F SERIES

Fluid Mechanics Series

The Armfield F series is known worldwide for its durability, reliability and easy operation. This family of products covers all of the relevant aspects of Fluid Mechanics: Fluid Dynamics, Hydrostatics, Open and Closed Channel flow as well as Rotodynamic Machines.

The latest upgrade of the range includes a Digital Hydraulic Bench, a redesigned Series and Parallel pumps accessory and updated modules such as the Pascal Apparatus or the Cavitation Demonstration.

The series is also now complemented with the exclusive Armfield F1-ABASIC software supplied along with both versions of the Basic Hydraulic bench. This facilitates the laboratory sessions for students and instructors by enabling manual datalogging and permitting the users to focus on the understanding of the principles of the phenomena being simulated in the Fluid Mechanics Laboratory.

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F SERIES

Hydraulics Bench - F1-10

This F1-10 unit is a portable and self-contained service module providing a controlled flow of water to a range of optional accessories.

The mobile bench is constructed from lightweight corrosion-resistant plastic and incorporates an open channel with side channels to support the accessories on test. The hydraulics bench includes a volumetric measuring tank stepped to accommodate low or high flow rates and a stilling baffle to reduce turbulence. A remote sight tube with scale gives an instantaneous indication of water level.

The bench additionally includes a quick-release pipe connector situated in the benchtop enabling rapid exchange of accessories without the need for hand tools, a measuring cylinder for measurement of very small flow rates, stopwatch and a copy of Armfield's F1-aBASIC educational software.

The F1-10 hydraulics bench can be supplied with either a factory fitted electronic flow meter with digital display or an optional inline digital flow meter that can be added in line to the experiment on test at any time.

Optional factory fitted electronic flow meter

Optional Inline digital flow meter

Technical specifications	
Pump	Submersible
	Max head 21m H_2O
	Max flow 1.35 l/s
Motor rating	0.37kW
Sump tank capacity	250l
High flow volumetric tank	40l
Low flow volumetric tank	6l
Height of working surface	1m above floor level
Overall dimensions	
Length	1.13m
Width	0.73m
Height	1.0m
Packed and crated shipping specifications	
Volume	1.5m^3
Gross weight	160kg

Requirements

1Ph COLD

Scale

Electrical supply:

Basic Hydraulics Bench:

F1-10-A	220-240V / 1ph / 50Hz @ 10 amp
F1-10-B	110-120V / 1ph / 60Hz @ 20 amp
F1-10-G	220V / 1ph / 60Hz @ 10 amp

Digital Hydraulics Bench (with digital flow meter):

F1-10-2-A	220-240V / 1ph / 50Hz @ 10 amp
F1-10-2-B	110-120V / 1ph / 60Hz @ 20 amp
F1-10-2-G	220V / 1ph / 60Hz @ 10 amp

F1-10-1 Digital Flow Meter for F1-10 Hydraulics Bench:
110-120V / 1ph / 60Hz @ 20 amp
(attaches to water outlet and can be removed as necessary)

Water: Fill with clean water. No permanent connection required.

Ordering codes

▶ F1-10

▶ F1-10-2

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Issue: 2
URL: http://www.armfield.co.uk/f1

Applications: ChE ME CE IP

armSOFT Software F1-aBASIC

Armfield's **F1-aBASIC software** is now included as standard with either of the hydraulic benches. The Armfield software is a powerful manual data entry learning package which enhances the educational content and understanding of Armfield's F1 Fluid Mechanics accessories that utilise either of the F1-10 Hydraulics benches.

The software allows the user to manually input data from primary instrumentation and offers a powerful tool for displaying and processing the results.

Software additionally includes the electronic version of the manual for all the modules on test.

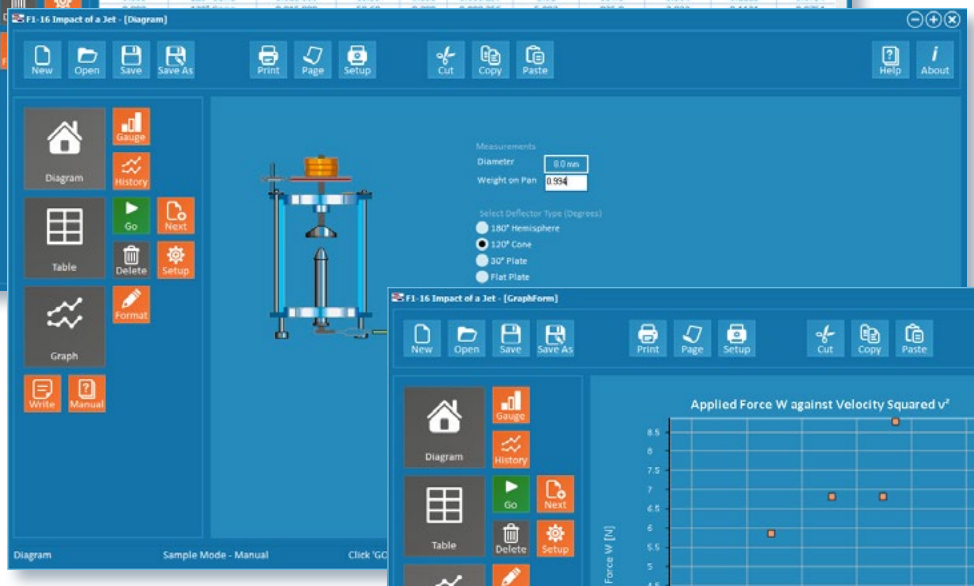
Some of the major features include:

Mimic Diagram - a pictorial representation of the equipment with fields to enter measurements from the equipment which displays any calculated variables directly in engineering units.

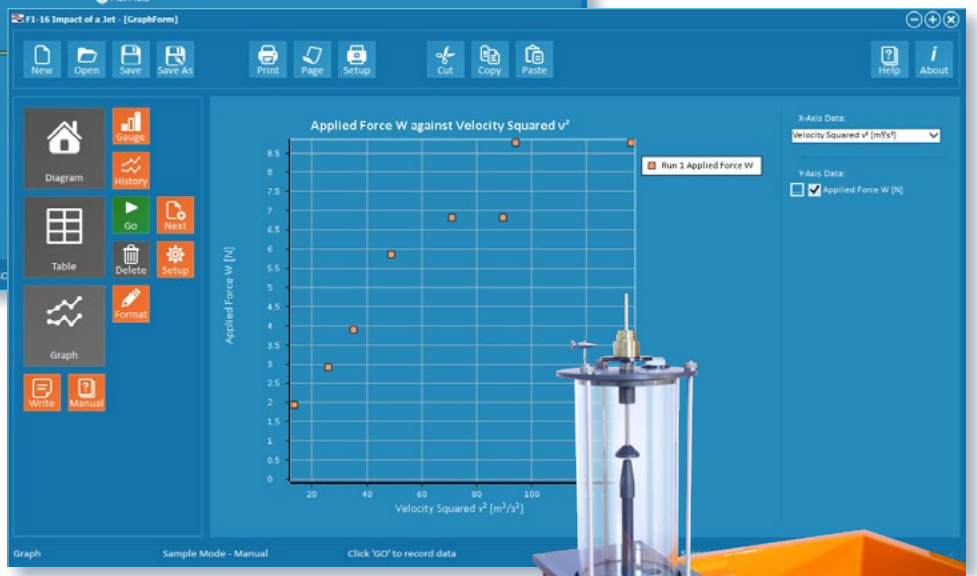
Tabular Display - As the data is entered, it is stored in a spreadsheet format. The table also contains columns for the calculated values.

Graphical Display - When several samples have been recorded, they can be viewed in graphical format. Powerful and flexible graph plotting tools are available in the software allowing the user full choice over what is displayed.

Tabular Display



Mimic Diagram



Graphical Display

Impact of a Jet F1-16

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F SERIES

Dead Weight Pressure Gauge Calibrator - F1-11

This calibrator functions under the same principle adopted in calibrating industrial pressure gauges.

Experimental content

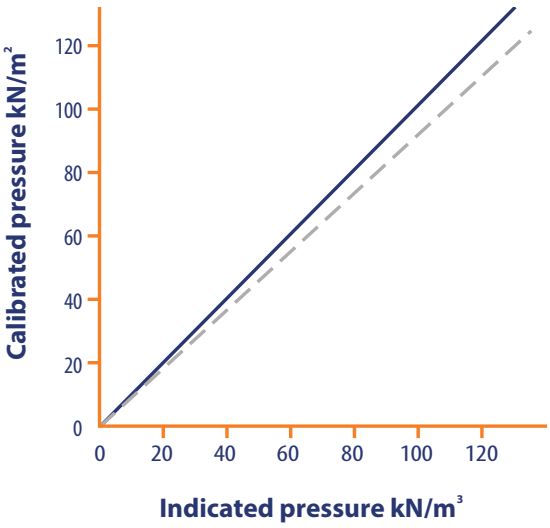
- To calibrate a Bourdon type pressure gauge and to determine the gauge errors
- To determine the measurement errors in the reference pressure source used for calibration

Description

The Dead Weight Pressure Gauge Calibrator consists of a precision-machined piston and cylinder assembly mounted on levelling screws.

A Bourdon gauge is supplied for calibration. The weights supplied are added to the upper end of the piston rod which is rotated to minimise friction effects.

The gauge is thus subject to known pressures which may be compared with the gauge readings and an error curve drawn.



