

1 THEORETICAL FUNDAMENTALS



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THEORETICAL FUNDAMENTALS OF PROCESS ENGINEERING



WL 377
Convection and Radiation

The theoretical fundamentals and laws for understanding process engineering are extremely manifold. Process engineering is an interdisciplinary science and also uses the knowledge of other engineering disciplines. In this chapter, we are presenting a device range with which you can impart the typical basic theoretical learning contents of a process engineering curriculum.

THERMODYNAMICS

For many processes, e.g. thermal process engineering, knowledge of thermodynamics is essential. Understanding a complex process such as, for example, rectification, initially requires the thermodynamic basics of evaporation and condensation. With the help of the laws of thermodynamics the dependencies of the variables temperature, pressure, density and concentration in the system of steam and liquid can be described. Only with this knowledge is it possible to design and construct process engineering apparatus and systems.

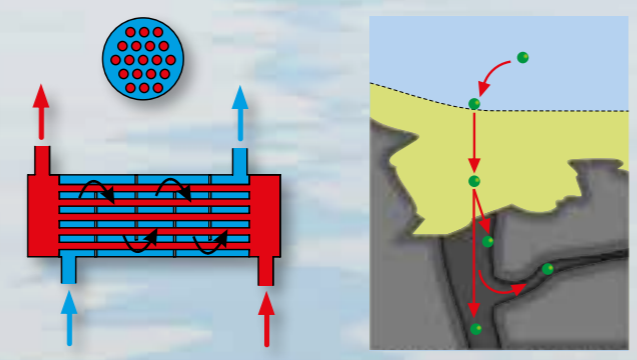


WL 230 Condensation Process

HEAT AND MASS TRANSFER

The speed of production processes is often determined by heat and mass transfer processes. For example, in many chemical and biological mass transformations, it is not the reaction rates that limit the conversion, but the mass transportation processes, which bring about the contact between the reacting agents and the removal of the reaction products. These processes are closely linked with the mass flows, i.e. the actual output of a process. Knowledge of the laws of heat and mass transfer is thus another important basis for designing process engineering systems.

Heat transfer processes are fundamental for the calorific design of process engineering systems. Knowledge of the laws of heat transfer are essential for designing heat transfer surfaces and facilities for heating and cooling. The selection, optimisation and designing of heat exchangers are typical tasks of experts in the process engineering sector.

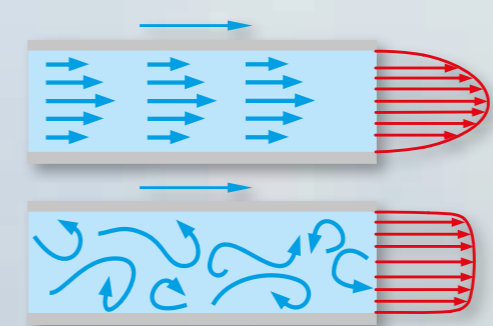


Heat transfer in shell & tube heat exchangers

Mass transfer during adsorption

FLUID MECHANICS

The transportation of substances involved in process engineering often takes place through pipelines. This leads to different flow profiles in conjunction with varying pressure losses, depending on the diameter of the pipelines, flow velocity, substance properties and other influencing factors. The pressure losses in turn influence the necessary output of pumps and compressors. The flow profiles also influence the heat and mass transfer processes.



Laminar and turbulent flow profile in pipelines

MEASURING METHODS

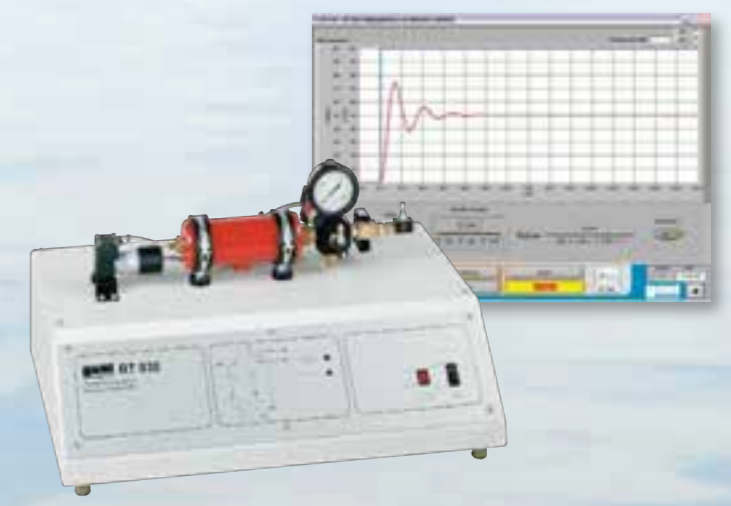
To control processes, first of all it is necessary to record the process variables. The different properties of the process variables, but also of the substances used and the respective aggregate states, make different measuring methods necessary. The different measuring methods can be illustrated in a simple way using the instructional units selected here.



WL 202 Fundamentals of Temperature Measurement

FUNDAMENTALS OF CONTROL ENGINEERING

Mastering industrial-scale process engineering systems without process control engineering is unimaginable. Process variables such as pressure, flow rate or temperature have different properties with regard to their control response. The control response can be approximated and specified with the help of theoretical functions. We have compiled a selection of simple instructional units with which it is easy to impart these theoretical fundamentals of control engineering.



RT 030 Training System: Pressure Control, HSI

WL 204 Vapour Pressure of Water - Marcet Boiler

Technical Description

In a closed system filled with fluid, a thermodynamic equilibrium sets in between the fluid and its vaporised phase. The prevailing pressure is called vapour pressure. It is substance-specific and temperature-dependent.

When a fluid is heated in a closed tank, the pressure increases as the temperature rises. Theoretically, the pressure increase is possible up to the critical point at which the densities of the fluid and gaseous phases are equal. Fluid and vapour are then no longer distinguishable from each other. This knowledge is applied in practice in process technology for freeze drying or pressure cooking.

The WL 204 experimental unit can be used to demonstrate the relationship between the pressure and temperature of water in a straightforward manner. Temperatures of up to 200°C are possible for recording the vapour pressure curve. The temperature and pressure can be continuously monitored via a digital temperature display and a Bourdon tube pressure gauge.

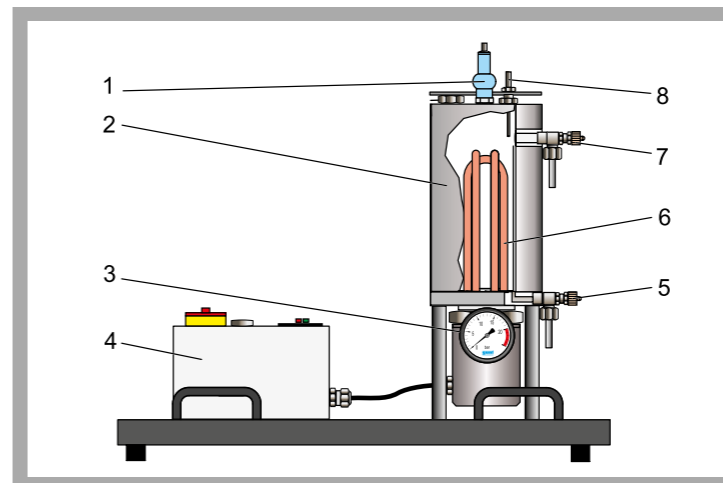
A temperature limiter and pressure relief valve are fitted as safety devices and protect the system against overpressure.

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

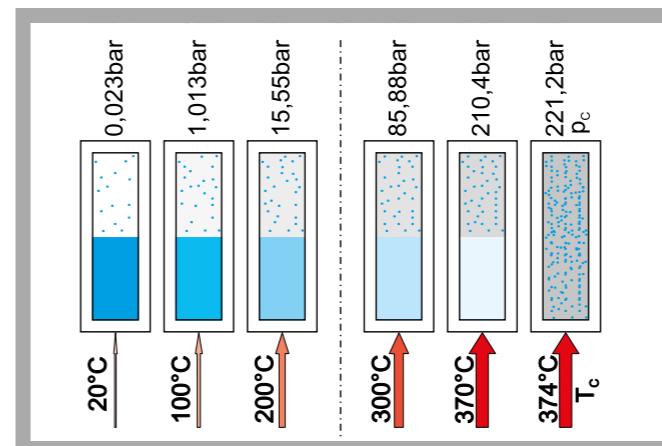
Learning Objectives / Experiments

- recording the vapour pressure curve of water
- presentation of the relationship between pressure and temperature in a closed system
- temperature and pressure measurement
- influence of foreign gases (air) on the pressure

- * Recording the vapour pressure curve of water
- * Saturation pressure of water vapour as a function of the temperature

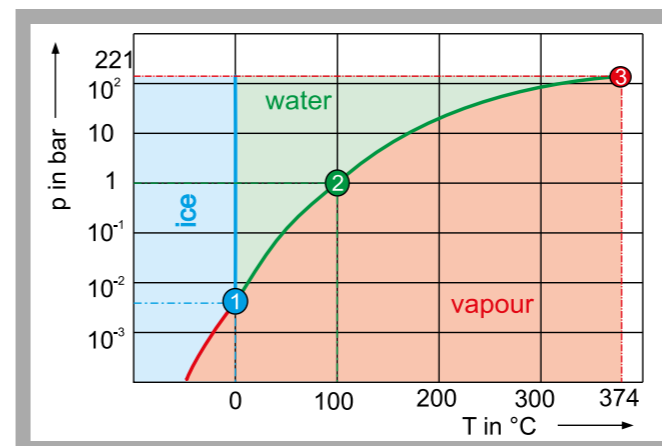
WL 204 Vapour Pressure of Water - Marcet Boiler


1 safety valve, 2 boiler with insulating jacket, 3 Bourdon tube pressure gauge, 4 switch cabinet with temperature display, 5 drain valve, 6 heater, 7 overflow, 8 temperature sensor



Heating up water in a closed tank: the pressure and temperature increase proportionally up to the critical point, at which fluid and vapour are no longer distinguishable from each other; critical point at $T_c = 374^\circ\text{C}$,

$p_c = 221\text{bar}$, dotted line: temperature limit of the experimental unit



Temperature-pressure diagram of water
red: sublimation curve, green: boiling point curve, blue: melting point curve;
1 triple point, 2 boiling point, 3 critical point

Specification

- [1] measuring a vapour pressure curve for saturated vapour
- [2] boiler with insulating jacket
- [3] temperature limiter and safety valve protect against overpressure in the system
- [4] Bourdon tube pressure gauge to indicate pressure
- [5] digital temperature display

Technical Data

Bourdon tube pressure gauge: -1...24bar
Temperature limiter: 200°C
Safety valve: 20bar
Heater: 2kW
Boiler, stainless steel: 2L

Measuring ranges

- temperature: 0...250°C
- pressure: 0...20bar

Dimensions and Weight

LxWxH: 600x400x680mm
Weight: approx. 35kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 funnel
- 1 set of tools
- 1 set of instructional material

Order Details

060.20400 WL 204 Vapour Pressure of Water -
Marcet Boiler

WL 102 *Change of State of Gases*


- * Isothermal and isochoric change of state of air
- * GUNT software for acquisition, processing and display of measured data

Technical Description

Gas laws belong to the fundamentals of thermodynamics and are dealt with in every training course on thermodynamics.

The WL 102 unit enables two changes of state to be studied experimentally: isothermal change of state, also known as the Boyle-Mariotte law, and isochoric change of state, which occurs at constant volume. Transparent tanks enable the change of state to be observed. Air is used as the test gas.

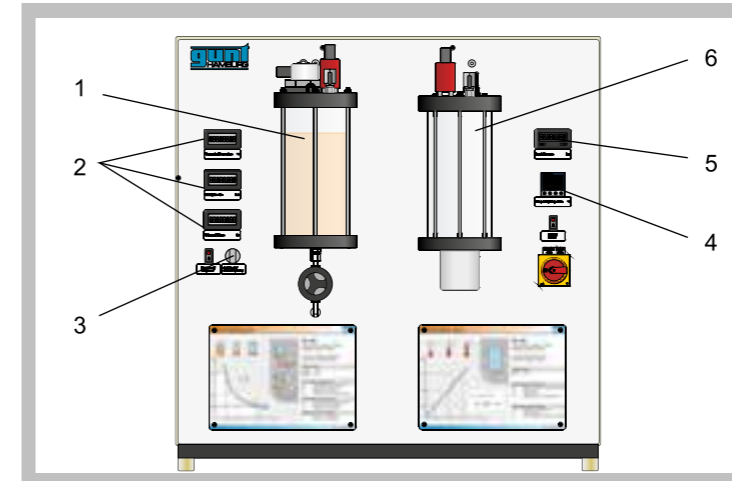
In the first tank, positioned on the left, the enclosed air volume is reduced or increased using a compressor and hydraulic oil. This results in an isothermal change of state. The compressor can also operate as a vacuum pump. If the changes occur slowly, the change of state takes place at an almost constant temperature.

In the second tank, positioned on the right, the temperature of the test gas is increased by a controlled electric heater and the resulting pressure rise is measured. The volume of the enclosed gas remains constant. Temperatures, pressures and volumes are measured electronically, digitally displayed and transferred to a PC for processing.

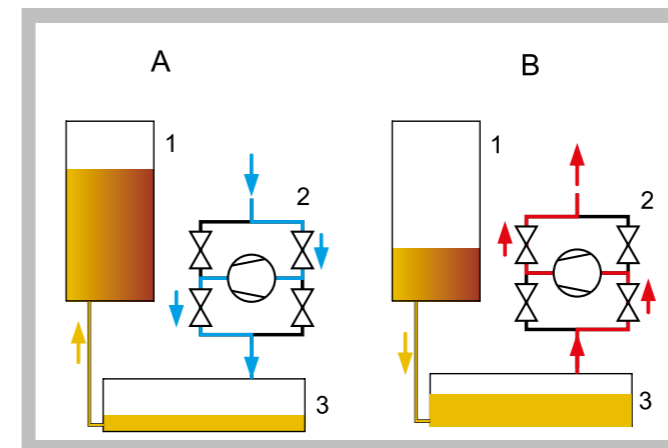
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

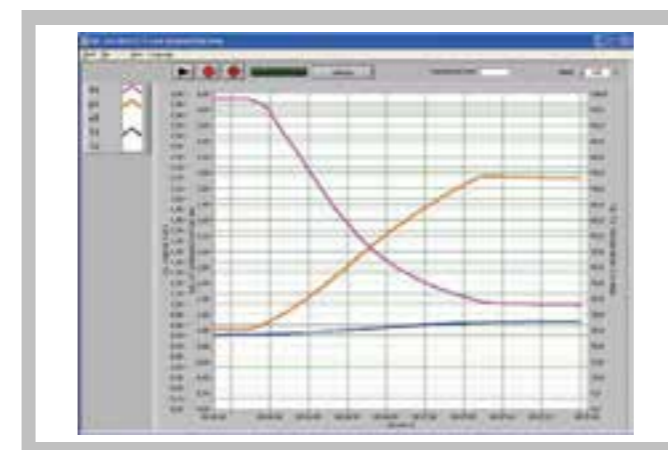
- demonstrating the laws of state changes in gases experimentally
- isothermal change of state, Boyle-Mariotte law
- isochoric change of state, Gay-Lussac's 2nd law

WL 102 *Change of State of Gases*


1 tank 1 for isothermal change of state, 2 digital displays, 3 5/2-way valve for switching between compression and expansion, 4 heating controller, 5 digital display, 6 tank 2 for isochoric change of state



Representation of the change of volume
1 oil-filled tank for isothermal change of state, 2 valve arrangement with compressor, 3 storage tank
A compression (blue), B expansion (red)



Software screenshot: charts for isothermal compression

Specification

- [1] experimental investigation of gas laws
- [2] transparent measuring tank 1 for investigation of isothermal change of state
- [3] hydraulic oil filling for changing volume of test gas
- [4] built-in compressor generates necessary pressure differences to move the oil volume
- [5] compressor can also be used as vacuum pump
- [6] 5/2-way valve for switching between compression and expansion
- [7] transparent measuring tank 2 for investigation of isochoric change of state
- [8] electrical heater with temperature control in tank 2
- [9] sensors and digital displays for temperatures, pressures and volumes
- [10] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

Compressor / vacuum pump
- power output: 60W
- delivery side: 2bar
- intake side: 213mbar
Temperature controller: PID, 300W, limited to 80°C

Measuring ranges

Temperature
- tank 1: 0...80°C
- tank 2: 0...80°C
Pressure
- tank 1: 0...4bar absolute
- tank 2: 0...2bar absolute
Volume
- tank 1: 0...3L

Dimensions and Weight

LxWxH: 900x550x900mm
Weight: approx. 50kg

Required for Operation

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

Scope of Delivery

1 experimental unit
1 GUNT software CD + USB cable
1L hydraulic oil
1 feed hopper
1 set of instructional material

Order Details

060.10200 WL 102 Change of State of Gases

WL 210 Evaporation Process

Technical Description

During the generation of vapour, the medium that is to evaporate runs through different flow forms dependent on the heat transfer area. The medium flows into a tube evaporator as a single-phase fluid and exits the tube evaporator as single-phase superheated vapour. In practice, the water vapour generated in big systems is used e.g. for heating plants or machine drives. To design steam generators, it is important to have knowledge of the evaporation process with the boiling crises in order to ensure reliable operation. Boiling crises are caused by a sudden deterioration of the heat transfer, whereby the high heat flux density leads to a dangerous increase in the wall temperature.

The WL 210 experimental unit can be used to examine and visualise the evaporation process in its various flow forms. This is done by heating evaporating liquid, Solkatherm SES36, in a tube evaporator made of glass. Compared with water, this liquid has the advantage that its boiling point is at 36,7°C (1013hPa), whereby the entire evaporation process takes place at much lower temperatures and a lower heating power. The pressure can be varied via the cooling circuit. Negative pressure (vacuum) can be generated by a water jet pump in the cooling circuit.

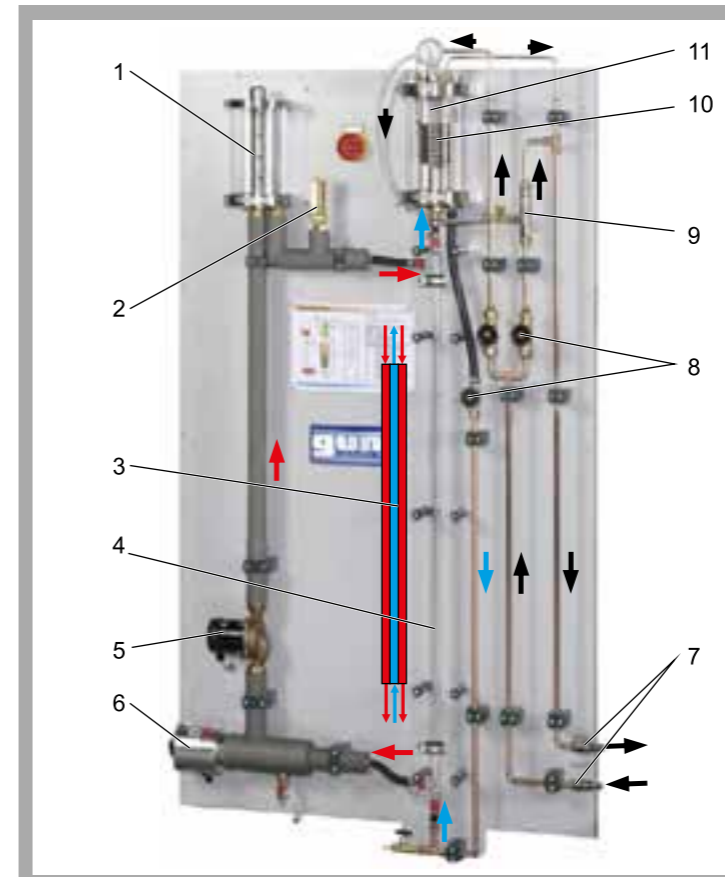
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

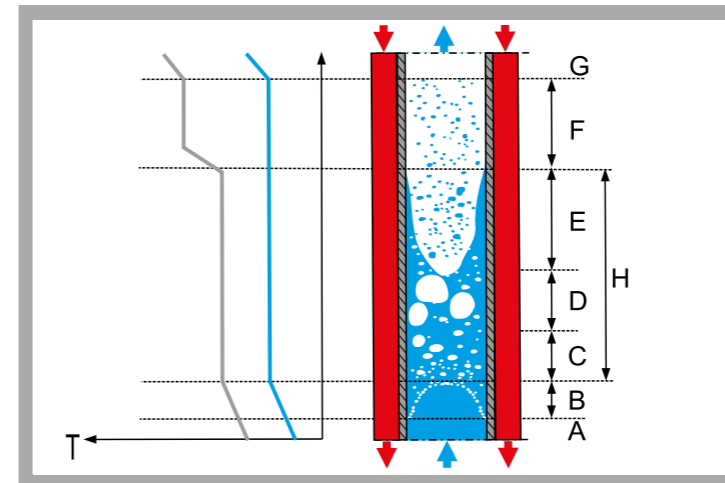
- observation of typical forms of evaporation
- single phase liquid flow
 - sub-cooled boiling
 - slug flow
 - annular flow
 - film boiling
 - dispersed flow
 - single phase vapour flow
 - wet steam
- effect on the evaporation process by
- flow rate
 - temperature
 - pressure

* **Demonstration of evaporation in a double-wall pipe evaporator made of glass**

* **Operation with harmless, special low boiling point liquid**

WL 210 Evaporation Process


1 heating circuit tank, 2 thermometer, 3 tube evaporator, schematic drawing, 4 tube evaporator, 5 pump, 6 heater, 7 cooling water connection, 8 valves, 9 water jet pump, 10 tube coil, 11 collector with manometer and safety valve; red: heating circuit, blue: evaporation circuit, black: cooling circuit



Evaporation in a tube evaporator:
A subcooled fluid, B initial boiling point, C bubbly flow, D slug flow, E annular flow, F dispersed flow, G superheated vapour, H boiling range; blue: fluid temperature, grey: heating surface temperature

Specification

- [1] visualisation of evaporation in a tube evaporator
- [2] heating and cooling medium: water
- [3] tube evaporator made of double-wall glass
- [4] heating circuit with heater, pump and expansion vessel
- [5] safety valve protects against overpressure in the system
- [6] cooling circuit with water jet pump to generate negative pressure (vacuum)
- [7] evaporation circuit with CFC-free evaporating liquid Solkatherm SES36

Technical Data

- Heater
- power rating: 2kW
 - temperature range: 5...80°C
- Heating and cooling medium: water
- Pump
- 3 stages
 - max. flow rate: 1,9m³/h
 - max. head: 1,5m
 - power consumption: 58W
- Tube evaporator
- length: 1050mm
 - inner diameter: 16mm
 - outer diameter: 24mm
- Condenser: coiled tube made of copper

Measuring ranges

- pressure: -1...1,5bar relative
- temperature: 0...100°C

Dimensions and Weight

- LxWxH: 1250x790x1970mm
Weight: approx. 170kg

Required for Operation

- 230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
Water connection: 500mbar, min. 320L/h; drain

Scope of Delivery

- 1 trainer
- 1kg refrigerant Solkatherm SES36
- 1 set of hoses
- 1 set of instructional material

Order Details

060.21000 WL 210 Evaporation Process

WL 220 Boiling Process


- * Visualisation of boiling and evaporation
- * Software for data acquisition

Technical Description

Heating a liquid over a heating surface produces different modes of boiling dependent on the heat flux density. They can accelerate the evaporation process (nucleate boiling) or impair it (film boiling). In practice, a limitation of the heat flux density must be assured in order to prevent damage to the heating surface. This knowledge is applied in practice e.g. when designing steam boilers for steam-powered drives.

The WL 220 experimental unit can be used to demonstrate boiling and evaporation processes in a straightforward manner. The processes take place in a transparent tank. A condenser in the form of a water-cooled tube coil ensures a closed circuit within the tank. Solkatherm SES36 is used as evaporating liquid. Compared with water, this liquid has the advantage that its boiling point is at 36,7°C (1013hPa), whereby the evaporation process takes place at much lower temperatures and a lower heating power.

Sensors record the flow rate of the cooling water, the heating power, pressure and temperatures at all relevant points. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

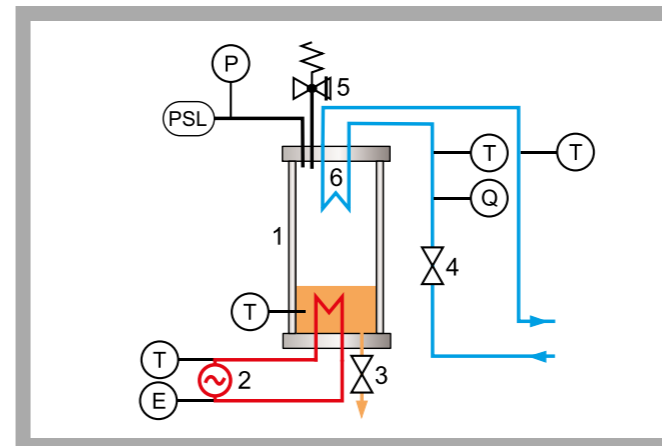
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

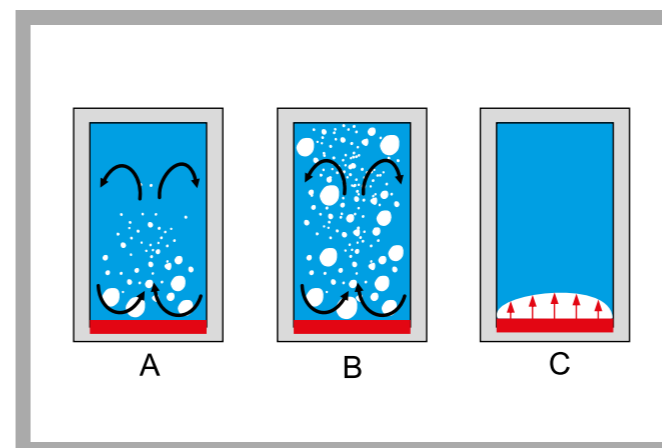
- visualisation of different forms of evaporation
- heat transfer
- effect of temperature and pressure on the evaporation process

WL 220 Boiling Process


1 safety valve, 2 displays for temperature, flow rate and pressure, 3 condenser, 4 pressure vessel, 5 drain valve for the evaporating liquid, 6 heater, 7 cooling water connection, 8 valve for adjusting the cooling water, 9 cooling water flow rate sensor



1 pressure vessel, 2 heater, 3 drain valve, 4 cooling water valve, 5 safety valve, 6 condenser; orange: evaporating liquid, red: heater, blue: cooling circuit; PSL pressure switch, E output, T temperature, Q flow rate, P pressure



Different modes of boiling: A free convection boiling, B nucleate boiling, C film boiling; red: heater, blue: evaporating liquid, white: steam, black: convection flow

Specification

- [1] visualisation of boiling and evaporation in a transparent pressure vessel
- [2] evaporation with heating element
- [3] condensation with tube coil
- [4] safety valve protects against overpressure in the system
- [5] pressure switch for additional protection of the heating circuit, adjustable
- [6] sensors for pressure, flow rate and temperature with digital display
- [7] GUNT software for data acquisition via USB under Windows Vista or Windows 7
- [8] CFC-free evaporating liquid Solkatherm SES36

Technical Data
Heater

- power: 250W, continuously adjustable

Safety valve: 2bar rel.

Pressure vessel: 2850mL

Condenser: coiled tube made of copper

Measuring ranges

- tank pressure: 0...4bar abs.
- power of heater: 0...300W
- flow rate (cooling water): 0,05...1,8L/min
- temperature: 4x 0...100°C

Dimensions and Weight

LxWxH: 900x450x820mm

Weight: approx. 65kg

Required for Operation

230V, 50/60Hz, 1 phase, 120V, 60Hz/CSA, 1 phase
Water connection, drain

Scope of Delivery

- 1 experimental unit
- 2kg refrigerant Solkatherm SES36
- 1 GUNT software CD + USB cable
- 1 set of hoses
- 1 set of instructional material

Order Details

060.22000 WL 220 Boiling Process

WL 230 **Condensation Process**


- * Visualisation of different condensation processes
- * Software for data acquisition

Technical Description

Condensation forms when steam meets a medium with a lower temperature than the saturation temperature for the existing partial pressure of the steam. Factors such as the material and surface roughness of the medium influence the heat transfer and thus the type of condensation. In practice, it is usually film condensation. Dropwise condensation only forms when the cooling surface is very smooth and poorly wettable, e.g. Teflon. Knowledge of condensation processes is applied e.g. in steam power plants or at distillation processes.

The WL 230 experimental unit can be used to demonstrate the different condensation processes using two tubular shaped water-cooled condensers made of different materials. Dropwise condensation can be demonstrated by means of the condenser with a polished gold-plated surface. Film condensation forms on the matt copper surface of the second condenser, thus making it possible to examine film condensation.

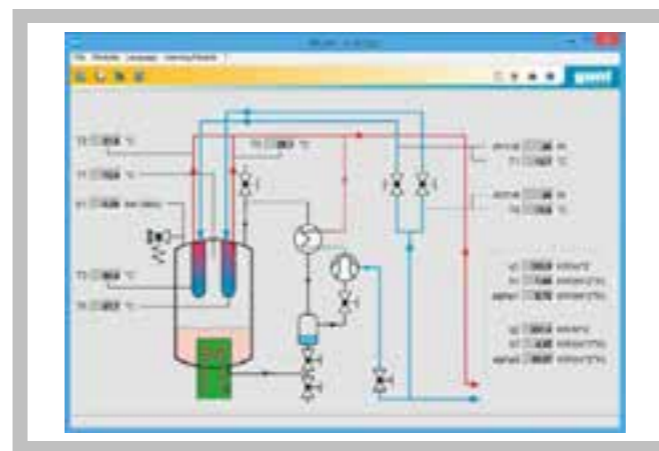
The tank can be evacuated via a water jet pump in order to vary the pressure in the tank together with the heating temperature and to set the boiling point. Sensors record the temperature, pressure and flow rate at all relevant points. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included. The heat transfer coefficient is calculated from the measured values. The influence of non-condensing gases, pressure and the temperature difference between the surface and steam can be examined in further experiments. The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

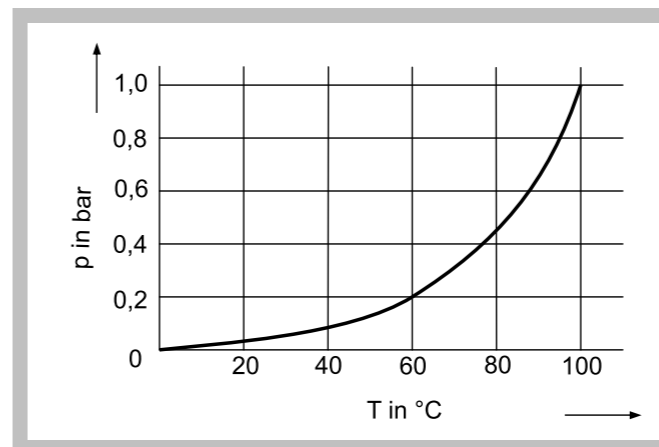
- dropwise and film condensation
- determination of the heat transfer coefficient
- effect of pressure, temperature and non-condensable gases on the heat transfer coefficient

WL 230 **Condensation Process**


- 1 condensers, 2 heat exchanger, 3 steam trap, 4 displays for temperature, flow rate and pressure, 5 heater, 6 cooling water connections, 7 water jet pump, 8 temperature sensor, 9 valve for adjusting the cooling water, 10 cooling water flow rate sensor



Software screenshot



Vapour pressure curve for water: p pressure, T temperature

Specification

- [1] visualisation of the condensation process of water in a transparent tank
- [2] two water-cooled tubes as condensers with different surfaces to realise film condensation and dropwise condensation
- [3] controlled heater to adjust the boiling temperature
- [4] water jet pump to evacuate the tank
- [5] pressure switch and safety valve for safe operation
- [6] sensors for temperature, pressure and flow rate with digital display
- [7] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data
Heater

- output: 3kW, freely adjustable

Condenser

- 1x tube with matt copper surface
- 1x tube with a polished gold-plated surface

Water jet pump

- flow rate: 4...12L/min
- max. delivery pressure: 16mbar
- Safety valve: 2200mbar absolute

Measuring ranges

- pressure: 0...10bar absolute
- flow rate: 0,2...6L/min
- temperature: 4x 0...100°C, 3x 0...200°C

Dimensions and Weight

- LxWxH: 1000x550x790mm
- Weight: approx. 85kg

Required for Operation

- 230V, 50/60Hz, 1 phase or 230V, 60Hz/CSA, 3 phases
- Water connection: 1bar, max. 1000L/h, drain

Scope of Delivery

- 1 experimental unit
- 5L distilled water
- 1 set of hoses
- 1 GUNT software CD + USB cable
- 1 set of instructional material

Order Details

060.23000 WL 230 Condensation Process

ET 805.50 Determination of the Vapour Content

Technical Description

The vapour content x is a dimensionless ratio between 0 and 1. It is defined by the ratio of mass of vapour and total mass. The total mass is calculated from the sum of fluid mass and vapour mass. If the vapour content is $x=0$, the evaporation medium is completely liquid, $x=1$ means dry saturated vapour, a value in between means wet steam with a variable liquid content. Separating and throttling calorimeters are used to determine the vapour content. In practice, devices to determine the vapour content are used in steam power plants, downstream of steam turbines or at steam boilers upstream of the superheater.

