

# 1 FUNDAMENTALS OF FLUID MECHANICS

## HYDROSTATICS

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## BASIC KNOWLEDGE

## FUNDAMENTALS OF HYDROSTATICS

Hydrostatics is the study of fluids at rest.

The experimental units from GUNT cover the basic principles of the following topics from the field of hydrostatics: hydrostatic pressure, buoyancy, surface tension, capillarity/adhesion.

## Physics and properties of fluids

- pressure measurement with manometers and pressure sensors
- temperature measurement
- vapour pressure curve
- change of state of the gases

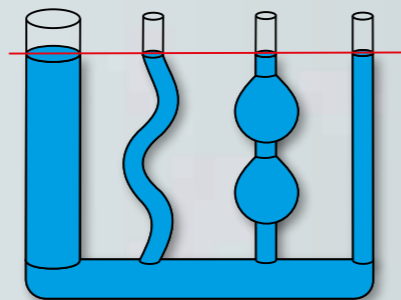
## Forces

- Coriolis force
- surface tension and forces
- lift forces
- hydrostatic pressure and resultant forces

## Communicating vessels

Communicating vessels are tubes that are open at the top and interconnected at the bottom. Regardless of the shape and size of the tubes, the level of the fluid in them is the same.

Applications include water levels, locks and drain traps in sewers.



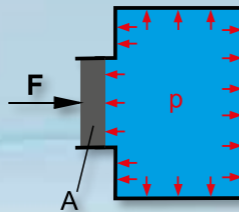
## Hydrostatic pressure

The pressure in fluids at rest does not depend on the direction. It is linearly dependent on the amount of fluid over the element being studied, for example water pressure while diving.

The hydrostatic pressure for incompressible fluids that are not subject to gravity is calculated according to Pascal's law.

## Pascal's law

The effect of a force  $F$  on a motionless liquid generates a pressure  $p$  within the liquid, which at any point acts equally in all directions. The pressure always acts perpendicular to the boundary surface  $A$  of the liquid.

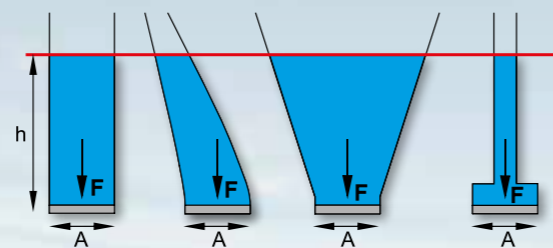


$$p = F/A$$

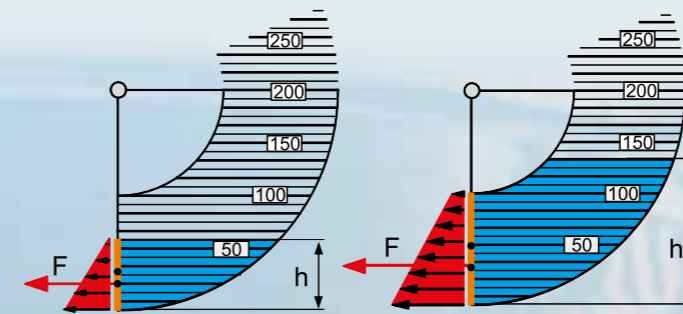
All force and pressure processes in liquids are based on this law.

## Hydrostatic paradox

The hydrostatic pressure generates a force  $F$  on the area  $A$ . If these areas are equal, this force only depends on the level  $h$ ; the shape of the vessel is irrelevant.



$h$  level,  $F$  force,  $A$  area,  
red line: level



$h$  level,  $F$  force,  $A$  effective area,  
■ pressure profile, ■ water level

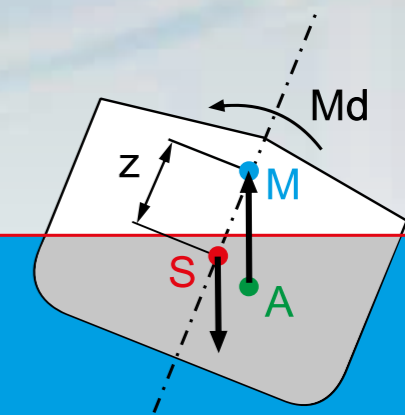
## Hydrostatic pressure on walls

In addition to the ground pressure of a fluid, it is often important to also know the hydrostatic pressure on boundary surfaces, for example in order to calculate the forces acting on the side walls (channels, aquariums, weirs).

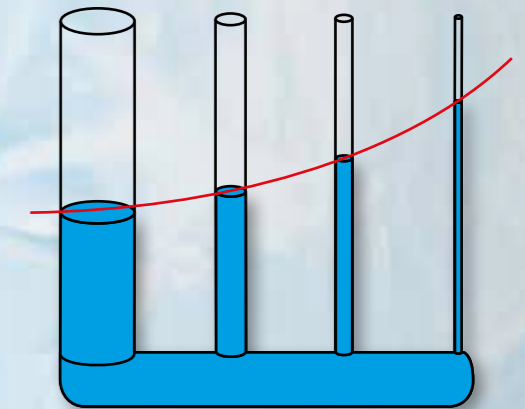
## Stability of floating bodies

In order to be able to assess whether a body floats stably or could capsize, it is necessary to determine its metacentre  $M$ . The location of the metacentre depends on the centre of gravity of the displaced water  $A$  and the angle of heel. The body floats stably when the metacentre  $M$  is located above the centre of gravity  $S$ . Then the restoring moment  $Md$  has a 'righting' effect.

The distance between the centre of gravity and the metacentre is known as the metacentric height  $z$ .



$M$  metacentre,  $S$  centre of gravity,  
 $A$  centre of buoyancy,  $z$  metacentric height,  
 $Md$  restoring moment that straightens the floating body back up,  
red line water level



## Capillarity

Liquids in capillaries rise or fall due to molecular forces between the liquid and the wall or between the liquid and air. The height of rise in the capillary depends on the surface tension and the diameter of the capillary.

In wetting liquids (e.g. water) the surface level in the capillary rises. In non-wetting liquids (e.g. mercury) the level falls.

**HM 115 Hydrostatics Trainer**


- \* Basic experiments in hydrostatics
- \* Wide range of experiments
- \* Closed water circuit with tank and pump

**Technical Description**

Hydrostatics is the study of fluids at rest. Phenomena occurring as a result of hydrostatic pressure are analysed and the force effect determined. Hydrostatic aspects play a crucial role in various areas of engineering, such as in plumbing and domestic engineering, in pump manufacturing, in aerospace and in shipping (buoyancy, load on the sides of a ship).

The HM 115 trainer can be used to conduct experiments in the field of hydrostatics, such as ground pressure measurement or demonstrating Boyle's law. Determining the centre of pressure completes the range of experiments. Furthermore, experimental units for studying capillarity and buoyancy are included. The hydrostatic pressure and surface tension are measured. Additionally, one experiment uses a Pitot tube and a tube for static pressure to study the pressure components in a flowing fluid.

To make the functions and processes visible, the tanks and the experimental units use a transparent design. Tanks and pipes are made entirely of plastic.

Various pressure gauges are available for measuring pressure and differential pressure of the liquid fluid, such as a Pitot tube, tube for static pressure a pressure sensor with digital display, twin tube manometers or a differential pressure manometer. A diaphragm manometer and a Bourdon tube manometer indicate the pressure of the gaseous fluid.

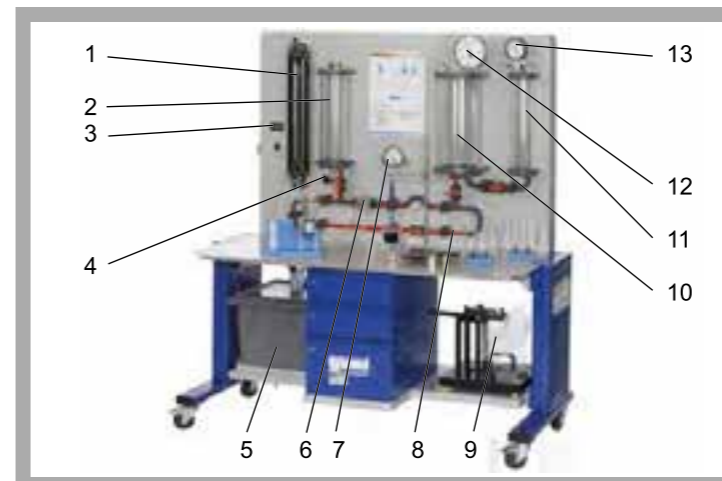
The trainer has its own air and water supply. The closed water circuit includes a supply tank with submersible pump. A compressor is included to generate negative pressures for the experiments with air.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

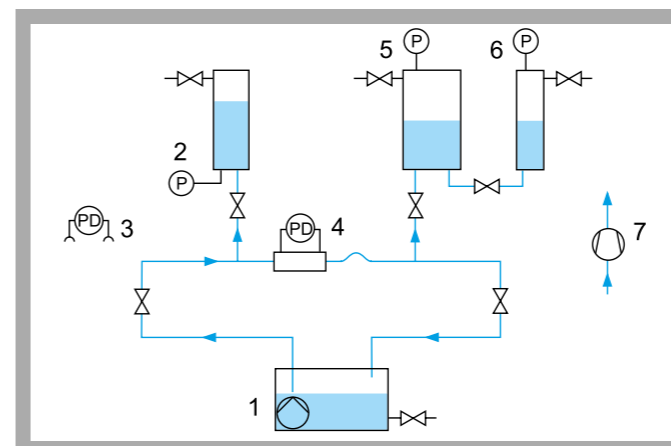
**Learning Objectives / Experiments**

- study of buoyancy on a variety of bodies
- study of the density of liquids
- hydrostatic pressure, Pascal's law
- communicating vessels
- determination of the centre of pressure
- study of surface tensions
- demonstration of capillarity
- Boyle's law
- study of static and dynamic pressure component in flowing fluid
- familiarisation with various methods of pressure measurement

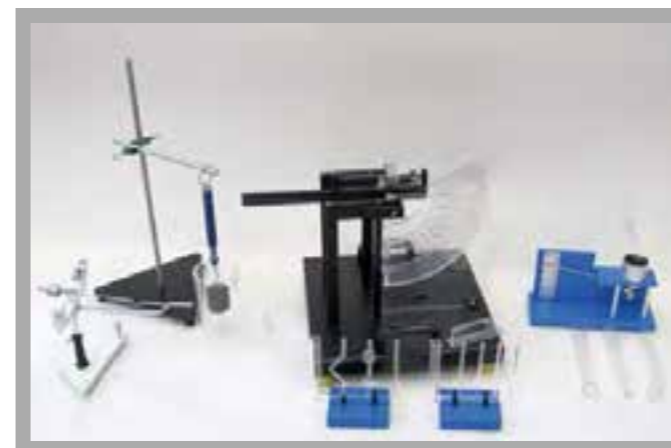
G.U.N.T Gerätebau GmbH, Hanskampring 15-17, D-22885 Barsbüttel, Phone +49 (40) 67 08 54-0, Fax +49 (40) 67 08 54-42, E-mail sales@gunt.de, Web http://www.gunt.de  
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**HM 115 Hydrostatics Trainer**


1 twin tube manometers, 2 tank, 3 digital pressure display, 4 pressure sensor, 5 supply tank with submersible pump, 6 Pitot tube and tube for static pressure, 7 differential pressure manometer, 8 pipe section, 9 hydrostatic pressure in liquids, 10 pressure vessel, 11 pressure vessel, 12 Bourdon tube manometer, 13 diaphragm manometer



1 supply tank with submersible pump, 2 tank with pressure sensor, 3 twin tube manometers, 4 Pitot tube + tube for static pressure with differential pressure manometer, 5 pressure vessel with Bourdon tube manometer, 6 pressure vessel with diaphragm manometer, 7 compressor; P pressure, PD differential pressure



Accessories for a wide range of experiments

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**Specification**

- [1] comprehensive experimental introduction to hydrostatics
- [2] transparent tank for observing the processes
- [3] wide range of accessories included: compressor for generating negative pressures, bottom pressure apparatus, two areometers
- [4] 1 experimental unit each: measuring the buoyancy force, investigation of the hydrostatic pressure in liquids, measuring the surface tension, communicating vessels, capillarity
- [5] Pitot tube for determining the total pressure and tube for static pressure
- [6] instruments: pressure sensor with digital display, differential pressure manometer, twin tube manometers, diaphragm manometer, Bourdon tube manometer

**Technical Data**
**Pump**

- power consumption: 250W
- max. flow rate: 9m<sup>3</sup>/h
- max. head: 7,6m

**Compressor**

- power: 65W
- delivery side: 2000mbar
- intake side: 240mbar

**3 tanks**

- height 500mm
- d=100mm, d=133mm, d=200mm

Supply tank for water: 55L

2 areometers with different measuring ranges

**Measuring ranges**

- pressure: 2x -1...1,5bar
- differential pressure: 0...500mmWC
- differential pressure: 0...0,4bar
- density: 1x 0,8...1g/cm<sup>3</sup>, 1x 1...1,2g/cm<sup>3</sup>

**Dimensions and Weight**

LxWxH: 1760x840x1950mm

Weight: approx. 250kg

**Required for Operation**

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase

**Scope of Delivery**

- 1 trainer
- 1 compressor
- 1 bottom pressure device
- 2 areometers
- 1 wedge-shaped tank
- 1 experimental unit each:
  - surface tension, hydrostatic pressure in fluids, buoyancy force, capillarity, communicating vessels
- 1 set of instructional material

**Order Details**

070.11500 HM 115 Hydrostatics Trainer

**HM 150.06 Stability of Floating Bodies**

**Technical Description**

In hydrostatics, the metacentre is an important point to be considered when assessing the stability of floating bodies. Stability refers to the ability of a ship to right itself from a heeled position. The metacentre is the intersection of the buoyancy vector and the vessel's axis of symmetry at a certain heel.

The HM 150.06 unit can be used to study the stability of a floating body and to determine the metacentre graphically. In addition, the buoyancy of the floating body can also be determined. The experiment is easy to set up and is particularly suitable for practical work in small groups.

The experiment is conducted in a tank filled with water. A transparent body with a rectangular frame cross-section is used as the floating body. Clamped weights that can be moved horizontally and vertically make it possible to adjust the centre of gravity and the heel.

The position of the clamped weights can be read on scales. A clinometer indicates the heel.

The accessory HM 150.39 is available as an optional extra for further experiments with different frame shapes.

