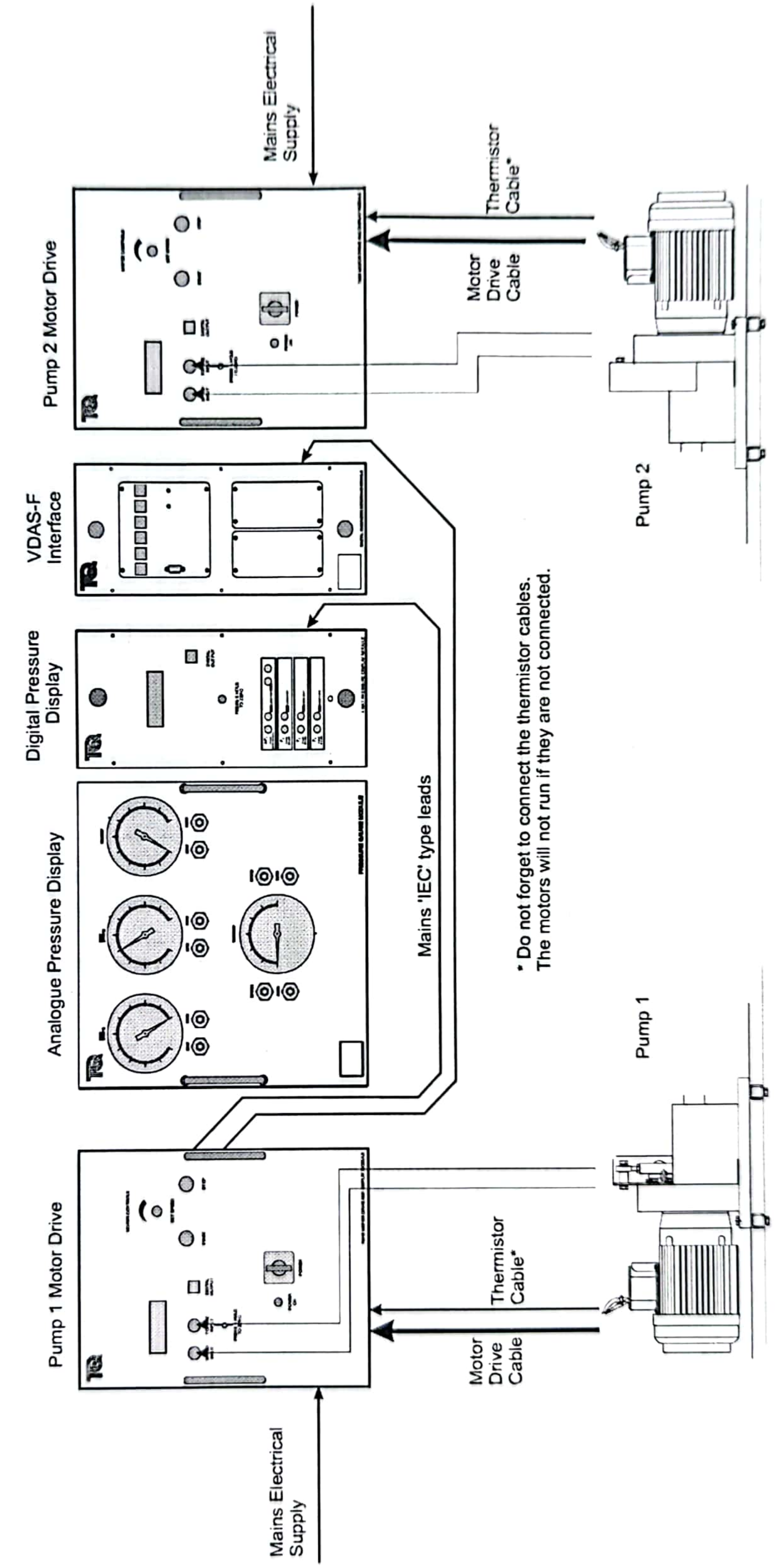


Figure 20 Full Electrical Connections (Includes the optional modules)

