5 Thermodynamic applications in supply engineering: HVAC

Introduction

Hot water generation

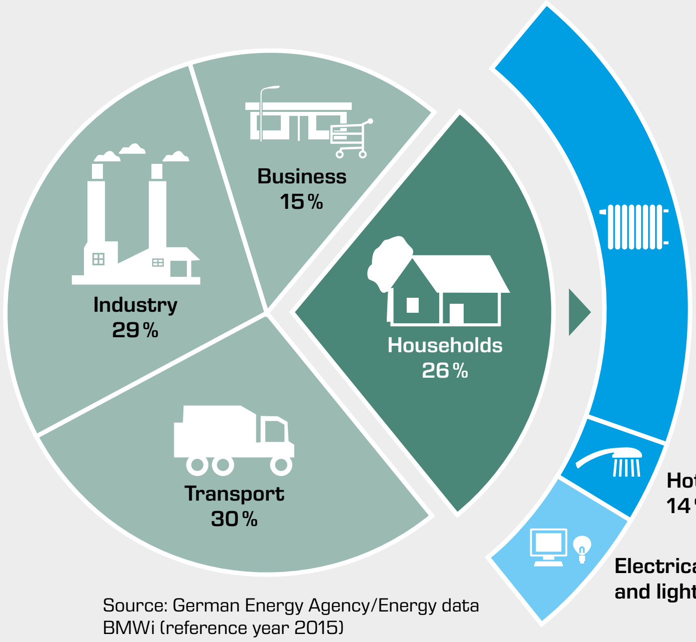
Air conditioning technology and ventilation

GUNT-RHLine Renewable Heat

Thermodynamic applications in supply engineering: HVAC

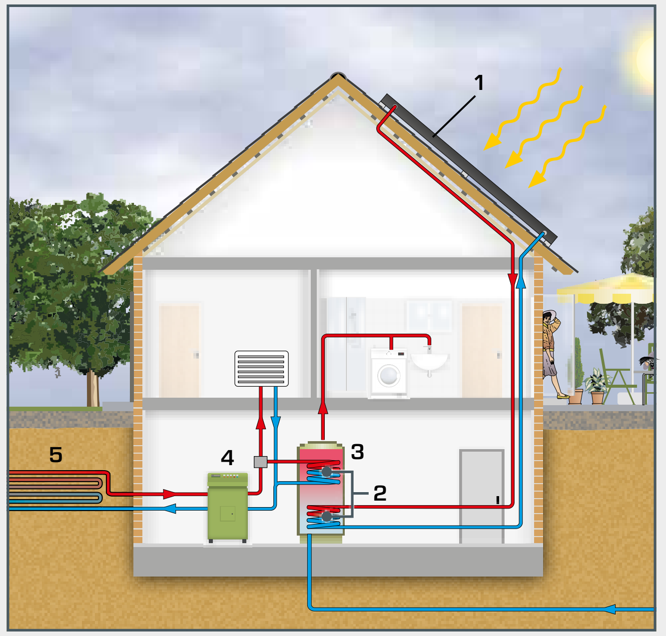
Energy efficiency in building services engineering

A large proportion of the energy used worldwide concerns the supply of buildings. Efficiency improvements can make a significant contribution to reducing the primary energy demand. Measures that result in a building using energy more efficiently involve nearly all areas of modern building services engineering. In addition to consumption by electronic equipment, lighting and water heating, these include in particular the consumption by heating, ventilation and air conditioning. Depending on the geographic location, the design of systems in building services engineering focuses on either heating or cooling requirements, always taking both aspects into account. The diagram opposite shows, using Germany as an example, that a large proportion of energy is used for heating rooms.



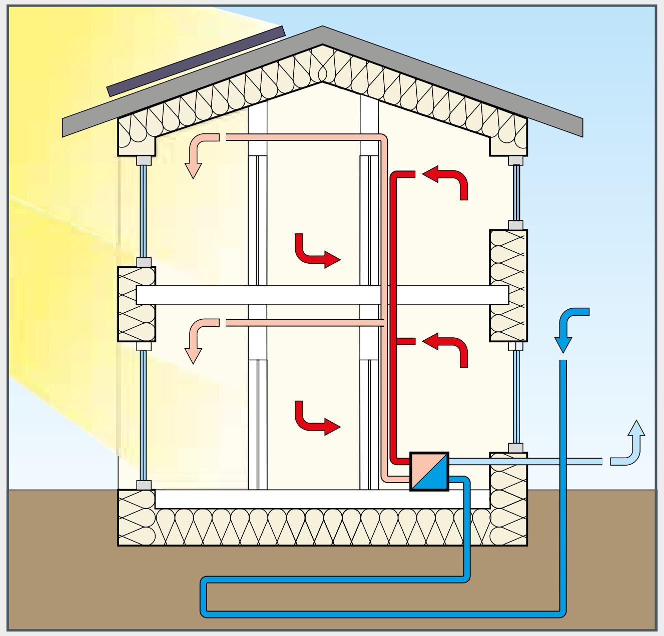
Source: German Energy Agency/Energy data BMWi (reference year 2015)

Components for the combined use of renewable heat sources in the domestic supply



Components for the combined use of renewable heat sources in the domestic supply

1 flat collector, **2** heat exchanger, **3** hot water storage tank, **4** heat pump, **5** geothermal absorber;
hot heat transfer fluid,
cold heat transfer fluid



Ventilation with heat recovery

outside air: air drawn in from the environment,
outgoing air: air released into the environment,
supply air: air entering a room or facility after it has been treated, e.g. by filtering or heating
exhaust air: air leaving a room

Structural and technical techniques for resource conservation

Structural and technical measures are needed in order to reduce the primary energy demand of buildings. Heat insulation in cold regions and the use of transparent façades, for example, are some of the possible structural measures. In warm regions, attention is paid to shading and insulation from heat radiation. This area is becoming increasingly important in the training of architects, urban planners and construction engineers.

Efficient components and systems, controlled by means of modern building services engineering, are at the forefront of technical measures for optimisation of the energy supply. Taking into account modern concepts for combined heat and power, distributed power grids and energy storage, it is possible to achieve energy production and distribution that is adapted to demand.

Standards for energy efficiency in building services engineering

Directives have been passed by the European Parliament on energy efficiency in buildings. Below is an excerpt from Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings:

> [...] (3) Buildings account for 40% of total energy consumption in the Union. The sector is expanding, which is bound to increase its energy consumption. Therefore, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the Union's energy dependency and greenhouse gas emissions. Together with an increased use of energy from renewable sources, measures taken to reduce energy consumption in the Union would allow the Union to comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). [...]

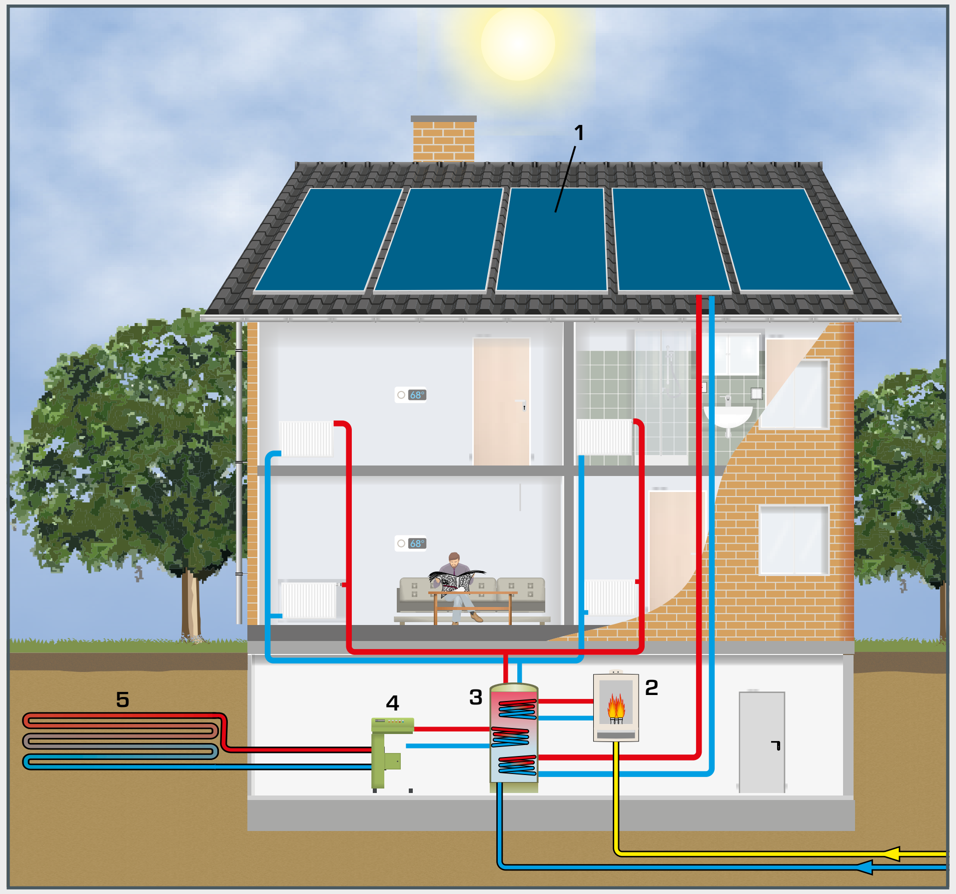
To implement the EU Directive in Germany, the energy efficiency of buildings is categorised in the energy efficiency classes A to G in an energy certificate in accordance with the German Energy Efficiency Act. Buildings are classified according to the specific primary and final energy demand. For highly efficient passive houses, the annual energy demand is well below 50 kWh/m^2.

Basic knowledge

Hot water central heating systems

A hot water central heating system has four partial tasks:

- central generation of hot water
- transporting hot water
- heat transfer to rooms
- controlling and regulating temperature

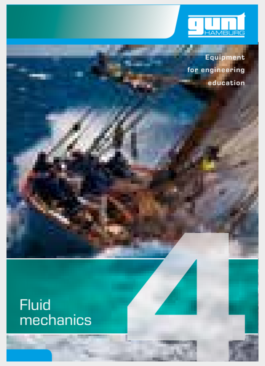


1 flat collector, **2** heating boiler, **3** hot water storage tank, **4** heat pump, **5** geothermal absorber;
hot heat transfer fluid, cold heat transfer fluid, fuel supply

Suitable control technology ensures a uniformly comfortable room climate all year round.

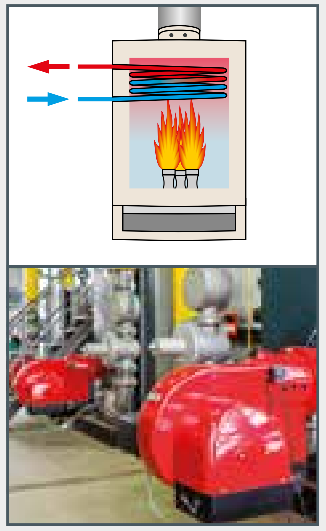
Modern systems allow the heating system to be controlled remotely.

There are different ways of transferring the heat to the rooms, depending on the requirements and size of the room.

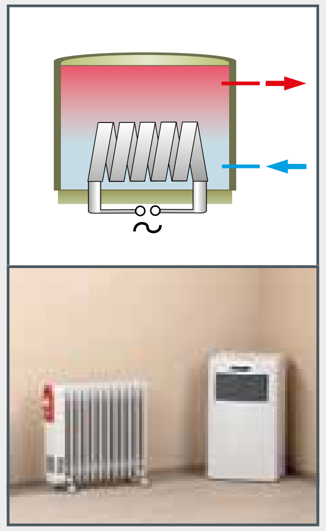


The design of piping systems for the transport of hot water requires knowledge of fluid mechanics, for example the characteristic variables of pumps and friction or pressure losses in pipe elements. GUNT's **product area 4 Fluid mechanics** deals with these aspects.

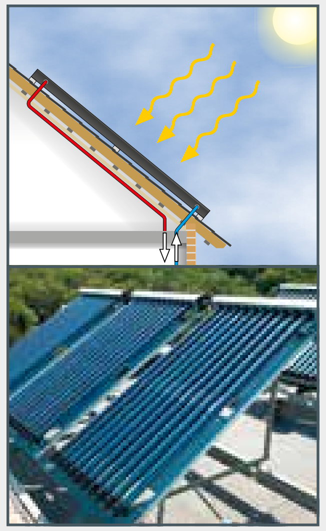
Generation of hot water



Oil, gas or wood-fired boiler



Electric resistance heating



Solar thermal energy

Heat pump

Hot water

Water as a heat transfer medium

Advantages

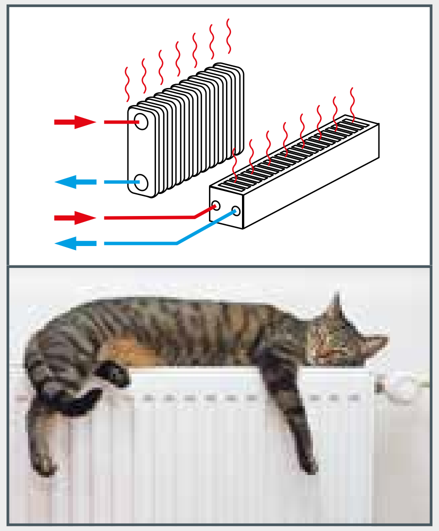
- high heat capacity
- inexpensive and easily obtainable
- non-toxic and environmentally friendly

Disadvantages

- temperature range only 0–100°C at ambient pressure
- corrosive in the presence of oxygen

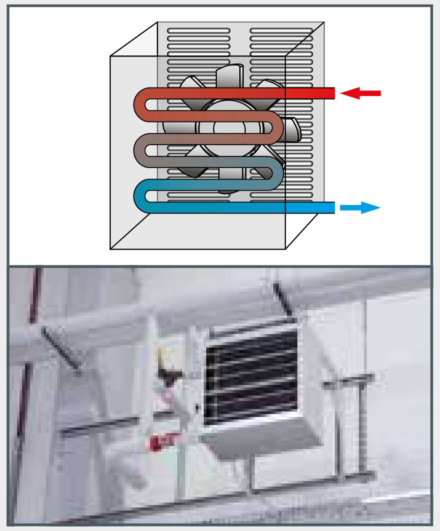
Cold water

Heat transfer to rooms



Radiator with natural convection

Underfloor or wall heating with natural convection



Air heater with forced convection

HL 352
Test stand for oil, natural gas and propane gas burners

The illustration shows the trainer together with the HL 352.01 oil burner accessory

Learning objectives/experiments

- design and operating behaviour of a heating boiler
- comparison of burners (3 different burners available as accessories)
- changes in settings during operation with observation of the effects on the flame pattern
- temperature measurements in different areas of the combustion chamber
- oil pressure measurements on the burner with observation of the effect on the flame pattern
- thermal balance
- calculation of the thermal output of a heating boiler
- function of a plate heat exchanger

Description

- **investigation of gas and oil burners**
- **viewing window for observing the flame pattern**

Gas and oil burners can be used to generate heat for central hot water heating systems. Burners convert the chemically stored energy of the fuels into thermal energy. There are diferent types of burners that differ mainly in their design. Oil burners are distinguished as yellow flame or atomizing burners and blue flame burners. Gas burners can be built in the form of gas fan burners, which are optimised for different gases depending on the heating medium.

The HL 352 test stand can be used to study gas and oil burners and compare their thermal balance. The test stand consists of a heating boiler, a heating control unit and a domestic water heater.

The accessories HL 352.01 oil burner, HL 352.02 natural gas burner and HL 352.03 propane gas burner are available. The flue gas can be analysed with the HL 860 Exhaust gas analyser. The test stand is supplied with a fuel oil tank.

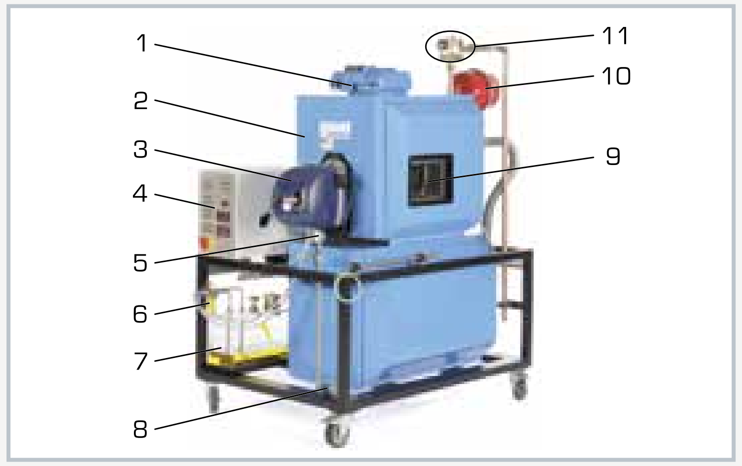
A viewing window is installed in the boiler body, which allows the flame to be observed and the settings on the burner to be immediately assessed.

The test stand is equipped with the prescribed safety devices. A heatable domestic water tank serves as a second heat consumer.

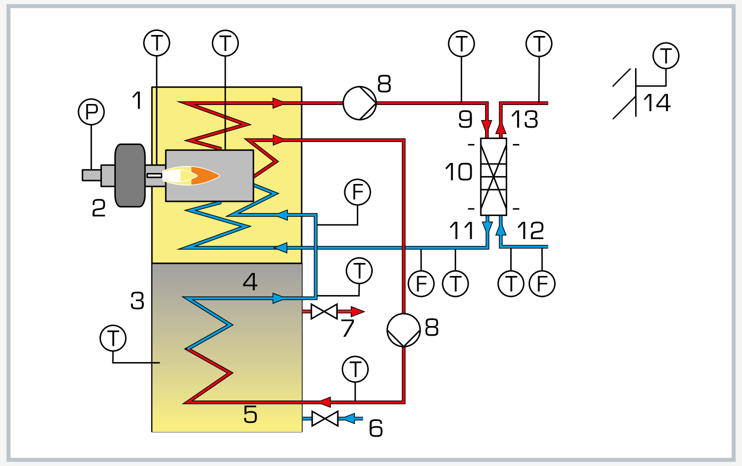
In addition to oil pressure and flow rate, all relevant temperatures, water flow rates and the combustion chamber temperature are measured. A thermal balance can be created from the measurement data and the energy efficiency can be determined.

An integrated heating circuit with plate heat exchanger simulates a heater circuit. The measured values are transmitted directly to a PC via USB where they can be analysed using the software included.

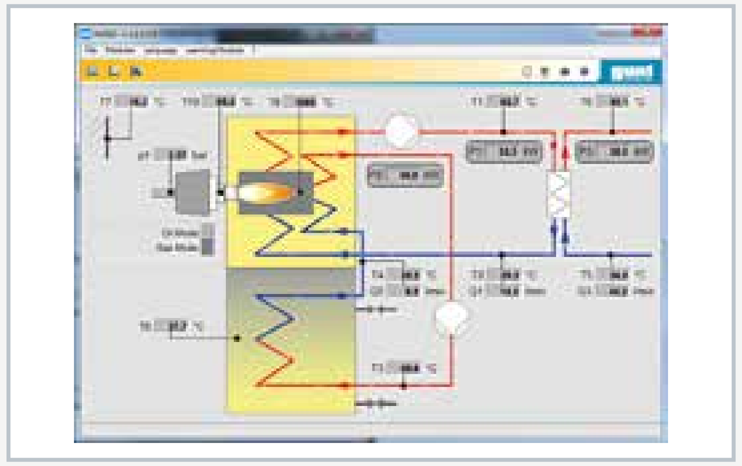
HL 352
Test stand for oil, natural gas and propane gas burners



1 heating control unit, 2 heating boiler, 3 HL 352.01 Oil burner (not included), 4 switch cabinet with digital displays and control panel, 5 gas pressure manometer, 6 two-strand oil filter, 7 fuel oil tank with fittings, 8 gas connection, 9 viewing window in the heating controller, 10 expansion tank, 11 boiler safety group



Process schematic: 1 heating boiler, 2 burner, 3 domestic water heater, 4 domestic water heater return, 5 domestic water heater feed, 6 cold water connection, 7 hot water drain, 8 circulation pump, 9 heating circuit feed, 10 plate heat exchanger, 11 heating circuit return, 12 cooling water connection, 13 cooling water drain, 14 external temperature sensor



Software screenshot

Specification

[1] comparison of burners
[2] oil burner, natural gas burner and propane gas burner available as accessories
[3] function of a heating boiler
[4] boiler body with 1 viewing window made of special glass
[5] domestic water heater with circulation pump
[6] transparent heating oil tank with filling and venting valve
[7] digital displays for oil pressure sensor, temperature and flow rate sensor
[8] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Boiler
- nominal power output: 18kW
- control unit with temperature limiter

Circulation pump
- max. power consumption: 70W
- max. flow rate: 45L/min
- max. head: 4m

Plate heat exchanger: 10 plates

Boiler safety group according to DIN 4751
- 3bar
- 50kW

Domestic water heater: 160L
Heating oil tank, transparent: 15L

Measuring ranges
- oil pressure: 0...16bar
- gas pressure (nozzle): 0...10mbar
- temperature: 1x 0...1.500°C / 9x 0...100°C
- flow rate (water): 3...60L/min
- flow rate (oil): 0...40L/min

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1000x1440x1920mm
Weight: approx. 377kg

Required for operation

water connection, drain, ventilation, exhaust gas routing, PC with Windows

Scope of delivery

1 trainer without burner
1 GUNT software CD + USB cable
1 set of instructional material

HL 352.01
Oil burner

The illustration shows a similar unit.

Learning objectives/experiments

- investigation of an oil burner
- thermodynamic balance

Specification

[1] oil burner for installation in the HL 352 test stand
[2] fuel supplied via the HL 352 test stand
[3] sensor and digital displays for initial oil pressure, temperatures and flow rate on the HL 352 test stand

Technical data

Oil burner
- max. output: 18kW

LxWxH: 800x400x400mm
Weight: approx. 11kg

Required for operation

fuel oil

Scope of delivery

1 experimental unit
1 manual

Description

- **oil burner for installation in the HL 352 test stand**
- **blue flame burner**

Oil burners are divided into yellow flame and blue flame burners, depending on the flame colour. In the case of yellow flame burners, the heating oil is only atomized before combustion; in the case of blue flame burners, the heating oil is evaporated and some of the hot exhaust gases are returned to the root of the burner flame. In blue flame burners, combustion takes place in a gaseous state, which produces the blue flame. This results in cleaner combustion with a lower nitrogen oxide content and very low carbon monoxide content in the exhaust gas.

The HL 352.01 Oil burner is a commercially available blue flame burner in the power range that is commonly used for residential buildings.

The HL 352 test stand can be used to measure important temperatures and pressures, which are then available for further calculations. A thermal balance can be created from the measurement data and the energy efficiency can be determined.

HL 352.02
Natural gas burner

The illustration shows a similar unit.

Learning objectives/experiments

- investigation of a natural gas burner
- thermodynamic balance

Specification

[1] natural gas burner for installation in the HL 352 test stand
[2] hoses with connections and gas pressure controller for the fuel supply
[3] sensor and digital displays for gas pressure, temperatures and flow rate on the HL 352 test stand

Technical data

Natural gas burner
- max. output: 15kW

LxWxH: 800x400x400mm
Weight: approx. 11kg

Required for operation

natural gas connection

Scope of delivery

1 experimental unit
1 manual

Description

- **natural gas burner for installation in the HL 352 test stand**
- **gas fan burner**

In a gas fan burner, the ratio of combustion air to gas quantity can be precisely dosed. The combustion air is supplied via a fan, which means that the combustion process is less dependent on ambient conditions such as the draught of the chimney. Due to the precise dosing, the burner can be operated with a small surplus of air and thus achieves a good firing efficiency.

Gas fan burners can be used for H/L natural gas or biogas or liquefied petroleum gas. They differ in their gas connection with the gas hoses, burner settings and pressure controller.

HL 352.02 is configured to use natural gas by default.

The HL 352.02 Natural gas burner is a commercially available gas fan burner in the power range that is commonly used for residential buildings.

The HL 352 test stand can be used to measure important temperatures and pressures, which are then available for further calculations. A thermal balance can be created from the measurement data and the energy efficiency can be determined.

HL 352.03
Propane gas burner

The illustration shows a similar unit.

Description

- **propane gas burner for installation in the HL 352 test stand**
- **gas fan burner**

In a gas fan burner, the ratio of combustion air to gas quantity can be precisely dosed. The combustion air is supplied via a fan, which means that the combustion process is less dependent on ambient conditions such as the draught of the chimney. Due to the precise dosing, the burner can be operated with a small surplus of air and thus achieves a good firing efficiency.

Gas fan burners can be used for H/L natural gas or biogas or liquefied petroleum gas. They differ in their gas connection with the gas hoses, burner settings and pressure controller.

HL 352.03 is configured to use liquefied petroleum gas, in this case propane gas, by default.

The HL 352.03 Propane gas burner is a commercially available gas fan burner in the power range that is commonly used for residential buildings.

The HL 352 test stand can be used to measure important temperatures and pressures, which are then available for further calculations. A thermal balance can be created from the measurement data and the energy efficiency can be determined.

Learning objectives/experiments

- investigation of a propane gas burner
- thermodynamic balance

Specification

[1] propane gas burner for installation in the HL 352 test stand
[2] hoses with connections and gas pressure controller for the fuel supply
[3] sensor and digital displays for gas pressure, temperatures and flow rate on the HL 352 test stand

Technical data

Propane gas burner
- max. output: 18kW

LxWxH: 800x400x400mm
Weight: approx. 11kg

Required for operation

propane gas connection

Scope of delivery

1 experimental unit
1 manual

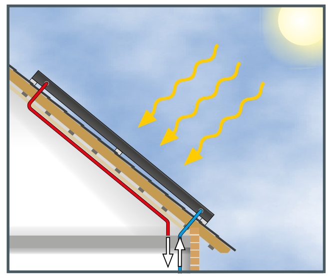
Visit
our website

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

Basic knowledge

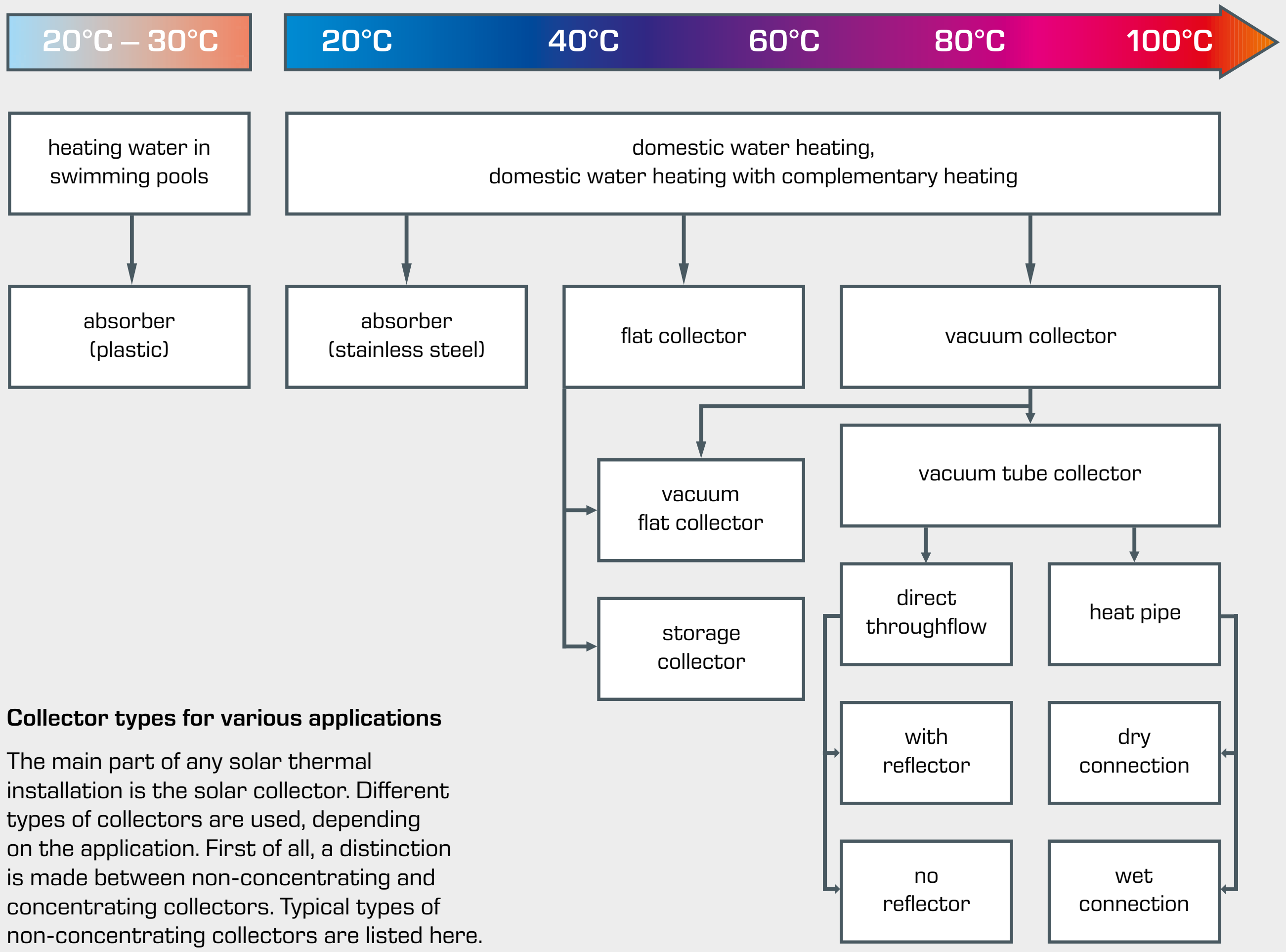
Solar thermal energy

Solar thermal energy is defined as using solar power to provide heat. The heat can be used for heating in the home and for heating domestic water, as well as for process heat in industry and for steam generation in power stations and even for cooling.



Typical applications for solar thermal collectors:

- heating water in swimming pools
- low-temperature heat for heating rooms
- domestic water heating
- process heat (concentrated solar power)
- electricity generation (concentrated solar power)



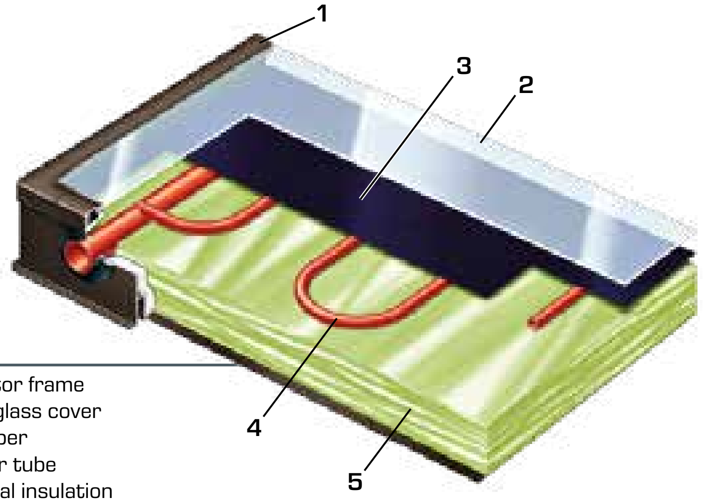
Collector types for various applications

The main part of any solar thermal installation is the solar collector. Different types of collectors are used, depending on the application. First of all, a distinction is made between non-concentrating and concentrating collectors. Typical types of non-concentrating collectors are listed here.

