

FLUID MECHANICS LAB

EQUIPMENTS

1. HYDRAULIC BENCH

DESCRIPTION

The hydraulics bench consists of a moulded plastic sump tank which supports GRP bench top incorporating a flow channel and volumetric measuring tank.

A self-priming centrifugal pump and draws water from the sump tank and delivers to a quick release hose connector in the flow channel via a panel mounted control valve. Special purpose terminations may be connected to the pump supply by unscrewing the hose connector. No hand tools are required for either of these operations. A drain valve is incorporated in the end wall of the sump tank to facilitate emptying.

Electrical supply to the pump motor is via a switch and RCD mounted in the recess on the front of the bench.

The moulded bench top incorporates an open flow channel with ridges at either side to support the accessory on test. In addition to the hose connector the channel incorporates a pair of wall slots and a weir carrier for use with accessory F1-13.

Water discharging from the accessory on test is collected in the volumetric measuring tank. This tank is stepped to accommodate low or high flow rates and incorporates a stilling baffle to reduce turbulence. A remote sight tube and scale, is connected to a tapping in the base of the volumetric tank and gives an instantaneous indication of water level.

A dump valve in the base of the volumetric tank is operated by a remote actuator. Lifting the actuator opens the dump valve allowing the water to return to the sump for recycling. When lifted, a twist of 90° at the actuator will retain the dump valve in the open position. An overflow adjacent to the sump returns water to the sump in the event of incorrect use.

A measuring cylinder is provided for measurement of very small flow rates.

IMPACT OF A JET

DESCRIPTION

Fluid mechanics has developed as an analytical discipline from the application of the classical laws of statics, dynamics and thermodynamics, to situations in which fluids can be treated as continuous media. The particular laws involved are those of the conservation of mass, energy and momentum and, in each application, these laws may be simplified in an attempt to describe quantitatively the behaviour of the fluid.

The hydraulics bench service module, F1-10, provides the necessary facilities to support a comprehensive range of hydraulic models each of which is designed to demonstrate a particular aspect of hydraulic theory.

The specific hydraulic model that we are concerned with for this experiment is the Impact of Jet Apparatus, F1-16. This consists of clear acrylic test cylinder, into which water is fed vertically through a nozzle. The water strikes a target mounted on a stem. A weight pan mounted at the top of the stem allows the force of the water to be counterbalanced by applied masses. A full description of the apparatus is given later in these texts.

2. DEAD WEIGHT CALIBRATOR

DESCRIPTION

The dead weight calibrator equipment consists of:

Piston

The F1-11 Dead Weight Calibrator accessory comprises a precision ground piston and cylinder.

Weights

Weights may be added to the piston so that a number of predetermined pressures may be set up within the cylinder.

Baseboard

The cylinder is mounted on a baseboard which is supported on levelling screws and fitted with a spirit level.

Gauge Connection

The gauge under test is linked to the cylinder connection by a flexible tube.

Waste Water

Leakage of water past the piston is taken to waste through connection to a second flexible tube. This tube is connected to a tapping which is drilled into the cylinder and is opposite an annular recess in the cylinder.

SPECIFICATION

Mass of piston MP = 498g
Diameter of piston d = 0.01767m

3. HYDROSTATIC PRESSURE APPARATUS

DESCRIPTION

A fabricated quadrant is mounted on a balance arm which pivots on knife edges. The knife edges coincide with the centre of arc of the quadrant. Thus, of the hydrostatic forces acting on the quadrant when immersed in water, only the force on the rectangular end face gives rise to a moment about the knife edges (forces on the curved surfaces resolve through the pivot and have no effect on the moment). This moment is counteracted by variable weights at a fixed distance from the pivot allowing the magnitude and position of the hydrostatic force to be determined for different water depths. The quadrant can be operated with the vertical end face partially or fully submerged, allowing the difference in theory to be investigated.