To Connect the Optional VDAS®

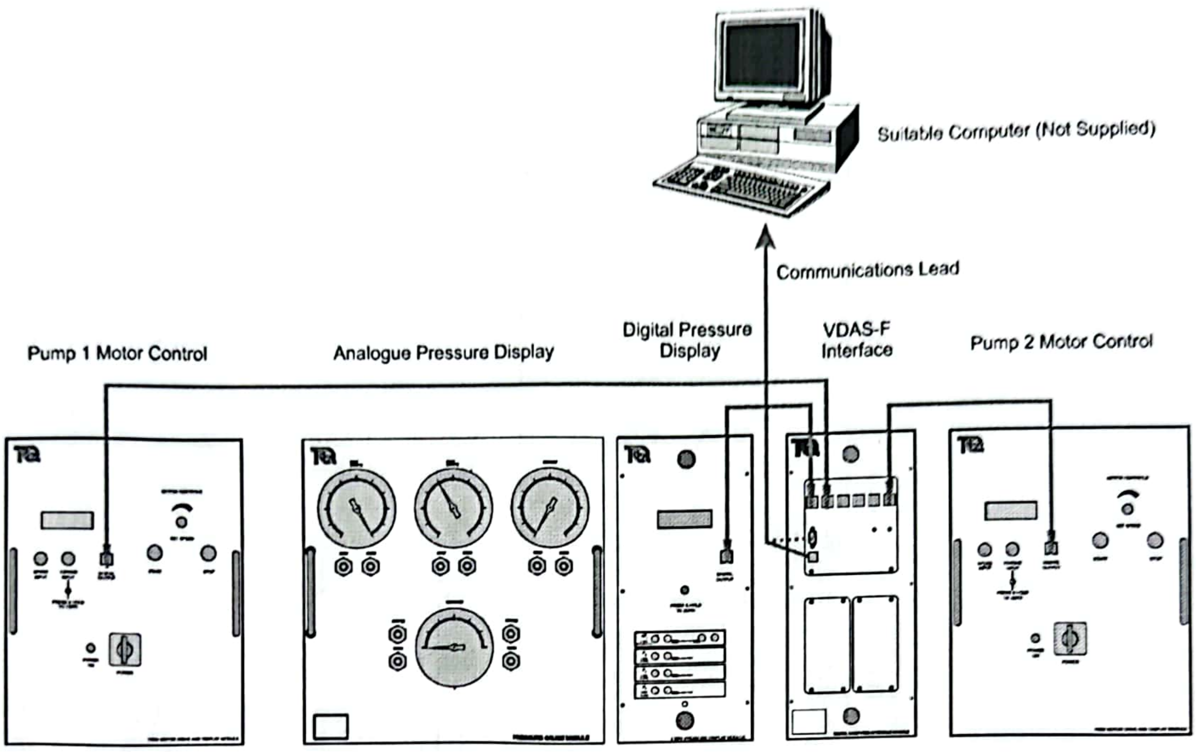


Figure 21 Connections From the Optional VDAS®

1. Connect a lead from the 'Digital Output' socket on the Digital Pressure Display and from the two Pump Motor Drives to any of the six sockets on the VDAS-F Interface.

2. Connect the USB (or RS232) lead from the VDAS-F Interface to a spare USB (or serial) socket on your computer.

NOTE *TecQuipment recommends that you use a modern computer with USB connection for use with VDAS®. TecQuipment do not supply an RS232 serial lead.*

Useful Equations and Theory

Notation

Pump Inlet Static Pressure	p_I	$N.m^{-2}$
Pump Delivery Static Pressure	p_O	$N.m^{-2}$
Volumetric Flow Rate	Q	$m^3.s^{-1}$
Pump Speed	N	$rev.min^{-1}$ or $Rad.s^{-1}$
Power Input to Pump	W_1	Watts
Hydraulic Power of Pump	W_2	Watts
Losses (W_1-W_2)	L	Watt
Efficiency of Pump	η	%
Impeller Diameter	D	m
Pipework Internal Diameter	d	m
Pump Total Head	H	Pa or $N.m^{-2}$
Acceleration due to gravity	g	$m.s^{-2}$
Torque	T	Nm
Viscosity	μ	Pa.s
Water Density	ρ	$kg.m^3$

Pump Performance

The performance of a centrifugal pump may be found by use of the 'Steady Flow Energy Equation'. In its simple form (where the working fluid is incompressible); the equation per unit time may then be written:

$$p_O Q - p_I Q = W_1 - L \qquad (1)$$

This equation states that the work done upon the fluid by the pump, ignoring kinetic energy and difference in level between pump inlet and outlet, is equal to the power input to the pump, less any losses.

A full explanation allows for the velocity heads at inlet and the outlet and the difference between static and total heads. These are not important for the H83 experiments, because the inlet and outlet water velocities are approximately equal.

Head

Total Head (H) is the pressure change across a pump (outlet pressure - inlet pressure).

For Total Head (in Pascals), you must use the equation:

$$H = p_O - p_I$$

Remember that the gauges display pressure in bar, so you must multiply your answer by 100000 to give H in Pascals.

For single (Pump 1) tests, the total head is simply the difference between the inlet and outlet pressure.

For parallel pumps tests, you must take an average of the two inlet pressures and subtract this from the combined outlet pressure. The inlet pressures should be very similar if the pumps run at the same speed.

For series pump tests, you use the inlet pressure of the first pump and subtract it from the outlet pressure of the second pump.

NOTE *The inlet pressure is indicated as a negative (suction) pressure, include this when you calculate the Total Head.*

Hydraulic Power

The hydraulic power (sometimes known as 'water horsepower') of the pump is given by:

$$W_2 = (p_O - p_I)Q \qquad (2)$$

Efficiency

The overall efficiency of the pump is given by:

$$\eta = \frac{W_2}{W_1} \qquad (3)$$

Power Input

The power input to the pump is given by:

$$W_1 = \frac{2\pi NT}{60} \text{ (where N = rev.min}^{-1}\text{)} \qquad (4)$$

NOTE *The H83 Motor Drive Display already calculates the power input to the pump for you.*

Flow Rate

NOTE *If you use TecQuipment's optional VDAS®, the software will automatically calculate the flow for you.*

To calculate the flow rate (Q) (in $m^3.s^{-1}$) from the pressure drop along the venturi, use the formula:

$$Q = C_d A_1 \sqrt{\frac{2\Delta p}{\rho\left(\frac{A_1^2}{A_2^2} - 1\right)}}$$

Where:

A_1 = Venturi Inlet Area (m^2)
A_2 = Venturi Throat Area (m^2)
C_d = Coefficient of discharge
ρ = Water density ($kg.m^3$) - For clean water at room temperature you may use 1000 $kg.m^{-3}$ for calculations)
Δp = Pressure drop across the venturi (Pascals or $N.m^{-2}$)

Refer to **Technical Details** on page 13 for the Venturi dimensions.

Unit Conversions

To convert the flow rate from $m^3.s^{-1}$ to $L.s^{-1}$ multiply by 1000. (1 $m^3.s^{-1}$ = 1000 $L.s^{-1}$)

To convert pressure from bars to Pascals, multiply by 100000. (1 bar = 100000 Pa)

Similarity Laws

When a mechanical engineer chooses a new pump or tests an existing pump to do a certain job, they can save time and money if they test a small pump to estimate the performance of an identical but larger pump.The engineer can then use dimensional analysis and similarity laws to reduce the amount of measurements they need and to provide a compact presentation of the results.

The dimensionless groups commonly used to express the similarity laws are:

$$C_Q = \text{Flow coefficient} = \frac{Q}{ND^3} \qquad (5)$$

$$C_H = \text{Head coefficient} = \frac{gH}{N^2D^2} \text{ or } \frac{H}{\rho N^2 D^2} \qquad (6)$$

$$C_P = \text{Power coefficient} = \frac{W_2}{\rho N^3 D^5} \qquad (7)$$

$$Re = \text{Reynolds Number, based on rotor dimension} = \frac{\rho N D^2}{\mu} \qquad (8)$$

All these equations assume that N = rad.s^{-1}.

The coefficients will allow you to plot all the information on one chart for a given design. The Reynolds number is based on the impeller dimension of the pump and will change for different pump speeds. It is useful to note the change in Reynolds number over a range of pump speeds.