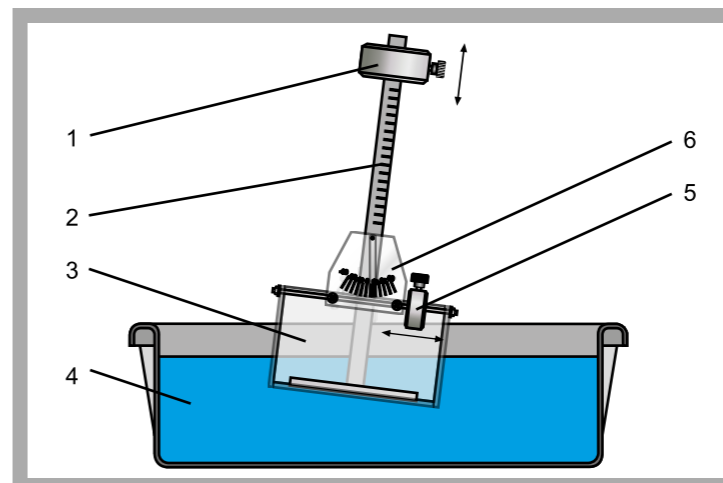
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

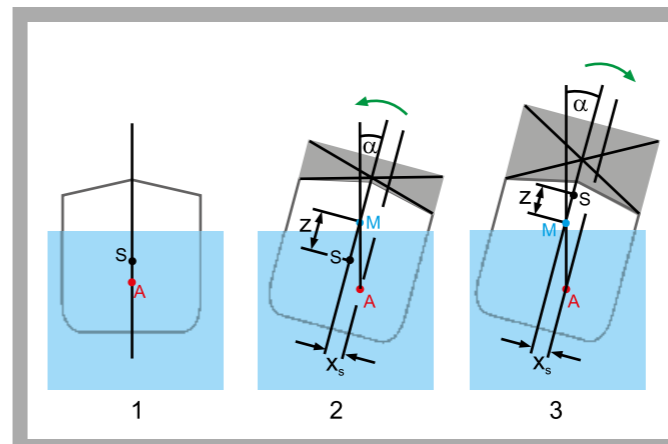
Study and determination of

- buoyancy, centre of buoyancy
- centre of gravity, metacentre, stability
- heel

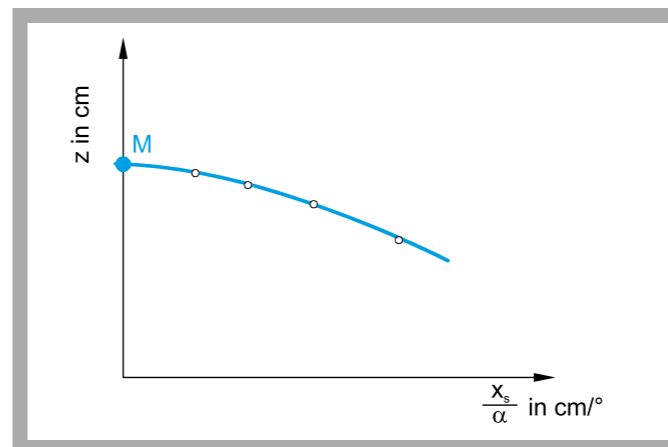
- \* **Stability of a floating body**
- \* **Determining the metacentre**
- \* **Other floating bodies with different shapes of frame optionally available, HM 150.39**

**HM 150.06 Stability of Floating Bodies**


1 adjustment of the centre of gravity, 2 scale, 3 floating body, 4 tank with water, 5 adjustment of the heel, 6 clinometer with scale



1 stable position, 2 stable position despite load, metacentre above the centre of gravity, 3 unstable position due to load, metacentre under the centre of gravity; green arrow: restoring moment, M metacentre, S centre of gravity, A centre of buoyancy, z metacentric height,  $\alpha$  angle of heel



Graphical determination of the metacentre: M metacentre, z vertical centre of gravity,  $x_s/a$  stability gradient

**Specification**

- [1] investigating the stability of a floating body and determining the metacentre
- [2] transparent floating body with rectangular frame cross-section
- [3] one horizontally movable clamped weight for adjusting the heel
- [4] one vertically movable clamped weight for adjusting the centre of gravity
- [5] clinometer with scale for displaying the heel
- [6] other floating bodies with different shapes of frame available as accessories: HM 150.39

**Technical Data**

- Floating body
- LxWxH: 300x130x190mm
- mast height: 400mm
- Horizontal scale: 180mm
- Vertical scale: 400mm
- Height scale of the floating body: 120mm
- Clinometer scale: +/- 35°
- Weights
- floating body without clamped weights: 2,8kg
- vertical clamped weight: 550g
- horizontal clamped weight: 193g
- Tank for water: 50L

**Dimensions and Weight**

- LxWxH: 660x450x220mm (tank)
- Empty weight: approx. 6kg

**Scope of Delivery**

- 1 experimental unit
- 1 set of instructional material

**Order Details**

070.15006 HM 150.06 Stability of Floating Bodies

**HM 150.39 Floating Bodies for HM 150.06**

**\* Stability of floating bodies with different frame shapes**
**Technical Description**

The HM 150.39 accessory includes two transparent floating bodies with different frame shapes (hard chine and round bilge). The floating bodies are used together with HM 150.06 and extend this device's range of experiments.

The design of the floating bodies and the possible experiments are similar to those of HM 150.06.

**Learning Objectives / Experiments**

- comparison of two different frame shapes: hard chine and round bilge

**Scope of Delivery**

2 floating bodies  
1 manual

**Specification**

[1] determination of the metacentre of 2 floating bodies with different frame shapes  
[2] 1 shape of frame: hard chine, 1 shape of frame: round bilge  
[3] for use with HM 150.06

**Technical Data**

Hard chine frame: LxWxH 300x200x140mm  
Round bilge frame: LxWxH 300x200x100mm  
Mast length: 240mm  
Horizontal scale: 180mm  
Vertical scale: 240mm  
Height scale of the floating body: 120mm  
Scale for heel: +/- 35°  
Weights  
- floating body without clamped weights:  
hard chine: 3,6kg, round bilge: 2,5kg  
- vertical clamped weight: 550g  
- horizontal clamped weight: 193g

**Dimensions and Weight**

LxWxH: 310x210x300mm  
Weight: approx. 7kg total

**Order Details**

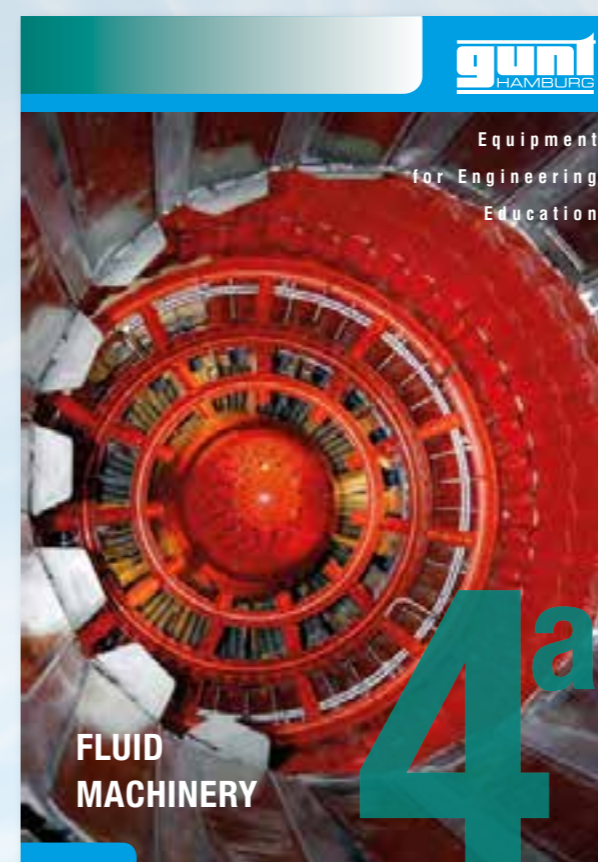
070.15039 HM 150.39 Floating Bodies for HM 150.06

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**THE CATALOGUE STRUCTURE IN THE PRODUCT RANGE 4**

**Catalogue 4  
"Fluid Mechanics"**

- fundamentals of fluid mechanics
- steady flow
- flow around bodies
- examples of transient flow
- hydraulic fluid energy machines
- components in piping systems and plant design
- fluidic experimental plants


**Catalogue 4a  
"Fluid Machinery"**

- fundamentals
- power engines
- machines
- power plants and applied cycles
- equipment series

## BASIC KNOWLEDGE

## FUNDAMENTALS OF HYDRODYNAMICS

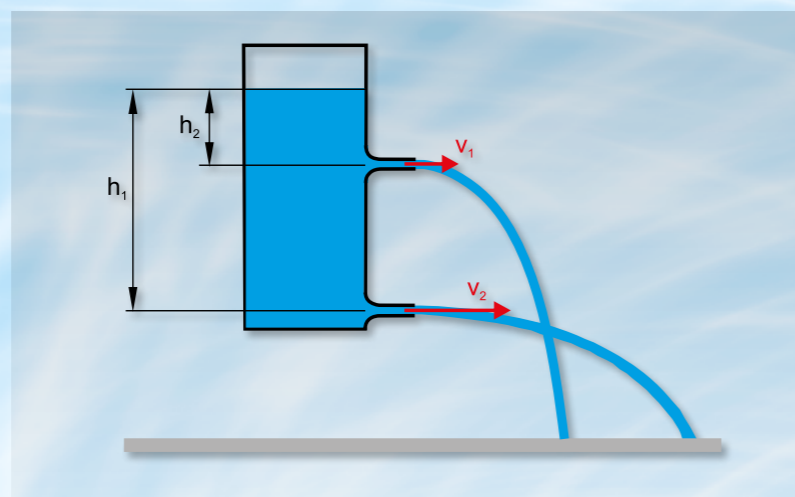
Hydrodynamics is concerned with the study and description of fluids in motion. The main emphasis is the teaching of the conservation laws of mass, energy and momentum.

Flowing fluids possess kinetic energy. This energy can be converted into potential energy (pressure, height) and vice versa.

Typical keywords include Bernoulli's equation, continuity equation and conservation of momentum. For ease of understanding, it is mostly steady states of incompressible fluids that are considered.

Other topics within hydrodynamics

- pipe flow (laminar/turbulent) (chapter 1; for more details see programme area 4)
- methods of flow rate measurement (chapter 1; for more details see programme area 4)
- open-channel flow (chapter 2)
- flow around bodies (chapter 1; for more details see programme area 4)
- turbomachines (chapter 1; for more details see programme area 4)
- flow of compressible fluids (programme area 4)



$h$  head, distance between discharge and water level,  
 $v$  velocity

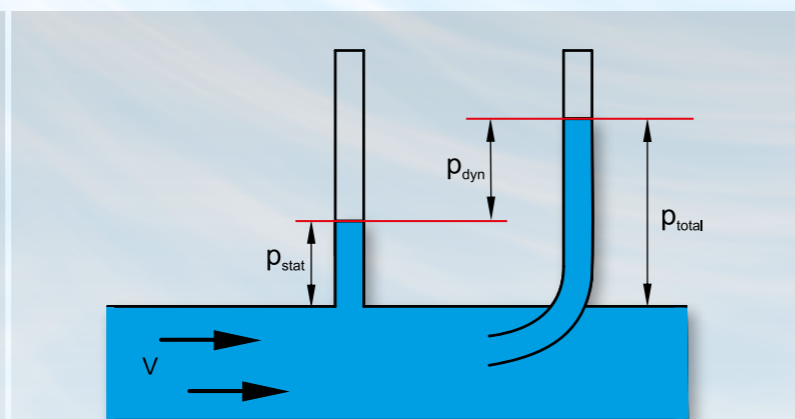
**Flow from a tank**

The flow from a tank can be regarded as both stationary and transient. In the steady case the fill level, and thus the width of the jet, remains constant (e.g. discharge under a weir). The outlet velocity only depends on the head  $h$  and is calculated according to Torricelli's law.

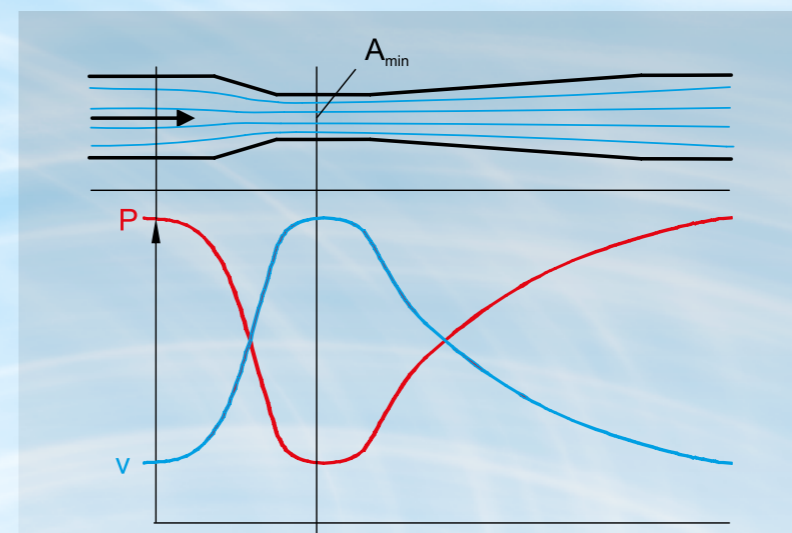
$$v = \sqrt{2gh}$$

$v$  velocity,  $g$  gravitational acceleration,  
 $h$  distance between discharge and water level

When the tank is emptying during the discharge process, it is in what is referred to as the transient state.



$v$  velocity,  $p_{stat}$  static pressure,  $p_{dyn}$  dynamic pressure,  
 $p_{total}$  total pressure



■ velocity, ■ static pressure curve

**Venturi nozzle**

The velocity of the flowing fluid is at its greatest at the narrowest cross-section (**continuity equation**  $A \cdot v = const$ ). Bernoulli discovered that a part of the pressure energy is converted into kinetic energy. When velocity increases it therefore results in a drop in pressure, so that the lowest pressure occurs in the narrowest cross-section. **Bernoulli's equation** states that the energy of a frictionlessly flowing, incompressible fluid is constant.

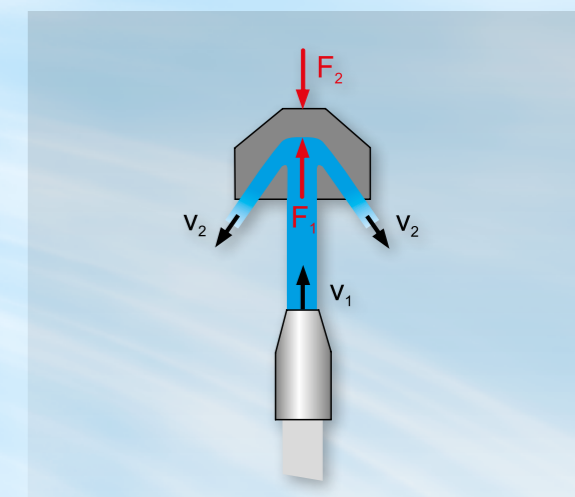
Applications include water jet pumps, carburetors, flow measurement

**Vortex formation**

Vortices occur when, within a fluid, a portion of the fluid flows more quickly than the rest of the fluid. This results in a velocity gradient within the fluid. Energy is dissipated in vortices.

Free vortices (potential vortex, e.g. whirlpool) are formed during discharge from a tank, for example. With free vortices all fluid particles move in concentric circular paths without rotating around their own axis. Free vortices are formed solely by hydrodynamic forces.

Forced vortices are rotational and are formed by external forces, such as a stirrer.



$F_1$  jet force,  $F_2$  reaction force,  
 $v_1$  jet velocity,  
 $v_2$  velocity after deflection

**Jet forces**

If the flow velocity changes then the momentum of a fluid changes according to the magnitude and/or direction. This results in forces that, for example, could drive a free jet turbine or a water vehicle.

These forces can be easily demonstrated and measured when the jet hits the wall and is deflected.

**Pressure in a flowing fluid**

The energy of the flowing fluid is determined by pressure, velocity and density. The total pressure is made up of a static and a dynamic component. The dynamic component grows quadratically as the flow velocity increases. A flowing fluid can contain potential, kinetic and pressure energy. In the ideal case the total energy is conserved. In this case, the proportions may vary, so for example pressure energy is converted into kinetic energy.

# EXPERIMENTAL UNITS ON THE FUNDAMENTALS OF HYDRODYNAMICS

## CONTINUITY EQUATION, BERNOULLI

### HM 150.07 BERNOULLI'S PRINCIPLE



- investigation and verification of Bernoulli's law
- recording pressure distribution in the venturi nozzle
- 6 tube manometers for displaying the static pressure and a single tube manometer for displaying the total pressure

## LAMINAR AND TURBULENT FLOW

### HM 150.18 OSBORNE REYNOLDS EXPERIMENT

- representation of laminar and turbulent flow and the transition zone
- determining the critical Reynolds number
- visualisation of flow conditions using ink as a contrast medium



## DISCHARGE FROM OPENINGS

### HM 150.09 HORIZONTAL FLOW FROM A TANK



- visualising the trajectory of a water jet with HM 150.09
- investigations on the outlet jet (diameter, velocity) with HM 150.12
- determination of the contraction coefficient in two experimental units

### HM 150.12 VERTICAL FLOW FROM A TANK



## VISUALISATION OF STREAMLINES

### HM 150.10 VISUALISATION OF STREAMLINES



- visualisation of streamlines using ink as a contrast medium
- various models included: drag bodies and changes in cross-section
- influence of sources and sinks

### HM 150.21 VISUALISATION OF STREAMLINES IN AN OPEN CHANNEL



- demonstration of flow phenomena in open channels
- incident flow and flow around various weirs and drag bodies
- visualisation of streamlines using ink as a contrast medium

## JET FORCE

### HM 150.08 MEASUREMENT OF JET FORCES

- investigation of jet forces and demonstration of the momentum equation
- four different shaped deflectors: flat surface, oblique surface, semi-circular surface, conical surface
- influence of mass flow and deflection



**HM 150.18 Osborne Reynolds Experiment**

**Technical Description**

The Osborne Reynolds experiment is used to display laminar and turbulent flows. During the experiment it is possible to observe the transition from laminar to turbulent flow after a limiting velocity. The Reynolds number is used to assess whether a flow is laminar or turbulent.

With HM 150.18 the streamlines during laminar or turbulent flow are displayed in colour with the aid of an injected contrast medium (ink). The experimental results can be used to determine the critical Reynolds number.

The experimental unit consists of a transparent pipe section through which water flows, with flow-optimised inlet. A valve can be used to adjust the flow rate in the pipe section. Ink is injected into the flowing water. A layer of glass beads in the water tank ensures an even and low-turbulence flow.