The balance arm incorporates a weight hanger for the weights supplied and an adjustable counterbalance weight to ensure that the balance arm is horizontal before immersing the quadrant in water. The assembled balance arm is mounted on top of a clear acrylic tank which may be leveled by adjusting three screwed feet. Correct alignment is indicated on a circular spirit level mounted on the base of the tank.

A level indicator attached to the side of the tank shows when the balance arm is horizontal. Water is admitted to the top of the tank by a flexible tube and may be drained through a cock in the side of the tank. The water level is indicated on a scale on the side of the quadrant.

Length of Balance	L	275 mm
Quadrant to Pivot	H	200 mm
Height of Quadrant	D	100 mm
Width of Quadrant	B	75 mm

4. FLOW OVER WEIRS

DESCRIPTION

The apparatus has five basic elements used in conjunction with the flow channel in the moulded bench top of Hydraulics Bench Description.

A stilling baffle and the inlet nozzle combine to promote smooth flow conditions in the channel.

A Vernier hook and point gauge is mounted on an instrument carrier, to allow measurement of the depth of flow above the base of the notch.

Finally, the weir notches are mounted in a carrier at the outlet end of the flow channel.

To connect the delivery nozzle, the quick release connector is unscrewed from the bed of the channel and the nozzle screwed in place. The stilling baffle is slid into slots in the wall of the channel. These slots are polarized to ensure correct orientation of the baffle.

The instrument carrier is located on the side channels of the moulded top. The carrier may be moved along the channel to the required measurement position. The gauge is provided with a coarse adjustment locking screw and a fine adjustment nut. The vernier is locked to the mast by screw and is used in conjunction with the scale. The hook and point is clamped to the base of the mast by means of a thumb screw.

The weir may be clamped to the weir carrier by thumb nuts, the weir plates incorporate captive studs to aid assembly.

5. METACENTRIC HEIGHT

DESCRIPTION

The apparatus comprises a rectangular pontoon, with a vertical mast.

Vertical Mast

The vertical mast carries a sliding mass, which may be adjusted to vary the position of the centre of gravity of the pontoon.

Plumb Line

A plumb line, attached to the top of the mast, is used to measure the angle of heel of the pontoon in conjunction with a degree scale.

Transverse Mass

This heel is controlled by a transversely adjustable mass, whose position is indicated on a linear scale.

SPECIFICATION

Pontoon Length	l	=	0.350 m
Pontoon Width	b	=	0.200 m
Pontoon Height	d	=	0.075 m
Pontoon Weight (total)	W	=	1305 gm (Both weights fitted)
Traversing Weight only	P	=	305 gm

6. BERNOULLI'S THEOREM DEMONSTRATION

DESCRIPTION

The test section is an accurately machined clear acrylic duct of varying circular cross section. It is provided with a number of side hole pressure tappings which are connected to the manometers housed on the rig. These tappings allow the measurement of static pressure head simultaneously at each of 6 sections. To allow the calculation of the dimensions of the test section, the tapping positions and the test section diameters are shown on the following diagram:

The dimensions of the tube are detailed below

Tapping Position	Manometer Legend	Diameter (mm)
A	h_1	25.0
B	h_2	13.9
C	h_3	11.8
D	h_4	10.7
E	h_5	10.0
F	h_6	25.0

7. ORIFICE AND FREE JET FLOW

DESCRIPTION

The rig is designed to be positioned on the side channels of the hydraulics bench top channel. The inlet pipe should be connected to the bench supply.

An adjustable overflow pipe is provided adjacent to the header tank to allow changes in the head. A flexible hose attached to the overflow pipe returns excess water to the sump tank. A scale indicates the water level. Finally a baffle at the base of the tank promotes smooth conditions prior to the orifice plates.

Two orifice plates of differing diameters are provided and may be interchanged by slackening the two thumb nuts. The orifice plate is sealed against an 'O'-ring by means of a special fitting which gives a flush inside surface.

The trajectory of the jet may be plotted using the vertical needles. In operation, a piece of paper is attached to the backboard, and the needles are adjusted to follow the profile of the water jet. The needles may be locked using a screw on the mounting bar. The profile may be plotted by marking the position of the needle top.