Technical specifications

Pressure gauge	Bourdon tube
	range 0 to 200 kN/m² (kPa)
Area of piston	244.8 x 10^{-6} m²
Mass of piston	0.5kg
Ancillary masses	2x 0.5kg, 1.0kg and 2.5kg
Overall dimensions	
Length	0.25m
Width	0.125m
Height	0.50m

Ordering codes

- F1-11

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Applications: ChE ME CE IP

Hydrostatic Pressure - F1-12

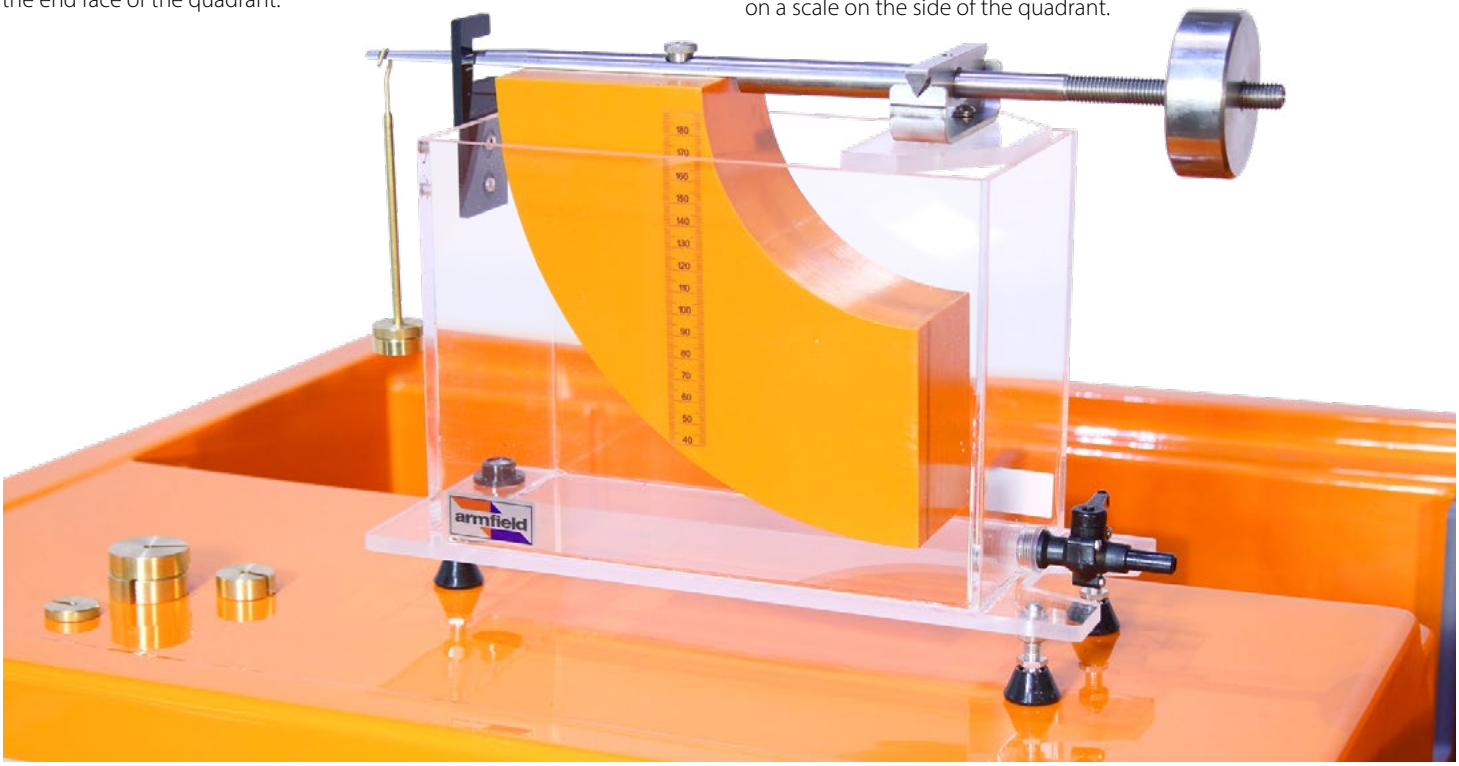
The Hydrostatic Pressure accessory has been designed to determine the static thrust exerted by a fluid on a submerged surface and enables comparison of the measured magnitude and position of this force with simple theory.

A fabricated quadrant is mounted on a balance arm which pivots on knife edges. The knife edges coincide with the centre of the arc of the quadrant. This means that when the quadrant is immersed, the only force that gives rise to a moment about the knife edges is the hydrostatic force acting on the end face of the quadrant.

The balance arm incorporates a hanger for the weights supplied and an adjustable counterbalance.

This assembly is mounted on top of an acrylic tank which may be levelled by adjusting screwed feet. Correct alignment is indicated on a circular spirit level mounted on the base of the tank.

An indicator attached to the side of the tank shows when the balance arm is horizontal. Water is added to the tank via a flexible tube and may be drained through a valve in the side of the tank. The water level is indicated on a scale on the side of the quadrant.

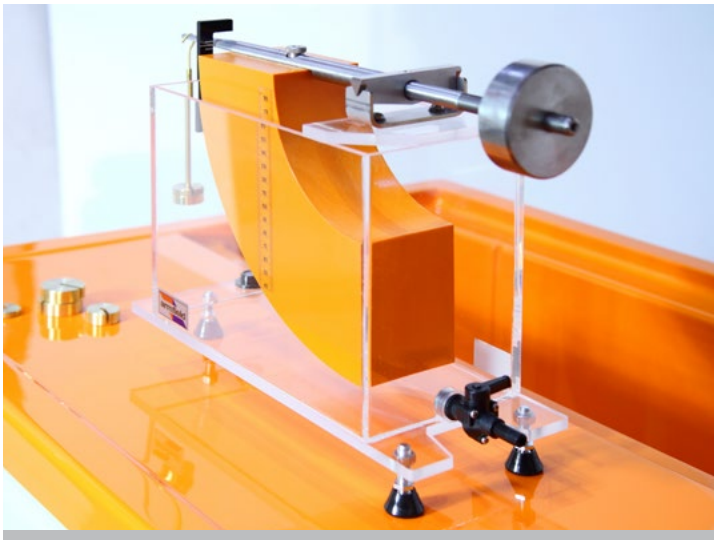


Experimental content

- To determine the hydrostatic thrust acting on a plane surface immersed in water when the surface is partially submerged or fully submerged
- To determine the position of the line of action of the thrust and to compare the position determined by experiment with the theoretical position

Technical specifications

Tank capacity	5.5l
Distance between suspended mass and fulcrum	275mm
Cross-sectional area of quadrant (toroid)	7.5 x $10^{-3}m^2$
Total depth of completely immersed quadrant	160mm
Height of fulcrum above quadrant	100mm
Overall dimensions	
Length	0.435m
Width	0.13m
Height	0.30m



Ordering codes

- F1-12

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Applications: ChE ME CE IP

Flow over weirs - F1-13

F SERIES

Two different weir plates are provided enabling familiarisation and comparison with theory.

Experimental content

- To determine the characteristics of open channel flow over a rectangular notch
- To determine the characteristics of open channel flow over a triangular (vee) notch
- To determine values of the discharge coefficient for both notches

Description

The flow over weirs consists of five basic elements used in conjunction with the flow channel in the moulded benchtop of the Hydraulics Bench.

A quick-release connector in the base of the channel is unscrewed and a delivery nozzle screwed in its place.

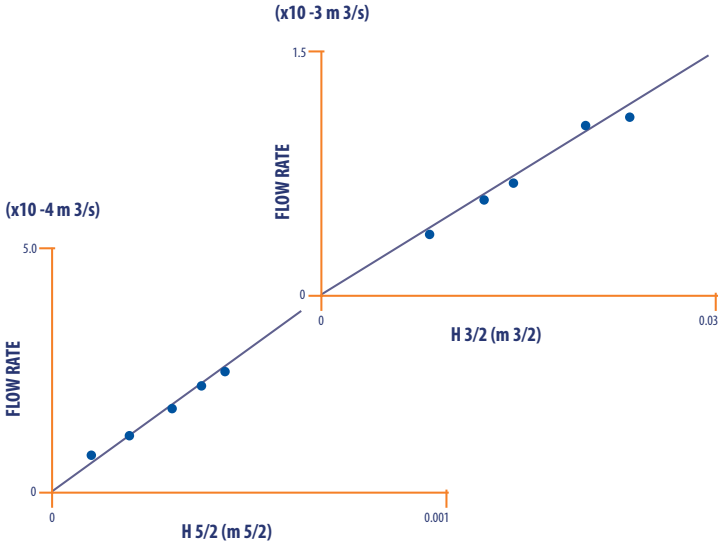
A stilling baffle locates into slots in the walls of the channel. The combination of the inlet nozzle and stilling baffle promote smooth flow conditions in the channel.

A Vernier hook and point gauge is mounted on an instrument carrier which is located on the side channels of the moulded top. The carrier may be moved along the channels to the required measurement position.

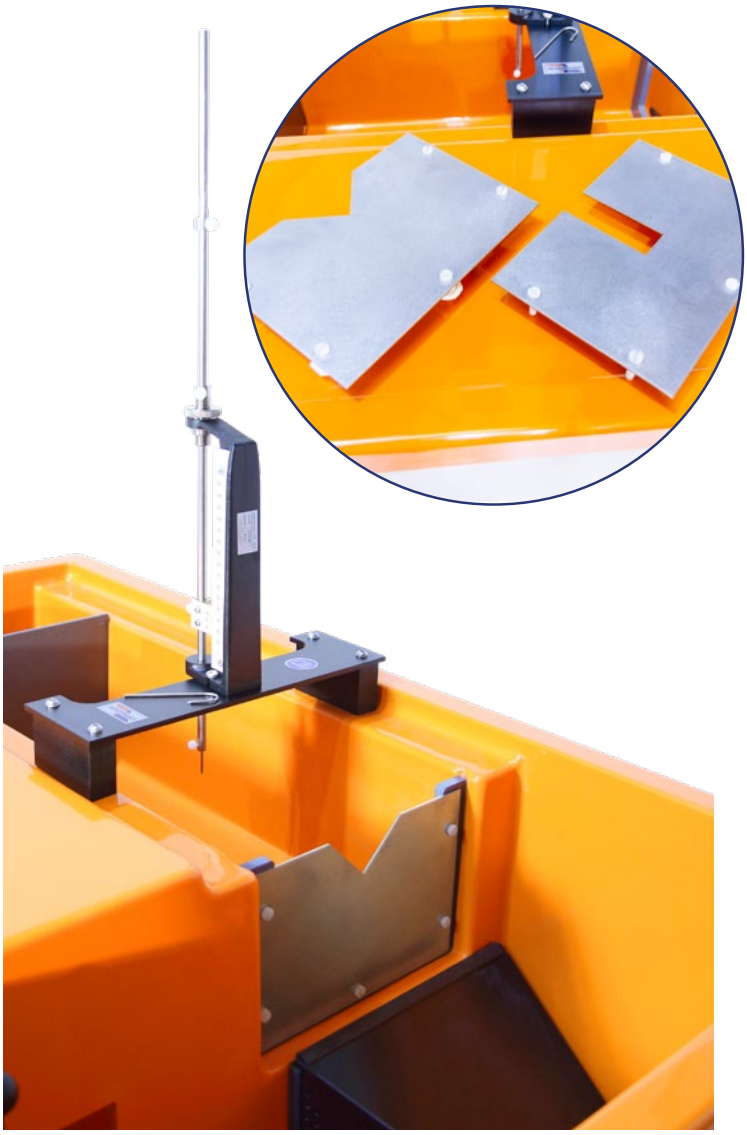
The rectangular notch weir or V notch weir to be tested is clamped to the weir carrier in the channel by thumb nuts. The stainless steel weir plates incorporate captive studs to aid assembly.