The dimensionless equations are not perfectly correct - there some minor problems. Refer to a suitable fluid mechanics textbook for more details.

Pump Tests

Safety

WARNING

If you do not use the equipment as described in these instructions, its protective parts may not operate correctly.

Never operate the motor controls or electrical supply with wet hands.

Clean up water spills immediately.

Never operate the apparatus with any covers or guards removed.

WARNING

The water in this apparatus can reach pressures of greater than 2 bar.

Wear suitable clothes and eye protection when using this equipment.

CAUTION

Never block the main outlet pipe. Pressure will build up in the venturi and cause damage to the venturi seals.

Initial Setup and Checks

Before the apparatus is first used, the pumps must contain water. The pumps must never run without water. The one way valves in the inlet pipes to the pumps will normally hold water in the pipework up to and inside the pumps for several days, so this procedure does not need to be done each time the apparatus is used.

The pumps must be filled (primed) if the apparatus has been unused for several weeks and before the first use of the apparatus.

CAUTION

Never run the pumps without water. They will be damaged.

To Prime the Pumps:

1. Make sure that all the pressure pipes are connected.
2. Switch off the Motor Drive isolators.
3. Fully open the Pump inlet (suction) valves. Undo the upper pipe connections on the pump (see Figure 22).

4. Use a suitable container to pour water into the pump body (see Figure 23). This may take several minutes, the water is actually filling the pump body and the inlet pipe all the way down to the one way valve. Stop when the pump body is full and water comes back out the hole.

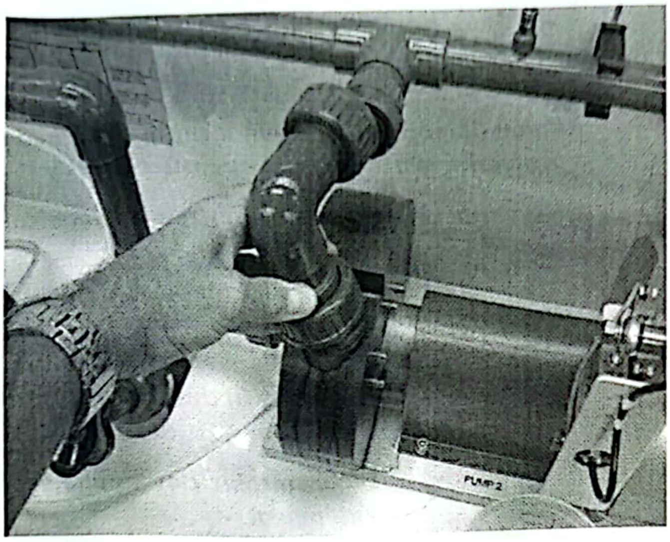


Figure 22 Undo the Upper Pipe Connections

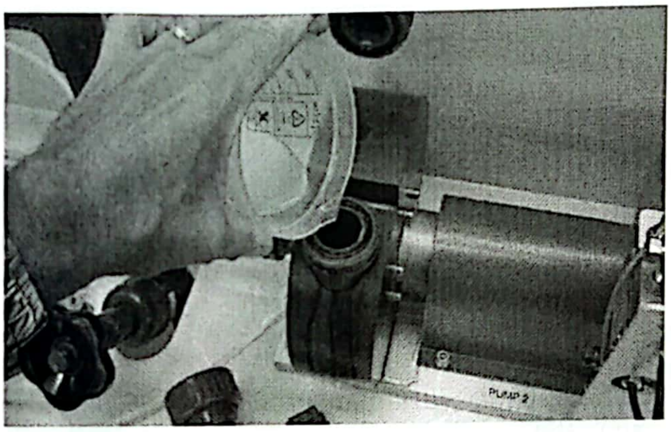


Figure 23 Use a Suitable Container to Fill the Pump with Water.

5. Refit the pipe connections and clear up any spills.
6. Turn Pump 1 motor speed control to zero.
7. Reconnect the electrical supply and switch ON the mains isolator at each pump Motor Drive.
8. Start pump 1. Slowly turn its speed control to 2000 rev.min^{-1}. Water is flowing when you see a pressure drop across the Venturi meter.
9. The water will start to circulate around the pipework and force out any trapped air. It will fill pump 2 and the pipework around pump 2 inlet. It may take several seconds before this happens.
10. Start pump 2. Slowly turn its speed control to 2000 rev.min^{-1}.
11. Watch the water in the reservoir. The flow will become steady when all the air is forced out.

12. Check for leaks in the pipework. Turn the motor speed controls down to zero and press the motor stop buttons.

13. The apparatus is now ready for use.

Normal Start Up:

1. Make sure the reservoir is filled with clean water to the fill level marker.
2. Make sure the pumps have been used recently and are full of water. If not, refer to the **Initial Setup and Checks** on page 29.
3. Switch ON the mains isolator at each Motor Drive.
4. Set the valves as described in the tests.
5. Start the motor (or motors).
6. Use the bleed line to bleed the pressure gauges.
7. Adjust the motor speed to the speed suitable for the experiment.

Normal Shut Down:

1. Reduce the motor speed controls down to zero.
2. Press the motor stop button.
3. Switch OFF the mains isolator at each Motor Drive.

Emergency Shut Down:

Switch off the mains isolator at each Motor Drive.

Important Notes

Pump Tests are made easier if two students work together. One student operates the controls, while the other student records results.

CAUTION *Do not run the pumps for long periods with the inlet and outlet valves fully closed.*

NOTE *Gently 'tap' each mechanical gauge as you take its reading. This will reduce any errors caused by friction in the mechanism of the gauge.*

When you stop the pumps, the pressure gauges will show a slight negative reading. This is normal, it is due to the head of water in the pressure pipes.