SPECIFICATION

Diameter of Small Orifice			0.003 m
Diameter of Small Orifice			0.006 m
Surface Area of Reservoir	A_R	=	$1.812 \times 10^{-3} \text{ m}^2$

8. FLOW THROUGH AN ORIFICE

DESCRIPTION

The Orifice Discharge accessory consists of a cylindrical tank which has a hole in the base to accept one of five orifices, each with a different profile. The flexible inlet pipe is connected to the quick release connector on the hydraulics bench. Water is delivered to the tank via an inlet pipe which is adjustable in height and fitted with a diffuser to reduce disturbances in the tank. An overflow pipe maintains the water at a fixed level in the tank and excess water is returned to the sump tank of the hydraulics bench.

A traverse assembly mounted beneath the base of the tank enables a pitot tube to be positioned anywhere in the jet of water. Attached to the pitot is a fine wire which can be traversed across the jet to measure the diameter of the jet at the vena-contracta and so determine the contraction coefficient. The traverse assembly incorporates a graduated knob which moves the pitot tube a distance of 1 mm for each full rotation of the knob. Each graduation on the knob corresponds to a movement of 0.1mm (Note: Measurement of the jet diameter at the vena-contracta is only practical using the knife edged orifice).

The pitot tube and a tapping in the base of the tank are connected to manometer tubes adjacent to the tank. These allow the head over the orifice and the total head of jet to be measured and compared.

In addition to a standard knife edged orifice, four orifices with different profiles are supplied. These are supplied in a plastic storage box. The dimensions of each orifice are given below. The required orifice is located in a recess beneath the base of the tank and secured by tightening two thumb screws. An 'O' ring in the base of the tank seals the gap between the orifice and the base of the tank.

The accessory should be positioned over the channel in the hydraulics bench and levelled by adjusting the feet. A spirit level mounted on the base of the tank indicates when the accessory is level.

9. ENERGY LOSSES IN PIPES

DESCRIPTION

The accessory is designed to be positioned on the side channels of the hydraulics bench top channel.

There are two methods of supplying water to the test pipe. For higher flow rates the inlet pipe is connected directly to the bench supply. For lower flow rates, the inlet pipe is connected to the outlet at the base of the constant head tank and the inlet to the tank is connected to the bench supply.

The test section of pipe is mounted vertically on the rig and is instrumented using two manometers. Water over mercury manometer is used to measure large pressure differentials and a pressurized water manometer is used to measure small pressure differentials. When not in use a manometer may be isolated using Hoffman clips.

Flow through the test section is regulated using a flow control valve. In use this valve should face the volumetric tank. A short length of flexible piping attached to the valve will prevent splashing.

SPECIFICATION

Length of test pipe	L	=	0.500 m
Diameter of test pipe	d	=	0.003 m

10. FLOW CHANNEL

DESCRIPTION

The rig is designed to be positioned on the side channels of the hydraulics bench top channel. The inlet pipe should be connected to the bench supply.

Water is fed to the streamlined channel entry via a stilling tank, which incorporates marbles to reduce turbulence. The channel consists of a Perspex working section of large depth to width ratio incorporating an undershot weir, with an overshot weir at the inlet and discharge ends respectively. Water discharging from the channel is collected in the volumetric tank of the hydraulics bench and returned to the sump for recirculation.

A dye injection system, consisting of a reservoir, flow control valve, manifold and hypodermic tubes, is incorporated at the inlet to the channel and permits flow visualization in conjunction with a graticule on the rear face of the channel.

The overshot weir is fully raised for flow visualization experiments; this is achieved by releasing the thumbscrew and weir support, moving the weir to the desired position and locking the screws.

The flexible inlet has a Y connector with a bypass that incorporates a flow control device. The end of the bypass should be located securely in the overflow slot in the side of the volumetric tank so that excess water is returned directly to the sump tank. During use, the flow control device in the bypass should be adjusted in conjunction with the flow control valve on the FI-10 to give the required flow conditions in the flow channel.