Flat collector

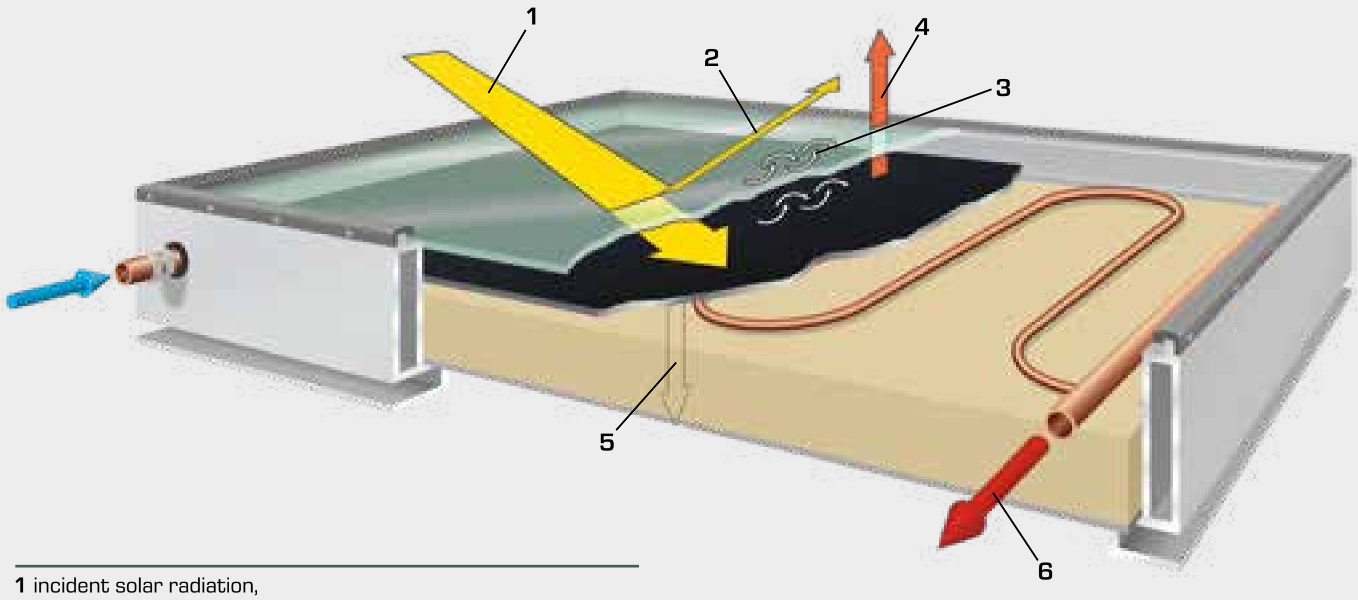
A widely-used type of collector is the flat collector. It represents a balanced compromise between a simple, cost-effective design and efficiency. The back is insulated against heat loss. The copper tube can be fed through the collector in different ways. The construction will seek a compromise between good convective heat transfer through to turbulent flow and low pressure loss. The absorber may be made of copper, aluminium or steel.

The absorber's dark colour is caused by the selective coating. The glass cover is made of high-quality, low-iron solar glass with a low absorption factor.



1 collector frame
2 solar glass cover
3 absorber
4 copper tube
5 thermal insulation

Energy balance of a flat collector



1 incident solar radiation,
2 losses through reflection,
3 losses through convection,
4 thermal radiation losses,
5 losses through heat conduction,
6 generated heat at the collector outlet

Minimising losses

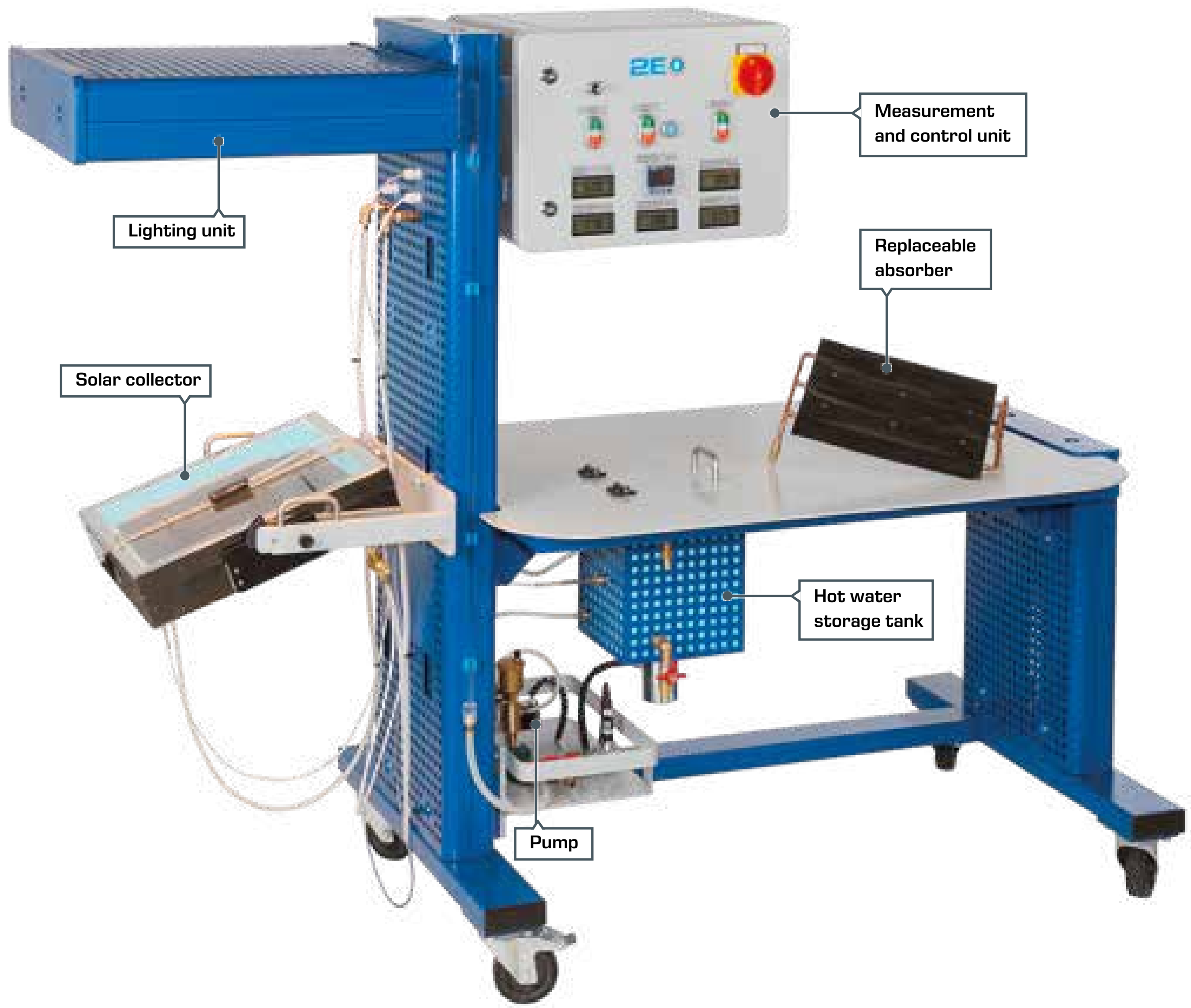
One of the main objectives for modern collectors is to minimise losses. The proportions of the major loss types in thermal solar energy utilisation with flat collectors are shown diagramally in the figure above.

ET 202
Principles of solar thermal energy

ET 202 is a device from the solar thermal energy training area and enables systematic experiments to be carried out on a solar thermal system with a flat collector.

This trainer may be used to study the key factors that affect solar thermal domestic water heating. As such, ET 202 includes a fully functional model of a solar thermal system. In order to facilitate laboratory experiments that do not rely on weather conditions, the trainer is fitted with its own lighting unit. This lighting unit simulates natural solar radiation. The light is converted into heat in an absorber and transferred to a heat transfer fluid. A pump conveys the heat transfer fluid through a hot water storage tank. There the heat is released to the contents of the tank by an integrated heat exchanger.

The flat collector offers a removable glass cover and a removable absorber for studying losses in the system.

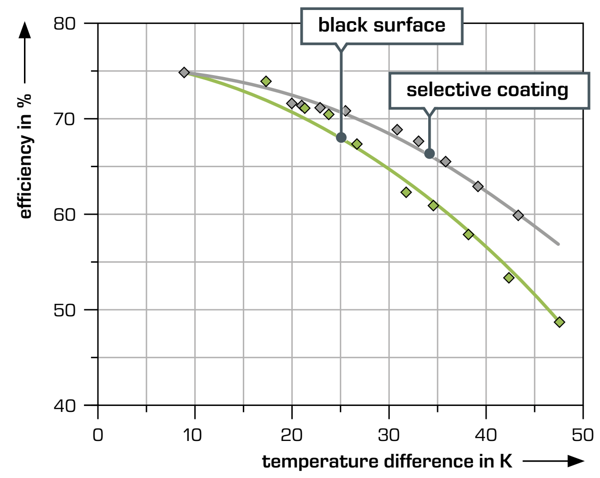


GUNT software for data acquisition

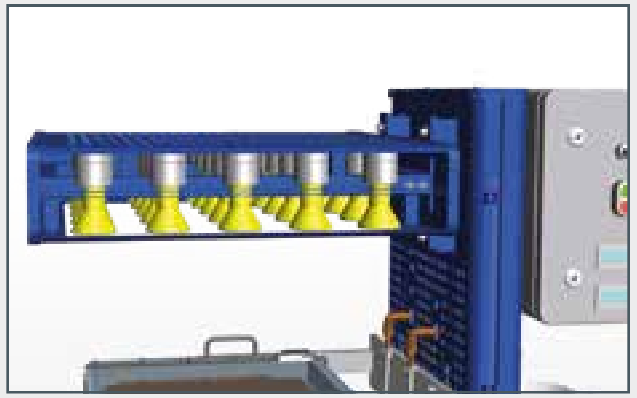
The ET 202 software displays the current values in a system diagram, and facilitates the recording of individual data points or plotting a graph of progression over time.

Digital readouts on the device also allow the device to be used without a PC.

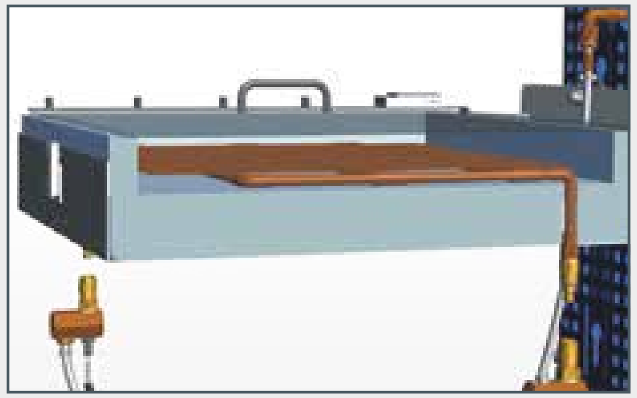
- design and operation of a simple solar thermal system
- determining the net power
- energy balance on the solar collector
- influence of illuminance, angle of incidence and flow rate
- efficiency as a function of the temperature difference
- influence of various absorbing surfaces



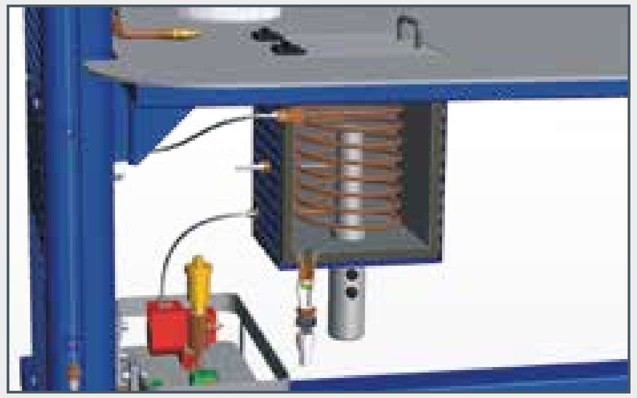
The illustration shows measured values for the efficiency as a function of the collector temperature. A special coating on the absorber allows higher efficiencies.



The lighting unit ensures uniform illumination. The spectral composition of the light is similar to that of natural solar radiation.



The solar collector converts the absorbed radiation into usable heat. Parts of the insulation and the absorber can easily be removed.



The heat exchanger is built into the hot water storage tank. An electrical heater which makes it possible to achieve different collector operating states in just a short time is additionally available.

ET 202
Principles of solar thermal energy

Description

- **demonstration model of a solar thermal system**
- **lighting unit for operation in the laboratory**
- **hot water storage tank with electrical auxiliary heater**
- **inclinable flat collector with replaceable absorbers**

Solar thermal systems convert solar energy into usable thermal energy. ET 202 allows you to demonstrate solar thermal heating of domestic water in an illustrative manner.

A lighting unit simulates natural solar radiation and allows a range of experiments to be carried out in the laboratory. The light is converted into heat in an absorber and transferred to a heat transfer fluid. A pump conveys the heat transfer fluid through a hot water storage tank. The heat is released to the water by an integrated heat exchanger in the tank.

ET 202 can be used to study a variety of angles of incidence and different illuminance. The pre-installed absorber with selective coating can be replaced for a more simple blackened absorber, so as to obtain comparative measurements of collector losses. External heat consumers can be attached to the tank via two connectors.

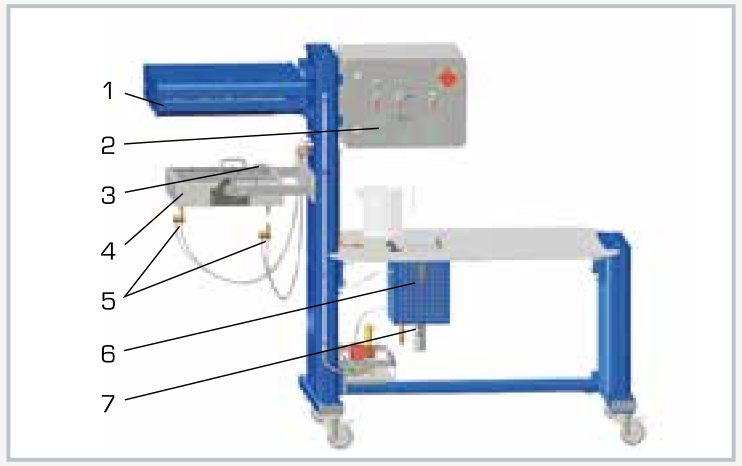
The trainer is fitted with sensors to detect the relevant temperatures (collector inlet, collector outlet, ambient air and tank) and the illuminance.

The measured values are displayed on the device and can simultaneously be transferred to a PC via USB. Using the PC, the data can be clearly displayed in the software provided and analysed further.

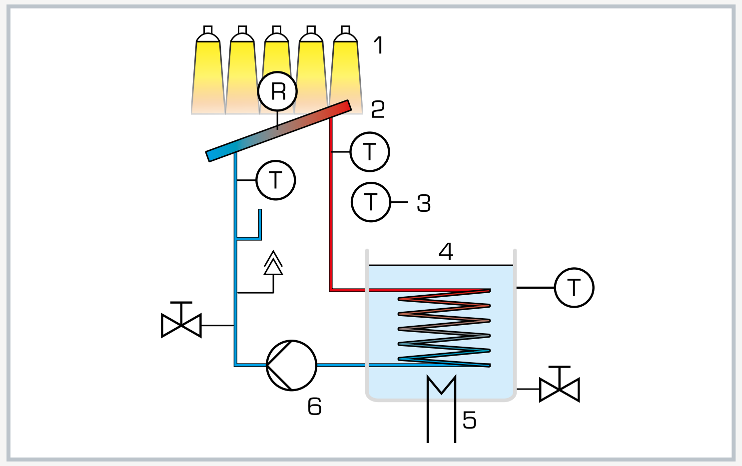
Learning objectives/experiments

- design and operation of a simple solar thermal system
- determining the net power
- energy balance on the solar collector
- influence of illuminance, angle of incidence and flow rate
- determining efficiency curves
- influence of various absorbing surfaces

ET 202
Principles of solar thermal energy



1 lighting unit, 2 control cabinet, 3 illuminance sensor, 4 flat collector with spacing and tilt adjustment, 5 temperature sensor, 6 hot water storage tank, 7 electrical auxiliary heater



Main components: 1 lighting unit, 2 flat collector, 3 temperature sensor ambient air, 4 hot water storage tank, 5 electrical auxiliary heater, 6 pump; R illuminance, T temperature

Specification

[1] functional demonstration model of a solar thermal system
[2] lighting unit with 25 halogen bulbs
[3] spacing and tilt adjustable collector
[4] 2 replaceable absorbers with different coating
[5] solar circuit with pump and variable flow
[6] hot water storage tank with tube coil as heat exchanger and electrical auxiliary heater
[7] sensors detect temperature and illuminance
[8] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Flat collector
- absorbing surface: 320x330mm
- tilt angle: 0...60°

Lighting unit
- lamp field: 25x 50W

Pump
- adjustable flow: 0...24L/h

Measuring ranges
- temperature: 4x 0...100°C
- flow rate: 0...30L/h
- illuminance: 0...3kW/m^2

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
230V, 60Hz, 3 phases
UL/CSA optional
LxWxH: 1840x800x1500mm
Weight: approx. 167kg

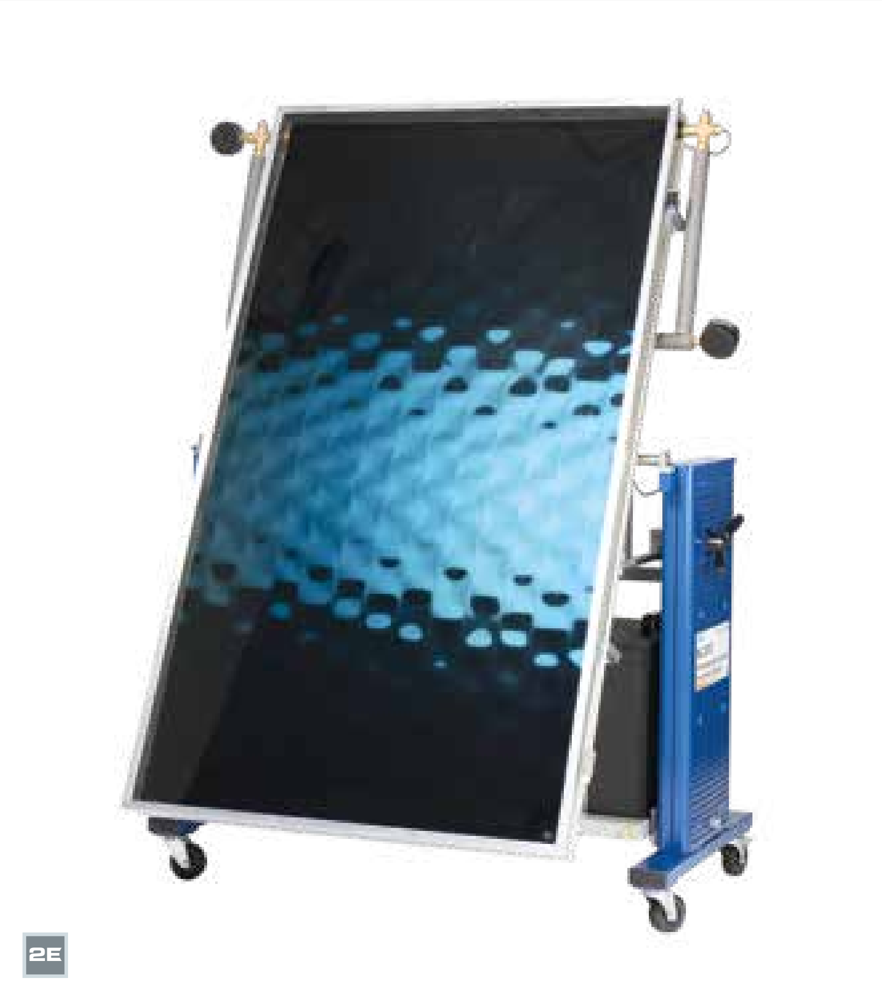
Required for operation

PC with Windows recommended

Scope of delivery

1 trainer
1 measuring beaker
1 absorber
1 CD with GUNT software + USB cable
1 set of instructional material

HL 313
Domestic water heating with flat collector



Learning objectives/experiments

- familiarisation with the functions of the flat collector and the solar circuit
- determining the net power
- relationship between flow and net power
- determining the collector efficiency
- relationship between temperature difference (collector/environment) and collector efficiency

Description

- **conversion of solar energy into heat**
- **trainer with real-world components**
- **pivotable flat collector**
- **system with heat exchanger and two separate circuits**
- **solar controller with data logger and USB interface**

The HL 313 trainer can be used to demonstrate the principal aspects of solar thermal domestic water heating in a system with components used in real world applications.

Radiant energy is converted into heat in a commercially available flat collector and transferred to a heat transfer fluid in the solar circuit. The heat then gets into the hot water circuit via a heat exchanger.

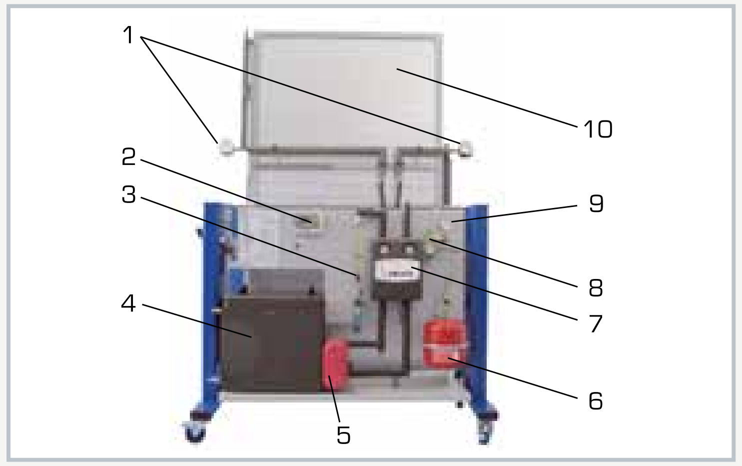
A solar controller controls the pumps for the hot water and solar circuits. The solar circuit is protected by an expansion tank and a safety valve.

The trainer has been designed so that it is possible to carry out a complete preheating as part of a practical experiment.

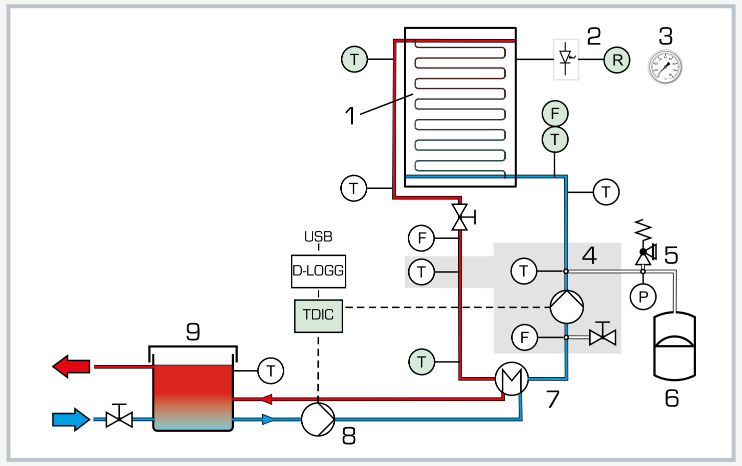
The temperatures in the storage tank, at the outlet from and the inlet to the collector are measured, as is the flow in the solar circuit. Additionally, as in practice, the temperatures of the inlet and return are displayed on the solar circulation station.

In order to ensure there is sufficient illuminance, the system should be operated with solar radiation or the optionally available HL 313.01 Artificial light source.

HL 313
Domestic water heating with flat collector



1 inlet and return thermometer, 2 solar controller, 3 flow meter, 4 buffer tank, 5 heat exchanger, 6 expansion vessel, 7 solar circuit pump, 8 pressure relief valve, 9 ambient air thermometer, 10 collector



TDIC solar controller with USB interface
1 collector, 2 illuminance sensor, 3 ambient air thermometer, 4 solar circulation station with solar circuit pump, 5 safety valve, 6 expansion tank, 7 heat exchanger, 8 hot water circuit pump, 9 buffer tank;
F flow rate, T temperature, P pressure, R illuminance

Specification

[1] trainer for investigating the function and operating behaviour of a flat collector
[2] solar thermal flat collector with selectively absorbing coating
[3] adjustable collector inclination angle
[4] solar circuit with collector, pump, expansion vessel and safety valve
[5] hot water circuit with buffer tank, pump and plate heat exchanger
[6] 4 bimetallic thermometers
[7] solar controller with temperature, flow rate and illuminance sensors
[8] data logger with USB interface
[9] operation with solar radiation or HL 313.01 Artificial light source

Technical data

Solar circuit
- collector
  - absorbing surface: 2,3m^2
  - rated throughput: 20...70L/h
  - operating pressure: 1...3bar
- safety valve 4bar

Hot water circuit
- plate heat exchanger: 3kW, 10 plates
- buffer tank 70L

Measuring ranges
- flow rate: 20...150L/h
- temperature: 4x 0...120°C

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 1660x800x2300mm
Weight: approx. 240kg

Scope of delivery

1 trainer
1 set of instructional material

Basic knowledge

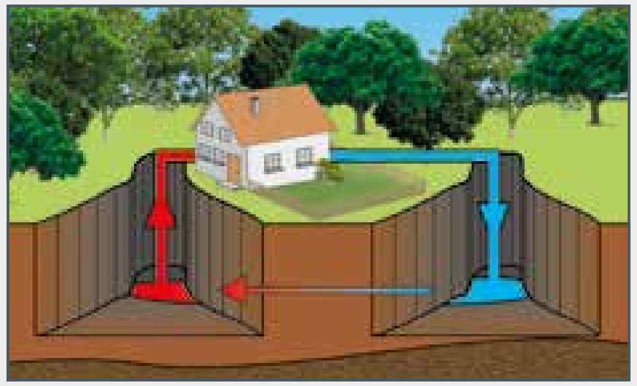
Shallow geothermal energy

The thermal utilisation of the soil to a maximum depth of 400m is called near-surface or shallow geothermal energy. The ground is the heat source. Due to its large mass, the ground can store thermal energy particularly well and does not react to temperature fluctuations of the ambient air. This is the advantage of the ground over air as a heat source.

There is an underground pipe system in which a liquid heat transfer medium circulates. The medium heats up in the ground and is transported to the surface for further use, e.g. for a heat pump.

Technical implementations

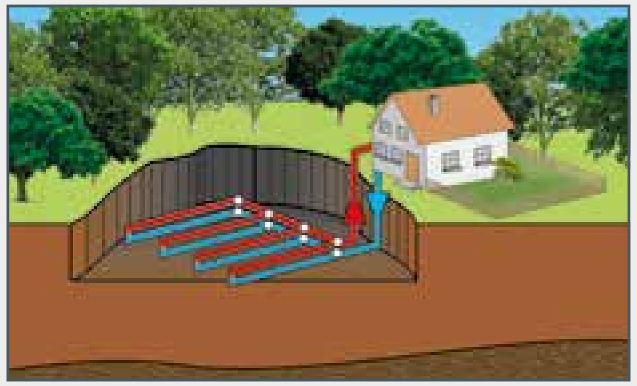
There are various options for using the thermal energy of the earth's surface. The technical implementation is dependent upon the local conditions, the desired power and the combination with other energy systems. In the field of shallow geothermal energy, firstly a distinction is made between open and closed systems and secondly between collectors and probes.



Dual well system

The dual well system is an open geothermal system without thermal retroaction on the heat source. It can be used for heating or cooling purposes, where groundwater serves as a geothermal heat source or heat sink. These systems require sufficient groundwater to be present at the site in layers near the surface.

This groundwater is pumped from a well to the surface of the earth. The well depths are between 6m and 15m for small installations in one- and two-family houses. In heating mode, a heat exchanger extracts heat from the groundwater. If groundwater quality is good and purity high, the heat exchanger can be designed as an evaporator of a heat pump and the groundwater can be used directly by the heat pump. In order to conserve the groundwater reservoir, the groundwater must be returned to the soil after thermal use via a discharge well. There must be sufficient distance between the well and discharge well so that there is no hydraulic short circuit. There must be no thermal retroaction in the system. One advantage of this system is the almost constant groundwater temperature throughout the year.



Geothermal collectors

Geothermal collector is the generic term for closed geothermal heat exchangers with thermal retroaction on the surrounding ground. The standard design is the horizontal geothermal collector.

These collectors are installed approx. 1m to 1,5m below unsealed ground surfaces. Due to the low installation depth, the heat transfer medium in the collector can reach temperatures below 0°C in heating mode and must therefore be frost-proof. The surrounding soil also usually freezes during the heating period. Regeneration of the temperature of the ground is mainly carried out by heat transport from nearby layers of the earth, ambient air, solar radiation and penetrating precipitation.

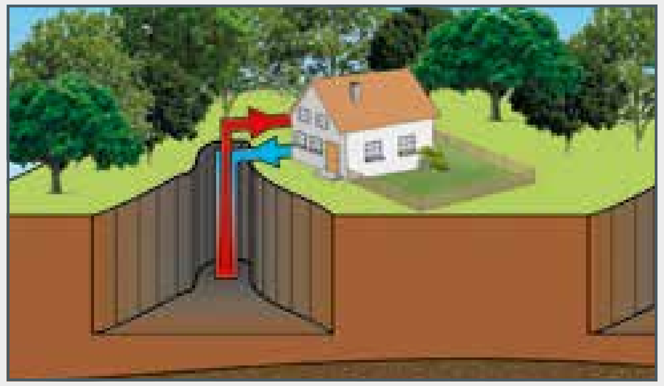
Depending on the ground conditions, about 15m^2 to 30m^2 collector surface area per kW of heating power is required. Due to the relatively high ground temperatures, geothermal collectors are rather unsuitable for cooling buildings compared to other systems.

Geothermal probes

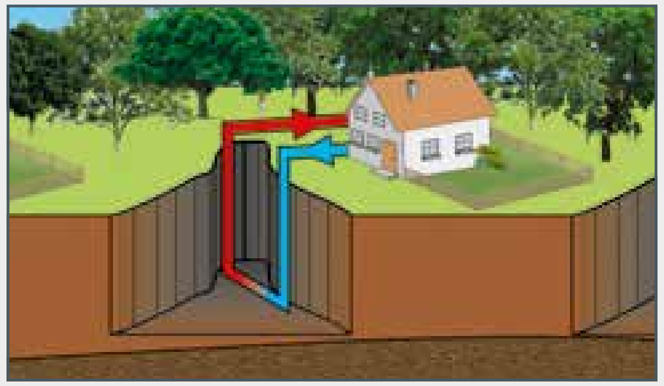
Geothermal probes are heat exchangers that are inserted vertically or at an angle into the ground. In most cases, these consist of plastic pipes inserted into boreholes. The probes can be designed in different ways. Geothermal probes are a closed geothermal system with thermal retroaction on the ground.

For small heating systems up to 30kW, geothermal probes usually tap depths between 50m and 150m, with one or two geothermal probes usually being sufficient for a single-family house. If required, more geothermal probes can also be combined to form a geothermal probe field.