Overall dimensions of weir plate	
Thickness	0.002m
Width	0.23m
Height	0.16m
Dimensions of rectangular notch	
Width	0.03m
Height	0.082m
Angle of V notch weir	90° inclusive
Hook & point gauge range	0-150mm
Accuracy	0.1mm

Requires Hydraulics Bench Service unit F1-10



F1-13 V notch & rectangular notch weir plates



Ordering codes

- F1-13

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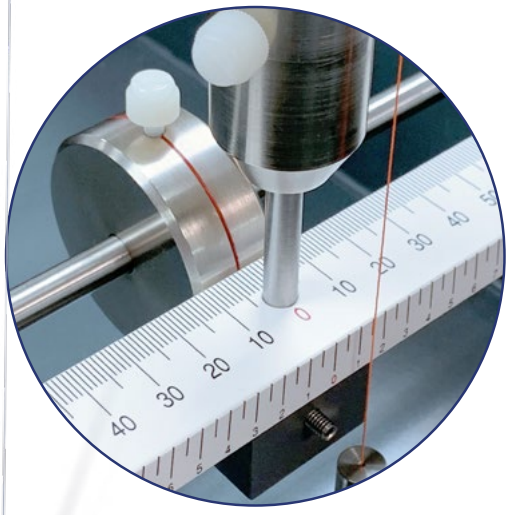
F SERIES

Metacentric Height - F1-14

This equipment enables a thorough investigation of the factors affecting the stability of a floating body.



F1-14 Calibrated scale

Experimental content

- Determining the centre of gravity of the pontoon
- Determining the metacentric height and from this the position of the metacentre for the pontoon
- Varying the metacentric height with angle of heel

Description

The position of the metacentre can be varied to produce stable and unstable equilibrium.

The equipment consists of a plastic rectangular floating pontoon where the centre of gravity can be varied by an adjustable weight which slides and can be clamped in any position on a vertical mast.

A single plumb bob is suspended from the mast which indicates the angle of heel on a calibrated scale.

A weight with lateral adjustment enables the degree of heel to be varied and hence the stability of the pontoon determined.

The equipment does not require a separate water tank as it may be used on the hydraulics bench by filling the volumetric tank.

Technical specifications

Overall dimensions:	
Length	0.35m
Width	0.20m
Height	0.475m
Max angle of heel	±13°
Corresponding linear dimension	±90mm

Ordering codes

- F1-14

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Bernoulli's Theorem Demonstration - F1-15

F SERIES

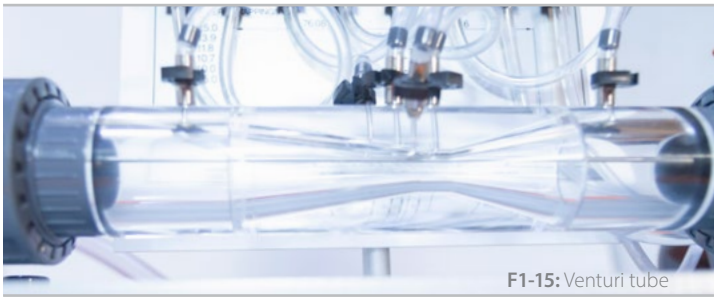
This accessory illustrates the circumstances to which Bernoulli's Theorem may be applied.

It also explains why in other circumstances the theorem gives an inadequate description of the fluid behaviour.

F1-15: Manometer bank

Experimental content

- To investigate the validity of the Bernoulli equation when applied to the steady flow of water in a converging or a diverging duct
- Conservation of energy divergent/convergent pipe flow
- Effect of friction loss on Bernoulli equation
- Recording the pressure curve in a Venturi nozzle
- Recording the velocity curve in a Venturi nozzle
- Determining the flow coefficient



F1-15: Venturi tube

Description

The test section consists of a classical Venturi machined in clear acrylic.

A series of wall tappings enable measurement of the static pressure distribution along the converging and diverging duct. A total head tube is provided to traverse along the centre line of the test section.

These tappings are connected to a manometer bank incorporating a manifold with an air bleed valve.

Pressurisation of the manometers is facilitated by a hand pump. The test section is arranged so that the characteristics of flow through both a converging and diverging section can be studied.

Water is fed through a hose connector and is controlled by a flow regulator valve at the outlet of the test section.

The Venturi can be demonstrated as a means of flow measurement and the discharge coefficient can be determined.

Technical specifications (Requires Hydraulics Bench Service unit F1-10/F1-10-2)

Manometer range	0-300mm
Number of manometer tubes	8
Throat diameter	10.0mm
Upstream diameter	25.0mm
Upstream taper	14°
Downstream taper	21°

Overall dimensions

Length	0.55m
Width	0.25m
Height	0.60m

Ordering codes

- F1-15

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Applications: ChE ME CE IP

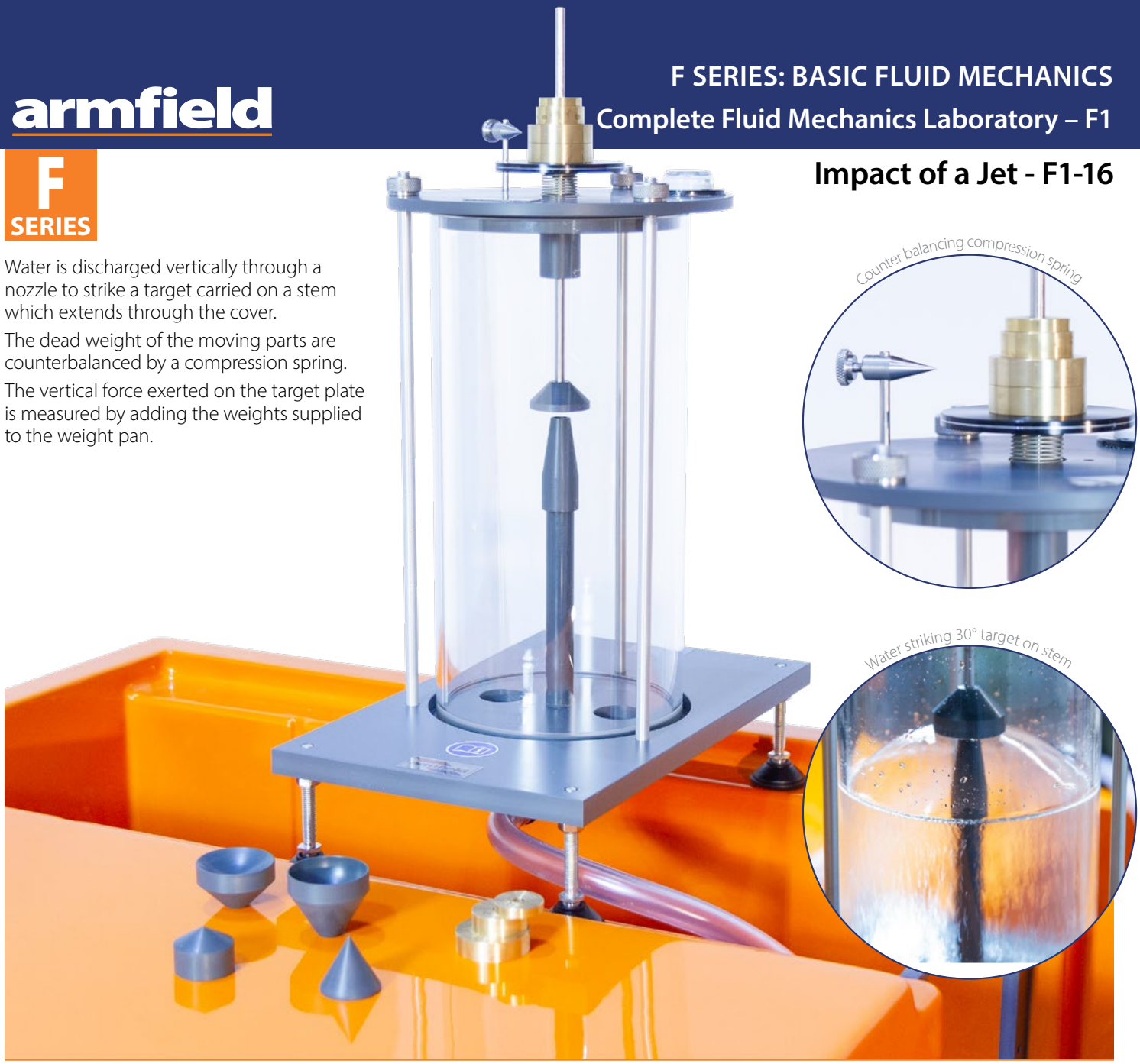
F SERIES

Impact of a Jet - F1-16

Water is discharged vertically through a nozzle to strike a target carried on a stem which extends through the cover.

The dead weight of the moving parts are counterbalanced by a compression spring.

The vertical force exerted on the target plate is measured by adding the weights supplied to the weight pan.



Experimental content

- Principle of linear momentum
- To investigate the reaction forces produced by the change in momentum of a fluid flow
- Measurement of the forces produced by a jet impinging on solid surfaces which produce different degrees of flow deflection

Description

The apparatus consists of a cylindrical clear acrylic fabrication with provision for levelling.

Water is fed through a nozzle and discharged vertically to strike a target carried on a stem which extends through the cover. A weight carrier is mounted on the upper end of the stem.

The dead weight of the moving parts is counterbalanced by a compression spring. The vertical force exerted on the target plate is measured by adding the weights supplied to the weight pan until the mark on the weight pan corresponds with the level gauge.

A total of five targets are provided.

Technical specifications (Requires Hydraulics Bench Service unit F1-10/F1-10-2)

Nozzle diameter	8mm
Distance between nozzle & target plate	20mm
Diameter of target plate	36mm
Target plate	180° hemispherical target
	120° target (cone)
	flat target
	30° target
	60° target

Overall dimensions

Length	0.325m
Width	0.20m
Height	0.50m

Ordering codes

- F1-16

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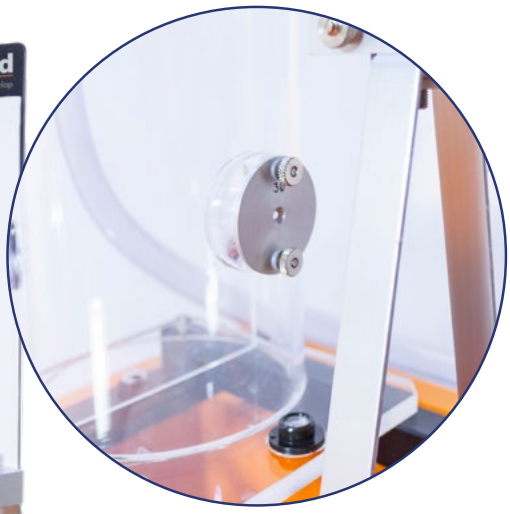
F SERIES

Orifice and Free Jet Flow - F1-17

A constant head tank is maintained with water supplied from the hydraulics bench.

The orifice (3mm or 6mm) is installed at the base of this tank ensuring a flush inside surface.

The jet trajectory is mapped using 8-point gauges to determine the discharge coefficient.



F1-17: Free Jet Flow Orifice

This equipment permits calibration of two orifices of differing diameter and enables the trajectory of the jet to be plotted.