11.OSBORNE REYNOLDS' DEMONSTRATION

DESCRIPTION

Osborne Reynolds' demonstration equipment consists of

Positioning the Accessory

The accessory is designed to be positioned in the ridges at either side of the channel in the top of the hydraulics bench.

Inlet Pipe

The inlet pipe is connected between the bench supply and the base of the constant head tank, where glass marbles still the flow.

Flow Visualization Pipe

The flow visualization pipe is fitted with a bellmouth which promotes smooth entry to the pipe.

Flow Control Valve

Flow through the pipe is regulated using a flow control valve. In use this valve should face the volumetric tank. A short length of flexible piping attached to the valve will prevent splashing.

Dye Reservoir and Dye Injection

Dye contained in a reservoir is injected into the pipe via a hypodermic tube. The flow of dye is controlled via a valve and its position is adjusted using a screw.

SPECIFICATION

Diameter of test pipe	$d = 0.010 \text{ m}$
Cross sectional area of test pipe	$A = 7.854 \times 10^{-5} \text{ m}^2$

12. FLOW METER DEMONSTRATION

DESCRIPTION

The accessory is designed to be positioned on the side channels of the hydraulics bench top channel.

The Venturi meter, variable area meter and the orifice plate are installed in a series configuration to permit direct comparison.

Flow through the test section is regulated using a flow control valve. This together with the bench control valve permits variation of the system static pressure.

Pressure tappings in the circuit are connected to an eight-bank manometer which incorporates an air inlet/outlet valve in the top manifold with facilities to connect a hand pump. This enables the levels in the manometer bank to be adjusted to a convenient level to suit the system static pressure. The pressure tappings for the manometers are arranged to give a set of readings around the flow meters in the system. The setup is detailed elsewhere.

For the Venturi Meter

Upstream Pipe Diameter		= 0.03175	m
Cross sectional area of upstream pipe	A_1	= 7.92×10^{-4}	m^2
Throat diameter		= 0.015	m
Cross sectional area of throat	A_2	= 1.77×10^{-4}	m^2
Upstream Taper		= 21	degrees
Downstream Taper		= 14	degrees

For the Orifice Plate

Upstream Pipe Diameter		= 0.03175	m
Cross sectional area of upstream pipe	A_1	= 7.92×10^{-4}	m^2
Throat diameter		= 0.020	m
Cross sectional area of throat	A_2	= 3.14×10^{-4}	m^2

13. ENERGY LOSSES IN BENDS

DESCRIPTION

The accessory is designed to be positioned on the side channels of the hydraulics bench top channel.

The following fittings are connected in a series configuration to allow direct comparison:

- long bend
- area enlargement
- area contraction
- elbow bend
- short bend
- valve fitting
- mitre bend

Flow rate through the circuit is controlled by a flow control valve.

Pressure tappings in the circuit are connected to a twelve bank manometer, which incorporates an air inlet/outlet valve in the top manifold. An air bleed screw facilitates connection to a hand pump. This enables the levels in the manometer bank to be adjusted to a convenient level to suit the system static pressure.

A clamp which closes off the tappings to the mitre bend is introduced when experiments on the valve fitting are required. A differential pressure gauge gives a direct reading of losses through the gate valve.

SPECIFICATION

Internal diameter of pipe work $d = 0.0183 \text{ m}$

Internal diameter of pipe work at enlargement $d = 0.0240 \text{ m}$

14. FREE AND FORCED VORTICES

DESCRIPTION

The F1-23 Free and Forced Vortices apparatus consists of a clear acrylic cylinder mounted on a PVC base plate. Four orifices in the side of the cylinder allow the water to enter and leave, while an overflow duct prevents the level from getting too high. There is also hole in the base of the cylinder, into which can be fitted orifices of various sizes, or a paddle wheel. The whole assembly is designed to be positioned above the channel on the hydraulics bench.

The two 12mm diameter inlet tubes, which are angled at 15 degrees, are used as entry tubes for the free vortex experiment. In this case, the water exits the vessel via one of the interchangeable orifices in the base of the tank. Three orifices are provided, having diameters of 8mm, 16mm and 24mm.