Standard Performance Test - Single Pump

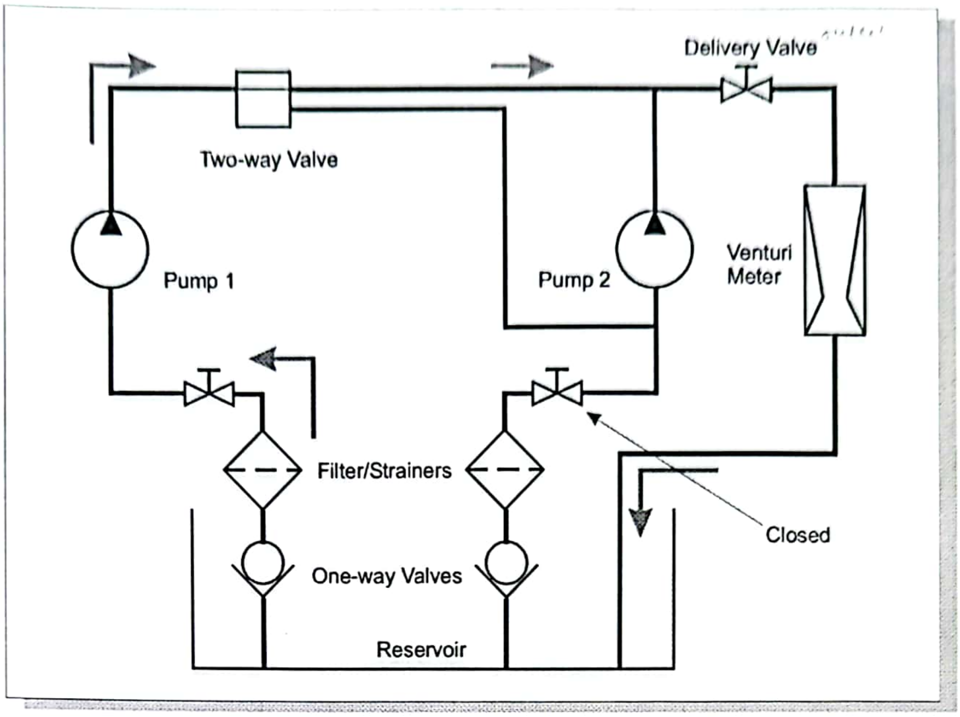


Figure 24 Flow Diagram for A Single Pump Test

NOTE *If you are to use VDAS, the series calculated parameters work for both series and single pump test results, as they use the inlet pressure of pump 1 and the delivery pressure, exactly as in the series tests.*

1. Create a blank results table similar to Table 2.
2. Use Pump 1 only. Switch off both Motor Drive isolators.
3. Close Pump 2 inlet valve and set the two-way valve to direct flow straight to the delivery pipe (see Figure 24). Fully open Pump 1 inlet and the delivery valve.
4. Switch on Pump 1 Motor Drive isolator. Start the pump motor and run it to maximum speed.
5. Use the bleed line to bleed all pressure gauges.
6. Adjust the motor to the speed needed for the experiment - normally 3000 rev.min^{-1}.
7. Make sure the delivery valve is fully open. Re-adjust the motor speed if necessary. Record all pressure readings.
8. In 0.1 bar steps, use the delivery valve to increase the outlet pressure. **Do not adjust the inlet valve.** At each step, adjust the motor speed back to its initial setting and take pressure readings.
9. Plot graphs of efficiency, power input and total head against flow rate. Note: If you use the TecQuipment VDAS® and the Digital Pressure Display for this test, H (in Pa) = $P_4 - P_2 \times 100000$.

10. Plot the dimensionless characteristics of head coefficient and power coefficient against flow coefficient. Calculate the Reynolds number.

Extra Experiment - Reynolds Number

Repeat the performance test at a range of speeds.

Calculate and compare the Reynolds Number for each speed.

Standard Performance Test - Parallel Pumps

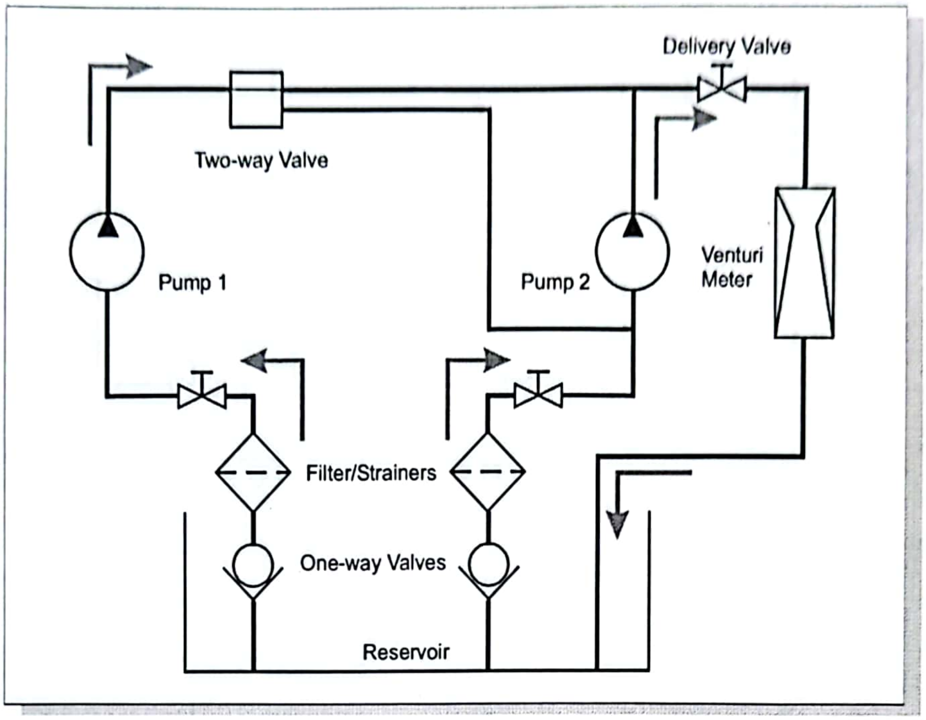


Figure 25 Flow Diagram for A Parallel Pump Test

1. Create a blank results table similar to Table 2.
2. Use both pumps. Switch off both Motor Drive isolators.
3. Open both inlet valves and set the two-way valve to direct flow straight to the delivery pipe (see Figure 25). Fully open the delivery valve.
4. Switch on both Motor Drive isolators. Start the pump motors and run them to maximum speed.
5. Use the bleed line to bleed all pressure gauges.
6. Adjust the motors to the speed needed for the experiment - normally 3000 rev.min^{-1}.
7. Record all pressure readings.
8. In 0.1 bar steps, use the delivery valve to increase the outlet pressure. Do not adjust the inlet valve. At each step, adjust the motor speed back to its initial setting and take pressure readings.
9. Plot graphs of efficiency, input power and total head against flow rate. Note: If you use the TecQuipment VDAS® and the Digital Pressure Display for this test, H (in Pa) = $P_4 - [(P_2+P_3)/2] \times 100000$.