The ET 805.50 trainer uses a two-stage method to determine the vapour content. A separating calorimeter with cyclone water separator is used to determine vapour contents with a high liquid content ($0,5 < x < 0,95$). The liquid part is separated, cooled and collected in a measuring beaker.

A downstream throttling calorimeter is used to determine vapour contents between $x=0,95$ and $x=1$. The wet steam is depressurised in this process. The remaining vapour part is depressurised and then liquefied in a water-cooled condenser and also collected in a measuring beaker. The two quantities can be used to determine vapour mass and total mass to calculate the vapour content.

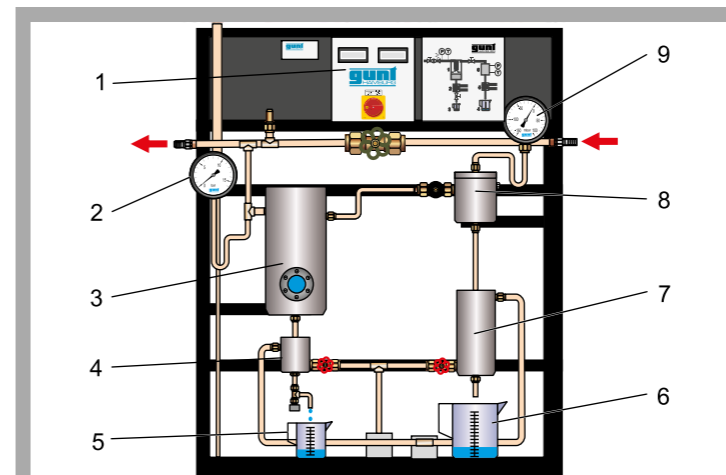
Sensors measure the pressure and temperature before and after depressurisation. The measuring results can be used to determine the vapour content with the h-s diagram.

The water vapour has to be generated externally, e.g. with the electrical steam generator WL 315.02. To determine the vapour content of the steam power plants ET 805, ET 830, ET 850 or ET 833, ET 805.50 is recommended.

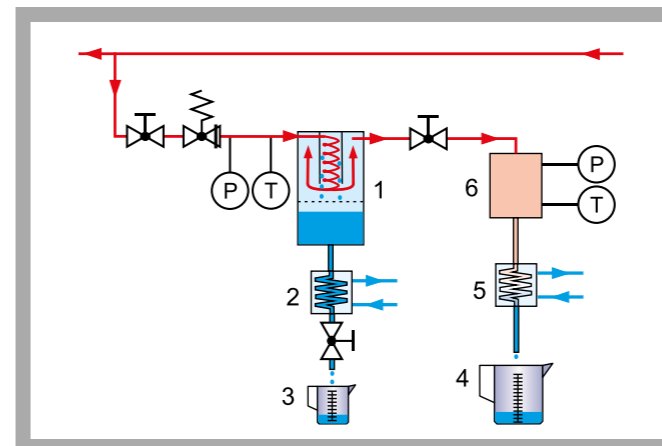
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Learning Objectives / Experiments

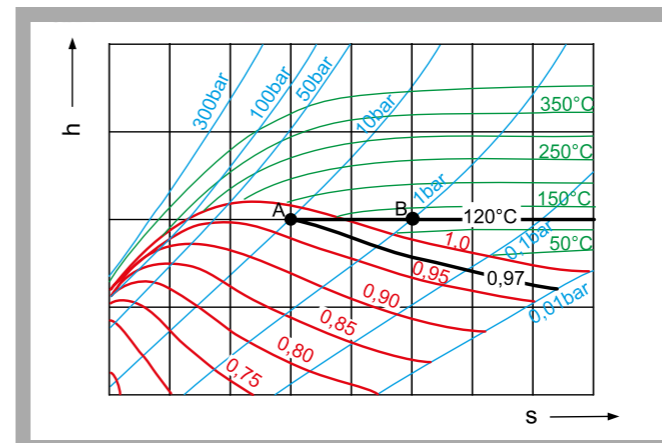
- determining the vapour content using
 - * a separating calorimeter with cyclone water separator
 - * a throttling calorimeter with vapour depressurisation
- using an h-s diagram

*** Two different ways to determine the vapour content**
ET 805.50 Determination of the Vapour Content


1 displays for temperature, 2 vapour inlet manometer, 3 cyclone water separator, 4 cooler for separated water, 5 measuring beaker for separated water, 6 measuring beaker for liquefied vapour, 7 condenser, 8 tank for depressurising the vapour, 9 manometer for depressurisation process; red: vapour inlet and outlet



1 water separator with cyclone, 2 cooler, 3 measuring beaker for separated water, 4 measuring beaker for liquefied vapour, 5 condenser, 6 tank for depressurising the vapour; red: wet steam, orange: depressurised steam, blue: water; P pressure, T temperature



h-s diagram; h enthalpy, s entropy; red: vapour content, green: temperature, blue: pressure; black: example of measuring result: A steam at 10bar, B steam after adiabatic depressurisation at 1bar, vapour content 0,97

Specification

- [1] two different ways to determine the vapour content
- [2] separating calorimeter for vapour content $0,5 < x < 0,95$, with water-cooled aftercooler
- [3] throttling calorimeter for vapour content $x > 0,95$, with water-cooled condenser
- [4] safety valve for safe operation
- [5] water vapour has to be supplied by an external steam generator, e.g. electrical steam generator WL 315.02
- [6] accessory for steam power plants ET 805, ET 830, ET 850 or ET 833

Technical Data

Supplied steam
 - max. temperature: 240°C
 - max. pressure: 10bar
 Safety valve: 10bar

Measuring ranges

- temperature: 0...400°C
- pressure (intake): 0...16bar
- pressure (after expansion): -150...100mbar

Dimensions and Weight

LxWxH: 890x600x1890mm
 Weight: approx. 90kg

Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
 Steam: max. 10bar, 240°C, water connection, drain

Scope of Delivery

- 1 trainer
- 2 measuring beakers
- 1 set of tools
- 1 set of instructional material

Order Details

061.80550 ET 805.50 Determination of the Vapour Content

ET 850

Steam Generator



Technical Description

A steam generator generates water vapour which will later be used in combined heat and power stations or machine drives. Steam generators and steam consumers together form a steam power plant. Steam power plants work according to the steam power process which is still one of the most important industrially used cyclic processes. Steam power plants are mainly used for electrical power generation.

The ET 850 steam generator and the ET 851 axial steam turbine together form a complete laboratory-scale steam power plant.

The ET 850 trainer serves to familiarise students with the components and principle of operation of a steam generator and enables them to examine the characteristic values of the system. The numerous safety devices of the steam generator can be tested and checked using various monitoring devices.

If the steam generator is operated without the steam turbine, the generated steam is directly liquefied in a condenser and fed back into the evaporation circuit via a tank.

As all components are clearly arranged on the front panel, the cyclic process can be easily monitored and understood. Sensors record the temperature, pressure and flow rate at all relevant points. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

The steam generator has been constructed according to the German "Technische Regeln Dampf" (TRD) (Technical Regulations for Steam), pressure-tested and is equipped with all legally required safety devices.

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

Learning Objectives / Experiments

- familiarisation with and analysis of the specific characteristic values of a steam boiler
- efficiency of a steam generator
- analysis of the exhaust gases
- influence of different burner settings
- saturation temperature and pressure
- steam enthalpy
- determination of the heat flux density and the overall heat transfer coefficient

* Laboratory-scale steam generator for wet or overheated steam

* Characteristic values of a steam boiler

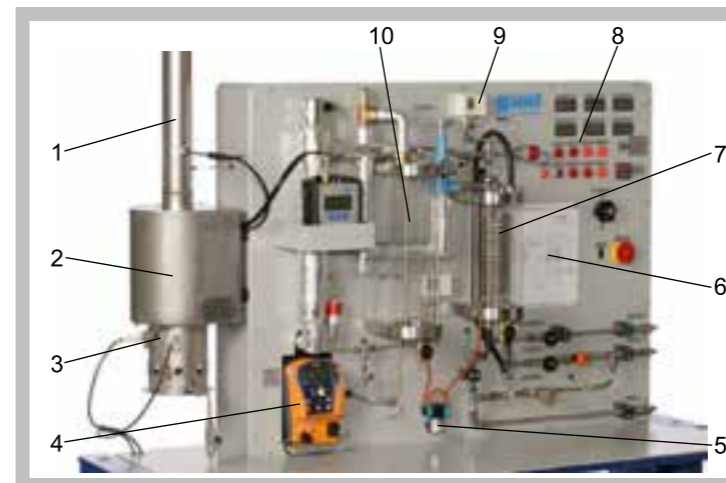
* Various safety and monitoring devices

* Analysis of the measured values at the PC

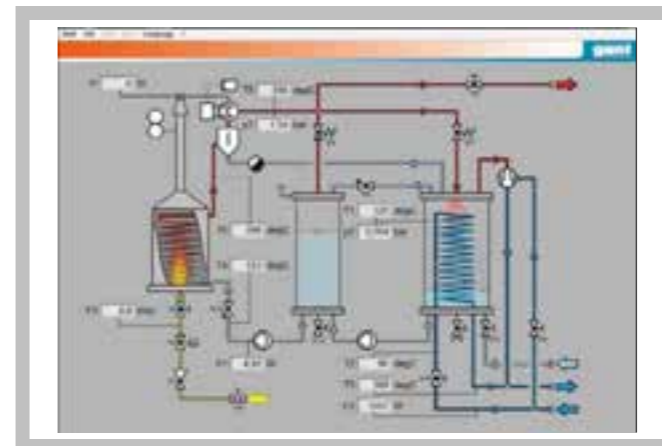
* Setting up a complete steam power plant in conjunction with the ET 851 steam turbine

ET 850

Steam Generator



1 chimney, 2 steam boiler, 3 burner, 4 feed water pump, 5 condensate pump, 6 process schematic, 7 condenser, 8 displays and controls, 9 pressure switch, 10 tank



Software screenshot: process schematic



Left: ET 850 steam generator; right: ET 851 axial steam turbine; set up ready for operation, together they form a steam power plant

Specification

- [1] trainer with gas-powered heater for steam generation
- [2] ET 851 steam turbine can be connected to operate a steam power plant
- [3] condenser as a thick-walled glass cylinder with water-cooled tube coil and water jet pump for air extraction
- [4] closed-circuit feed water supply
- [5] sensor for temperature, pressure, flow rate
- [6] exhaust gas analysis with exhaust gas analyser
- [7] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

Burner
- heating power: 8kW

Measuring ranges
- temperature: 0...400°C
- pressure
condenser: 0...1,6bar abs.
live steam: 0...16bar
- power consumption
superheater: 750W
- flow rate
gas: 0...14L/min
cooling water: 0...720L/h
feed water: 0...15L/h

Dimensions and Weight

LxWxH: 1830x790x1770mm (without chimney)
Weight: approx. 280kg

Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase
Gas supply (propane): 700g/h, 50mbar
Water connection: 720L/h, 2bar, drain
Ventilation and exhaust gas routing required

Scope of Delivery

- 1 trainer
- 1 GUNT software CD + USB cable
- 1 exhaust gas analyser
- 1 packing unit of distilled water (20L)
- 1 set of tools
- 1 set of instructional material

Order Details

061.85000 ET 850 Steam Generator

ET 350 Changes of State in the Refrigeration Circuit


- * Refrigeration circuit demonstrated clearly
- * Transparent components offer insights into the changes of state
- * Energetic analyses of the refrigeration cycle

Technical Description

In a compression refrigeration system a refrigerant flows through the refrigeration circuit and is subject to different changes of state. Here, the physical effect is used that during the transition of the refrigerant from a liquid to a gaseous state energy is required which is removed from the environment (evaporation enthalpy).

The experimental unit ET 350 represents a typical refrigeration circuit consisting of a hermetic piston compressor, condenser, expansion valve and evaporator. The evaporator and condenser are transparent to provide good monitoring of the phase transition process during evaporation and condensation. The operation of the float valve as expansion valve is also easy to observe. Before the entry into the evaporator the aggregate state of the refrigerant can be monitored at a sight glass. A water circuit cools the condenser or supplies the cooling load for the evaporator. Cold and hot water and refrigerant flows are adjustable. The low pressure level of the refrigerant SES36 used permits the use of an evaporator and condenser out of glass. The refrigerant is CFC-free and environmentally friendly.

Temperatures and pressures are recorded and displayed. The key points of the cyclic process can be read and entered into a log p-h diagram. The power of the compressor and flow rates of the water flows and the refrigerant are also indicated.

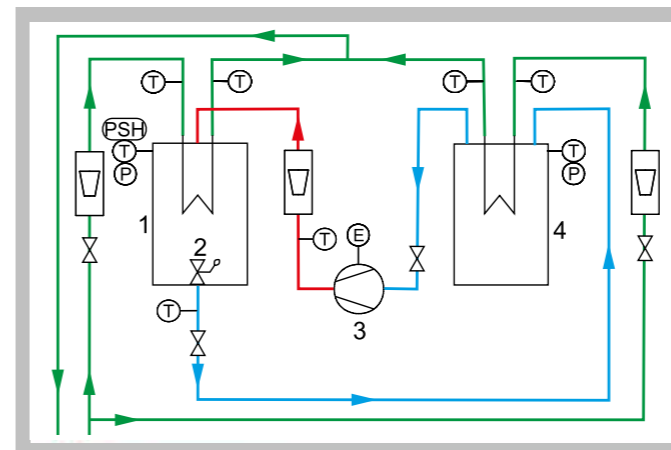
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

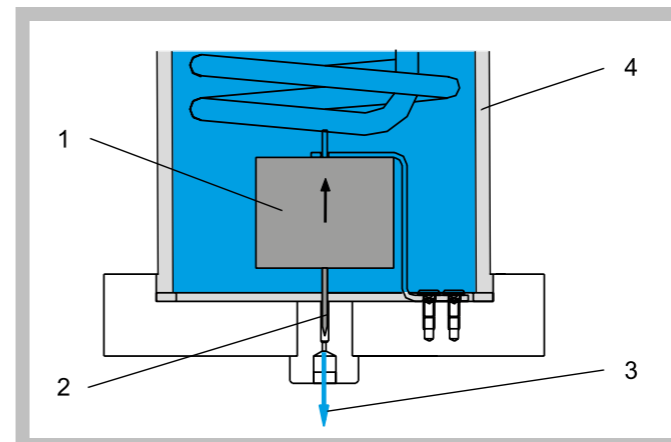
- design and operation of a compression refrigeration system
- observe the evaporation and condensation of the refrigerant
- represent and understand the refrigeration cycle in the log p-h diagram
- energy balances
- calculation of the coefficient of performance

ET 350 Changes of State in the Refrigeration Circuit


1 pressure switch, 2 flow meter, 3 condenser, 4 expansion valve, 5 compressor, 6 evaporator, 7 sight glass, 8 temperature display, 9 manometer



1 condenser, 2 expansion valve, 3 compressor, 4 evaporator; T temperature, P pressure, E electrical power, PSH pressure switch; blue: low pressure, red: high pressure, green: water



Expansion valve in the shape of a float valve: 1 float lifts the needle from the valve seat, 2 needle, 3 refrigerant escapes, 4 tank

Specification

- [1] demonstration of the processes in a refrigeration circuit
- [2] for better process monitoring the evaporator and condenser are of transparent design
- [3] evaporator and condenser with pipe coil
- [4] expansion valve in the shape of a float valve
- [5] pressure switch to protect the compressor
- [6] temperature sensor, power meter, manometer in the refrigeration circuit, flow meter for hot and cold water and refrigerant
- [7] safety valves at the evaporator and condenser
- [8] refrigerant Solkatherm SES36, CFC-free

Technical Data

Hermetic piston compressor
- capacity: 18,3cm³
Evaporator capacity: approx. 2800mL
Condenser capacity: approx. 2800mL

Measuring ranges

- temperature: 8x -20...200°C
- pressure: 2x -1...1,5bar
- flow rate (water): 2x 0...48L/h
- flow rate (refrigerant): 1x 0...700L/h
- power: 0...1200W

Dimensions and Weight

LxWxH: 1200x500x900mm
Weight: approx. 110kg

Required for Operation

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

Scope of Delivery

1 experimental unit
3,5kg refrigerant Solkatherm SES36
1 set of supply hoses
1 set of instructional material

Order Details

061.35000 ET 350 Changes of State in the Refrigeration Circuit

CE 110 Diffusion in Liquids and Gases

*** Diffusive mass transport of substances in gases and aqueous solutions**
*** Application of Fick's law**
Technical Description

Diffusion is the microscopic mass transport of particles such as atoms, molecules and ions due to differences in concentrations. It plays an important role in numerous processes. For example, diffusion can bring together the reactants in chemical reactions and, in some cases, it can be the rate-limiting step for the process.

CE 110 is equipped with two experimental units for investigating diffusion in liquids and gases. To investigate diffusion in liquids, a concentrated salt solution is used. The solution is contained in a U-tube, one end of which has a disc with several vertical capillaries. The U-tube is immersed into a tank containing demineralised water so that the disc with the capillaries is positioned below the surface of the water. The concentration gradient between water and the solution causes the salt ions to move out of the U-tube through the capillaries into the demineralised water. The capillaries ensure that the ions move in one dimension. A stirrer in the tank prevents the salt concentration increasing near to the disc, thus preventing concentration differences in the tank. A conductivity meter measures the salt concentration in the tank.

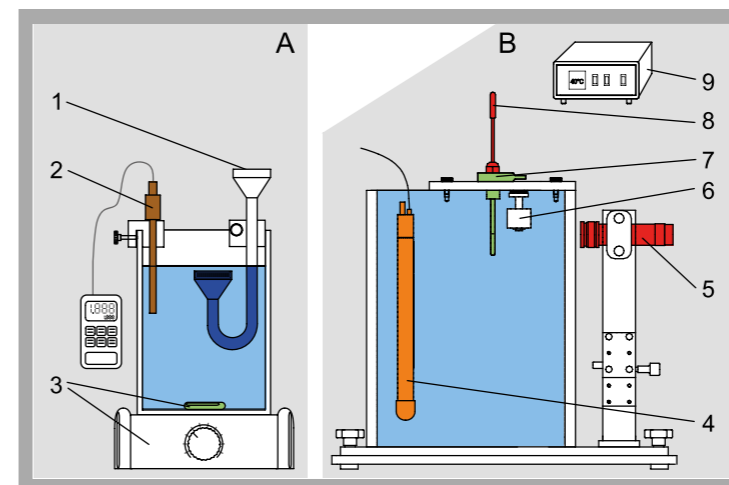
To investigate diffusion in gases, a highly volatile solvent is used. The solvent is contained in a vertical tube which is immersed into a heated water bath. The thermal energy from the water bath causes the solvent to evaporate. A fan generates an air flow, which moves horizontally at the upper end of the tube. The gaseous solvent diffuses due to the concentration gradient from the surface of the liquid solvent upwards to the pure air flow. The air flow transports the solvent molecules away, thus ensuring a constant concentration at the upper end of the tube. The volume of liquid solvent in the tube decreases over time. A scale

microscope enables the level to be determined. A heater with controller keeps the temperature in the water bath constant.

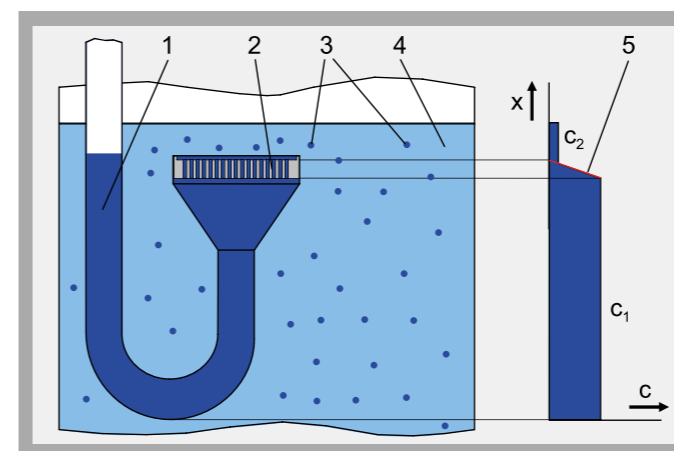
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

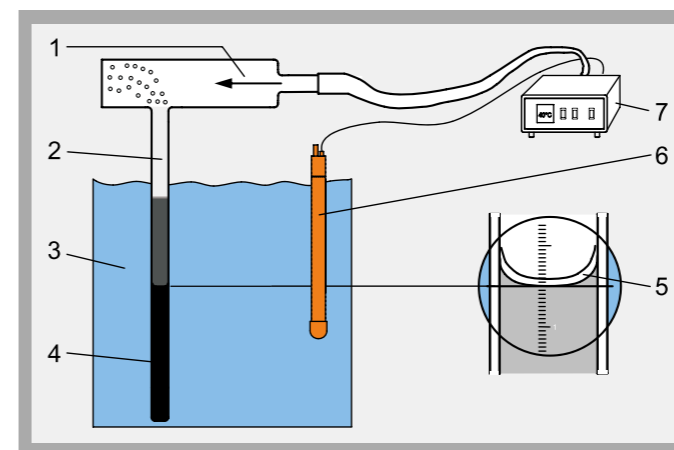
- fundamentals of diffusion: Fick's law
- derivation of the calculation formula for the diffusion coefficients for the given experimental conditions
- determination of the diffusion coefficient for the mass transport in gas
- determination of the diffusion coefficient for the mass transport in liquid

CE 110 Diffusion in Liquids and Gases


Units for diffusion in liquids (A) and in gases (B):
1 U-tube with capillaries, 2 conductivity sensor, 3 magnetic stirrer with magnetic stir bar, 4 heater in the water bath, 5 microscope, 6 float switch, 7 diffusion tube, 8 temperature sensor, 9 display and control unit



Diffusion in liquids: 1 concentrated salt solution, 2 capillaries, 3 salt ions, 4 water, 5 concentration gradient;
x path, c concentration, c_1 concentrated solution, c_2 diluted solution



Diffusion in gases: 1 air flow, 2 gaseous solvent, 3 water bath, 4 liquid solvent, 5 meniscus in the microscope, 6 heater, 7 display and control unit

Specification

- [1] investigation of diffusion in liquids and gases
- [2] transparent tank with magnetic stirrer, conductivity meter and U-tube with capillaries for investigating diffusion in aqueous solutions
- [3] evaporation of a highly volatile solvent with a diffusion tube in a heated water bath for investigating diffusion in gases
- [4] removal of gaseous solvent at the upper end of the diffusion tube with a fan
- [5] heater with controller and sensor for adjusting the temperature in the water bath
- [6] height-adjustable microscope for monitoring and determining the solvent volume in the diffusion tube
- [7] separate display and control unit contains temperature controller and fan

Technical Data

Tank with stirrer: approx. 1500mL
Speed stirrer: 0...1500min⁻¹
253 capillaries made of stainless steel
- diameter: 1mm, length: 5mm

Water bath: approx. 2L
Diffusion tube for solvent
- diameter: 3,4mm, length: 85mm
Power output heater: approx. 150W
Fan: 120...320L/h
Microscope scale division: 0,1mm

Measuring ranges
- temperature: 0...100°C
- conductivity: 0...200mS/cm

Dimensions and Weight

LxWxH: approx. 210x210x280mm
(experimental unit for diffusion in liquids)
LxWxH: approx. 220x290x450mm
(experimental unit for diffusion in gases)
LxWxH: approx. 370x340x200mm
(display and control unit)
Weight: approx. 16kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit for diffusion in liquids
- 1 experimental unit for diffusion in gases
- 1 display and control unit
- 1 conductivity meter
- 1 magnetic stirrer with 2 magnetic stir bars
- 1 stopwatch
- 1 set of instructional material

Order Details

083.11000 CE 110 Diffusion in Liquids and Gases

WL 352 Heat Transfer by Convection

*** Free and forced convection in an air flow**
*** 3 interchangeable heating elements with different heat transfer surfaces**
Technical Description

Convection is one of the three basic types of heat transfer. The heat transport is substance-bound. In the convection process, the whole fluid is moving. So-called bulks of fluid move (and thus transfer heat) from warm zones into cold zones. The different temperatures lead to density differences in the fluid so that a flow develops. In the case of free convection, the density differences result in a rather slow flow of the fluid with a more intensive heat transfer. In the case of forced convection, the flow is generated by a fan or pump. In this case, the heat transfer to fluid particles is lower, but more heat is transported than with free convection due to the much larger mass flow.

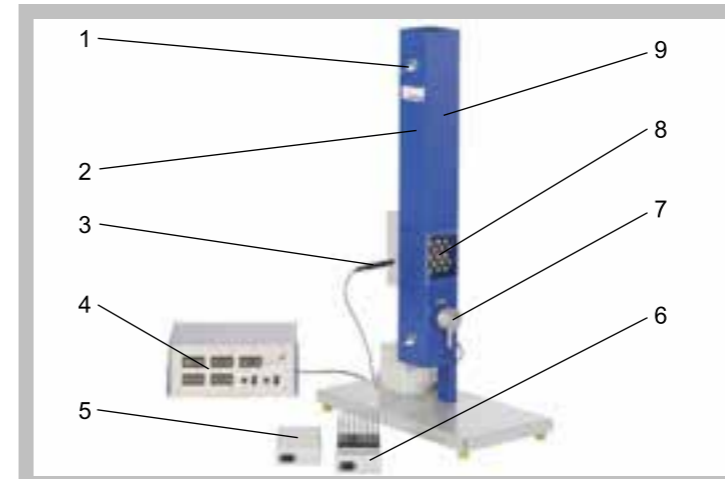
The core element of the WL 352 experimental unit is a vertical duct into which a heating element is inserted. Air flows past the heating element and absorbs heat in the process. Three heating elements with different surfaces are available: a flat plate, a tube bundle or fins. For experiments on forced convection, an additional fan has to be activated.

Sensors record the flow velocity of the air, the heating power and the temperatures at all relevant points. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

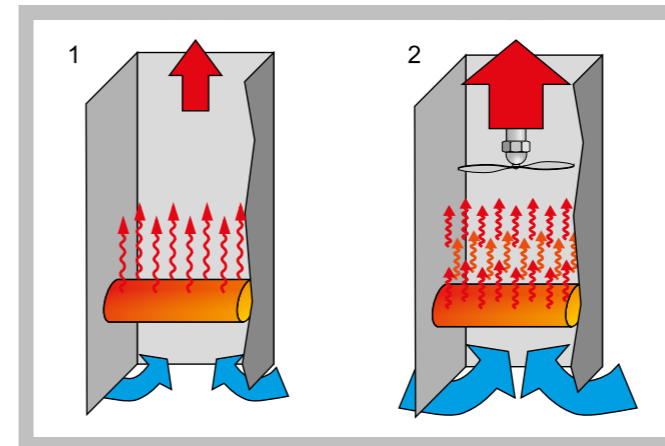
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

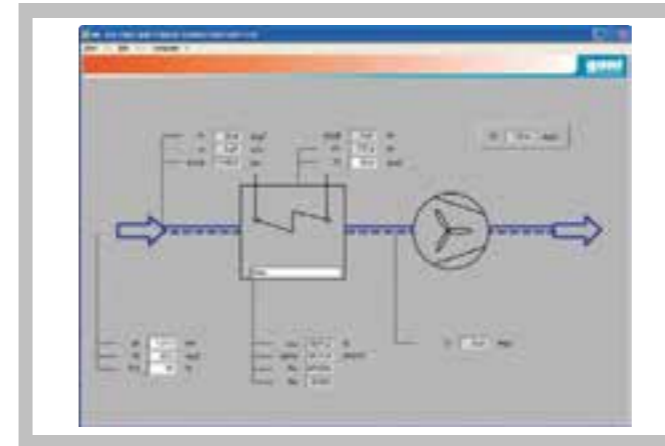
- free and forced convection
- heat transfer at different surfaces:
 - * flat plate
 - * pipe bundle
 - * fins
- temperature distribution in the heat exchanger
- determination of the Reynolds and Nusselt numbers
- calculation of heat transfer coefficient for free and forced convection
- calculation of heat transfer rate and efficiency

WL 352 Heat Transfer by Convection


1 temperature sensor, 2 air duct, 3 thermocouple type K, 4 display and control unit, 5 "flat plate" heating element, 6 "finned" heating element, 7 flow sensor, 8 "pipe bundle" heating element, 9 measuring glands for thermocouple



1 free convection at the heating element, 2 forced convection at the heating element; blue arrows: cold air, red arrows: heated air



Software screenshot: process schematic

Specification

- [1] heat transfer in the air duct by free and forced convection
- [2] air duct with axial fan
- [3] 3 heating elements with different surfaces: flat plate, tube bundle or fins
- [4] sensors measure temperatures (upstream and downstream of the heating element and inside the heating element), flow velocity of the air and heating power
- [5] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

Air duct
- flow cross-section: 120x120mm
- height: 1m

Axial fan

- max. flow rate: 170m³/h
- max. pressure difference: 54Pa
- power consumption: 6,5W
- nominal speed: 2900min⁻¹

Heating elements

- temperature limitation: max. 120°C
- max. heating power: 170W
- surface of flat plate: 140cm²
- surface of tube bundle: 980cm²
- surface of fins: 1400cm²

Measuring ranges

- flow velocity: 0...10m/s
- temperature: 2x 0...100°C, 1x 0...200°C
- heating power: 0...375W

Dimensions and Weight

LxWxH: 700x350x1200mm (air duct)
LxWxH: 410x410x180mm (display and control unit)
Weight: approx. 43kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 3 heating elements
- 1 display and control unit
- 1 GUNT software CD + USB cable
- 1 set of instructional material

Order Details

060.35200 WL 352 Heat Transfer by Convection

WL 372 Heat Transfer by Conduction

*** Demonstration of heat conduction in solid materials**
*** Linear and radial heat conduction**
*** Software to represent the temperature profiles**
Technical Description

Heat conduction is one of the three basic types of heat transfer. Kinetic energy is transferred between two neighbouring atoms or molecules. The heat transport is not substance-bound. This type of heat transfer is an irreversible process in which the heat is transferred from a higher energy level, i.e. a level with a higher absolute temperature, to the lower level with a lower temperature. If the heat transport is kept up constantly by applying heat, this is called stationary heat conduction. In technology, heat conduction is mostly used in heat exchangers.

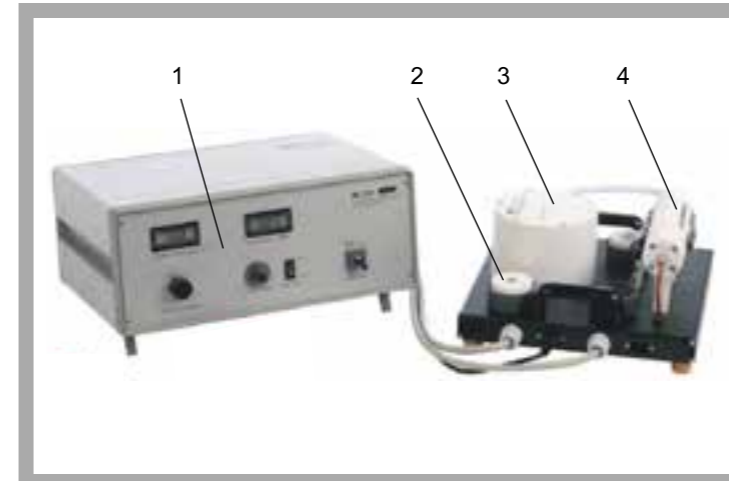
The WL 372 experimental unit enables users to experimentally determine basic laws and characteristic variables of heat conduction in solids. The experimental unit includes a linear and a radial experimental set-up, each equipped with a heating and cooling element. Various measuring objects with different heat transfer characteristics can be incorporated in the experimental set-up for linear heat conduction. The experimental unit is delivered together with a display and control unit.