Experimental content

- Establishing the coefficient of velocity for a small orifice
- Finding the coefficient of discharge for a small orifice with flow under constant head and flow under varying head
- Comparing the measured trajectory of a jet with that predicted by simple theory of mechanics
- Effect of tank level on jet outlet velocity

Description

The Orifice & Free Jet Flow accessory incorporates a constant head tank fed with water from the hydraulics bench. The orifice is installed at the base of this tank by means of a special wall fitting which provides a flush inside surface.

The head is maintained at a constant value by an adjustable overflow pipe and is indicated by a level scale. A series of adjustable probes enable the path followed by the jet to be ascertained.

Adjustable feet permit levelling.

Technical specifications

Orifice diameters	3.0mm and 6.0mm
Jet trajectory probes	8
Max constant head	410mm

Requires hydraulics bench service unit F1-10/F1-10-2

Overall dimensions

Length	0.67m
Width	0.33m
Height	0.60m

Ordering codes

- F1-17

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Applications: ChE ME CE IP

Orifice Discharge - F1-17a

The Orifice Discharge accessory enables full analysis of the flow through seven different orifices over a range of flow rates.

Description

The Orifice Discharge accessory consists of a cylindrical clear acrylic tank which has an orifice fitted in the base.

A traverse assembly is provided which enables a pitot tube to be positioned anywhere in the jet. Attached to this pitot tube is a fine wire which can be traversed across the jet to accurately measure the jet diameter and the vena contracta diameter and so determine the contraction coefficient.

The pitot head and the total head across the orifice are shown on manometer tubes adjacent to the tank.

In addition to the sharp edged orifice, four additional orifices with different profiles are supplied. All orifices have a common bore of 13mm for direct comparison of performance.

Experimental content

- To determine the Coefficient of Discharge (CD), Coefficient of Velocity (CV) and Coefficient of Contraction (CC) for flow of water through a small orifice

Ordering specification

The Orifice Discharge accessory enables full analysis of the flow through different orifices over a range of flow rates. It consists of:

- Seven orifice plates: 1 x knife edged orifice
  4 x orifices with different internal profiles
  1 x square aperture
  1 x triangular aperture
- A cylindrical clear acrylic tank with an orifice fitted in the base
- A carrier enables a pitot tube to be accurately positioned anywhere in the jet
- A wire micrometre is used to accurately measure the jet diameter and the vena contracta diameter and so determine the contraction coefficient

Technical specifications (Requires hydraulics bench service unit F1-10/F1-10-2)

Standard orifice	Sharp-edged 13mm diameter
Max head	365mm
Traverse mechanism	Lead screw with adjusting nut Calibrated 0.1mm per division
Overall dimensions	
Length	0.33m
Width	0.33m
Height	0.60m

F1-17a: Manometer

F1-17a: Orifice plates

Ordering codes

- F1-17a

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Applications: ChE ME CE IP

Energy Losses in Pipes - F1-18

The unit consists of a vertical test pipe on the side of the equipment which can be fed directly from the hydraulics bench supply or, alternatively, from the integral constant head tank above.

These in turn provide high or low flow rates which may be controlled by a valve at the discharge end of the test pipe. Manometers are used to measure the head loss. For large pressure differentials we would recommend the Armfield H12-8 Digital Pressure meter, although a water-over-mercury manometer is also built into the unit. In addition, a pressurised water manometer for small pressure differentials is also fitted to the unit.

Experimental content

- To investigate the head loss due to friction in the flow of water through a pipe and to determine the associated friction factor over a range of flow rates in laminar flow
- To investigate the head loss due to friction in the flow of water through a pipe and to determine the associated friction factor over a range of flow rates in turbulent flow
- Determining the critical Reynolds number

Description

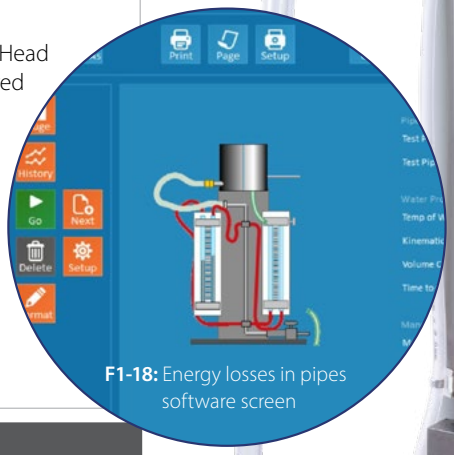
The Energy Losses in Pipes accessory consists of a test pipe, orientated vertically on the side of the equipment, which may be fed directly from the hydraulics bench supply or, alternatively, from the integral constant head tank.

These sources provide high or low flow rates which can be controlled by a valve at the discharge end of the test pipe. Head loss between two tapping points in the test pipe is measured using two manometers, a water over mercury manometer or an H12-8 for large pressure differentials and a pressurised water manometer for small pressure differentials.

Excess water discharging from the constant head tank is returned to the sump tank of the hydraulics bench, adjustable feet permit levelling.

Mercury is not supplied:

The H12-8 Digital Pressure Meter is available as an alternative to mercury manometers – for more information view online www.armfield.co.uk/h-12



F1-18: Energy losses in pipes software screen

Technical specifications

Diameter of test pipe	3.0mm
Length of test pipe	760mm
Distance between pressure tapping points	500mm
Range of mercury manometer	500mm
Range of water manometer	500mm
Measuring cylinder capacity	1000ml

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	0.33m
Width	0.28mm
Height	0.75m

Ordering codes

- F1-18

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F SERIES

Flow Channel - F1-19

The Flow Channel introduces students to the characteristics of flow in an open channel at an elementary level.

- Demonstrating basic phenomena associated with open channel flow
- Visualisation of flow patterns over or around an immersed object

F1-19: Mounted on top of the hydraulics bench

F1-19: Dye injection system

Technical specifications

Diameter of test pipe	3.0mm
Length of test pipe	760mm
Distance between pressure tapping points	500mm
Range of mercury manometer	500mm
Range of water manometer	500mm
Measuring cylinder capacity	1000ml

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Description

The channel consists of a clear acrylic working section of large depth-to-width ratio incorporating undershot and overshot weirs at the inlet and discharge ends respectively. Water is fed to the streamlined channel entry via a stilling tank to reduce turbulence. 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 incorporated at the inlet to the channel enables flow visualisation in conjunction with a graticule on the rear face of the channel.

Models supplied with the channel include broad and sharp-crested weirs, large and small-diameter cylinders and symmetrical and asymmetrical aerofoils. These in conjunction with the inlet and discharge weirs, permit a varied range of open channel and flow visualisation demonstrations.

Experimental content

- To visualise flow patterns around immersed objects in an open channel
- Demonstration of flow phenomena in an open channel
- Undershot and Overshot weirs
- Broad Crested and Sharp Crested Weirs
- Discharge beneath a sluice gate
- Creation of a hydraulic jump downstream of a sluice gate and weir
- Drowning of a sluice gate and weir
- Flow over a broad crested and sharp edged weir
- Supercritical (fast) and sub-critical (slow) flows over the weir

Overall dimensions

Length	0.865m
Width	0.33m
Height	0.50m

Ordering codes

- F1-19

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Osborne Reynolds' Demonstration - F1-20

F SERIES

This item is intended to reproduce the classic experiments conducted by Professor Osborne Reynolds concerning the nature of laminar and turbulent flow.

- Reproducing the classic experiments conducted by Professor Osborne Reynolds concerning fluid flow condition
- Observing the laminar, transitional, turbulent flow and velocity profile

$$\mathrm{Re} = \frac{\rho u L}{\mu} = \frac{u L}{\nu}$$

F1-20: Glass marbles

F1-10 bench

Experimental content

- Reproducing the classic experiments conducted by Professor Osborne Reynolds concerning fluid flow condition
- Observing the laminar, transitional, turbulent flow and velocity profile

Description

The equipment operates in a vertical orientation. A header tank containing stilling media provides a constant head of water through a bellmouth entry to the flow visualisation pipe.

Flow through this pipe is regulated using a control valve at the discharge end. The flow rate of water through the pipe can be read on the digital flow meter or can be measured using the volumetric tank (or measuring cylinder) of the hydraulics bench. Velocity of the water can therefore be determined to enable calculation of Reynolds' number.

The equipment uses a similar dye injection technique to that of Reynolds' original apparatus to enable observation of flow conditions.

Technical specifications

Test pipe diameter	10.0mm (precision bore glass)
Length of test pipe	700mm
Dye reservoir capacity	0.45l
Requires Hydraulics Bench Service unit F1-10/F1-10-2	

Overall dimensions

Length	0.50m
Width	0.33m
Height	1.24m

Ordering codes

- F1-20

UK office - email: sales@armfield.co.uk tel: +44 (0) 1425 478781 (for ROW)
USA office - email: info@armfield.inc tel: +1 (609) 208-2800 (USA only)
Service and maintenance support: armfieldassist.com

Issue: 2
URL: http://www.armfield.co.uk/f1
Applications: ChE ME CE IP

Flow Meter Demonstration - F1-21

F SERIES

This accessory is designed to introduce students to three basic types of flow meter:

- Venturi meter
- Variable area flowmeter (Rotameter)
- Orifice plate
- 8 pressure tappings are connected and displayed on the manometer bank to visualise pressure profiles

Experimental content

- To investigate the operation and characteristics of a Venturi meter, variable area meter and orifice plate including accuracy and energy losses
- Comparison of pressure drops across each flow measurement device
- Calibrating each flow meter using the volumetric measuring tank of the bench
- Application of the Bernoulli equation for incompressible fluids

Description

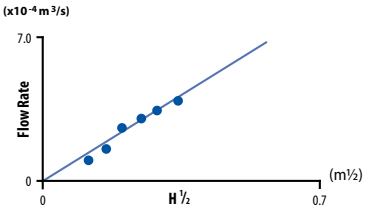
The equipment consists of a Venturi meter, variable area meter and orifice plate installed in a series configuration to permit direct comparison.

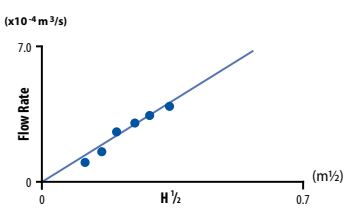
A flow control valve permits variation of the flow rate through the circuit. Pressure tappings are incorporated so that the head loss characteristics of each flow meter may be measured. These tappings are connected to an eight-tube manometer bank incorporating a manifold with an air bleed valve.

Pressurisation of the manometers is facilitated by a hand pump.

The circuit and manometer are attached to a support framework, which stands on the working top of the Hydraulics Bench.

The bench is used as the source of water supply and for volumetrically calibrating each flow meter.