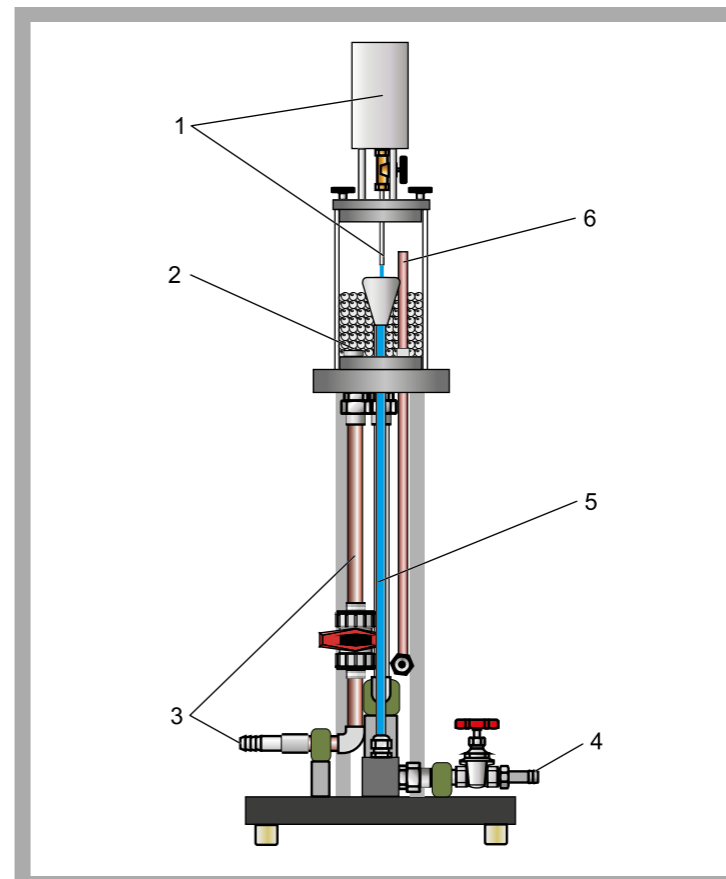
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

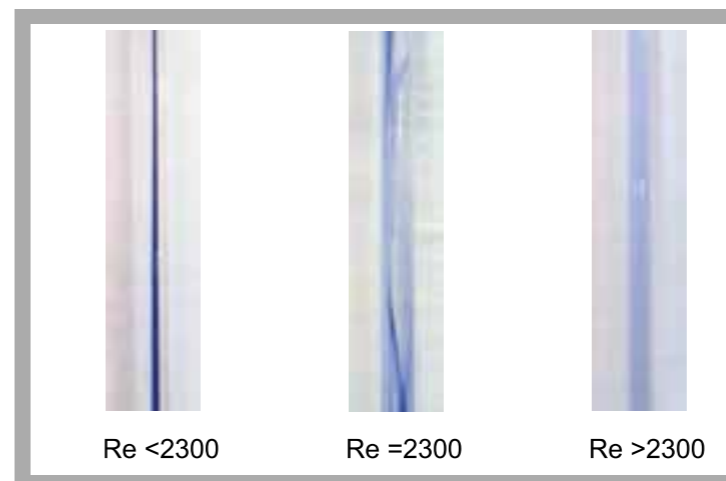
**Learning Objectives / Experiments**

- visualisation of laminar flow
- visualisation of the transition zone
- visualisation of turbulent flow
- determination of the critical Reynolds number

- \* Visualisation of laminar and turbulent flow
- \* Determining the critical Reynolds number
- \* Traditional experiment based on the model of the British physicist Osborne Reynolds

**HM 150.18 Osborne Reynolds Experiment**


1 tank for ink with inlet pipe, 2 overflow, 3 water supply, 4 water drain, 5 pipe section with valve, 6 water tank with glass beads



Flow conditions from left to right: laminar flow, transition from laminar to turbulent flow, turbulent flow

**Specification**

- [1] visualisation of laminar and turbulent flow in the Osborne Reynolds experiment
- [2] water as flowing medium and ink as contrast medium
- [3] vertical glass pipe section
- [4] water tank with glass beads to stabilise the flow
- [5] flow rate in the pipe section can be adjusted via a valve
- [6] flow rate determined by HM 150 base module
- [7] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Water tank
  - capacity: 2200mL
- Pipe section
  - length: 675mm
  - inside diameter: 10mm
- Tank for ink
  - capacity: approx. 250mL

**Dimensions and Weight**

- LxWxH: 400x400x1140mm
- Empty weight: approx. 16kg

**Required for Operation**

- HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 1 bag of glass beads
- 1L ink
- 1 set of instructional material

**Order Details**

070.15018 HM 150.18 Osborne Reynolds Experiment

**HM 150.07 Bernoulli's Principle**


- \* Investigation and verification of Bernoulli's principle
- \* Static pressures and total pressure distribution along the Venturi nozzle
- \* Determination of the flow coefficient at different flow rates

**Technical Description**

Bernoulli's principle describes the relationship between the flow velocity of a fluid and its pressure. An increase in velocity leads to a reduction in pressure in a flowing fluid, and vice versa. The total pressure of the fluid remains constant. Bernoulli's equation is also known as the principle of conservation of energy of the flow.

The HM 150.07 experimental unit is used to demonstrate Bernoulli's principle by determining the pressures in a Venturi nozzle.

The experimental unit includes a pipe section with a transparent Venturi nozzle and a movable Pitot tube for measuring the total pressure. The Pitot tube is located within the Venturi nozzle, where it is displaced axially. The position of the Pitot tube can be observed through the Venturi nozzle's transparent front panel.

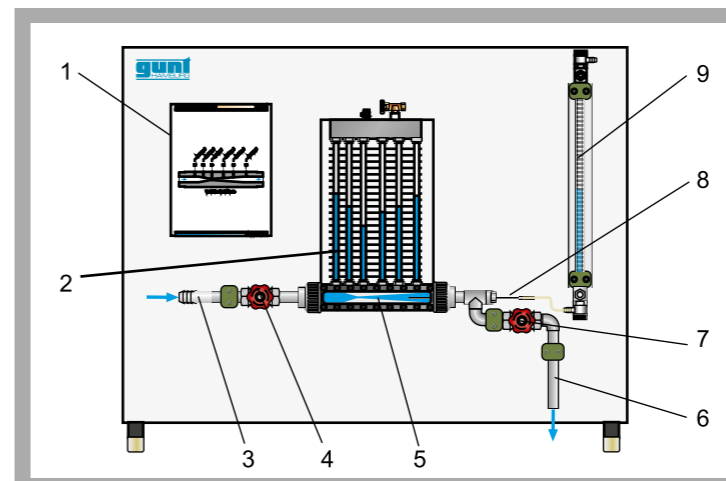
The Venturi nozzle is equipped with pressure measuring points to determine the static pressures. The pressures are displayed on the six tube manometers. The total pressure is measured by the Pitot tube and displayed on another single tube manometer.

The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

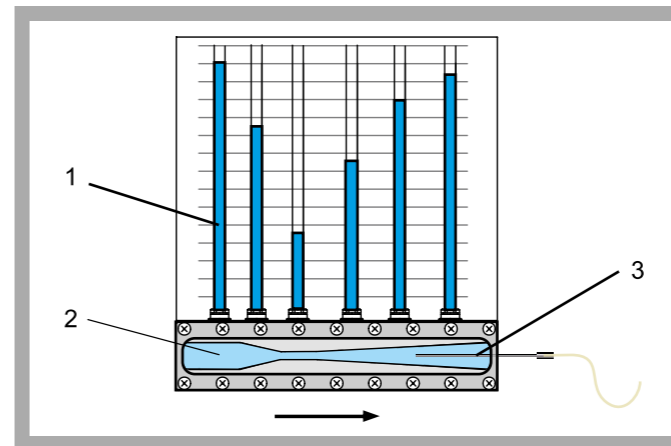
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

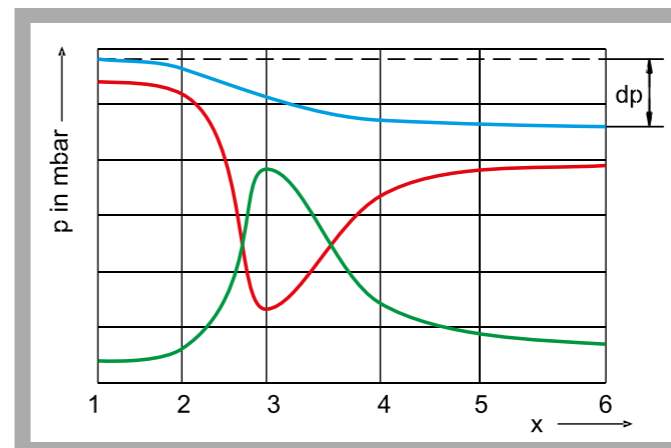
- energy conversion in divergent/convergent pipe flow
- recording the pressure curve in a Venturi nozzle
- recording the velocity curve in a Venturi nozzle
- determining the flow coefficient
- recognising friction effects

**HM 150.07 Bernoulli's Principle**


1 diagram, 2 tube manometers (static pressures), 3 water supply, 4 valve, 5 Venturi nozzle, 6 water outlet, 7 valve for water outlet, 8 Pitot tube, 9 single tube manometer (total pressure)



Measuring the pressures in a Venturi nozzle  
1 tube manometers for displaying the static pressures, 2 Venturi nozzle with measuring points, 3 Pitot tube for measuring the total pressure, axially movable



Pressure curve in the Venturi nozzle: blue: total pressure, red: static pressure, green: dynamic pressure; x pressure measuring points, p pressure

**Specification**

- [1] familiarisation with Bernoulli's principle
- [2] Venturi nozzle with transparent front panel and measuring points for measuring the static pressures
- [3] axially movable Pitot tube for determining the total pressure at various points within the Venturi nozzle
- [4] 6 tube manometers for displaying the static pressures
- [5] single tube manometer for displaying the total pressure
- [6] flow rate determined by HM 150 base module
- [7] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Venturi nozzle
- A: 84...338mm<sup>2</sup>
- angle at the inlet: 10,5°
- angle at the outlet: 4°
- Pitot tube
- movable range: 0...200mm
- diameter: 4mm
- Pipes and pipe connectors: PVC

**Measuring ranges**

- static pressure: 0...290mmWC
- total pressure: 0...370mmWC

**Dimensions and Weight**

- LxWxH: 1100x680x900mm
- Weight: approx. 28kg

**Required for Operation**

- HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 1 set of instructional material

**Order Details**

070.15007 HM 150.07 Bernoulli's Principle

**HM 150.08 Measurement of Jet Forces**

**Technical Description**

During deceleration, acceleration and deflection of a flowing fluid, there is a change of velocity and thus a change in momentum. Changes in momentum result in forces. In practice, the motive forces are used to convert kinetic energy into work done, for example in a Pelton turbine.

In HM 150.08 jet forces are generated and studied with the aid of a water jet that acts on and is diverted by an interchangeable deflector.

The experimental unit includes a transparent tank, a nozzle, four interchangeable deflectors with different deflection angles and a weight-loaded scale. The force of the water jet is adjusted via the flow rate.

Experiments study the influence of flow velocity and flow rate as well as of different deflection angles. The jet forces generated by the water jet are measured on the weight-loaded scale. The forces are calculated using the momentum equation and compared with the measurements.

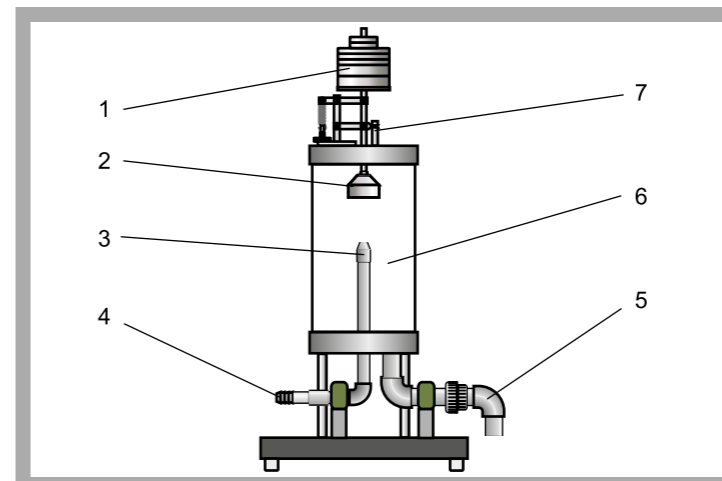
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

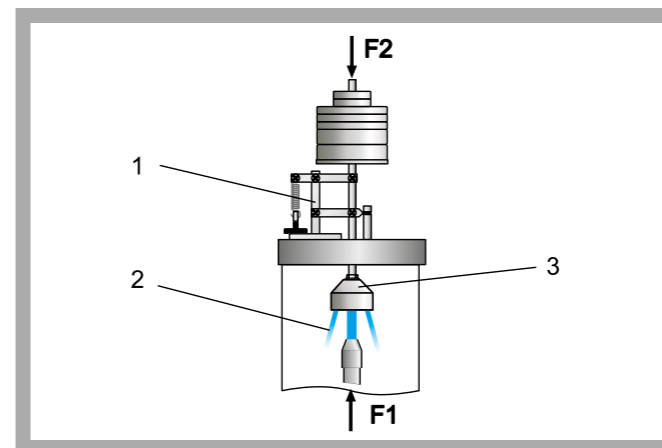
**Learning Objectives / Experiments**

- demonstration of the principle of linear momentum
- study of the jet forces
- influence of flow rate and flow velocity
- influence of different deflection angles

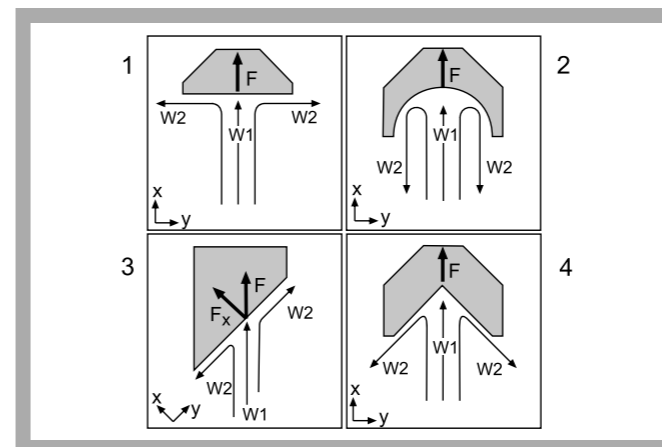
- \* Investigation of jet forces on deflectors
- \* Demonstration of the principle of linear momentum
- \* 4 interchangeable deflectors with different deflection angles

**HM 150.08 Measurement of Jet Forces**


1 weight, 2 deflector, 3 nozzle, 4 water supply, 5 water drain, 6 tank, 7 lever apparatus



Measurement of the jet forces via the weight-loaded scale  
1 lever apparatus, 2 deflected water jet, 3 deflector with conical surface;  
F1 jet force, F2 weight force



Distribution of velocities  $v$  and forces  $F$  on deflectors  
1 deflector with flat surface, 2 deflector with semi-circular surface, 3 deflector with oblique surface, 4 deflector with conical surface

**Specification**

- [1] investigation of jet forces and demonstration of the principle of linear momentum
- [2] tank made of transparent material for observing the experiments
- [3] nozzle for generating the water jet
- [4] jet force can be adjusted via flow rate
- [5] four different shaped deflectors: flat surface, oblique surface, semi-circular surface, conical surface
- [6] measurement of the jet forces via the weight-loaded scale
- [7] flow rate determined by HM 150 base module
- [8] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Tank
- inner diameter: 200mm
  - height: 340mm
- Nozzle
- diameter: 10mm
- Deflector
- flat surface: 90°
  - oblique surface: 45°/135°
  - semi-circular surface: 180°
  - conical surface: 135°
- Weights
- 4x 0,2N
  - 3x 0,3N
  - 2x 1N
  - 2x 2N
  - 2x 5N

**Dimensions and Weight**

- LxWxH: 400x400x880mm  
Weight: approx. 23kg

**Required for Operation**

- HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 1 set of weights
- 4 deflectors
- 1 set of instructional material

**Order Details**

070.15008 HM 150.08 Measurement of Jet Forces

**HM 150.21** *Visualisation of Streamlines in an Open Channel*


- \* Flow around various drag bodies
- \* Incident flow of different weirs
- \* Ink as contrast medium for visualising the streamlines

**Technical Description**

HM 150.21 can be used to visualise flow around drag bodies and flow phenomena in open channels.

Either a drag body or weir is fixed in the experimental flume. The streamlines are made visible by injecting a contrast medium. The experimental flume is made of transparent material so that the streamlines and the formation of vortices can easily be observed. The water level in the experimental flume can be adjusted via a sluice gate at the inlet and via a weir at the outlet.