Sensors record the temperatures at all relevant points. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

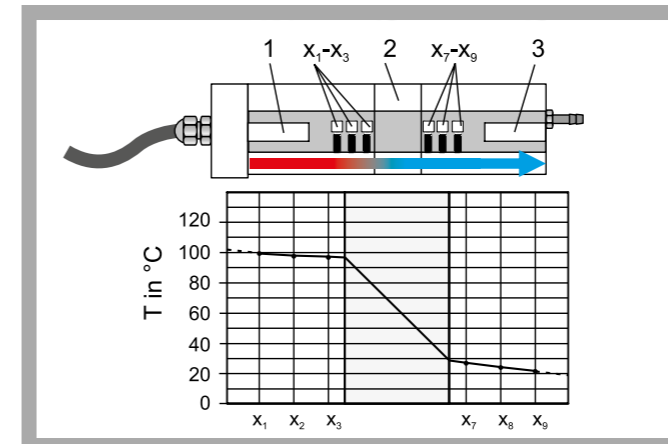
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

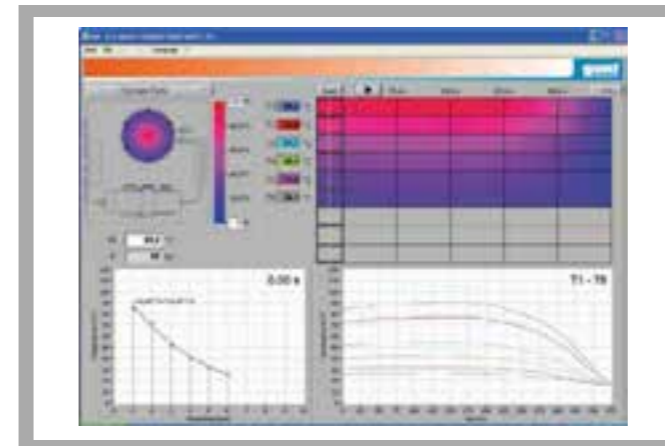
- linear heat conduction (flat wall)
- determination of temperature profiles with different materials
 - determination of the temperature profile during a malfunction
 - determination of thermal conductivity k
- radial heat conduction
- determination of the temperature profile
 - determination of thermal conductivity k

WL 372 Heat Transfer by Conduction


1 display and control unit, 2 measuring object, 3 experimental set-up for radial heat conduction, 4 experimental set-up for linear heat conduction



Experimental set-up for linear heat conduction with graphical display of the temperature profile: 1 heater, 2 measuring object, 3 cooling element; x_1-x_3 and x_7-x_9 measuring points



Software screenshot: temperature profile for radial heat conduction

Specification

- [1] examination of heat conduction in solids
- [2] experimental set-up consisting of experimental unit and display and control unit
- [3] linear heat conduction: 3 measuring objects, heating and cooling element, 9 temperature measuring points
- [4] radial heat conduction: brass disc with heating and cooling element, 6 temperature measuring points
- [5] cooling with mains water
- [6] electric heating element
- [7] representation of the temperature profiles with GUNT software
- [8] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

- Linear heat conduction
- 3 measuring objects, insulated
 - 1x DxL: 25x30mm, steel
 - 1x DxL: 15x30mm, brass
 - 1x DxL: 30x30mm, brass
 - heater: 140W
- Radial heat conduction
- disc diameter: 110x4mm
 - heater in the middle of the disc: 125W
 - cooling coil at outer diameter of disc

Measuring ranges

- temperature: 0...100°C
- power: 0...200W

Dimensions and Weight

- LxWxH: 400x360x210mm (experimental unit)
- LxWxH: 470x380x210mm (display and control unit)
- Weight: approx. 22kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 display and control unit
- 1 set of measuring objects
- 1 set of hoses
- 1 GUNT software CD + USB cable
- 1 set of instructional material

Order Details

060.37200 WL 372 Heat Transfer by Conduction

WL 373 Heat Conduction in Gases and Liquids


- * **Steady-state heat conduction in gases and liquids**
- * **Determination of thermal conductivities k of various fluids**

Technical Description

Heat conduction in physics means the transfer of thermal energy between neighbouring atoms and molecules in a solid or in a fluid at rest. The heat transport is substance-bound. The effect of pure heat conduction is hindered in fluids by convection effects. This can be prevented by enclosing the fluids in gaps.

The WL 373 experimental unit serves to examine heat conduction properties of various fluids. The experimental unit is delivered together with a display and control unit.

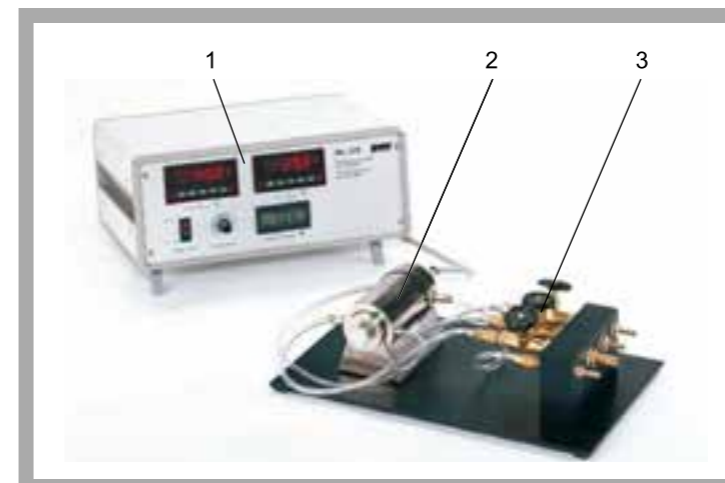
The core element of the experimental unit is a cylindrical heat exchanger with a heated inner cylinder made of aluminium and a water-cooled jacket. There is a ring-shaped gap between the inner cylinder and the jacket, which is completely filled with the fluid to be examined. The width of the gap is such that the heat transfer by convection is negligible. Due to the low temperature level and polished surfaces, radiation is also negligible.

The thermal conductivities k of various fluids such as water, oil, air, oxygen or carbon dioxide can be determined in experiments. Sensors record the temperatures and the consumed heating power at all relevant points. The measured values can be read on digital displays.

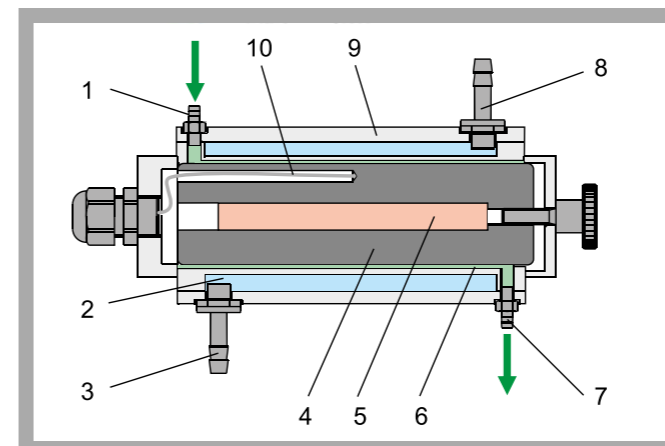
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

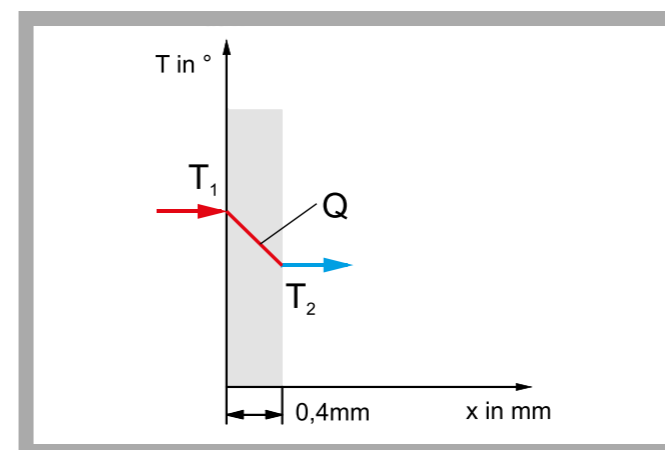
- steady-state heat conduction in gases and liquids
- determination of thermal conductivities k of various fluids at different temperatures

WL 373 Heat Conduction in Gases and Liquids


1 display and control unit, 2 heat exchanger with heated inner cylinder and water-cooled jacket, 3 valves for fluid and cooling water



Design of the heat exchanger:
1 fluid inlet, 2 cooling water inlet, 3 cooling water outlet, 4 inner cylinder, 5 heater, 6 gap for fluid (water, oil or air), 7 fluid outlet, 8 cooling water inlet, 9 jacket, 10 temperature sensor; green: fluid (water, oil, air), blue: cooling water, red: heater



Heat conduction in the gap: Q heat flux in W, T_1 and T_2 in °C

Specification

- [1] examination of heat conduction in gases and fluids (water, oil, air)
- [2] experimental set-up consisting of experimental unit and display and control unit
- [3] heat exchanger with heated inner cylinder and water-cooled jacket
- [4] the fluid to be examined is in the ring-shaped gap between inner cylinder and jacket
- [5] heat transfer by convection and radiation negligible due to small gap dimensions, low temperatures and polished surfaces
- [6] adjustable electric heater
- [7] valves for adjusting the flow rates in the cooling water and in the fluid
- [8] sensors for temperatures and electric heating power
- [9] digital displays for temperature difference and heating power

Technical Data

- Heat exchanger
- effective heat transfer area: 1500cm²
 - mean effective diameter: 39,6mm
 - gap width: 0,4mm
- Heater
- max. power consumption 160W
 - switch-off: at 95°C

Measuring ranges

- temperature: 0...100°C
- power: 0...600W

Dimensions and Weight

- LxWxH: 400x250x180mm (experimental unit)
- LxWxH: 410x400x180mm (display and control unit)
- Weight: approx. 15kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 display and control unit
- 1 set of instructional material

Order Details

060.37300 WL 373 Heat Conduction in Gases and Liquids

WL 377 Convection and Radiation


* **Heat transport between heating element and vessel wall by convection and radiation**

* **GUNT software for data acquisition**

Technical Description

Under real conditions, the heat transport between two objects is normally substance-bound, i.e. convection and/or heat conduction, and not substance-bound, i.e. radiation, at the same time. Determining the individual heat quantities of one type of transfer is difficult.

The WL 377 trainer enables users to match the individual heat quantities to the corresponding type of transfer. The core element is a metal cylinder in a pressure vessel. A temperature-controlled heating element is located at the centre of the cylinder. Sensors capture the wall temperature of the cylinder, the heating temperature and the heating power. This metal cylinder is used to examine the heat transfer between the heating element and the vessel wall.

The pressure vessel can be put under vacuum or positive gauge pressure. In the vacuum, heat is transported primarily by radiation. If the vessel is filled with gas and is under positive gauge pressure, heat is also transferred by convection. It is possible to compare the heat transfer in different gases. In addition to air, nitrogen, helium, carbon dioxide or other gases are also suitable.

A rotary vane pump generates negative pressures down to approx. 0,02mbar. Positive gauge pressures up to approx. 1bar can be realised with compressed air. Two pressure sensors with suitable measuring ranges are available for the pressure measurement: the negative pressure is captured with a Pirani sensor; a piezo-resistive sensor is used for experiments with a filled cylinder.

The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB, where they can be analysed with the GUNT software.

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

Learning Objectives / Experiments

experiments in vacuum:

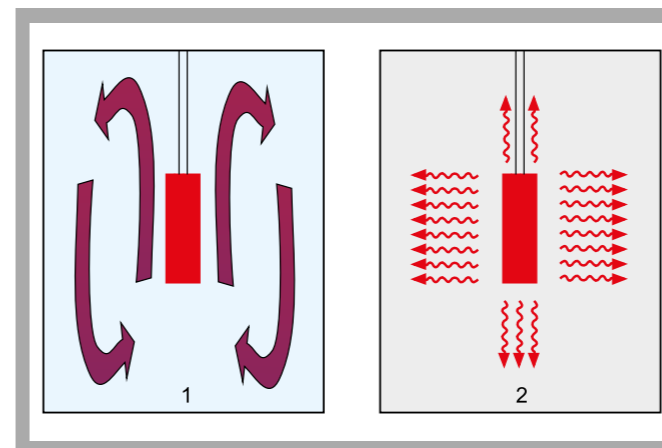
- heat transfer by radiation
- determination of the radiation coefficient

experiments at ambient pressure or positive gauge pressure:

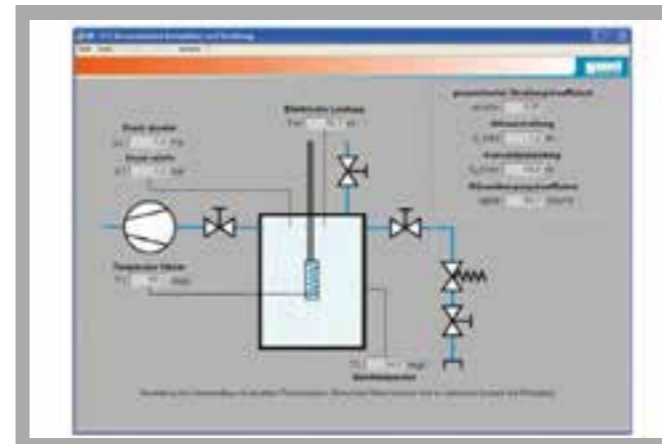
- heat transfer by convection and radiation
- determination of the heat quantity transferred by convection
- determination of the heat transfer coefficient based on measured values
- theoretical determination of the heat transfer coefficient based on the Nusselt number
- comparison of the heat transfer in different gases

WL 377 Convection and Radiation


1 temperature controller with temperature display, 2 temperature display, 3 power display, 4 vacuum pump, 5 pressure vessel, 6 vessel's absolute pressure display, 7 vessel's relative pressure display



Heat transfer in the vessel:
1 convection (vessel filled with gas), 2 radiation (vessel filled with vacuum)



Software screenshot: process schematic

Specification

- [1] heat transfer between heating element and vessel wall by convection and radiation
- [2] operation with various gases possible
- [3] experiments in vacuum or at a slight positive gauge pressure
- [4] electrically heated metal cylinder in the pressure vessel as experimental vessel
- [5] temperature-controlled heating element
- [6] vacuum generation with rotary vane pump
- [7] instrumentation: 1 temperature sensor at the heater, 1 temperature sensor at the vessel wall, 1 power sensor at the heating element, 1 Pirani pressure sensor, 1 piezo-resistive pressure sensor
- [8] digital displays for temperature, pressure and heating power
- [9] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

Heating element

- output: 20W
 - radiation surface area: approx. 61cm²
- Pump for vacuum generation
- power consumption: 370W
 - nominal suction capacity: 5m³/h
 - final pressure with gas ballast: 20*10⁻³mbar
 - final pressure without gas ballast: 5*10⁻³mbar

Measuring ranges

- negative pressure: 0,5*10⁻³...1000mbar
- pressure: -1...1,5bar rel.
- temperature: 2x 0...200°C
- output: 0...20W

Dimensions and Weight

LxWxH: 1340x790x1500mm
Weight: approx. 160kg

Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
Compressed air: 1500mbar

Scope of Delivery

1 trainer
1 GUNT software CD + USB cable
1 set of instructional material

Order Details

060.37700 WL 377 Convection and Radiation

WL 110 MODULAR HEAT EXCHANGER TRAINING EQUIPMENT



Teaching the fundamentals of heat transfer through experiments

Clear, simple, reliable, progress tracking

WL 110 Heat Exchanger Supply Unit with the WL 110.03 Shell & Tube Heat Exchanger



Perfect educational concept...

The supply unit can accommodate four different types of heat exchangers

... modular, flexible, versatile

WL 110.20 WATER CHILLER



The cold water needed for all the experiments is usually supplied from a laboratory tap. However when the ambient temperature in the laboratory is too high, the water chiller is recommended for reasonable experimental conditions.

Hot water is also needed for the experiments. It is supplied from the service unit WL 110.

INTERCHANGEABLE ACCESSORIES



WL 110.01 Tubular Heat Exchanger



WL 100.04 Jacketed Vessel with Stirrer & Coil



WL 110.02 Plate Heat Exchanger



WL 110.03 Shell & Tube Heat Exchanger

SOFTWARE FOR DATA ACQUISITION



The data acquisition software supports the complete range of experiments with four different types of heat exchangers.

Main features

- temperature curves along the heat exchanger
- selectable parallel flow or counterflow operation
- calculation of heat flows
- calculation of mean heat transfer coefficient

Convenient connection to any PC or laptop via USB.

Learning Objectives

- function and behaviour during operation of different heat exchangers
- plotting temperature curves
 - ▶ in parallel flow operation
 - ▶ in counterflow operation
- calculation of mean heat transfer coefficient
- comparing different heat exchanger types

Didactic Advantages

Ideally suited for student-centered experiments

A small group of 2 to 3 students can independently and conveniently go through the various experiments.

The lecturer can demonstrate characteristic aspects of heat exchangers in front of a bigger audience when using the data acquisition software and a video projector connected to a PC.

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

WL 110 Heat Exchanger Supply Unit


- * Heat exchanger supply unit (WL 110.01-WL 110.04)
- * Heat exchanger operation in parallel flow or counterflow possible

Technical Description

Heat exchangers transfer thermal energy from the flow of one medium to another. The two flows do not come into direct contact with one another. Efficient heat transfer is a prerequisite for economical processes. Therefore, different heat exchanger types are used in practice depending on the requirements.

This experimental unit can be used to investigate and compare different heat exchanger designs. The complete experimental set-up consists of two main elements: WL 110 as supply and control unit and choice of heat exchanger: Tubular heat exchanger (WL 110.01), plate heat exchanger (WL 110.02), shell and tube heat exchanger (WL 110.03) and jacketed vessel with stirrer and coil (WL 110.04). Water is used as the medium.

The heat exchanger to be investigated is connected to the supply unit. The hot water flows through the heat exchanger. Part of the thermal energy of the hot water is transferred to the cold water. Reversing the water connections changes the direction of flow and thus allows parallel flow or counterflow operation.

The main function of the WL 110 is to provide the required cold and hot water circuits. To do this, the supply unit is equipped with a heated tank and pump for the hot water circuit, connections for the cold water circuit and a switch cabinet with displays and controls. A temperature controller controls the hot water temperature. The flow rate in the hot water and cold water circuit is adjusted using valves. The cold water circuit can be fed from the laboratory mains or the WL 110.20. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

In experiments, the typical characteristic value determined are the mean heat transfer coefficients.

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

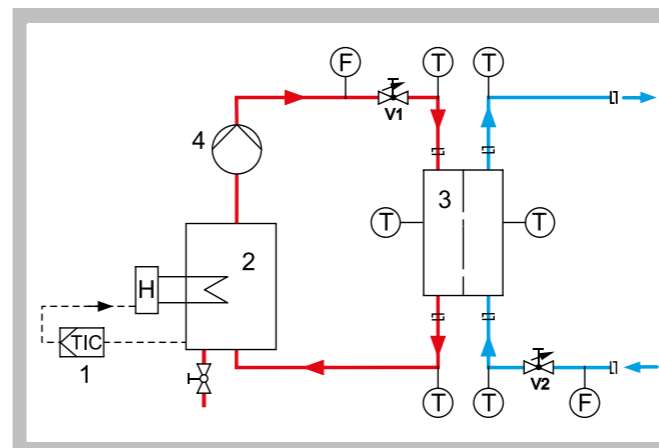
Learning Objectives / Experiments

in conjunction with a heat exchanger (WL 110.01 to WL 110.04)

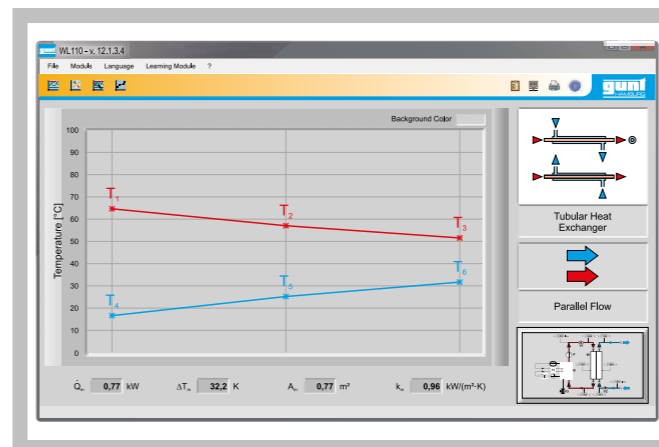
- plotting temperature curves
- determining the mean heat transfer coefficient
- comparing different heat exchanger types

WL 110 Heat Exchanger Supply Unit


1 temperature controller, 2 temperature displays, 3 flow rate displays, 4 jacketed vessel with stirrer and coil WL 110.04, 5 cold water circuit connections, 6 process schematic, 7 hot water tank



1 temperature controller, 2 heated tank, 3 heat exchanger (WL 110.01 to WL 110.04 accessories), 4 pump; red = hot water circuit, blue = cold water circuit; F flow rate, T temperature



Software screenshot: temperature curve for WL 110.01 in parallel flow operation

Specification

- [1] supply unit for heat exchangers
- [2] hot water circuit with tank, heater, temperature controller, pump and protection against lack of water
- [3] cold water circuit from laboratory mains or water chiller WL 110.20
- [4] temperature controller controls the temperature of hot water
- [5] flow adjustable using valves
- [6] digital displays for 6 temperature and 2 flow rate sensors
- [7] water connections with quick-release couplings
- [8] stirring machine connection with speed adjustment (WL 110.04)
- [9] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data
Pump

- power consumption: 120W
- max. flow rate: 600L/h
- max. head: 30m

Heater

- power output: 3kW
- thermostat: 0...70°C
- Hot water tank: approx. 10L

Measuring ranges

- temperature: 6x 0...100°C
- flow rate: 2x 20...250L/h

Dimensions and Weight

LxWxH: 1000x670x550mm
Weight: approx. 60kg

Required for Operation

230V, 50/60Hz, 1 phase or 230V, 60Hz/CSA,
3 phases
Cooling water 500L/h

Scope of Delivery

- 1 experimental unit
- 1 GUNT software CD + USB cable
- 1 set of instructional material

Order Details

060.11000 WL 110 Heat Exchanger Supply Unit

WL 110.01 Tubular Heat Exchanger


- * Tubular heat exchanger for connection to WL 110 supply unit
- * Visible flow channel due to transparent outer tube

Technical Description

Tubular heat exchangers represent the simplest type of heat exchangers and are the preferred solution for transferring heat with high pressure differences or between high viscosity media (e.g. sludge). An advantage is the uniform flow through the tube space. This space is free of flow dead zones.

The WL 110.01 is part of a series of units enabling experiments to be performed on different heat exchanger types. In conjunction with the WL 110 supply unit, which has a hot and cold water circuit and all of the necessary connections, the experimental unit is ideally suited for investigating the functioning and behaviour of a tubular heat exchanger in operation.

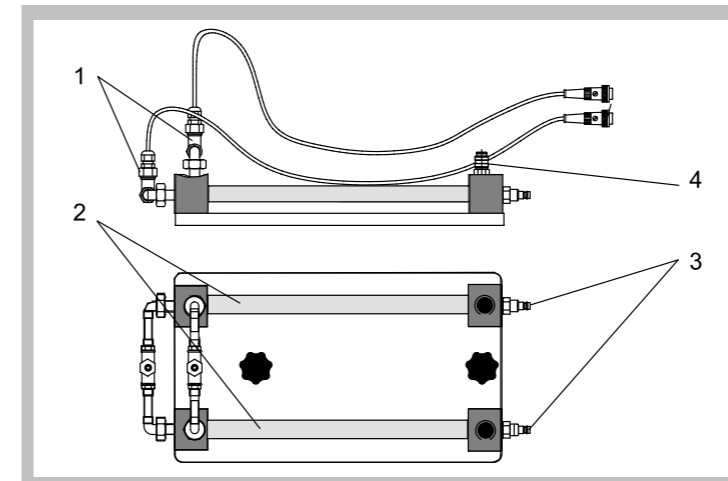
The WL 110.01 is connected to the WL 110 using quick-release couplings. Hot water flows continuously through the inner tube and cold water through the outer tube. Part of the thermal energy of the hot water is transferred to the cold water. Valves on the supply unit are used to adjust the flow rates of hot and cold water. The supply hose can be reconnected using quick-release couplings, allowing the flow direction to be reversed. This allows parallel flow and counterflow operation. Temperature sensors for measuring the inlet and outlet temperatures are located at the supply connections on the WL 110. There are two additional temperature sensors on the tubular heat exchanger for measuring the temperature after half of the transfer section.

During experiments, temperature curves are plotted and displayed graphically. Additionally, the measured values can be recorded and processed using data acquisition software. The mean heat transfer coefficient is then calculated as a characteristic variable.

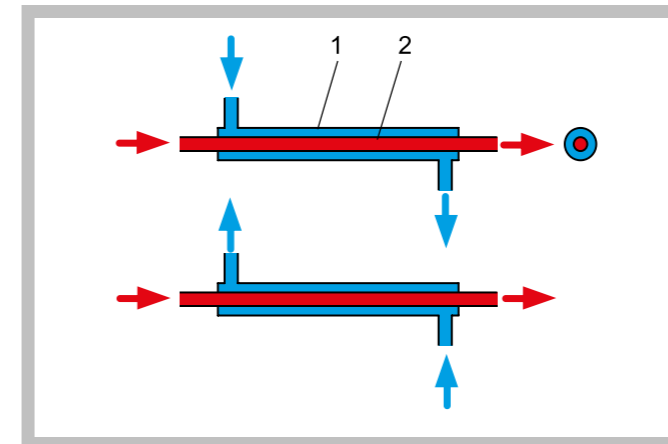
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

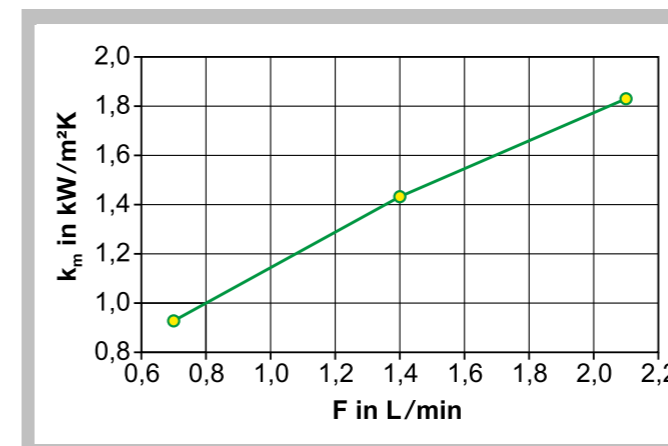
- in conjunction with WL 110 supply unit
- function and behaviour during operation of a tubular heat exchanger
 - plotting temperature curves
 - * in parallel flow operation
 - * in counterflow operation
 - calculation of mean heat transfer coefficient
 - comparison with other heat exchanger types

WL 110.01 Tubular Heat Exchanger


1 temperature sensor, 2 concentric tubes, 3 hot water connections, 4 cold water connections



Functional principle of tubular heat exchanger
1 outer tube with cold water, 2 inner tube with hot water;
red: hot water, blue: cold water



Mean heat transfer coefficient k_m as function of flow rates cold water and hot water

Specification

- [1] tubular heat exchanger for connection to WL 110
- [2] hot and cold water supply from WL 110
- [3] parallel flow and counterflow operation possible
- [4] recording of temperature using WL 110 and two additional temperature sensors for measuring the central temperature

Technical Data

- Heat transfer areas
- mean transfer area: 250cm²
 - Inner tube, stainless steel
 - outer diameter: 12mm
 - wall thickness: 1mm
 - Outer tube, transparent (PMMA)
 - outer diameter: 20mm
 - wall thickness: 2mm

- Measuring range
- temperature: 2x 0...100°C

Dimensions and Weight

- LxWxH: 480x230x150mm
Weight: approx. 4kg

Scope of Delivery

- 1 tubular heat exchanger
- 1 set of instructional material

Order Details

060.11001 WL 110.01 Tubular Heat Exchanger

WL 110.02 Plate Heat Exchanger

*** Plate heat exchanger for connection to WL 110 supply unit**
Technical Description

The key feature of plate heat exchangers is their compact design, in which optimum use is made of all of the material for heat transfer. The pressed in profile on the plates creates narrow flow channels, in which significant turbulence occurs. The turbulent flow allows effective heat transfer even with low flow rates and also has a self-cleaning effect. Plate heat exchangers are used in the food industry, offshore technology, refrigeration and domestic engineering.

The WL 110.02 is part of a series of units enabling experiments to be performed on different heat exchanger types. In conjunction with the WL 110 supply unit, which has a hot and cold water circuit and all of the necessary connections, the experimental unit is ideally suited for investigating the functioning and behaviour of a plate heat exchanger in operation.

The WL 110.02 is connected to the WL 110 using quick-release couplings. The plate heat exchanger is made up of profiled plates with water flowing through the spaces between them. The plates are soldered in such a way that two separate flow channels are formed. These are one "cold" and one "hot" flow channel, in an alternating arrangement. Hot and cold water flow continuously. Part of the thermal energy of the hot water is transferred to the cold water. Valves on the supply unit are used to adjust the flow rates of hot and cold water. The supply hose can be reconnected using quick-release couplings, allowing the flow direction to be reversed. This allows parallel flow and counterflow operation. The temperature sensors for measuring the inlet and outlet temperature are located at the supply connections on the WL 110.

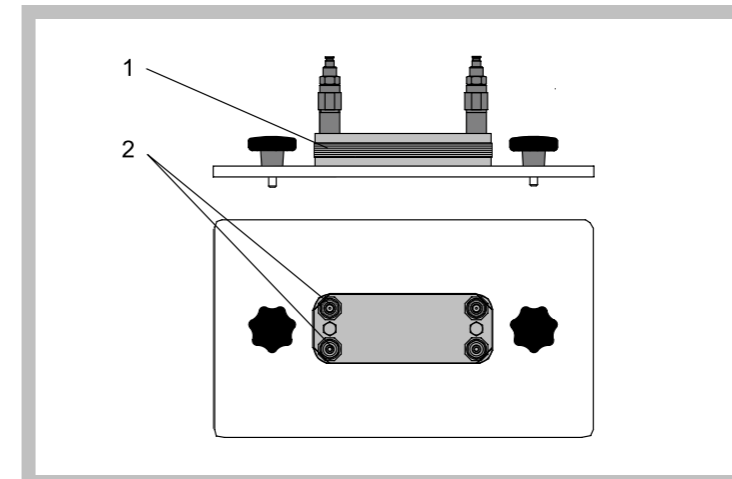
During experiments, temperature curves are plotted and displayed graphically. Additionally, the measured values can be recorded and processed using data acquisition software. The mean heat transfer

coefficient is then calculated as a characteristic variable.

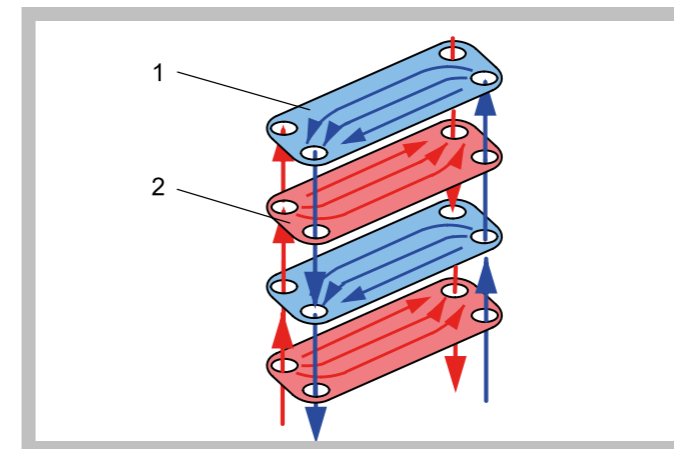
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

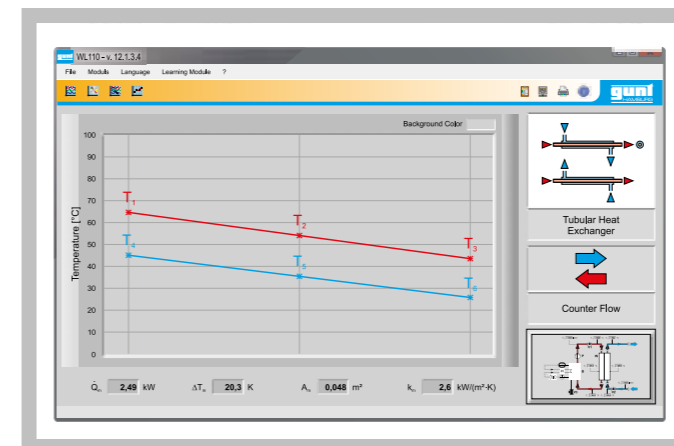
- in conjunction with WL 110 supply unit
- function and behaviour during operation of a plate heat exchanger
- plotting temperature curves
 - * in parallel flow operation
 - * in counterflow operation
- calculation of mean heat transfer coefficient
- comparison with other heat exchanger types

WL 110.02 Plate Heat Exchanger


1 plates, 2 water connections



1 plate with cold water, 2 plate with hot water;
red: hot water, blue: cold water



Software screenshot: temperature curve in counterflow operation

Specification

- [1] plate heat exchanger for connection to WL 110
- [2] hot and cold water supply from WL 110
- [3] parallel flow and counterflow operation possible
- [4] six soldered plates
- [5] recording of temperature using WL 110

Technical Data

6 plates, stainless steel
Heat transfer area: 480cm²

Dimensions and Weight

LxWxH: 400x230x85mm
Weight: approx. 3kg

Scope of Delivery

- 1 plate heat exchanger
- 1 set of instructional material

Order Details

060.11002 WL 110.02 Plate Heat Exchanger

WL 110.03 Shell & Tube Heat Exchanger


* Shell and tube heat exchanger for connection to WL 110 supply unit

* Media flowing in cross flow

Technical Description

Shell and tube heat exchangers are in widespread use. The main advantages of this design are the large heat transfer area and the compact design. Shell and tube heat exchangers are used in the chemical and pharmaceutical industries, in refineries and in process engineering plants.

The WL 110.03 is part of a series of units enabling experiments to be performed on different heat exchanger types. In conjunction with the WL 110 supply unit, which has a hot and cold water circuit and all of the necessary connections, the experimental unit is ideally suited for investigating the functioning and behaviour of a shell and tube heat exchanger in operation.