Technical specifications

Manometer range	0-400mm
Number of manometer tubes	8
Orifice plate diameter	20mm
Variable area meter	2-20 l/min
Venturi dimensions	
Throat diameter	15mm
Upstream pipe diameter	31.75mm
Upstream taper	21° inclusive
Downstream taper	14° inclusive

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	0.68m
Width	0.33m
Height	0.83m

Ordering codes

- F1-21

UK office - email: sales@armfield.co.uk tel: +44 (0) 1425 478781 (for ROW)
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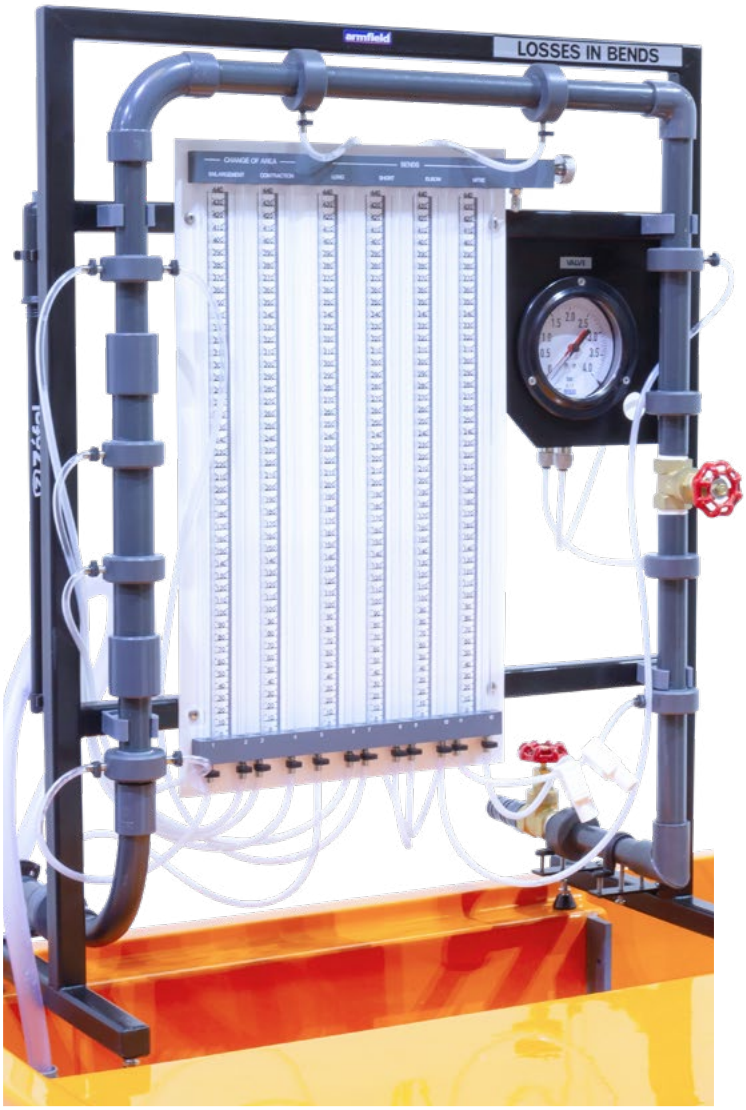
Energy Losses in Bends and Fittings - F1-22

This accessory permits losses in different bends and fittings, sudden contraction, sudden enlargement and a typical control valve to be demonstrated.

- Mitre bend - 90° elbow - Swept bends (large and small radius)
- Sudden contraction and sudden enlargement
- Fully instrumented with upstream and downstream pressure tappings
- A bank of 12 water manometer tubes mounted on the framework for visualisation of the pressure drop profiles



Experimental content

Measuring the losses in the devices related to flow rate and calculating loss coefficients related to velocity head including:

- Long bend
- Area enlargement
- Area contraction
- Elbow bend
- Mitre bend
- Short bend
- Gate valve fitting
- Comparing the pressure drop across each device

Description

The equipment is mounted on a free-standing framework which supports the test pipework and instrumentation. The following typical pipe fittings are incorporated for study: mitre bend, 90° elbow, swept bends (large and small radius), sudden contraction and sudden enlargement.

All are instrumented with upstream and downstream pressure tappings. These tappings are connected to a bank of 12 water manometer tubes mounted on the framework. Pressurisation of the manometers is facilitated by a hand pump. A gate valve is used to control the flow rate.

A separate gate valve is instrumented with upstream and downstream pressure tappings which are connected to a differential gauge on the edge of the framework. The unit stands on the working top of the hydraulics bench which is also used as the source of water supply.

Overall dimensions

Length	0.63m
Width	0.33m
Height	0.83m

Technical specifications

Pipe diameter	19.48mm
Differential pressure gauge	0-3 bar
Enlargement diameter	26.2mm
Contraction diameter	19.48mm
Fittings	45° mitre
	elbow
	short bend
	large bend
	enlargement
	contraction
Manometer range	0-440mm
Number of manometer tubes	12
Differential manometers	6

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Ordering codes

- F1-22

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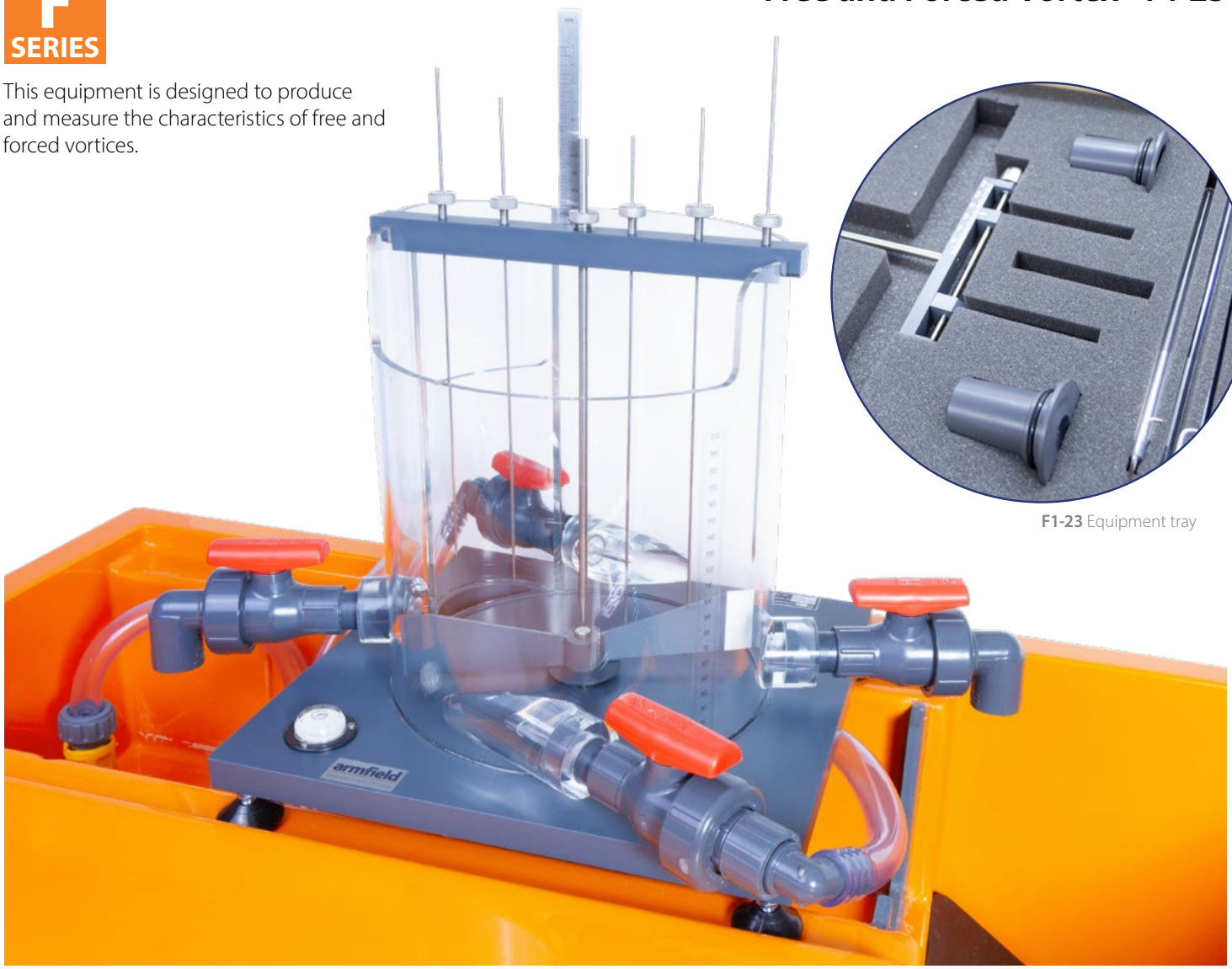
F SERIES

Free and Forced Vortex - F1-23

This equipment is designed to produce and measure the characteristics of free and forced vortices.



F1-23 Equipment tray

Experimental content

- Understanding the difference between free and forced vortices
- Determining the surface profile of a forced vortex
- Determining the surface profile and total head distribution of a free vortex
- Visualisation of secondary flow in a free vortex

Description

The apparatus comprises a clear acrylic cylinder on a plinth designed to produce and measure free and forced vortices.

The free vortex is generated by water discharging through an interchangeable orifice in the base of the cylinder, and the resulting profile is measured using a combined calliper and depth scale.

The forced vortex is induced by a paddle in the base of the cylinder, which is rotated by jets of water. The profile of the forced vortex is determined using a series of depth gauges.

Velocity at any point in the free or forced vortices may be measured using the appropriate pitot tube supplied.

Dye crystals (not supplied) may be used to demonstrate secondary flow at the base of the free vortex.

Technical specifications

Tank diameter	245mm
Height to overflow point	180mm
Orifice diameters	8, 16 and 24mm
Forced vortex measuring probes	
Distance from centre	0, 30, 50, 70, 90 and 110mm
Pitot tubes having measuring point (nose) at	15, 25 and 30mm radius
Inlet tubes	9 and 12.5mm diameter

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	0.60m
Width	0.50m
Height	0.46m

Ordering codes

- F1-23

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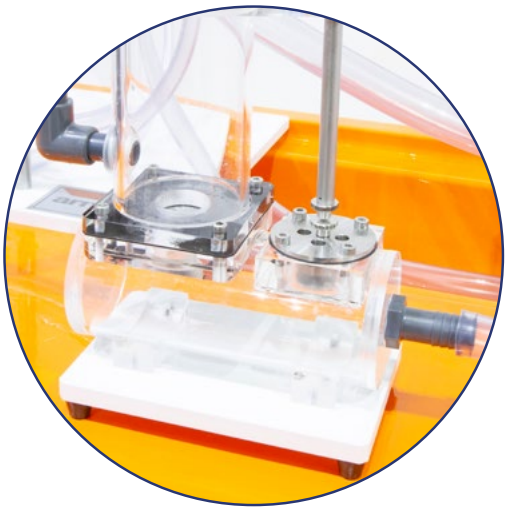
Hydraulic Ram - F1-24

F SERIES

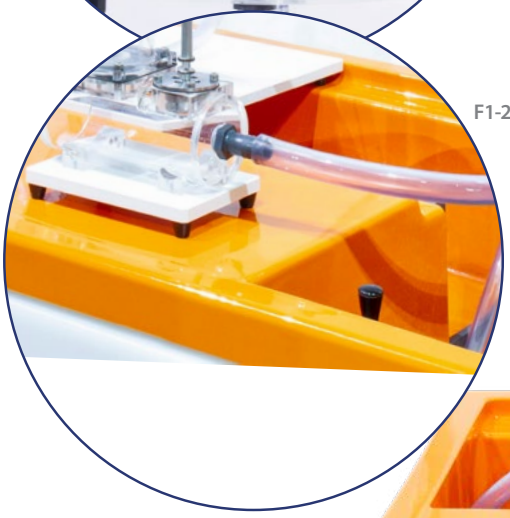
If flowing water is suddenly brought to rest in a long pipe, a phenomenon known as water hammer occurs. This produces a pressure wave that travels along the pipe.