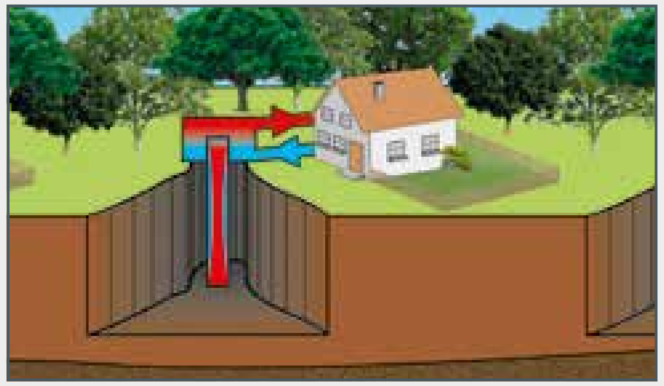
Geothermal probes are further subdivided according to the type of heat transfer and heat transport. Probes in which a water/antifreeze mixture is pumped by means of a circulation pump in the circuit between the geothermal probe and the consumer are referred to as geothermal probes with forced circulation. The absorbed geothermal heat is released at the earth's surface in a heat exchanger, which is located, for example, in a heat pump. Geothermal probes with forced circulation can also be used according to the reverse principle for cooling purposes by transferring heat from a building to the cooler ground via the geothermal probe. In other words the ground can also be used as a thermal store.



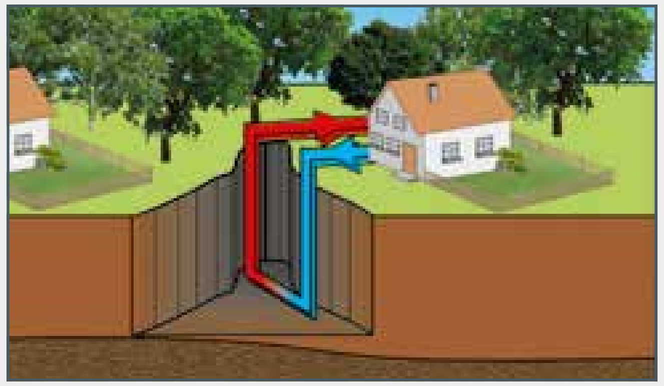
Coaxial probe



U-shaped probe



Probe with heatpipe principle



Dual U-shaped probe

ET 262
Geothermal probe with heat pipe principle

Description

- **transparent components allow observing how the state of the heat transfer medium changes**
- **operation with low-boiling heat transfer medium**

In shallow geothermal energy generation the thermal energy stored under the earth's surface is used for heating purposes.

ET 262 demonstrates the operation of a geothermal probe with heat pipe principle. The transparent experimental set-up provides an insight into the closed circuit of the heat transfer: it allows a clear view on the evaporation in the heat pipe, the condensation in the probe head and the reflux of the heat transfer medium on the inside wall of the heat pipe. The set-up also allows to take a closer look at the basic methods applied for determining the thermal conductivity of the surrounding soil of the geothermal probe.

The heat pipe whose operating behaviour is examined constitutes the core element of the trainer. The heat pipe contains a low-boiling heat transfer medium. The heat input from the soil is simulated via a temperature control jacket with heating circuit. The heat from the heat transfer medium is transferred to a working medium inside the probe head. Sensors detect the temperature and flow rate of the working medium in the heat exchanger. These measured values are used to calculate the thermal power that is transferred. The GUNT software uses the measured values to simulate the energy balance of a connected heat pump.

One method to determine the thermal conductivity of the surrounding soil is the so-called thermal response test. A pump circulates constantly heated water through a U-tube geothermal probe that is sunk in sand. During this process, the inlet and outlet temperature, the flow rate and the heating power of the geothermal probe are recorded. These measured values are used to calculate the thermal conductivity.

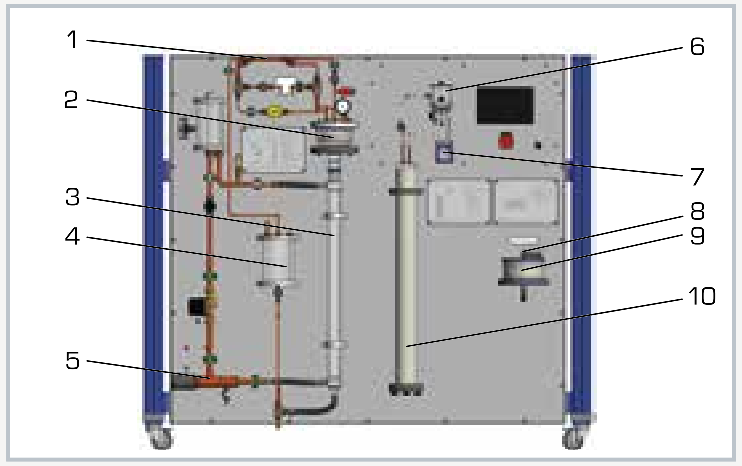
During another experiment, a sand cylinder is heated with a cylindrical heat source. The radially dispersed thermal temperature profile within the sand sample is detected and used to calculate the thermal conductivity within the sand sample. The results of both methods will then be compared.

The measured values are transmitted directly to a PC via USB where they can be analysed using the software included.

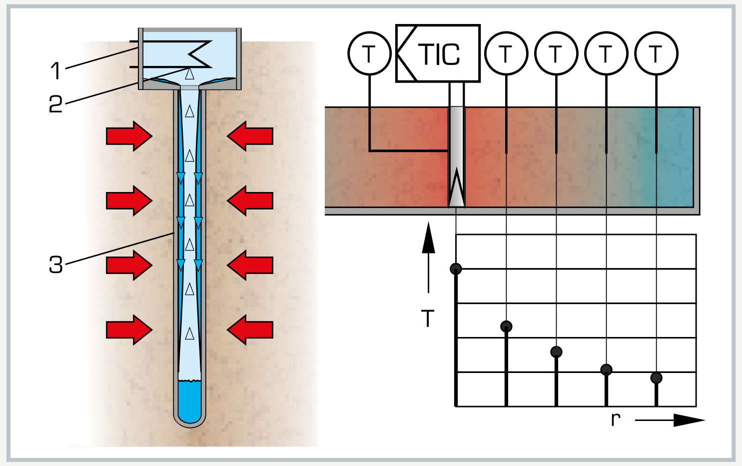
Learning objectives/experiments

- fundamentals of geothermal energy
- operating behaviour of a geothermal probe with heat pipe principle
- determination of the amount of heat that can be dissipated in the heat pipe with variation of the thermal load
- variation of the filling level of the heat transfer medium contained
- examination of the radial temperature profile in a sand sample and determination of the thermal conductivity
- determination of the sand's thermal conductivity by means of a thermal response test
- fundamentals and energy balance of a heat pump

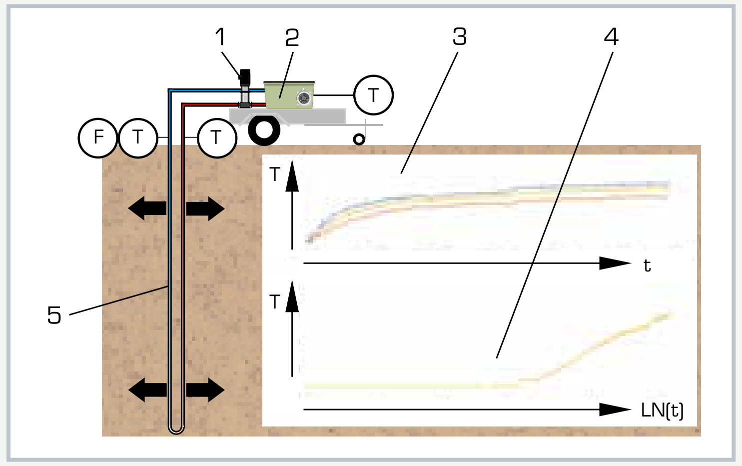
ET 262
Geothermal probe with heat pipe principle



1 condensate separator, 2 heat exchanger, 3 heat pipe with temperature control jacket, 4 storage tank for heat transfer medium, 5 heater in the heating circuit, 6 water tank with heating element, 7 pump, 8 heating element, 9 sand cylinder, 10 U-tube geothermal probe



left: geothermal probe with heat pipe principle: 1 sensor head, 2 heat exchanger, 3 heat pipe, blue: liquid heat transfer medium, light blue: gaseous heat transfer medium, red arrow: geothermal heat;
right: radial heat conduction in a sand sample: T temperature, TIC temperature controller of the heater, r radius



Thermal response test: 1 pump, 2 water tank with heating element, 3 time dependency of the measured temperatures, 4 logarithmic time dependency of the central water temperature, 5 U-tube geothermal probe; T temperature, F flow rate, t time, LN(t) natural logarithm of time

Specification

[1] demonstration of the operation of a geothermal probe with heat pipe principle
[2] heat pipe made of glass with transparent temperature control jacket
[3] water as a working medium for heat dissipation in the heat exchanger
[4] supply of the working medium via the lab network or via water chiller WL 110.20
[5] simulation of the energy balance of a heat pump in the GUNT software
[6] CFC-free heat transfer medium Solkatherm SES36
[7] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Heat pipe
- length: approx. 1200mm
- external diameter heat pipe: approx. 56mm
- external diameter temperature control jacket: approx. 80mm

Heater in the heating circuit
- output: 2kW

Pump in the heating circuit
- max. flow rate: 1,9m^3/h
- power consumption: 58W

U-tube geothermal probe made of copper
- length: approx. 1000mm

Pump in the thermal response test
- flow rate: 4,8...28,2L/h
- power consumption: max. 60W

Heating element in the water tank
- output: 100W

Heating element in the sand container
- output: 50W

Measuring ranges
- temperature of the heating element in the sand sample: 0...250°C
- flow rate: 0,4...6L/min

230V, 50Hz, 1 phase
LxWxH: approx. 1500x790x1900mm
Weight: approx. 250kg

Required for operation

water connection or water chiller WL 110.20

Scope of delivery

1 trainer
1 sand (25kg; 1...2mm grain size)
1 GUNT software CD + USB cable
1 set of instructional material

ET 264
Geothermal energy with two-well system

Description

- **use of geothermal energy in an open system without thermal repercussion**
- **simulation of the energy balance of a heat pump**

The scope of geothermal energy is the study and use of the heat and the temperature distribution in the ground. A geothermal plant uses the thermal energy stored below the earth's surface. Using a two-well system, for example, thermal energy is extracted from the near-surface groundwater for heating purposes. ET 264 demonstrates the operation of such a two-well system.

The trainer contains a closed water circuit with storage tank and pump. The core element is a sand bed through which water flows with a production well and an absorption well. Water (groundwater) flows in and out via two side-mounted chambers.

In the experiment, the groundwater is delivered from the production well to a heat exchanger and the thermal energy is transmitted from the groundwater to the working medium.

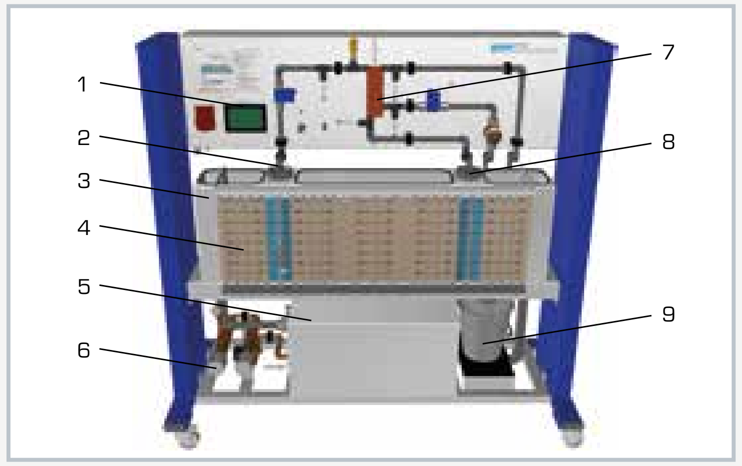
The water then flows into an absorption well. From here, the water is delivered via the drain chamber into the storage tank, is heated and returned to the experimental section. The groundwater temperature in the storage tank is adjusted by means of a controlled heater. The flow rate of the pump in the production well can be adjusted. The groundwater flow through the sand bed is adjusted using height-adjustable discharges. The working medium is added either via the laboratory supply or via the WL 110.20 water chiller.

From the measured temperatures and the flow rate, the transmitted thermal output is determined. A multi-tube manometer visualises the groundwater levels of both wells. The measured values are displayed on the trainer and can be transmitted simultaneously via USB directly to a PC, where they can be analysed using the GUNT software included. By means of the measured values, a heat pump which is connected to the two-well system is simulated.

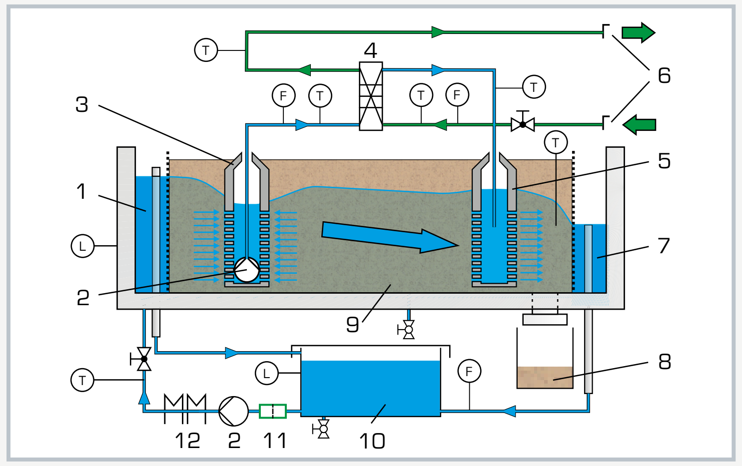
Learning objectives/experiments

- fundamentals of geothermal use
- operating behaviour of a two-well system
- hydraulic and thermal properties of the ground
- determination of the usable heat capacity
- fundamentals and energy balance of a heat pump

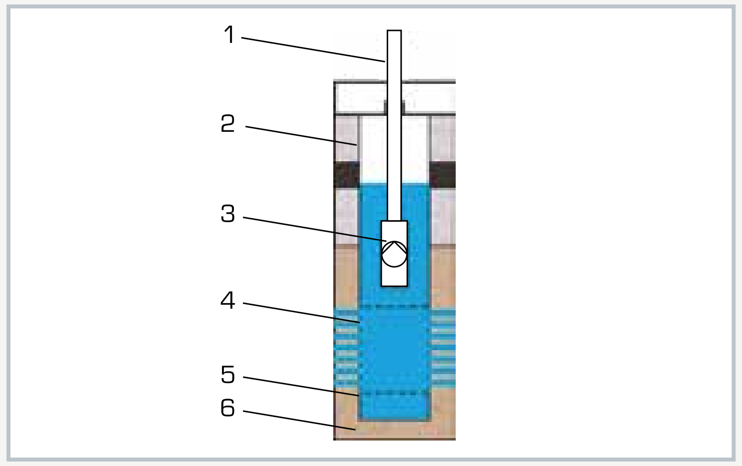
ET 264
Geothermal energy with two-well system



1 display, 2 production well, 3 experimental tank, 4 multi-tube manometer, 5 storage tank, 6 heater, 7 heat exchanger, 8 absorption well, 9 tank



1 feed chamber, 2 pump, 3 production well, 4 heat exchanger, 5 absorption well, 6 working medium connection, 7 drain chamber, 8 tank, 9 experimental section, 10 storage tank, 11 filter, 12 heater; F flow rate, L level, T temperature, blue: water, green: working medium



Typical design of a production well: 1 rising pipe, 2 extension pipe, 3 pump, 4 filter pipe, 5 sump pipe, 6 filter gravel

Specification

[1] demonstration and operation of a two-well system for using geothermal energy
[2] temperature-controlled groundwater circuit
[3] height-adjustable overflows for adjusting the groundwater flow
[4] adjustable flow rate of the pump in the production well
[5] measurement of temperature and flow rate to determine the transmitted heat capacity
[6] multi-tube manometer for visualising the groundwater levels
[7] supply of the working medium via laboratory supply or the WL 110.20 water chiller
[8] calculation of the transmitted heat capacity and simulation of the energy balance of a heat pump
[9] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Experimental section
- LxWxH: approx. 1600x270x470mm

Production well pump
- power consumption: max. 72W
- max. flow rate: approx. 17L/min

Storage tank pump
- power consumption: approx. 70W
- max. flow rate: approx. 20L/min

Storage tank
- capacity: approx. 135L

Plate heat exchanger
- heat transfer surface: 0,39m^2
- number of plates: 30

Heater
- power consumption: max. 8kW

Measuring ranges
- temperature: 0...45°C
- flow rate:
  - 0...17L/min (production well)
  - 5...50L/min (groundwater circuit)

400V, 50Hz, 3 phases
230V, 60Hz, 3 phases; 400V, 60Hz, 3 phases
UL/CSA optional
LxWxH: 1990x790x1920mm
Empty weight: approx. 320kg

Required for operation

water connection, drain or WL 110.20, PC with Windows recommended

Scope of delivery

1 trainer
1 sand (250kg, grain size 1...2mm)
1 GUNT software CD + USB cable
1 set of instructional material

Basic knowledge

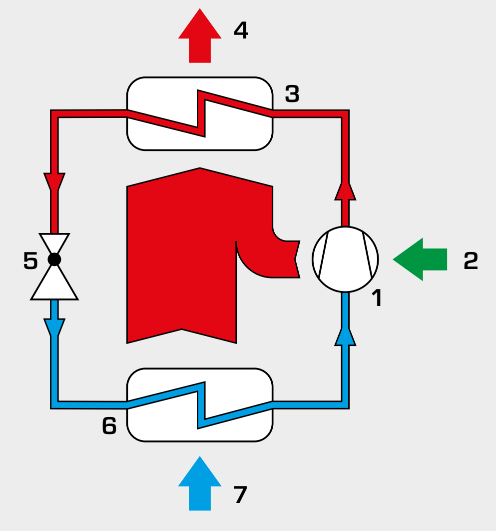
Heat pump

What is a heat pump?

A heat pump transports heat from a low temperature level to a higher temperature level. To do this, the heat pump requires drive power. This can be mechanical, electrical or thermal. Usually heat pumps which operate according to the principle of a compression refrigeration system are used. Less often, heat pumps running on the absorption process are used.

The COP is an important indicator for the operation of heat pumps. COP stands for “Coefficient of Performance”. The COP indicates how efficiently a heat pump works. The COP indicates the ratio of heat capacity and the required drive power. This value allows an easy comparison between different heat pumps.

The COP is directly dependent on the temperature of the heat source and the heating temperature in the building. Therefore, the COP changes at each operating point of the heat pump. The larger the COP, the more effective the heat pump.



1 compressor, **2** mechanical work, **3** condenser, **4** heat dissipation, **5** expansion valve, **6** evaporator, **7** heat absorption

Where does the heat pump get its energy from?

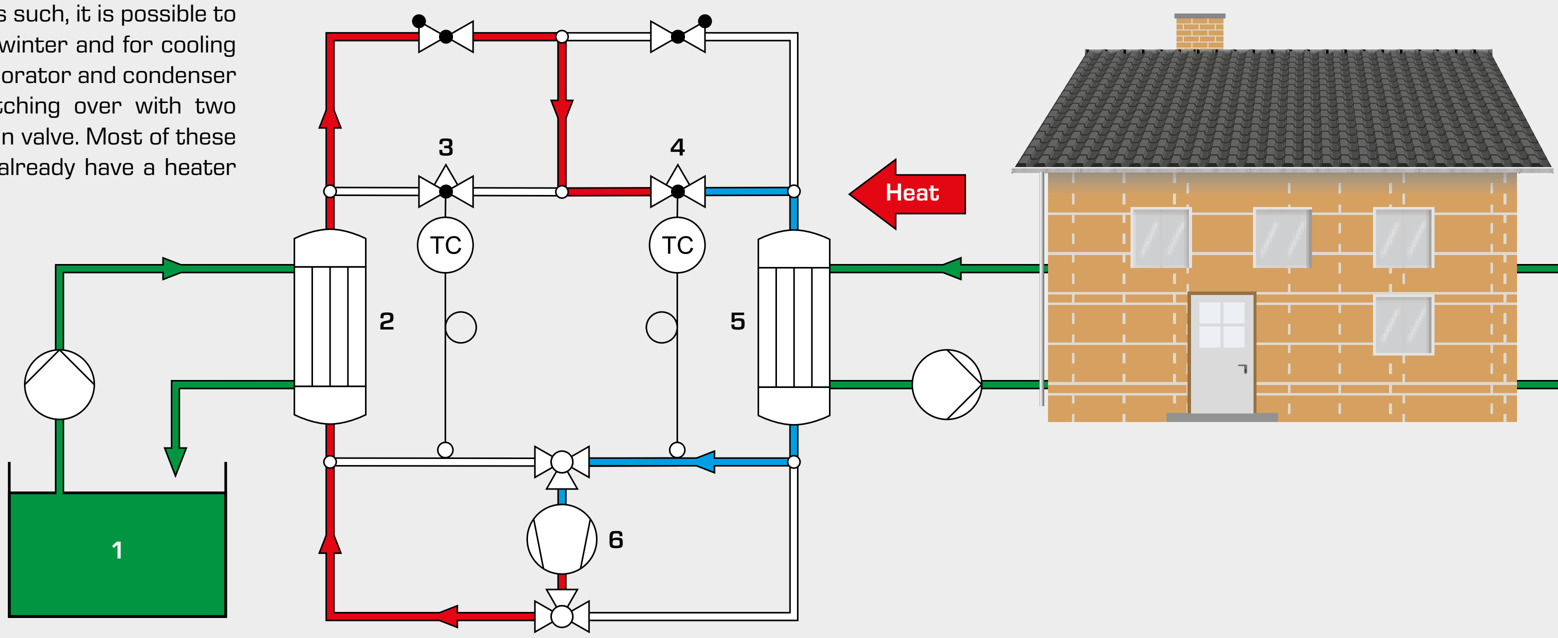
A heat pump usually extracts the energy from the environment. Air, groundwater, the earth or river water are common. If the energy is extracted from the ground, this is known as shallow geothermal energy. An energy source temperature which is as high and constant as possible is the key for high efficiency. The temperature must not drop off too much in winter, when the most heating power has to be provided. For groundwater and the ground, the heat exchangers have to be very large in order to avoid any local sub-cooling. When choosing the heat source, factors such as investment cost, efficiency, availability and obtaining permission have to be weighed against each other. Using low-order waste heat such as exhaust air or cooling water is particularly cost-effective.

The lower the temperature difference between heat source (evaporator) and heating temperature (condenser), the larger the COP.

Energy source	Advantage	Disadvantage
outside air	low investment	low COP in winter
river water	low investment	low COP in winter
groundwater	good, constant power	high investment, permission
ground	good, constant power	large space requirement

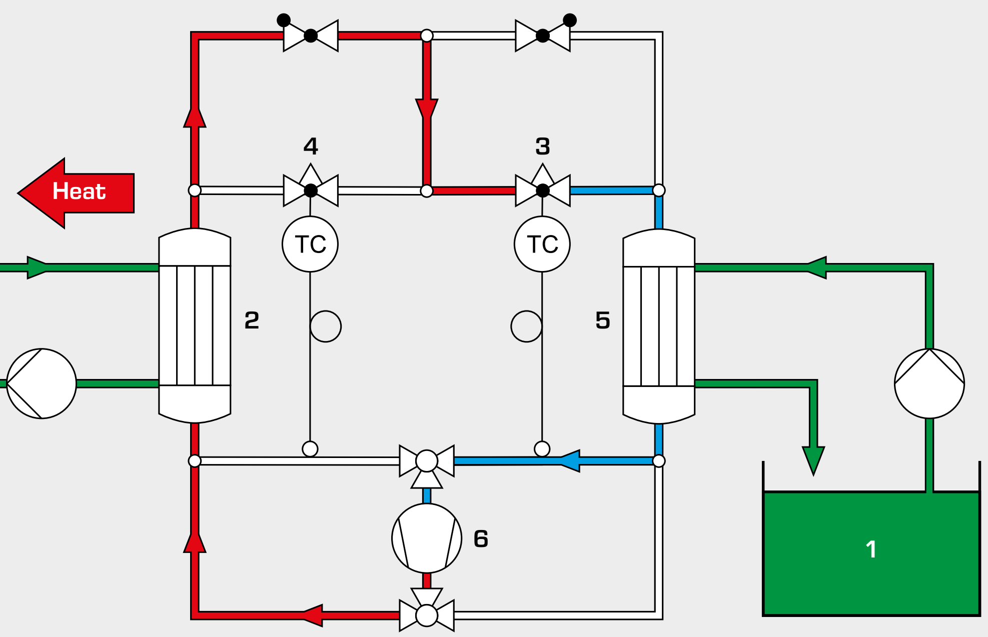
A heat pump can be used for cooling or heating

Because they have the same principle of operation, a heat pump can function as a refrigeration system. As such, it is possible to use the same system for heating in the winter and for cooling in the summer. Only the functions of evaporator and condenser are swapped. This takes place by switching over with two non-return valves and a second expansion valve. Most of these so-called split devices for room cooling already have a heater function included.



Summer

1 heat sink, **2** condenser, **3** expansion valve 1,
4 expansion valve 2, **5** evaporator, **6** compressor,
water/solar circuit, refrigerant (low pressure),
refrigerant (high pressure)



Winter

1 heat source, **2** condenser, **3** expansion valve 1,
4 expansion valve 2, **5** evaporator, **6** compressor,
water/solar circuit, refrigerant (low pressure),
refrigerant (high pressure)

ET 102
Heat pump

Learning objectives/experiments

- design and operation of an air-to-water heat pump
- representation of the thermodynamic cycle in the log p-h diagram
- energy balances
- determination of important characteristic variables
  - compressor pressure ratio
  - ideal coefficient of performance
  - real coefficient of performance
- dependence of the real coefficient of performance on the temperature difference (air-to-water)
- operating behaviour under load

Description

- **utilisation of ambient heat for water heating**
- **display of all relevant values at the location of measurement**

With the air-to-water heat pump ET 102 the ambient heat of the air is used to heat water.

The heat pump circuit consists of a compressor, an evaporator with fan, a thermostatic expansion valve and a coaxial coil heat exchanger as condenser. All components are clearly arranged in the trainer.

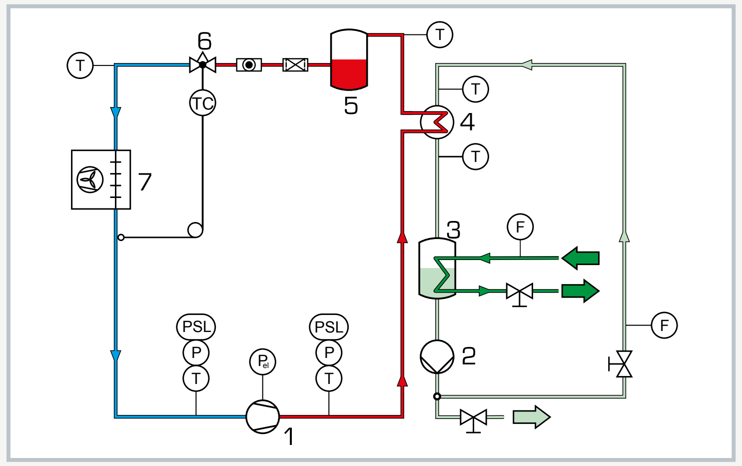
The compressed refrigerant vapour condenses in the outer pipe of the condenser and thereby discharges heat to the water in the inner pipe. The liquid refrigerant evaporates at low pressure in the finned tube evaporator and thereby absorbs heat from the ambient air.

The hot water circuit consists of a tank, a pump and the condenser as heater. For a continuous operation the generated heat is dissipated via an external cooling water connection. The cooling water flow rate is set via a valve and measured.

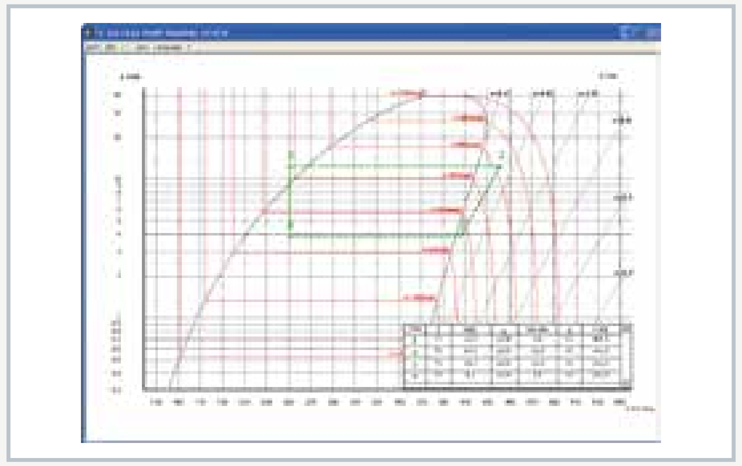
All relevant measured values are recorded by sensors and displayed. The simultaneous transmission of the measurements to a data recording software enables analysis and the representation of the process in the log p-h diagram. The software also displays the key characteristics variables of the process, such as the compressor pressure ratio and the coefficient of performance.

ET 102
Heat pump

1 expansion valve, 2 evaporator with fan, 3 pressure sensor, 4 pressure switch, 5 displays and controls, 6 compressor, 7 cooling water flow meter, 8 pump, 9 hot water tank, 10 receiver, 11 cocondenser



1 compressor, 2 pump, 3 hot water tank with external cooling water connection, 4 condenser, 5 receiver, 6 expansion valve, 7 evaporator with fan;
T temperature, P pressure, F flow rate, P_{el} power, PSH, PSL pressure switch;
blue/red: refrigeration circuit, light green: hot water circuit, green: cooling water



Software screenshot: log p-h diagram

Specification

[1] investigation of a heat pump with a water circuit as load
[2] refrigeration circuit with compressor, evaporator with fan, thermostatic expansion valve and coaxial coil heat exchanger as condenser
[3] hot water circuit with pump, tank and condenser as heater
[4] additional cooling via pipe coil in the hot water tank and external cooling water
[5] record and display of all relevant measured values and
[6] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Compressor
- capacity: 372W at 7,2/32°C

Coaxial coil heat exchanger (condenser)
- refrigerant content: 0,55L
- water content: 0,3L

Finned tube evaporator
- transfer area: approx. 0,175m²

Pump
- max. flow rate: 1,9m³/h
- max. head: 1,4m

Hot water tank volume: approx. 4,5L

Measuring ranges
- pressure: 2x -1...15bar
- temperature: 4x 0...100°C, 2x -100...100°C
- power: 1x 0...6000W
- flow rate (water): 1x 0...108L/h
- flow rate (cooling water): 1x 10...160L/h

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
120V, 60Hz, 1 phase
LxWxH: 1620x790x1910mm
Weight: approx. 192kg

Required for operation

water connection, drain
PC with Windows recommended

Scope of delivery

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

ET 405
Heat pump for cooling and heating operation

Description

- **air-to-water heat pump**
- **heating and cooling operation possible**
- **high practical relevance by using industrial components from refrigeration**
- **different operating modes can be set via solenoid valves**

Refrigeration systems and heat pumps only differ in the definition of their use, but can be of the same design. For example, goods can be refrigerated in a supermarket and the store heated with the waste heat. The store can also be cooled with the same system in the summer.

With ET 405 the cooling and heating operation can be investigated. Different operating modes can be selected via solenoid valves.

The refrigeration circuit with compressor and condenser (heat exchanger with fan) includes two evaporators with fans (refrigeration stage and freezing stage) and thermostatic expansion valves. The two evaporators can be connected in parallel or in series. For the connection in series the capillary tube serves as expansion element for the refrigeration stage evaporator. The refrigerant circuit is connected to a glycol-water circuit via a coaxial coil heat exchanger. Via solenoid valves the coaxial coil heat exchanger can be switched as an evaporator or condenser. Thus the glycol-water mixture in the tank can be heated or cooled. In pure cooling operation (without heating function) the heat exchanger with fan as air-cooled condenser dissipates the heat. This heat exchanger can be also switched as an evaporator.