The WL 110.03 is connected to the WL 110 using quick-release couplings. The shell and tube heat exchanger consists of seven tubes, surrounded by a transparent outer shell. The hot water flows through the tube space and the cold water through the space in the shell. Part of the thermal energy of the hot water is transferred to the cold water. Baffle plates are used to deflect the flow in the shell in such a way as to create greater turbulence and thus a more intensive transfer of heat. The media flows continuously in a crossflow. Valves on the supply unit are used to adjust the flow rates of hot and cold water. The supply hose can be reconnected using quick-release couplings, allowing the flow direction to be reversed. This allows cross parallel flow and cross counterflow operation. Temperature sensors for measuring the inlet and outlet temperature are located at the supply connections on the WL 110.

During experiments, temperature curves are plotted and displayed graphically. Additionally, the measured values can be recorded and

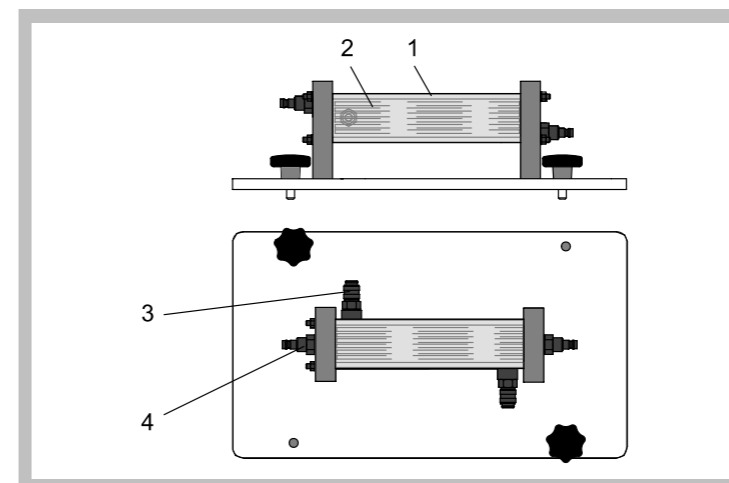
processed using data acquisition software. The mean heat transfer coefficient is then calculated as a characteristic variable.

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

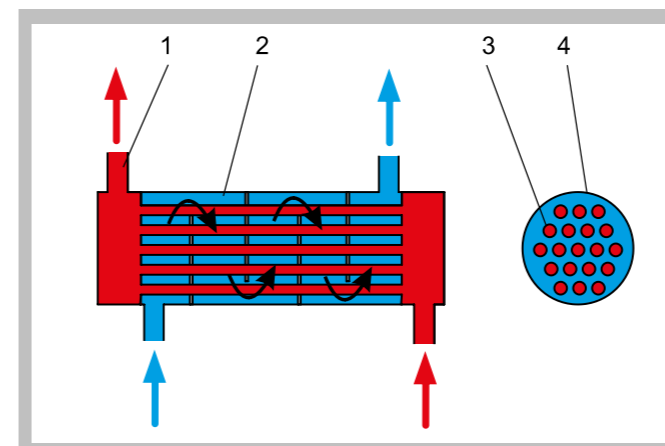
Learning Objectives / Experiments

in conjunction with WL 110 supply unit

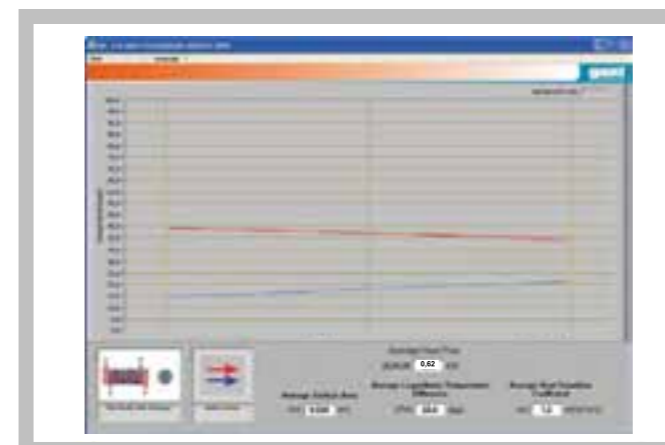
- function and behaviour during operation of shell and tube heat exchanger
- plotting temperature curves
 - * in cross parallel flow operation
 - * in cross counterflow operation
- calculation of mean heat transfer coefficient
- comparison with other heat exchanger types

WL 110.03 Shell & Tube Heat Exchanger


1 transparent shell, 2 tube bundle, 3 shell water connection, 4 tube bundle water connection



1 hot water, 2 cold water, 3 tube, 4 shell
red: hot water, blue: cold water



Software screenshot: temperature curve in cross parallel flow operation

Specification

- [1] shell and tube heat exchanger (cross flow) for connection to WL 110
- [2] hot and cold water supply from WL 110
- [3] cross parallel flow and cross counterflow operation possible
- [4] transparent shell, visible tube bundle
- [5] tube bundle consisting of 7 tubes and 4 baffle plates
- [6] recording of temperature using WL 110

Technical Data

Heat transfer area: 200cm²
 Tube bundle, stainless steel
 - outer diameter: 6mm
 - wall thickness: 1mm
 Shell, transparent (PMMA)
 - outer diameter: 50mm
 - wall thickness: 3mm

Dimensions and Weight

LxWxH: 400x230x110mm
 Weight: approx. 3kg

Scope of Delivery

1 shell and tube heat exchanger
 1 set of instructional material

Order Details

060.11003 WL 110.03 Shell & Tube Heat Exchanger

WL 110.04 Jacketed Vessel with Stirrer & Coil


- * Jacketed vessel with stirrer and coil for connection to WL 110 supply unit
- * Stirrer for improved mixing of medium
- * Heating using jacket or coiled tube

Technical Description

In many engineering processes, several basic operations are combined. For example, in a tank a chemical reaction takes place during which heat is to be supplied or removed. Such tanks are equipped with jacket or a coiled tube. Depending on the process, the medium in the jacket or in the coiled tubing is used for heating or cooling of the tank content. For a better mixing of the tank content and an even temperature distribution stirring machines are used. The product temperature at an even temperature distribution is precisely adjustable. Considered here, the jacketed heat exchanger is a model for such tanks.

The WL 110.04 is part of a series of units enabling experiments to be performed on different heat exchanger types. In conjunction with the WL 110 supply unit, which has a hot and cold water circuit and all of the necessary connections, the experimental unit is ideally suited for investigating the functioning and behaviour of a jacketed heat exchanger in operation.

The WL 110.04 is connected to the WL 110 using quick-release couplings. The jacketed heat exchanger consists of a tank surrounded by a jacket. The tank is fitted with a coiled tube. In heating mode with jacket the hot water flows through the jacket and transfers a part of the thermal energy to the cold water in the tank. In heating mode with coiled tube the hot water flows through the coil and heats the cold water in the tank. A stirring machine can be used in all modes. Valves on the supply unit are used to adjust the flow rate of hot water. The temperature sensors for measuring the inlet and outlet temperature are located at the supply

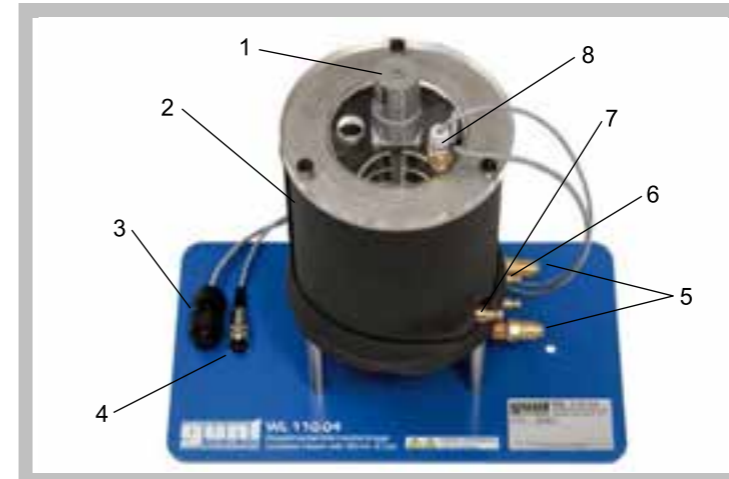
connections on the WL 110. An additional temperature sensor measures the temperature in the tank.

During experiments, time curves are plotted and displayed graphically. Additionally, the measured values can be recorded and processed using data acquisition software.

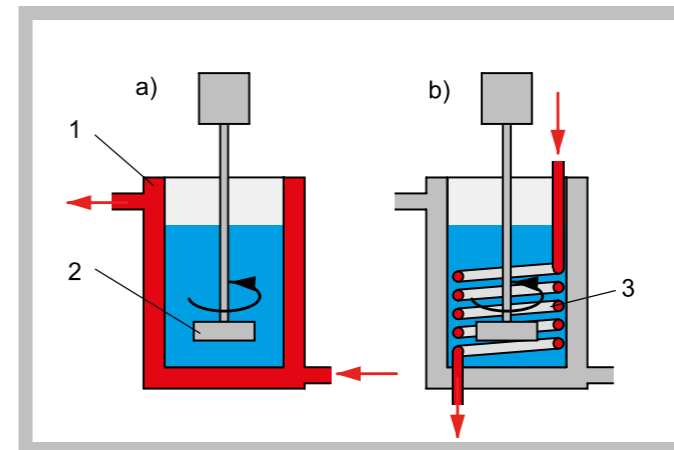
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

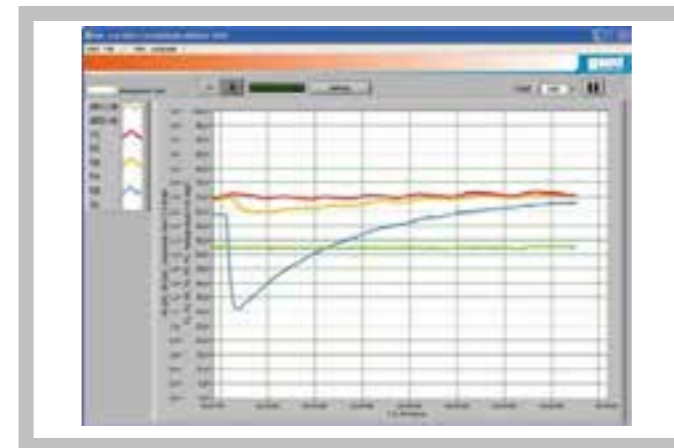
- in conjunction with WL 110 supply unit
- function and behaviour during operation of a jacketed heat exchanger
 - plotting time curves
 - * heating mode with jacket
 - * heating mode with coiled tube
 - influence of a stirring machine
 - comparison with other heat exchanger types

WL 110.04 Jacketed Vessel with Stirrer & Coil


1 stirring machine, 2 tank, 3 stirring machine connection, 4 temperature sensor connection, 5 water outlet and inlet in tank, 6 coiled tube water connection, 7 jacket water connection, 8 temperature sensor



a) heating using jacket: 1 jacket, 2 stirrer
b) heating using coiled tube: 3 coiled tube;
red: hot water, blue: cold water



Software screenshot: Time curve for heating using jacket

Specification

- [1] jacketed heat exchanger for connection to WL 110
- [2] hot and cold water supply from WL 110
- [3] heating using jacket or coiled tube
- [4] stirring machine can be used in all modes
- [5] speed of stirring machine adjustable using WL 110
- [6] visible working area due to transparent cover
- [7] recording of temperature using WL 110 and additional temperature sensor for measuring temperature in tank

Technical Data

- Tank
- nominal value: approx. 1200mL
- Stirring machine
- speed: 0...330min⁻¹

Heat transfer area

- jacket (stainless steel): approx. 500cm²
- coil (stainless steel): approx. 500cm²

Measuring range

- temperature: 0...100°C

Dimensions and Weight

- LxWxH: 400x230x400mm
Weight: approx. 8kg

Scope of Delivery

- 1 jacketed vessel with stirrer & coil
- 1 set of instructional material

Order Details

- 060.11004 WL 110.04 Jacketed Vessel with Stirrer & Coil

WL 110.20 Water Chiller for WL 110

*** Cold water supply for WL 110**
Technical Description

WL 110.20 is designed for use with the WL 110 supply unit for heat exchangers. The cold water supply allows for reasonable operation at high ambient and water temperatures.

The unit is equipped with an integral refrigeration system, water tank and circulating pump. In the water tank, a pipe coil acts as an evaporator for the refrigeration cycle and cools the water.

An electronic controller keeps the water temperature constant.

Scope of Delivery

1 water chiller
1 set of hoses
1 manual

Specification

- [1] water chiller
- [2] main components: refrigeration unit to chill water, water tank, circulating pump
- [3] electronic controller for water temperature
- [4] connection to WL 110 using hoses with rapid action couplings
- [5] refrigerant R134a, environmentally friendly

Technical Data

Centrifugal pump
- max. flow rate: 600L/h
- max. head: 30m
- power consumption: 120W
Refrigeration system
- refrigerating capacity: 833W at -10/32°C
- power consumption: 367W
Tank: 15L

Dimensions and Weight

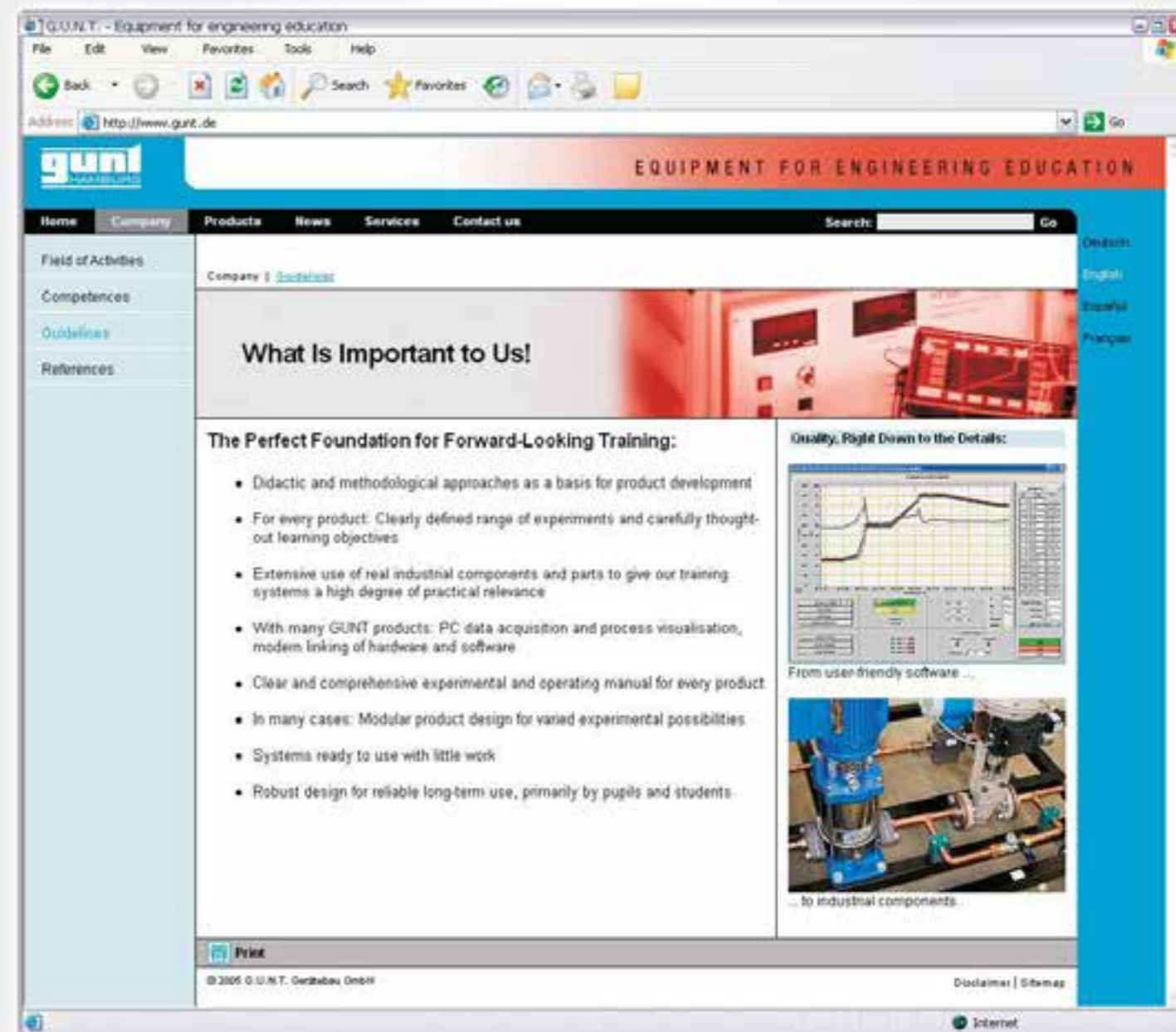
LxWxH: 1000x630x530mm
Weight: approx. 76kg

Required for Operation

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

Order Details

060.11020 WL 110.20 Water Chiller for WL 110



Visit our website, where you will find all you need to know, including all the latest news.



WL 225 Heat Transfer in the Fluidised Bed


- * Fluidised bed formation with air in a glass reactor
- * Illuminated glass reactor for optimal observation of the fluidisation process

Technical Description

Fluidised beds are used in a broad range of applications, e.g. for industrial drying, fluidised bed combustion or heat treatment of materials. Bulk solids are transformed from a fixed bed into a fluidised bed when fluids pass through them. In terms of fluid mechanical and thermodynamic properties, the fluidised bed behaves like an incompressible fluid.

The heat transfer between hot fluid and a fixed bed occurs mainly through heat conduction. Due to the movement of the particles, the fluid and the particles are very well mixed in the fluidised bed. This enables optimum heat transfer between fluid and particles and ensures an even temperature distribution in the reactor.

The core element in WL 225 is a backlit glass reactor which enables students to observe the fluidisation process. Compressed air flows upwards through a porous sintered-metal plate. On the sintered-metal plate is a fixed bed. If the velocity of the air is less than the so-called fluidisation velocity, the flow merely passes through the fixed bed. At higher velocities the bed is loosened to such an extent that individual solid particles are suspended by the fluid and form a fluidised bed. The air escapes through a filter at the top end of the glass reactor.

The air flow rate is set via a valve and measured with a flow meter. The pressure at the inlet into the reactor and in the fluidised bed is also measured.

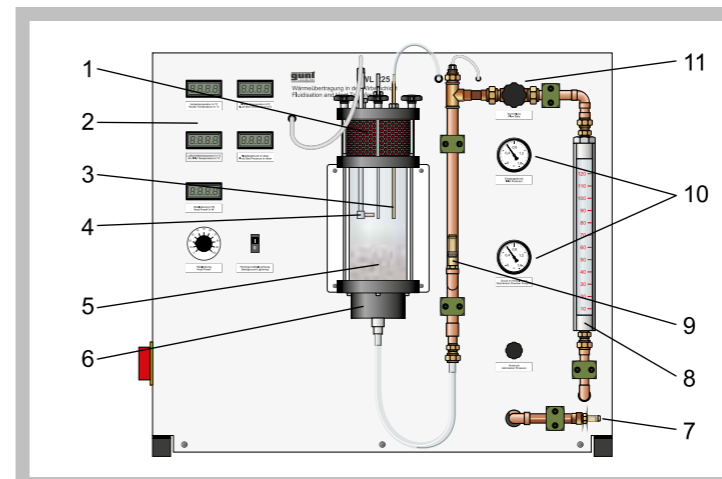
A submersible heating element in the reactor enables examination of the heat transfer in the fluidised bed. Temperatures are measured by sensors at the air inlet of the reactor, on the surface of the heating element and in the fluidised bed and digitally displayed. The power

output of the heating element is also digitally displayed. Aluminium oxide in various particle sizes is included in the scope of delivery as bulk solid.

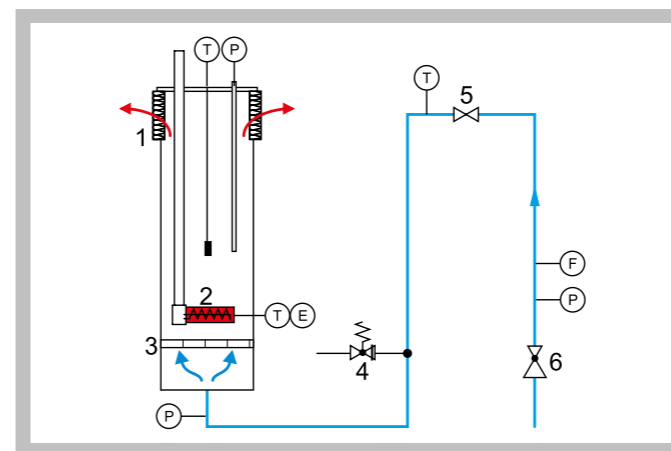
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

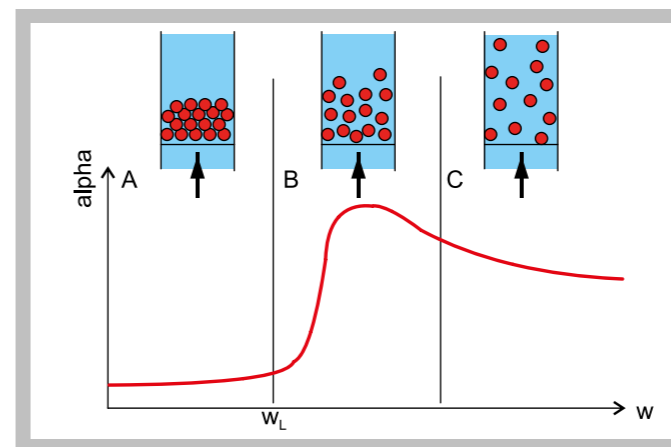
- basic information on the fluidisation of fixed beds
- pressure curve within the bed
- pressure losses depending on
 - * flow velocity
 - * particle size of the bulk solid
- determination of the fluidisation velocity
- separation of mixtures with different particle sizes by sedimentation
- heat transfer in the fluidised bed
 - * influence of the air flow rate on the heat transfer
 - * influence of the heater position
 - * influence of the particle size
 - * determination of the heat transfer coefficient

WL 225 Heat Transfer in the Fluidised Bed


1 air filter, 2 display and control panel, 3 fluidised bed pressure sensor, 4 heater element, 5 reactor with fluidised bed, 6 reactor base made of sintered metal, with distribution chamber, 7 compressed air connection, 8 flow meter, 9 safety valve, 10 manometer, 11 valve for adjusting the air flow rate



Process schematic: 1 air filter, 2 heating element, 3 sintered-metal plate, 4 safety valve, 5 valve for adjusting the air flow rate, 6 pressure reducing valve, E power output, F flow rate, T temperature



Dependency of the heat transfer coefficient alpha on the flow velocity w:
A fixed bed, B fluidised bed, C sediment discharge, w_L fluidisation velocity

Specification

- [1] examination of the fluidised bed formation and the heat transfer in the fluidised bed
- [2] fluidised bed of compressed air and aluminium oxide, particle sizes either 125 μ m or 300 μ m
- [3] glass reactor, backlit
- [4] glass reactor with sintered-metal plate at the inlet and air filter at the outlet
- [5] heating element, submersible and with adjustable power output
- [6] manual setting of the air flow rate via valve and flow meter
- [7] instrumentation: temperature sensors at heater, air inlet, in fluidised bed, pressure measurement upstream of the reactor and in the reactor (manometer, pressure sensor), flow meter for measuring the air flow rate, power output of the heating element
- [8] digital displays for temperatures, power output, pressure in the fluidised bed
- [9] steel rulers for measuring the immersion depth of the heating element and the height of the fluidised bed
- [10] safety valve, temperature switch at the heater, air filter at the outlet

Technical Data

Glass reactor
- capacity: 2150mL
- filling volume: approx. 1000mL
- operating pressure: 500mbar
Heating element
- power: 0...100W

Measuring ranges
- temperature: 1x 0...100°C, 2x 0...400°C
- flow rate: 10...124 NL/min
- pressure: 2x 0...0...1600mbar
- power: 0...200W

Dimensions and Weight

LxWxH: 900x460x830mm
Weight: approx. 75kg

Required for Operation

230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
Compressed air connection: min. 2bar

Scope of Delivery

1 experimental unit
2x 125 μ m aluminium oxide
2x 300 μ m aluminium oxide
1 steel ruler
1 compressed air hose
1 set of instructional material

Order Details

060.22500 WL 225 Heat Transfer in the Fluidised Bed

WL 320 WET COOLING TOWER

The interchangeable cooling columns for wet cooling tower WL 320 enable comparative investigations as well as experiments for teaching the fundamentals. In this way, the main properties of the wet cooling tower can be learned by experiments.



ADDITIONAL COOLING COLUMNS FOR COMPARATIVE MEASUREMENTS

WL 320.01
Cooling Column,
Type 2,
small
surface area



WL 320.02
Cooling Column,
Type 3,
large
surface area



WL 320.03
Cooling Column,
Type 4,
without
wet deck
surface



WL 320.04
Cooling Column,
Type 5,
variable
surface area



Interchangeable cooling columns

Five different cooling columns are available:

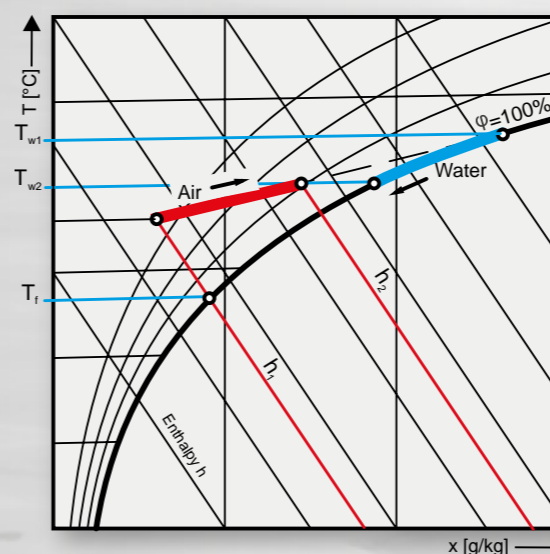
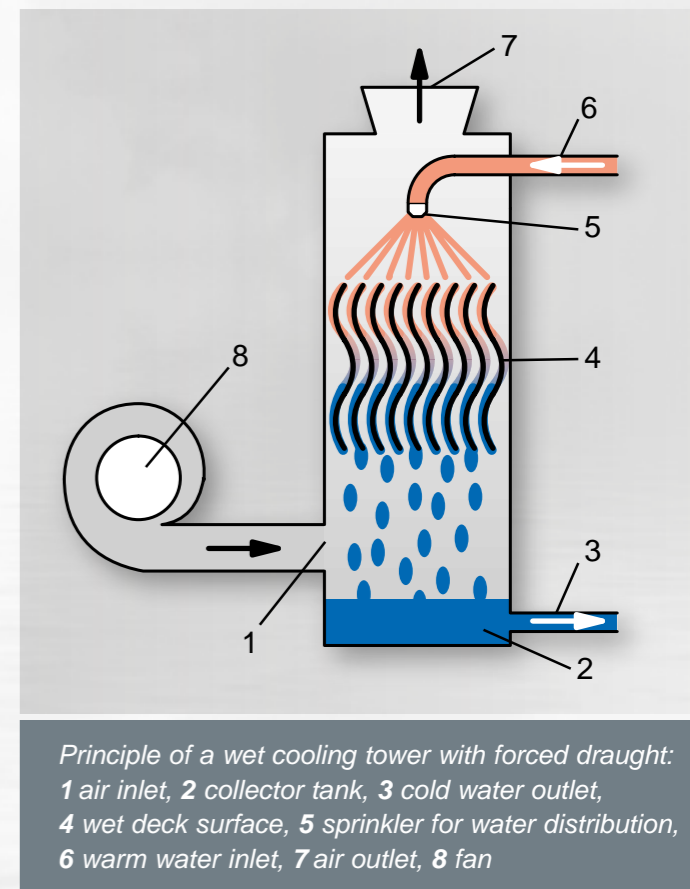
- three cooling columns with different surface areas
- one cooling column without a wet deck surface for investigation of heat transfer at free water droplets or for wet deck surfaces of your own design
- one cooling column with a divided wet deck surface for varying the surface area and the possibility of measuring temperature and humidity inside the cooling column

How does a cooling tower work?

Cooling towers are used to dissipate the waste heat produced in thermal processes such as steam power plants, air conditioning systems and process coolers. A distinction is made between wet and dry cooling towers. For equal cooling capacities the wet cooling tower allows for a simpler and smaller design at the expense of a water loss (1...2,5%).

WL 320 is a wet cooling tower. The water is cooled by direct contact with the air. The warm water is sprayed into the top of the cooling tower, is cooled by running down the wet deck surfaces and is drawn out at the base. The air enters the cooling tower from below, rises in counterflow to the water and leaves at the top.

A distinction is made between cooling towers with natural and forced draught. Large cooling towers use the natural draught principle. In this case the flow of air is caused by the difference in density of the air inside and outside the cooling tower. For small cooling towers the difference in density is too small to cause sufficient flow of air. Forced draught has to be applied.



Two different kinds of heat transfer occur inside the wet cooling tower. Firstly, heat is transferred directly from water to air by convection. Secondly, the water is cooled due to partial evaporation. For the evaporation process to function efficiently, the air must not be too humid. For this reason water outlet temperature T_{w2} has to be significantly higher than saturation temperature of the air (wet-bulb temperature T_f).

WL 320 Wet Cooling Tower


* Principle and characteristic variables of a wet cooling tower with forced ventilation

* Transparent, easily interchangeable cooling column with wet deck surface

* 4 additional cooling columns available as accessory

Technical Description

Wet cooling towers are a proven method of closed-circuit cooling and heat dissipation. Typical areas of application are: air conditioning, heavy industry and power stations.

In wet cooling towers the water to be cooled is sprayed over a wet deck surface. Water and air come into direct contact in the counterflow. The water is cooled by convection. Some of the water evaporates and the evaporation heat removed further cools down the water.

WL 320 examines the main components and principle of a wet cooling tower with forced ventilation. Water is heated in a tank and transported by a pump to an atomiser. The atomiser sprays the water to be cooled over the wet deck surface. The water trickles from the top to the bottom along the wet deck surface whilst air flows from the bottom to the top. The heat is transferred directly from the water to the air by convection and evaporation. The evaporated water volume is recorded. The air flow is generated by a fan and adjusted using a throttle valve.

The cooling column is transparent allowing clear observation of the wet deck surface and the trickling water. Interchangeable cooling columns (WL 320.01 - WL 320.04) enable comparative studies.

All important process parameters are recorded (volumetric air flow rate, temperatures of air and water, air humidity, water flow rate). The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included. The changes of state of the air

are represented in an h-x diagram.

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

Learning Objectives / Experiments

- thermodynamic principles of the wet cooling tower
- changes of state of the air in the h-x diagram
- determination of the cooling capacity
- energy balances
- calculation of process parameters, such as maximum cooling distance, cooling zone width etc.

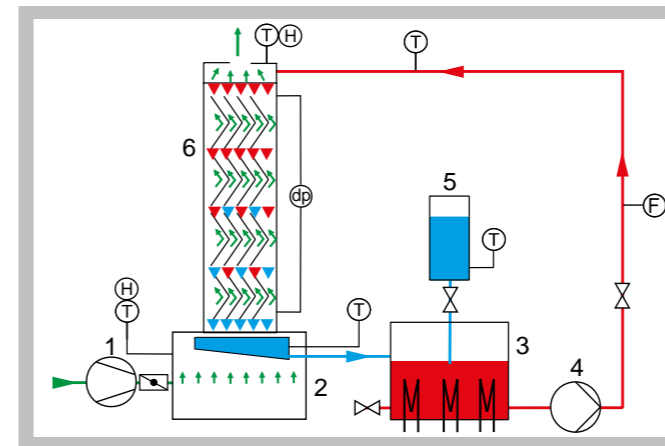
in conjunction with the cooling columns

WL 320.01-WL 320.04

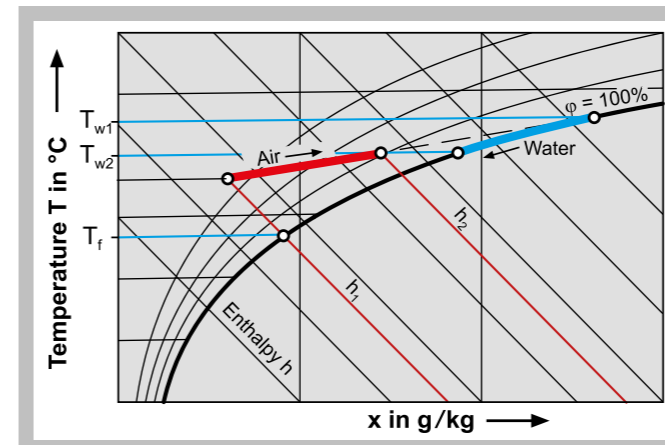
- comparison of different wet deck surfaces

WL 320 Wet Cooling Tower


1 nozzle as atomiser, 2 wet deck surface, 3 displays and controls, 4 air chamber, 5 fan with throttle valve, 6 pump, 7 tank with heating, 8 tank for additional water, 9 combined temperature/humidity sensor



1 fan, 2 air chamber, 3 tank with heater, 4 pump, 5 tank for additional water, 6 cooling column with wet deck surface; T temperature, H humidity, dp differential pressure, F water flow rate



Changes of state of air and water in the h-x diagram as online representation in the software

Specification

- [1] principle of a wet cooling tower with cooling column and forced ventilation
- [2] interchangeable cooling columns with different wet deck surfaces available as accessories
- [3] water circuit with pump, filter, valve and a nozzle as atomiser
- [4] three-stage heater with thermostat for water heating
- [5] radial fan for forced ventilation
- [6] throttle valve to adjust the air flow
- [7] demister unit at the outlet of the cooling columns minimises water loss
- [8] tank for additional water compensates for water loss
- [9] display of temperature, differential pressure, flow rate and humidity
- [10] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

Cooling column

- specific surface of the wet deck surface: $110\text{m}^2/\text{m}^3$
- cross-section: $150\text{x}150\text{mm}$
- Volumetric air flow measurement via orifice: $D=80\text{mm}$
- Heater, adjustable in three stages: 500-1000-1500W
- Thermostat: switches off at 50°C

Fan

- power consumption: 250W
- max. differential pressure: 430Pa
- max. flow rate: $13\text{m}^3/\text{min}$

Pump

- max. head: 70m
- max. flow rate: 100L/h

Tank for additional water: 4,2L

Measuring ranges

- differential pressure (air): 0...1000Pa
- flow rate (water): 12...360L/h
- temperature: 2x 0... 50°C , 3x 0... 100°C
- humidity: 10...100% r.h.