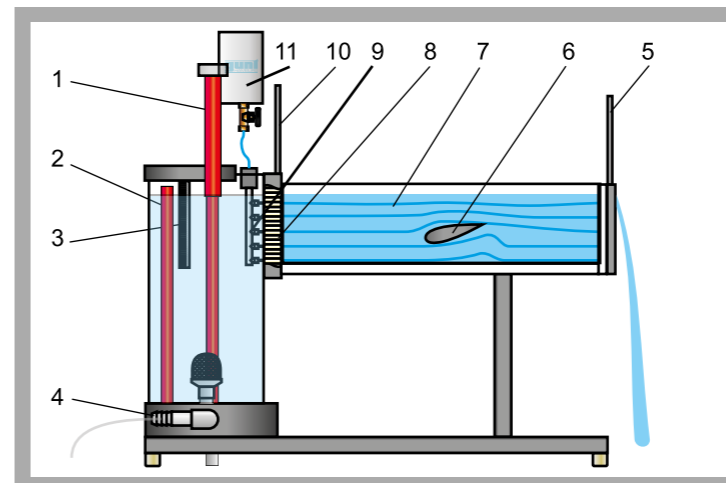
There are two weirs and four different drag bodies available for the experiments. A stabiliser ensures an even and non-vortical flow of water.

The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

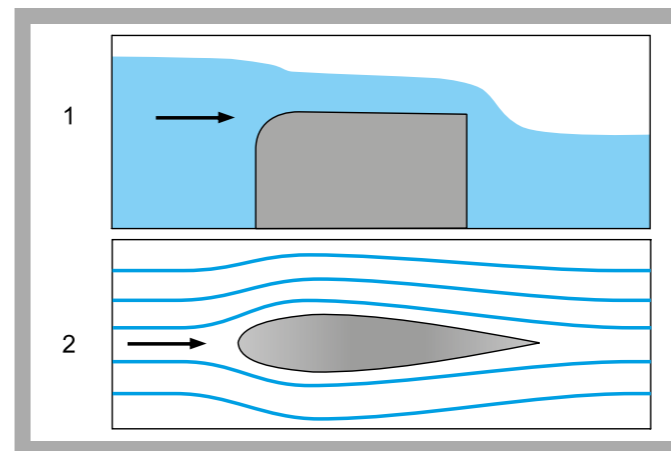
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

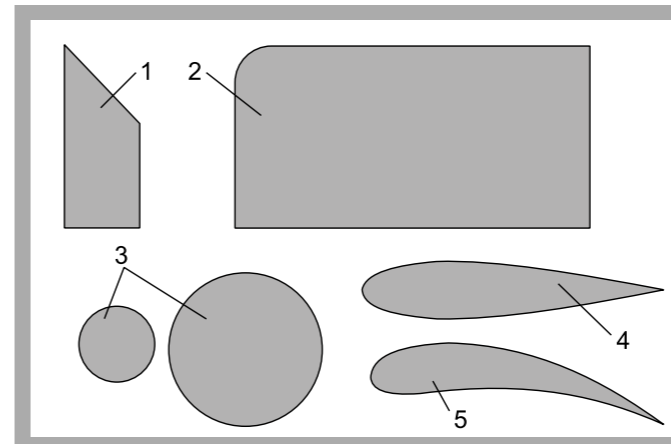
- how differently shaped weirs affect the flow
- visualisation of streamlines for flow incident to a weir
- visualisation of streamlines when flowing around various drag bodies

**HM 150.21** *Visualisation of Streamlines in an Open Channel*


1 adjustable overflow, 2 tank, 3 scale, 4 water supply from HM 150, 5 weir at the water outlet, 6 drag body, 7 experimental flume, 8 flow straightener, 9 distributor for contrast medium, 10 sluice gate at the water inlet to the experimental flume, 11 tank for contrast medium



1 incident flow at the broad-crested weir, 2 flow around a streamlined body



Drag bodies and weirs supplied  
1 sharp-crested weir, 2 broad-crested weir, 3 cylinders, 4 streamlined body, 5 guide vane profile

**Specification**

- [1] visualisation of streamlines during incident flow and flow around various weirs and drag bodies
- [2] transparent experimental flume
- [3] incident flow demonstrated on two weirs
- [4] demonstration of flow around four different drag bodies
- [5] contrast medium: ink
- [6] distributor for contrast medium with seven nozzles
- [7] water level in the experimental flume adjustable via sluice gate at the water inlet and weir at the water outlet
- [8] flow straightener for even, non-vortical water inlet
- [9] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Experimental flume
  - LxWxH: 625x20x150mm
- Contrast medium: ink
- Injection of the contrast medium
  - 7 nozzles
- Tank for water: 12,5L
- Tank for ink: 200mL
- Drag bodies
  - small cylinder, diameter: 35mm
  - large cylinder, diameter: 60mm
  - streamlined body
  - guide vane profile
- Weirs
  - broad-crested weir
  - sharp-crested weir

**Dimensions and Weight**

- LxWxH: 895x640x890mm
- Weight: approx. 24kg

**Required for Operation**

- HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental flume
- 1 set of drag bodies and weirs
- 1L of ink
- 1 set of tools
- 1 set of instructional material

**Order Details**

- 070.15021 HM 150.21 Visualisation of Streamlines in an Open Channel

**HM 150.10 Visualisation of Streamlines**


- \* Visualisation of streamlines
- \* Ink as a contrast medium
- \* Various models included: drag bodies and changes in cross-section
- \* Sources and sinks, individually or in combination

**Technical Description**

The laminar, two-dimensional flow in HM 150.10 is a good approximation of the flow of ideal fluids: the potential flow.

HM 150.10 can be used to visualise streamline fields for flows around drag bodies and flow through changes in cross-section. The streamlines are displayed in colour by injecting a contrast medium (ink). Sources and sinks are generated via four water connections in the bottom plate. The streamlines can be clearly observed through the glass plate during flow around and flow through.

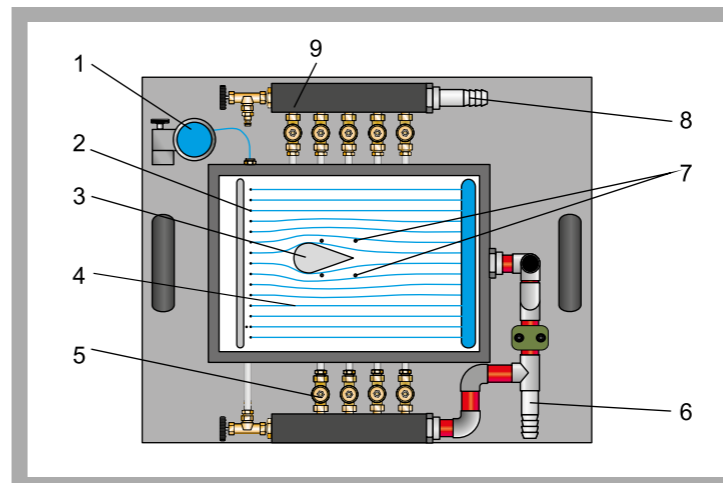
The water flow rate and the quantity of contrast medium injected can be adjusted by valves. The water connections are also activated by valves and can be combined as required. Individual models can be cut out of a rubber plate that is included.

The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

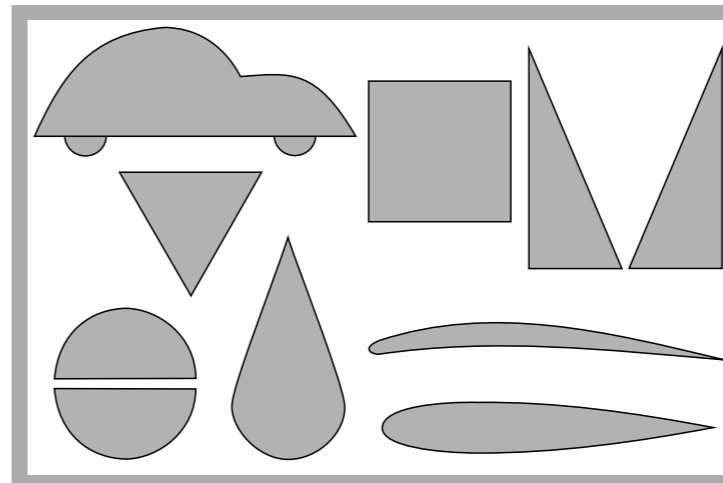
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

- visualisation of streamlines in
  - \* flow around drag bodies
  - \* flow through changes in cross-section
- influence of sources and sinks

**HM 150.10 Visualisation of Streamlines**


1 tank for contrast medium, 2 holes for injecting the contrast medium, 3 drag body, 4 experiment area, 5 valves for sinks, 6 water drain, 7 holes for sources and sinks, 8 water supply, 9 valves for sources



Included models  
car, triangle, square, 2 triangles for change in cross-section, 2 semi-circles, droplet, streamlined body, guide vane profile

**Specification**

- [1] visualisation of streamlines
- [2] water as flowing medium and ink as contrast medium
- [3] upper glass plate, hinged for interchanging models
- [4] bottom plate with water connections for generating sources/sinks
- [5] sources/sinks can be combined as required
- [6] different drag bodies and changes in cross-section included
- [7] rubber plate for creating your own models included
- [8] flow velocity, water supply and water drain in sources/sinks as well as dosage of the contrast medium can be adjusted by using valves
- [9] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Flow chamber contains two plates
  - distance between the plates: 2mm
  - upper plate made of glass
  - bottom glass plate with four water connections for sources/sinks
  - size experiment area: LxW: 400x280mm
- 10 drag bodies and changes in cross-section
- Rubber plate for your own models
  - LxH: 300x400mm
  - thickness: 2mm
- Injection of the contrast medium (ink)
  - 15 holes
- Tank for contrast medium: 500mL

**Dimensions and Weight**

LxWxH: 640x520x520mm  
Weight: approx. 24kg

**Required for Operation**

HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 1 set of models
- 1 rubber plate
- 2x 30mL ink
- 1 set of water hoses
- 1 set of instructional material

**Order Details**

070.15010 HM 150.10 Visualisation of Streamlines

**HM 150.09 Horizontal Flow from a Tank**


- \* Visualisation of the trajectory of the outlet jet
- \* Study of openings with different diameters and contours
- \* Determination of the contraction coefficient

**Technical Description**

Hydrodynamics considers the relationship between the trajectory, the outlet contour and the outlet velocity during flow from tanks. These considerations have practical applications in hydraulic engineering or in the design of bottom outlets in dams, for example.

HM 150.09 allows a user to study and visualise the profile of a water jet. Additionally, the contraction coefficient can be determined as a characteristic for different contours.

The experimental unit includes a transparent tank, a point gauge and a panel for visualising the jet paths. An interchangeable insert is installed in the tank's water outlet to facilitate the investigation of various openings. Four inserts with different diameters and contours are provided along with the unit.

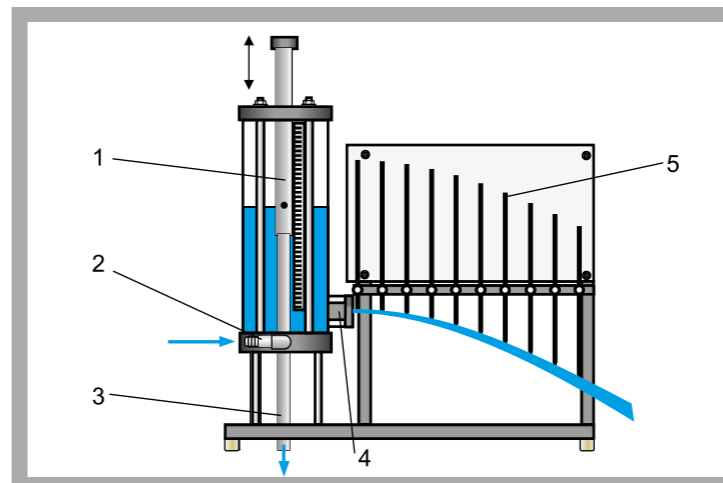
To visualise the trajectory, the issued water jet is measured via a point gauge that consists of movable rods. The rods are positioned depending on the profile of the water jet. This results in a trajectory that is transferred to the panel.

The tank contains an adjustable overflow and a scale. In this way, a precise adjustment and accurate reading of the fill level are possible. The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

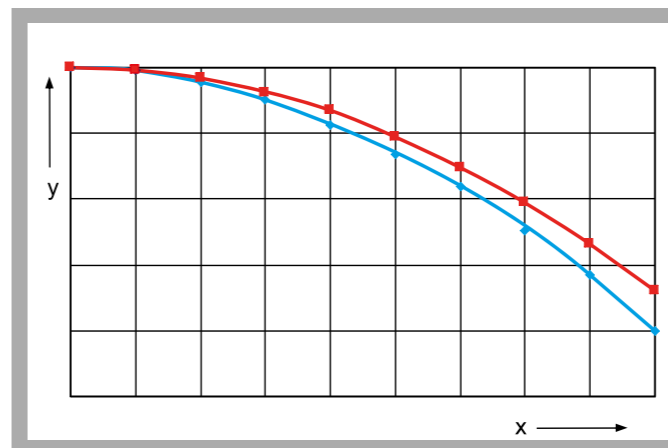
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

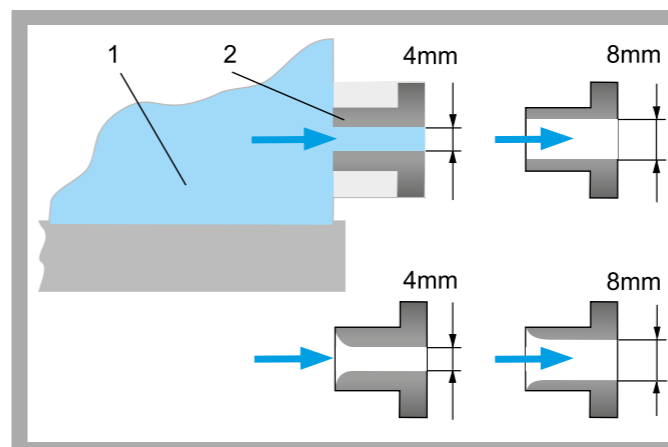
- recording the trajectory of the water jet at different outlet velocities
- study of how the level in the tank affects the outlet velocity
- determination of the contraction coefficient for different contours and diameters
- comparison of the actual and theoretical outlet velocity

**HM 150.09 Horizontal Flow from a Tank**


1 tank with adjustable overflow, 2 water supply, 3 water overflow, 4 water outlet, 5 point gauge for the water jet



Measured and calculated (theoretical) trajectory of the outlet jet; red: theoretical, blue: measured



Interchangeable inserts to study different openings: 1 tank, 2 insert; top: outlet from the tank through square contour, bottom: outlet from the tank through rounded contour

**Specification**

- [1] study of horizontal flows from tanks
- [2] determining the contraction coefficient for different outlet contours and diameters
- [3] tank with adjustable overflow and scale
- [4] four interchangeable inserts with different diameters and contours
- [5] point gauge with eight movable rods for visualisation of the jet path
- [6] white panel for recording the trajectory
- [7] flow rate determined by HM 150 base module
- [8] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Tank
- height: 510mm
  - diameter: 190mm
  - contents: approx. 13,5L
- Inserts with rounded contour
- 1x diameter: 4mm
  - 1x diameter: 8mm
- Inserts with square contour
- 1x diameter: 4mm
  - 1x diameter: 8mm
- Point gauge, 8 movable rods
- length: 350mm

**Dimensions and Weight**

- LxWxH: 865x640x590mm  
Weight: approx. 27kg

**Required for Operation**

- HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit  
4 inserts  
1 set of instructional material

**Order Details**

070.15009 HM 150.09 Horizontal Flow from a Tank

**HM 150.12 Vertical Flow from a Tank**

**Technical Description**

Pressure losses in the flow from tanks are essentially the result of two processes: the jet deflection upon entry into the opening and the wall friction in the opening. As a result of the pressure losses the real discharge is smaller than the theoretical flow rate.

HM 150.12 determines these losses at different flow rates. Different diameters as well as inlet and outlet contours of the openings can be studied. Additionally, the contraction coefficient can be determined as a characteristic for different contours.

The experimental unit includes a transparent tank, a measuring device as well as a Pitot tube and twin tube manometers. An interchangeable insert is installed in the tank's water outlet to facilitate the investigation of various openings. Five inserts with different diameters, inlet contours and outlet contours are provided along with the unit.

The issued water jet is measured using a measuring device. A Pitot tube detects the total pressure of the flow. The pressure difference (read on the manometer) is used to determine the velocity.