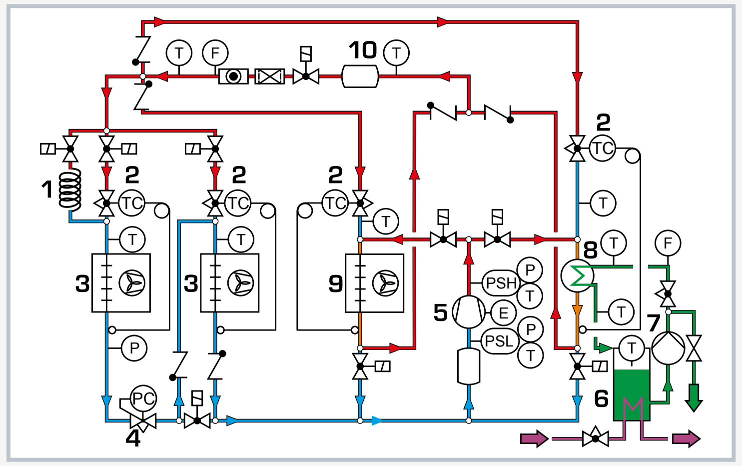
The measured values are read from digital displays and can at the same time be transmitted via USB directly to a PC where they can be analysed using the software included. The software enables a clear representation of the process.

Learning objectives/experiments

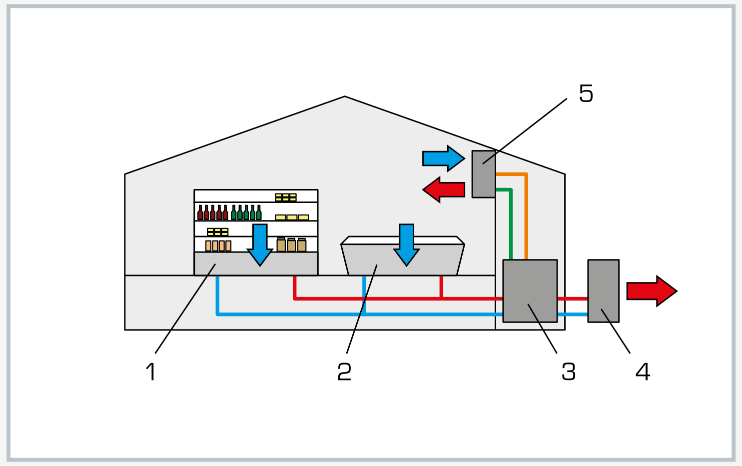
- design, operation and key components of a heat pump or refrigeration system
- representation of the thermodynamic cycle in the log p-h diagram
- comparing different operating modes
- measurement of compressor capacity and heating or cooling capacity in the glycol-water circuit
- determination of
  - efficiency
  - coefficient of performance of heat pump and refrigeration system
  - specific compressor load
  - compressor pressure ratio
  - specific cooling capacity
  - specific refrigeration capacity
- comparing key figures of heat pump and refrigeration system

ET 405
Heat pump for cooling and heating operation

1 evaporator, 2 expansion valve, 3 capillary tube, 4 freezing stage evaporator, 5 evaporation pressure controller, 6 compressor, 7 receiver, 8 heat exchanger with fan, 9 pump, 10 display and control elements, 11 tank for glycol-water mixture, 12 flow meter, 13 solenoid valve, 14 coaxial coil heat exchanger



1 capillary tube, 2 expansion valve, 3 evaporator, 4 evaporation pressure controller, 5 compressor, 6 tank for glycol-water mixture, 7 pump, 8 coaxial coil heat exchanger, 9 heat exchanger with fan, 10 receiver, T temperature, P pressure, F flow rate, PSH, PSL pressure switch



Supermarket application: 1 refrigeration units, 2 freezer, 3 heat pump, 4 external condenser, 5 convector to heat or cool the sales room

Specification

[1] air-to-water heat pump for cooling or heating operation
[2] different operating modes selectable via solenoid valves
[3] refrigeration circuit with compressor, condenser (heat exchanger with fan), 2 evaporators with fan (refrigeration and freezing stage)
[4] glycol-water circuit with tank, pump and coaxial coil heat exchanger
[5] coaxial coil heat exchanger and heat exchanger with fan can both be used as condenser or evaporator in the refrigeration circuit
[6] 1 thermostatic expansion valve each for all heat exchangers and evaporators
[7] 1 additional evaporation pressure controller and 1 capillary tube for the refrigeration stage evaporator
[8] displays for temperature, pressure, flow rate and power consumption of the compressor
[9] GUNT software for data acquisition via USB under Windows 7, 8.1, 10
[10] refrigerant R134a, CFC-free

Technical data

Compressor
- refrigeration capacity: 934W at -6,7/55°C
- power consumption: 620W at -6,7/55°C

Heat exchanger with fan
- transfer area: 1,25m^2, volumetric air flow rate: 650m^3/h, capacity: 1148W at DT=15K

Evaporators with fan
- refrigeration stage
  - transfer area: 1,21m^2, volumetric air flow rate: 80m^3/h, capacity: 140W (t_{L1}=5°C, DT1=10K)
- freezing stage
  - transfer area: 3,62m^2, volumetric air flow rate: 125m^3/h, capacity: 330W (t_{L1}=5°C, DT1=10K)

Coaxial coil heat exchanger
- capacity: 1,6kW at 0°C; DT=9K

Measuring ranges
- temperature: 11x -50...150°C
- pressure: 2x -1...15bar, 1x -1...24bar
- flow rate: 1x 4...40L/h (refrigerant)
- flow rate: 1x 2,5...65g/s (glycol-water)
- power: 0...1150W

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 2210x800x1900mm
Weight: approx. 330kg

Required for operation

water connection, drain
PC with Windows recommended

Scope of delivery

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

ET 420
Ice stores in refrigeration

With growing decentralisation of the energy supply, the storage of energy is becoming increasingly important. The storage of thermal energy for domestic water heating has been used successfully in building services engineering for years. However, the use of ice stores for cooling buildings is still an exception.

The heat to be dissipated, to cool buildings, fluctuates during the course of the day. The demand for cooling is usually much higher during the day than at night. In order to be able to cool buildings under the highest possible load demand, refrigeration plants are designed to meet the expected peak load. This leads to an over-dimensioning of the refrigeration technology, so that affected plants are operated very inefficiently under partial load conditions.

Ice stores can support the refrigeration plant in the case of particularly high cooling loads. Ice stores for assisting the refrigeration plant are mainly used in large non-residential buildings. In times of low cooling demand, the store is charged via the refrigeration plant and can be discharged again in case of peak loads to support the refrigeration plant. The capacity of the refrigeration technology can thus be designed to be smaller. The use of smaller refrigeration plants saves operating and investment costs.

If heat is removed from a liquid store, the temperature of the storage medium falls. The water remains liquid and there is no change to the aggregate state. The ice store belongs to the group of latent storage. The water in the ice store changes its aggregate state. The temperature of the water is constant during the phase transition. If heat is still dissipated, the temperature of the water in the ice store remains constant at 0°C.

The discharged energy corresponds to the phase change work during water freezing.

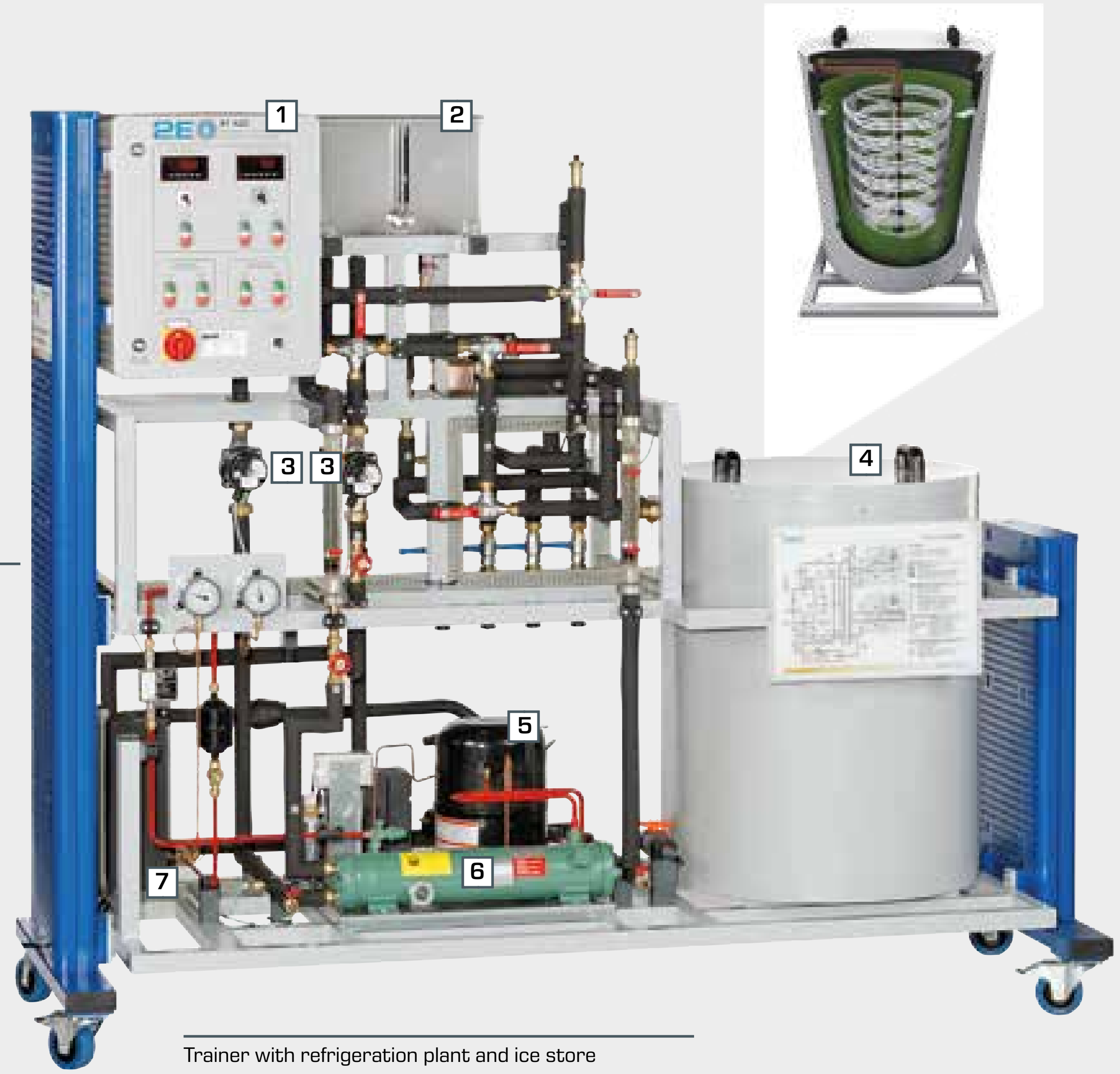
To discharge the ice store, heat is transferred to the ice. The temperature is constant until the ice in the store has melted. Due to the phase change work, a large amount of thermal energy can be stored at a low temperature difference.

ET 420 offers a refrigeration plant with ice store, which can be operated entirely as required. The plant concept includes a dry cooling tower **9**, which represents the heat exchanger in the building to be supplied during the experiments and a wet cooling tower **8**, which represents the heat dissipation to the free environment. The ice store enables various operating states to efficiently serve as the fluctuating heating and cooling demand of a building.

The following operating states can be set via the position of the valves:

- charging the ice store
- cooling via the ice store
- cooling via the refrigeration plant
- cooling via the refrigeration plant and ice store
- heating via heat pump
- heating via heat pump and charging the ice store
- heat dissipation via the wet cooling tower

1 switch cabinet
2 glycol storage tanks
3 circulation pumps
4 ice store
5 refrigerant compressor
6 refrigerant condenser
7 refrigerant evaporator
8 wet cooling tower
9 dry cooling tower



Trainer with refrigeration plant and ice store

Wet cooling tower

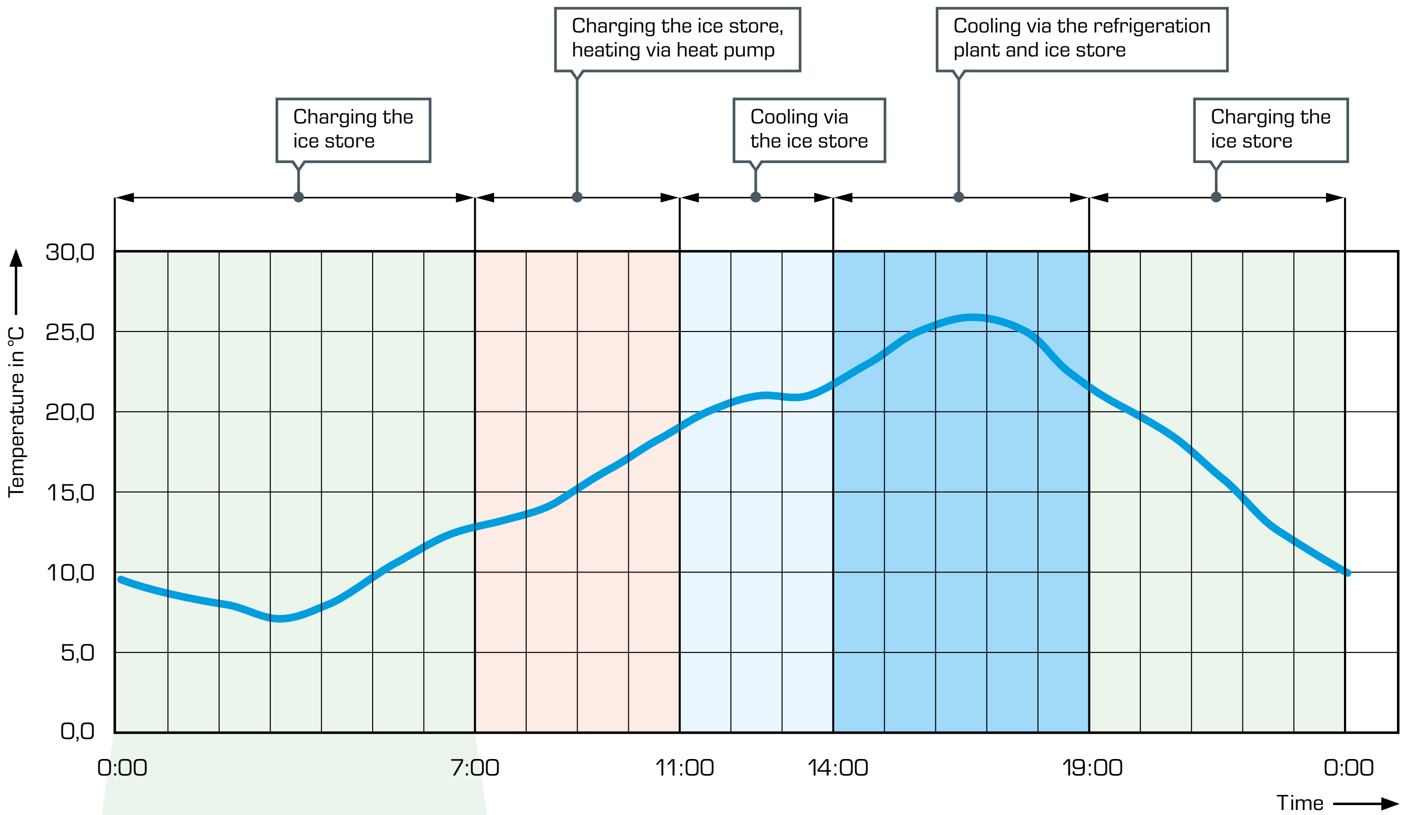
Dry cooling tower

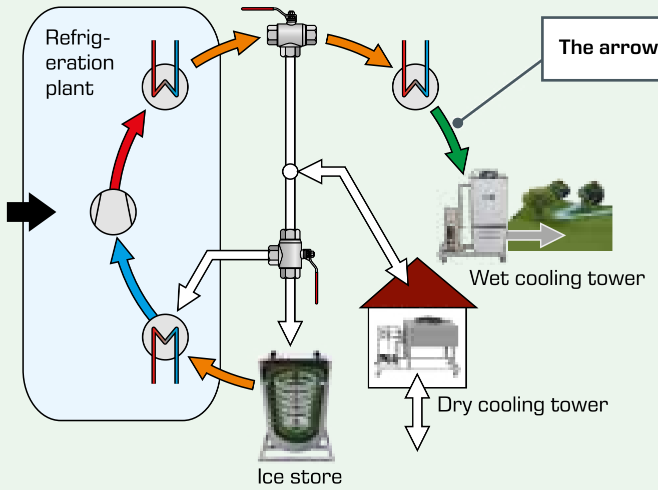
ET 420
Ice stores in refrigeration

Thermal supply of a building, using the operating modes of ET 420 as an example

The following shows how a demand-based supply of thermal energy via a refrigeration plant with ice store functions in practice. The load profile of an office building is taken as an example.

The ice store is operated using the example of a daily cycle. The primary objective is to respond to variable cooling and heating loads and to achieve an efficient supply of the building via a sensible sequence of operating states.





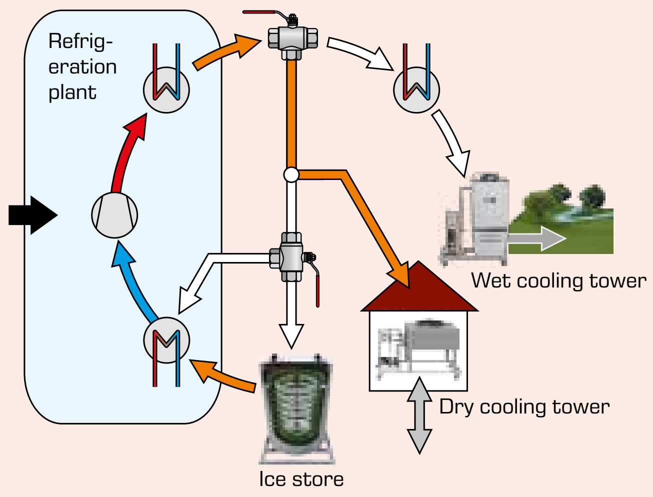
Charging the ice store

No persons are present between midnight and 7 am. There is no need for air conditioning, the ice store is charged.

To do this, the heat is dissipated from the ice store via the evaporator of the refrigerant circuit. (This heat dissipation causes the water in the ice store to freeze; the ice store is charged.)

The waste heat from the refrigerant circuit is dissipated to the environment via the wet cooling tower.

glycol, LP refrigerant, HP refrigerant, water, air,
electrical power, inactive process

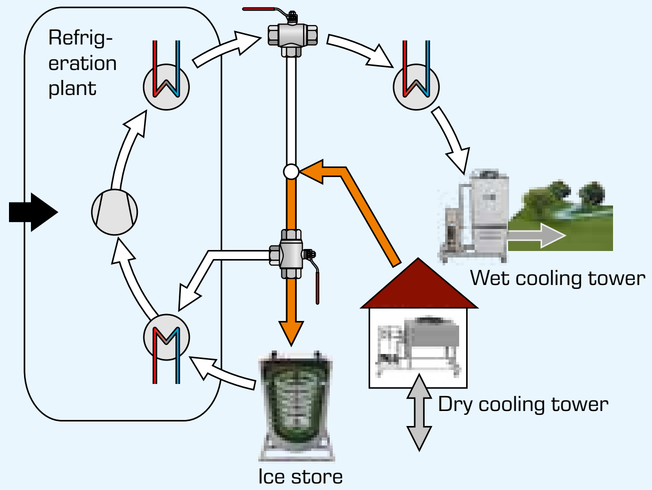


Charging the ice store and heating via waste heat

In the morning hours between 7 am and 11 am the temperature in the building is less than 20°C. There is a need for heating.

The heat generated during the ice store charging process can be used for heating. To do this, the heat is dissipated from the ice store via the evaporator of the refrigerant circuit. The ice store is charged by this heat dissipation.

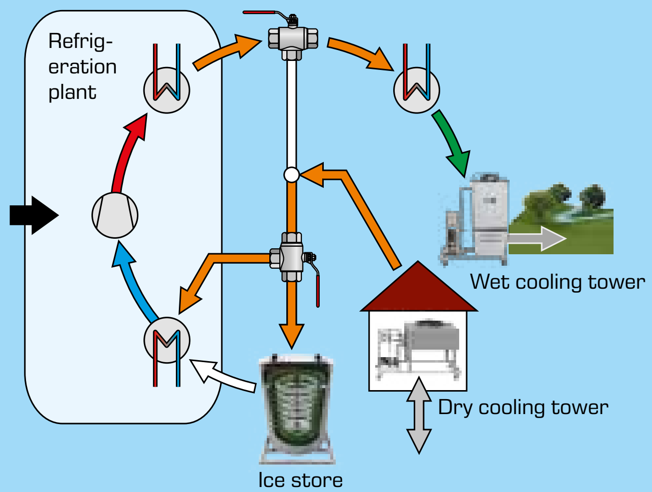
The usable waste heat from the refrigerant circuit is transferred to the dry cooling tower via the condenser, thus heating the building. The system operates in heat pump mode, while simultaneously using heat and cold.



Cooling via the ice store

In the period between 11 am and 2 pm, the temperatures in the building are between 20 and 23°C. There is a relatively low cooling demand, which can be covered via the ice store.

The ice in the ice store melts and absorbs heat from the dry cooling tower. This cools the dry cooling tower. This causes the building to cool down. The refrigeration plant does not need to be operated to dissipate the cooling load.



Cooling via the refrigeration plant and ice store

In the period between 2 pm and 7 pm, the temperatures in the building are between 23 and 27°C. This peak in the cooling load is covered by the combined cooling from ice store and refrigeration plant.

The heat is dissipated from the dry cooling tower and the building is cooled in this way. Part of the heat is transferred to the ice store, where the ice melts in the ice store and absorbs the heat from the dry cooling tower. In order to dissipate the particularly high cooling load, the refrigeration plant is also operated and transfers part of the heat from the dry cooling tower, via the evaporator.

The waste heat from the refrigerant circuit is dissipated to the environment via the wet cooling tower.

Charging the ice store

No persons are present in the building from 7 pm onwards. There is no demand for air conditioning. During this time, the ice store is charged via the refrigeration plant.

ET 420
Ice stores in refrigeration

The illustration shows the trainer on the left, the dry cooling tower in the middle and the wet cooling tower on the right.

Description

- **industrial refrigeration system with ice store, dry cooling tower and wet cooling tower**
- **energy efficiency in refrigeration and air conditioning technology**

Ice stores are used in refrigeration to cover an increased additional cooling requirement (peak load). The ice stores are usually charged over night when general energy requirements and energy costs are low.

To charge and discharge the ice store a circuit with glycol-water mixture is used between the ice store and the compression refrigeration system. When charging the ice store the glycol-water mixture is cooled via a compression refrigeration system to below 0°C and thereby withdraws heat from the water in the ice store, causing the water to freeze. During discharging the melting ice withdraws heat from the glycol-water mixture causing the mixture to cool down. During this cooling process the ice store replaces or supports the compression refrigeration system.

ET 420 consists of an ice store, a refrigeration system, a circuit with glycol-water mixture, a dry and a wet cooling tower. During the evaporation of the refrigerant in the refrigeration circuit and during discharging of the ice store, heat is withdrawn from the mixture, whereas during the condensing of the refrigerant heat is added. As required the cooling towers add heat to or withdraw heat from the mixture.

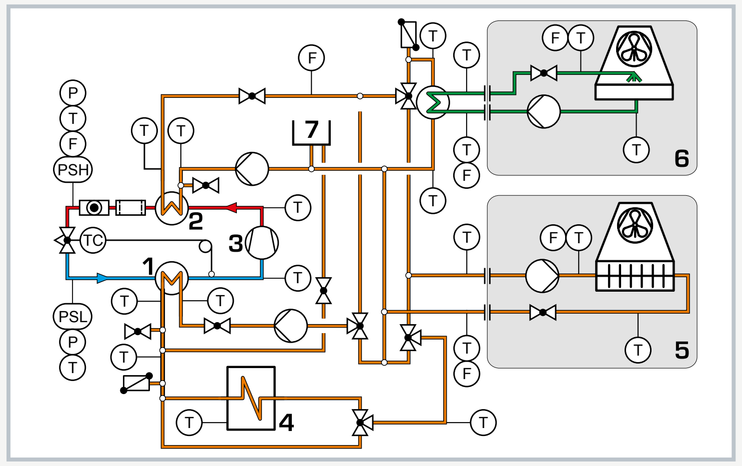
The record of all required variables enables an energy balance for the individual processes. The measured values are read from digital displays and can be transmitted simultaneously via USB directly to a PC where they can be analysed using the software included.

Learning objectives/experiments

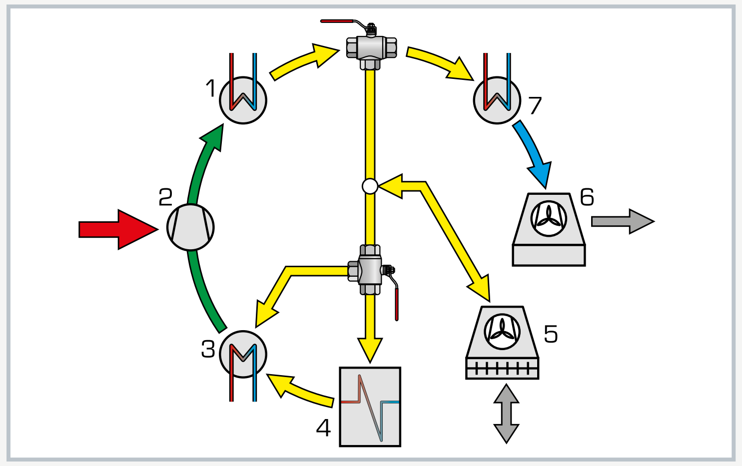
- design and operation of an energy-efficient refrigeration system
- function and operation of an ice store
  - charge
  - discharge
- energy flow balance
- energy transport via different media
- compression refrigeration cycle in the log p-h diagram
- function and operation of a wet cooling tower
- function and operation of a dry cooling tower

ET 420
Ice stores in refrigeration

1 displays and controls, 2 pump, 3 manometer, 4 flow meter, 5 evaporator, 6 condenser, 7 compressor, 8 ice store, 9 3-way valve, 10 compensation tank (glycol-water mixture)



1 evaporator, 2 condenser, 3 compressor, 4 ice store, 5 dry cooling tower, 6 wet cooling tower, 7 compensation tank; pipes: green: water, blue/red: refrigerant, orange: glycol-water mixture



Energy flows in the system: 1 condenser, 2 compressor, 3 evaporator, 4 ice store, 5 dry cooling tower, 6 wet cooling tower, 7 heat exchanger to wet cooling tower; blue: water, yellow: glycol-water mixture, green: refrigerant, grey: air, red: electric power

Specification

[1] investigation of the charging and discharging of an ice store
[2] system with ice store, compression refrigeration system, dry and wet cooling towers
[3] refrigeration circuit for R134a with compressor, condenser, evaporator and expansion valve
[4] glycol-water circuits with pumps: cooling of the refrigerant condenser, heating of the refrigerant evaporator, charging/discharging of the ice store, operation of the dry cooling tower
[5] water circuit with pump to operate the wet cooling tower
[6] measurement of all relevant temperatures, pressures, flow rates and power consumption to balance the processes
[7] GUNT software for data acquisition via USB under Windows 7, 8.1, 10

Technical data

Compressor, refrigeration capacity: approx. 1,7kW at -15/32°C
Pumps (glycol-water mixture)
- max. flow rate: $4,5m^3/h$
- max. head: 5,6m

Pump wet cooling tower (water)
- max. flow rate: $4,5m^3/h$
- max. head: 18m

Ice store: 150L
Compensation tank: 20L
Wet cooling tower, rated cooling capacity: 12kW
Dry cooling tower, rated cooling capacity: 13,8kW

Measuring ranges
- temperature: 12x -20...100°C, 4x -50...150°C, 4x 0...60°C
- pressure: 1x -1...9bar, 1x -1...24bar
- flow rate: 3x 100...1200L/h, 2x 60...1500L/h, 1x 150...1600L/h, 1x 10...100L/h (R134a)
- power: 0...2250W

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase; 230V, 60Hz, 3 phases
UL/CSA optional
LxWxH: approx. 2200x790x1900mm (trainer)
LxWxH: approx. 1250x790x1700mm (wet cool. tower)
LxWxH: approx. 1600x900x1140mm (dry cool. tower)
Total weight: approx. 650kg

Required for operation

water connection, drain
ventilation, exhaust air
PC with Windows recommended

Scope of delivery

1 trainer
1 wet cooling tower
1 dry cooling tower
1 set of hoses
1 GUNT software CD + USB cable
1 set of instructional material

Basic knowledge

Ventilation systems and their components

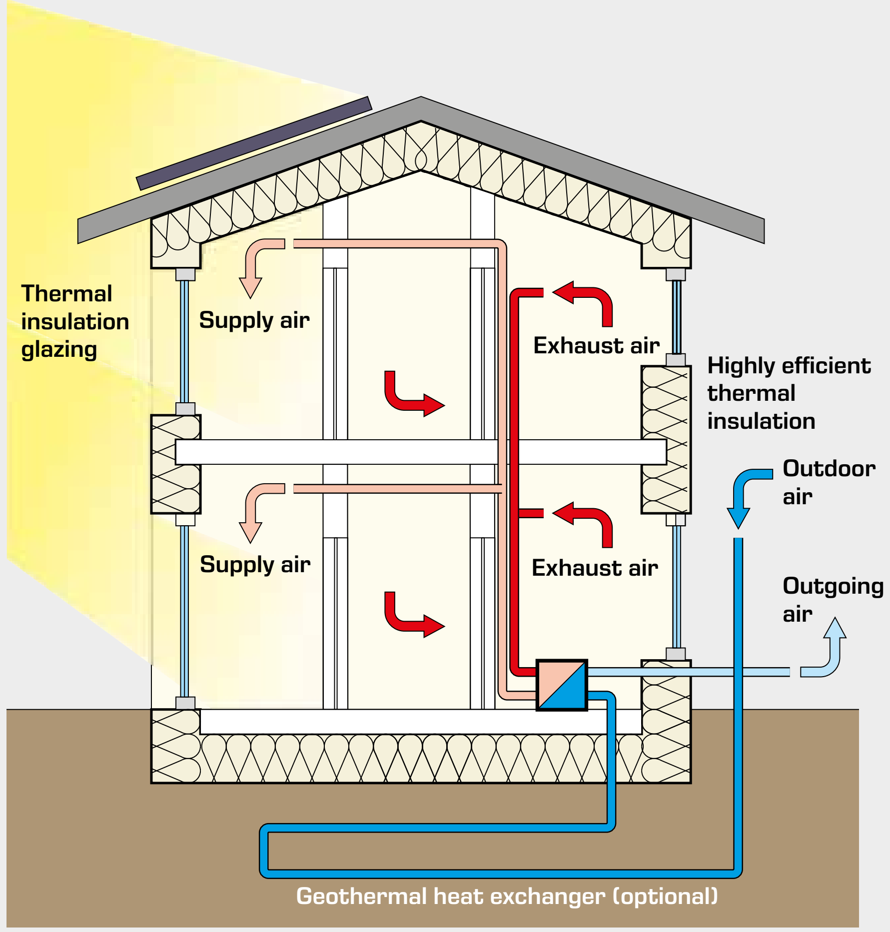
Ventilation systems ensure the change of air in residential, office and equipment rooms.