Dimensions and Weight

LxWxH: 1110x540x1230mm
Weight: approx. 120kg

Required for Operation

230V, 50/60Hz, 1 phase or 230V, 60Hz/CSA,
3 phases

Scope of Delivery

- 1 trainer
- 1 cooling column type 1
- 1 GUNT software CD + USB cable
- 1 set of instructional material

Order Details

060.32000 WL 320 Wet Cooling Tower

HM 150 SERIES A SIMPLE INTRODUCTION INTO THE FUNDAMENTALS OF FLUID MECHANICS

GUNT devices from the HM 150 series 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*



HM 150.18 Osborne Reynolds Experiment

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*



HM 150.15 Hydraulic Ram - Pumping Using Water Hammer

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*



HM 150.08 Measurement of Jet Forces

JET FORCES

- HM 150.08 *Measurement of Jet Forces*

DETERMINING THE METACENTRE

- HM 150.06 *Stability of Floating Bodies*



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 150.18 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.

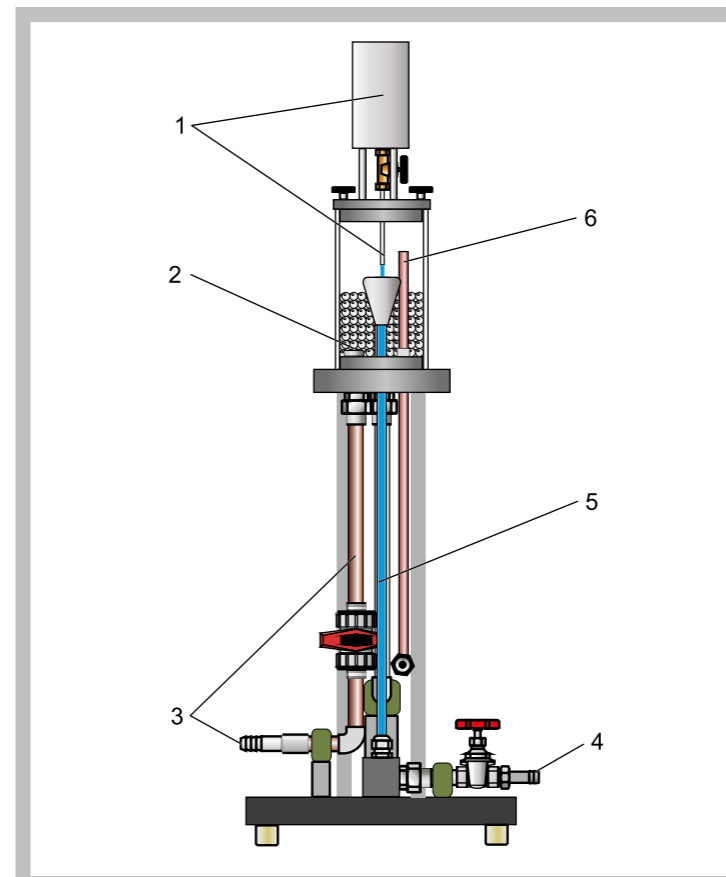
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

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

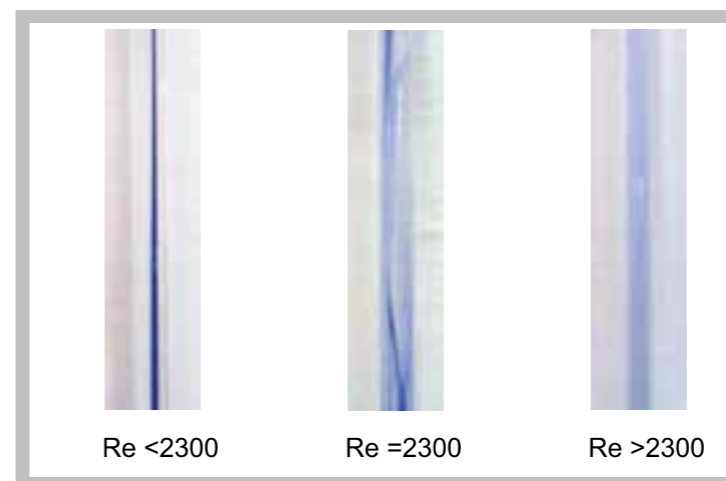
Learning Objectives / Experiments

- 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.

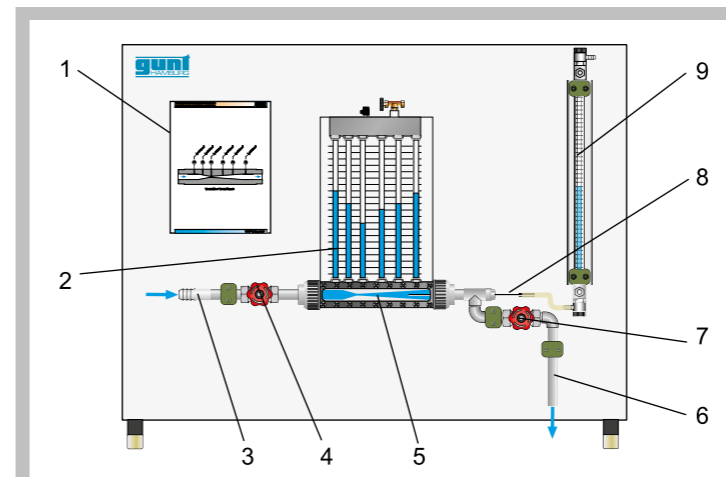
The Venturi nozzle is equipped with pressure measuring points to determine the static pressures. The pressures are displayed on the six tube manometers. The total pressure is measured by the Pitot tube and displayed on another single tube manometer.

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.

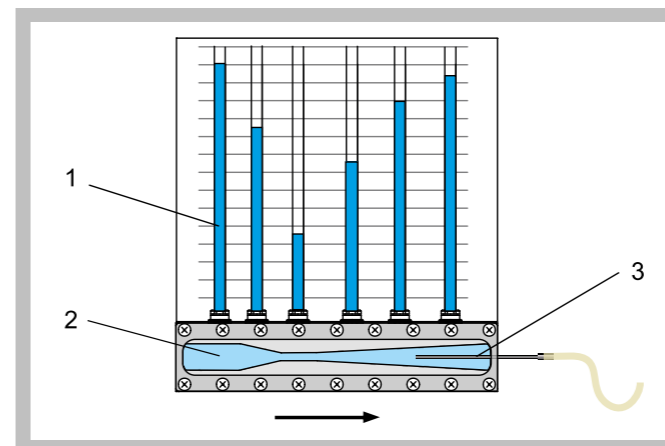
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

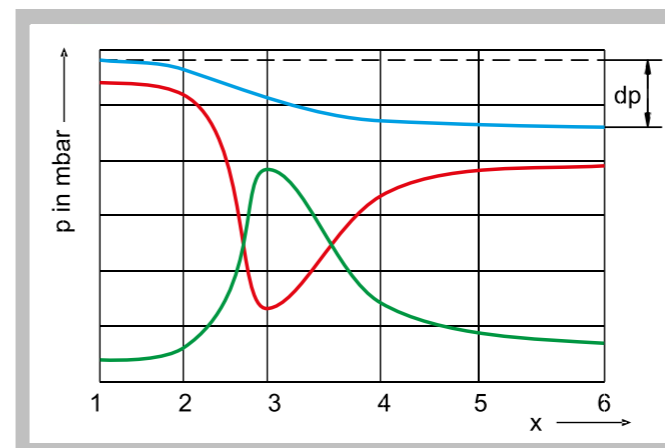
- energy conversion in divergent/convergent pipe flow
- recording the pressure curve in a Venturi nozzle
- recording the velocity curve in a Venturi nozzle
- determining the flow coefficient
- recognising friction effects

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] learning 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...338mm²
 - 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 150.01 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.

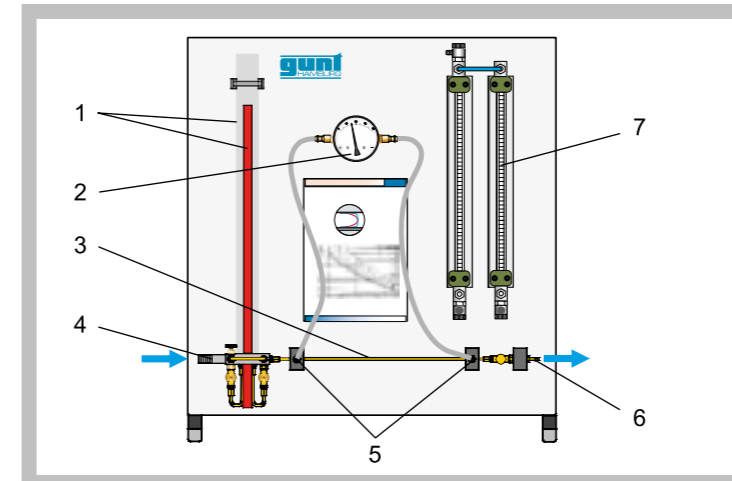
The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

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

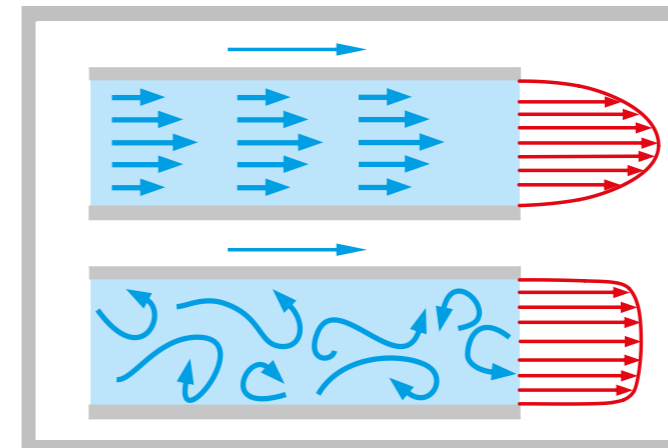
Learning Objectives / Experiments

- 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

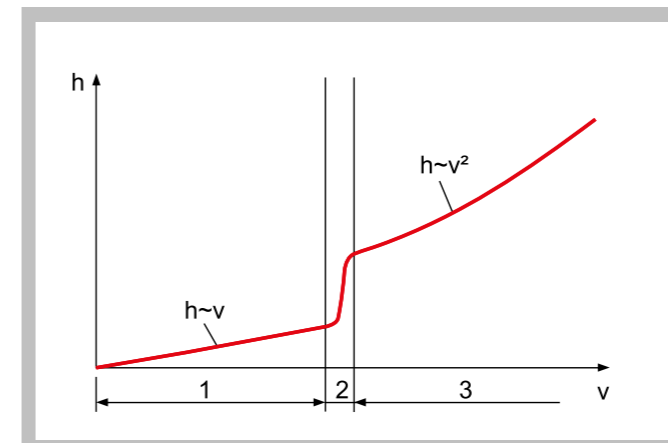
- * Pipe friction losses in laminar and turbulent flow
- * Determining the critical Reynolds number

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 manometer 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 manometer):
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 150.12 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.

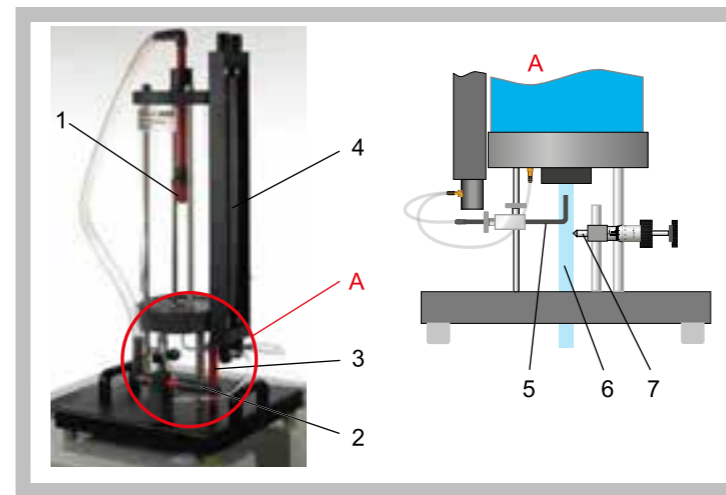
The tank is fitted with an adjustable overflow and a measuring point for static pressure. In this way, the level can be precisely adjusted and read on the manometer. The experimental unit is positioned easily and securely on the work surface of the HM 150 base module. The water is supplied and the flow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

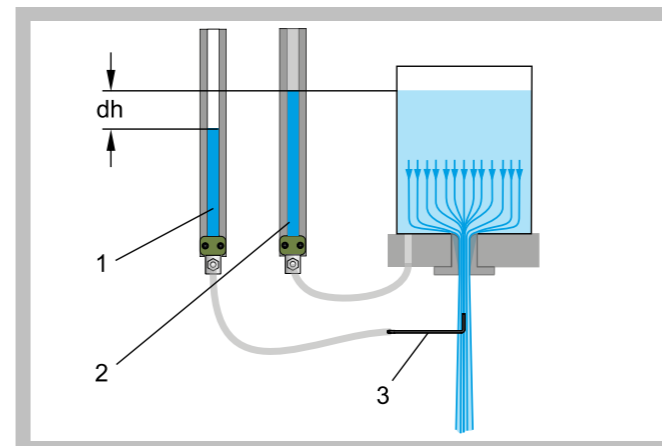
Learning Objectives / Experiments

- 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

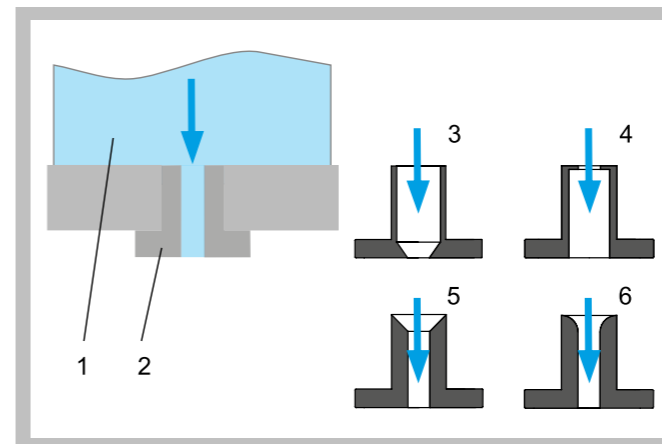
- * **Determination of the diameter and velocity of the outlet jet**
- * **Study of openings with different inlet and outlet contours**
- * **Determining the contraction coefficient**

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

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

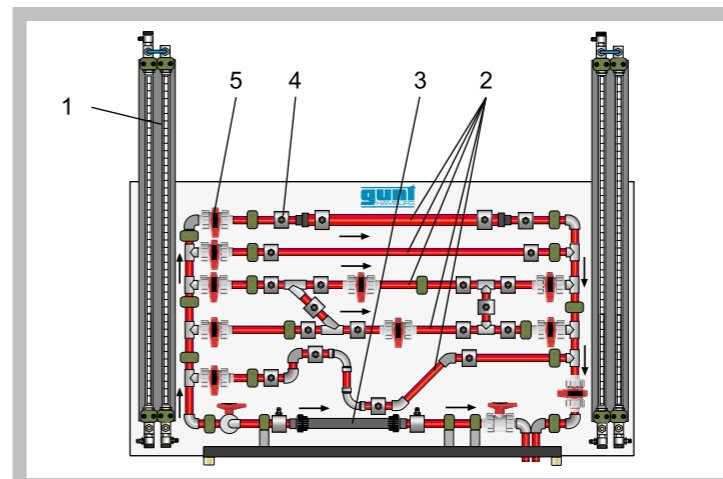
rate measured by HM 150. Alternatively, the experimental unit can be operated by the laboratory supply.

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

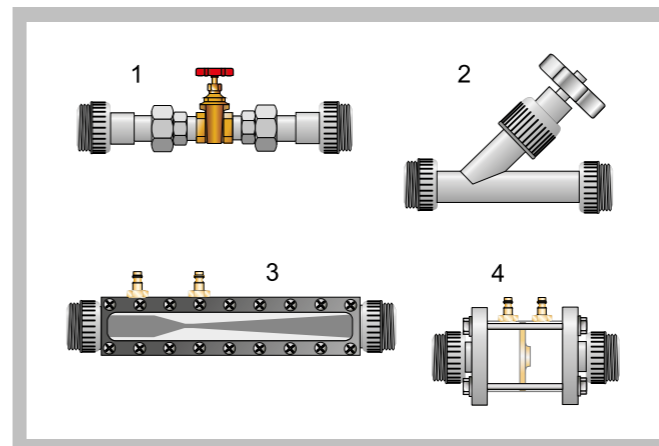
Learning Objectives / Experiments

- 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

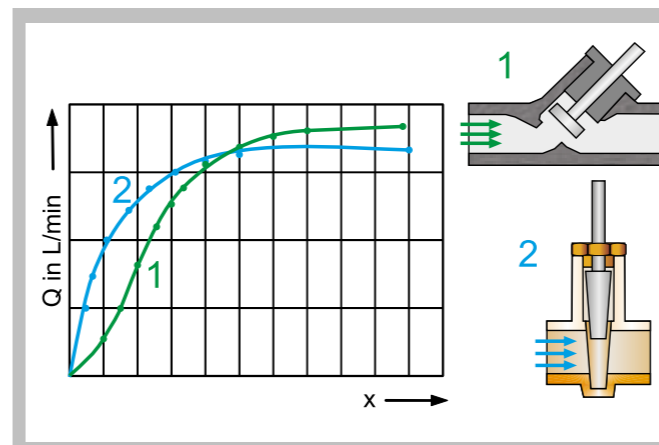
HM 150.11 Losses in a Pipe System



1 tube manometer, 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 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**

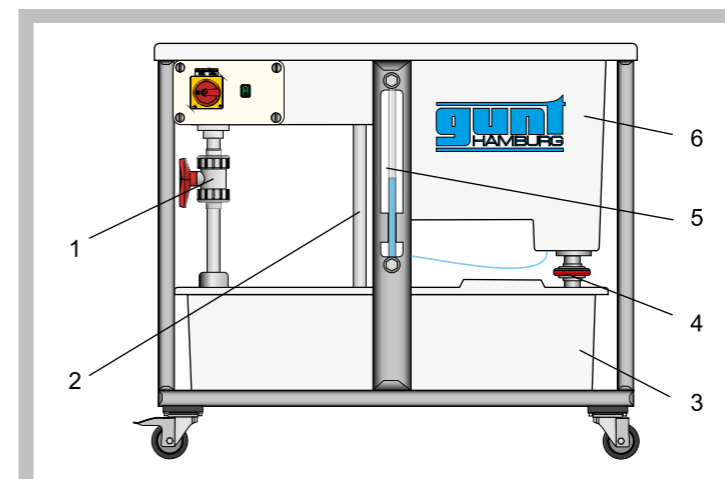
Technical Description

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.

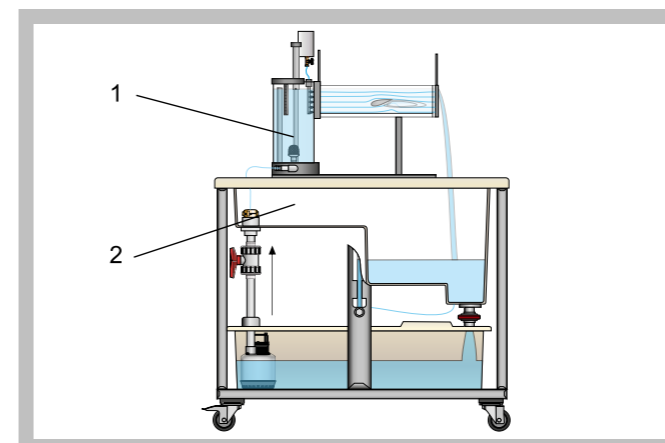
The closed water circuit consists of the underlying storage tank with a powerful submersible pump and the measuring tank arranged above, in which the returning water is collected.

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

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.

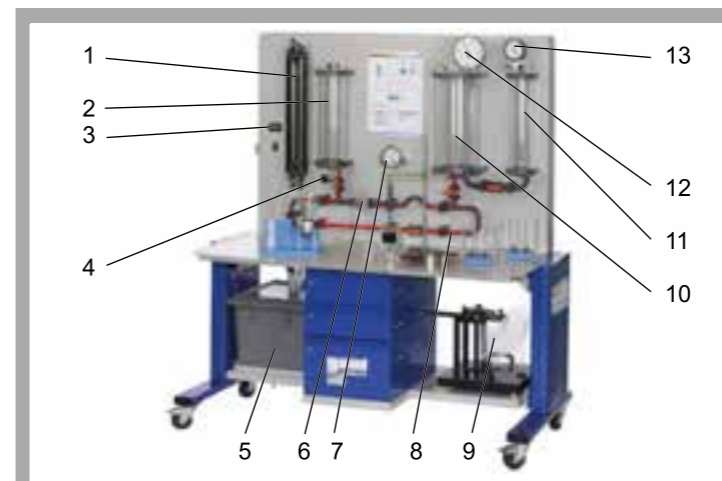
The trainer has its own air and water supply. The closed water circuit includes a supply tank with submersible pump. A compressor is included to generate negative pressures for the experiments with air.

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

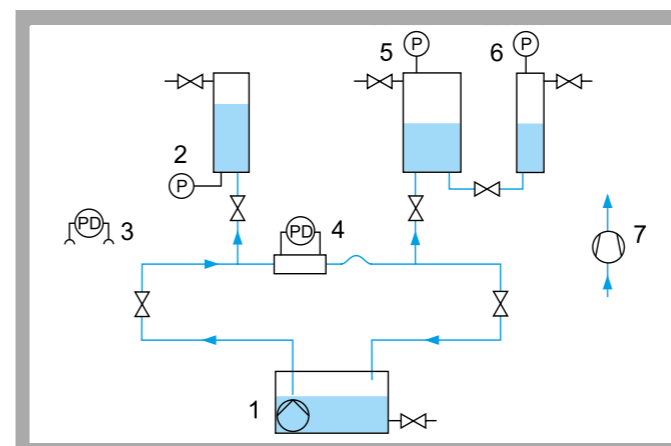
Learning Objectives / Experiments

- 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
- learning of various methods of pressure measurement

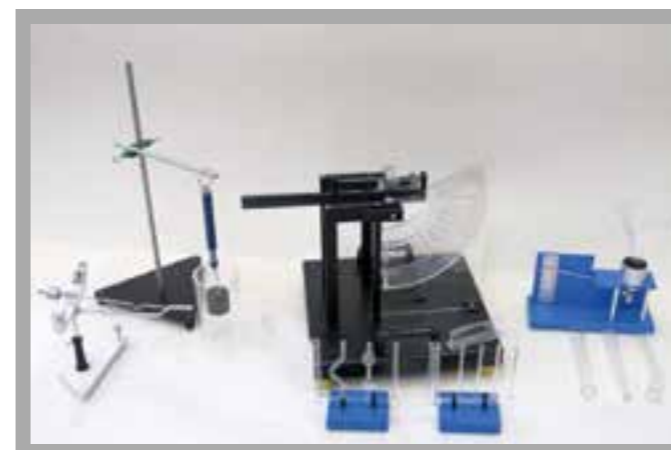
G.U.N.T Gerätebau GmbH, Hanskampring 15-17, D-22885 Barsbüttel, Phone +49 (40) 67 08 54-0, Fax +49 (40) 67 08 54-42, E-mail sales@gunt.de, Web http://www.gunt.de
We reserve the right to modify our products without any notifications.

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

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
We reserve the right to modify our products without any notifications.

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: 9m³/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/cm³, 1x 1...1,2g/cm³

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 135 Determination of the Settling Velocity

Technical Description

The settling velocity of solids in fluids is an important factor in fluid mechanics and process engineering. For example, the settling velocity is the decisive factor when planning sedimentation tanks for water treatment.

HM 135 contains two transparent cylinders for comparative examinations. The two cylinders enable comparing the influence of the sphere diameter, sphere density and different fluids on the settling velocity. Guide tubes in the cover of the two cylinders enable safe insertion of the sphere. Two O-rings per cylinder mark the measuring section. At the lower end of the cylinder there is a sluice through which the spheres can be removed again without significant loss of fluid.

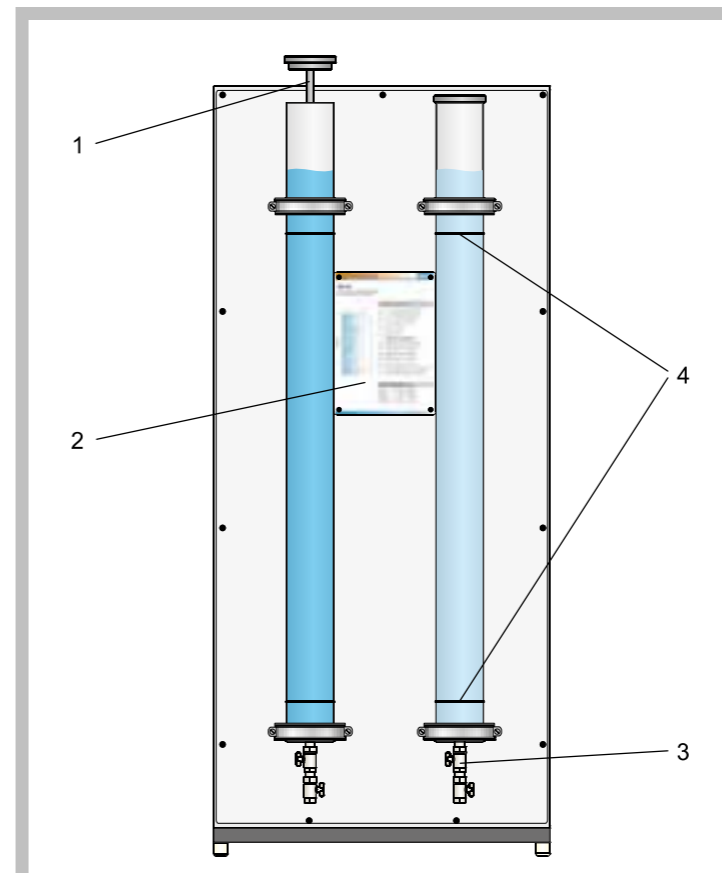
A stopwatch measures the sedimentation time. Two areometers with different measuring ranges enable the determination of the fluid densities.

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

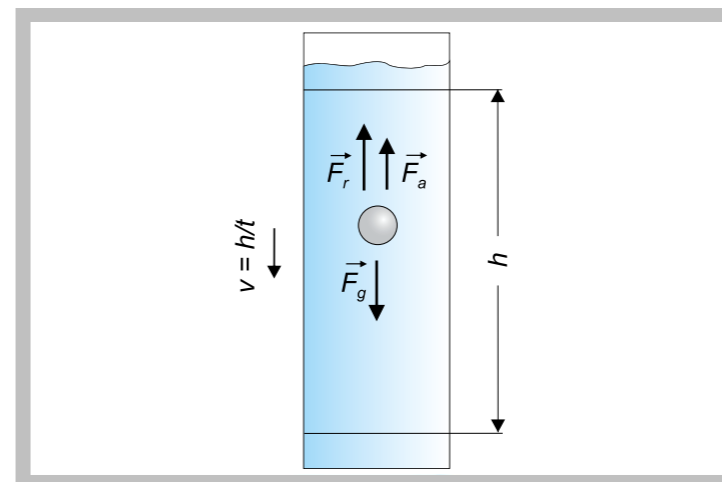
Learning Objectives / Experiments

- influence of the following parameters on the settling velocity of spheres:
 - * diameter of the sphere
 - * density of the sphere
 - * density of the fluid
 - * viscosity of the fluid

* Settling velocity of spheres of various diameters and densities

HM 135 Determination of the Settling Velocity


1 cover with guide tube, 2 info panel, 3 sluice, 4 marking of the measuring section



Determination of the settling velocity
v settling velocity, h sink height, t sedimentation time, F_g weight, F_a lift, F_r drag

Specification

- [1] experimental unit to determine the settling velocity of different spheres
- [2] 2 transparent cylinders
- [3] marking of the measuring section
- [4] cover with guide tube to insert the sphere
- [5] sluice to remove the spheres from the cylinder
- [6] 10 spheres of various densities and diameters
- [7] 2 areometers to determine the density of the fluids
- [8] stopwatch to measure the sedimentation time

Technical Data

- 2 cylinders
 - inner diameter: 92mm each
 - height: 1330mm each
 - sink height: 1000mm each
- Spheres
 - aluminium (density: 2,7kg/dm³)
 - 2x 5mm diameter
 - 2x 10mm diameter
 - polyoxymethylene (POM), density: 1,41kg/dm³
 - 2x 5mm diameter
 - 2x 10mm diameter
 - polyamide (PA), density: 1,13kg/dm³
 - 2x 10mm diameter

- Measuring range
 - density: 1x 0,8...1,0kg/dm³, 1x 1,0...1,2kg/dm³

Dimensions and Weight

- LxWxH: 720x640x1650mm
- Weight: approx. 45kg

Scope of Delivery

- 1 experimental unit
- 1 set of spheres
- 2 areometers
- 1 glass cylinder for areometer
- 1 stopwatch
- 1 set of instructional material

Order Details

070.13500 HM 135 Determination of the Settling Velocity

HM 155 Water Hammer in Pipes


- * Investigation of water hammer and pressure waves in pipes
- * 60m long pipe section
- * Measuring the velocity of sound in water
- * Solenoid valve with adjustable closing time
- * GUNT software for displaying the pressure curve

Technical Description

Water hammer in pipes is a significant problem in engineering as they can cause severe damage to piping, fittings and system components. Water hammer is caused by the inertia effect of the flowing fluid being subjected to an abrupt changes in velocity, e.g. when rapidly closing a valve. Therefore, knowledge about the emergence of water hammer is an important aspect of designing pipework systems.

The HM 155 trainer can be used to study water hammer and pressure waves in long pipelines. Water hammer is generated by closing a valve at the end of the pipe section. The water hammer is then reflected to the beginning of the pipe as an inverted wave. A pressure vessel with air cushion at the start of the pipe section simulates the open beginning of the pipe, so that there is a clear reflection of the wave. In order to achieve reflection times that are large enough, a 60m long pipe section has been installed, which is shaped as a coiled tube to save space.

In experiments, the emergence of water hammer is studied as a function of the valve closing times. The trainer therefore includes two solenoid valves, one with constant closing time and one with adjustable closing time. The resulting pressure oscillations are measured by a pressure sensor and the pressure curve is displayed by the GUNT software.

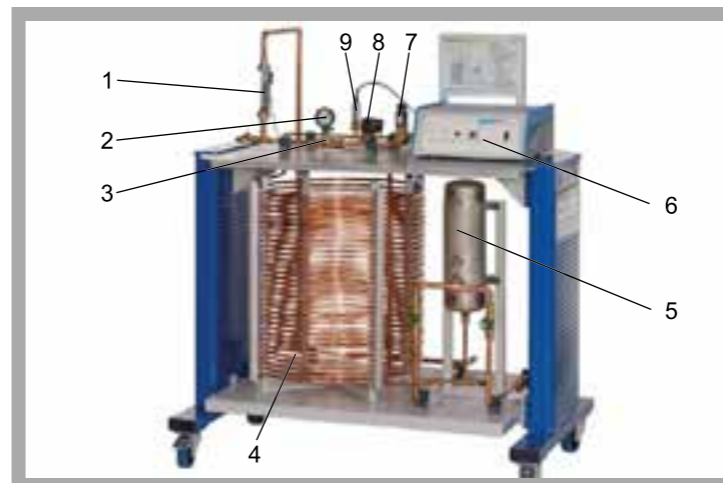
A valve is used to adjust the flow rate. System pressure and flow rate

are displayed. A safety valve protects the system against overpressure.