Standard Performance Test - Series Pumps

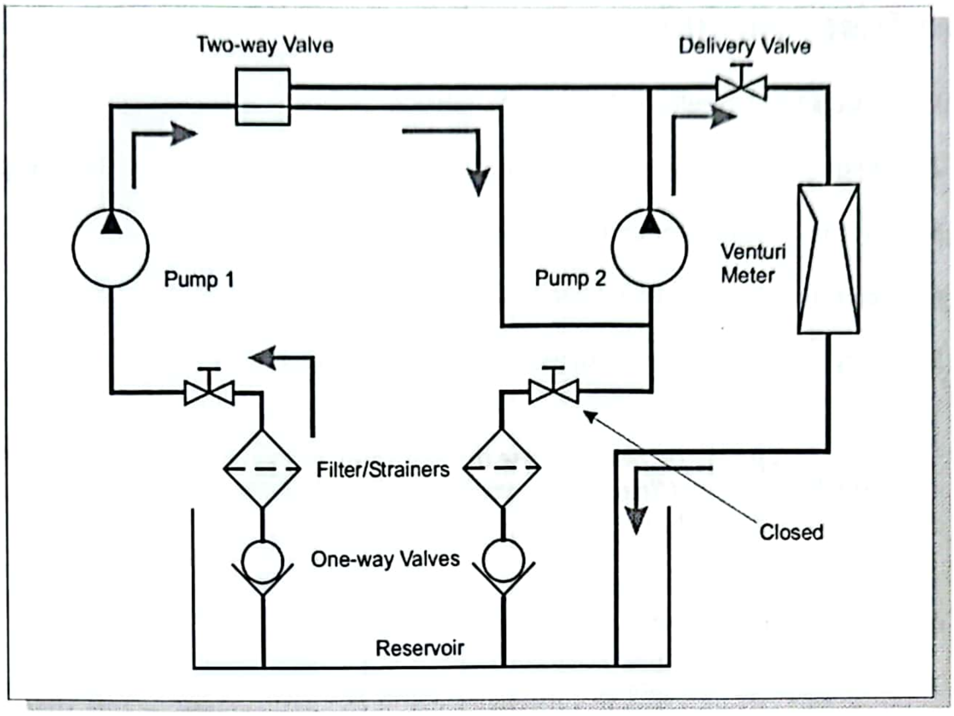


Figure 26 Flow Diagram for a Series Pump Test

CAUTION *Connect the pressure displays correctly. The outlet pressure of two series pumps will exceed 2 bar and will damage the pressure displays if you do not connect them correctly.*

1. Create a blank results table similar to Table 2.
2. Use both pumps. Switch off both Motor Drive isolators.
3. Open Pump 1 inlet valve. Close Pump 2 inlet valve. Set the two-way valve to direct flow straight to the inlet of pump 2 (see Figure 26). Fully open the delivery valve.
4. Switch on both Motor Drive isolators. Start the pump motors and run them to maximum speed.Use the bleed line to bleed all pressure gauges.
5. Adjust the motors to the speed needed for the experiment - normally 3000 rev.min^{-1}.
6. Slowly adjust the delivery valve to give a suitable delivery (outlet) pressure of 0.3 bar. Re-adjust the motor speeds if necessary. Record all pressure readings.

NOTE *Pump 2 inlet pressure is Pump 1 outlet pressure. This pressure is useful for comparison, but not used in the calculations.*

7. In 0.2 to 0.3 bar steps, use the delivery valve to increase the outlet pressure. Do not adjust the inlet valves. At each step, adjust the motor speed back to its initial setting and take pressure readings.

8. Plot graphs of efficiency, power and total head against flow rate. Note: If you use the TecQuipment VDAS® and the Digital Pressure Display for this test, H (in Pa) = $P_4 - P_2 \times 100000$.

Suction Test - Single Pump

1. Create a blank results table similar to Table 2.
2. Set Pump 1 and its valves as in **Standard Performance Test - Single Pump**.
3. Start the pump motor and run it to 3000 rev.min^{-1}.
4. Record the speed and total head.
5. Slowly close Pump 1 inlet (suction) valve in steps of 0.05 bar.

NOTE *Do not fully close the inlet valve. At each step, look at the Venturi pressure difference. Stop your test before the pressure difference becomes near to zero (no flow).*

6. At each step, re-adjust the pump speed if necessary and record the flow rate.
7. Plot a graph of flow rate against suction (inlet) pressure.

Cavitation Demonstration - Single Pump

1. Set Pump 1 and its valves as in **Standard Performance Test - Single Pump**. Run the motor to maximum speed.
2. Gradually close Pump 1 inlet valve. The pump noise will increase and water vapour bubbles will appear in the reservoir around the outlet pipe. The pump is cavitating.

CAUTION *Do not run the pump cavitating for more than a few minutes at a time. This will damage the pump.*

At a certain point the pump ceases to deliver water because of the formation of a partial vacuum in the eye of the impeller. You may need to re-prime the pump after this test.