Ventilation systems are not only concerned with air supply and exhaust, but also with the consideration of **thermal energy:** sophisticated ventilation systems can transfer the heat of the outflowing air to the incoming air, so that hardly any thermal energy leaves the system.

There are basically three types of system:

1. exhaust air system: the "used" air from the building is expelled to the outside (outgoing air)
2. ventilation system: in addition to the exhaust air system, a supply system supplies fresh air to the living areas
3. different techniques that target the saving of heating energy, e.g. via heat recovery or geothermal heat exchangers

These systems are grouped together under the term controlled residential ventilation. Non-controlled ventilation of living space, on the other hand, is the free ventilation of living space by means of window ventilation, joint ventilation or shaft ventilation.



Ventilation with heat recovery

- **outside air:** air drawn in from the environment,
- **outgoing air:** air released into the environment,
- **supply air:** air entering a room or facility after it has been treated, e.g. by filtering or heating
- **exhaust air:** air leaving a room

The design of ventilation systems requires knowledge of fluid mechanics, e.g. the characteristic variables of fans and the pressure losses of pipe elements. GUNT's **product area 4 Fluid mechanics** deals with these aspects.

Heat recovery ventilation

Processes in which the residual heat of a mass flow is used after its primary use are referred to as heat recovery. The heat gained in this way would otherwise be wasted without heat recovery. Heat recovery can be used to reduce the primary energy consumption for heating buildings.

Ventilation systems with heat recovery are state-of-the-art today. For heat recovery, heat exchangers are built into the supply and exhaust air ducts of the ventilation system. They utilise the temperature difference between exhaust air and fresh air and can be operated according to demand. The thermal energy of the outgoing air is used to heat up outside air in winter and cool it in summer.

Ventilation system: in addition to the exhaust air system, a supply system supplies fresh air to the living areas.

HL 720
Ventilation system

The illustration shows a similar unit.

Learning objectives/experiments

- design and operation of a ventilation system
- pressure measurements in the air duct
- determine the electric drive power of the fan
- determine the flow rate
- design and operation of components such as
  - protective grating
  - multi-leaf damper
  - filter
  - heat exchanger
  - fan
  - inspection cover
  - sound insulation link
  - ventilation grill with adjustable flow rate
  - fire protection flap
  - ceiling vents

Description

- **ventilation system with air handler**
- **high practical relevance due to the use of industrial components from ventilation technology**
- **representation of pressure curves**

In building services engineering ventilation systems are used for commercial premises, hospitals, restaurants or conference rooms to ensure the air exchange in the individual rooms. In real air handling units the air is heated or cooled by a heat exchanger and cleaned by filters, e.g. from pollen.

HL 720 demonstrates the operation of a ventilation system and its components. The components used are common in commercial ventilation technology and therefore are of high practical relevance. The ventilation system is operated as a pure air supply system.

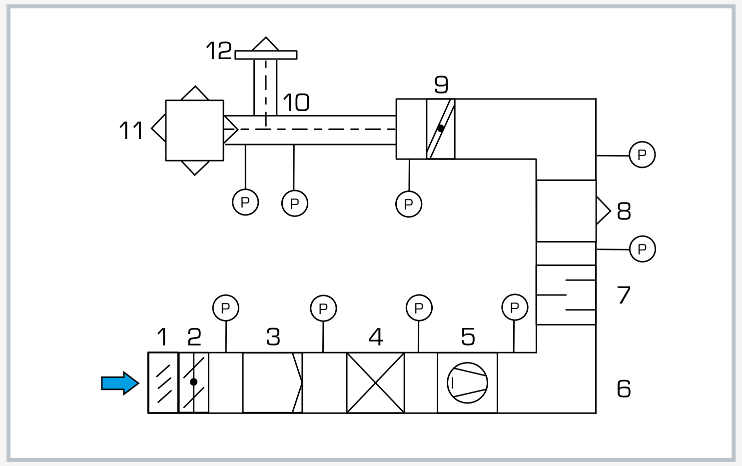
The air enters via a weather louvre and flows through the components of the ventilation system, such as multi-leaf damper and filter. A fan ensures the air transport. Further down the air duct, typical components, such as sound insulation link, inspection flap, various air outlets and fire protection flap are arranged.

Sight windows enable an insight into the sound insulation link, filter and fan. The original component function remains intact.

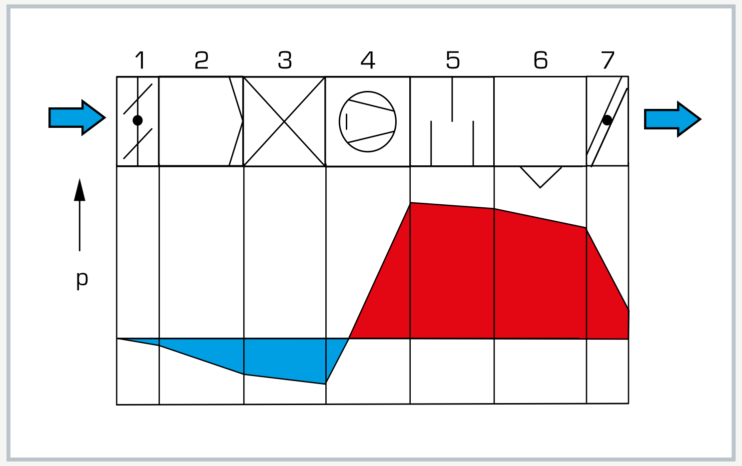
The record of pressures and differential pressures at relevant measuring points enables the representation of a pressure curve for the whole system. The components act as in real ventilation systems as flow resistances. The electric drive power of the fan and the volumetric air flow rate are calculated.

HL 720
Ventilation system

1 fire protection flap, 2 inclined tube manometer, 3 weather louvre, 4 multi-leaf damper, 5 filter, 6 heat exchanger, 7 fan with drive motor, 8 inspection cover, 9 air duct, 10 disc valve, 11 ceiling vent, 12 wall vent



1 weather louvre, 2 multi-leaf damper, 3 filter, 4 heat exchanger, 5 fan, 6 air duct, 7 sound insulation link, 8 wall vent, 9 fire protection flap, 10 branch, 11 air outlet for ceiling installations, 12 disc valve; P pressure



Pressure curve within the ventilation system: 1 multi-leaf damper, 2 filter, 3 heat exchanger, 4 fan, 5 sound insulation link, 6 wall vent, 7 fire protection flap;
red: overpressure, blue: vacuum

Specification

[1] design and operation of a ventilation system
[2] all components from ventilation technology, some with sight windows
[3] protective grating and adjustable multi-leaf damper at the air inlet
[4] filter for air purification
[5] belt-driven radial fan
[6] 2 sound insulation links
[7] various air outlets for air distribution in the room: disc valve, ceiling vent and ventilation grill with adjustable flow rate
[8] inspection cover for inspection purposes
[9] fire protection flap prevents the cross-over of fire and smoke in the air duct
[10] air duct with pressure measurement connections
[11] pressure measurements with inclined tube manometer
[12] current measurement to determine the power consumption of the fan
[13] determine the flow rate via differential pressure

Technical data

Air duct:
- 2 parts with WxH 630x305mm and 630x630mm

Fan
- max. flow rate: 2500m^3/h
- drive motor: 750W

Measuring ranges
- pressure: 0...7,5mbar
- current: 0...4A

400V, 50Hz, 3 phases
400V, 60Hz, 3 phases; 230V, 60Hz, 3 phases
UL/CSA optional
LxWxH: 1960x900x2000mm
Weight: approx. 263kg

Scope of delivery

1 experimental plant
1 set of instructional material

Basic knowledge

Fundamentals of air conditioning

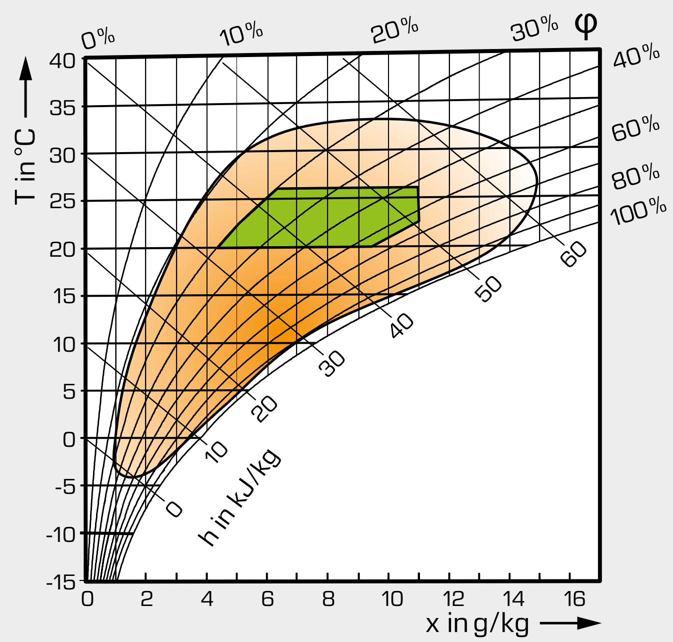
The purpose of air conditioning is to create a room climate comfortable for people. The conditions for describing comfort are standardised in accordance with DIN 1946 and DIN EN 13779. While the temperature should be between 20 and 26°C, a relative humidity between 30 and 65 % is permitted.

Air conditioning therefore means to affect the room air in such a way that people are comfortable and their productivity is not impeded.

The condition of the air is characterised by temperature, pressure and humidity.

(Normally, the air pressure is not changed. Exception: air conditioning in the aircraft cabin)

Comfort zone in the h-x diagram for humid air by mollier



In the h-x diagram temperature **T**, enthalpy **h** and relative humidity **φ** are plotted above the absolute humidity **x**.

In the exemplary diagram the comfort zone according to DIN 1946 is drawn in green.

The orange area represents the range of outside temperatures and humidities prevailing in Central Europe. You can see that the outside temperatures and humidities usually do not match the conditions for comfort and that the room air needs to be air conditioned.

In Central Europe this is usually heating and humidification, whereas in the Tropics cooling and dehumidification is required.

For full air conditioning there are four partial functions:

- heating
- humidifying
- cooling
- dehumidifying

Air humidity

Humid air contains water in a vaporous state. A difference is made between absolute humidity and relative humidity. Absolute humidity is measured in g H2O/kg dry air.

For air conditioning the relative humidity is more important. It is perceived by humans. Relative humidity is measured in % of the maximum possible humidity at a given temperature. 100 % r.h. means that the air cannot absorb any more humidity, it is saturated. Excessive humidity then remains as a liquid (mist) in the air. The saturation curve is the lower limit curve in the h-x diagram.

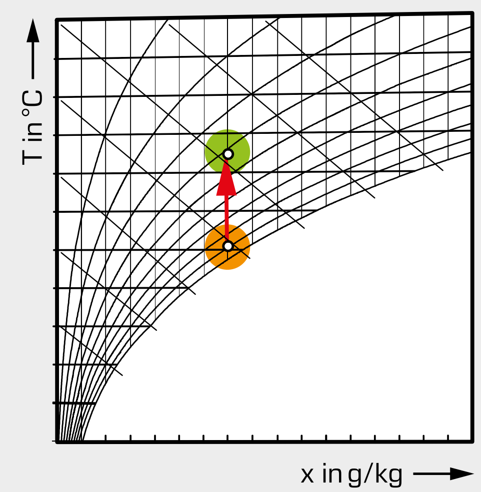
Basic processes of air conditioning

The basic processes of air conditioning can be exceptionally well represented in the h-x diagram.

A change of temperature at constant absolute humidity also always results in a change of the relative humidity and enthalpy. The relative humidity and enthalpy also change with a change of the absolute humidity at constant temperature.

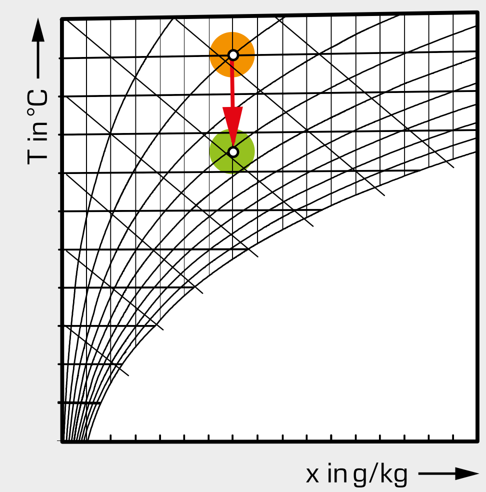
Thus temperature and relative humidity cannot be set independently of each other. An increase in the air temperature (heating), for example, always also results in a reduction in the relative humidity. To keep the relative humidity constant, humidification is therefore also required when heating. Conversely, the relative humidity increases during cooling.

Four basic processes of air conditioning in the h-x diagram



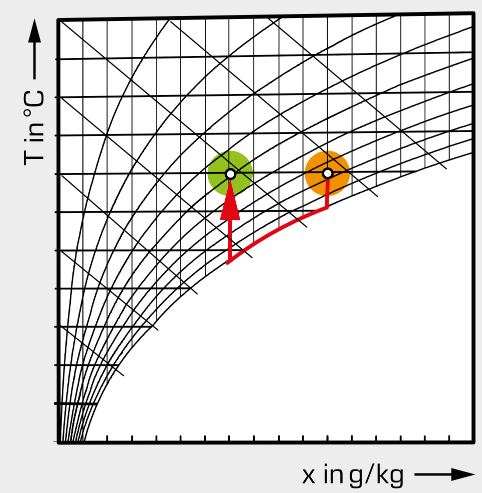
Heating

supply of heat, relative humidity reduces



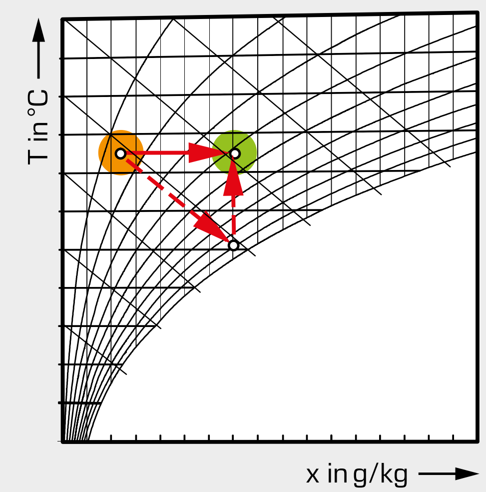
Cooling

removal of heat, relative humidity increases



Dehumidifying

cooling to 100 % r.h. (saturation), condensation of the humidity on cold surfaces. Followed by heating to the desired temperature.



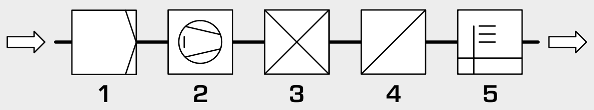
Humidifying

supply of water steam or water mist (for mist additional heating required to compensate cooling due to vaporisation enthalpy 1-1'-2)

Basic knowledge

Setup of an air conditioning system

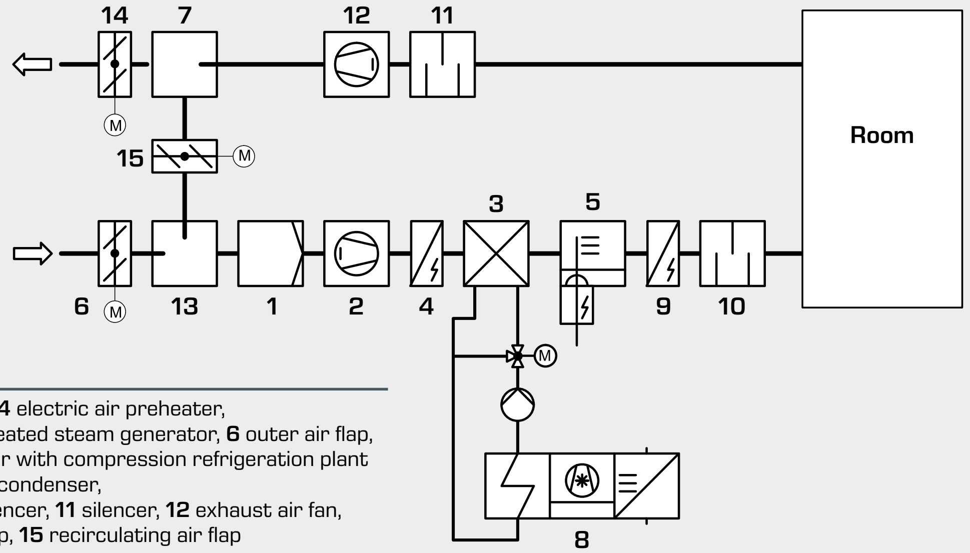
Simple full air conditioning system



A full air conditioning system consists in its most simple form of the following components:

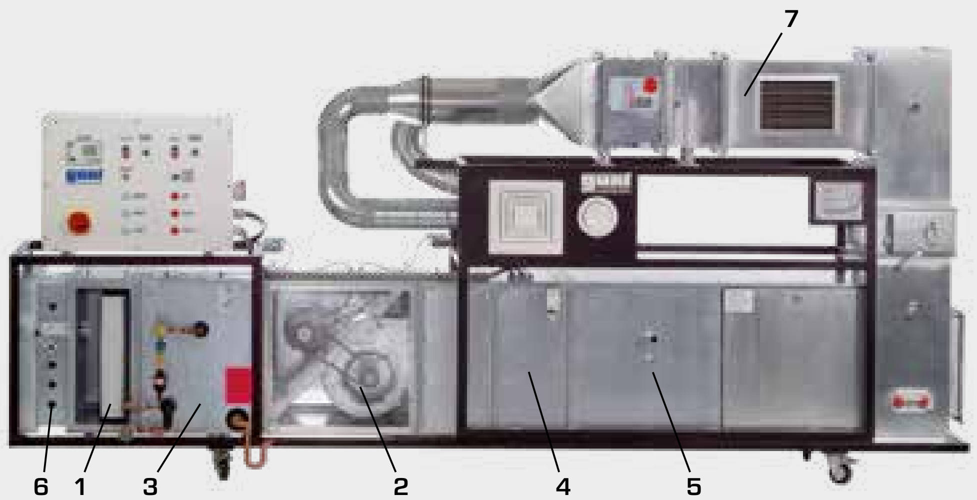
1 air filter: removes dust and dirt from the air
2 fan: aspirates the air and transports it through the system
3 air cooler: cools and dehumidifies the air
4 air heater: heats the air and compensates for the temperature loss during humidification and dehumidification
5 air humidifier: adds humidity to the air

Real air conditioning systems are usually more complex in design. To save energy, the waste air from the room can be returned to the room after processing. This is called recirculating operation. The ratio of recirculating air and outer air is controlled by throttle valves or flaps. In the diagram shown below the air cooler is supplied with cold water from a water chiller. Steam humidifier and air heater are heated electrically.



Complex air conditioning system with recirculating operation

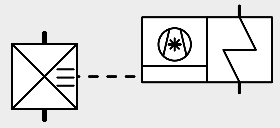
1 air filter, **2** air inlet fan, **3** air cooler, **4** electric air preheater, **5** steam humidifier with electrically heated steam generator, **6** outer air flap, **7** distribution chamber, **8** water chiller with compression refrigeration plant in block construction with air-cooled condenser, **9** electric air reheater, **10** inlet air silencer, **11** silencer, **12** exhaust air fan, **13** mixing chamber, **14** exhaust air flap, **15** recirculating air flap



ET 620 Air conditioning and ventilation system

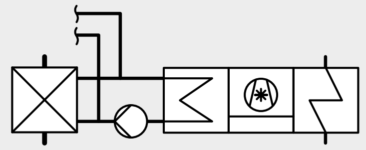
1 air filter,
2 fan,
3 air cooler,
4 air heater,
5 humidification chamber,
6 ventilation flap,
7 distribution system with flaps and outlets

Air cooler



- **direct evaporator of a compression refrigeration system**

Advantage:
simple and cheapdesign

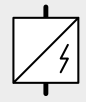


- **cold water circuit with compression refrigeration system**

Advantage:
several coolers can be operated via one refrigeration system

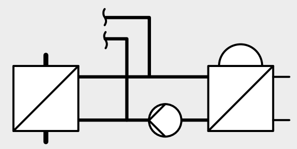
Direct evaporator as air cooler

Air heater



- **electric air heater**

Advantage:
simple design, easy to control

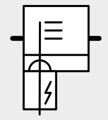


- **hot water circuit with boiler**

Advantage:
all fuels and heat sources possible, several air heaters can be connected to one heat source

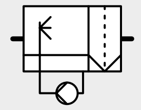
Electric air heater

Air humidifier



- **steam humidifier**

Advantage:
no cooling by condensation, hygienic



- **spray humidifier with mist collector**

Advantage:
can also operate as air cooler

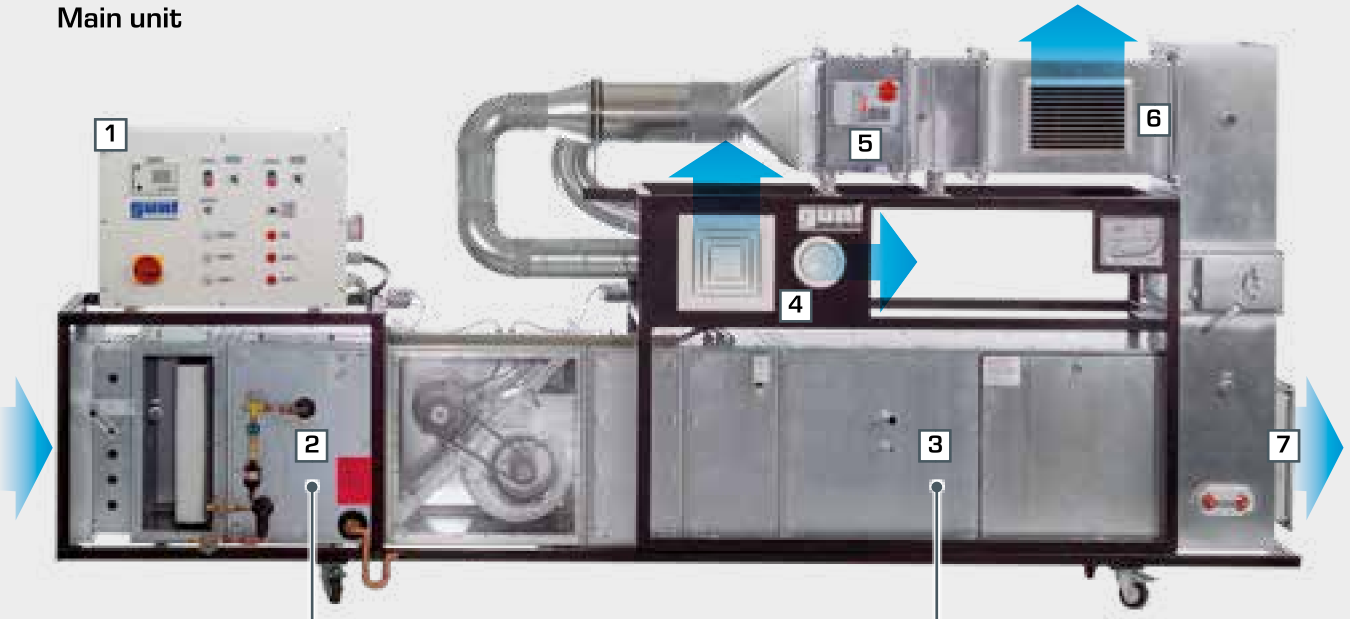
Steam humidifier

An example from practice: industrial air conditioning system with comprehensive filters for clean room production

ET 620
Real air conditioning and ventilation system

ET 620 is a real air conditioning system with connected air duct. The trainer consists of the main unit, a condensing unit and a steam humidifier. The conditioned air flows through an air duct and exits into the room through air outlets. Alternatively an external ductwork can also be connected.

Main unit



Condensing unit

Steam humidifier

1 switch cabinet with PLC, **2** cooler with connections for the condensing unit,
3 humidification section with connections for steam humidifier, **4**+**6** outlets for the conditioned room air,
5 fire protection flap, **7** standard connection for external ductwork

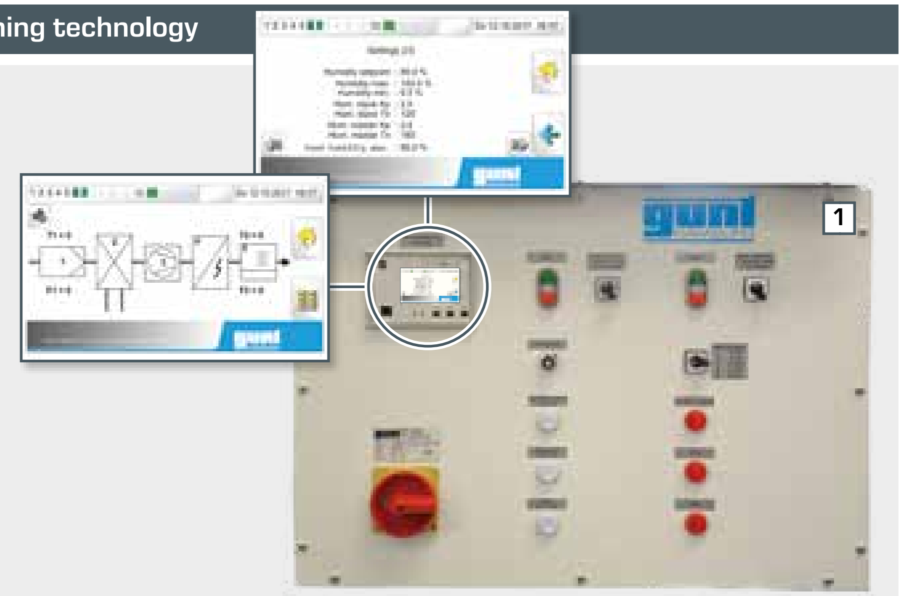
Real components from air conditioning technology

Control via PLC

The operation of the air conditioning system is via a PLC. Handling the different PLC functions is learned step by step:

- display of alarms
- display of measured values
- input of reference variables
- input of control parameters
- input of limit values

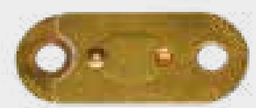
...and much more



Safety in air conditioning technology

A fire protection flap is fitted in the air duct. Fire protection flaps are used to separate the ventilation network from the source of a fire in an emergency. To trigger and close the fire protection flap a spring and a thermal trip element are used. In case of a fire, the solder melts, the two metal plates are released and the spring shuts the fire protection flap.

Fire protection flap



Trip element with intact solder joint

Trip element with melted solder joint

Typical air outlets

In order for people to find the room climate comfortable, a strong draught must be avoided.

The air duct of ET 620 features different types of air outlets. The purpose of air outlets is the distribution of the air in the room with a minimum air velocity. Air distribution, air velocity and pressure loss of the different air outlets can be compared.

Ventilation grill

Ceiling vent (left) and disc valve (right)

ET 620
Air conditioning and ventilation system

Description

- **complete air conditioning and ventilation system for laboratory operation**
- **high practical relevance due to real dimensions and use of commercial components**
- **manual or automatic operation by PLC air conditioning controller**
- **connection of an external air duct system possible**

The experimental setup represents a real air conditioning and ventilation system. The system capacity is sufficient to climatise a laboratory room.

The air conditioning and ventilation system includes a filter element, a fan with controlled speed, a direct evaporator as air cooler, an electric air heater and humidification by steam humidifier. The following functions are possible: heating / cooling and humdifiying / dehumidifying. For this purpose the active components can be run either manually individually or via a central PLC air conditioning controller in automatic operation. The air conditioning controller controls the temperature and air humidity independent of each other. Via time programs, operation is possible dependent on the time of the day or the day of the week, as in reality. Pressure losses can be measured at each section of the duct.

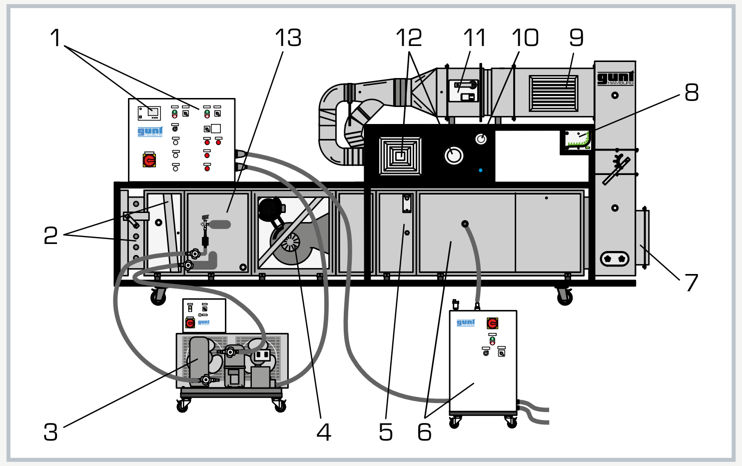
All common components, such as filter, air heater / air cooler, outlets, smoke detector, multi-leaf dampers, inspection and fire protection flaps are available and can be explained. A standard connection piece in the air duct enables the connection to an external air duct system to climatise an existing room.

The air conditioning and ventilation system consists of three independent system components: main unit, steam humidifier and condensing unit. The connection is performed via hoses. Due to the waste heat the condensing unit should not be placed inside the room to be climatised.

