6.10 Exercise H: Series and Parallel Pumps

Objective

To investigate the performance of two similar Centrifugal pumps when connected and operated in Series and in Parallel.

Method

Running two Centrifugal pumps (C3-MKII-20 with C3-MKII-20SP) together under different operating conditions (by throttling the discharge valve) in order to obtain the operating characteristics when the pumps are connected in Series or in Parallel.

Repeating these tests at different operating speeds to give a family of performance curves when plotted graphically.

Equipment Required

C3-MKII Multi Pump Test Rig

Second Centrifugal Pump (Option C3-MKII-20SP)

Optional Equipment

Armfield C3-MKII-304 Data Logger with educational software.

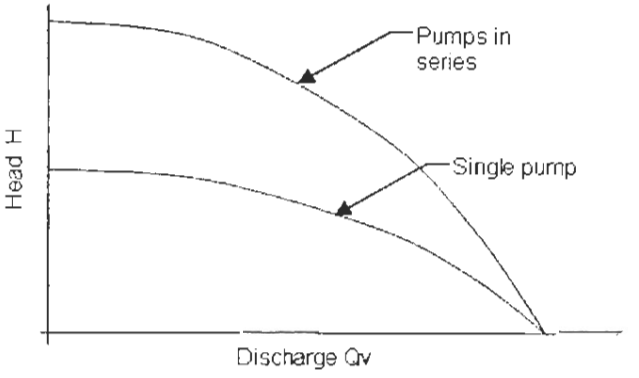
Thermometer suitable for fluid temperature measurement (Not supplied)

Theory

A single pump may be insufficient to produce the maximum performance required for a particular application. Sometimes two pumps are combined to give increased pumping capacity rather than the use of a larger single pump. This allows a single pump to be operated efficiently when demand is low but two pumps to be operated together when demand is high. The two pumps can be connected in series or in parallel, resulting in totally different characteristics.

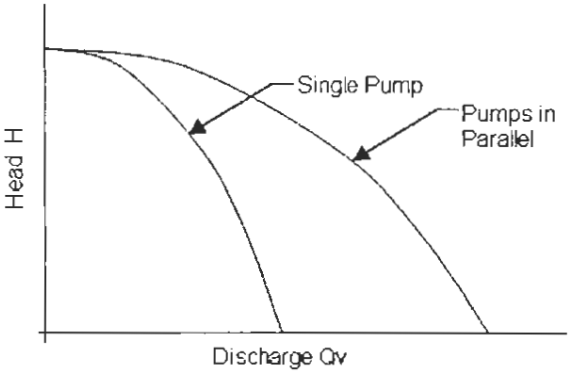
Pumps in Series

Two pumps may be connected in series, so that the fluid passes first through one pump and then through the second. When two pumps operate in series, the flow rate is the same as for a single pump but the maximum total head is increased. Theoretically the combined pump head-capacity curve should be found by adding the heads of the single pump curves at the same capacity. However, this figure is not quite realised because of increased losses in the system created by the additional pipework.



Pumps in Parallel

Two pumps may be connected in parallel, so that half of the flow passes through one of the pumps and the other half through the second pump. When two pumps operate in parallel the total head increase remains unchanged but the maximum flow rate is increased. The head-capacity curve for two pumps in parallel is not twice the flow from a single pump at the same head because of increased losses in the interconnecting pipework and increase in the system resistance at the higher flow rate.



A system will normally be designed so that a single pump is sufficient for normal operating conditions. Additional pumps may then be integrated into the design, which can be switched on when required to cope with increased demand, for example to provide emergency capacity during flood conditions.

Equipment Set Up

The second Centrifugal Pump should be installed in position 2 alongside the centrifugal pump that is permanently fitted to the base unit. Check that the base of the pump is securely fastened to the C3-MKII frame and that all pipework is connected and secured.

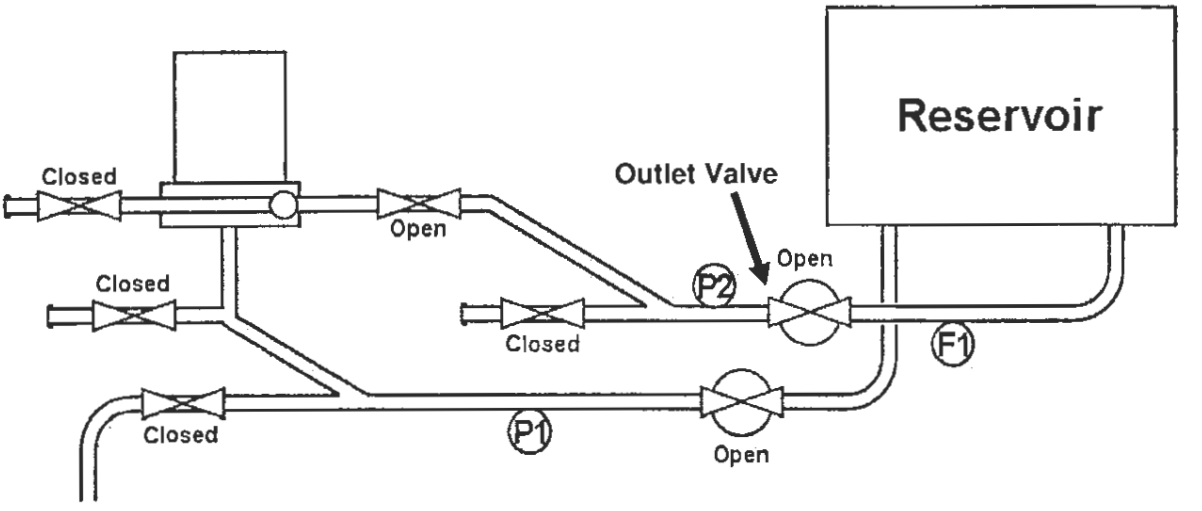
Check that the reservoir on the C3-MKII has been filled with clean water and that the equipment is connected to an appropriate mains electricity supply.