The 9mm inlet tubes, which are angled at 60 degrees, are used to create a forced vortex. The flow from these tubes impacts on a paddle which acts as a stirrer. The paddle rotates on a stud mounted on a bushed plug inserted in the central orifice. In this case, the water exits the vessel through the control valve via the 12mm. orifices.

A bridge piece incorporating measuring needles is used to determine the profile of the forced vortex. The needles are set at fixed distances from the centre of the tank. If the profile of the free vortex is required this can be determined by replacing the measuring needles with a gauge which measures the depth of the vortex at different diameters.

Velocity heads may be visualized by the insertion of various pitot tubes in this measuring bridge.

15. HYDRAULIC RAM PUMP

DESCRIPTION

The Hydraulic Ram Pump is designed to be positioned in the flow channel in the top of the hydraulics bench, with the header tank placed in the ridges at the side of the channel.

Water is taken from the hydraulics bench into the header tank via the inlet diffuser and from the tank to the pump body using the fall pipe. An overflow ensures that the inlet head remains constant. The ram pump body contains an inlet, the pulse valve and the non-return delivery valve. An air vessel above this delivery valve dampens the pressure fluctuations produced by the pulse valve.

The pulse valve may be loaded with additional masses placed on the weight platform attached to the valve in order to change the pressure required to close the valve. The frequency of the valve may also be varied using the adjustable collar.

The output from the hydraulic ram is taken by a flexible pipe to a siphon breaker located at the top of the support stand. Another flexible tube takes the output flow back to the hydraulics bench.

The height of the inlet header tank can be adjusted by loosening the two clamps and sliding the tank up or down the support stand. Similarly, the outlet head can be varied by moving the siphon breaker using the clamp.

16. DEMONSTRATION PELTON TURBINE

DESCRIPTION

The flow of water through the turbine is controlled by a fully retractable spear valve. The water exits through an opening in the base of the turbine and discharges into the channel then into the volumetric tank or the FI-10 where the flow rate can be determined. The buckets mounted around the periphery of the Pelton wheel are clearly visible through the transparent plate on the front of the turbine body. A Bourdon pressure gauge mounted on the support frame allows the inlet pressure of the turbine to be monitored.

The mechanical output power generated by the turbine is absorbed by a friction dynamometer that consists of a simple band brake. The brake belt, wrapped around a pulley on the turbine shaft, is connected to two spring balances that allow the load applied to the turbine to be varied and measured by adjustment of the tensioning device at the top.

The rotational speed of the turbine shaft can be determined using a non-contactable type tachometer (not supplied) for which a clamping arrangement is provided.

The basic principle of the Pelton turbine and spear valve can be demonstrated and the various measurements allow the following operating characteristics to be determined, graphically:

- Output Torque v rotor speed
- Output Power v rotor speed
- Overall Efficiency v rotor speed

SPECIFICATION

Item	Value
Speed range	0 to 2000 r.p.m.
Break power	10 Watts
Pressure gauge range	0 to 25 m H ₂ O
Force balance range	0 to 10 N × 0.1 N
Number of pelton buckets	16
Diameter of pelton wheel	123 mm

17. SERIES/PARALLEL PUMP CHARACTERISTICS

DESCRIPTION

The equipment is used in conjunction with the sump tank and volumetric tank on F1-10 to demonstrate the head / flow characteristics of a single centrifugal pump. The F1-26 is used in conjunction with the pump on F1-10 to demonstrate the characteristics of two similar pumps when connected in series or parallel.

The accessory pump is mounted on a support frame that is designed to be positioned on the floor beside the hydraulics bench. The feet are adjustable, so that the assembly can be levelled. Two pressure gauges are mounted on the pump, one at the inlet and one at the outlet.

The pump is driven by an AC motor with a separate switch to turn the motor On or Off.