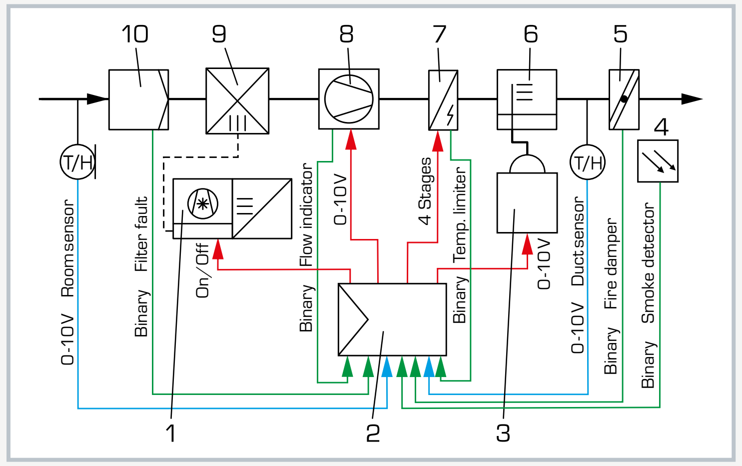
Learning objectives / experiments

- practice-oriented principles of air conditioning and ventilation technology
- design and servicing of an air conditioning and ventilation system
- principles of room air conditioning (h-x diagram)
- explanation of components: filter, air heater, air cooler, humidifier, condensing unit, air conditioning controller, flaps, outlets
- operation of safety devices
- measurement of pressure curve and pressure losses
- effect of air cooler, air heater and humidifier on the state of the air at the outlet
- investigation of the control behaviour of an automatic air conditioning controller, determination of limiting factors

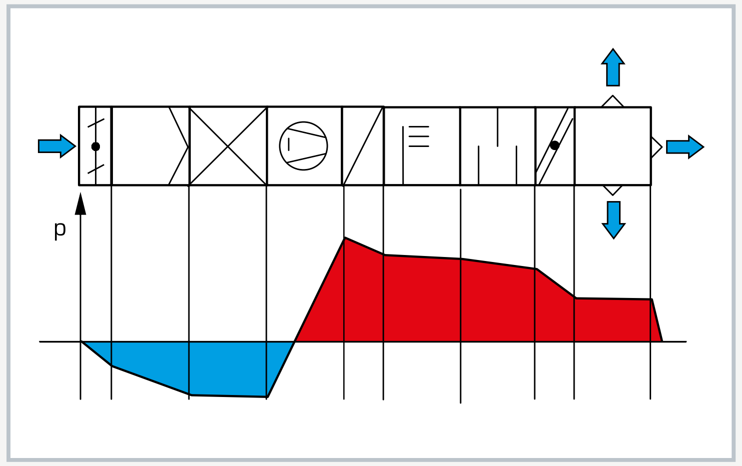
ET 620
Air conditioning and ventilation system



1 switch cabinet with controller, 2 air inlet with filter, 3 condensing unit, 4 fan, 5 air heater, 6 steam humidifier, 7 standard connector to connect an external air duct system, 8 inclined tube manometer, 9 ventilation grille with volume adjustment, 10 smoke detector, 11 fire protection flap, 12 ceiling vents, 13 air cooler (direct evaporator)



Control schematic: 1 condensing unit, 2 controller, 3 steam humidifier, 4 smoke detector, 5 fire protection flap, 6 humidification section, 7 electric air heater, 8 fan, 9 air cooler (direct evaporator), 10 filter, T/H temperature/humidity



Pressure curve in the system

Specification

[1] practice-oriented air conditioning and ventilation system with 3 independent system components: main unit, condensing unit, steam generator
[2] manual or automatic operation via PLC air conditioning controller
[3] main unit with air duct, fan, air conditioning system
[4] air conditioning system with direct evaporator as air cooler, electric air heater, humidification
[5] hoses connect direct evaporator to condensing unit, humidification system to steam humidifier
[6] air duct from hot galvanised sheet with sight window and pressure measurement connections to record pressure curves
[7] air duct with filter, multi-leaf damper, ceiling vent, protective grating, ventilation grille, fire protection flap, inspection flap, sound insulation link, smoke detector
[8] standard connection piece to connect to external ventilation system
[9] refrigerant R404a, CFC-free

Technical data

Fan, speed-controlled 0...1500min^{-1}
- max. volumetric air flow rate: 2500m^3/h
- max. pressure level: 715Pa
- drive motor power: 1,1kW

Air heater, 4 stages: 0-5-10-15-20kW
Air cooler (direct evaporator), cooling capacity: 27kW
Condensing unit
- rated cooling capacity: approx. 16,6kW at 7.2/32°C
- power consumption: approx. 7,4kW at 7.2/32°C

Steam humidifier
- steam capacity: 10kg/h
- power consumption: 7,5kW

External standard connection piece: 400x400mm
Duct cross-sections
- bottom: WxH: 630x630mm, top: WxH: 358x358mm

Inclined tube manometer: 0...750Pa

400V, 50Hz, 3 phases
400V, 60Hz, 3 phases; 230V, 60Hz, 3 phases
UL/CSA optional
LxWxH: 3870x850x1760mm; 540kg (trainer)
LxWxH: 1110x740x1120mm; 163kg (condensing unit)
LxWxH: 510x500x1060mm; 50kg (humidifier)

Required for operation

water connection, drain

Scope of delivery

1 trainer
1 condensing unit
1 steam humidifier
1 set of accessories
1 set of instructional material

ET 915 HSI training system refrigeration and air conditioning technology

The ET 915 HSI Training system refrigeration and air conditioning technology, base unit provides basic experiments for the different areas of refrigeration and air conditioning technology.

The term HSI refers to our overall didactic concept: **H**ardware – **S**oftware – **I**ntegrated.

Refrigeration

ET 915.01
Refrigerator model

ET 915.02
Model of a refrigeration system with refrigeration and freezing stage

Air conditioning

ET 915.06
Model of a simple air conditioning system

ET 915.07
Air conditioning model

All attachments contain expansion elements and evaporators

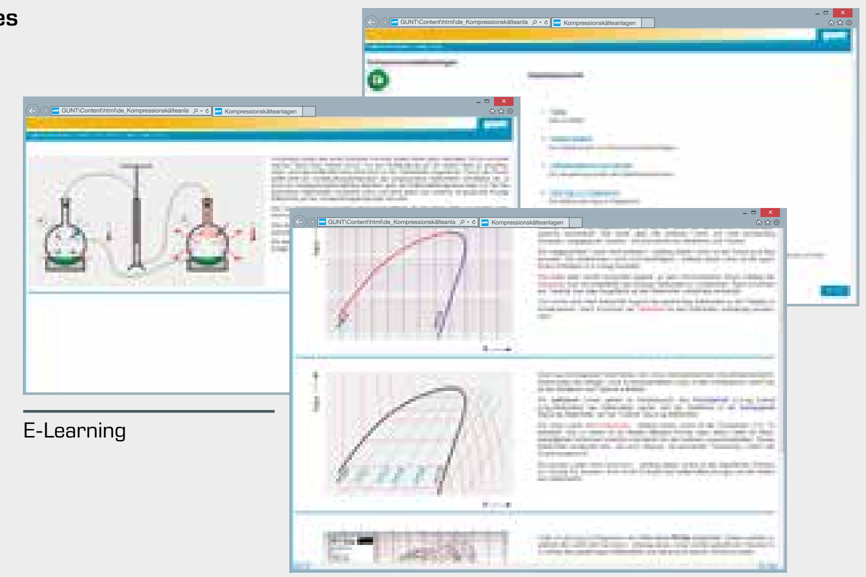
The ET 915 base unit contains the main compressor and condenser components

Modular system with extensive teaching possibilities

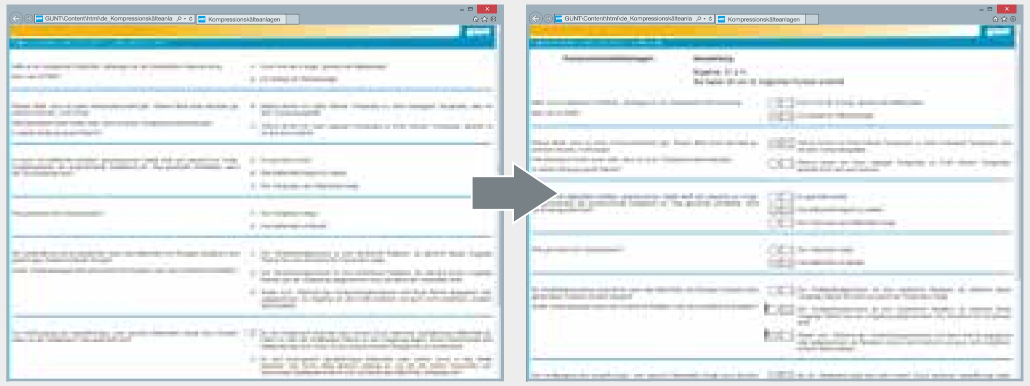
Training software

...with didactically valuable course of studies

- use the training software on the students' own PCs
- complete course of studies for refrigeration and air-conditioning technology including quiz
- very flexible thanks to the structure of own learning modules and tests
- intuitive user interface



E-Learning



Quiz with detailed evaluation

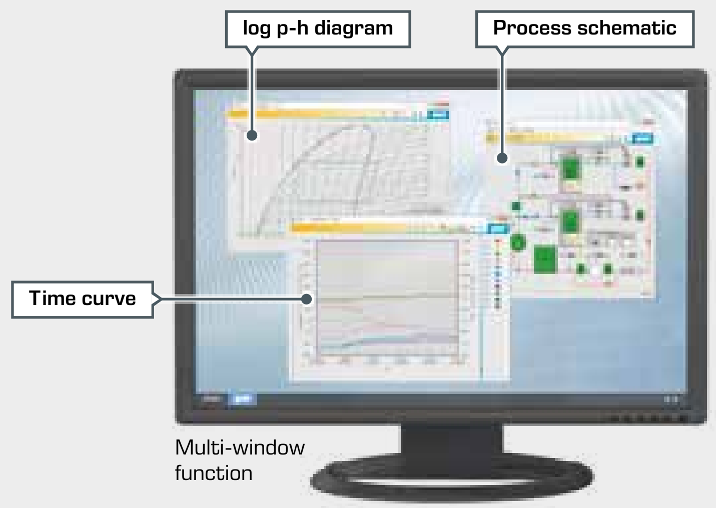
Targeted review of the learning content

- learning progress can be monitored discretely and automatically
- detect weaknesses and provide targeted support

Data acquisition

...with unlimited networking capability

- interactive experiments for students via network connection
- real-time display of the processes in the log p-h diagram and h-x diagram
- plug & play system via USB connection



Multi-window function

ET 915.06
Model of a simple air conditioning system

Description

- **model of a simple air conditioning system for room cooling**
- **component operation and fault simulation via the GUNT software**

ET 915.06 is part of the HSI training system for refrigeration and air conditioning technology. In combination with the base unit ET 915 the operational model of a simple air conditioning system is created. The model is plugged onto the base unit, secured using fasteners and connected with refrigerant hoses to become a complete refrigeration circuit for the air cooler.

In systems for room cooling the air to be cooled is aspirated from the room by a fan, cooled and fed back into the room. This model demonstrates the principles of room cooling and the components of an air conditioning system.

The model ET 915.06 includes an air duct with transparent front, fan for air transport, an evaporator as air cooler and an expansion valve. All components are clearly arranged on a panel.

The individual components of the system, here the compressor and the fan, are operated via the software. The software offers the option to simulate faults.

The volumetric air flow rate is determined via a differential pressure measurement. Temperatures and humidity before and after the evaporator are recorded by sensors, digitised and dynamically represented in the software.

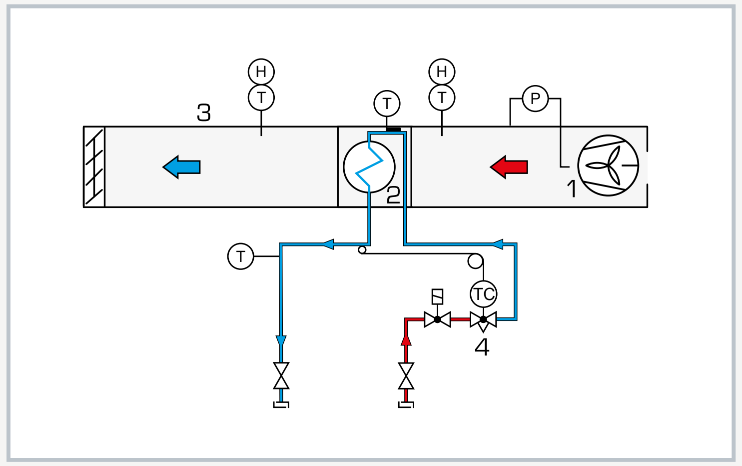
Fundamentals and individual components are represented in the educational software for ET 915.06. Performance assessments check the learning progress. With the aid of the authoring system further exercises and performance assessments can be created.

Learning objectives/experiments

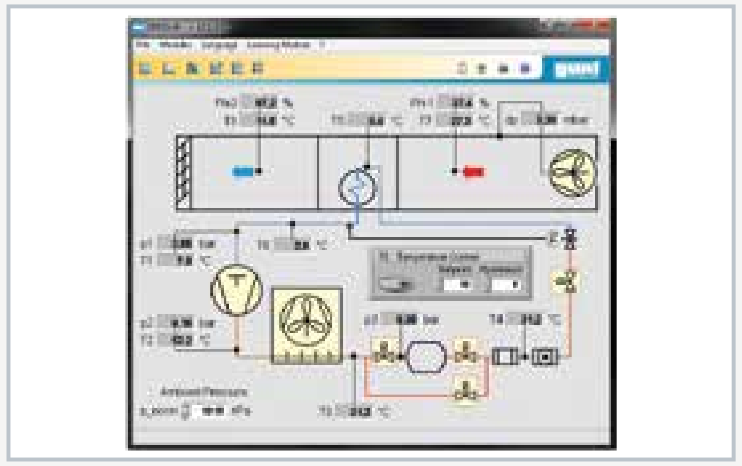
- air conditioning system for room cooling and its main components
- principle of operation of an evaporator as air cooler
- fault simulation

ET 915.06
Model of a simple air conditioning system

1 evaporator as air cooler, 2 air duct, 3 temperature and humidity sensor, 4 process schematic, 5 connections for ET 915, 6 solenoid valve, 7 expansion valve, 8 radial fan, 9 differential pressure sensor



Process schematic of the simple air conditioning system model: 1 radial fan, 2 air cooler, 3 air duct, 4 expansion valve; T temperature, P pressure, H humidity; red arrow: hot, blue arrow: cold; blue: low pressure, red: high pressure



Software screenshot: process schematic

Specification

[1] model of a simple air conditioning system to plug onto the base unit ET 915
[2] GUNT training system with HSI technology
[3] air duct with transparent front
[4] evaporator as air cooler
[5] radial fan with throttle valve
[6] thermostatic expansion valve as expansion element
[7] sensors to record temperature, humidity and differential pressure for determining the volumetric air flow rate
[8] operation of individual components and of the system and fault simulation via software
[9] GUNT software with control functions and data acquisition via USB under Windows 7, 8.1, 10
[10] GUNT software: educational software, data acquisition, system operation

Technical data

Air duct: 136x136x435mm
Evaporator as air cooler
- transfer area: approx. 900cm^2

Radial fan
- max. power consumption: 80W
- max. flow rate: 255m^3/h

Measuring ranges
- temperature: 2x ±50°C, 2x 0...100°C
- differential pressure: 0...10mbar
- humidity: 2x 10...100% rel.

LxWxH: 970x370x600mm
Weight: approx. 35kg

Scope of delivery

1 model of a simple air conditioning system, filled with refrigerant
1 GUNT software CD + USB cable

ET 915.07
Air conditioning model

Description

- **complete model of a full air conditioning system**
- **heating, cooling, humidifying and dehumidifying**
- **outer air and recirculation operation possible**
- **component operation and fault simulation via the GUNT software**

ET 915.07 is part of the HSI training system for refrigeration and air conditioning technology. In combination with the base unit ET 915 the operational model of a full air conditioning system is created. The model is plugged onto the base unit, secured using fasteners and connected with refrigerant hoses to become a complete refrigeration circuit for the air cooler.

The room climate is created by the interaction of air temperature, heating temperature and air humidity. The purpose of room air conditioning is to shape the room climate in accordance with the requirements of people or sensitive goods. This model introduces the operation of an air conditioning system and the recirculating air and outer air operating modes.

The model ET 915.07 includes two air ducts with transparent front. The top air duct serves as climatic chamber whilst the bottom air duct contains the air cooler, two electric air heaters and a steam humidifier. A fan between the two air ducts recirculates the air. A motorised butterfly valve in the top air duct allows a change between outer air and recirculating operation. Dependent on the switching of the two air heaters, the air cooler and the humidifier, the air in the duct system can be cooled, heated, humidified or dehumidified.

The individual system components are operated via the GUNT software. Temperature and humidity before and after the evaporator and in the climatic chamber are recorded by sensors, digitised and represented dynamically in the software. The conditioning of the air can be monitored online in the h-x diagram.

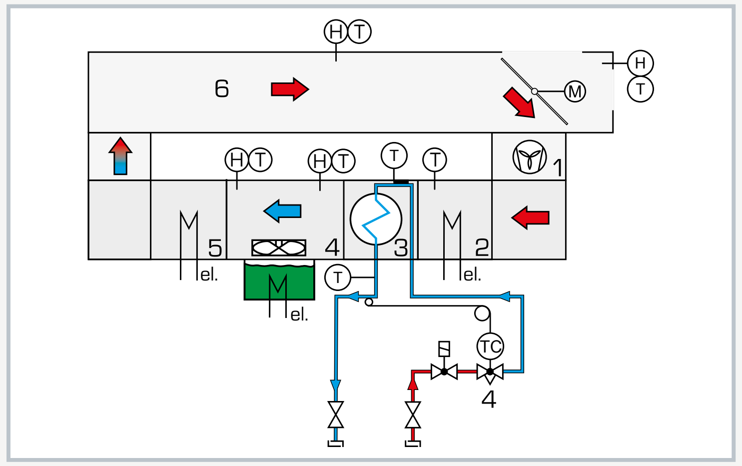
Fundamentals and individual components are represented in the educational software for ET 915.07. Performance assessments check the learning progress. With the aid of the authoring system further exercises and performance assessments can be created.

Learning objectives/experiments

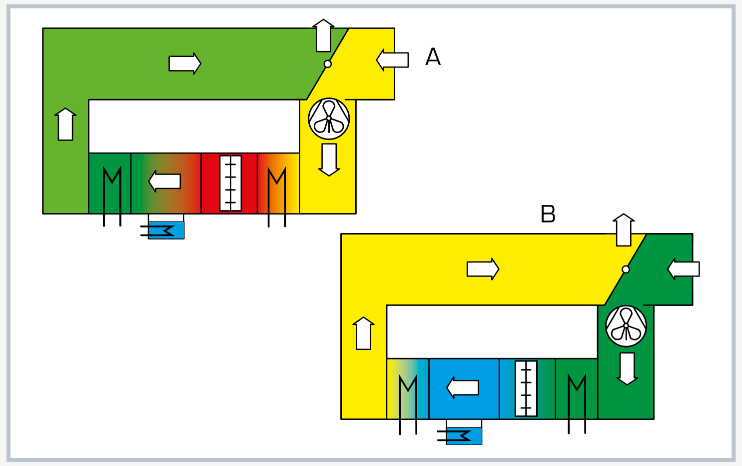
- full air conditioning system and its main components
- heating and cooling in the h-x diagram
- humidifying and dehumidifying in the h-x diagram
- outer air and recirculating operation
- fault simulation

ET 915.07
Air conditioning model

1 air duct, 2 air reheater, 3 process schematic, 4 air humidifier, 5 connections for ET 915, 6 evaporator, 7 expansion valve, 8 air preheater, 9 fan, 10 sensors for humidity and temperature, 11 ventilation flap



Air conditioning with recirculating operation:
1 fan, 2 air preheater, 3 air cooler, 4 air humidifier, 5 air reheater, 6 air duct, 7 ventilation flap with servomotor, 8 expansion valve; T temperature, P pressure, H humidity; red arrow: hot, blue arrow: cold; blue: low pressure, red: high pressure



Air conditioning with outer air operation; A: humidification, B: dehumidification; yellow: dry, green: humid, blue: cooling, red: heating

Specification

[1] model of an air conditioning system to plug onto the base unit ET 915
[2] GUNT training system with HSI technology
[3] air duct with transparent front and adjustable ventilation flap for recirculating or outer air operation
[4] evaporator as air cooler
[5] 2 heaters as air preheater and reheater
[6] air humidifier with float switch, fan, filling level indication
[7] thermostatic expansion valve as expansion element
[8] sensor to record temperature and combined sensor for humidity and temperature
[9] operation of individual components and of the system and fault simulation via software
[10] GUNT software with control functions and data acquisition via USB under Windows 7, 8.1, 10
[11] GUNT software: educational software, data acquisition, system operation

Technical data

Air duct, top: 136x136x800mm
Evaporator as air cooler
- transfer area: approx. 900cm^2

Air heater:
- 2x 250W

Axial fan
- max. power consumption: 20W
- max. flow rate: 160m^3/h

Humidifier
- heater: 200W

Measuring ranges
- temperature: 2x -50...50°C, 5x 0...50°C
- humidity: 4x 10...100% r.h.

LxWxH: 850x400x680mm
Weight: approx. 51kg

Scope of delivery

1 air conditioning system model, filled with refrigerant
1 narrow mouth bottle
1 GUNT software CD + USB cable

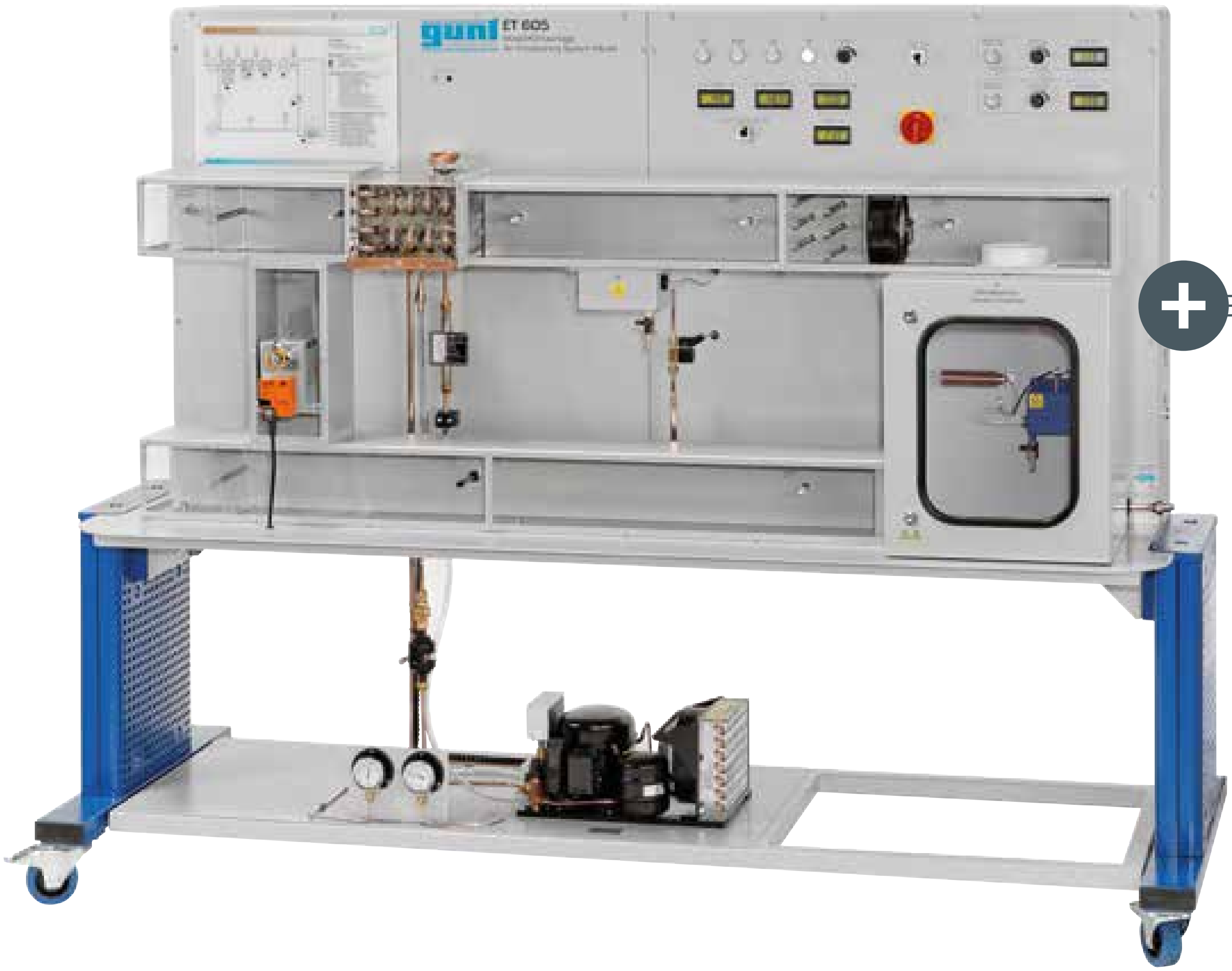
ET 605 Air conditioning system model plus automation solutions

A practical air conditioning system model with all elements and functions

The principles of air conditioning technology can be taught optimally with the model ET 605. The air conditioning system consists of an air duct with transparent front and a climatic chamber with two different cooling loads. The overall design of the system is guided by instructional and methodological aspects and thereby supports the learning process.

The main functions of the system – cooling, heating, humidifying, air transport – are activated or deactivated via switches. Recirculating and outer air operation are possible. All relevant measuring data can be read on digital displays.

An important extension of the teaching objectives is provided by the option to extend the system with different additions into a fully automated system.

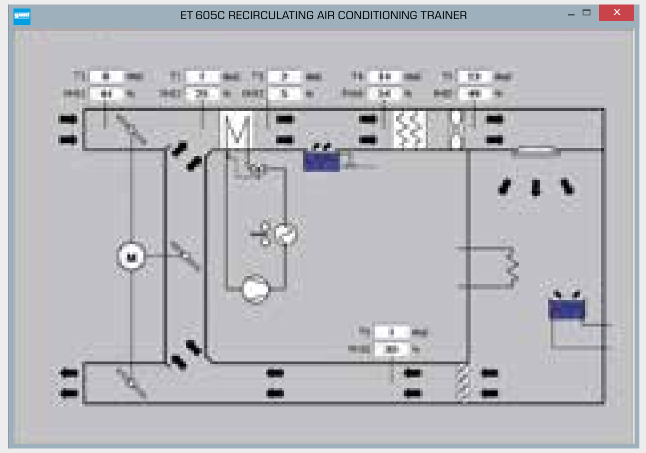


The software solution: clear and versatile

ET 605.01 Software controller with data acquisition

Data acquisition and visualisation, control and operation in a single software solution.

This solution is recommended if the focus is on instructional and methodological criteria. Compared to an industrial controller the software offers an attractive and very clear representation of the air conditioning process.



The industrial solution

ET 605.02 Air conditioning controller

This automation solution is recommended if the training objective focuses on the exact familiarisation with an industrial air conditioning controller. The controller matched to the ET 605 system offers a wide functional spectrum and a graphical display. Dependent on the desired temperature and humidity in the climatic chamber it controls the components.

The right tool for implementing your own ideas

ET 605.03 I/O connection box

This solution is recommended if the focus is on the topic of automation and own solutions are to be created. The connection box provides all relevant input and output signals which the user can further process according to his own requirements and ideas. The connection of any industrial air conditioning controller or independently written software are possible.

ET 605
Air conditioning system model

Description

- **climatic chamber with latent and sensitive heat source as cooling load**
- **recirculating and outer air operation**
- **optional data acquisition software (ET 605.01)**
- **connection options for the use of different automation solutions**

Air conditioning technology is a key topic in building services engineering. For this reason air conditioning technology plays an important role during the training of skilled workers and engineers.

The clear trainer ET 605 represents a complete air conditioning system with an air duct and a climatic chamber. The main components of the air conditioning system are the air cooler with condensing unit, fan, steam humidifier and air heater. Three motorised ventilation flaps control the air distribution in the air conditioning system. The climatic chamber is equipped with two different heat sources (wet and dry). Temperature and relative humidity are measured at relevant points in the air duct and displayed digitally. For the refrigeration circuit two manometers with integrated temperature scale and a flow meter provide all relevant measurements.

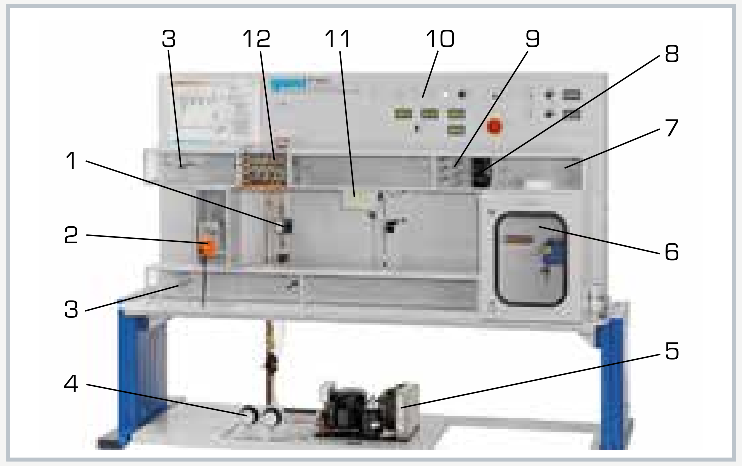
ET 605 is operated manually. A key feature of the air conditioning system is that it is fully ready for various automation solutions. The user can thus focus on this important topic during a lesson. The following solutions are available:

- software controller ET 605.01
- industrial air conditioning controller ET 605.02
- signal connection box ET 605.03 for the integration of an individual user solution.