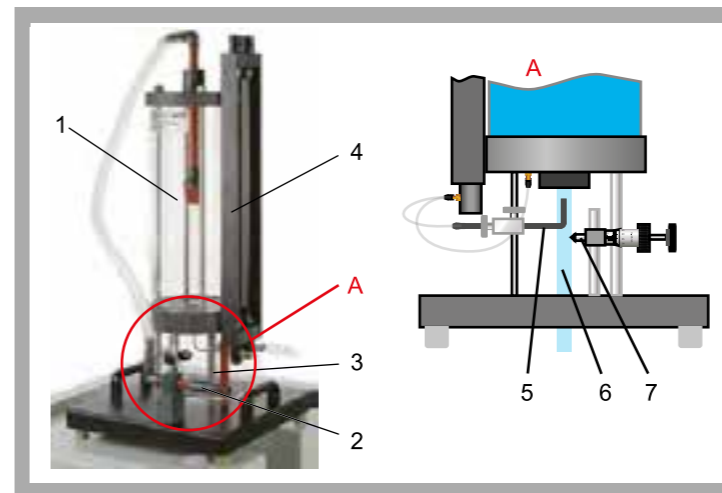
The tank is fitted with an adjustable overflow and a measuring point for static pressure. In this way, the level can be precisely adjusted and read on the manometer. The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

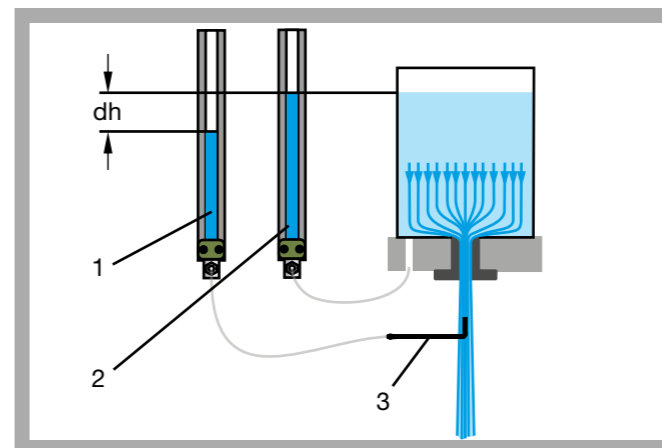
**Learning Objectives / Experiments**

- study of the outlet jet (diameter, velocity)
- determination of pressure losses and contraction coefficient for different outlet contours
- determination of flow rate at different discharge heads

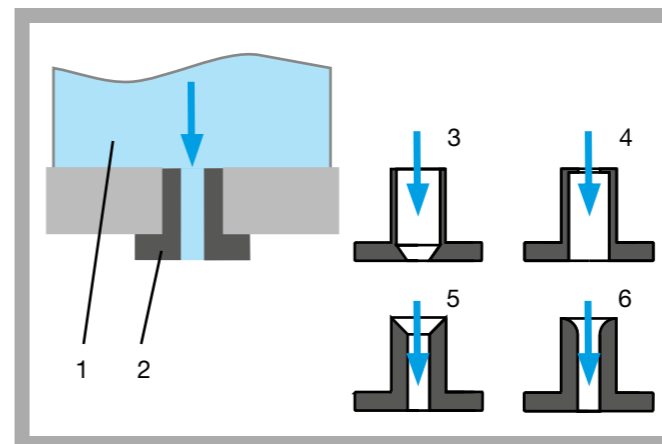
- \* **Determination of the diameter and velocity of the outlet jet**
- \* **Study of openings with different inlet and outlet contours**
- \* **Determining the contraction coefficient**

**HM 150.12 Vertical Flow from a Tank**


1 inlet strainer, 2 water connection, 3 overflow, 4 twin tube manometers, 5 Pitot tube, 6 water jet, 7 measuring device for jet diameter



Measuring the pressures  
1 total pressure in the free jet, 2 static pressure in the tank, 3 Pitot tube;  
dh loss due to conversion of pressure into velocity



Interchangeable inserts to study different inlet and outlet contours  
1 tank, 2 insert with cylindrical hole, 3 insert with conical outlet, 4 insert with orifice plate at the inlet, 5 insert with conical inlet, 6 insert with rounded inlet

**Specification**

- [1] study of pressure losses in vertical flows from tanks
- [2] determining the contraction coefficient for different contours and diameters
- [3] tank with adjustable overflow
- [4] 5 interchangeable inserts with different contours
- [5] measuring device for determining the jet diameter
- [6] Pitot tube for determining the total pressure
- [7] pressure display on twin tube manometers
- [8] flow rate determined by HM 150 base module
- [9] water supply using HM 150 base module or via laboratory supply

**Technical Data**
**Tank**

- capacity: approx. 13L
- overflow height: max. 400mm
- max. flow rate: 14L/min

**Inserts**

Inside diameters:  $d_1$ =inlet,  $d_2$ =outlet

- 1x cylindrical hole,  $d=12$ mm
- 1x outlet from the insert: cone  
 $d_1=24$ mm,  $d_2=12$ mm
- 1x inlet to the insert: orifice plate  
 $d_1=24$ mm,  $d_2=12$ mm
- 1x inlet to the insert: cone  
 $d_1=30$ mm,  $d_2=12$ mm
- 1x inlet to the insert: rounded,  $d=12$ mm

**Measuring ranges**

- pressure: 500mmWC
- jet radius: 0...10mm

**Dimensions and Weight**

LxWxH: 400x400x830mm  
Weight: approx. 18kg

**Required for Operation**

HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 5 inserts
- 1 set of hoses
- 1 set of instructional material

**Order Details**

070.15012 HM 150.12 Vertical Flow from a Tank

# STEADY FLOW OF INCOMPRESSIBLE FLUIDS

## Fluid

Fluid mechanics is concerned with the study of forces and movements of liquids and gases. Both substances are continua whose elements can easily move against each other. They are grouped together under the term 'fluid'.

## Incompressible flow

Liquids are incompressible. In technical fields of application of fluid mechanics, **incompressibility** is also assumed for gases as long as the flow velocity remains below Mach 0,3. Based on air at 20°C this limiting value corresponds to a velocity of approximately 100 m/s and the change in density is roughly 4%. It is therefore broadly possible to treat liquid and gas flows with common fundamental principles in fluid mechanics.

## Steady and transient flow

**Steady flow:** the velocity of a fluid particle changes with the position:  $v = f(s)$ .

**Transient flow:** the velocity of a fluid particle changes with the time and the position:  $v = f(s, t)$ .

Transient flows occur during discharge processes, during startup and shutdown processes of turbomachines or in the case of fluid oscillations and water hammer processes.

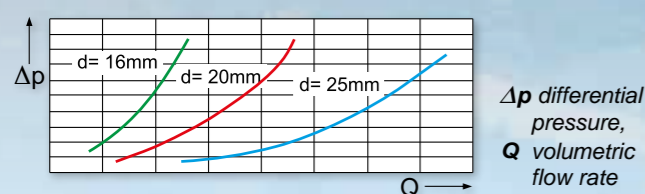
## LEARNING OBJECTIVES

### FLOW IN PIPE SYSTEMS

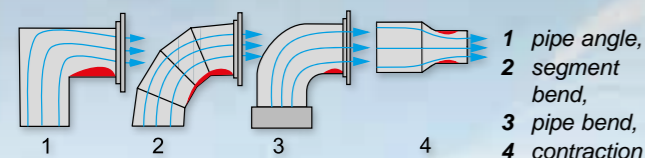


Velocity profile in fully developed flow

- laminar (left)
- turbulent (right)

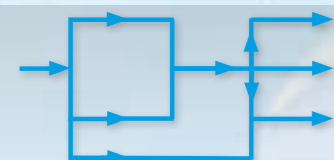


Pressure losses in straight pipes

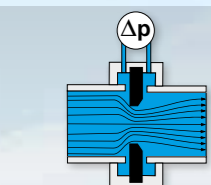


Pressure losses in pipe fittings

- enlargement/constriction/change of direction
- pipe bends
- segment bends/pipe angles



Losses in single-strand and multi-strand pipe systems

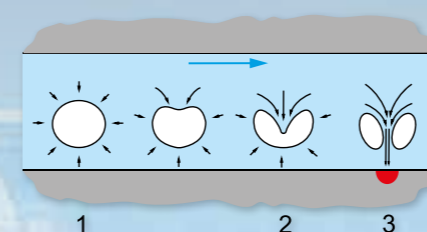


$\Delta p$  differential pressure

Flow rate metrology: representation of the common industry measuring methods

## LEARNING OBJECTIVES

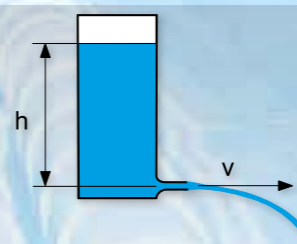
### CAVITATION



- 1 formation of the vapour bubble,
- 2 collapse of the vapour bubble,
- 3 jet of water hits the surface and leads to material destruction

Cavitation effects in industrial piping systems: formation and consequences

### DISCHARGE PROCESSES

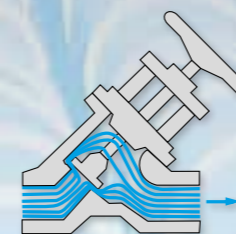


$h$  head,  
 $v$  velocity

Flows from tanks

- how the discharge cross-section and the shape affect the jet cross-section
- vertical discharge / horizontal discharge

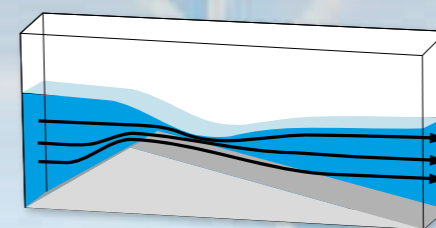
### FLOW IN VALVES



Special emphasis on technical issues

- constructions
- valve characteristics
- K values

### OPEN-CHANNEL FLOW



- subcritical and supercritical flow
- control structures
- discharge measurement

*This topic is covered extensively in a separate chapter.*

For the field of **Steady Flow of Incompressible Fluids** we have tried to capture the many learning objectives found in the literature around the world within the list of learning objectives defined above. Of course, variations in some sub-fields are possible. For example, we could argue whether or not **industrial flow rate metrology** should be covered here.

GUNT provides a programme that allows to work through all of the items listed in the learning objectives in educational laboratory experiments.

**HM 150.01 Pipe Friction for Laminar / Turbulent Flow**

**Technical Description**

During flow through pipes, pressure losses occur due to internal friction and friction between the fluid and the wall. When calculating pressure losses, we need to know the friction factor, a dimensionless number. The friction factor is determined with the aid of the Reynolds number, which describes the ratio of inertia forces to friction forces.

HM 150.01 enables the study of the relationship between pressure loss due to fluid friction and velocity in the pipe flow. Additionally, the pipe friction factor is determined.

The experimental unit includes a small diameter pipe section in which the laminar and turbulent flow is generated. The Reynolds number and the pipe friction factor are determined from the flow rate and pressure loss. In turbulent flow, the pipe is supplied directly from the water supply. The constant pressure at the water supply required for laminar flow is provided by a standpipe on the overflow.

The pressures in laminar flow are measured with twin tube manometers. In turbulent flow, the pressure is read on a dial-gauge manometer.

The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

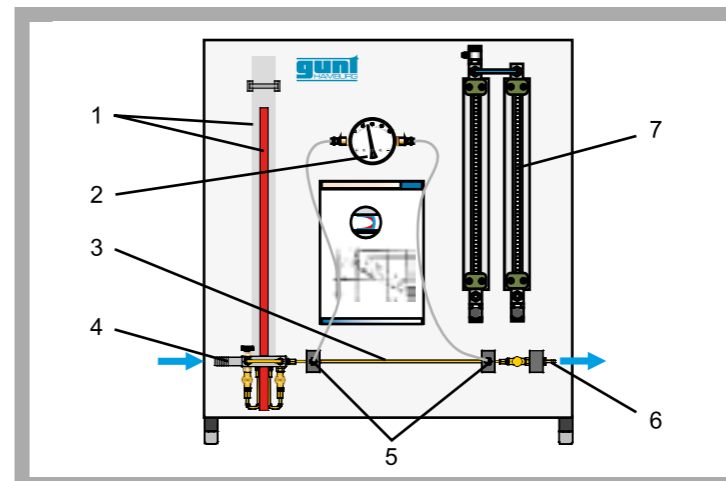
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

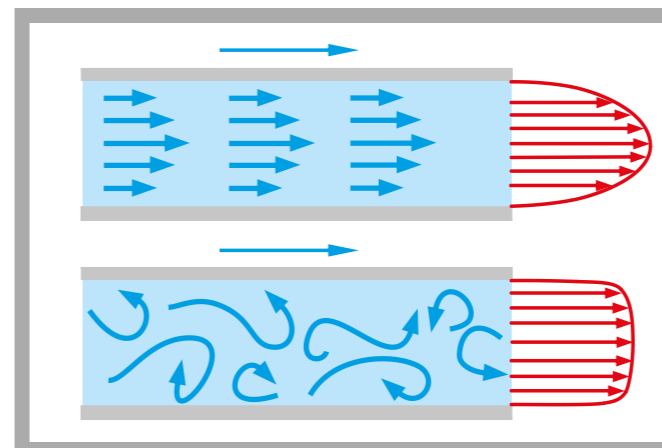
- measurements of the pressure loss in laminar flow
- measurements of the pressure loss in turbulent flow
- determining the critical Reynolds number
- determining the pipe friction factor
- comparing the actual pipe friction factor with the theoretical friction factor

\* Pipe friction losses in laminar and turbulent flow

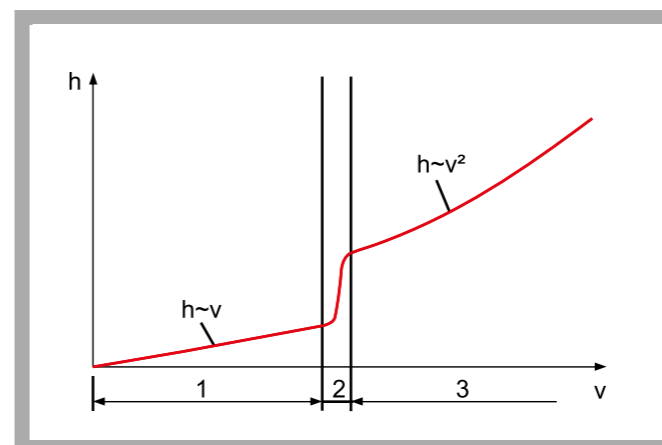
\* Determining the critical Reynolds number

**HM 150.01 Pipe Friction for Laminar / Turbulent Flow**


1 tank with overflow, 2 dial-gauge manometer, 3 pipe section, 4 water supply, 5 pressure measuring points, 6 water drain, 7 twin tube manometers



Representation of the laminar and turbulent flow in the pipe  
top: laminar flow; bottom: turbulent flow; blue flow, red velocity profile



Pressure losses as a function of velocity in pipe flow  
1 laminar flow, 2 transition from laminar to turbulent, 3 turbulent flow;  
h pressure loss, v velocity

**Specification**

- [1] investigation of the pipe friction in laminar or turbulent flow
- [2] transparent tank with overflow ensures constant water inlet pressure in the pipe section for experiments with laminar flow
- [3] water supply via HM 150 or via laboratory supply for experiments with turbulent flow
- [4] flow rate adjustment via valves
- [5] twin tube manometers for measurements in laminar flow
- [6] dial-gauge manometer for measurements in turbulent flow
- [7] flow rate determined by HM 150 base module
- [8] water supply using HM 150 base module or via laboratory supply

**Technical Data**

Pipe section  
- length: 400mm  
- inside diameter: 3mm  
Tank: 5L

**Measuring ranges**

- differential pressure (twin tube manometers): 2x 370mmWC
- differential pressure (dial-gauge manometer): 0...0,4bar

**Dimensions and Weight**

LxWxH: 850x680x930mm  
Weight: approx. 23kg

**Required for Operation**

HM 150 (closed water circuit) or water supply, drain

**Scope of Delivery**

- 1 experimental unit
- 1 set of instructional material

**Order Details**

070.15001 HM 150.01 Pipe Friction for Laminar / Turbulent Flow

**HM 150.11 Losses in a Pipe System**


- \* Pressure losses in the piping system
- \* Pressure measurement without interaction via annular chambers
- \* Transparent measuring objects for determining flow rate

**Technical Description**

Pressure losses occur during the flow of real fluids due to friction and turbulence (vortices). Pressure losses in pipes, piping elements, fittings and measuring instruments (e.g. flow meter, velocity meter) cause pressure losses and must therefore be taken into account when designing piping systems.

HM 150.11 allows to study the pressure losses in pipes, piping elements and shut-off devices. In addition, the differential pressure method is presented for measuring the flow rate.

The experimental unit contains six different pipe sections capable of being shut off individually. The pipe sections are equipped with piping elements such as bends, elbows and branches. In one pipe section, different shut-off devices and measuring objects are installed to determine the flow rate. The measuring objects are made of transparent material and provide excellent insight into the inner structure. The pressure measuring points in the piping system are designed as annular chambers. This creates a largely interference-free pressure measurement.

The experiments measure the pressure losses in pipes and piping elements, such as branches and bends. The opening characteristic of the shut-off devices are also recorded. The pressures are measured with tube manometers.