If a thermometer is available remove the reservoir lid and measure the temperature of the water. Remove the thermometer and replace the reservoir lid.

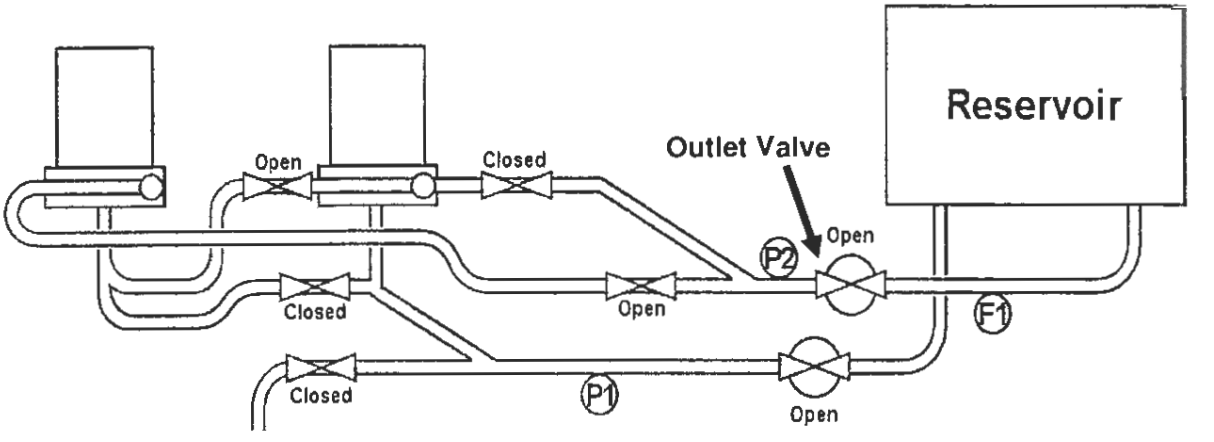
If using the optional C3-MKII software, check that the USB cable is connected to the PC. Run the C3-MKII software and check that IFD:OK is indicated in the bottom right hand corner of the screen.

Once the second centrifugal pump is fitted to the bench, the two centrifugal pumps may be configured for single pump, series operation or parallel operation by changing the valve settings and selecting the appropriate setting on the Control Panel. The valves are set as follows:

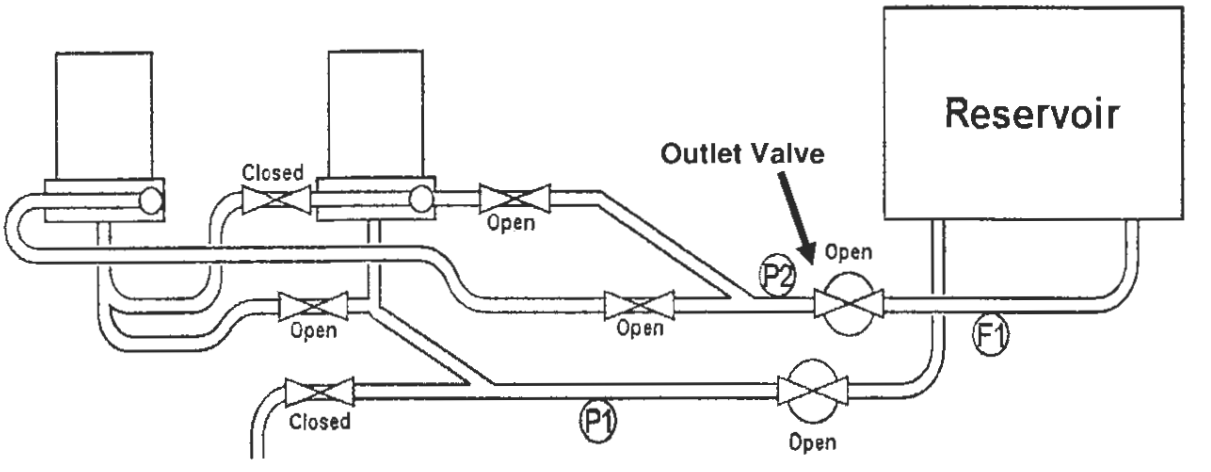
Setup for single pump operation



Setup for pumps in series



Setup for pumps in parallel



Procedure

Use the outlet valve to adjust the flow rate. The other valves should remain open or closed throughout the experiment, as marked on the diagrams above.