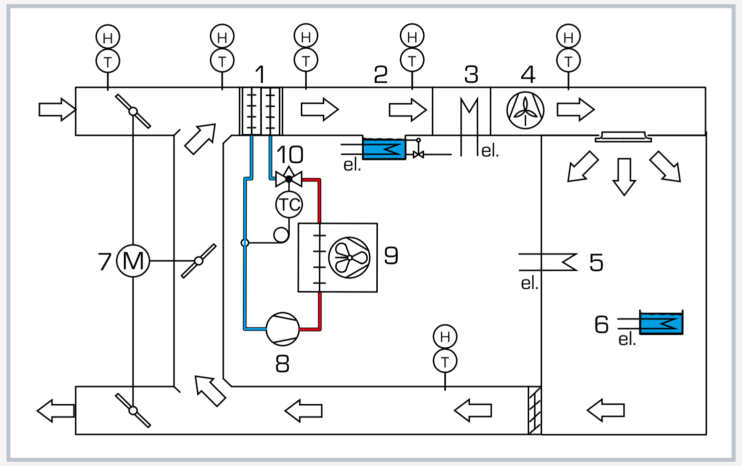
Learning objectives/experiments

- air conditioning system and its components
- conditioning room air
- mixing different air flows
- representation in the h-x diagram for humid air
  - humidification and dehumidification
  - heating and cooling
- representation of the circuit in the log p-h diagram
- effect of a cooling load (dry and wet)
- recirculating and outer air operation In conjunction with optional accessories
- automation in an air conditioning system

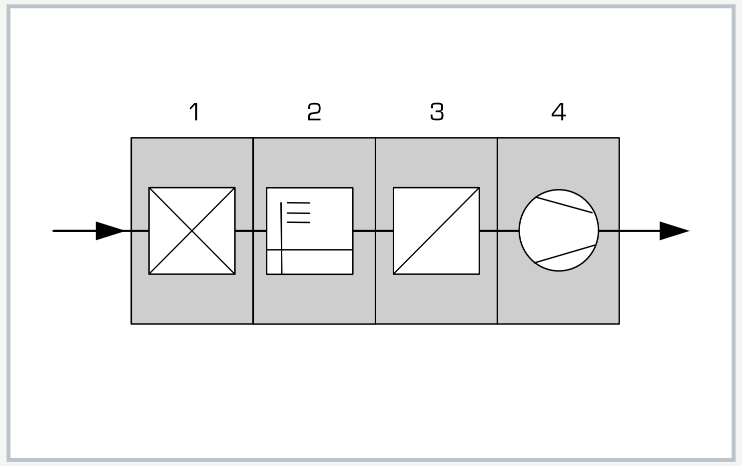
ET 605
Air conditioning system model



1 refrigerant flow meter, 2 servomotor, 3 ventilation flap, 4 refrigerant manometer, 5 condensing unit, 6 climatic chamber with sensitive and latent heat source, 7 air duct with temperature/humidity sensor, 8 fan, 9 air heater, 10 displays and controls, 11 humidifier, 12 air cooler



1 air cooler, 2 humidifier, 3 air heater, 4 fan, 5 sensitive heat source, 6 latent heat source, 7 servomotor for ventilation flaps, 8 compressor, 9 condenser, 10 expansion valve; T temperature, H humidity



Schematic setup of the air conditioning system in accordance with DIN 1946
1 air cooler, 2 air humidifier, 3 air heater, 4 fan

Specification

[1] model of an air conditioning system with outer air and recirculating operation
[2] air duct with transparent front
[3] air duct with fan, air cooler, humidifier, flaps, air heater and sensors
[4] chamber with wet (latent) and dry (sensitive) heat source as cooling load
[5] motorised flaps for recirculating and outer air operation
[6] process schematic with signal lamps
[7] air conditioning system ready for different automation solutions: 4 data cable connections to integrate the accessories
[8] refrigerant R134a, CFC-free

Technical data

Air-cooled condensing unit
- power consumption: 140W at -10°C
- refrigeration capacity: 320W at +5/40°C

Humidifier
- heating power: 400W

Air heater
- heating power: 360W

2 heaters in the chamber as cooling load
- power output: 0...250W each, freely adjustable

Flow cross-section of the air duct
- WxH: 155x155mm

Measuring ranges
- temperature: 0...50°C
- rel. humidity: 10...90%
- power consumption: 0...600W (condensing unit)
- power: 2x 0...300W (cooling load)
- pressure: -1...9bar / -1...24bar (refrigerant)
- Dflow rate: 1,5...23,5L/h (refrigerant)
- air velocity: 0...2,5m/s

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
230V, 60Hz, 3 phases
UL/CSA optional
LxWxH: 2210x800x1740mm
Weight: approx. 280kg

Required for operation

water connection, drain

Scope of delivery

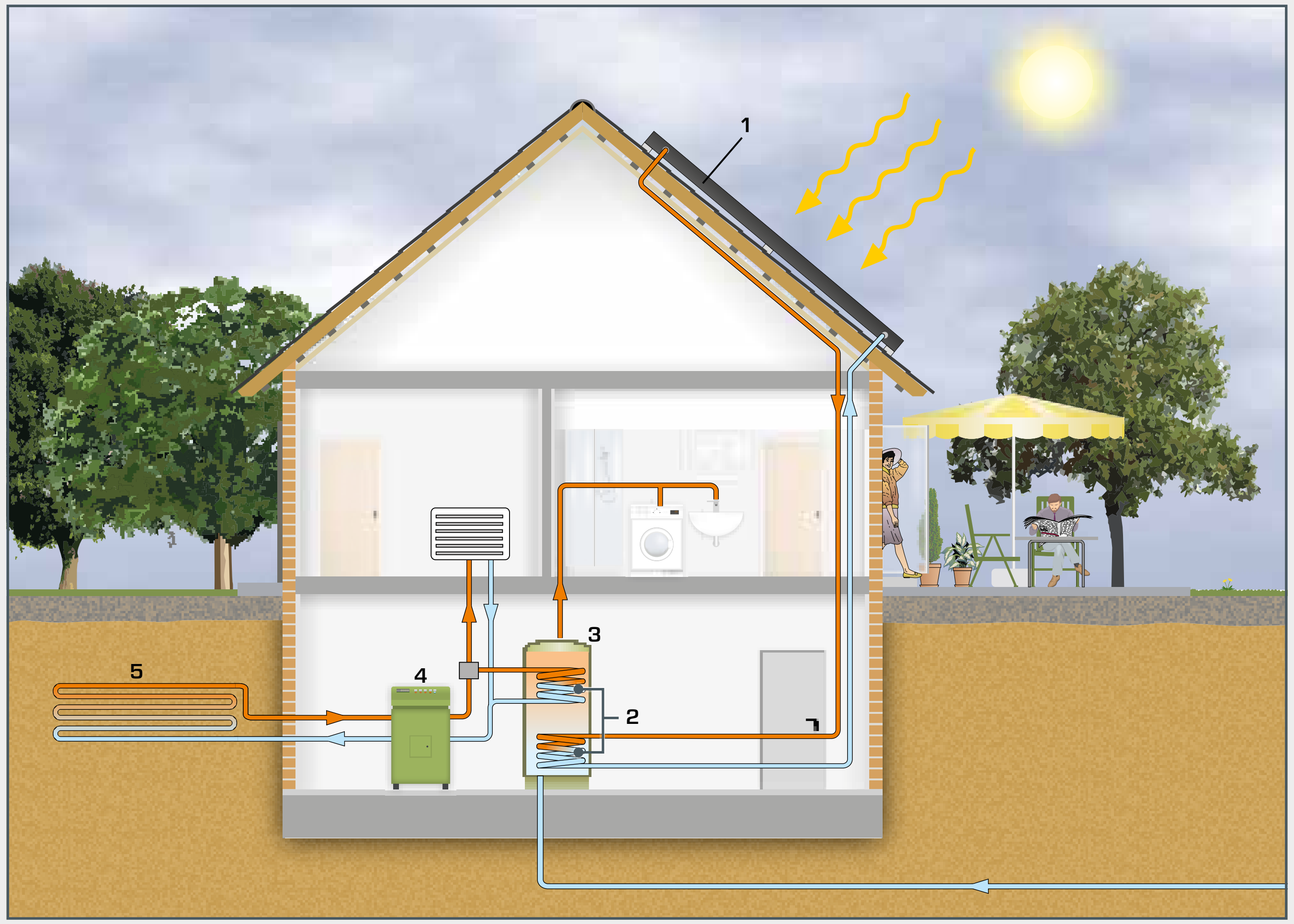
1 trainer, filled with refrigerant
1 set of instructional material

GUNT-RHLine Renewable Heat
Solar thermal energy and heat pump modular system

The HL 320 modular system allows you to investigate heating systems with various renewable and traditional energy sources. Solar thermal energy can be combined with heat generation from heat pumps. The modular design of the HL 320 system makes it possible to achieve different combinations and configurations.

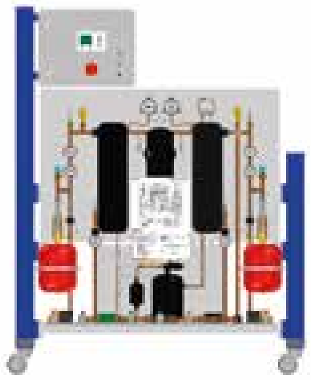
Combined use of renewable heat sources

Doing away with a conventional heating system represents a genuine alternative for modern residential buildings with good thermal insulation in many cases. The combination of solar thermal collectors with a heat pump very often guarantees significant savings with reliable year-round supply.



1 flat collector, **2** heat exchanger, **3** hot water storage tank, **4** heat pump, **5** geothermal energy absorber;
- hot heat transfer fluid,
- cold heat transfer fluid,
- refridgerant, high pressure,
- refridgerant, low pressure

HL 320.01
Heat pump



HL 320.02
Conventional heating

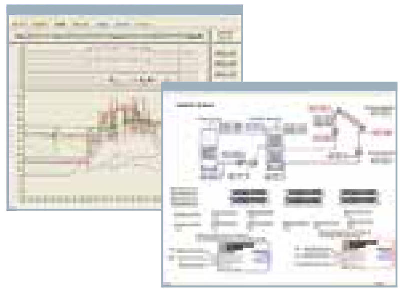
HL 320.03
Flat collector

HL 320.04
Evacuated tube collector

HL 320.05
Central storage module with controller

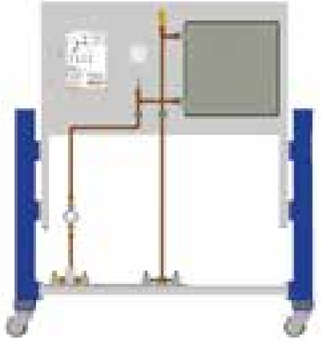
The storage module provides bivalent storage and buffer storage. The controller can be used to log measured values over longer periods for analysis of the system behaviour.

Freely programmable controller with extensive software



HL 320.07
Underfloor heating / geothermal energy absorber

HL 320.08
Fan heater / air heat exchanger

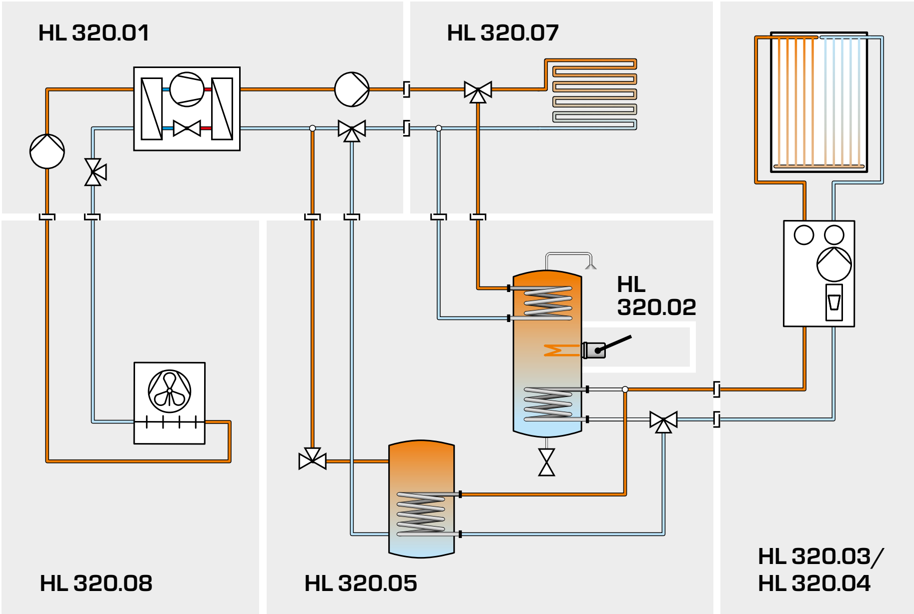


The HL 320.07 and HL 320.08 modules can be used as heat sources or as heat sinks.

GUNT-RHLine Renewable Heat
Solar thermal energy and heat pump modular system

The right configuration for every application

In heating technology, both correct composition of necessary components and optimisation of cabling and controller settings depend on the local conditions. GUNT has developed experiments for a selection of relevant module combinations in order to be able to teach the corresponding learning content in balanced steps. In addition, you may of course create your own system configurations to investigate further issues from the field of regenerative heating technology.

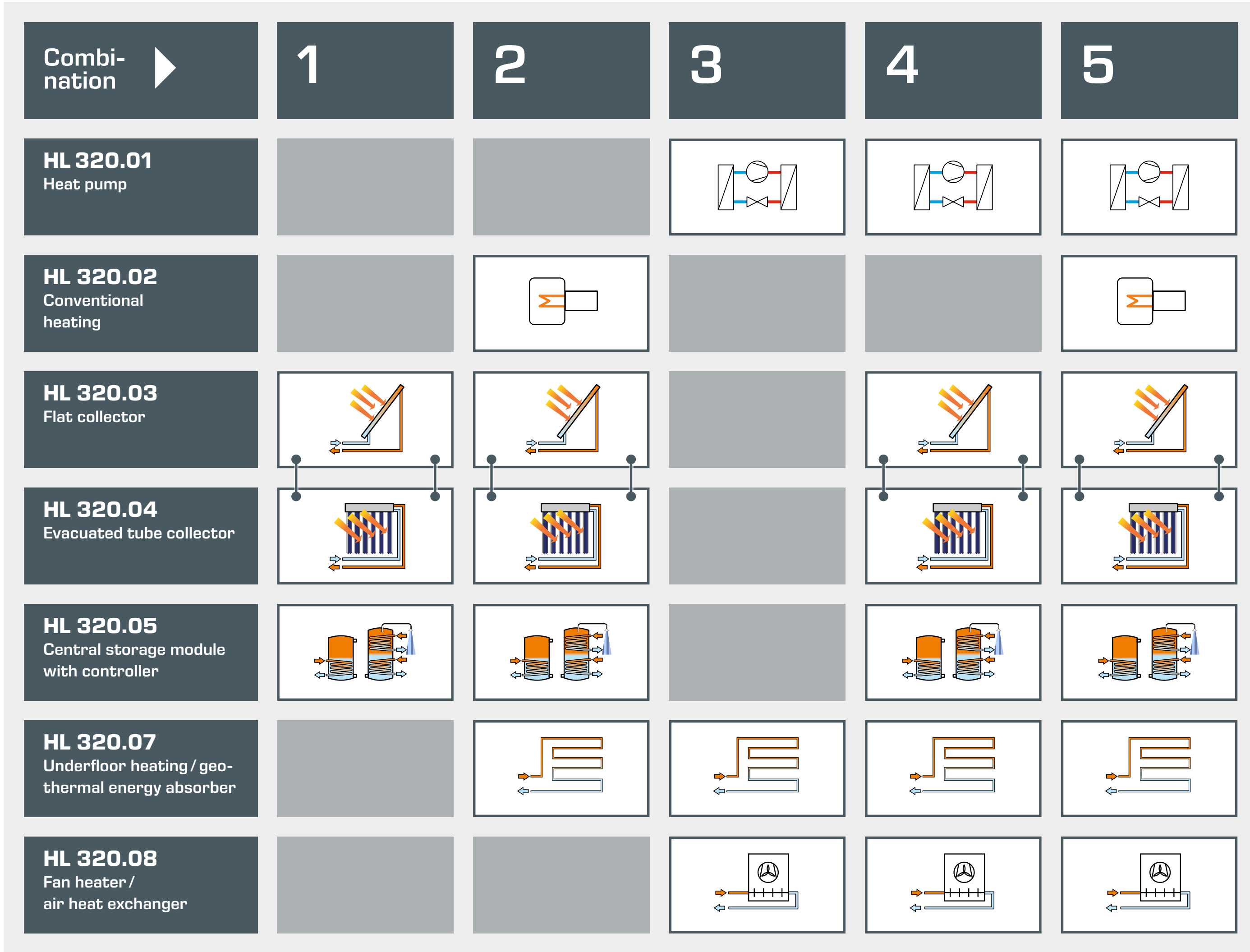


- hot heat transfer fluid,
- cold heat transfer fluid,
- refridgerant, high pressure,
- refridgerant, low pressure

Example for a system diagram for complementary heating and domestic water heating with a solar thermal collector and a heat pump (combination 5).

HL 320.08 | HL 320.01 | HL 320.07 | HL 320.05 | HL 320.04

Recommended combinations for the HL 320 modular system



Learning objectives and experiments

Combination 1
- function of a solar thermal heating system
- commissioning
- collector efficiency and losses

Combination 2
- combined use of traditional and solar thermal energy
- efficient indoor heating with underfloor heating

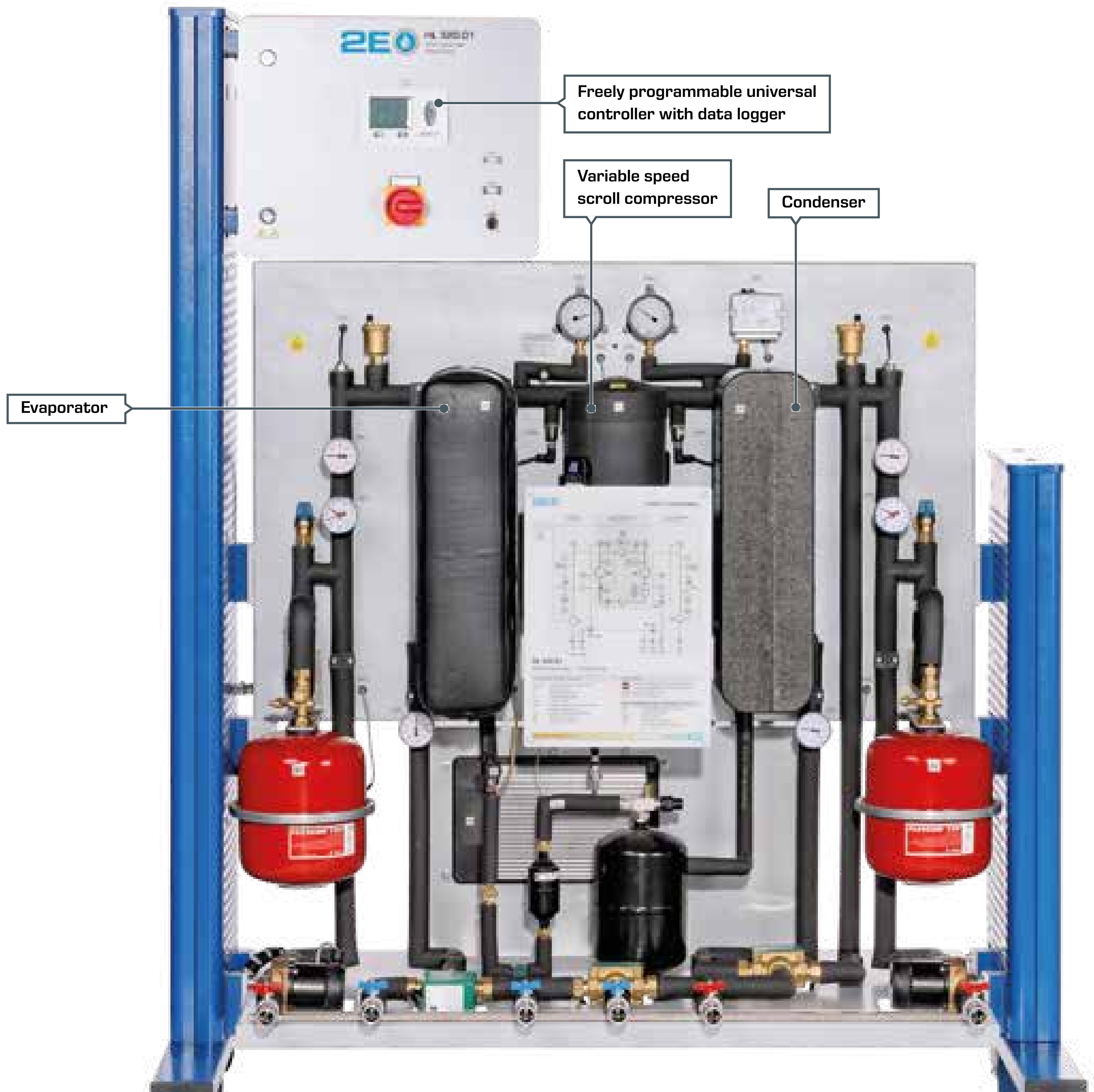
Combination 3
- function and design of a heat pump
- parameterisation of a heat pump controller
- factors influencing the COP (Coefficient of Performance)

Combination 4
- efficient use of solar thermal and geothermal energy
- strategies for heat supply in various consumption profiles

Combination 5
- use of renewable and fossil fuels for heating and hot water
- bivalent parallel and bivalent alternative heat pump mode

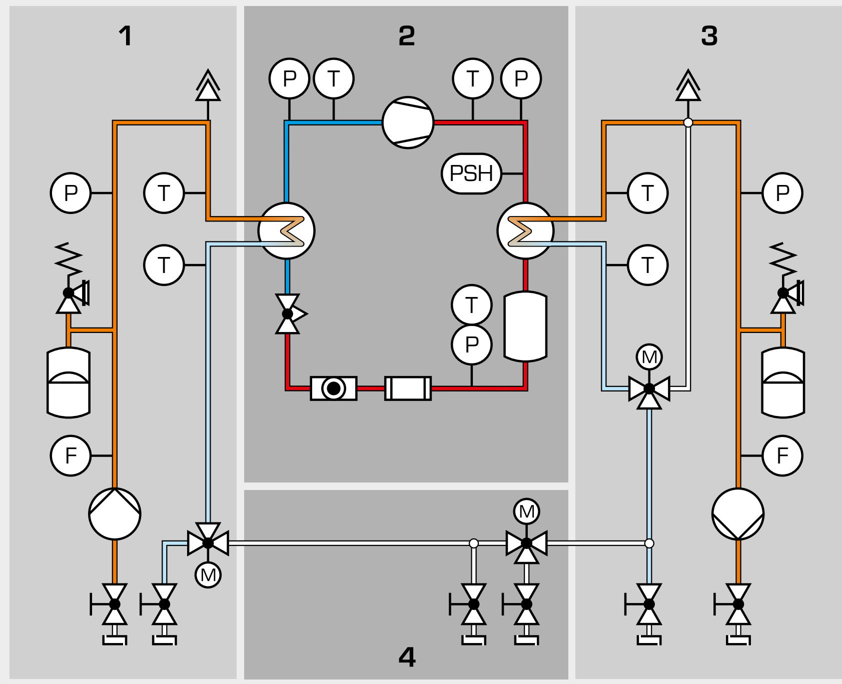
GUNT-RHLine Renewable Heat
Solar thermal energy and heat pump modular system

HL 320.01 Heat pump



Sensors for temperature and flow rate are included at all the necessary positions to draw up an energy balance of the energy flows. Data from other HL 320 modules can be transferred to the configurable heating controller of the heat pump module via a CAN bus connection.

The HL 320.01 Heat pump is part of the HL 320 modular system and provides you with a variety of combination options from geothermal and solar thermal energy in a modern heating system. The heat pump is driven by a variable speed scroll compressor. This means it is possible to adapt the heating power of the heat pump to the current heating system demand.



Process schematic of the HL 320.01 Heat pump module

1 source circuit connections, **2** refrigeration circuit, **3** heating circuit connections, **4** additional options for including HL 320 modules;
hot heat transfer fluid,
cold heat transfer fluid,
refridgerant, high pressure,
refridgerant, low pressure

Fixed and movable spirals of a scroll compressor

In combination 3 of the HL 320 system, the following modules are combined to create one system:

- HL 320.01 Heat pump
- HL 320.07 Underfloor heating/geothermal energy absorber
- HL 320.08 Fan heater/air heat exchanger

This combination allows fundamental experiments on the operating behaviour of the heat pump. For more detailed experiments a storage module (HL 320.05) and a thermal solar collector, for example, can be connected.

Learning objectives

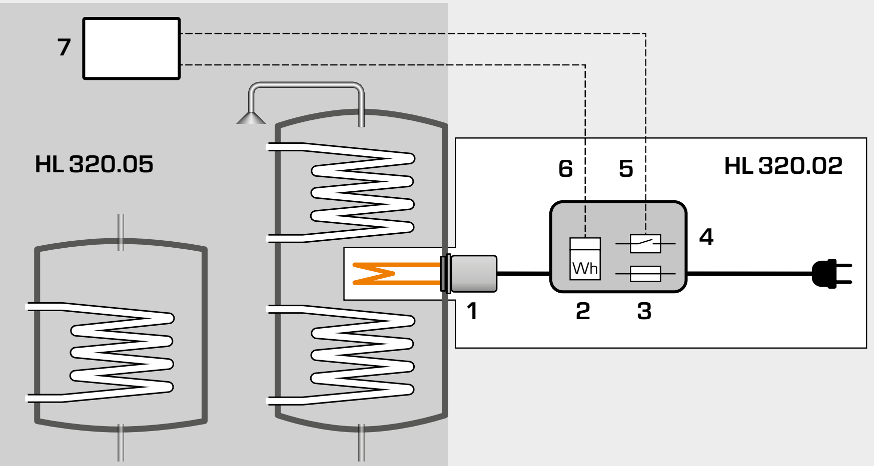
- function and design of a heat pump
- distinguishing different operating conditions
- factors influencing the COP (coefficient of performance)
- parameterisation of a heat pump controller

GUNT-RHLine Renewable Heat
Solar thermal energy and heat pump modular system

HL 320.02 Conventional heating

In heating systems using different renewable heat sources, it may be economically feasible to cover the peak demand by means of a conventional heater. In order to be able to investigate this aspect in the HL 320 modular system, the HL 320.02 module provides an additional heater that can easily be integrated into different system configurations.

The practical cost of operating this heater for your experiments remains low because an electrically operated heating element is used. The heating element is inserted into the storage tank of the HL 320.05 Central storage module and can be controlled by the storage module's controller via CAN bus. An integrated meter records the amount of electricity consumed. The data from this meter can be sent to the controller of the HL 320.05 Central storage module via the CAN bus connection for capture by a data logger.



1 heating element, **2** energy meter, **3** fuse, **4** switch box,
5 connection between contactor and controller output,
6 connection between energy meter and controller input,
7 HL 320.05 module's controller

The storage tank is emptied in preparation for the experiment. The auxiliary heater can easily be inserted subsequently in just a few steps.

Learning objectives

- complementary heating and/or domestic water heating by conventional additional heater
- bivalence point and heating load
- control strategies for complementary heating

HL 320.03 Flat collector

In conjunction with other HL 320 modules, you can conduct experiments on solar thermal energy domestic water heating with the HL 320.03 Flat collector. The control engineering for the combined production of domestic hot water and heating is of particular practical relevance. Here, the system is controlled and data captured via CAN bus via the HL 320.05 Central storage module.

Modules are easily connected via hoses and quick-release couplings. Different combinations for renewable heat sources can be tested and optimised in conjunction with other modules from the HL 320 system.

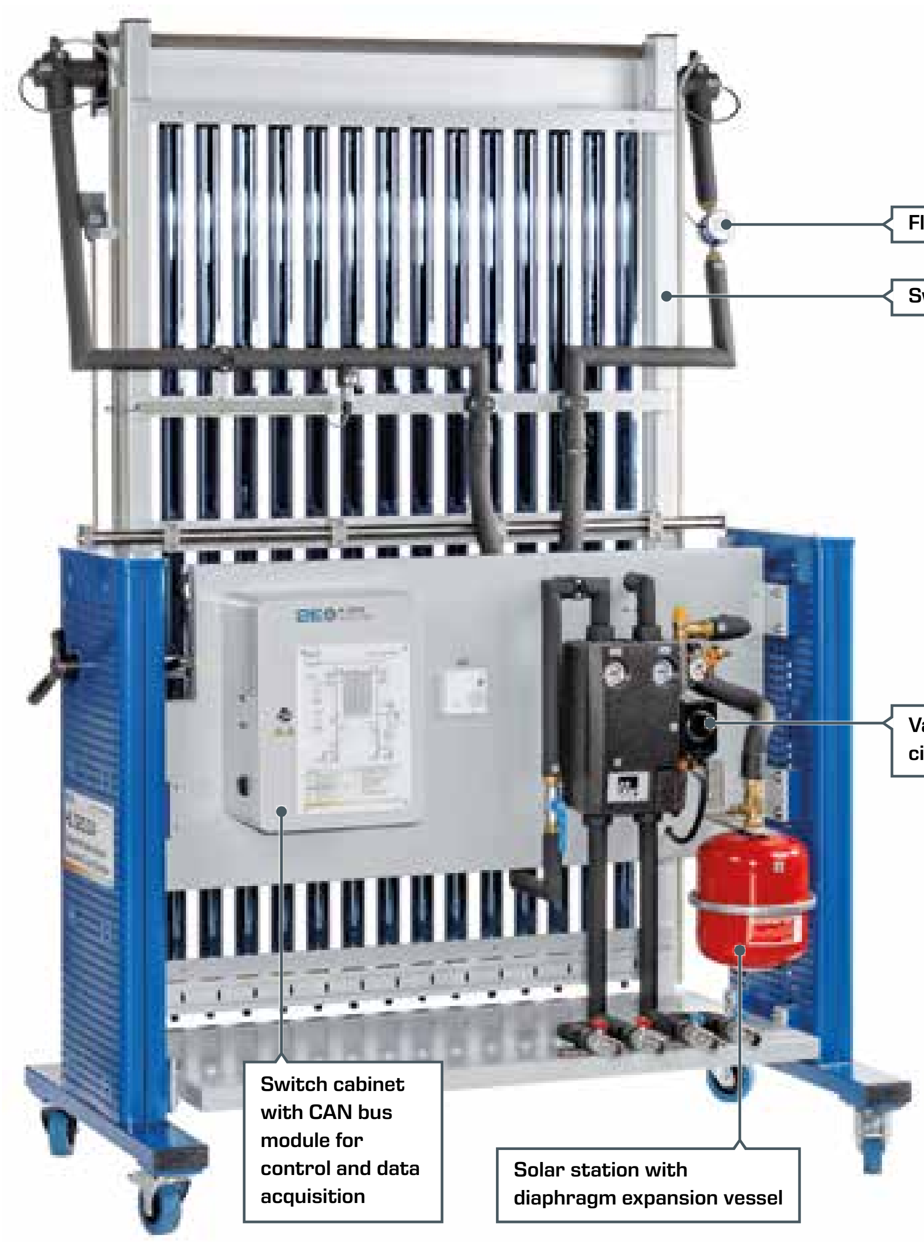
Learning objectives

- determining the net power
- how temperature, illuminance and angle of incidence affect the collector efficiency
- integration of a flat collector in a modern heating system
- hydraulic and control engineering operating conditions
- energy balances
- optimisation of operating conditions for different types of use

GUNT-RHLine Renewable Heat
Solar thermal energy and heat pump modular system

HL 320.04 Evacuated tube collector

The HL 320.04 unit provides you with an evacuated tube collector in a modern design. Evacuated tube collectors reach much higher operating temperatures compared to simple flat collectors due to the lower thermal losses. In practice, evacuated tube collectors are used where there is limited floor space, for example. In the year-round heating operation, evacuated tube collectors enable the reduction of the seasonal demand on a conventional auxiliary heater. HL 320.04 is one of the modules from the HL 320 Solar thermal energy and heat pump modular system. The experiment module can be incorporated into the modular system in a variety of different ways. The module can be used both for generating heated domestic water and for the combined production of domestic hot water and for heating rooms. Pipe connections for the heat transfer fluid are easy to create and alter thanks to the quick-release couplings.



Learning objectives

- design and operation of an evacuated tube collector
- determining the net power and parameters affecting collector efficiency
- integration of an evacuated tube collector in a modern heating system

HL 320.05 Central storage module with controller

The HL 320.05 Central storage module with controller has been developed for your experiments as a central component of the HL 320 modular system. HL 320.05 contains two different heat storage systems, pipes, a pump, two motorised 3-way valves and safety devices. Quick-release couplings on the front of the module enable hydraulic connections to other modules in the modular system. In addition, HL 320.05 contains a freely-programmable heating controller, which is connected to the respective modules via control and data lines (CAN bus). This controller allows you to operate and study all intended module combinations.

Learning objectives

- fundamentals and commissioning of heating systems with solar thermal energy and heat pump
- properties of various heat storage methods
- electrical, hydraulic and control engineering operating conditions
- energy balances for different system configurations
- optimisation of control strategies for solar station with different operating modes

GUNT-RHLine Renewable Heat
Solar thermal energy and heat pump modular system

HL 320.07 Underfloor heating / geothermal energy absorber

Underfloor heating systems transfer heat through piping systems arranged in a spiral or winding pattern underneath the floor covering. Underfloor heating requires much lower feed flow temperature than conventional radiators. Besides its function as a heat sink when used as an underfloor heating system, HL 320.07 can also be used as a heat source for a heat pump in the HL 320 modular system. In this case, the direction of the heat transport is reversed. HL 320.07 is equipped with three separately selectable piping systems of different lengths. The pipes are surrounded by a tank which can be filled with water.

Sensors are mounted on the piping system to detect the temperatures in the feed and return. Heat quantities and energy balances can be calculated using these temperatures together with the measurement data from the integrated flow meter. Data is transferred to the controller of each main module (HL 320.01 or HL 320.05) via the CAN bus connection. The integrated 3-way mixing valve can also be controlled by the controller via the CAN bus connection.

Learning objectives

- energy balance in combined heating systems for domestic hot water generation and heating
- heat transfer in an underfloor heating system
- use of heat sources for heat pump systems

HL 320.08 Fan heater / air heat exchanger

When heating rooms, fan heaters offer the possibility of achieving a comparatively good transfer of heat to the room air compared to traditional heating radiators, even at small dimensions. When combined with a heat pump, the fan heater often represents a beneficial application both economically and in terms of energy, especially when renovating heating systems in old buildings. The HL 320.08 experiment module completes your HL 320 modular system. This module can also be operated as either a heat sink or a heat source for a heat pump. Sensors for temperature and flow rate are available to create energy balances. Data is transferred to the controller of each main module (HL 320.01 or HL 320.05) via the CAN bus connection.