This principle is used in the hydraulic ram to pump water.

F1-24 Header tank



F1-24 Hydraulic ram pump



F1-24 Weight platform

Experimental content

- To demonstrate the operating principles of the hydraulic ram
- Establishing flow/pressure characteristics and determining efficiency of the hydraulic ram

Description

The Hydraulic Ram comprises an acrylic base incorporating pulse and non-return valves and a supply reservoir on a stand which is fed by the hydraulics bench. An air vessel above the valve chamber smooths cyclic fluctuations from the ram delivery.

The weights supplied may be applied to the pulse valve to change the closing pressure and thus the operating characteristics.

Technical specifications

Supply head	300-700mm variable
Delivery head	750-1500mm variable

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	0.75m
Width	0.33m
Height	1.62m

Ordering codes

- F1-24

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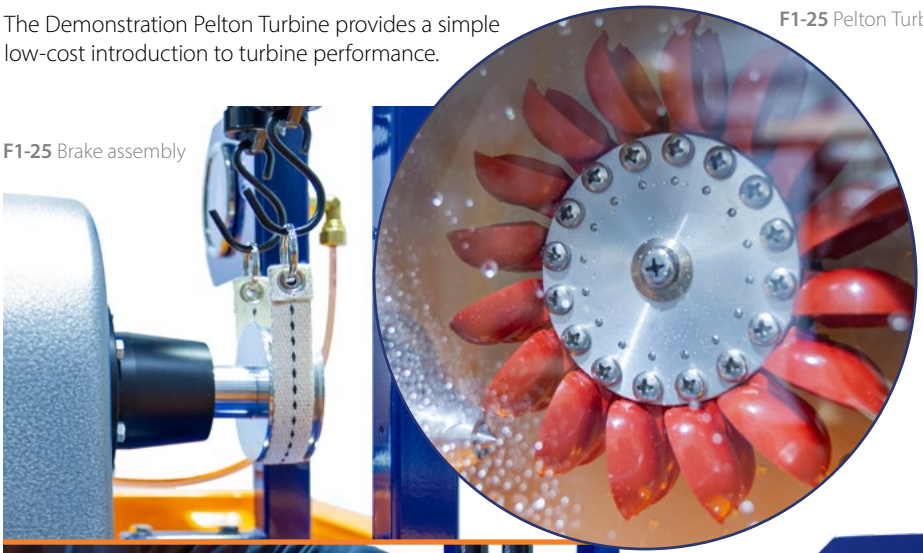
F SERIES

Demonstration Pelton Turbine - F1-25

The Demonstration Pelton Turbine provides a simple low-cost introduction to turbine performance.

F1-25 Brake assembly



F1-25 Pelton Turbine buckets

Pelton Turbine brake being operated

Experimental content

- To determine the operating characteristics of a Pelton Turbine
- Performance charts of power, speed, torque and efficiency
- Turbine output torque v rotor speed
- Turbine output power v rotor speed
- Turbine overall efficiency v rotor speed

Description

This accessory comprises a miniature Pelton wheel with a spear-valve arrangement mounted on a support frame which fits onto the hydraulics bench top channel. Mechanical output from the turbine is absorbed using a simple friction dynamometer.

Pressure at the spear-valve is indicated on a remote gauge.

A non-contacting tachometer option 100-2/1 may be used to determine the speed of the Pelton wheel. Basic principles of the Pelton turbine may be demonstrated and with appropriate measurements, power produced and efficiency may be determined.

Technical specifications

Speed range	0-2000 rpm
Brake power	10W
Pressure gauge range	0-25m H_2O
Force balance range	2x0-50 N spring balance
Number of Pelton buckets	16
Diameter of Pelton wheel	123mm

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	0.40m
Width	0.30m
Height	0.60m

Ordering codes

- F1-25
- 100-2/1 Tachometer including carrying pouch

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Issue: 2
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Applications: ChE ME CE IP

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F SERIES

Centrifugal Pump Characteristics - F1-27

This accessory offers enhanced capabilities provided by the inclusion of a variable-speed pump with inverter drive rather than a fixed-speed pump.

F1-27 Centrifugal pump attached to F1-10 bench

Experimental content

- Determining the relationship between head, discharge, speed, power and efficiency for a centrifugal pump at various speeds
- Determining the head/flow rate characteristics of two similar pumps operating in either parallel or series configuration at the same speed

Description

This accessory comprises a variable speed pump assembly and independent discharge manifold interconnected by flexible tubing with quick release connectors. This auxiliary pump is intended to be used in conjunction with the basic Hydraulics Bench F1-10/F1-10-2.

The pump speed is varied by an inverter drive. The motor speed, output voltage and motor current can be monitored on the inverter display. A compound pressure gauge is mounted on the pump inlet and a pressure gauge is mounted on the pump outlet.

An independent discharge manifold incorporates a pressure gauge and flow control valve prior to a discharge pipe with diffuser.

The auxiliary pump is mounted on a support plinth designed to be positioned on the floor besides the hydraulics bench , adjustable feet allowing levelling.

Overall dimensions

Length	0.36m
Width	0.16m
Height	0.325m

Technical specifications

Pump	Centrifugal type
Max head	21m H_2O
Max flow	1.35 l/s
Motor rating	0.36kW
Speed controller	Frequency inverter
Speed range	0-1500 rpm
Pressure gauge range	0-60m H_2O
Compound gauge range	–10 to +32m H_2O

See Hydraulics Bench F1-10 technical details for primary pump characteristics.

Requirements

Scale

Electrical supply:

F1-27-A:	220-240V / 1ph / 50Hz @ 10 amp
F1-27-G:	220V / 1ph / 60Hz @ 10 amp

G version has optional 1.5kVA transformer available to accommodate 120V / 1ph / 60Hz.

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Ordering codes

- F1-27

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Applications: ChE ME CE IP

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F SERIES

Cavitation Demonstration - F1-28

This equipment demonstrates to students visually, audibly and numerically the phenomenon of cavitation and its association with the vapour pressure of a liquid.

F1-28 Vacuum gauge

Experimental content

- To demonstrate the appearance and sound of Cavitation in a hydraulic system
- To demonstrate the conditions for Cavitation to occur (liquid at its vapour pressure)
- To observe the difference between air release from the water and true Cavitation
- To show how Cavitation can be prevented by raising the static pressure of a liquid above its vapour pressure
- Verification of Bernoulli's equation
- Comparison of theoretical and actual pressure at cavitation conditions

Description

This accessory consists of a circular Venturi-shaped test section manufactured from clear acrylic to enable visualisation inside the section.

As the flow of water increases, the pressure at the throat falls in accordance with the Bernoulli equation until a limit is reached corresponding to the vapour pressure of the liquid. At this low pressure small bubbles of vapour form then collapse violently as the pressure rises again downstream.

This process is called cavitation.

Bourdon gauges indicate the pressure upstream of the contraction, inside the throat and downstream of the expansion in the test section. Flow control valves upstream and downstream of the test section enable the flow and pressure to be adjusted, enabling cavitation to be clearly demonstrated.

Technical specifications

Upstream pressure gauge	
Diameter	63mm
Range	0 to 1 bar
Throat vacuum gauge	
Diameter	100mm
Range	-1 to 0 bar
Downstream pressure gauge	
Diameter	63mm
Range	0 to -1 bar

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	0.30m
Width	0.30m
Height	0.15m

Ordering codes

- F1-28

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Issue: 2
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Applications: ChE ME CE IP

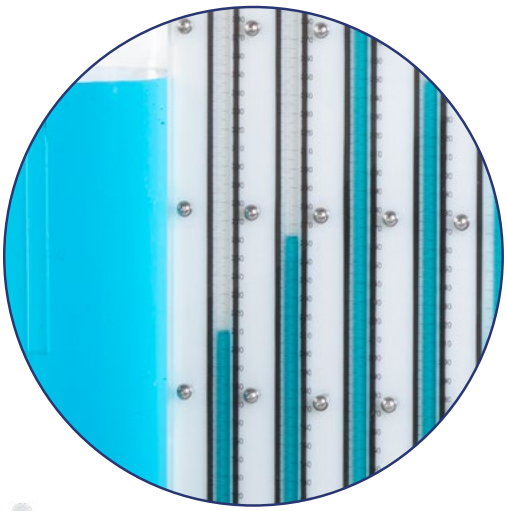
Fluid Statics and Manometry - F1-29

The right-hand manometer tube is separate from the other tubes and incorporates a pivot and indexing mechanism at the base that enables this tube to be inclined at fixed angles of 5°, 30°, 60° and 90° (vertical).

The reservoir incorporates a hook and point gauge with Vernier scale mounted through the lid that enables large changes in level to be measured with precision.

A vertical transparent piezometer tube through the lid of the reservoir enables the static head above the water in the reservoir to be observed when the air space above the water is not open to the atmosphere.

F1-29: Different inclination angles in the inclined manometer



F1-29 Manometer

Experimental content

- Demonstrating the behavior of liquids at rest (hydrostatics)
- Showing that the free surface of a liquid is horizontal and independent of cross section or inclination of the container
- Effect of changes in air pressure above a liquid surface
- Measuring the level of a liquid using basic measuring techniques such as a scale, vernier depth gauge and inclined scale and the effect of parallax
- Measuring small changes in liquid level using a micro-manometer
- Measuring changes in liquid level using a Vernier hook and point gauge
- Using a single limb manometer / piezometer tube to measure head
- Using manometer tubes to measure differential pressure
- Using an inclined manometer to measure small pressure differences
- Using a 'U' tube manometer to measure pressure differences in a gas (air over liquid)
- Using an inverted pressurised 'U' tube manometer to measure pressure differences in a liquid
- Enlarged limb manometer
- Using liquids with different densities to change the sensitivity of a 'U' tube manometer
- Demonstrating the effect of trapped air on the accuracy of a manometer
- Demonstrating the effects caused by friction when a fluid is in motion

Overall dimensions

Length	0.425m
Width	0.15m
Height	1.09m

Technical specifications

Max depth inside reservoir	574mm
Inside diameter of reservoir	100mm
Scale length of manometer tubes	460mm

Ordering codes

- F1-29

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F SERIES

Fluid properties apparatus - F1-30

This apparatus provides an introduction to the fundamental properties of liquids that affect their behaviour in practical applications.