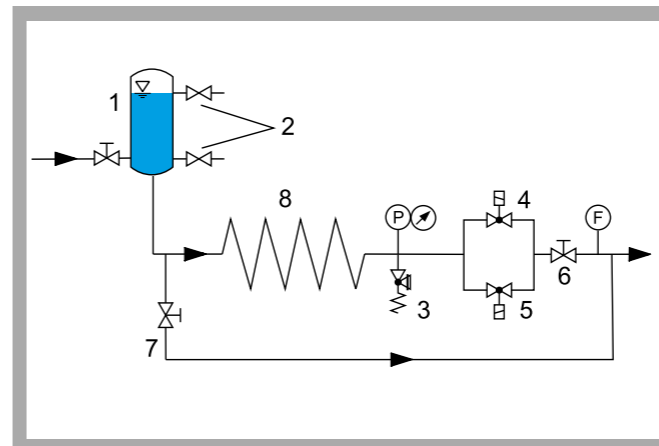
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

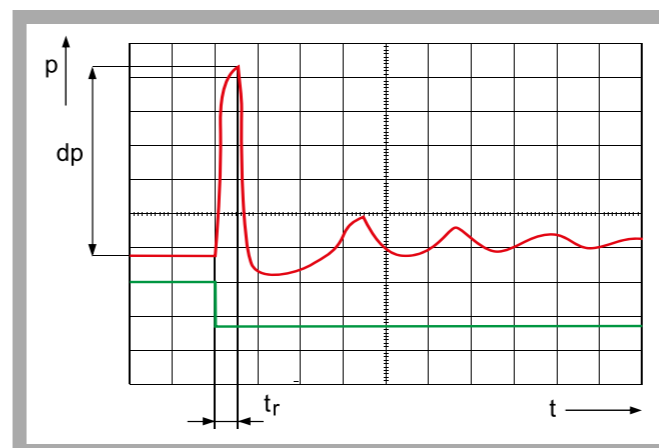
- water hammer as a function of flow rate
- water hammer as a function of valve closing time
- display pressure curve
- determine reflection time
- calculation of the velocity of sound in water

HM 155 Water Hammer in Pipes


1 flow meter, 2 manometer, 3 valve for flow rate adjustment, 4 pipe section, 5 pressure vessel, 6 control unit, 7 adjustable solenoid valve, 8 constant solenoid valve, 9 pressure sensor



1 pressure vessel with air cushion, 2 valves for adjusting the level, 3 safety valve, 4 adjustable solenoid valve, 5 constant solenoid valve, 6 valve for adjusting flow rate, 7 valve for emptying the pressure vessel, 8 pipe section; P pressure, F flow rate



Course of pressure over time at solenoid valve with constant closing time; red: pressure curve, green: trigger signal; p pressure, t time, t_r reflection time, dp: water hammer

Specification

- [1] investigation of water hammer and pressure waves in pipes
- [2] pipe section as coiled tube to save space
- [3] generation of water hammer via solenoid valve with constant closing time
- [4] generation of water hammer via solenoid valve with adjustable closing time
- [5] pressure vessel with air cushion reflects the wave
- [6] safety valve protects against overpressure in the system
- [7] instruments: pressure sensor, rotameter, manometer
- [8] representation of the pressure curves and the flow rate with GUNT software
- [9] GUNT software for data acquisition via USB under Windows Vista or Windows 7

Technical Data

- Solenoid valve, constant closing time
 - closing time: 20...30ms
 - operating pressure: 0...10bar
- Solenoid valve, adjustable closing time
 - closing time: 1...4s
 - operating pressure: 0,2...12bar
- Safety valve: 16bar
- Pipe section, copper
 - length: 60m
 - inner diameter: 10mm
- Pressure vessel: 5L

Measuring ranges

- pressure: 0...16bar
- flow rate: 30...320L/h

Dimensions and Weight

- LxWxH: 1310x790x1500mm
- Weight: approx. 155kg

Required for Operation

- 230V, 50/60Hz, 1 phase or 120V, 60Hz/CSA, 1 phase
- Water connection 300L/h, drain

Scope of Delivery

- 1 trainer
- 1 CD with GUNT software
- 1 set of hoses
- 1 set of instructional material

Order Details

070.15500 HM 155 Water Hammer in Pipes

HM 136 Flow through Packed Columns

Technical Description

Packed columns have a variety of uses in process engineering, waste water and air purification and in biotechnical systems. For example, in an adsorption column the two substances can be brought into close contact using the packing. When used as a fixed bed reactor, the packing carries the catalyst necessary for the reaction. Packing is available in the widest variety of shapes and materials.

Observing the desired flow conditions is vital for proper functioning. Wetting, contact time and flow resistance play a key role. These packed column properties can be studied with the HM 136 trainer, and important phenomena such as the wall effect or the flooding point can be demonstrated.

The central element of the trainer is the transparent packed column. The pressures in the top, middle and bottom of the column are measured, so that the pressure losses in the fixed bed can be determined. The column can be operated with air or water. When operating with water, the direction of flow can be changed, so that even a fully flooded column can be studied, such as in a fixed bed reactor. Operating the column with air and water in counterflow simulates the application as an absorption column. The packed bed is interchangeable, so that a laboratory's own packing can also be tried out.

The experimental unit has its own air and water supply. The closed water circuit consists of storage tank, pump, flow meter and valve. The air supply includes a compressor with flow meter and valve.

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

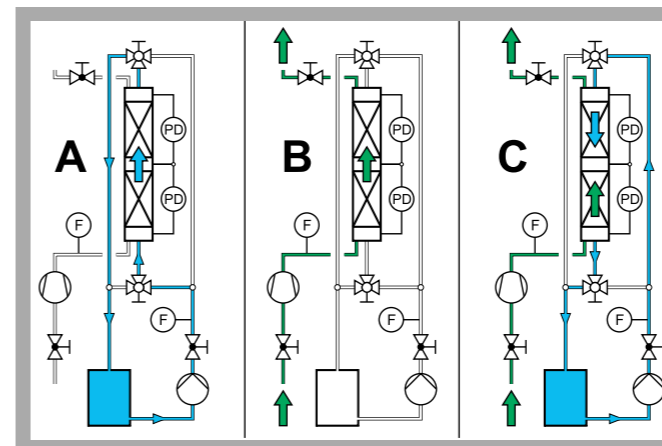
Learning Objectives / Experiments

- function of a packed column
- record pressure loss characteristic curve
- compare operating modes
 - * with water
 - * with air
 - * air/water counterflow mode
- demonstration of
 - * wall effect
 - * stream formation
 - * loading point
 - * flooding point

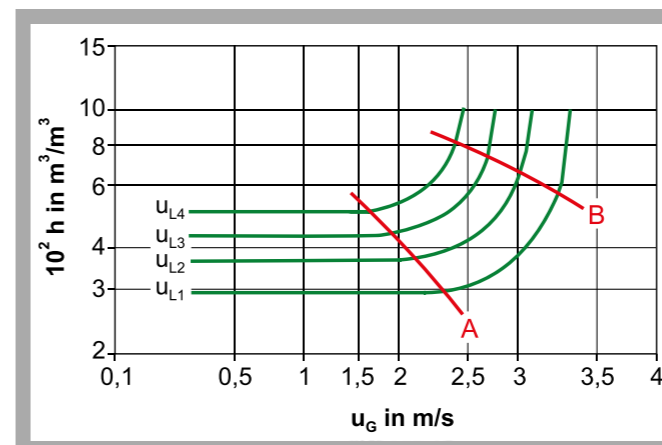
- * Transparent model of a packed column
- * Flow through the column with water or air
- * Parallel flow or counterflow mode

HM 136 Flow through Packed Columns


1 digital pressure indicators, 2 air flow meter, 3 compressor for air, 4 storage tank, 5 pump for water, 6 bottom rising-falling switch valve, 7 water flow meter, 8 two-piece packed column, 9 top rising-falling switch valve



Different operating modes: A water rising, B air rising, C water falling, air rising (counterflow); F flow rate, PD differential pressure



Liquid content of the column at different gas and liquid velocities: A loading point, B flooding point, h specific liquid content, u_G gas velocity, $u_{L1...4}$ specific liquid load

Specification

- [1] trainer for studying the flow in packing layers
- [2] transparent DURAN glass packed column with interchangeable packed bed
- [3] operation with water and/or air
- [4] water-air operation in parallel flow or counterflow
- [5] water direction of flow can be reversed
- [6] closed water circuit with a pump and storage tank
- [7] compressor for air supply
- [8] measurement of flow rate and pressure loss

Technical Data

- Pump
- max. flow rate: 18L/min
 - max. head: 50m
- Compressor
- max. flow rate: 8m³/h
 - max. delivery pressure: 1bar
- Packed column
- inner diameter: 80mm
 - length: 2x 500mm
- Storage tank: 35L

Measuring ranges

- flow rate (air): 1...10m³/s
- flow rate (water): 50...600L/h
- differential pressure: 3x 0...100mbar

Dimensions and Weight

- LxWxH: 1350x790x1980mm
Weight: approx. 200kg

Required for Operation

- 230V, 50Hz, 1 phase

Scope of Delivery

- 1 trainer
- 1 set of tools
- 1 packing package (Raschig rings)
- 1 set of instructional material

Order Details

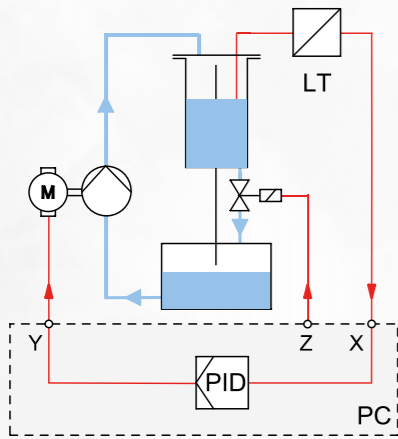
070.13600 HM 136 Flow through Packed Columns

RT 010 – RT 060

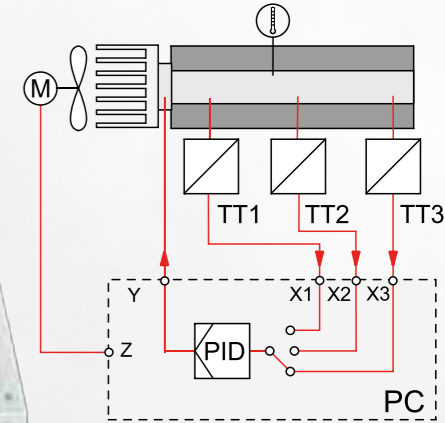
FUNDAMENTALS OF PROCESS CONTROL ENGINEERING

RT 010 *Level Control*

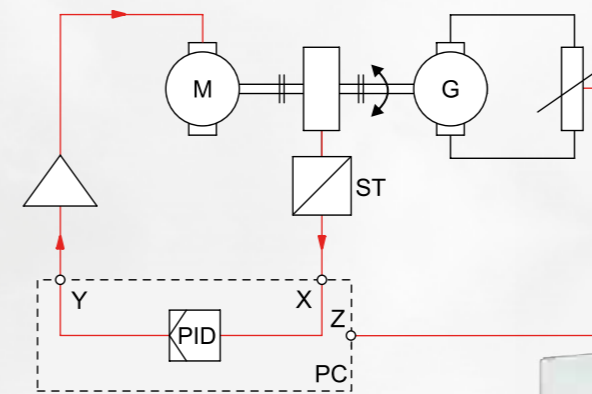
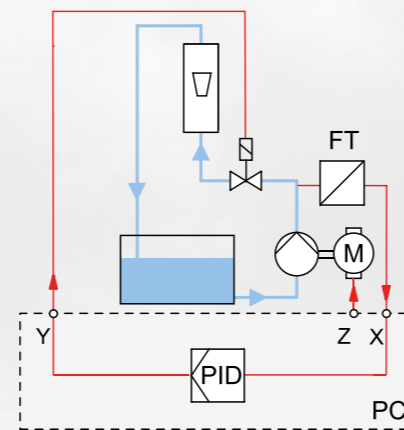
- level recording by pressure sensor
- level control by speed of pump
- electromagnetic valve to generate disturbance variables

RT 040 *Temperature Control*

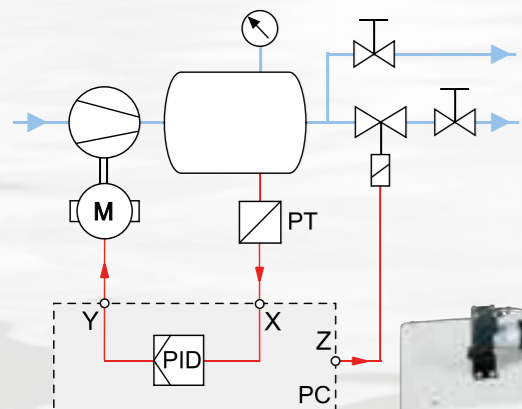
- temperature sensors at three positions
- heating and cooling of a metal bar by Peltier element
- switchable fan to generate disturbance variables

RT 020 *Flow Control*

- turbine wheel flow sensor
- electromagnetic proportional valve as actuator
- variable pump speed to generate disturbance variables

RT 050 *Speed Control*

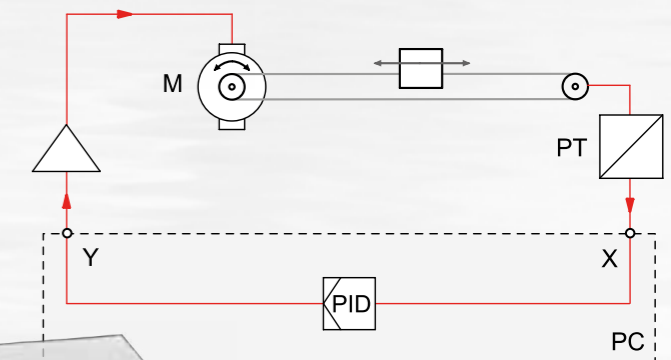
- inductive speed sensor
- speed control by DC motor
- adjustable load to generate disturbance variables

RT 030 *Pressure Control*

- electronic pressure sensor
- speed controlled diaphragm pump as actuator
- solenoid valve to generate disturbance variables

RT 060 *Position Control*

- rotary encoder as displacement sensor
- position control of a carriage by gear motor
- two microswitches to shut down at end positions



RT 010 Training System: Level Control, HSI

Technical Description

This compact experimental unit offers every opportunity to learn the fundamentals of control engineering through experimentation on a level control system.

The experimental set-up is mounted in a housing which also accommodates all the electronics. The transparent level-controlled tank is fed from the storage tank with the aid of a speed-controlled pump. The liquid level is measured using a pressure sensor. The sensor output signal is sent to the software controller. The controller's output signal influences the speed of the pump motor and therefore delivery flow rate. To investigate the influence of disturbance variables, an electromagnetic proportional valve in the tank outlet can be activated by the software.

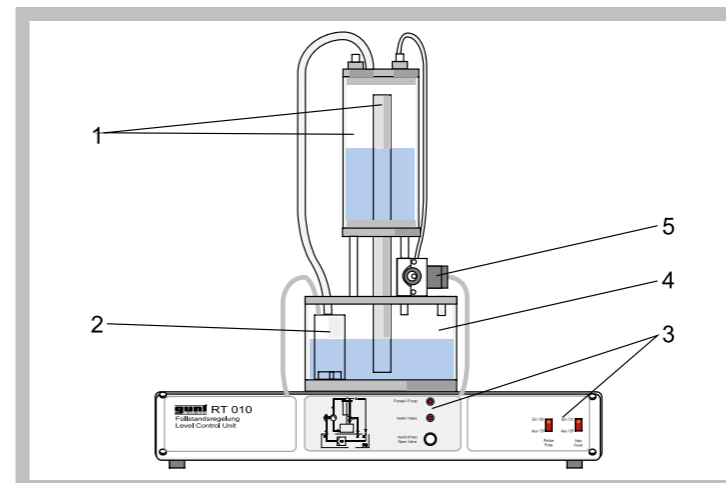
The powerful state-of-the-art software is an integral part of the training system, embodying the principle of hardware/software integration (HSI). It enables the experiments to be conducted and evaluated in a user-friendly manner. The software has network capability. The link between the experimental unit and the PC is made via a USB port.

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

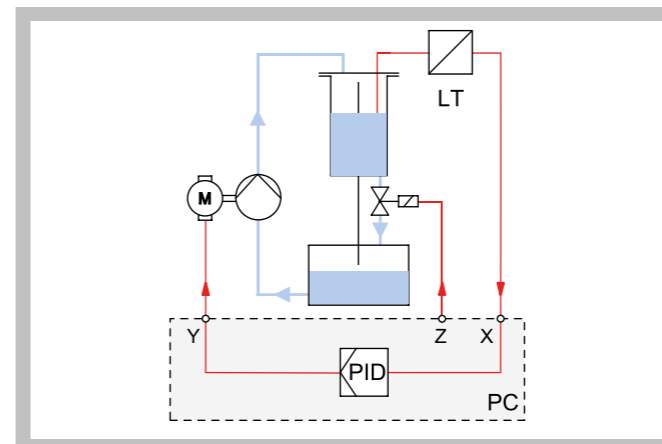
Learning Objectives / Experiments

- fundamentals of control engineering based on the example of a level control system with integral control action
- open loop control response
- investigation of a controlled system without feedback
- effects of different controller parameters and methods on the response of the closed loop system
- recording of step responses
 - * reference variable
 - * disturbance variable
- controller optimisation
- software-based controlled system simulation
 - * comparison of different controlled system parameters

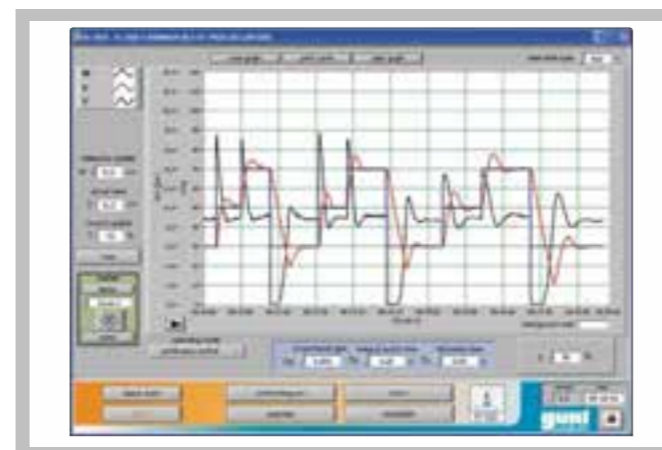
- * Experimental unit with clear level control system
- * Extensive range of experiments on fundamentals of control engineering
- * State-of-the-art software for all experimental units of the RT 010 - RT 060 series, with extensive controller and recorder functions
- * Software-based simulation of the controlled system

RT 010 Training System: Level Control, HSI


1 level-controlled tank with overflow, 2 pump, 3 displays and controls, 4 storage tank, 5 proportional valve



Process schematic



Software screenshot: PI control of level control system: step response to change in reference variable with different values for K_p and T_n

Specification

- [1] experimental unit for control engineering experiments
- [2] level control process with transparent tank
- [3] speed-controlled pump
- [4] level measurement by pressure sensor
- [5] disturbance variables generated by electromagnetic proportional valve in tank outlet
- [6] tank with overflow and graduated scale
- [7] software-based controlled system simulation
- [8] process schematic on front panel
- [9] networkable GUNT software via USB under Windows Vista or Windows 7

Technical Data

- Level-controlled tank
 - capacity: 1200mL
- Storage tank
 - capacity: 3700mL
- Pump
 - power consumption: 18W
 - max. flow rate: 8L/min
 - max. head: 6m
- Proportional valve: K_{vs} : 0,7m³/h
- Pressure sensor: 0...30mbar (0...300mm)
- Software controller configurable as P, PI, PID and switching controller
- Software
 - process schematic with controller type selection (manual, continuous controller, two- or three-point controller, programmer)
 - time functions
 - simulation function
 - disturbance variable input

Dimensions and Weight

- LxWxH: 600x450x800mm
- Weight: approx. 22kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 GUNT software CD + USB cable
- 1 hose
- 1 handbook: fundamentals of control engineering (RT 010 - RT 060)
- 1 manual for RT 010

Order Details

080.01000 RT 010 Training System:
Level Control, HSI

RT 020 Training System: Flow Control, HSI


- * **Experimental unit with clear flow control system**
- * **Extensive range of experiments on fundamentals of control engineering**
- * **State-of-the-art software for all experimental units of the RT 010 - RT 060 series, with extensive controller and recorder functions**
- * **Software-based simulation of the controlled system**

Technical Description

This compact experimental unit offers every opportunity to learn the fundamentals of control engineering through experimentation on a flow control system. The experimental set-up is mounted in a housing which accommodates all the electronics.

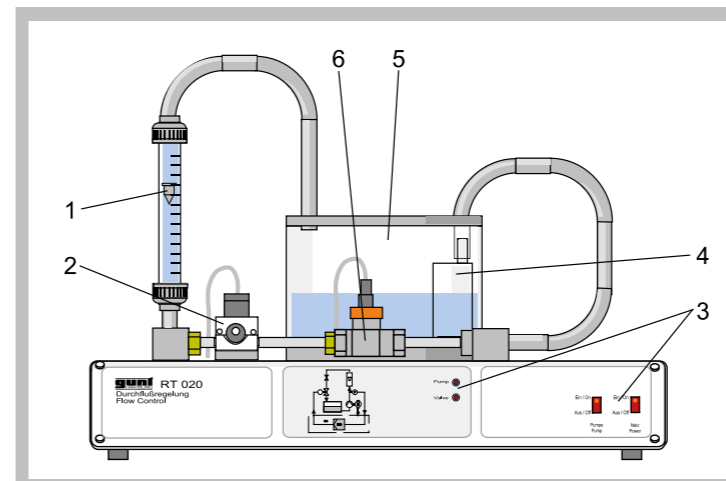
A piping system with two flowmeters is supplied with flow by a speed-controlled pump from the transparent storage tank. The rotameter offers the advantage that the flow rate can be observed directly at any time. The flow rate is measured by a turbine wheel flow sensor. The sensor output signal is sent to the software controller. The output signal from the controller influences the setting of an electromagnetic proportional valve. To investigate the influence of disturbance variables, the pump speed can be altered by way of the software.

The powerful state-of-the-art software is an integral part of the training system, embodying the principle of hardware/software integration (HSI). It enables the experiments to be conducted and evaluated in a user-friendly manner. The software has network capability. The link between the experimental unit and the PC is made via a USB port.

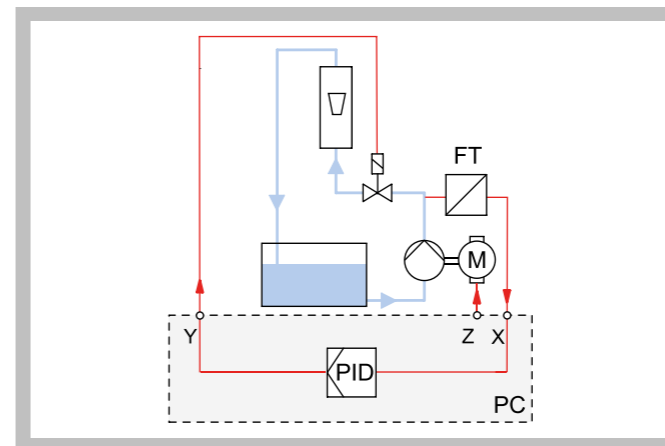
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

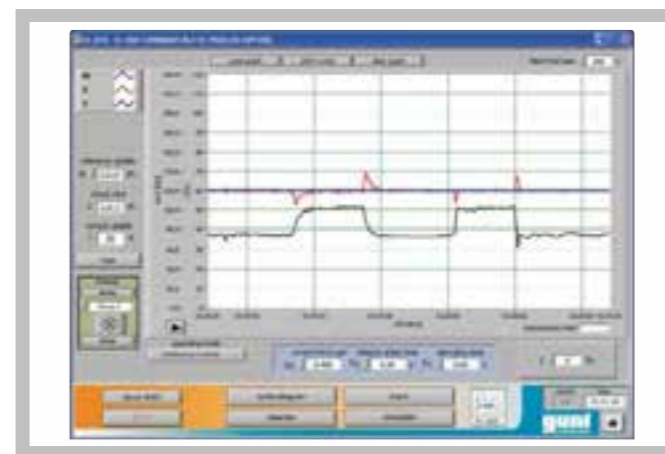
- fundamentals of control engineering based on the example of a rapid flow control system
- open loop control response
- effects of different controller parameters and methods on the response of the closed loop system
- recording of step responses
 - * reference variable
 - * disturbance variable
- controller optimisation
- software-based controlled system simulation
 - * comparison of different controlled system parameters

RT 020 Training System: Flow Control, HSI


1 rotameter, 2 proportional valve, 3 displays and controls, 4 pump, 5 storage tank, 6 flow sensor



Process schematic



Software screenshot: flow control, controller with PI response with different values for K_p and T_n , introduction of a disturbance variable

Specification

- [1] experimental unit for control engineering experiments
- [2] flow control system with variable-area flowmeter
- [3] electromagnetic proportional valve as actuator
- [4] turbine wheel flow sensor
- [5] generation of disturbance variables by altering pump speed
- [6] software-based controlled system simulation
- [7] process schematic on front panel
- [8] networkable GUNT software via USB under Windows Vista or Windows 7

Technical Data

- Storage tank
 - capacity: approx. 3000mL
- Pump
 - power consumption: 18W
 - max. flow rate: 8L/min
 - max. head: 6m
- Rotameter: 20...250L/h
- Proportional valve: Kvs: 0,7m³/h
- Flow sensor: 0,5...3L/min
- Software controller configurable as P, PI, PID and switching controller
- Software
 - process schematic with controller type selection (manual, continuous controller, two- or three-point controller, programmer)
 - time functions
 - simulation function
 - disturbance variable input

Dimensions and Weight

- LxWxH: 600x450x600mm
- Weight: approx. 21kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 hose
- 1 GUNT software CD + USB cable
- 1 handbook: fundamentals of control engineering (RT 010 - RT 060)
- 1 manual for RT 020

Order Details

- 080.02000 RT 020 Training System:
Flow Control, HSI

RT 030 Training System: Pressure Control, HSI


- * **Experimental unit with diaphragm gas pump and pressure tank**
- * **Extensive range of experiments on fundamentals of control engineering**
- * **State-of-the-art software for all experimental units of the RT 010 - RT 060 series, with extensive controller and recorder functions**
- * **Software-based simulation of the controlled system**

Technical Description

This compact experimental unit offers every opportunity to learn the fundamentals of control engineering through experimentation on a pressure control system.

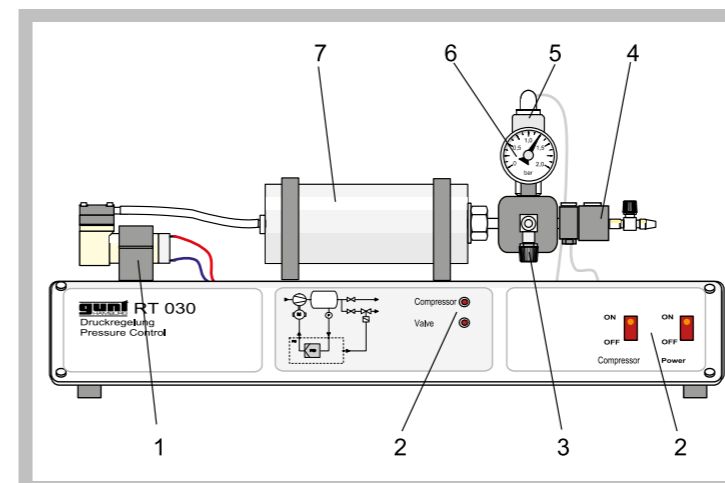
The experimental set-up is mounted on a housing which accommodates all the electronics. The pressure tank is charged with compressed air by a diaphragm gas pump. The advantage of the dial-gauge manometer is that the pressure in the tank can be observed directly at any time. The pressure is measured using a pressure sensor. The sensor output signal is sent to the software controller. The output signal from the controller influences the speed of the diaphragm gas pump and hence the flow rate. An air consumer is simulated by way of a flow control valve. A solenoid valve through which air can escape can be activated by the software to investigate the influence of disturbance variables.

The powerful state-of-the-art software is an integral part of the training system, embodying the principle of hardware/software integration (HSI). It enables the experiments to be conducted and evaluated in a user-friendly manner. The software has network capability. The link between the experimental unit and the PC is made via a USB port.

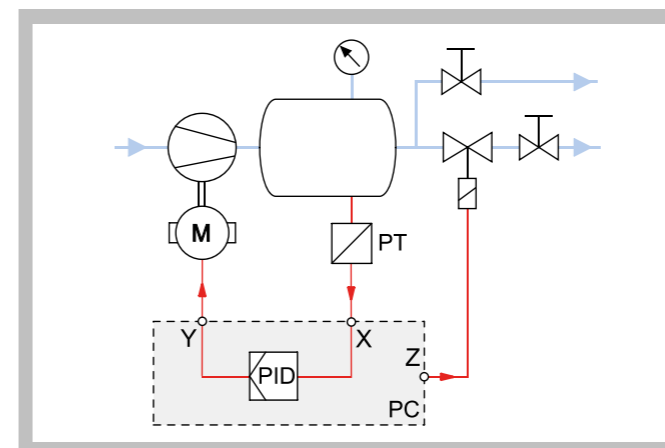
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

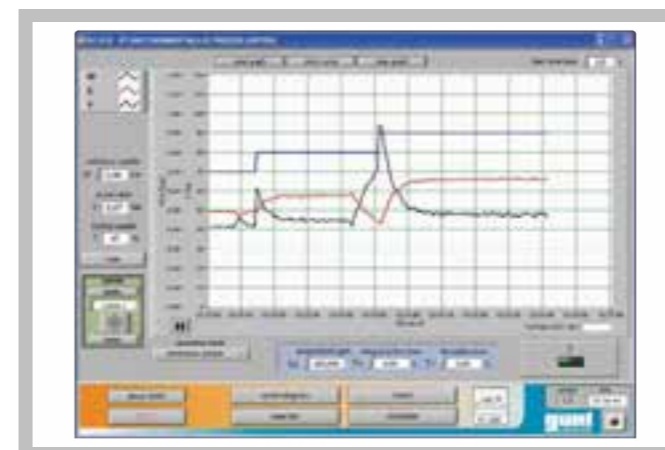
- fundamentals of control engineering based on the example of a pressure control system with PT_1 behaviour
- open loop control response
- effects of different controller parameters and methods on the response of the closed loop system
- recording of step responses
- * reference variable
- * disturbance variable
- controller optimisation
- software-based controlled system simulation
- * comparison of different controlled system parameters

RT 030 Training System: Pressure Control, HSI


1 diaphragm gas pump, 2 displays and controls, 3 drain valve, 4 solenoid valve to generate disturbance variables, 5 pressure sensor, 6 manometer, 7 pressure tank



Process schematic



Software screenshot: continuous P control: a step of the reference variable results in a permanent control deviation

Specification

- [1] experimental unit for control engineering experiments
- [2] pressure control in a tank
- [3] speed controlled diaphragm gas pump
- [4] electronic pressure sensor
- [5] solenoid valve to generate disturbance variables
- [6] software-based controlled system simulation
- [7] process schematic on front panel
- [8] networkable GUNT software via USB under Windows Vista or Windows 7

Technical Data

- Diaphragm gas pump
 - max. flow rate: 3L/min
 - max. positive pressure: 1bar
 - max. negative pressure: 250mbar abs.
- Pressure tank
 - capacity: 400mL
 - operating pressure: 1bar
 - max. pressure: 10bar
- Pressure control range: 0...1bar
- Solenoid valve: K_{vs} : 0,11m³/h
- Pressure transducer: 0...1bar
- Manometer: 0...1bar
- Software controller configurable as P, PI, PID and switching controller
- Software
 - process schematic with controller type selection (manual, continuous controller, two- or three-point controller, programmer)
 - time functions
 - simulation function
 - disturbance variable input

Dimensions and Weight

- LxWxH: 600x450x340mm
- Weight: approx. 18kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 GUNT software CD + USB cable
- 1 handbook: fundamentals of control engineering (RT 010 - RT 060)
- 1 manual for RT 030

Order Details

080.03000 RT 030 Training System:
Pressure Control, HSI

RT 040 Training System: Temperature Control, HSI


- * Experimental unit with temperature control system
- * Extensive range of experiments on fundamentals of control engineering
- * Heating and cooling with Peltier element
- * State-of-the-art software for all experimental units of the RT 010 - RT 060 series, with extensive controller and recorder functions
- * Software-based simulation of the controlled system

Technical Description

This compact experimental unit offers every opportunity to learn the fundamentals of control engineering through experimentation on a temperature control system.

The experimental set-up is mounted on a housing which accommodates all the electronics. A metal bar, which is thermally insulated with cladding, is heated or cooled at one end by a Peltier element. Three temperature transducers along the axis of the bar allow the variation in temperature along the length of the bar, and hence the associated thermal lags, to be obtained for differing operating conditions. A dial-gauge thermometer offers the advantage that the temperature can be read off directly at any time. The temperature is measured using a thermal resistor (PTC). The sensor output signal is sent to the software controller. The output signal from the controller influences the operating voltage of the Peltier element and hence the heating capacity. A fan that dissipates part of the heating power can be activated by the software to investigate the influence of disturbance variables.