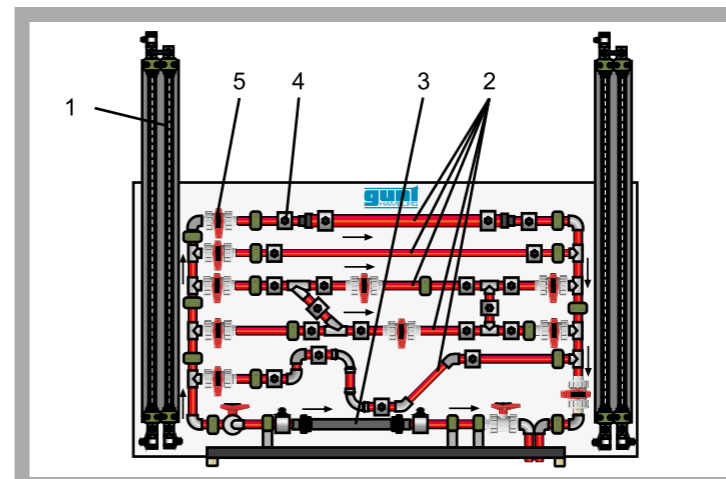
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow

rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

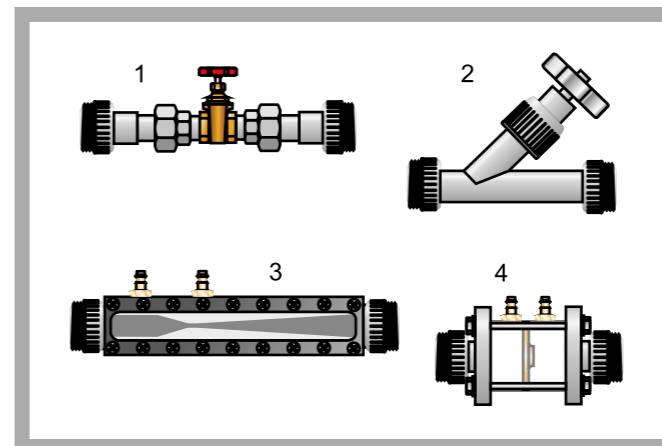
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

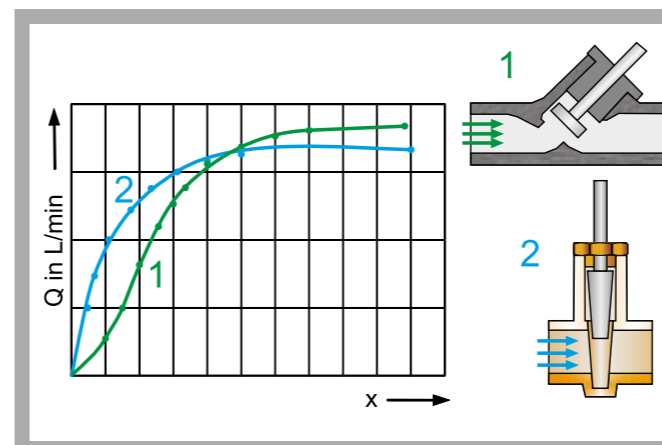
- pressure losses in pipes, piping elements and fittings
- how the flow velocity affects the pressure loss
- determining resistance coefficients
- opening characteristics of angle seat valve and gate valve
- familiarisation with various measuring objects for determining flow rate:
  - \* Venturi nozzle
  - \* orifice plate flow meter and measuring nozzle

**HM 150.11 Losses in a Pipe System**


1 tube manometers, 2 various pipe sections, 3 pipe section for interchangeable shut-off/measuring objects, 4 annular chamber, 5 ball valve



Shut-off devices and measuring objects for determining flow rate  
1 gate valve, 2 angle seat valve, 3 Venturi nozzle, 4 orifice plate flow meter or measuring nozzle



Opening characteristics of shut-off devices; Q flow rate, x opening, blue: angle seat valve, green: gate valve;  
1 angle seat valve, 2 gate valve

**Specification**

- [1] investigation of pressure losses in piping elements and shut-off devices
- [2] different measuring objects for determining flow rate according to the differential pressure method
- [3] six pipe sections capable of being individually shut off, with different piping elements: sudden contraction, sudden enlargement, Y-pieces, T-pieces, corners and bends
- [4] one pipe section to hold interchangeable shut-off/measuring objects
- [5] measuring objects made of transparent material: Venturi nozzle, orifice plate flow meter and measuring nozzle
- [6] shut-off devices: angle seat valve, gate valve
- [7] annular chambers allow measurement of pressure without interaction
- [8] 2 twin tube manometers for measuring the pressure difference
- [9] flow rate determined by HM 150 base module
- [10] water supply using HM 150 base module or via laboratory supply

**Technical Data**

- Pipe section to hold fittings or measuring objects - 20x1,5mm, PVC
- Pipe sections
- Inside diameter: d
- straight: d=20x1,5mm, length: 800mm, PVC
- sudden contraction: d=32x1,8-20x1,5mm, PVC
- sudden enlargement: d=20x1,5-32x1,8mm, PVC
- with 2x Y-piece 45° and 2x T-piece
- with 2x 90° elbow/bend: d=20x1,5mm, PVC and 2x 45° elbow: d=20x1,5mm, PVC
- 2x twin tube manometers: 0...1000mmWC

Measuring range

- pressure: 0...0,1bar

**Dimensions and Weight**

- LxWxH: 1550x640x1300mm
- Weight: approx. 58kg

**Required for Operation**

HM 150 (closed water circuit) or water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 2 shut-off devices (angle seat valve, gate valve)
- 1 Venturi nozzle, 1 orifice plate flow meter or measuring nozzle
- 1 set of hoses
- 1 set of tools
- 1 set of instructional material

**Order Details**

070.15011 HM 150.11 Losses in a Pipe System

**HM 164 Open Channel and Closed Channel Flow**


- \* Flow processes in the open channel: gate, sill and various weirs
- \* Flow processes in the closed channel: pipe flow
- \* Closed water circuit with tank and pump

**Technical Description**

HM 164 is used to demonstrate different flow processes at different control structures in the open channel. In the closed channel, pressure components in a pipe are determined.

The trainer includes a transparent experimental flume with upper limit, a height-adjustable sill and a closed water circuit. The water level in the experimental section is set with an adjustable plate weir at the water outlet. With a simple alteration, the experimental flume can be used as an open or closed channel.

The water level must be low when investigating the open-channel flow. To conduct the experiment, a weir is attached to the bottom of the channel or the height-adjustable sill is used. Furthermore, the discharge under a gate can also be demonstrated. Various weirs, which can be exchanged quickly and safely, are available as control structures.

When studying the closed channel, the water level needs to be high enough that the entire experimental section is flowed through. In this case the sill is used to change the cross-section flowed through.

The static pressures and the total pressure over the cross-section are detected by measuring tubes. The pressure difference is used to calculate the flow velocity.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**
**Open channel**

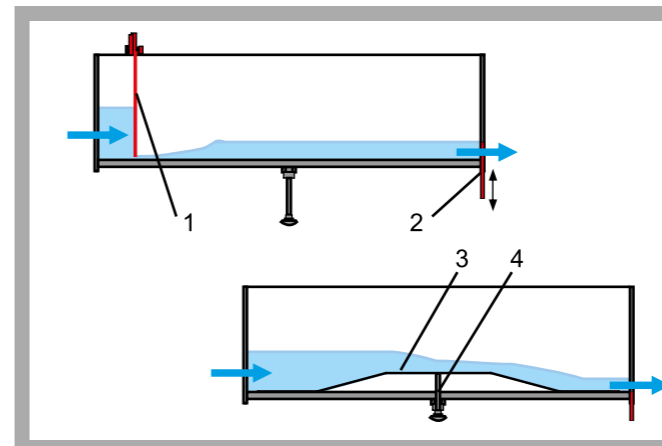
- flow over control structures: broad-crested weir, narrow-crested weir, ogee-crested weir with ski jump spillway, sill
- discharge under a gate
- hydraulic jump

**Closed channel**

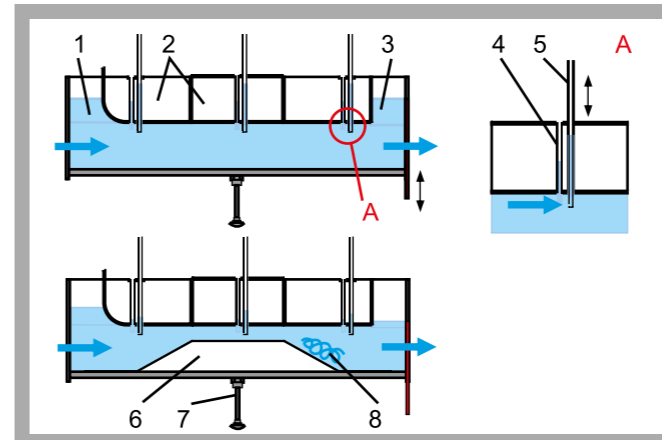
- pipe flow with constant and variable flow cross-section
- measurement of static pressure and total pressure
- calculation of the flow velocity

**HM 164 Open Channel and Closed Channel Flow**


1 sluice gate, 2 water supply, 3 sill height adjustment, 4 supply tank, 5 ogee-crested weir used in the experimental flume, 6 upper limit, 7 water drain with plate weir at the water outlet, 8 measuring tube



Flow processes in the open channel; 1 flow under a gate, 2 plate weir at the water outlet, 3 flow over a sill, 4 height adjustment of the sill



Flow processes in the closed channel; 1 inlet, 2 upper limit, 3 outlet, 4 static pressure measurement, 5 total pressure measurement, 6 sill, 7 height adjustment of the sill, 8 turbulence

**Specification**

- [1] investigation of flow processes in the open and closed channel
- [2] experimental flume with upper limit, made of transparent material
- [3] height-adjustable sill in the bottom of the experimental flume
- [4] water level adjustable via plate weir at the water outlet
- [5] simple conversion from open to closed channel
- [6] control structures for experiments in the open channel: broad-crested weir, narrow-crested weir, ogee-crested weir with ski jump spillway, sill, gate
- [7] fully flowed-through experimental section and change in cross-section over sill for experiments in the closed channel
- [8] closed water circuit with supply tank and pump
- [9] transparent measuring tubes for measuring static pressure and total pressure

**Technical Data**

- Experimental section
- length: 1,1m
- cross-section WxH: 40x300mm
- Supply tank: 70L
- Pump
- power consumption: 250W
- max. flow rate: 150L/min
- max. head: 7,6m

**Dimensions and Weight**

- LxWxH: 1900x800x1350mm
- Weight empty: approx. 150kg

**Required for Operation**

- 230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase

**Scope of Delivery**

- 1 trainer
- control structures: broad-crested weir, narrow-crested weir, ogee-crested weir with ski jump spillway, sill, gate
- 1 plate weir
- 1 tool
- 1 set of instructional material

**Order Details**

- 070.16400 HM 164 Open Channel and Closed Channel Flow

**HM 111 Pipe Networks**


- \* Structure of various pipe networks
- \* Pressure losses at various piping elements and pipe networks
- \* Closed water circuit with tank and pump

**Technical Description**

An important task in the construction of pipelines is to determine the pressure and flow rate in complex piping systems. In practice, the calculation of the total pressure losses serves as a foundation for the design of suitable drive units for heating and air conditioning systems, drinking water supply systems and parts of wastewater systems. Knowledge of pressure losses is also used to optimise operation.

HM 111 enables the construction and investigation of various pipe networks, such as parallel and series connections of pipes, their branching and merging, and the study of individual pipes. In analogy to Kirchhoff's laws of electricity, it is possible to conduct nodal analysis.

The five pre-installed pipe sections on the top of the trainer are connected to pipe networks using the piping elements. Tank, pipes, piping elements and valves and fittings are made entirely of plastic. The individual pipe sections are shut off by ball valves. During the experiments, the pressure losses in various pipes and piping elements are recorded and evaluated.

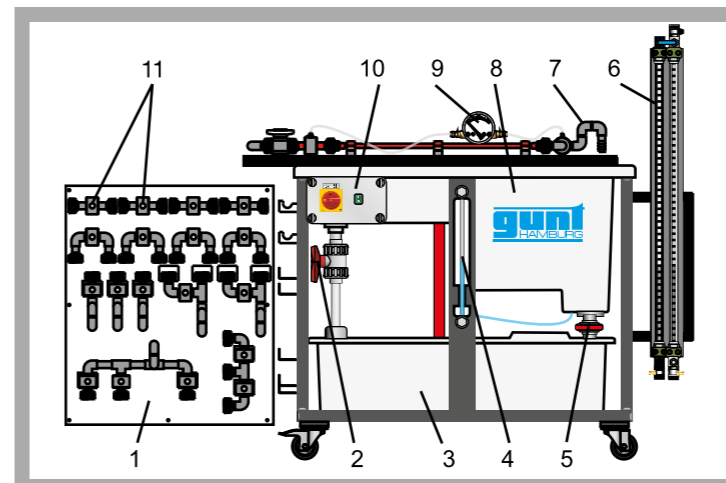
Two manometers for different measuring ranges are included to measure differential pressure. The flow rate is measured volumetrically.

The trainer has its own water supply. The closed water circuit includes a supply tank with submersible pump.

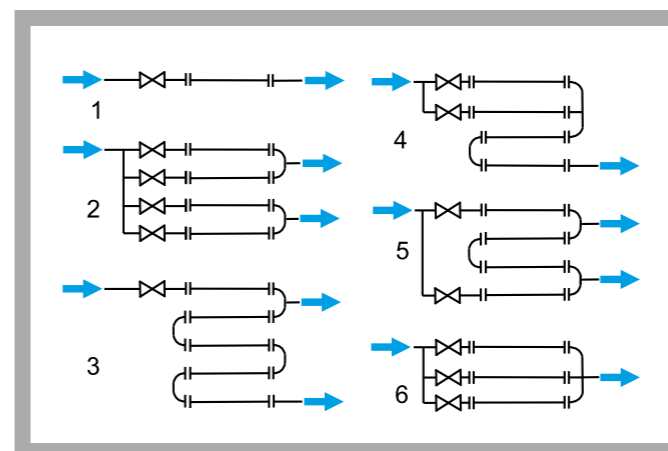
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

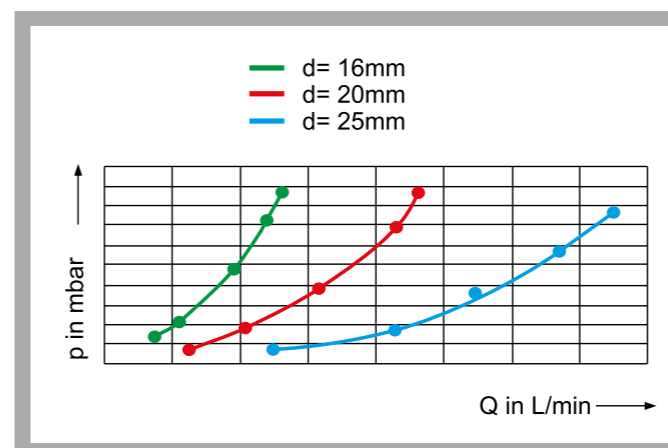
- recording the calibration curve for pipe sections: pressure loss over flow rate
- pipe sections connected in parallel
- pipe sections connected in series
- combined series and parallel connection
- investigation of a closed circular pipeline
- differential pressure measurement
- pressure losses at various piping elements

**HM 111 Pipe Networks**


1 panel with piping elements, 2 valve for adjusting the flow rate, 3 supply tank with submersible pump, 4 measuring tank level indicator, 5 gate valve for emptying the measuring tank, 6 twin tube manometers, 7 pipe sections, 8 measuring tank, 9 differential pressure manometer, 10 switch box, 11 pressure measuring point



Different pipe networks constructed from pipe sections:  
1 calibration of pipe sections, 2 doubling, 3 series connection, 4 parallel and series connection, 5 closed circular pipeline, 6 parallel connection



The diagram shows the pressure loss over flow rate for different pipe diameters:  
p pressure, Q flow rate, d inner diameter

**Specification**

- [1] investigation of different pipe networks
- [2] five pre-installed pipe sections with different diameters
- [3] panel for piping elements
- [4] construction of pipe networks from pipe sections and various piping elements
- [5] calibration of pipe sections
- [6] parallel and series connection of pipe sections
- [7] construction of a closed circular pipeline
- [8] differential pressure measurement with twin tube manometers and differential pressure manometer
- [9] flow rate measurement with measuring tank (can be shut off), stopwatch and level indicator

**Technical Data**
**Pump**

- power consumption: 250W
- max. flow rate: 9m<sup>3</sup>/h
- max. head: 7,6m

Pipe network, max. flow rate: 4,8m<sup>3</sup>/h

Pipe sections, length 700mm each

- 1x: 25x1,9mm
- 2x: 20x1,5mm
- 2x: 16x1,2mm

Twin tube manometers

Tank for water: 180L

Tank for flow rate measurement

- small measuring range: 10L

- large measuring range: 60L

Stopwatch: 1/100s

**Measuring ranges**

- differential pressure: 1x 0...1bar
- differential pressure with tube manometers: 2x 0...100mbar

**Dimensions and Weight**

LxWxH: 1550x800x1600mm

Weight: approx. 117kg

**Required for Operation**

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA,  
1 phase

**Scope of Delivery**

- 1 trainer
- 1 stopwatch
- 1 set of instructional material

**Order Details**

070.11100 HM 111 Pipe Networks

## EXPERIMENTAL UNITS FROM THE FIELD OF TURBO MACHINERY

One important field of fluid mechanics concerns turbomachines, these are divided into power engines and machines. Turbines are power machines, while pumps are classic machines.