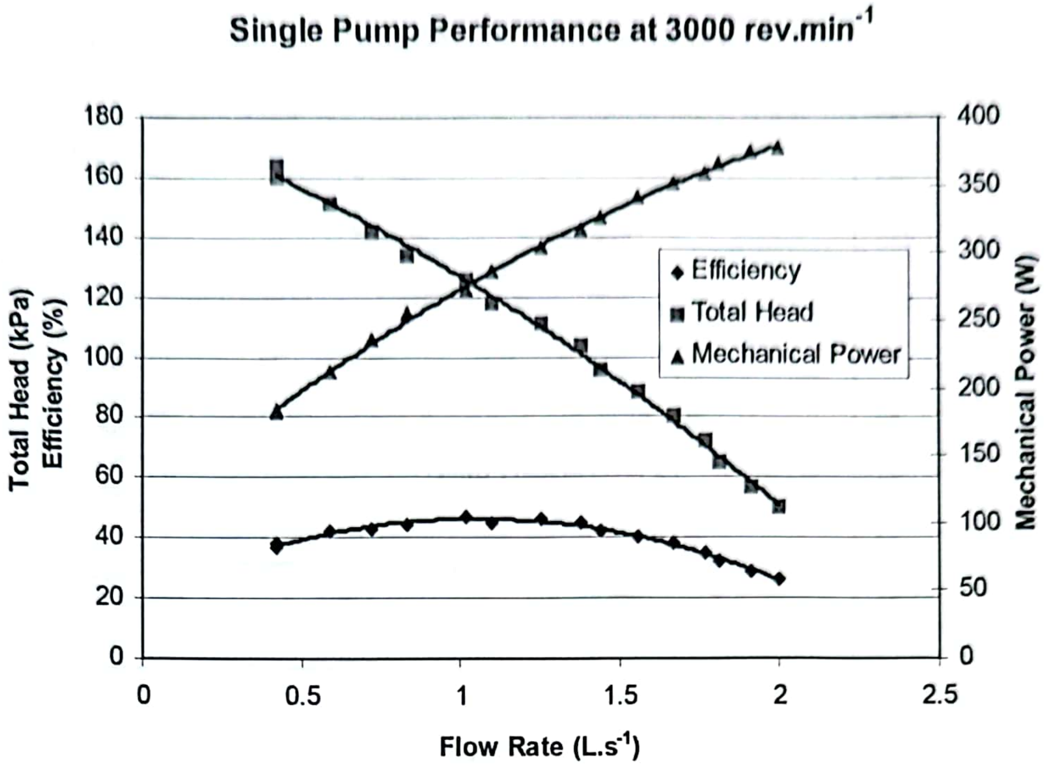
If you have the optional stroboscope, hold the stroboscope near to the transparent window of the pump. Adjust the strobe frequency until you see a steady image of the pump impeller and the water vapour bubbles. You may need to darken your laboratory or classroom to see the image more clearly.

H83 Two-stage Centrifugal Pump Test Set				**Test Type:** Single/Parallel/Series/Suction							
Pump 1 Inlet (Suction) Pressure P_2 (bar)	**Average pump inlet pressure (Parallel Tests only)**	**Pump 2 Inlet (Suction) Pressure P_3 (bar)**	**Outlet (Delivery) Pressure P_4 (bar)**	**Total Head H (kPa)**	**Pump 1 Speed N (rev.min^{-1})**	**Pump 2 Speed N (rev.min^{-1})**	**Venturi pressure difference (Δp)**	**Flow (L.s^{-1})**	**Total Power Input W_1 (Watts)**	**Total Hydraulic Power (Watts)**	**Efficiency (%)**
Date:				Atmospheric Pressure:				Ambient Temperature:			