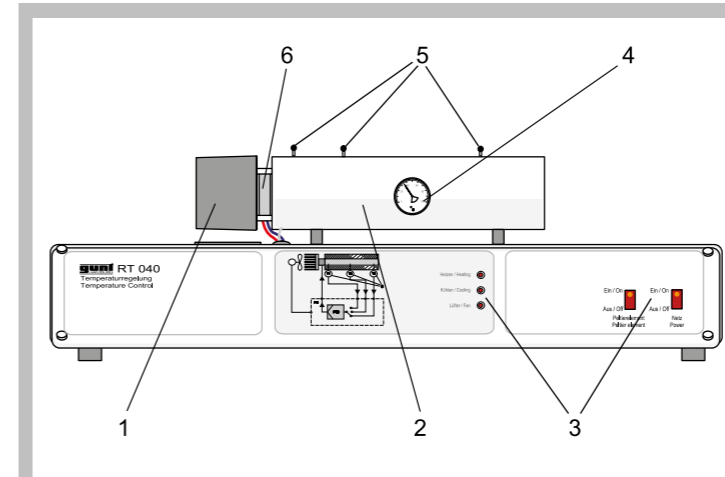
The powerful state-of-the-art software is an integral part of the training system, embodying the principle of hardware/software integration (HSI). It enables the experiments to be conducted and evaluated in a user-

friendly manner. The software has network capability. The link between the experimental unit and the PC is made via a USB port.

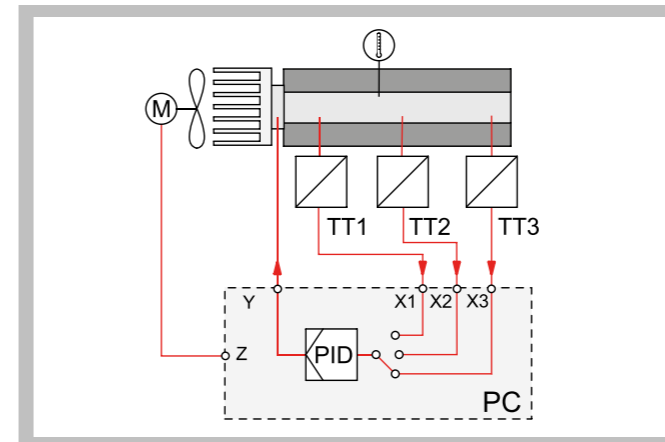
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

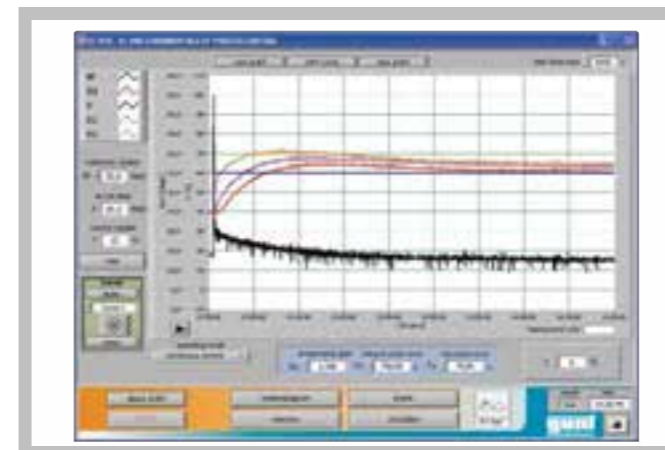
- fundamentals of control engineering based on the example of a temperature control system. System dead time can be obtained from the response
- open loop control response.
- effects of different controller parameters and methods on the response of the closed loop system
- recording of step responses
- * reference variable
- * disturbance variable
- controller optimisation
- software-based controlled system simulation
- * comparison of different controlled system parameters

RT 040 Training System: Temperature Control, HSI


1 fan, 2 bar in cladding tube, 3 displays and controls, 4 thermometer, 5 temperature sensor, 6 heater/cooler



Process schematic



Software screenshot: step response to reference variable with PID controller with non-optimised values for K_p , T_n and T_v

Specification

- [1] experimental unit for control engineering experiments
- [2] temperature control of a heated metal bar
- [3] heating and cooling by Peltier element
- [4] temperature sensors at 3 different points along axis of bar to establish thermal lags
- [5] software activated fan to generate disturbance variables
- [6] software-based controlled system simulation
- [7] process schematic on front panel
- [8] networkable GUNT software via USB under Windows Vista or Windows 7

Technical Data

Heated bar: DxL: 20x200mm, aluminium
Peltier element

- power consumption depending on temperature
- power at 300K: 38,2W
- power at 50°C: 44,3W

- operated by DC voltage

Fan

- power consumption: 2W
- max. flow rate: 40m³/h

Temperature sensor: 0...100°C

Thermometer: 0...100°C

Temperature control range: 0...100°C

Software controller configurable as P, PI, PID and switching controller

Software

- process schematic with controller type selection (manual, continuous controller, two- or three-point controller, programmer)
- time functions
- simulation function
- disturbance variable input

Dimensions and Weight

LxWxH: 600x450x260mm

Weight: approx. 16kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 GUNT software CD + USB cable
- 1 handbook: Fundamentals of control engineering (RT 010 - RT 060)
- 1 manual for RT 040

Order Details

080.04000 RT 040 Training System:
Temperature Control, HSI

RT 050 Training System: Speed Control, HSI


- * Experimental unit with speed control system
- * Extensive range of experiments on fundamentals of control engineering
- * State-of-the-art software for all experimental units of the RT 010 - RT 060 series, with extensive controller and recorder functions
- * Software-based simulation of the controlled system

Technical Description

This compact experimental unit offers every opportunity to learn the fundamentals of control engineering through experimentation on a speed control system.

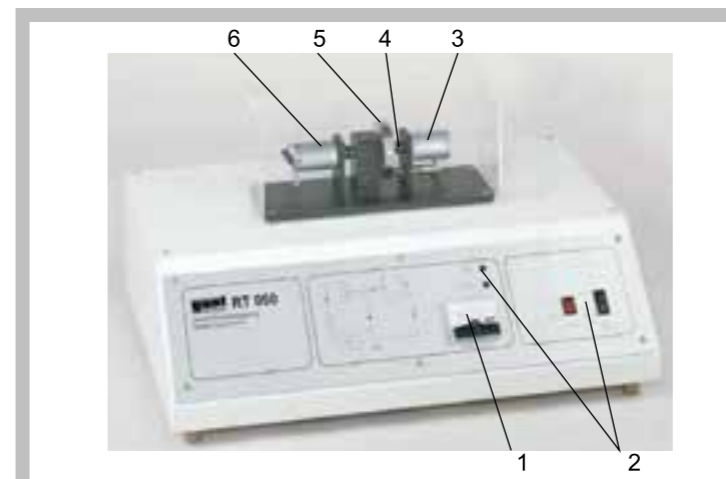
The experimental set-up is mounted on a housing which accommodates all the electronics. A transparent protective cover permits safe observation of the experiments. A DC motor drives a shaft with a mass flywheel. The dial gauge allows the speed to be read off directly at any time. The speed is measured inductively using a speed sensor. The output signal from the sensor is sent to the software controller. The output signal from the controller influences the motor current. A generator acting as a mechanical resistance to shaft rotation can be activated by the software to study the influence of disturbance variables.

The powerful state-of-the-art software is an integral part of the training system, embodying the principle of hardware/software integration (HSI). It enables the experiments to be conducted and evaluated in a user-friendly manner. The software has network capability. The link between the experimental unit and the PC is made via a USB port.

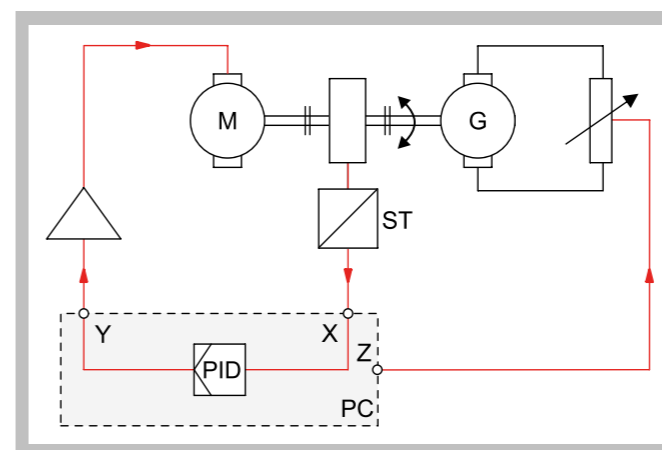
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

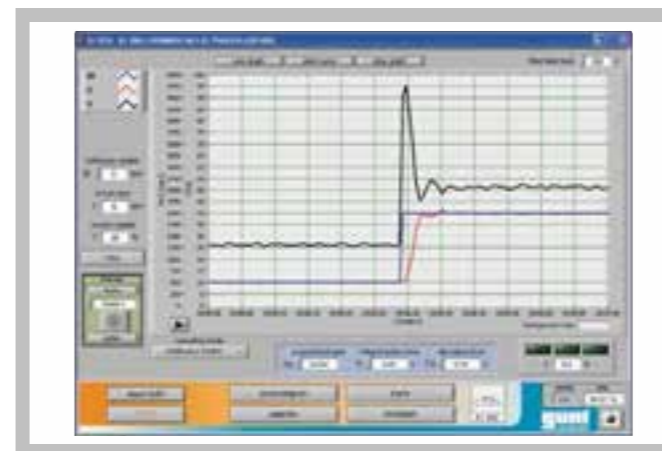
- fundamentals of control engineering based on the example of a speed control system with PT_1 behaviour
- open loop control response
- effects of different controller parameters and methods on the response of the closed loop system
- recording of step responses
 - * reference variable
 - * disturbance variable
- controller optimisation
- software-based controlled system simulation
 - * comparison of different controlled system parameters

RT 050 Training System: Speed Control, HSI


1 tachometer, 2 displays and controls, 3 generator, 4 speed sensor, 5 rotor, 6 motor



Process schematic



Software screenshot: step response to change in reference variable with PID controller (acceptable control quality)

Specification

- [1] experimental unit for control engineering experiments
- [2] speed control of a DC motor with shaft and flywheel
- [3] transparent protective cover for motor/generator set
- [4] inductive speed sensor
- [5] generation of disturbance variables by adjustable generator load
- [6] software-based controlled system simulation
- [7] process schematic on front panel
- [8] networkable GUNT software via USB under Windows Vista or Windows 7

Technical Data
Motor

- max. speed: 4500min^{-1}
- max. motor power output: 10W
- max. torque: $1,7\text{Ncm}$

Generator

- max. speed: 4500min^{-1}
- max. power output: 10W
- max. torque: $1,7\text{Ncm}$

Tachometer (analogue): $0 \dots 6.000\text{min}^{-1}$

Software controller configurable as P, PI and PID controller

Software

- process schematic with controller type selection (manual, continuous controller, programmer)
- time functions
- simulation function
- disturbance variable input

Dimensions and Weight

LxWxH: $600 \times 450 \times 310\text{mm}$
Weight: approx. 18kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 GUNT software CD + USB cable
- 1 handbook: fundamentals of control engineering (RT 010 - RT 060)
- 1 manual for RT 050

Order Details

080.05000 RT 050 Training System:
Speed Control, HSI

RT 060 Training System: Position Control, HSI


- * Experimental unit with clear linear position control system
- * Extensive range of experiments on fundamentals of control engineering
- * State-of-the-art software for all experimental units of the RT 010 - RT 060 series, with extensive controller and recorder functions
- * Software-based simulation of the controlled system

Technical Description

This compact experimental unit offers every opportunity to learn the fundamentals of control engineering through experimentation on a linear position control system.

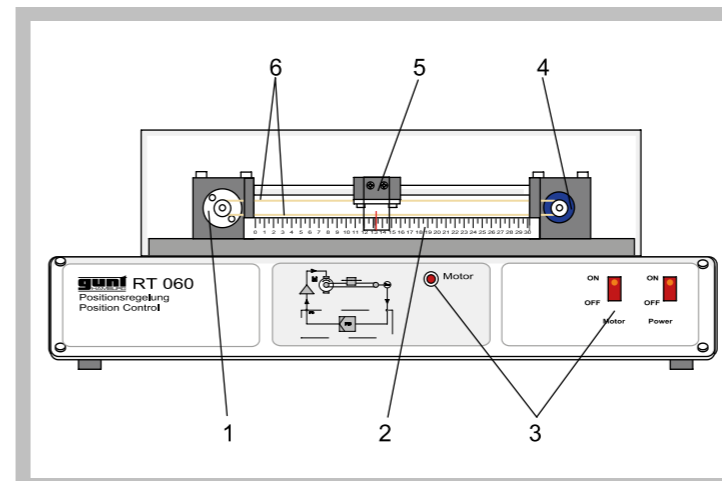
The experimental set-up is mounted on a housing which accommodates all the electronics. A transparent protective cover permits safe observation of the experiments. A carriage can be moved by a DC motor via a toothed belt. The linear positioning is measured by a rotary encoder and delivered as a voltage signal. The output signal from the sensor is sent to the software controller. The output signal from the controller influences the motor current. The motor is automatically shut down if the carriage reaches one of the two end positions.

The powerful state-of-the-art software is an integral part of the training system, embodying the principle of hardware/software integration (HSI). It enables the experiments to be conducted and evaluated in a user-friendly manner. The software has network capability. The link between the experimental unit and the PC is made via a USB port.

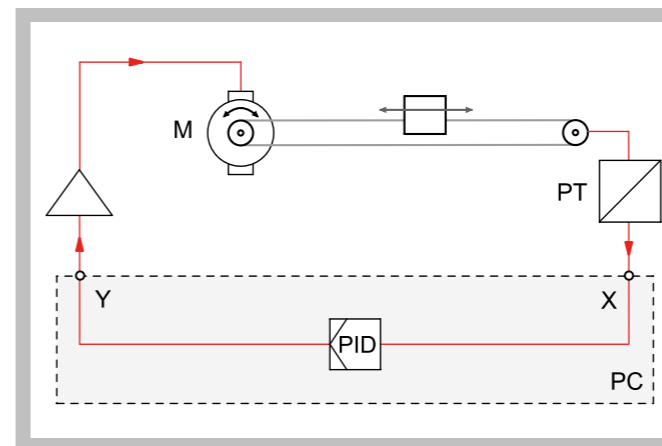
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

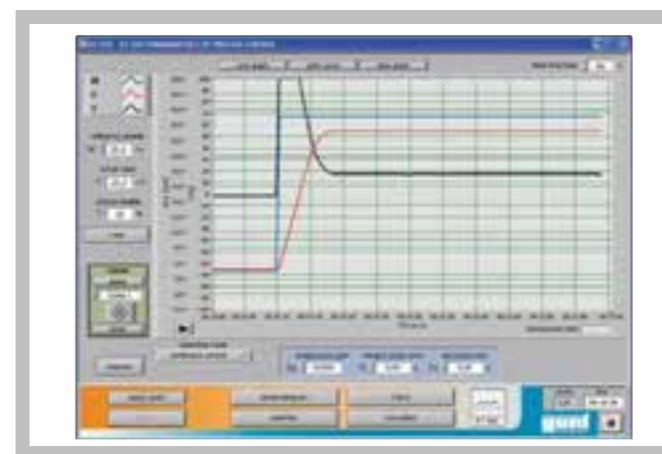
- fundamentals of control engineering based on the example of a linear position control system with integral control action
- open loop control response
- effects of different controller parameters and methods on the response of the closed loop system
- recording of step responses
 - * reference variable
- controller optimisation
- software-based controlled system simulation
 - * comparison of different controlled system parameters

RT 060 Training System: Position Control, HSI


1 motor, 2 scale, 3 displays and controls, 4 rotary encoder, 5 carriage, 6 toothed belt



Process schematic



Software screenshot: step response to change in reference variable with P controller (permanent control deviation)

Specification

- [1] experimental unit for control engineering experiments
- [2] linear position control of carriage with linear drive and gear motor
- [3] rotary encoder as displacement sensor
- [4] transparent protective cover
- [5] 2 microswitches to shut down at end positions
- [6] software-based controlled system simulation
- [7] process schematic on front panel
- [8] networkable GUNT software via USB under Windows Vista or Windows 7

Technical Data

- DC motor
 - transmission ratio: $i=50$
 - speed: 85min^{-1}
 - torque: 200Nmm
- Travel: max. 300mm
- Max. traverse rate: 45mm/s
- Scale: $0\text{...}300\text{mm}$
- Software controller configurable as P, PI, PID Software
 - process schematic with controller type selection (manual, continuous controller, programmer)
 - time functions
 - simulation function

Dimensions and Weight

- LxWxH: $600 \times 450 \times 280\text{mm}$
- Weight: approx. 20kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 GUNT software CD + USB cable
- 1 handbook: fundamentals of control engineering (RT 010 - RT 060)
- 1 manual for RT 060

Order Details

080.06000 RT 060 Training System:
Position Control, HSI

RT 800 PLC Application: Mixing Process

Technical Description

This trainer for PLC applications can be used to create complex PLC control functions from the field of process engineering, particularly for processes involving metering and mixing. The system consists of the base frame with a storage tank, a centrifugal pump and a demonstration panel on which all components are clearly laid out. A pump delivers water to three tanks, controlled via solenoid valves. The level of water in the three tanks is monitored by capacitive proximity switches with adjustable sensitivity. The fluid from the three tanks can be mixed together in the downstream mixing tank. The mixing tank is also equipped with three proximity switches. A stirring machine assists the mixing process. All the tanks are transparent, so the conveying and mixing processes are clearly observable.

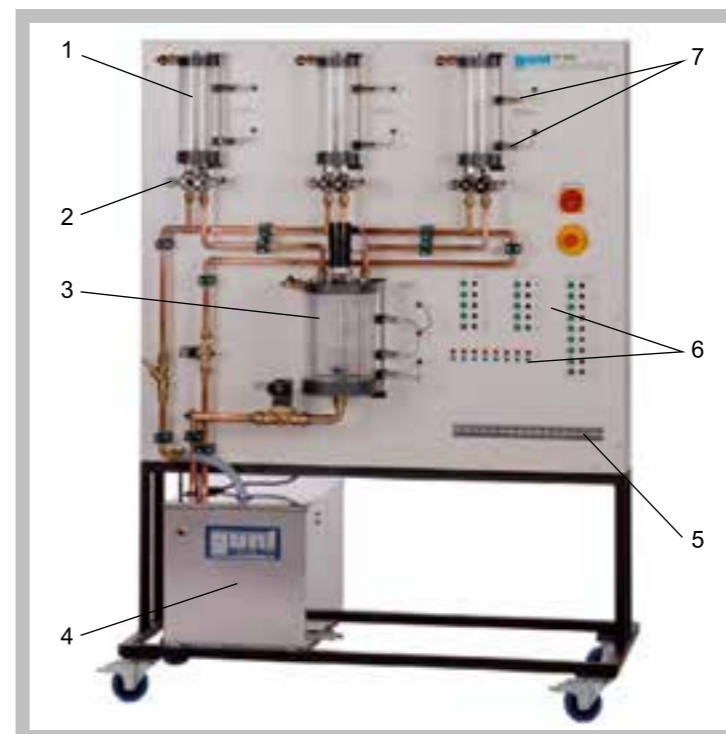
The trainer features a lab jack panel by which the signals from the capacitive proximity switches can be processed by PLC, and all the solenoid valves can be individually controlled. PLC systems from different manufacturers can be used. A rail on the model's front panel is provided so as to allow for connection of the PLC. Although a PLC is not included in the package, the operation of the system can be checked without one. We recommend the use of PLC module IA 130.

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

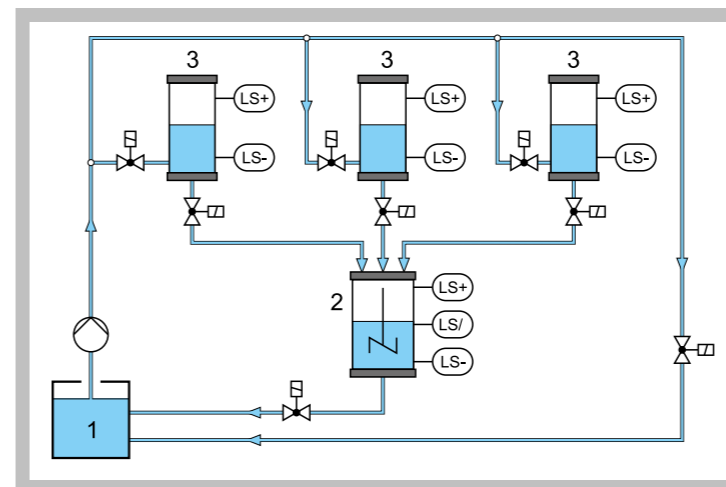
Learning Objectives / Experiments

- planning and implementation of a PLC controlled mixing process
- familiarisation with terms and symbols
- presentation of circuits
- functionality test of all sensors and actuators
- sensitivity adjustment of the capacitive proximity switches
- procedure for connecting up the PLC
- together with PLC module: performance of complex PLC control functions using a complex example from the field of process engineering
- discontinuous metering and mixing

- * **Trainer for control of discontinuous mixing processes by PLC**
- * **Use of standard industrial components**
- * **Capacitive proximity switches as level sensors**
- * **Built-in power supply unit to power all the components and the PLC**

RT 800 PLC Application: Mixing Process


1 measuring tank, 2 solenoid valve, 3 mixing tank with stirring machine, 4 storage tank, 5 rail for mounting of a PLC system, 6 lab jack panel for connection of a PLC, 7 level sensor



Process schematic: 1 storage tank, 2 mixing tank, 3 measuring tank; LS level sensors (+: high, /: middle, -: low)

Specification

- [1] clearly laid out trainer as basis for the use of a PLC in a process control application involving mixing processes
- [2] transparent mixing tank with 3 capacitive proximity switches to monitor the level
- [3] 3 transparent measuring tanks, each with 2 capacitive proximity switches
- [4] metering from the 3 measuring tanks into the mixing tank via solenoid valves
- [5] mixing assisted by stirring machine in mixing tank
- [6] proximity switch signals processed by PLC via lab jack panel
- [7] control of the 8 solenoid valves, the pump and the agitator also by PLC via lab jack panel
- [8] capacitive proximity switches with adjustable sensitivity
- [9] closed water circuit with centrifugal pump and stainless steel storage tank
- [10] power supply to all components and to PLC by built-in power supply unit

Technical Data

- Centrifugal pump (submersible pump)
- power consumption: 430W
- max. flow rate: 150L/min
- max. head: 7m

Tanks

- storage tank: 70L
- 3 measuring tanks: each 1500mL
- mixing tank: 7L

Capacitive proximity switches, NO contacts
2/2-way solenoid valves DN 8 and DN 20
Power supply unit: 24VDC, 8A

Dimensions and Weight

LxWxH: 1380x610x1850mm
Weight: approx. 145kg

Required for Operation

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

Scope of Delivery

- 1 trainer
- 1 set of instructional material

Order Details

080.80000 RT 800 PLC Application:
Mixing Process

IA 130 PLC Module


- * **Self-contained PLC module for basic exercises**
- * **Suitable for use in complex applications**
- * **Programming software to IEC 61131-3**

Technical Description

The IA 130 can be used to perform basic exercises on a PLC (programmable logic controller). A PLC is essentially a computer adapted to the needs of industry. Its inputs and outputs are not designed for humans, but for use in the control of machines. Machine and operator interact solely by way of limit switches, momentary-contact switches or photoelectric switches.

The front panel is designed as a laboratory patchboard, where the input ports and output ports of the PLC can be connected to switches and displays via laboratory cables. In order to write programs the PLC must be connected to a PC (not supplied) via an RS232 interface.

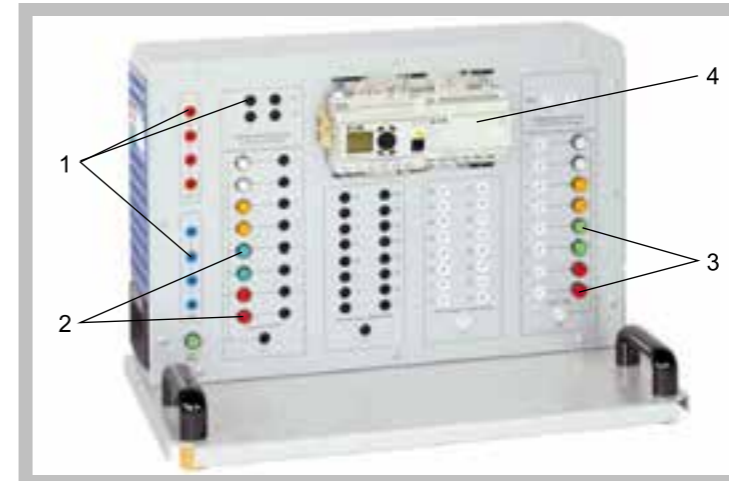
The PLC programming software conforms to the international standard IEC 61131-3, and permits programming in the following languages: Statement List (STL), Ladder Diagram (LD), Structured Text (ST) and Function Block Diagram (FBD). Ladder Diagrams are based on graphical representations with contacts, coils and boxes, as per the circuit diagrams. Function Block Diagram language is based on graphical representation of the interlinking of logical function blocks, analogous to the logic diagrams. Statement List is an assembler-type language with a small, standardised non-hardware-dependent command set. Structured Text is a language similar to PASCAL, with mathematical expressions, assignments, function calls, iteration, condition selection, and PLC-specific add-ons. An example program is included in the module.

IA 130 can be used as a control element in conjunction with electrical, pneumatic or hydraulic applications, such as with the handling device IA 210 or the mixing process RT 800.

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

Learning Objectives / Experiments

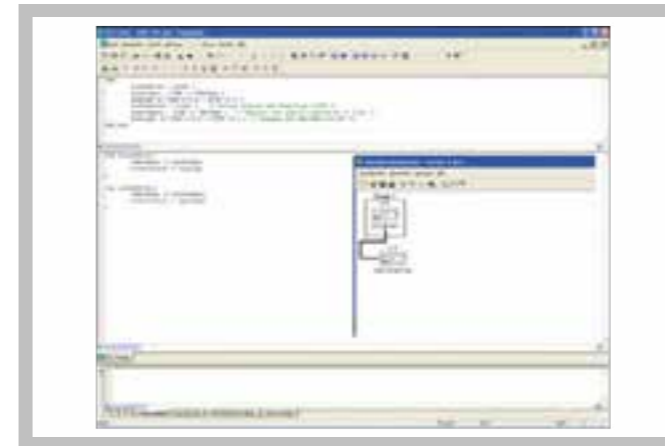
- familiarisation with a PLC
- familiarisation with the essential fundamentals such as
 - * Boolean algebra
 - * compiling statement lists
 - * interconnection diagrams and block diagrams
- exercises in
 - * programming
 - * logical "AND" / "OR" gates
 - * logic relays
 - * output and input
- configuration of program sequences by way of connectors, incorporating
 - * timers
 - * counters
 - * cascade circuits
 - * higher-order monitoring relays etc.
- fault finding

IA 130 PLC Module


1 lab jacks, 2 pushbutton, 3 lamps, 4 PLC



Screenshot of PLC software: start screen



Screenshot of PLC software: POU editor (POU = Program Organisation Unit) and topology configurator

Specification

- [1] module for basic exercises on a programmable logic controller (PLC)
- [2] self-contained PLC module, usable as part of a complex system
- [3] integrated patchboard for creating circuits with input and output elements
- [4] PLC with 2 integrated setpoint encoders
- [5] programming software to IEC 61131-3
- [6] example program supplied

Technical Data
PLC

- connections
 - * 16 digital inputs
 - * 16 digital outputs
 - * 2 analogue inputs
 - * 1 analogue output
- memory type: PLC back-up battery for 32kByte RAM and clock
- Rated voltage: 24VDC

Software

- graphical user interfaces
- programming languages to IEC/EN 61131-3:
 - * statement list (STL)
 - * ladder diagram (LD)
 - * function block diagram (FBD)
 - * structured text (ST)
- multiple dialogue languages (German, English, French, Spanish)
- graphical topology configurator
- system requirements: Windows Vista or Windows 7

Dimensions and Weight

LxWxH: 620x350x450mm
Weight: approx. 15kg

Required for Operation

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

Scope of Delivery

- 1 PLC Module
- 1 PLC software with programming cable
- 1 set of laboratory cables
- 1 set of instructional material

Order Details

058.13000 IA 130 PLC Module

IA 110 Calibrating a Pressure Sensor


- * Test-pressure generated with dead-weight piston manometer
- * Electronic pressure sensor with ceramic measuring cell
- * Plotting a calibration curve
- * Compact experimental unit for group working or demonstration

Technical Description

The experimental unit IA 110 can be used to calibrate an electronic pressure sensor under practical conditions.

The test pressure is generated with a conventional piston manometer. The piston is loaded with weight rings and generates a defined test pressure $p = F_w/A_p$, where F_w is the force due to the weights and A_p is the cross-sectional area of the piston. A hand-operated spindle is used to relieve the pressure after measurement allowing the piston to return to a rest position. The influence of friction is minimised by rotating the piston during measurement. The test pressure generated in this way is applied to the diaphragm of a pressure sensor. The pressure-dependent electrical output signal is indicated on a digital display.

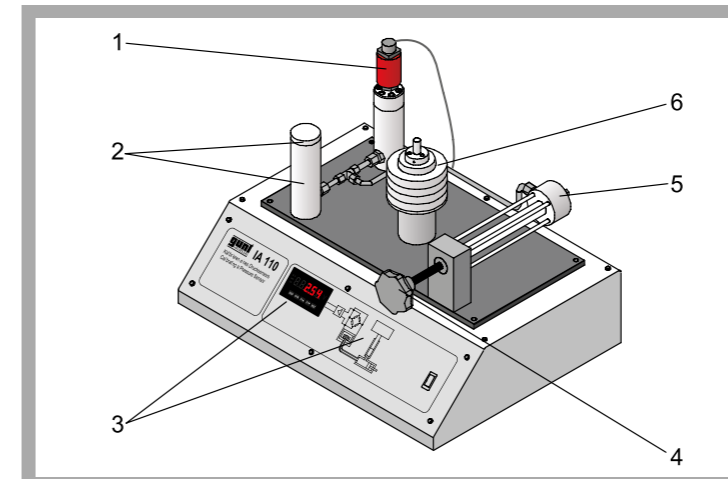
The pressure sensor used is a state-of-the-art ceramic measuring cell, in which strain-dependent piezo resistors are mounted on a ceramic diaphragm. The resistors are configured to form a measuring bridge. An integrated amplifier circuit evaluates the pressure-dependent detuning of the measuring bridge and outputs a proportional voltage signal.

The kit also includes a second pressure sensor in the form of a cutaway model for enhanced clarity. The entire experimental unit is contained in a compact housing, and is easy to handle.

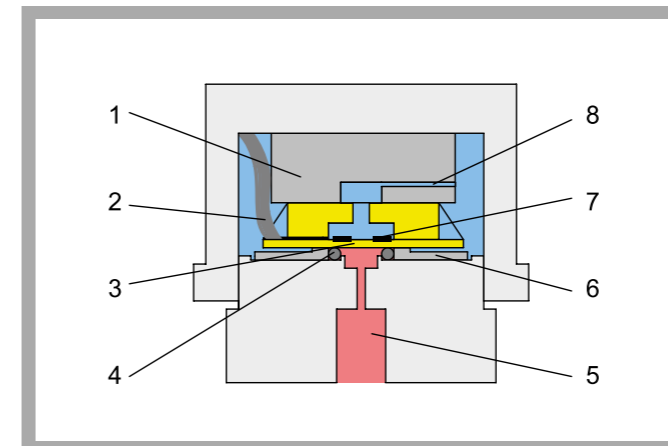
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

- familiarisation with, and carrying out of the calibration of an electronic pressure sensor
- plotting the sensor output signal dependent on the pressure applied
- familiarisation with the design and operation of a piezo-resistive electronic pressure sensor
- familiarisation with the installation and connection of the pressure sensor
- information on applications, measuring ranges and accuracies of typical electronic pressure sensors

IA 110 Calibrating a Pressure Sensor


1 pressure sensor being calibrated, 2 cylinder with cover to receive the loading device, 3 digital display for displaying the output signal and process schematic, 4 manual adjustment spindle for compensating cylinder, 5 compensating cylinder, 6 holder for weight carrier with piston and weights



1 brace, 2 connecting cable, 3 ceramic measuring cell with diaphragm, 4 sealing ring, 5 pressure connection, 6 pressure plate, 7 piezo resistors, 8 pressure equalisation bore for relative pressure measurement



Interior layout of an electronic pressure sensor

Specification

- [1] calibration unit with dead-weight piston manometer and hand-operated spindle
- [2] electronic pressure sensor with ceramic measuring cell, integrated amplifier and voltage output
- [3] digital display for output signal
- [4] additional pressure sensor as cutaway model
- [5] set of weights
- [6] transmission medium: hydraulic oil
- [7] process schematic on front panel

Technical Data

Pressure sensor
- measuring range: 0...2,5bar
- supply: 24VDC
- output signal: 0...10VDC

Piston manometer with pressure piston
- diameter: 12mm
- number of weights: 5
- pressure graduations: 0,5 - 1,0 - 1,5 - 2,0 - 2,5bar

Digital display: 4 1/2 digits

Hydraulic oil: HLP ISO 32

Dimensions and Weight

LxWxH: 600x450x450mm
Weight: approx. 20kg

Required for Operation

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

Scope of Delivery

- 1 experimental unit
- 1 set of weights
- 1L hydraulic oil
- 1 cutaway model of pressure sensor
- 1 set of instructional material

Order Details

058.11000 IA 110 Calibrating a Pressure Sensor

WL 201 Fundamentals of Humidity Measurement

Technical Description

The measurement of air humidity plays an important role in many branches of industry, e.g. during drying or in the air conditioning of buildings and vehicles. There are different measuring methods to determine humidity.