The experimental units presented here are all powered by water. They serve as an introduction into the subject of turbomachinery.

The experimental units are part of the HM 150 series. The water is supplied and the flow rate measured by the HM 150 base module.

### POWER ENGINES



#### HM 150.19 OPERATING PRINCIPLE OF A PELTON TURBINE

- model of an impulse turbine
- transparent front panel for observing the operating area
- adjustable nozzle needle for setting different nozzle cross-sections



#### HM 150.20 OPERATING PRINCIPLE OF A FRANCIS TURBINE

- model of a reaction turbine
- transparent front panel for observing the operating area
- adjustable guide vanes for setting different angles of incidence

### MACHINES

#### HM 150.04 CENTRIFUGAL PUMP

- studying a centrifugal pump and recording a typical pump characteristic curve
- determining the pump efficiency
- studying how speed affects flow rate and head



#### HM 150.16 SERIES AND PARALLEL CONFIGURATION OF PUMPS

- studying pumps individually, connected in series and in parallel
- recording pump characteristic curves and determining the operating point
- determining the hydraulic power of pumps



**HM 150.19 Operating Principle of a Pelton Turbine**

**Technical Description**

Water turbines are turbomachines utilising water power. The Pelton turbine is a type of impulse turbine; such turbines convert the pressure energy of water into kinetic energy entirely in the distributor. During the conversion, the water jet is accelerated in a nozzle and directed onto the blades of the Pelton wheel tangentially. The water jet is redirected by approximately 180° in the blades. The impulse of the water jet is transmitted to the Pelton wheel.

HM 150.19 is a model of a Pelton turbine demonstrating the function of an impulse turbine.

The experimental unit consists of the Pelton wheel, a needle nozzle used as distributor, a band brake for loading the turbine and a housing with a transparent front panel. The transparent cover enables to observe the water flow, the Pelton wheel and the nozzle during operation. The nozzle cross-section and thus the flow rate are modified by adjusting the nozzle needle.

The turbine torque is determined by force measurement on a band brake and is read on spring balances. For measuring the rotational speed, a non-contact speed sensor, e.g. HM 082, is required. A manometer shows the water pressure at the turbine inlet.

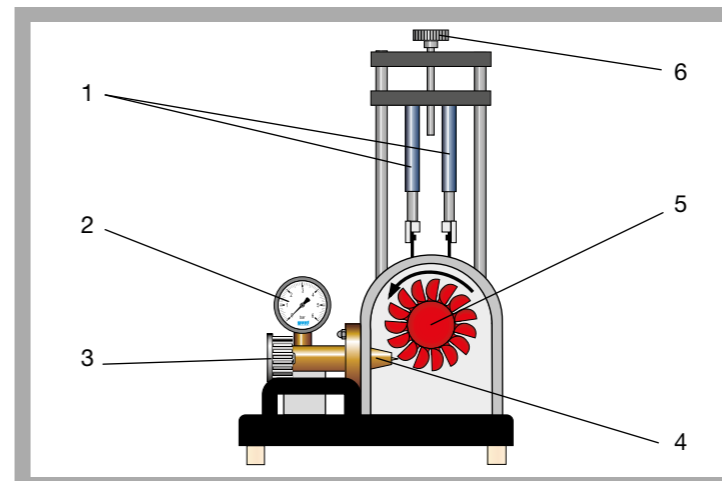
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

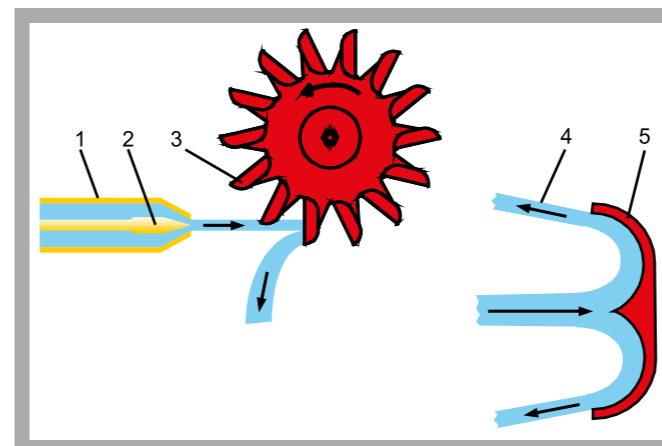
**Learning Objectives / Experiments**

- design and function of a Pelton turbine
- determination of torque, power and efficiency
- graphical representation of characteristic curves for torque, power and efficiency

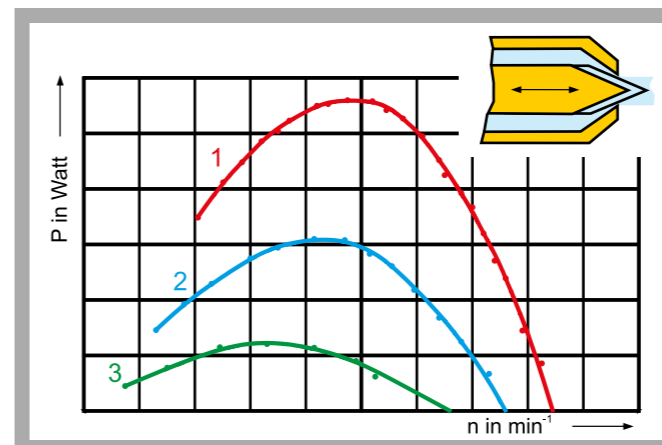
- \* Model of an impulse turbine
- \* Transparent operating area
- \* Adjustable nozzle cross-section
- \* Loading by band brake

**HM 150.19 Operating Principle of a Pelton Turbine**


1 spring balance, 2 manometer, 3 adjustment of the nozzle cross-section, 4 needle nozzle, 5 Pelton wheel, 6 adjustment of the band brake



Operating principle of the Pelton turbine:  
1 needle nozzle, 2 adjustable nozzle needle, 3 blade on the Pelton wheel, 4 redirected water jet, 5 profile of the blade



Turbine output curves at different positions of the nozzle needle:  
1: Q=31,6L/min, 2: Q=18,8L/min, 3: Q=11,5L/min; n speed, P turbine output

**Specification**

- [1] function of a Pelton turbine
- [2] transparent front panel for observing the operating area
- [3] loading the turbine by use of the band brake
- [4] adjustable nozzle needle for setting different nozzle cross-sections
- [5] marking on brake drum for non-contact speed measurement
- [6] instruments: spring balances for determining the torque, manometer shows pressure at turbine inlet
- [7] flow rate determination by base module HM 150
- [8] water supply using base module HM 150 or via laboratory supply

**Technical Data**

Pelton turbine

- output: 5W at 500min<sup>-1</sup>, approx. 30L/min, H=2m
- Pelton wheel
- 14 blades
- blade width: 33,5mm
- external diameter: 132mm
- Needle nozzle
- jet diameter: 10mm

Measuring ranges

- braking force (spring balance): 10N
- pressure: 0...1bar

**Dimensions and Weight**

LxWxH: 400x400x620mm  
Weight: approx. 15kg

**Required for Operation**

HM 150 (closed water circuit) or water supply, drain

**Scope of Delivery**

- 1 experimental unit
- 1 set of instructional material

**Order Details**

070.15019 HM 150.19 Operating Principle of a Pelton Turbine

**HM 150.20 Operating Principle of a Francis Turbine**

**Technical Description**

Water turbines are turbomachines utilising water power. The Francis turbine is a type of reaction turbine which converts the pressure energy of the water into kinetic energy in the distributor and in the rotor. The water is fed in the distributor by means of a spiral housing. The flowing water is accelerated in the distributor by the adjustable guide vanes and directed onto the rotor blades. The redirection and further acceleration of the water in the rotor generates an impulse which is transmitted to the rotor.

HM 150.20 is the model of a Francis turbine demonstrating the function of a reaction turbine.

The experimental unit consists of the rotor, the distributor with adjustable guide vanes, a band brake for loading the turbine and a housing with a transparent front panel. The transparent cover enables to observe the water flow, the rotor and the guide vanes during operation. The angle of attack and thus the power of the rotor are modified by adjusting the guide vanes.

The turbine torque is determined by force measurement on a band brake and is read on spring balances. For measuring the rotational speed, a non-contact speed sensor, e.g. HM 082, is required. A manometer shows the water pressure at the turbine inlet.

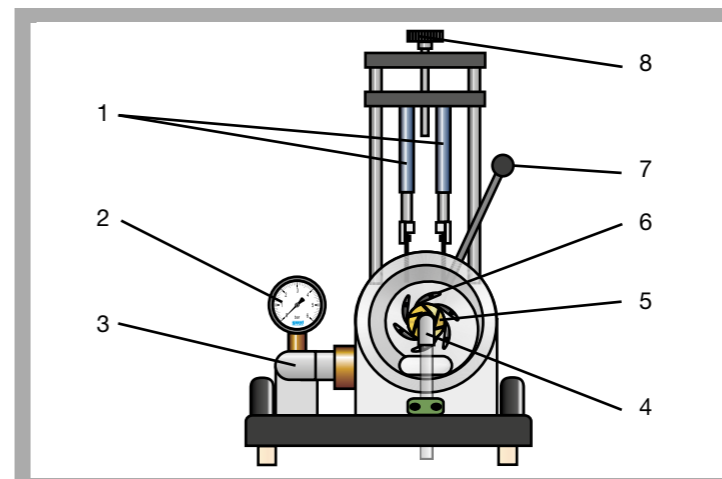
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

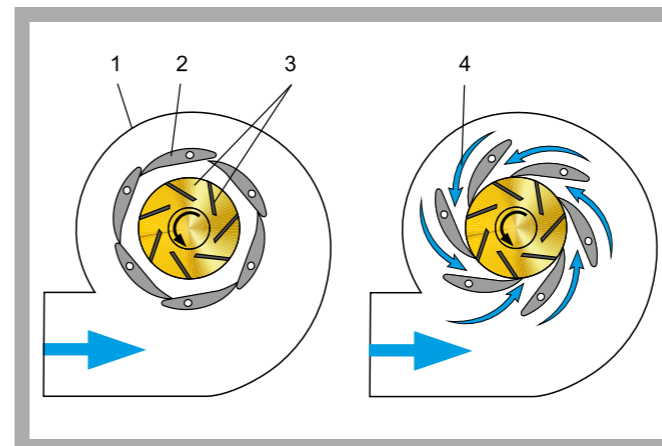
**Learning Objectives / Experiments**

- design and function of a Francis turbine
- determination of torque, power and efficiency
- graphical representation of characteristic curves for torque, power and efficiency

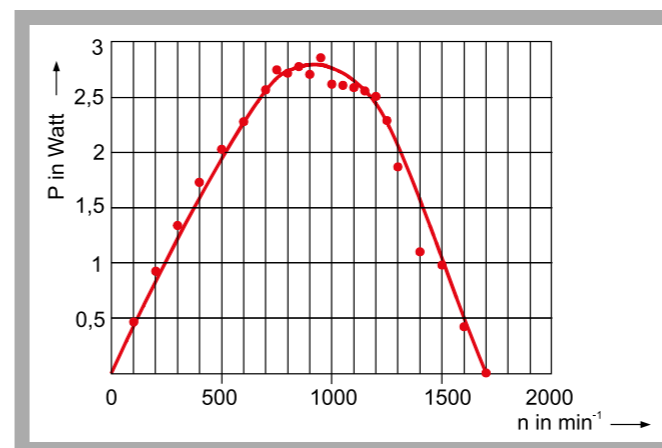
- \* Model of a reaction turbine
- \* Transparent operating area
- \* Turbine with adjustable guide vanes
- \* Loading by band brake

**HM 150.20 Operating Principle of a Francis Turbine**


1 spring balance, 2 manometer, 3 water inlet, 4 water outlet, 5 rotor, 6 guide vanes, 7 adjustment of the guide vanes, 8 adjustment of the band brake



Operating principle of the Francis turbine:  
1 spiral housing, 2 guide vane, 3 rotor with rotor blades, 4 flow  
on the left: guide vane position closed,  $Q=0$ ,  $P=0$   
on the right: guide vane position open,  $Q=\max.$ ,  $P=\max.$



Characteristic curve for power output on the turbine shaft;  
 $P$  turbine power output,  $n$  speed

**Specification**

- [1] function of a Francis turbine
- [2] transparent front panel for observing the operating area
- [3] loading the turbine by use of the band brake
- [4] adjustable guide vanes for setting different angles of attack
- [5] marking on brake drum for non-contact speed measurement
- [6] instruments: spring balances for determining the torque, manometer shows pressure at turbine inlet
- [7] flow determination by base module HM 150
- [8] water supply using the base module HM 150 or via lab supply

**Technical Data**

- Turbine
- output: 12W at  $n=1100\text{min}^{-1}$ , approx. 40L/min,  $H=8\text{m}$
  - rotor, 7 blades
  - blade width: 5mm
  - external diameter: 50mm
  - guide vanes: 6 vanes, adjustable (20 stages)

**Measuring ranges**

- braking force (spring balance): 10N
- pressure: 0...1,0bar

**Dimensions and Weight**

- LxWxH: 400x400x630mm  
Weight: approx. 17kg

**Required for Operation**

- HM 150 (closed water circuit) or water supply, drain

**Scope of Delivery**

- 1 experimental unit  
1 set of instructional material

**Order Details**

- 070.15020 HM 150.20 Operating Principle of a Francis Turbine

**HM 150.04 Centrifugal Pump**


The illustration shows HM 150.04 together with HM 150.

- \* **Characteristic curve of a centrifugal pump**
- \* **Variable speed via frequency converter**

**Technical Description**

Centrifugal pumps are turbomachines that are used for conveying fluids. The HM 150.04 unit can be used to study a centrifugal pump and to record a typical pump characteristic curve.

The experimental unit includes a self-priming centrifugal pump, a ball valve on the outlet side and manometers on the inlet and outlet side. It is driven by an asynchronous motor. The speed is infinitely adjustable by using a frequency converter. A ball valve is used to adjust the head.

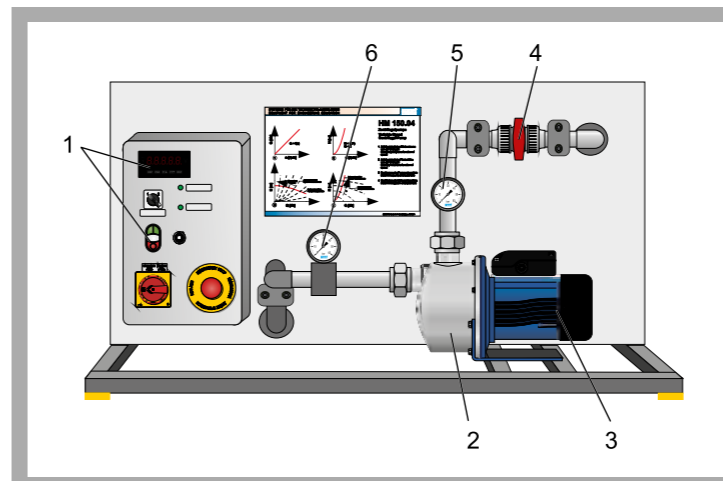
In experiments, the operating behaviour of the pump as a function of the flow rate is studied and displayed in characteristic curves. The motor's speed and electrical power are displayed digitally. Pressures on the inlet and outlet side are displayed on two manometers.

The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The pump draws in water from the tank on the base module HM 150. The flow rate is determined volumetrically by flowing back into the measuring tank on HM 150.