F1-30 Fluid properties components

Experimental content

- Measuring density and relative density (specific gravity) of a liquid using a universal hydrometer
- Measuring density and relative density (specific gravity) of a liquid using a pycnometer (density bottle)
- Measuring density and relative density of solid objects or granular material using a Pycnometer
- Measuring viscosity of various liquids at atmospheric temperature and pressure using a Falling Sphere Viscometer
- Measuring the effect of capillary elevation inside capillary tubes
- Demonstrate the effect of capillary elevation between two flat glass plates due to surface tension in a liquid
- Verifying Archimedes principle using a brass bucket & cylinder with a lever balance
- Measuring atmospheric pressure using an aneroid barometer

Description

A clear understanding about the physical properties of fluids is essential before studying the behaviour of fluids in static or dynamic applications.

This apparatus introduces students to the following properties of fluids:

- Density and relative density (specific gravity)
- Viscosity
- Capillarity – capillary elevation between flat plates and in circular tubes
- Buoyancy (Archimedes principle)
- Atmospheric pressure

The apparatus consists of a collection of components that demonstrate individual fluid properties. The components are stored on a common support frame manufactured from PVC with circular spirit level and adjustable feet for levelling.

The apparatus is designed to stand on a suitable benchtop where some of the components can be operated independently from the support frame.

A free-standing dual-scale lever balance is also supplied to support several of the demonstrations.

Technical specifications

The following components are included
2 hydrometer jars (clipped to stand)
1 universal hydrometer (in protective housing)
2 falling-sphere viscometer tubes (clipped to stand)
1 plastic storage box containing steel spheres
1 spirit-filled glass thermometer (in protective housing)
1 direct-reading aneroid barometer (fixed to stand)
1 parallel-plate capillary apparatus
1 capillary tube apparatus with six tubes of varying size
1 Archimedes apparatus comprising displacement vessel, machined bucket & matching cylinder
1 50ml density bottle (Pycnometer)
1 250ml plastic measuring cylinder
1 600ml glass beaker
1 dual-scale lever balance, adapted for use with the Archimedes apparatus

Overall dimensions	
Length	0.60m
Width	0.16m
Height	0.50m

Ordering codes

- F1-30

UK office - email: sales@armfield.co.uk tel: +44 (0) 1425 478781 (for ROW)
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Applications: ChE ME CE IP

Pascal's Apparatus - F1-31

The Pascal's Apparatus demonstrates in a simple way that the pressure in an incompressible fluid varies with depth and does not depend on the shape of the container.

Beaker and tapping point

Experimental content

- Demonstrating that the pressure in a liquid contained in a vessel, varies with depth and is not affected by the shape of the vessel

Description

This apparatus, designed to demonstrate Pascal's principle, consists of a machined body incorporating a horizontal flexible diaphragm to which one of three alternative glass vessels can be fitted.

The diameter at the base of each vessel is common, but the shape of each vessel varies, one-parallel sided, one conical and one tapering inward.

The diaphragm, located at the base of the vessel, conveys the force from the water inside the vessel to a lever arm with a sliding counterweight.

A spirit level indicates when the lever arm is horizontal and therefore balancing the force/pressure at the base of the vessel. The force on the diaphragm depends on the depth of water above the diaphragm and the area of the diaphragm that is constant for all three vessels.

A height-adjustable pointer enables each of the vessels to be filled to the same depth so that the force/pressure can be shown to be common for all three vessels, independent of shape.

Technical specifications

Parallel vessel	26mm inside diameter
Conical vessel	26-101mm inside diameter at top
Tapered vessel	26mm to 9mm inside diameter at top
Diameter at diaphragm	56mm
Maximum depth of water	228mm (to top of vessels)

Overall dimensions

Length	0.35m
Width	0.135m
Height	0.45m

Ordering codes

- F1-31

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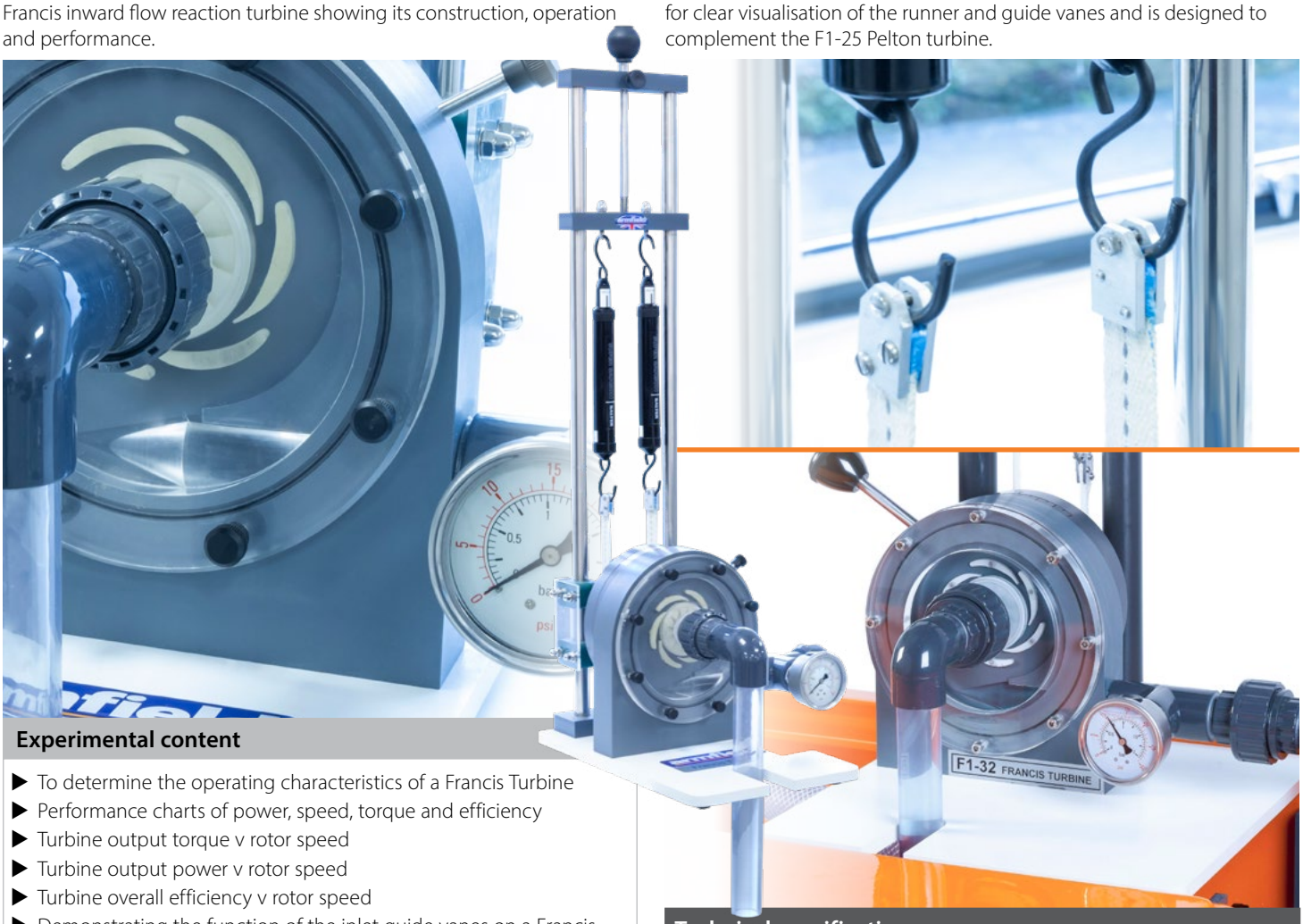
F SERIES

Francis Turbine - F1-32

This demonstration turbine provides a simple low-cost introduction to the Francis inward flow reaction turbine showing its construction, operation and performance.

The volute of the Francis Turbine incorporates a transparent front cover for clear visualisation of the runner and guide vanes and is designed to complement the F1-25 Pelton turbine.



Experimental content

- To determine the operating characteristics of a Francis Turbine
- Performance charts of power, speed, torque and efficiency
- Turbine output torque v rotor speed
- Turbine output power v rotor speed
- Turbine overall efficiency v rotor speed
- Demonstrating the function of the inlet guide vanes on a Francis Turbine to vary the flow through the turbine and consequently the power produced

Description

A tapering, spiral-shaped volute conveys water to the runner via a ring of guide vanes that are adjustable in angle to vary the flow through the turbine. Water enters the runner tangentially at the periphery, flows radially inward through the blades toward the hub then exits axially via a draft tube.

Power generated by the turbine is absorbed by a Prony friction brake consisting of a pair of spring balances attached to a brake belt that is wrapped around a pulley wheel driven by the runner. The load on the turbine is varied by tensioning both spring balances which increases the friction on the pulley wheel. Brake force is determined from the difference in the readings on the two spring balances and the torque calculated from the product of this force and the pulley radius.

The head of water entering the turbine is indicated on a Bourdon gauge and the speed of rotation is measured using a non-contacting tachometer (option) 100-2/1 Tachometer including carrying pouch.