The trainer WL 201 enables the measurement of air humidity with four different instruments which can be directly compared to each other: two different hygrometers, a capacitive hygrometer and a psychrometer.

Psychrometers operate based on the principle of evaporation cooling and compare the ambient temperature with the wet bulb temperature to determine the humidity. Hygrometers utilise the property of specific fibres, e.g. hair, to expand with increasing air humidity. In the capacitive sensor the dielectricity constant of a layer and with it its capacity changes due to the water molecules absorbed.

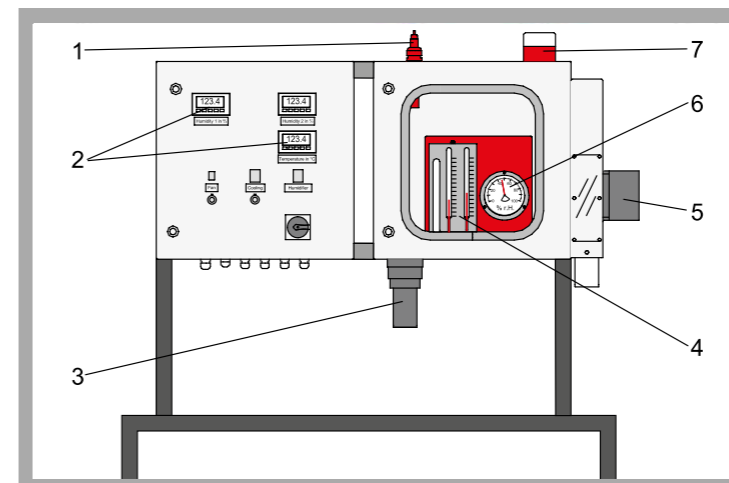
The core element of the trainer is a climatic chamber with transparent door. This chamber can be humidified and dehumidified and contains the four instruments. A Peltier cooling element is used for dehumidification. An ultrasonic atomiser is used for humidification. To circulate the air and ensure good mixing a fan is used.

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

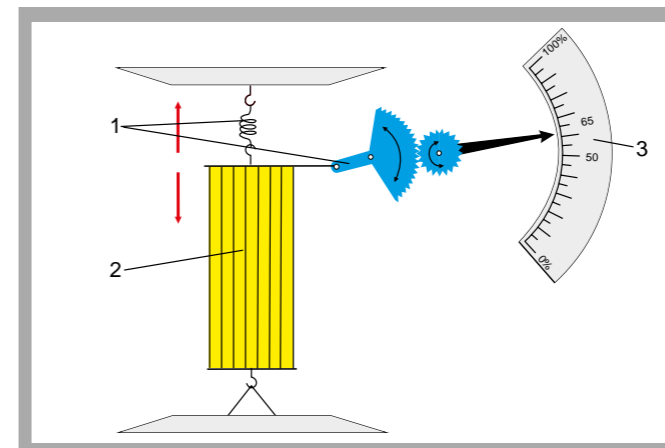
Learning Objectives / Experiments

- measuring methods for air humidity measurement
- * psychrometric humidity measurement
- * hygrometric humidity measurement
- * capacitive humidity measurement
- characteristic variables to describe air humidity
- changes of the state of humid air in the h-x diagram
- determination of the relative air humidity with
 - * psychrometer
 - * hair hygrometer
 - * hygrometer with synthetic fibre
 - * capacitive humidity sensor
- design and operation of the instruments
- comparison of the instruments

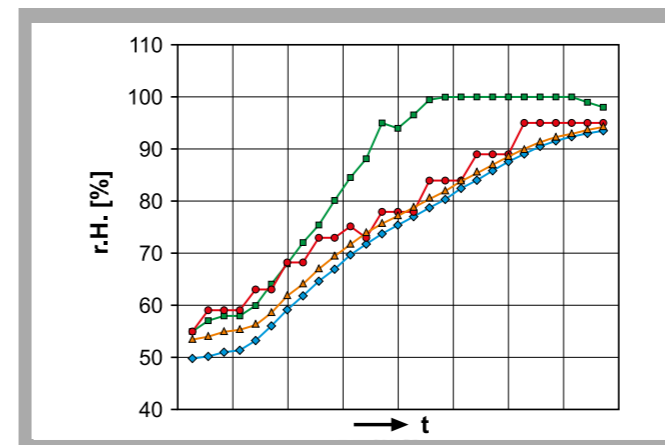
- * Different measuring methods for measuring humidity
- * Climatic chamber with adjustable humidity and transparent door

WL 201 Fundamentals of Humidity Measurement


1 capacitive humidity sensor, 2 temperature and humidity displays, 3 humidifier, 4 psychrometer, 5 dehumidifier, 6 hair hygrometer, 7 hygrometer with synthetic fibre and combined temperature sensor



Principle of the hair hygrometer: 1 mechanism to measure the humidity-dependent change in length of the hair bundle, 2 hair bundle, 3 humidity scale



Relative humidity (r. h.) over time (t) with rising content of humidity; blue: capacitive sensor, orange: hygrometer with synthetic fibre, red: psychrometer, green: hair hygrometer

Specification

- [1] different measuring methods for measuring humidity
- [2] climatic chamber with adjustable humidity and transparent door
- [3] humidification via ultrasonic atomiser
- [4] dehumidification via Peltier cooling element
- [5] fan for air recirculation
- [6] 2 mechanical instruments: psychrometer, hair hygrometer
- [7] 2 electronic instruments: capacitive sensor, hygrometer with synthetic fibre and combined temperature sensor

Technical Data

- Humidifier**
- ultrasonic atomiser
 - power consumption: 21,6W
 - low water cut-off
- Dehumidifier**
- Peltier element
 - cooling capacity: 56,6W (50°C ambient temperature)
 - cooling surface: 1600mm²

- Hair hygrometer with deflective needle**
- measuring range: 0...100% r. h.
- Hygrometer with synthetic fibre**
- output voltage: 0...10V
 - measuring ranges: 0...100% r. h. / -30...80°C
- Capacitive sensor with digital display**
- output voltage: 0...10V
 - measuring range: 1...100% r. h.
- Psychrometer with thermometer**
- measuring range: -10...60°C, graduation: 0,5°C

Dimensions and Weight

- LxWxH: 1270x730x1630mm
Weight: approx. 112kg

Required for Operation

- 230V, 50/60Hz, 1 phase

Scope of Delivery

- 1 trainer
- 1 psychrometer
- 2 hygrometers
- 1 set of instructional material

Order Details

060.20100 WL 201 Fundamentals of Humidity Measurement

WL 202 Fundamentals of Temperature Measurement


* **Experimental introduction to temperature measurement: methods, areas of application, characteristics**

* **Clearly laid out unit primarily for laboratory experiments, also suitable for demonstration purposes**

Technical Description

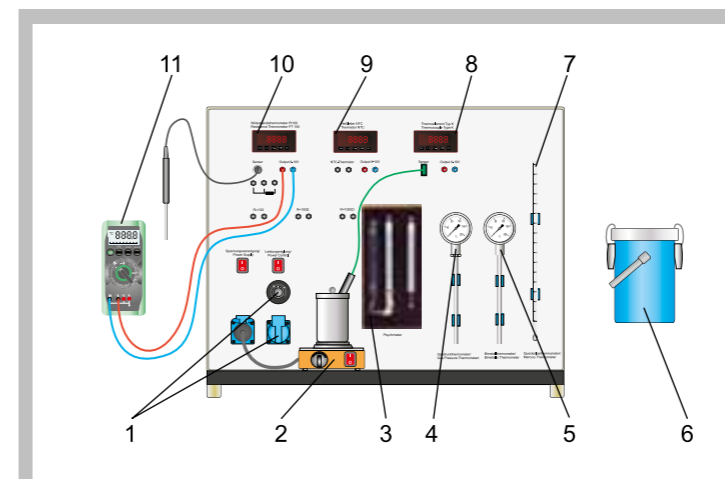
Recording temperature is one of the basic tasks in metrology. Electric temperature sensors are the most widely used in automation applications but conventional thermometer types are still widely applied in many areas. The WL 202 experimental set-up covers the full range of temperature measurement methods. As well as non-electrical measuring methods, such as gas- and liquid-filled thermometers and bimetallic thermometers, all typical electric measuring methods are covered in the experiments. The electrically measured temperatures are displayed directly on programmable digital displays. A temperature-proportionate output voltage signal (0...10V) is accessible from lab jacks, enabling temperature characteristics to be recorded with, for example, a plotter. For measuring the relative air humidity a psychrometer with two thermometers is available, one of the thermometers measures the dry bulb. The wet bulb thermometer is covered in a wet cotton cloth and measures the evaporative cooling. The temperature difference allows the relative air humidity to be determined.

A digital multimeter with precision resistors is used to calibrate the electrical measuring devices. Various heat sources or storage units (immersion heater, vacuum flask and laboratory heater) permit relevant temperature ranges to be achieved for the sensors being tested. A tool box houses the sensors, cables, temperature measuring strips and immersion heater.

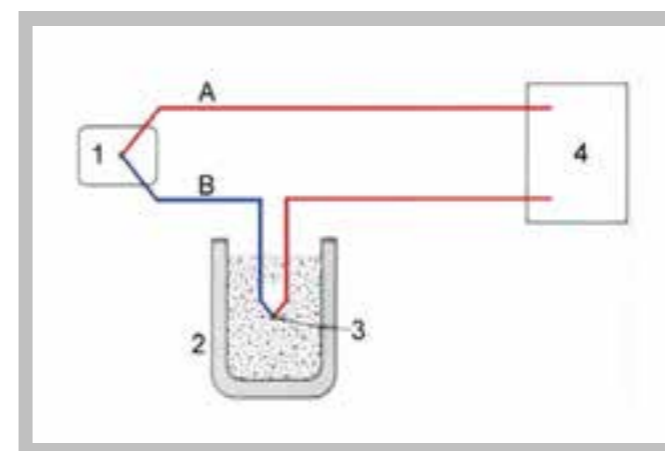
The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Learning Objectives / Experiments

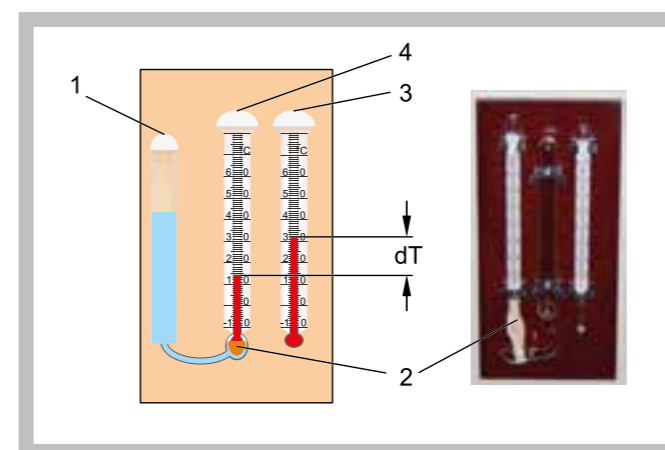
- learning the fundamentals of temperature measurement by experimentation
- familiarisation with the various methods, their areas of application and special features
- * non-electrical methods: gas- and liquid-filled thermometers, bimetallic thermometers and temperature measuring strips
- * electric methods: thermocouple, resistance temperature detector Pt100, thermistor (NTC)
- determining air humidity with a psychrometer
- calibrating electric temperature sensors

WL 202 Fundamentals of Temperature Measurement


1 power-regulated socket, 2 laboratory heater for water and sand, 3 psychrometer to determine air humidity, 4 gas pressure thermometer, 5 bimetal thermometer, 6 vacuum flask, 7 mercury thermometer, 8 digital display, thermocouple type K, 9 digital display, thermistor (NTC), 10 digital display, Pt100, 11 multimeter



Temperature measurement with a thermocouple type K: A) nickel chrome, B) nickel; 1 measuring point, 2 tank at constant temperature, 3 reference point, 4 voltmeter



Psychrometer: 1 water tank, 2 wet cotton cloth for covering the wet bulb thermometer, 3 dry bulb thermometer, 4 wet bulb thermometer; dT temperature difference

Specification

- [1] experiments in the fundamentals of temperature measurement with 7 typical measuring devices
- [2] various heat sources or storage units: laboratory heater, immersion heater, vacuum flask
- [3] calibration units: precision resistors and digital multimeter
- [4] mercury, bimetallic and gas pressure thermometers
- [5] temperature sensors: Pt100, thermocouple type K, thermistor (NTC)
- [6] various temperature measuring strips
- [7] psychrometer for humidity measurement
- [8] tool box for sensors, cables, measuring strips and immersion heater

Technical Data

- Immersion heater
 - power output: 300W
 - adjustment of power feed via power-regulated socket
- Laboratory heater with thermostat
 - power output: 450W
 - max. temperature: 425°C
- Vacuum flask: 1L

Measuring ranges

- resistance temperature detector Pt100: 0...100°C
- thermocouple type K: 0...1000°C
- thermistor (NTC): 20...55°C
- mercury thermometer: -10...300°C
- bimetallic, gas pressure thermometer: 0...200°C
- temperature measuring strips: 29...290°C
- Precision resistors: 10Ω, 100Ω, 1000Ω
- Psychrometer:
 - 2x temperature: 0...60°C
 - rel. humidity: 3...96%

Dimensions and Weight

- LxWxH: 800x450x650mm (experimental unit)
- Weight: approx. 45kg

Required for Operation

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

Scope of Delivery

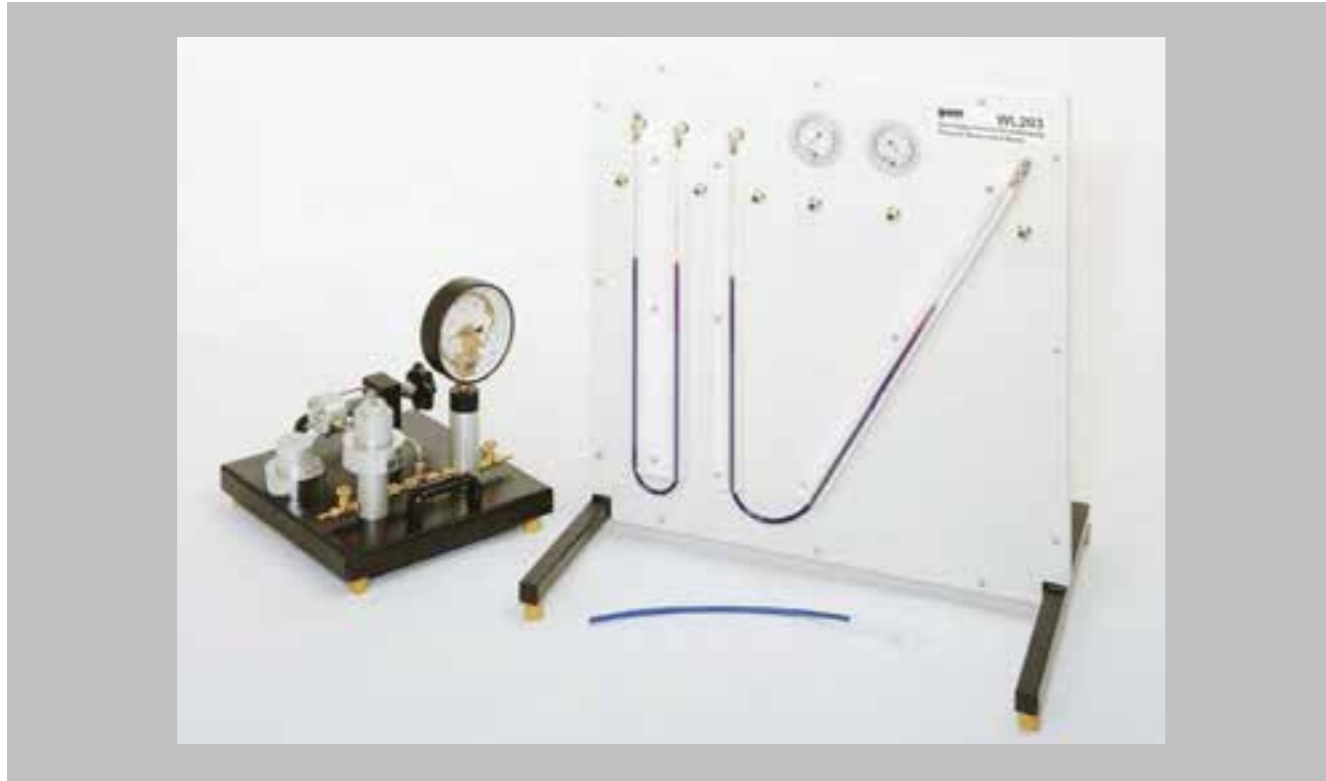
- 1 experimental unit
- 1 tool box
- 1 set of cables
- 1 laboratory heater
- 1 immersion heater
- 1 vacuum flask
- 1 digital multimeter
- 1 set of instructional material

Order Details

060.20200 WL 202 Fundamentals of Temperature Measurement

WL 203

Fundamentals of Pressure Measurement



The illustration shows WL 203 in conjunction with HM 150.02 Calibration of Pressure Gauges

- * Comparison of different pressure measurement methods
- * Measuring positive and negative pressure
- * Calibration device included in the scope of delivery

Technical Description

Measuring pressure is important in the engineering industry, e.g. in plant, turbomachine and aircraft construction and in process engineering. Other fundamental factors such as flow rate or flow velocity can also be determined based on a pressure measurement.

The WL 203 experimental unit enables the user to measure the pressure with two different measuring methods: directly by measuring the length of a liquid column (U-tube manometer, inclined tube manometer) and indirectly by measuring the change of shape of a Bourdon tube (Bourdon tube pressure gauge).

In a U-tube manometer, the pressure causes the liquid column to move. The pressure difference is read directly from a scale and is the measure for the applied pressure. In inclined tube manometers, one leg points diagonally up. A small height difference therefore changes the length of the liquid column significantly.

The principle of the Bourdon tube pressure gauge is based on the change in cross-section of the bent Bourdon tube under pressure. This change in cross-section leads to an expansion of the Bourdon tube diameter. A Bourdon tube pressure gauge is therefore an indirectly acting pressure gauge where the pressure differential is indicated via a transmission gearing and a pointer.

In experiments, pressures in the millibar range are generated with a plastic syringe and displayed on the manometers. The experimental unit is equipped with two Bourdon tube pressure gauges for measuring

positive and negative pressure. The U-tube manometer, inclined tube manometer and Bourdon tube pressure gauges at the experimental unit can be combined using tubes. A calibration device (HM 150.02), which is included in the scope of delivery, enables calibration of an additional Bourdon tube pressure gauge using a weight-loaded piston manometer.

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

Learning Objectives / Experiments

- familiarisation with 2 different measuring methods:
 - * direct method with U-tube manometer and inclined tube manometer
 - * indirect method with Bourdon tube pressure gauge
- principle of a Bourdon tube pressure gauge

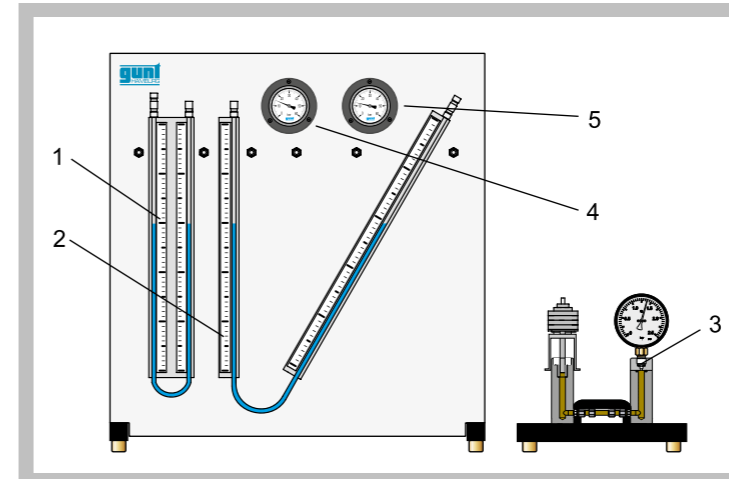
in conjunction with the HM 150.02 calibration device included in the scope of delivery

- calibrating mechanical manometers

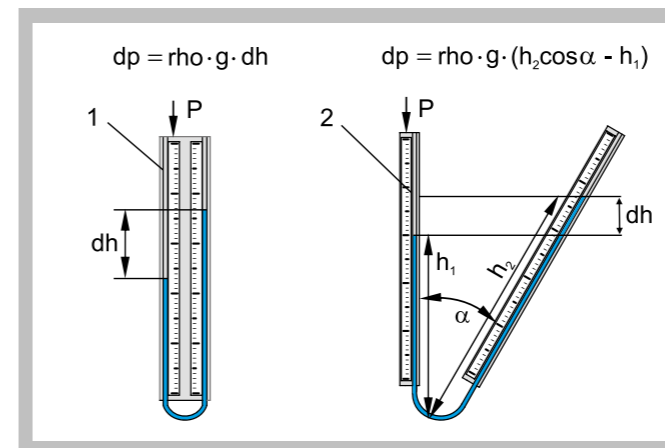
G.U.N.T Gerätebau GmbH, Hanskampring 15-17, D-22885 Barsbüttel, Phone +49 (40) 67 08 54-0, Fax +49 (40) 67 08 54-42, E-mail sales@gunt.de, Web http://www.gunt.de
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WL 203

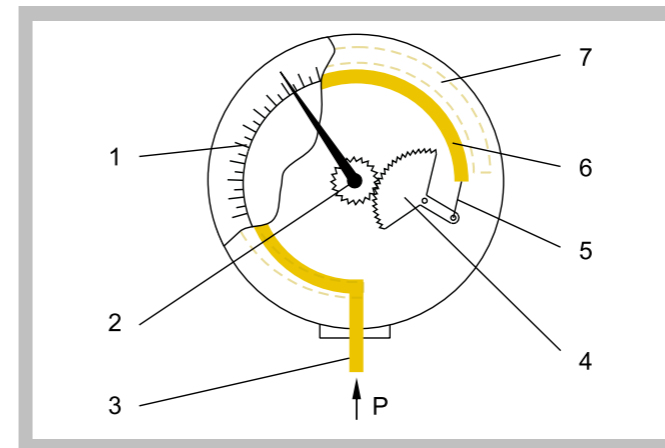
Fundamentals of Pressure Measurement



1 U-tube manometer, 2 inclined tube manometer, 3 HM 150.02 with Bourdon tube pressure gauge, 4 Bourdon tube pressure gauge for positive pressure, 5 Bourdon tube pressure gauge for negative pressure



Principle of operation of liquid column manometers
1 U-tube manometer, 2 inclined tube manometer; dp pressure difference, dh height difference, rho density of measuring fluid, g acceleration of gravity



Principle of operation of a Bourdon tube pressure gauge
1 scale, 2 pointer, 3 Bourdon tube fixed in place, 4 gearing, 5 tie rod, 6 Bourdon tube without pressure, 7 Bourdon tube expanded under pressure

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Specification

- [1] basic experiments for measuring pressure with three different measuring instruments
- [2] U-tube and inclined tube manometer
- [3] one Bourdon tube pressure gauge each for positive and negative pressure
- [4] plastic syringe generates test pressures in the millibar range
- [5] calibration device with Bourdon tube pressure gauge (HM 150.02) for calibrating mechanical manometers included in the scope of delivery

Technical Data

Inclined tube manometer: angle 30°

Measuring ranges

- Bourdon tube pressure gauge: 0...60mbar / -60...0mbar
- U-tube manometer: 0...500mmWC
- inclined tube manometer: 0...500mmWC

Dimensions and Weight

LxWxH: 750x610x780mm
Weight: approx. 23kg
LxWxH: 400x400x400mm (HM 150.02)
Weight: approx. 25kg (HM 150.02)

Scope of Delivery

- 1 experimental unit
- 1 HM 150.02 Calibration of Pressure Gauges
- 30mL ink
- 1 funnel
- 1 plastic syringe
- 1 set of hoses
- 1 set of instructional material

Order Details

060.20300 WL 203 Fundamentals of Pressure Measurement

HM 500 + ACCESSOIRES METHODS OF FLOW RATE MEASUREMENT

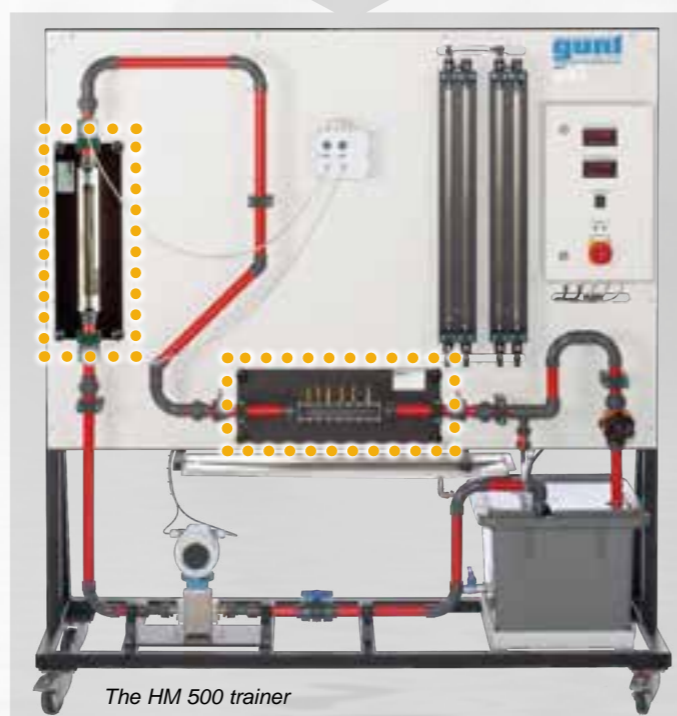
Properties and applications of different flow meters

The extensive range of accessories for the HM 500 trainer offers the opportunity to learn about many different types of flow meter. They can be quickly and easily installed in the HM 500 trainer.

The specific applications for which each flow meter is suitable can be established. The medium being transported and the accuracy demands imposed, as well as commercial considerations associated with the particular application, are the key criteria in flow meter selection. Knowledge of the pressure losses associated with the various meters is also important in this context. Consequently, each accessory flow meter for the HM 500 trainer is equipped with connections for measurement of pressure loss. The flow meters are connected to the trainer by hoses. The pressure losses are displayed on the trainer.

The instructional material details the principle of operation the flow meter concerned. The theory underlying the principle of operation is outlined. With this information the accuracy associated with the measurement principle and the subsequent applications for which the flow meter is suitable can be easily established.

Some of the flow meters, such as the paddle wheel flow meter, require auxiliary power in order to operate. The trainer supplies this auxiliary power in the form of DC voltage.



ALSO AVAILABLE:

HM 500.03 Rotameter with Transducer
Product no. 070.50003

HM 500.14 Turbine Wheel Flow Meter
Product no. 070.50014

HM 500.15 Bypass Flow Meter
Product no. 070.50015

HM 500 Flow Meter Trainer


- * Comparison and calibration of different flow meters
- * Plotting of pressure loss curves
- * Numerous flow meters available as accessories

Technical Description

Flow measurement plays a key role in many process engineering systems. Different flow meters are used for this, depending on the medium and application.

The HM 500 trainer is used to examine different principles of operation of flow meters. The flow meters are available as accessories (HM 500.01-HM 500.16). Pressure loss curves and accuracies can be compared to determine which flow meter is suitable for which area of application.

One horizontally or vertically installed flow meter can be operated in a closed water circuit. The flow rate can be adjusted via a valve. A high-precision electromagnetic flow rate sensor is available as a reference for calibrating the flow meters.

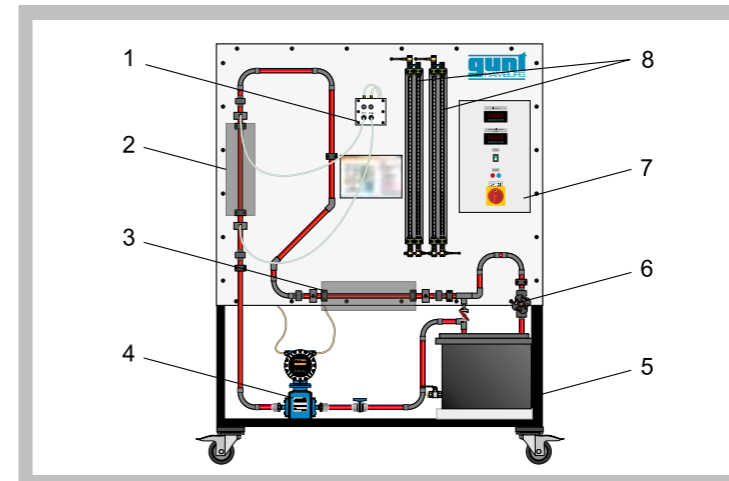
To be able to determine the pressure losses of the various flow meters, the trainer is equipped with two twin tube manometers and a differential pressure sensor. A DC voltage source ensures the power supply to the flow meters if required.

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

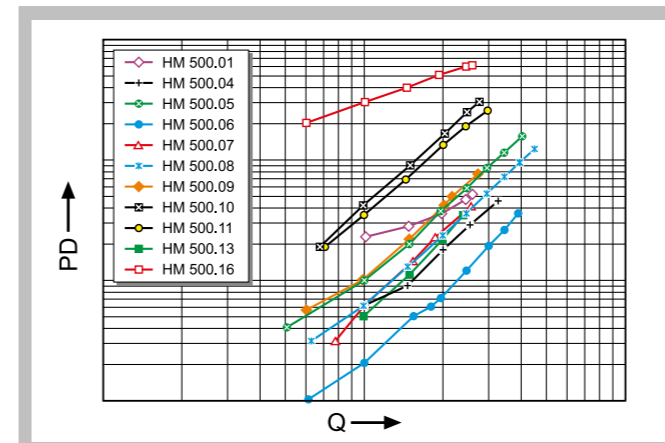
Learning Objectives / Experiments

together with different flow meters available as accessories

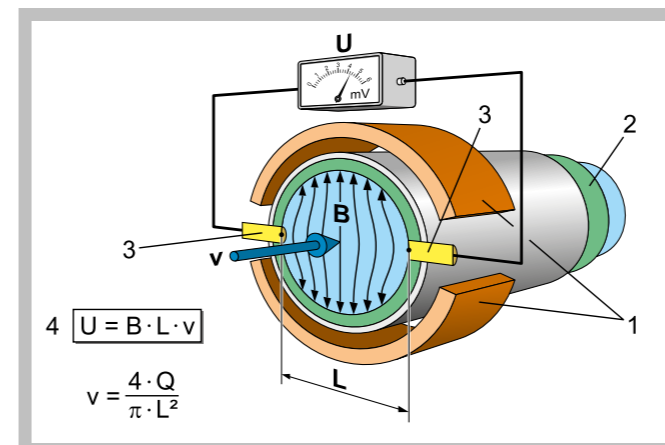
- different flow meters and their principles of operation
- calibration of different flow meters
- position dependency of flow meters
- plotting and comparison of pressure loss curves

HM 500 Flow Meter Trainer


1 differential pressure sensor, 2 vertical measuring location with HM 500.10, 3 horizontal measuring location with empty tube, 4 electromagnetic flow rate sensor, 5 tank with pump, 6 valve to adjust flow rate, 7 switch cabinet, 8 twin tube manometers



Pressure loss (PD) dependent on the flow rate (Q) for the flow meters available as accessories



Measurement principle of the electromagnetic flow rate sensor:
1 magnet, 2 insulation, 3 electrode, 4 Faraday's Law of Induction;
B magnetic flux density, L electrode gap, Q flow rate, U induced voltage,
v flow velocity of medium (blue)

Specification

- [1] comparison and calibration of different flow meters
- [2] water circuit with tank, pump and valve to adjust flow rate
- [3] 2 measuring locations for vertical or horizontal installation of the flow meters under test
- [4] electromagnetic flow rate sensor for reference measurement
- [5] 1 differential pressure sensor and twin tube manometers for measurement of pressure losses
- [6] DC voltage source to supply the flow meters with auxiliary power
- [7] flow meters available as accessories

Technical Data

Tank: approx. 55L

Pump

- max. flow rate: approx. 225L/min

- max. head: approx. 11m

DC voltage source

- voltage: 24VDC

- current: 2,0A

Accuracy of electromagnetic flow rate sensor

- 0.5% of final value

Measuring ranges

- flow rate (reference): 0...4760L/h

- differential pressure sensor: 0...2bar

- twin tube manometers: 0...680mmWC

Dimensions and Weight

LxWxH: 1770x670x1880mm

Weight: approx. 110kg

Required for Operation

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

Scope of Delivery

1 trainer

1 set of hoses

1 set of cables

1 set of instructional material

Order Details

070.50000 HM 500 Flow Meter Trainer