Single pump:

Set the valves as shown in the diagram above for a single pump.

Switch on the mains supply to the equipment, and switch on the power switch on the electrical console. The control panel on the front of the equipment will illuminate. Check for any warning messages – if 'Low water level' is displayed fill the reservoir to approximately 75 mm from the top then press the 'Exit' key.

Press the 'SELECT' key until 'Centrifugal Pump' is displayed then press the 'ENTER' key.

The pump will be run at maximum speed for the first part of this experiment. Press the 'SELECT' key until 'Pump Speed' is displayed then use the '↑' key for Pump 1 to increase the pump speed to 100%.

If using the control panel for sensor output readings:

At each setting of the outlet valve record the reading from each of the sensors by scrolling through the available parameters using the 'SELECT' key.

If using the optional computer software for taking sensor readings:

Enter the temperature of the working fluid in the box provided on the mimic diagram. At each setting of the outlet valve click the icon to record all of the readings from the sensors into the results table.

With the pump running at 100% speed, gradually open the outlet valve and allow the pump and pipework to fully prime. When the flow is steady record a set of readings from the sensors, namely;

Motor speed
Flow rate
Inlet pressure
Outlet Pressure
Motor Torque

Gradually close the outlet valve until the flow rate falls slightly, allow the conditions to settle then record another set of readings.

Continue to close the outlet valve in steps, taking readings from all of the sensors at each step, until a flow rate of 0 l/min is reached. Take one set of readings for zero flow conditions.

If using the software then create a new results sheet for each set of data using the icon. Alternatively, different groups of students may each produce results for a different speed setting to produce a full range of characteristic curves.

With the outlet valve fully closed press the 'Exit' key on the control panel to stop the pump.

If using the software, save your results using 'Save As...' from the File menu. Use a descriptive filename such as the date, equipment and exercise, so that the results can be easily retrieved later if required.

Pumps in Series:

Set the valves as shown in the diagram above for pumps in series.

Press the 'SELECT' key until 'Parallel/Series pumps' is displayed then press the 'ENTER' key.

The pumps will be run at maximum speed for the first part of this experiment. Press the 'SELECT' key until 'Pump Speed' is displayed then use the '↑' key for Pump 1 to increase the first pump speed to 100%. Use the '↑' key for Pump 2 to increase the second pump speed to 100%.

If using the software, create a new results sheet using the icon.

Repeat the procedure as for a single pump recording the measured values.

Pumps in Parallel:

Set the valves as shown in the diagram above for pumps in parallel.

Press the 'SELECT' key until 'Parallel/Series pumps' is displayed then press the 'ENTER' key.

The pumps will be run at maximum speed for the first part of this experiment. Press the 'SELECT' key until 'Pump Speed' is displayed then use the '↑' key for Pump 1 to increase the first pump speed to 100%. Use the '↑' key for Pump 2 to increase the second pump speed to 100%.

If using the software, create a new results sheet using the icon.

Repeat the procedure as for a single pump recording the measured values.

If time is available, additional sets of results may be taken for different pump speed settings, for example at 90%, 80% etc. Set both pumps to the same speed setting each time, to give comparable results. If using the software then create a new results sheet for each set of data using the icon. Alternatively, different sets of students may each produce results for a different speed setting to produce a full range of characteristic curves.

Fully close the outlet valve then stop the pump by pressing 'Exit' on the control panel.

If using the software, save your results using 'Save As...' from the File menu. Use a descriptive filename such as the date, equipment and exercise, so that the results can be easily retrieved later if required.

Results

If not using the optional software then you will need to obtain a value for the water density, ρ from the table in section 6.3. If a thermometer is not available assume the value to be 998 kg/m^3 corresponding to a water temperature of approximately 20°C.

Record the measured values under the following headings:

p_{in}	p_{out}	F	T	N	t	ρ
kN/m^2	kN/m^2	l/min	mNm	RPM	°C	kg/m^3

Record the calculated variables under the following headings:

Q	H_s	H_e	H_v	H_t	P_m	P_h	E_o
m^3/s	m	m	m	m	Watts	Watts	%
		0	0				
		0	0				
		0	0				

Remember to convert the sensor outputs into the correct units before using them in calculations. Pressures should be in Nm^{-2} (Pa), the flow rate in m^3/s, torque in Nm and speed in RPM. If using the software, this is done automatically by the computer.

Plot graphs of Total Head against Flow Rate, Mechanical Power against Flow Rate, and Overall Efficiency against Flow Rate for both Single and Series pumps on the same axes, and then for Single and Parallel pumps on the same axes.

Conclusion

Compare the graphs obtained with those provided in the theory. How do the practical results compare to the theoretical results? Discuss any differences, giving possible reasons for these and including a mention of any sources of error.

Give examples of real-world applications in which pumps might be connected in series or in parallel. Explain why the decision to connect two pumps in this way might be made. Discuss the advantages and limitations of doing so, and explain what difference in performance might be expected compared to selecting a single pump of greater capacity for the same application.