The discharge manifold supplied with F1-26 attaches to the weir carrier at the end of the moulded channel of the hydraulics bench, using the thumb nuts supplied. The manifold incorporates a pressure gauge and a flow control valve, with a discharge pipe that empties into the volumetric tank of the hydraulics bench. Flexible tubing and pipe clips are supplied to allow the pumps to be connected for single, series or parallel pump operation.

The adapter supplied allows connection to the bench pump via the inlet in the bed of the hydraulics bench channel (the bench pump outlet) without the restriction of the quick release fitting.

The separate orifice plate is used when operating the pumps in parallel, to measure the high flow rates generated. This orifice plate is fitted into the drain outlet in the base of the volumetric tank after raising the sealing ball and weight. Flow rate may then be determined from the water level scale on the side of the tank using a table provided in the experimental procedure.

SPECIFICATION

Datum to manifold gauge	$h_d = 0.960$ m
Datum to Outlet Gauge	$h_d = 0.170$ m
Datum to Inlet Gauge	$h_d = 0.020$ m
Datum to Bench pump Inlet	$h_d = 0.240$ m

18. CENTRIFUGAL PUMP CHARACTERISTICS

DESCRIPTION

The F1-27 is used in conjunction with the sump tank and volumetric tank on F1-10 to demonstrate the characteristics of a single centrifugal pump. The F1-27 is used in conjunction with the pump on F1-10 to demonstrate the characteristics of two similar pumps when connected in series or parallel.

The accessory pump is mounted on a support frame that is designed to be positioned on the floor beside the hydraulics bench. The feet are adjustable, so that the assembly can be levelled. Two pressure gauges are mounted on the pump, one at the inlet and one at the outlet.

The pump is driven by an AC motor. The speed of the motor is controlled through an inverter mounted on the support frame, and the electrical voltage and current may be displayed on the inverter display to determine the motor power.

The discharge manifold supplied with F1-27 attaches to the weir carrier at the end of the moulded channel of the hydraulics bench, using the thumb nuts supplied. The manifold incorporates a pressure gauge and a flow control valve, with a discharge pipe that empties into the volumetric tank of the hydraulics bench. Flexible tubing and pipe clips are supplied to allow the pumps to be connected for single, series or parallel pump operation.

The adapter supplied allows connection to the bench pump via the inlet in the bed of the hydraulics bench channel (the bench pump outlet) without the restriction of the quick release fitting.

The separate orifice plate is used when operating, the pumps in parallel, to measure the high flow rates generated. This orifice plate is fitted into the drain outlet in the base of the volumetric tank after raising the sealing ball and weight. Flow rate may then be determined from the water level scale on the side of the tank using a table provided in the experimental procedure.

SPECIFICATION

Datum to manifold gauge	$h_d = 0.960$ m
Datum to Outlet Gauge	$h_d = 0.170$ m
Datum to Inlet Gauge	$h_d = 0.020$ m
Datum to Bench pump Inlet	$h_d = 0.240$ m

19.CAVITATION DEMONSTRATION

DESCRIPTION

The test section incorporates a Venturi-shaped profile inside. Water enters the test section at relatively low velocity then, as the cross section contracts towards the throat, the velocity of the water increases and the static pressure falls in accordance with the Bernoulli equation. As the flow of water is increased the sub-atmospheric pressure at the throat causes free and dissolved gasses to be released as bubbles in the liquid. As the flow is increased further the pressure continues to fall at the throat until a limit is reached that corresponds to the vapour pressure of the liquid (the actual pressure depending on the temperature of the liquid). At this condition small bubbles of vapour are formed in the liquid at the throat. These bubbles collapse violently as the pressure rises again in the downstream expansion of the test section. This process is called Cavitation and can be regarded as one of the most destructive forces created in a liquid system – the large amounts of energy released resulting in erosion of even the hardest metal surfaces in real applications such as valve seats, propeller blades etc. Any further increase in the flow of liquid causes an increase in the Cavitation (the pressure cannot reduce any further than the vapour pressure of the liquid).

- Venture-shaped test section
- Flexible connections
- Diaphragm valve
- Ball valve
- Bourdon gauges
- Support plate