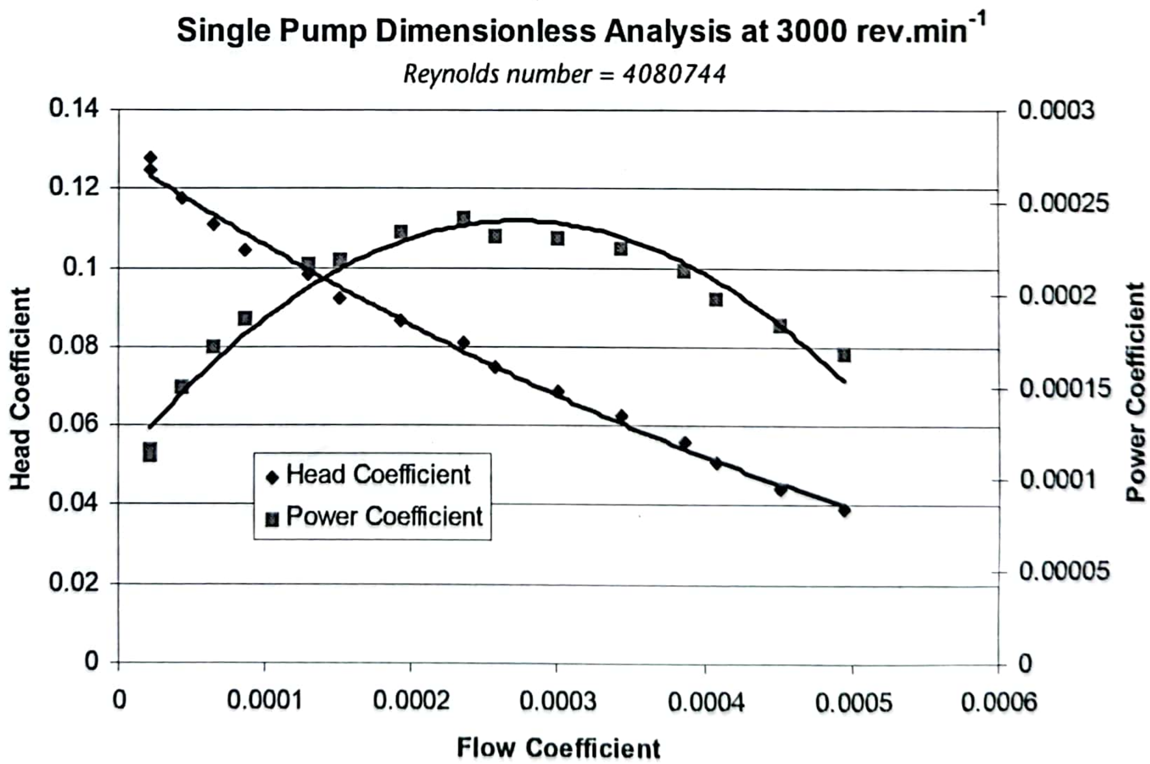
Table 2 Blank Results Table

Results

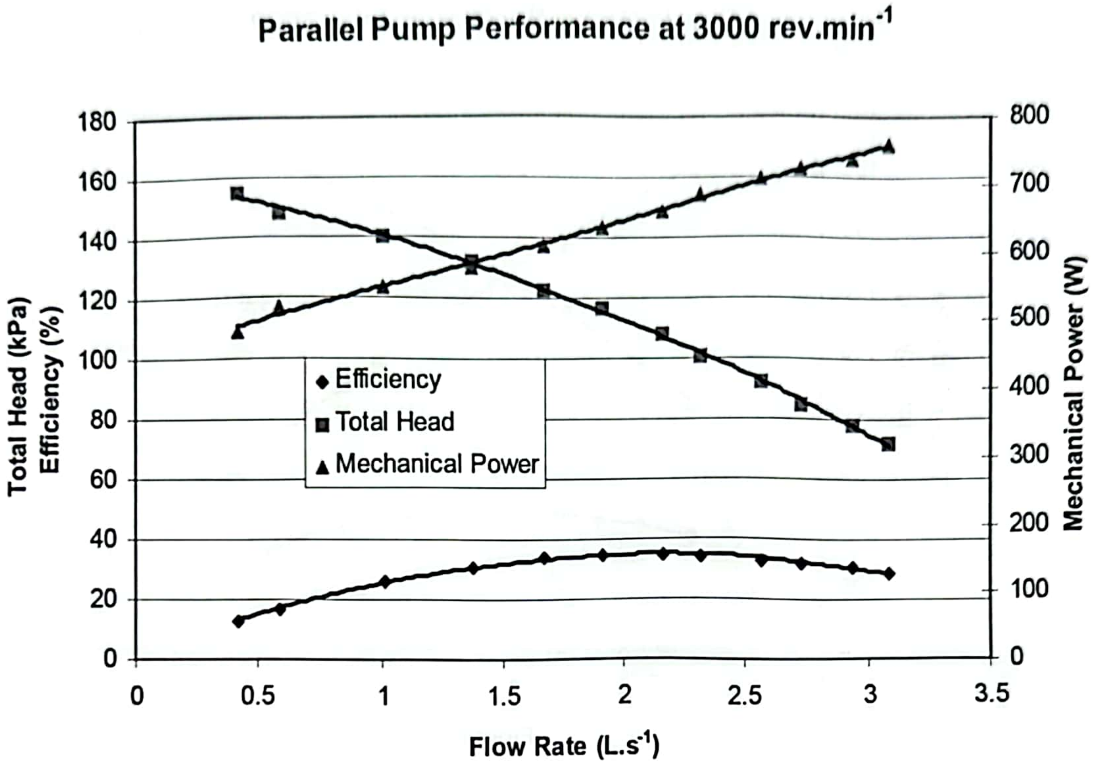
All results are for reference only. Actual results may differ slightly.



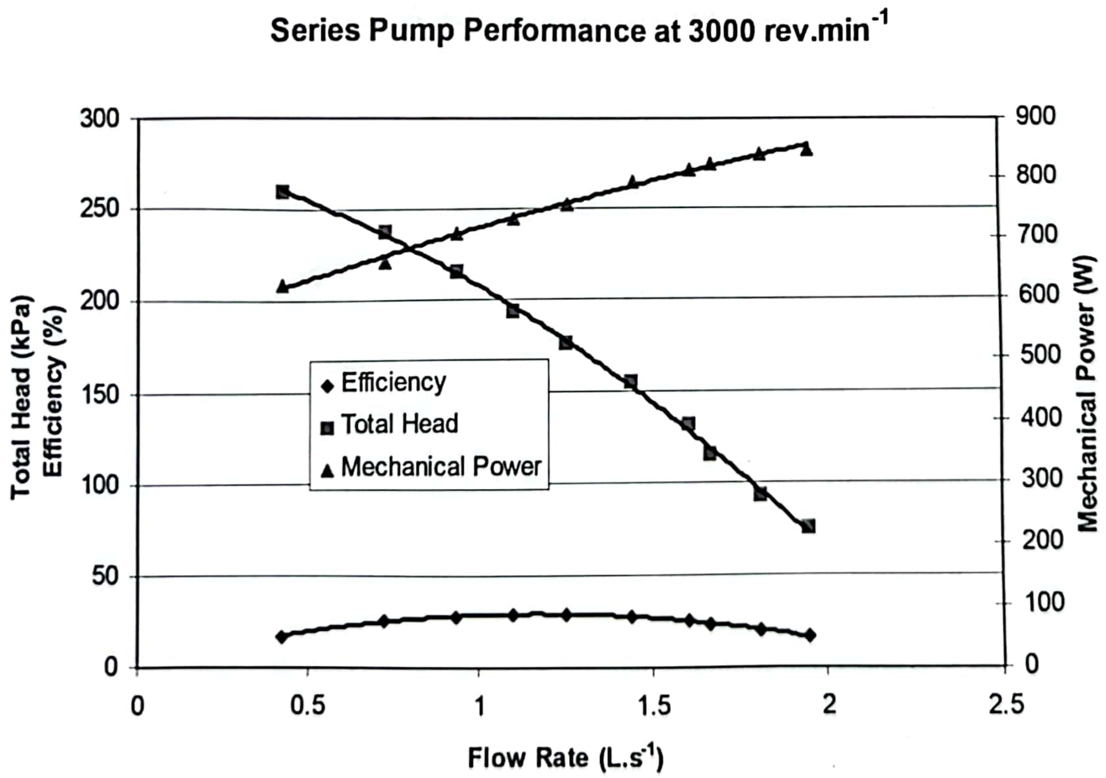
Graph 1 Results for Single Pump Test at 3000 rev.min^{-1}