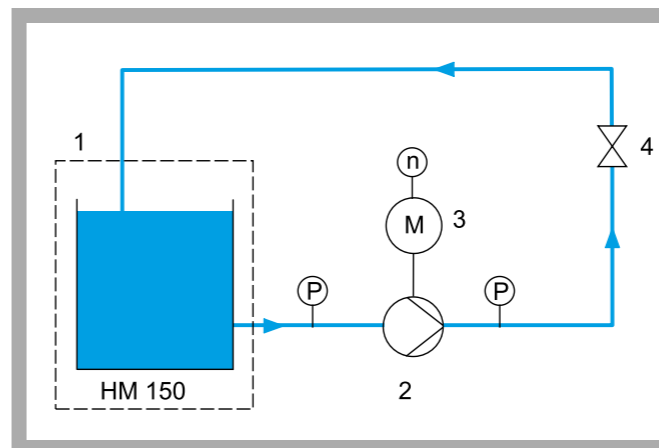
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

**Learning Objectives / Experiments**

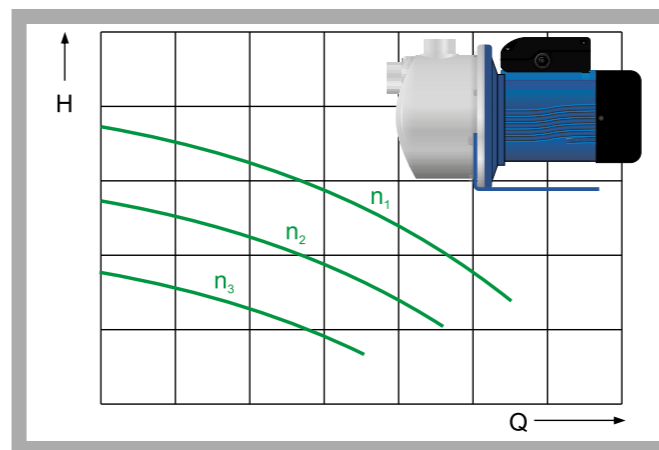
- familiarisation with operating behaviour and characteristics of a centrifugal pump through experiments
- recording the pump characteristic curve at a constant pump speed
    - \* measuring the inlet and outlet pressure
    - \* determining the flow rate
  - recording the pump characteristics for different speeds
    - \* power and efficiency curves
    - \* measuring the electrical drive power
    - \* determining the hydraulic power
    - \* calculating the efficiency

**HM 150.04 Centrifugal Pump**


1 display and controls, 2 centrifugal pump, 3 motor, 4 ball valve for adjusting the head, 5 outlet side manometer, 6 inlet side manometer



1 water supply via HM 150, 2 centrifugal pump, 3 motor, 4 ball valve for adjusting the head; P pressure, n speed



Pump characteristic curves at different speeds:  
H head, Q flow rate, n speed

**Specification**

- [1] investigation of a centrifugal pump
- [2] drive with variable speed via frequency converter
- [3] ball valve to adjust the head
- [4] manometers on the inlet and outlet side of the pump
- [5] digital display of speed and power
- [6] flow rate determined by base module HM 150
- [7] water supply using base module HM 150

**Technical Data**

- Centrifugal pump, self-priming
- max. flow rate: 3000L/h
  - max. head: 36,9m
- Asynchronous motor
- nominal power: 370W

**Measuring ranges**

- pressure (outlet side): -1...5bar
- pressure (inlet side): -1...1,5bar
- speed: 0...3000min<sup>-1</sup>
- power: 0...1000W

**Dimensions and Weight**

- LxWxH: 1100x640x600mm  
Weight: approx. 46kg

**Required for Operation**

- 230V, 50/60Hz/CSA, 1 phase or 230V, 60Hz/CSA,  
3 phases  
HM 150 (closed water circuit)

**Scope of Delivery**

- 1 experimental unit  
1 set of instructional material

**Order Details**

070.15004 HM 150.04 Centrifugal Pump

**HM 150.16 Series and Parallel Configuration of Pumps**


- \* Series and parallel configuration of pumps
- \* Determining pump characteristic curves

**Technical Description**

In complex systems, pumps can be connected in series or in parallel. In series operation the heads are added together and in parallel operation, the flow rates of the pumps are added. Series and parallel configuration of pumps behave similar to series and parallel configuration of electric resistances in electric circuits. The pump correlates with the electric resistance, the flow correlates with the electric current and the head with the voltage.

With HM 150.16 pumps are studied individually, in series and in parallel configuration.

The experimental unit contains two identical centrifugal pumps and an intake tank with overflow. The overflow ensures a constant suction head in the tank, regardless of the water supply. Ball valves in the pipes allow easy switching between series and parallel operation.

Pressures at inlet and outlet of the two pumps are displayed on manometers.

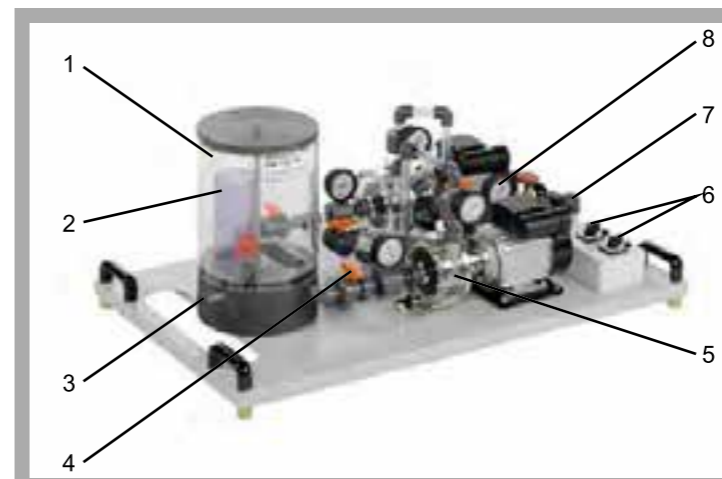
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

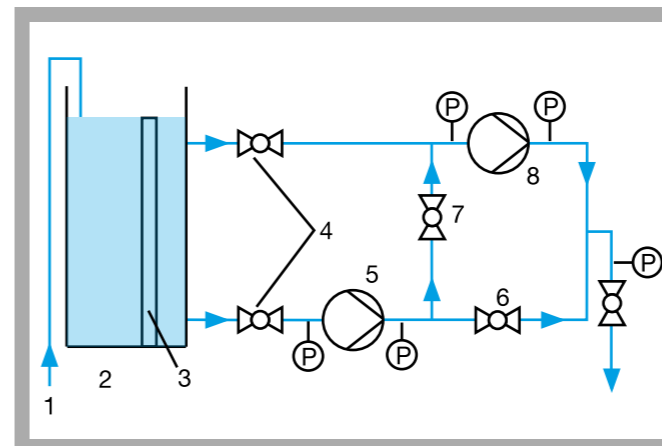
**Learning Objectives / Experiments**

Investigation of pumps in series and parallel configuration

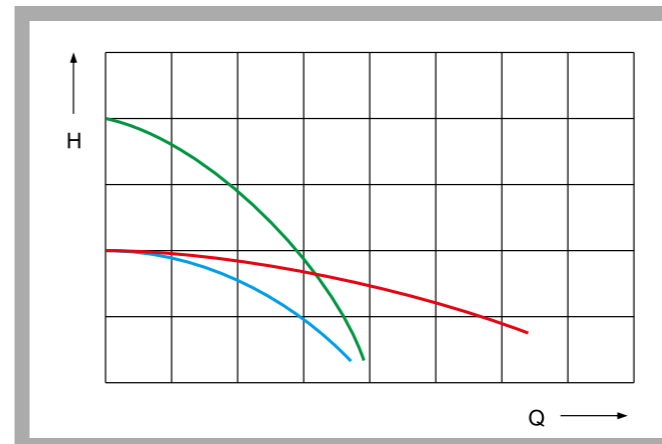
- determining the head
- recording the pump characteristics
- determining the hydraulic power
- determining the operating point

**HM 150.16 Series and Parallel Configuration of Pumps**


1 tank, 2 overflow, 3 water connection, 4 ball valve, 5 pump, 6 pump switch, 7 drain, 8 manometer



1 water connection, 2 tank, 3 overflow, 4 ball valve, 5 pump 1, 6 and 7 ball valves for switching the pumps between series and parallel operation, 8 pump 2; P pressure



Characteristic curves: blue: one pump in operation, red: parallel configuration of pumps, green: series configuration of pumps; H head, Q flow rate

**Specification**

- [1] investigation of series and parallel configuration of pumps
- [2] two identical centrifugal pumps
- [3] transparent tank as intake tank
- [4] overflow in the tank ensures constant suction head
- [5] ball valves used to switch between series and parallel operation
- [6] manometers at inlet and outlet of each pump
- [7] flow rate determined by base module HM 150
- [8] water supply via HM 150 or via laboratory supply

**Technical Data**

- 2x centrifugal pump
- power consumption: 370W
- max. flow rate: 21L/min
- max. head: 12m
- Tank: 13L
- Pipes and pipe connections: PVC

**Measuring ranges**

- pressure (inlet): 2x -1...1,5bar
- pressure (outlet): 3x 0...2,5bar

**Dimensions and Weight**

- LxWxH: 1110x650x500mm
- Weight: approx. 62kg

**Required for Operation**

- 230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
- HM 150 (closed water circuit) or alternatively water connection and drain

**Scope of Delivery**

- 1 experimental unit
- 1 set of instructional material

**Order Details**

070.15016 HM 150.16 Series and Parallel Configuration of Pumps

# HM 150 RANGE A SIMPLE INTRODUCTION INTO THE FUNDAMENTALS OF FLUID MECHANICS

GUNT devices from the HM 150 range demonstrate phenomena and facilitate simple experiments on the following topics of fluid mechanics:

- steady flow in pipes
- laminar/turbulent flow, Reynolds number
- continuity equation, Bernoulli's principle
- methods of flow rate measurement
- flow from tanks
- free/forced vortex formation
- open-channel flow
- flow around bodies
- transient flow at a hydraulic ram
- turbomachines
- jet forces

## STEADY FLOW IN PIPES

- HM 150.11 *Losses in a Pipe System*
- HM 150.01 *Pipe Friction for Laminar / Turbulent Flow*
- HM 150.29 *Energy Losses in Piping Elements*

## LAMINAR/TURBULENT FLOW, REYNOLDS NUMBER

- HM 150.18 *Osborne Reynolds Experiment*
- HM 150.01 *Pipe Friction for Laminar / Turbulent Flow*

## BERNOULLI'S PRINCIPLE / FLOW RATE MEASUREMENT

- HM 150.13 *Methods of Flow Measurement*
- HM 150.11 *Losses in a Pipe System*
- HM 150.07 *Bernoulli's Principle*

## TRANSIENT FLOW

- HM 150.15 *Hydraulic Ram – Pumping Using Water Hammer*

## TURBOMACHINES

- HM 150.04 *Centrifugal Pump*
- HM 150.16 *Series and Parallel Configuration of Pumps*
- HM 150.19 *Operating Principle of a Pelton Turbine*
- HM 150.20 *Operating Principle of a Francis Turbine*

## JET FORCES

- HM 150.08 *Measurement of Jet Forces*

## DETERMINING THE METACENTRE

- HM 150.06 *Stability of Floating Bodies*



HM 150.18 Osborne Reynolds Experiment



HM 150.15 Hydraulic Ram – Pumping Using Water Hammer



HM 150.08 Measurement of Jet Forces



HM 150.11 Losses in a Pipe System



HM 150.13 Methods of Flow Measurement



HM 150.04 Centrifugal Pump



HM 150.06 Stability of Floating Bodies



HM 150.21 Visualisation of Streamlines in an Open Channel



The HM 150 base module provides a closed water circuit to supply the separate experimental units. The experimental unit is connected to the base module for the water supply via a hose. The flow rate is measured volumetrically.

All devices are designed so that they can be placed securely and stably on the base module.

## STEADY OPEN-CHANNEL FLOW

- HM 150.21 *Visualisation of Streamlines in an Open Channel*
- HM 150.03 *Plate Weirs for HM 150*



HM 150.10 Visualisation of Streamlines

## FLOW AROUND BODIES

- HM 150.10 *Visualisation of Streamlines*
- HM 150.21 *Visualisation of Streamlines in an Open Channel*



HM 150.09 Horizontal Flow from a Tank

## FLOW FROM TANKS

- HM 150.09 *Horizontal Flow from a Tank*
- HM 150.12 *Vertical Flow from a Tank*

## FREE / FORCED VORTEX FORMATION

- HM 150.14 *Vortex Formation*



HM 150.14 Vortex Formation

**HM 150 Base Module for Experiments in Fluid Mechanics**


- \* **Water supply for experimental units for fluid mechanics**
- \* **Volumetric flow rate measurement for large and small flow rates**
- \* **Comprehensive range of accessories allows a complete course in the fundamentals of fluid mechanics**

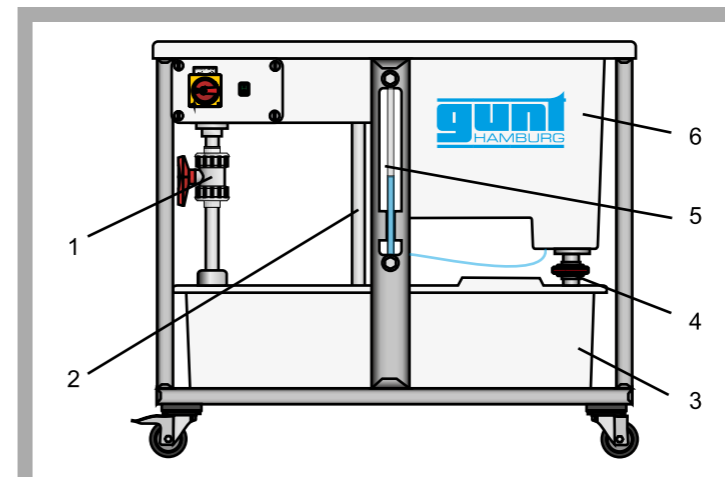
**Technical Description**

The HM 150 series of devices permits a varied experimental cross-section in the fundamentals of fluid mechanics. The base module HM 150 provides the basic equipment for individual experiments: the supply of water in the closed circuit; the determination of volumetric flow rate and the positioning of the experimental unit on the working surface of the base module and the collection of dripping water.

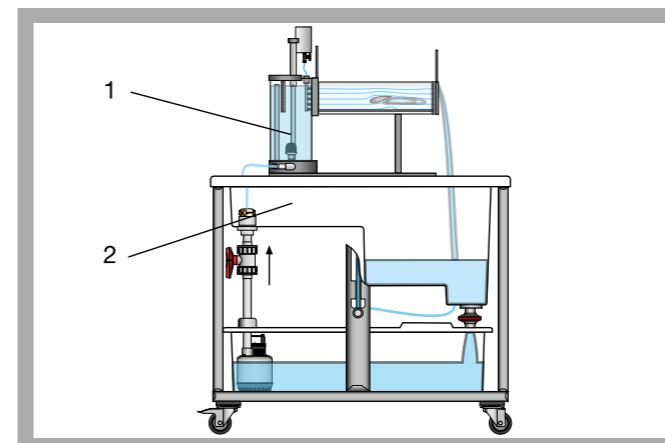
The closed water circuit consists of the underlying storage tank with a powerful submersible pump and the measuring tank arranged above, in which the returning water is collected.

The measuring tank is stepped, for larger and smaller volumetric flow rates. A measuring beaker is used for very small volumetric flow rates. The volumetric flow rates are measured using a stopwatch.

The top work surface enables the various experimental units to be easily and safely positioned. A small flume is integrated in the work surface, in which experiments with weirs (HM 150.03) are conducted.

**HM 150 Base Module for Experiments in Fluid Mechanics**


1 flow control valve, 2 overflow, 3 storage tank with submersible pump, 4 gate valve for emptying the measuring tank, 5 measuring tank level indicator, 6 measuring tank



HM 150.21 (1) placed on the base module HM 150 (2)



Base module for experiments in fluid mechanics with plate weir HM 150.03

**Specification**

- [1] base module for supplying experimental units in fluid mechanics
- [2] closed water circuit with storage tank, submersible pump and measuring tank
- [3] measuring tank divided in two for volumetric flow rate measurements
- [4] measuring beaker with scale for very small volumetric flow rates
- [5] measurement of volumetric flow rates by using a stopwatch
- [6] work surface with integrated flume for experiments with weirs
- [7] work surface with inside edge for safe placement of the accessory and for collecting the dripping water
- [8] storage tank, measuring tank and work surface made of GRP

**Technical Data**

- Pump**
- power consumption: 250W
  - max. flow rate: 150L/min
  - max. head: 7,6m
- Storage tank, capacity: 180L**
- Measuring tank**
- at large volumetric flow rates: 40L
  - at small volumetric flow rates: 10L
- Flume**
- LxWxH: 530x150x180mm
- Measuring beaker with scale for very small volumetric flow rates**
- capacity: 2L
- Stopwatch**
- measuring range: 0...9h 59min 59sec

**Dimensions and Weight**

- LxWxH: 1230x770x1070mm  
Weight: approx. 82kg

**Required for Operation**

- 230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase

**Scope of Delivery**

- 1 base module
- 1 stopwatch
- 1 measuring beaker
- 1 hose
- 1 manual

**Order Details**

- 070.15000 HM 150 Base Module for Experiments in Fluid Mechanics