Technical specifications

Speed range	0-4000 rpm
Diameter of Francis runner	60mm
Number of blades on runner	12
Number of guide vanes	6, adjustable from fully open to fully closed
Range of spring balances	0-50N x 0.5N
Range of Bourdon gauge	0-2 bar
Requires Hydraulics Bench Service unit F1-10/F1-10-2	

Overall dimensions

Length	0.60m
Width	0.34m
Height	0.85m

Ordering codes

- F1-32
- 100-2/1 Tachometer including carrying pouch

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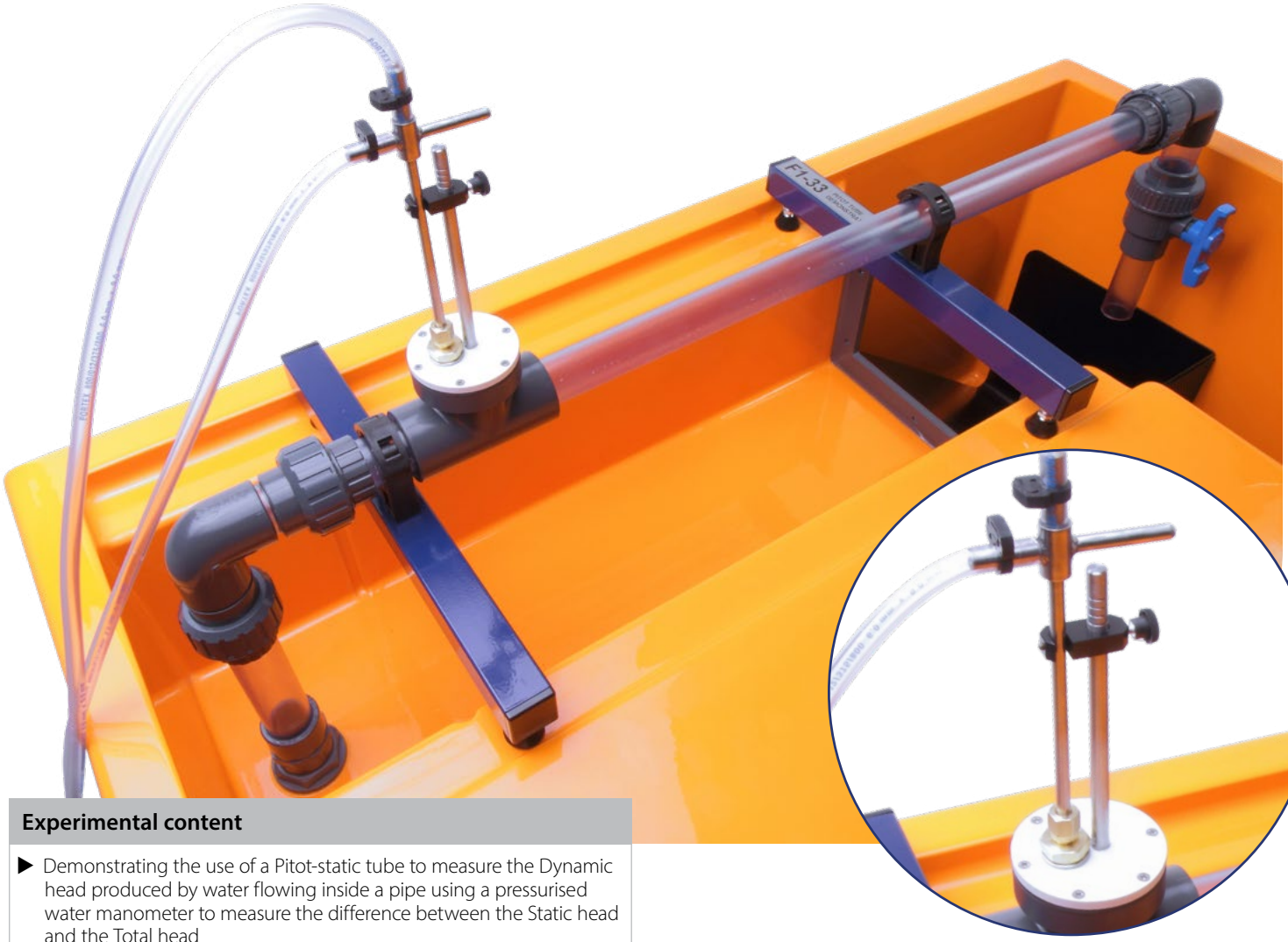
F SERIES

Pitot Tube Demonstrator - F1-33

The pitot tube can be moved across the cross-section of the pipe in order to measure the dynamic head profile.



F1-33 Pitot tube mounting base

Experimental content

- Demonstrating the use of a Pitot-static tube to measure the Dynamic head produced by water flowing inside a pipe using a pressurised water manometer to measure the difference between the Static head and the Total head
- Demonstrating the relationship between Static Head, Total Head and Dynamic head
- Demonstrating how a Pitot-static tube can be used to determine the velocity of a fluid
- Demonstrating how the Dynamic head of a fluid flowing inside a pipe varies with radius due to the development of a boundary layer at the wall of the pipe
- Demonstrating how the Dynamic head profile varies at the entrance to a pipe downstream of a 90 degree bend with undeveloped flow

Description

The pitot tube can be moved across the cross-section of the pipe in order to measure the dynamic head profile.

The position of the measuring tip relative to the wall of the pipe can be read on a scale.

The pitot tube is connected to a pressurised water manometer to measure the differential head across the pitot static tube.

Technical specifications

Inside diameter of test pipe	27mm
Pitot-static tube outside diameter	6mm
Pitot-static tube inside diameter	3.2mm
Scale length of manometer tubes	500mm
Cross section of manometer tubes	5.6mm diameter
Range of pitot-static tube traverse	21mm with 3mm scale increments

Requires Hydraulics Bench Service unit F1-10/F1-10-2

Overall dimensions

Length	1.00m
Width	0.35m
Height	0.52m

Ordering codes

- **F1-33**

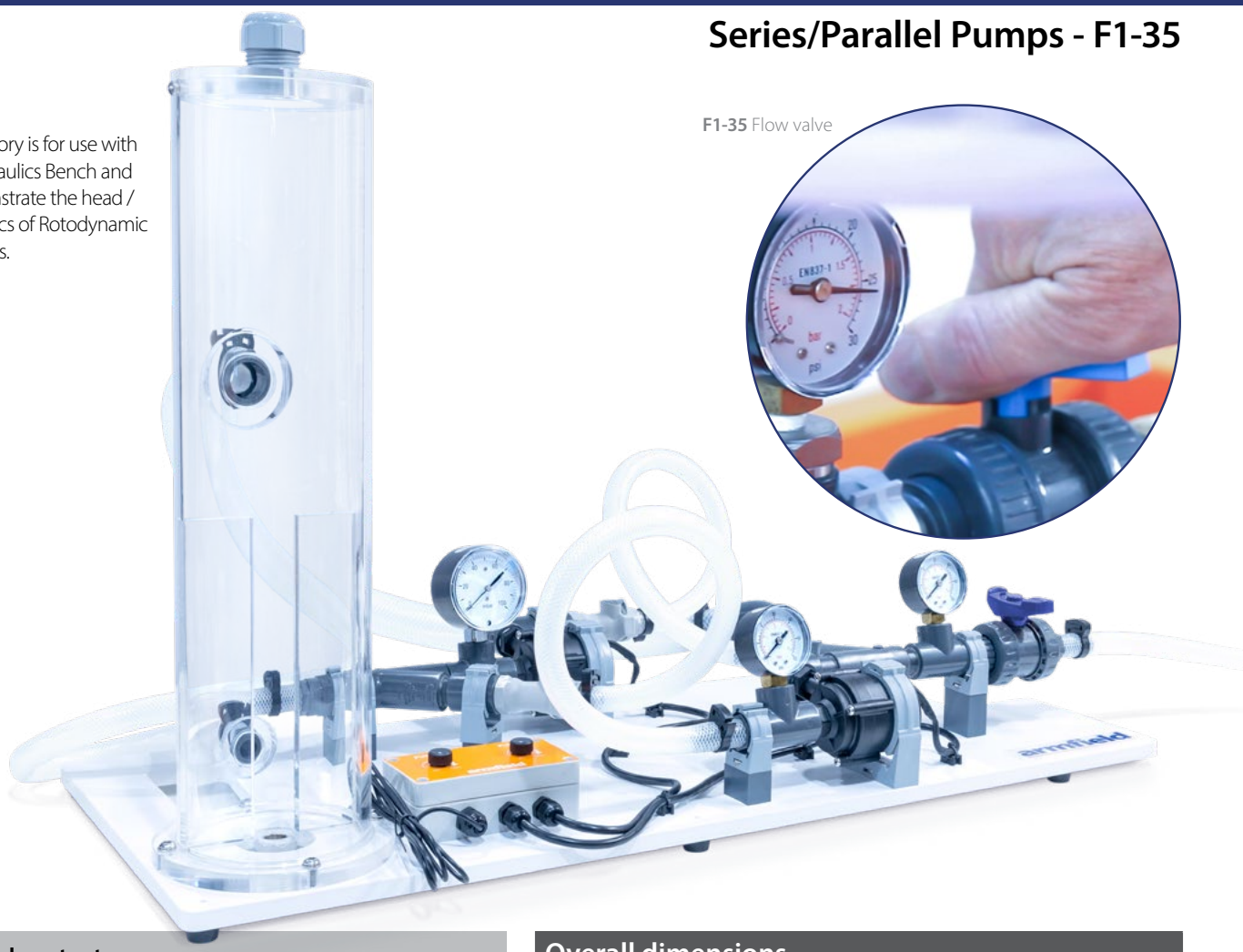
UK office - email: sales@armfield.co.uk tel: +44 (0) 1425 478781 (for ROW)
USA office - email: info@armfield.inc tel: +1 (609) 208-2800 (USA only)
Service and maintenance support: armfieldassist.com

Issue: 2
URL: http://www.armfield.co.uk/f1
Applications: ChE ME CE IP

Series/Parallel Pumps - F1-35

F SERIES

The F1-35 accessory is for use with the F1-10-2 Hydraulics Bench and is used to demonstrate the head / flow characteristics of Rotodynamic or Velocity pumps.



F1-35 Flow valve

Experimental content

Determining the head/flow rate characteristics of:

- A single centrifugal pump at a single speed
- Two similar pumps operating in parallel configuration at the same speed
- Two similar pumps operating in series configuration at the same speed
- Two similar pumps operating in parallel configuration at a variable speed
- Two similar pumps operating in series configuration at a variable speed

Description

The series and parallel accessory is designed to be positioned securely on the F1-10-2 Hydraulics Bench and has two pumps to demonstrate the characteristics of pumps connected in series or parallel. The pumps are driven by integral DC motors **with variable speed control**. Pressure gauges are mounted to measure the pressure at the inlet and outlet.

The pumps are fed from a constant head tank that forms part of the accessory, fed by the F1-10-2 pump. Flow discharges into the volumetric tank of the F1-10-2 via a flow control valve which permits an output pressure to be applied to load the pumps.

They can be operated either independently or in conjunction connected in series or parallel. Both pumps speeds are individually controlled and varied by using the controllers allocated on the frame.

Flexible tubing and quick release connectors are supplied to allow the pumps to be connected for single pump, series or parallel pump operation.

Overall dimensions

Length	0.85m
Width	0.35m
Height	0.55m
Packed and crated shipping specifications	
Volume	1.2m^3
Gross weight	20Kg
Technical details	
Power Consumption	48W (max. per pump, for this application)
Max. Flow Rate	22L/min (max per pump (series), for this application (44L/min in parallel)
Max. Head	0.96m (datum to manifold gauge) (max pump head = 11m)
Constant head tank	2L (approx)
Speed range	0-22 L/min
Measuring ranges	
Pressure (inlet)	1 x 2.0 bar
Pressure (outlet)	2 x 2.2 bar
See Hydraulics Bench F1-10 technical details for primary pump characteristics.	
Specifically requires Hydraulics Bench Service unit F1-10-2 for operation	

Ordering codes

- F1-35

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