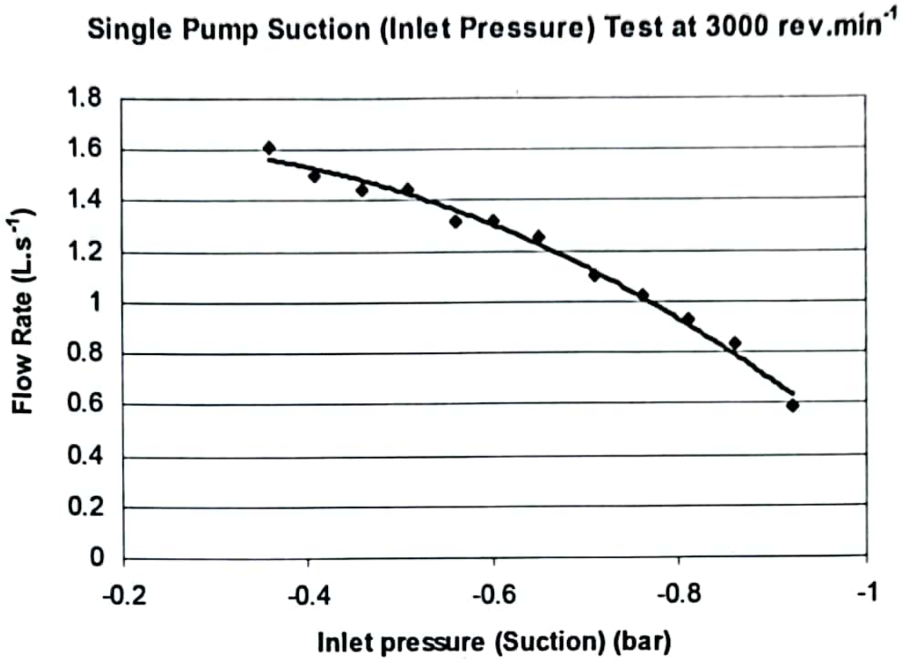
Graph 2 Dimensionless Analysis of the Single Pump at 3000 rev.min^{-1}



Graph 3 Parallel Test at 3000 rev.min^{-1}



Graph 4 Series Pump Performance Tests at 3000 rev.min^{-1}



Graph 5 Suction Test at 3000 rev.min^{-1}

Questions

1. Look at your results for the single pump tests. Describe the relationship between efficiency, head, and flow rate. What is the best efficiency for the single pump?

2. Compare your results for the series and parallel pump tests against the single pump tests at the same pump speed. Describe how the total head curves are affected by the parallel and series circuits. What do you notice about the efficiency for the series and parallel pumps?

3. The efficiency of large industrial pumps is normally approximately 75%. Why do you think the efficiency of the pumps on the H83 is different to that of a large industrial pump?

Conclusions

For the single pump, as flow rate increase, efficiency increases to an optimum level of around 45% at around 1 L.s^{-1} and then drops. Head decreases as flow increases. Mechanical power increases with flow.

For the series tests, total head is higher than the single or parallel tests. For the parallel tests, total head is almost the same as the single pump tests, but the maximum flow is around 50% greater than with the single or series pumps.

The maximum efficiency value for both parallel and series tests is similar (around 38%) and slightly lower than the single pump. The parallel pumps reach maximum efficiency at a higher flow rate than the series pumps.

The efficiency of this type of pump is low compared to normal values for industrial units. The reason for this is the small size of the machine, so the friction losses (bearings, gland losses and skin friction) become a larger factor in any ratio equations. This fact helps to show why the dimensionless similarity laws are not perfect when you compare a small pump to a large pump.

Useful Textbooks

The following textbooks are useful for further study of the specifications and theory of pump design.

Mechanics of Fluids

by B.S Massey

Sixth edition

Published by Chapman and Hall

ISBN 0 412 34280 4

Reynolds Thermofluid Dynamics

by A.J Reynolds

Published by John Wiley and Sons Ltd

ISBN: 0471717800

Understanding Hydraulics

by L.Hamill

Published by Macmillan Press Ltd

ISBN: 0 333 59910 1

Maintenance

General

When it is not in use, disconnect the apparatus from the electrical supply.

If the apparatus is not to be used for several weeks, drain out all the water.

To clean the apparatus, wipe clean with a damp cloth - do not use abrasive cleaners.

Do not use detergents to clean inside the reservoir. The water will start to foam up the next time the apparatus is used.

Check the water in the reservoir at least once a week during use. Change the water if it has become dirty or discoloured.

To drain the water, use the drain tap underneath the reservoir.

Electrical

WARNING ***Only qualified persons may do electrical maintenance on this equipment.***

Use this procedure:

- Assume the apparatus is energised until it is known to be isolated from the electrical supply.
- Use insulated tools where there are possible electrical hazards.
- Confirm that the apparatus earth circuit is complete.
- Identify the cause of a blown fuse or tripped circuit breaker before renewing or resetting.

To Replace the Fuses or reset any circuit breaker

- Isolate the apparatus from the electrical supply.
- Renew the faulty fuse or reset the circuit breaker.
- Reconnect the apparatus to the electrical supply and switch on.
- If the apparatus fails again, contact TecQuipment Ltd or your agent for advice.

NOTE *Renew faulty or damaged parts or detachable cables with an equivalent item of the same type or rating.*

Circuit Breaker Location

The circuit breakers for the motor drive and the instrument IEC sockets are inside each Motor Drive.

Fuse Location

There is one fuse located at the IEC socket of each of the instrument modules, use a small screwdriver to access and change the fuse.

Spare Parts and Customer Care

Refer to the Packing Contents List for any spare parts supplied with the apparatus.

If you require technical assistance or spares, please contact your local TecQuipment Agent, or contact TecQuipment direct.

To assist us in processing your request quickly and efficiently, when requesting spares please include the following:

- Your Name
- The full name and address of your college, company or institution
- Your email address
- The TecQuipment product name and product reference
- The TecQuipment part number (if known)
- The serial number
- The year of purchase (if known)

Please provide us with as much detail as possible about the parts you require and check the details carefully before contacting us.

If the product is no longer under warranty, TecQuipment will send you a price quotation for your confirmation.

We hope you find our products and manuals satisfactory. If you have any questions, do not hesitate to contact our Customer Care department immediately.

Customer Care:

Tel: +44 115 954 0155

Fax: +44 115 973 1520

email: **customercare@tecquipment.com**

For information about all TecQuipment products visit:

www.tecquipment.com