Learning objectives

- how the temperature difference between the heating feed and return affects the overall efficiency of a heating system
- operating conditions when used as an air heat exchanger in a heat pump system
- comparison of an air heat exchanger with other heat sources in a heat pump system

HL 320.01
Heat pump

Description

- **trainer from the HL 320 modular system**
- **heat pump for operation with different sources**
- **multiple system variants possible in conjunction with other HL 320 modules**

The HL 320 modular system allows experiments on the generation, storage and use of heat from renewable energies. HL 320.01 is one module in this system and includes a heat pump that can be connected to different heat sources and consumers.

The heat pump comprises a compressor, a condenser, an expansion valve and an evaporator. These components are connected to each other via a refrigeration circuit. The refrigerant circulates in the refrigeration circuit powered by the compressor. A source's thermal energy is absorbed at the evaporator. Additional energy is added to the evaporated refrigerant in the compressor. This energy can be output to a consumer as heat.

On the HL 320.01 trainer, the condenser can be incorporated into a heating circuit consisting of various consumers. The evaporator can be connected to a source circuit with different heat sources. The pipes with quick quick-release couplings, circulation pumps and accessories necessary to create these connections are provided.

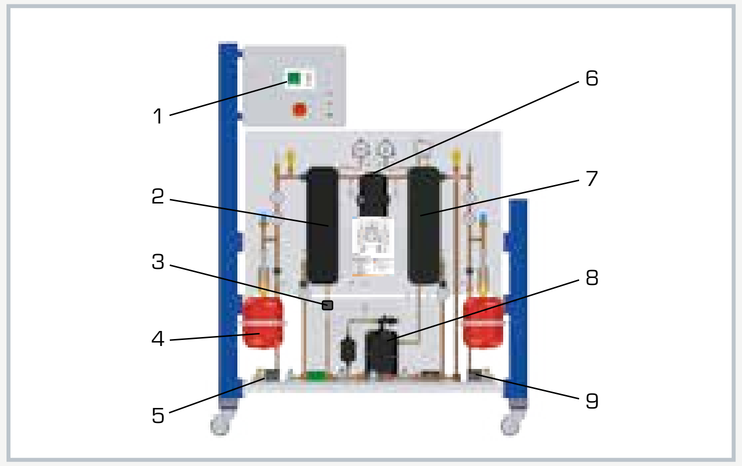
In practice and depending on the application, different system configurations are often required for optimal efficiency of a heating system. Using HL 320.01 and other HL 320 modules it is possible to systematically investigate the possible variants for incorporating a heat pump into a modern heating system.

Carefully structured instructional materials have been created for the recommended modular combinations with the HL 320.01 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

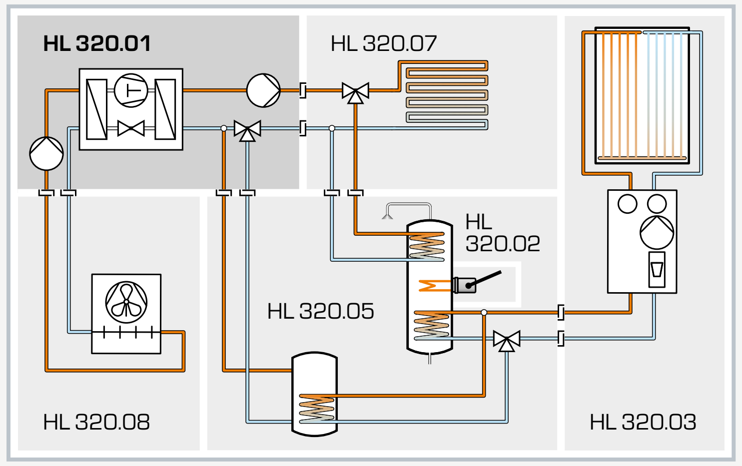
Learning objectives/experiments

- familiarisation with heat pump applications for heating rooms and hot water
- using the heat pump for cooling
- advantages and disadvantages of various system configurations (brine heat pump, air heat pump)
- configuring and adjusting a heat pump controller
- operating behaviour under varying heat supply and demand
- dependence of the coefficient of performance on source and sink temperature
- possibilities for optimising the seasonal performance factor

HL 320.01
Heat pump



1 controller, 2 evaporator, 3 expansion valve, 4 expansion vessel, 5 pump source circuit, 6 scroll compressor, 7 condenser, 8 receiver, 9 pump heating circuit



Inclusion of HL 320.01 in one possible configuration of the HL 320 modular system

	1	2	3	4	5
HL 320.01			X	X	X
HL 320.02		X			X
HL 320.03	X	X		X	X
HL 320.04	(X)	(X)		(X)	(X)
HL 320.05	X	X		X	X
HL 320.07		X	X	X	X
HL 320.08			X	X	X

Recomended combinations of the HL 320 modular system

Specification

[1] heat pump for the HL 320 modular system
[2] connections for various heat sources and sinks
[3] one circulation pump and one safety module each with expansion vessel for heating and source circuit
[4] sensors for temperature, flow rate and pressure with connection to the controller
[5] controller with data logger and LAN connection for acquisition of measurement data and for controlling the system
[6] software for transferring, displaying and evaluating the controller's measured data

Technical data

Heat pump
- heating capacity: approx. 2,3 kW at 5/65°C

Heating and source circuit pumps
- max. flow rate: $3m^3/h$
- max. head: 4m

Universal controller
- inputs: up to 16
- outputs: up to 16
- interfaces: DL bus, CAN, LAN

Measuring ranges
- temperature:
  - 4x -50...180°C
  - 3x 0...120°C
  - 1x -20...60°C
- flow rate: 2x $0,02...1,5m^3/h$
- pressure:
  - 1x -1...15bar
  - 1x -1...49bar
  - 2x 0...6bar
  - 2x 0...50bar
  - 1x 0...18bar
  - 2x 0...10bar

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
LxWxH: 1500x800x1700mm
Weight: approx. 125kg

Required for operation

PC with Windows

Scope of delivery

1 trainer
1 manual

HL 320.02
Conventional heating

HL 320.02 heater installed in the bivalent storage tank of HL 320.05

Learning objectives/experiments

- complementary heating and/or domestic water heating by conventional additional heater
- bivalence point and heating load
- control strategies for complementary heating
- energy balances in conventionally supported solar thermal and heat pump systems

Description

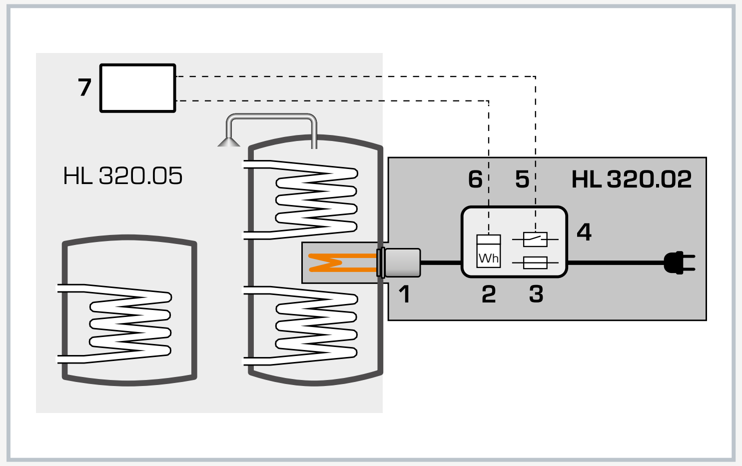
- **complementary heater for the HL 320 modular system**
- **heater with electricity meter**
- **easy installation in HL 320.05 storage tank**

In heating systems using different renewable heat sources, it may be economically feasible to cover the peak demand by means of a conventional heater. In order to be able to investigate this aspect in the HL 320 modular system, the HL 320.02 module provides an additional heater that can easily be integrated into different system configurations.

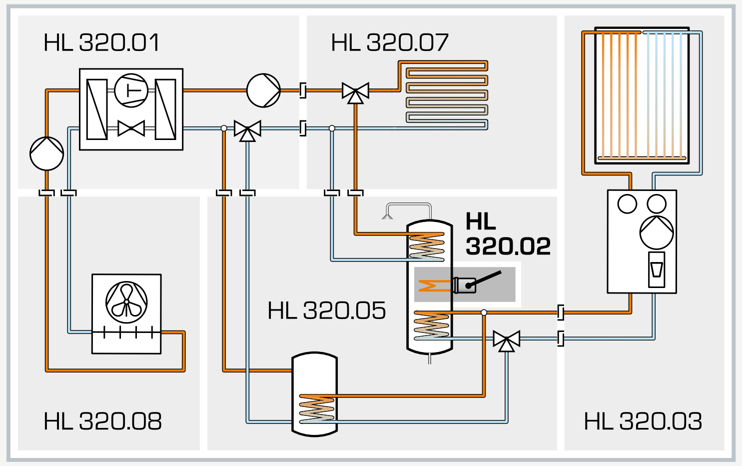
The practicality of operating this heater in laboratory experiments is kept simple by using an electrically operated heater. The heater is inserted into the storage tank of the HL 320.05 storage module and can be controlled by the storage module's controller. An integrated meter records the amount of electricity consumed. The data from this meter can be sent to the controller of the HL 320.05 storage module via a suitable data cable, by means of the data logger.

Carefully structured instructional materials have been created for the recommended modular combinations with the HL 320.02 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

HL 320.02
Conventional heating



1 heater, 2 energy meter, 3 fuse, 4 control cabinet 5 connection between contactor and controller output, 6 connection between energy meter and controller input, 7 controller attached to module HL 320.05



Inclusion of HL 320.02 in one possible configuration of the HL 320 modular system

	1	2	3	4	5
HL 320.01			X	X	X
HL 320.02		X			X
HL 320.03	X	X		X	X
HL 320.04	(x)	(x)		(x)	(x)
HL 320.05	X	X		X	X
HL 320.07		X	X	X	X
HL 320.08			X	X	X

Recomended combinations of the HL 320 modular system

Specification

[1] electrical heater for the HL 320 modular system
[2] control by means of the HL 320.05 module's controller
[3] control cabinet with power contactor, miniature circuit breaker and energy meter
[4] recording the amount of eenergy consumed by S0 connection to the HL 320.05 module's controller

Technical data

Heater
- electric output: 3kW
- thermostat: 30...110°C

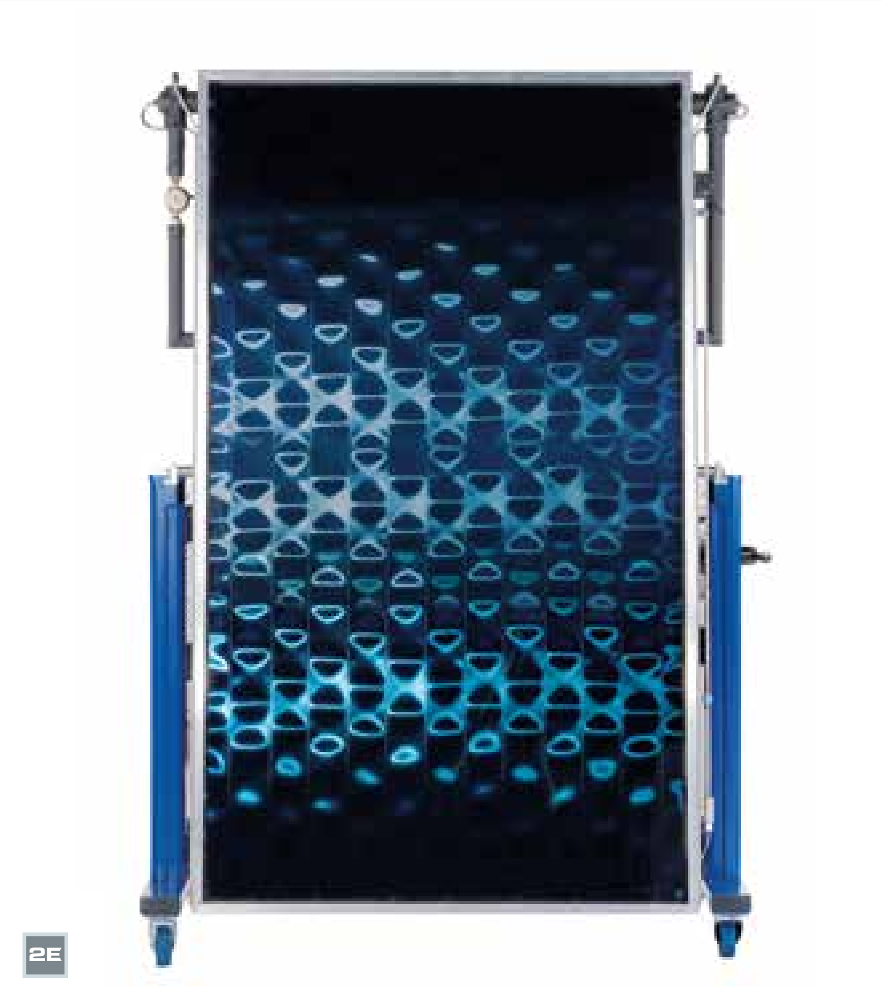
Electricity meter
- voltage: 230VAC, 50Hz
- max. current: 32A
- S0 output: 1000Imp./kWh

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
Dxh: 115x370mm (heater)
Weight: approx. 2kg
LxWxH: 300x250x200mm (switch box)
Weight: approx. 1,5kg

Scope of delivery

1 heater
1 switch box
1 manual

HL 320.03
Flat collector



Learning objectives/experiments

- layout and function of the flat collector
- determining the net power
- how temperature, illuminance and angle of incidence affect the collector efficiency
- integration of a flat collector in a modern heating system
- hydraulic and control engineering operating conditions
- energy balances
- optimisation of operating conditions for different types of use

Description

- **pivotable flat collector for converting solar energy into heat**
- **heat source with connections for the HL 320 modular system**
- **components for operational and system reliability from real-world modern heating technology**
- **suitable for sunlight and artificial light**

HL 320.03 is one of the modules from the HL 320 modular system and allows you to convert solar energy into heat using a modern flat collector.

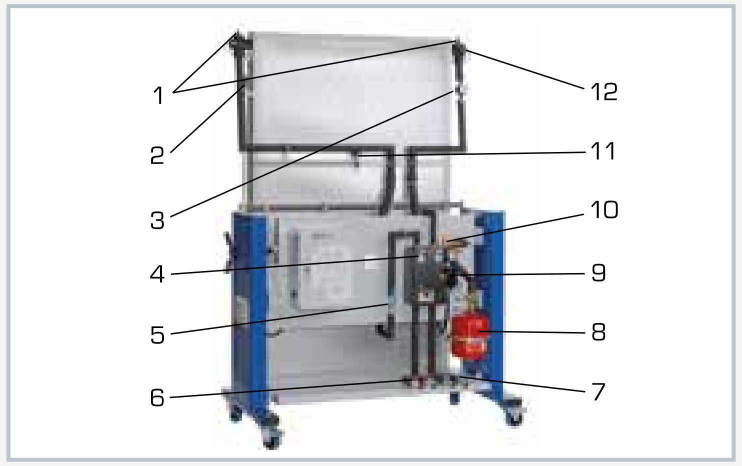
HL 320.03 can be incorporated into the HL 320 modular system in a variety of different ways. The trainer can be used both for generating heated domestic water and for the combined production of domestic hot water and for heating rooms.

Modules are connected rapidly and easily via hoses and quick-release couplings.

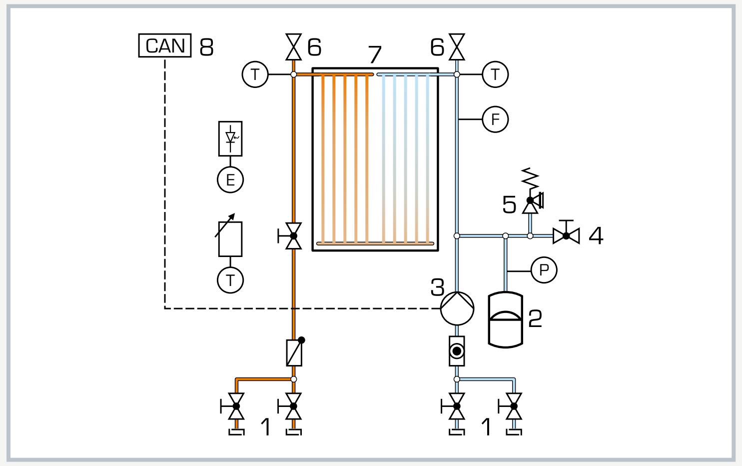
Different combinations for renewable heat sources can be tested and optimised in conjunction with other modules from the HL 320 system.

Carefully structured instructional materials have been created for the intended modular combinations with the HL 320.03 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

HL 320.03
Flat collector



1 vent valves, 2 lighting sensor, 3 flow sensor, 4 thermometer collector outlet, 5 shut-off valve, 6 connectors for warm water, 7 connectors for cold water, 8 diaphragm expansion vessel, 9 circulation pump, 10 pressure relief valve, 11 pressure sensor, 12 temperature sensor



1 connections for heat transfer pipes with shut-off valves and quick-release coupling, 2 diaphragm expansion vessel, 3 pump, 4 fill valve, 5 pressure relief valve, 6 bleed valves, 7 flat collector, 8 CAN bus;
E illuminance, F flow rate, T temperature, P pressure

	1	2	3	4	5
HL 320.01			X	X	X
HL 320.02		X			X
HL 320.03	X	X		X	X
HL 320.04	(X)	(X)		(X)	(X)
HL 320.05	X	X		X	X
HL 320.07		X	X	X	X
HL 320.08			X	X	X

Recomended combinations of the HL 320 modular system

Specification

[1] trainer for the HL 320 modular system for the investigation of functional and operational behaviour of a flat collector
[2] solar thermal flat collector with selectively absorbing coating
[3] adjustable collector tilt angle
[4] solar circulation station with pump, expansion tank and safety valve
[5] measurement instruments and controls by HL320.05
[6] operation with solar radiation or HL 313.01 artificial light source

Technical data

Collector
- absorbing surface: 2.5m^2
- rated throughput: 40...150L/h
- operating pressure: 1...3bar

Solar circuit station
- solar pump: 3-stage
- safety valve: 4bar
- balancing valve: 1...13L/min

Measuring ranges
- temperature:
  - 2x 0...160°C
  - 3x -50°C...180°C
- flow rate: 30...1000l/h
- pressure: 0...6bar

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
LxWxH: 1660x800x2300mm
Weight: approx. 220kg

Scope of delivery

1 trainer
1 manual

HL 320.04
Evacuated tube collector

Learning objectives/experiments

- design and operation of the evacuated tube collector
- determining the net power
- parameters affecting collector efficiency
- integration of an evacuated tube collector in a modern heating system
- hydraulic and control engineering operating conditions
- creating energy balances
- optimisation of operating conditions for different types of use

Description

- **conversion of solar energy into heat in the evacuated tube collector**
- **pivotable collector with connections for the HL 320 modular system**
- **components for operational and system reliability from real-world modern heating technology**
- **suitable for sunlight and artificial light**

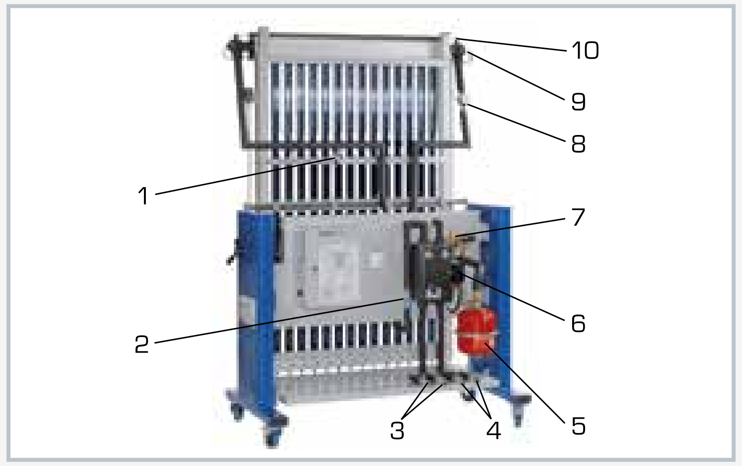
The HL 320.04 trainer contains a modern evacuated tube collector and allows you to convert solar energy into heat. Evacuated tube collectors reach much higher operating temperatures compared to simple flat collectors due to the lower thermal losses.

HL 320.04 is one of the modules from the HL 320 Solar thermal energy and heat pump modular system. The trainer can be incorporated into the modular system in a variety of different ways. The trainer can be used both for generating heated domestic water and for the combined production of domestic hot water and for heating rooms.

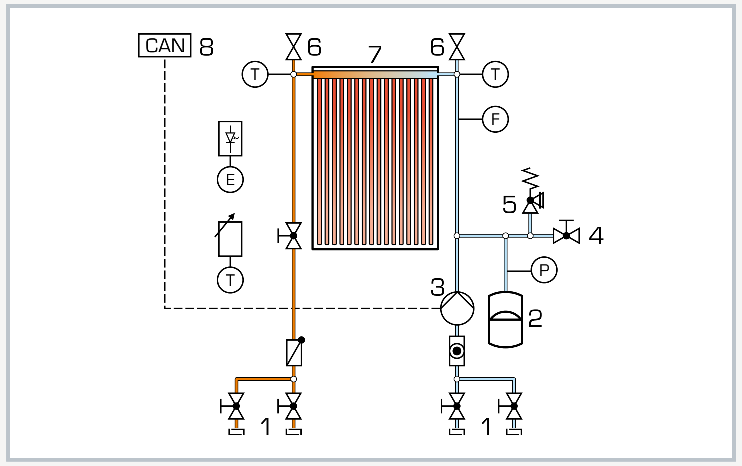
Pipe connections for the heat transfer fluid are easy to create and alter thanks to the quick-release couplings.

Carefully structured instructional materials have been created for the intended modular combinations with the HL 320.04 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

HL 320.04
Evacuated tube collector



1 pressure sensor, 2 shut-off valve, 3 connectors for warm water, 4 connectors for cold water, 5 diaphragm expansion vessel, 6 circulation pump, 7 pressure relief valve, 8 flow sensor, 9 temperature sensor, 10 vent valve



1 connections for heat transfer pipes with shut-off valves and quick-release coupling,
2 diaphragm expansion vessel, 3 pump, 4 fill valve, 5 pressure relief valve, 6 bleed valves,
7 evacuated tube collector, 8 CAN bus;
E illuminance, F flow rate, T temperature, P pressure

	1	2	3	4	5
HL 320.01			X	X	X
HL 320.02		X			X
HL 320.03	X	X		X	X
HL 320.04	(X)	(X)		(X)	(X)
HL 320.05	X	X		X	X
HL 320.07		X	X	X	X
HL 320.08			X	X	X

Recomended combinations of the HL 320 modular system

Specification

[1] trainer for investigating the function and operating behaviour of an evacuated tube collector
[2] evacuated tube collector with selective coating
[3] adjustable collector tilt angle
[4] solar circulation station with pump, expansion tank and safety valve
[5] measurement instruments and controls by HL 320.05
[6] operation with solar radiation or HL 313.01 artificial light source

Technical data

Collector
- total area: 2,1m^2
- absorbing surface: 1,5m^2
- absorber content: 1,5L
- rated throughput: 58L/h

Solar circuit station
- solar pump: 3-stage
- safety valve: 4bar
- balancing valve: 1...13L/min

Measuring ranges
- temperature:
  - 2x 0...160°C
  - 3x -50°C...180°C
- flow rate: 30....1000l/h
- pressure: 0...6bar

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
LxWxH: 1660x800x2300mm
Weight: approx. 230kg

Scope of delivery

1 trainer
1 manual

HL 320.05

Central storage module with controller

The illustration shows HL 320.05 with the switch box for HL 320.02

Description

- **module with buffer storage and bivalent storage for heating systems with renewable energies**
- **freely programmable universal controller with data logger and comprehensive software**
- **easily accessible quick-release couplings for all heat transfer pipes**
- **pump with speed control and driven three-way valve for various configurations**

The HL 320 modular system allows experiments on the generation, storage and use of heat from renewable energies. A variety of heat sources, storage types and consumers can be used. The system uses typical real-world components from the field of modern heating technology.

The HL 320.05 central storage module forms the core of the HL 320 modular system. HL 320.05 contains two different heat storage methods, piping, a pump, a driven 3-way valve and safety devices. Quick-release couplings on the front of the module enables the hydraulic connection to other modules of the HL 320 modular system.

HL 320.05 also includes the freely programmable universal controller UVR1611. This controller allows you to operate and study all intended HL 320 modular combinations.

Thoroughly documented configuration files for introductory and advanced experiments are available for all recommended HL 320 modular combinations. Newly created configurations or changes can be stored in the controller's memory. Easy-to-understand PC programs can be used to edit configurations and to acquire and display measured values.

Carefully structured instructional materials have been created for the intended modular combinations using the HL 320.05 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

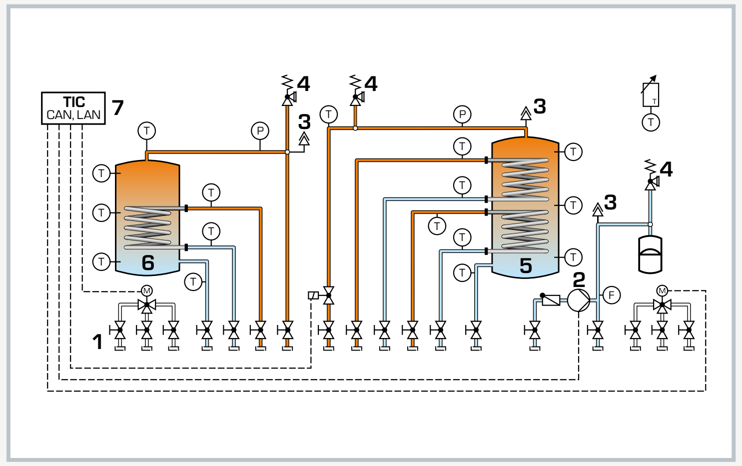
Learning objectives/experiments

- the following learning objectives can be worked through, depending on the selected HL 320 modular combination:
  - familiarisation with modern heating systems based on renewable energy sources
  - commissioning of heating systems with solar thermal energy and heat pump
  - electrical, hydraulic and control engineering operating conditions
  - properties of various heat storage methods
  - creation of energy balances for different system configurations
  - development of control strategies for different operating modes

HL 320.05

Central storage module with controller

1 fresh water inflow, 2 temperature sensor, 3 bivalent storage, 4 bleed valve, 5 pressure relief valve, 6 freely programmable universal controller, 7 pressure sensor, 8 buffer storage, 9 speed-controlled pump, 10 driven 3-way valve



1 connections for heat transfer pipes with shut-off valves and quick-release coupling, 2 pump, 3 bleed valves, 4 pressure relief valves, 5 bivalent storage, 6 buffer storage, 7 TIC programmable universal controller; F flow rate, P pressure, T temperature

	1	2	3	4	5
HL 320.01			X	X	X
HL 320.02		X			X
HL 320.03	X	X		X	X
HL 320.04	(X)	(X)		(X)	(X)
HL 320.05	X	X		X	X
HL 320.07		X	X	X	X
HL 320.08			X	X	X

Recomended combinations of the HL 320 modular system

Specification

[1] trainer with buffer storage and bivalent storage for experiments with the HL 320 modular system
[2] heat transfer pipes with quick-release coupling and shut-off valve
[3] pressure relief and bleed valves for safe operation
[4] circulation pump with differential pressure or speed control
[5] driven 3-way valves
[6] temperature sensors for heat storage and room temperature
[7] 2 pressure sensors for system monitoring
[8] flow meters and temperature sensors for determining the heat flows
[9] freely programmable universal controller with data logger and PC connection via LAN

Technical data

Buffer storage
- storage capacity: 150L
- number of heat exchangers: 1
- operating pressure: max. 5bar
- operating temperature: max. 95°C

Bivalent storage
- storage capacity: 200L
- number of heat exchangers: 2
- operating pressure: max. 5bar
- operating temperature: max. 95°C

Pump
- max. flow rate $3m^3/h$
- max. head: 4m

Universal controller
- inputs: up to 16 (expandable)
- outputs: up to 16 (expandable)
- interfaces: DL bus, CAN, LAN

Measuring ranges
- temperature:
  - 16x -50°C...180°C
  - 1x 0...40°C
- flow rate: 30...1000L/h
- pressure: 2x 0...6bar

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase, 120V, 60Hz, 1 phase
UL/CSA optional
LxWxH: 2400x810x1900mm
Weight: approx. 220kg

Required for operation

PC with Windows

Scope of delivery

1 trainer
1 set of instructional material (with sample programs for the universal controller)

HL 320.07
Underfloor heating / geothermal energy absorber

Description

- **trainer for the HL 320 "Solar thermal energy and heat pump" system**
- **can be used as heat sink or heat source**
- **option for heat transfer pipes in various lengths**
- **temperature and flow sensors for connection to the HL 320.05 controller module**

Underfloor heaters transfer heat by piping systems arranged in a spiral or winding pattern beneath the floor covering. Underfloor heating requires much lower feed flow temperature than conventional radiators. Underfloor heating systems are particularly well suited for use with heating systems that use solar thermal collectors.

Besides its function as a heat sink when used as an underfloor heating system, the HL 320.07 trainer can also be used as a heat source for a heat pump in the HL 320 modular system. In this case, the direction of the heat transport is reversed.

HL 320.07 is equipped with three individually selectable piping systems of different lengths. The pipes are surrounded by a tank which can be filled with water if necessary. Sensors are mounted on the piping system to detect the temperature on the feed and return.

Heat quantities and energy balances can be calculated using these temperatures together with the measurement data from the integrated flow meter.

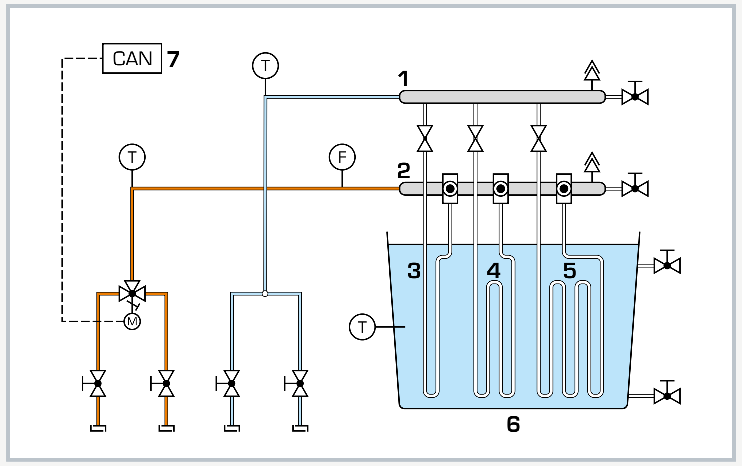
Carefully structured instructional materials have been created for the intended modular combinations with the HL 320.07 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

Learning objectives/experiments

- energy balance in combined heating systems for domestic hot water generation and heating
- heat transfer in an underfloor heating system
- use of heat sources for heat pump systems
- learning objectives of the HL 320 modular system

HL 320.07
Underfloor heating / geothermal energy absorber

1 connection for feed, 2 connection for return, 3 tanks for hot and cold water, 4 feed distributor, 5 flow meter, 6 return distributor, 7 info panel, 8 connection box for sensors, 9 return temperature sensor, 10 flow meter, 11 return temperature sensor



1 return distributor, 2 feed distributor, 3 10m piping circuit, 4 20m piping circuit, 5 30m piping circuit, 6 tanks for experiments with hot and cold water, 7 CAN bus; T temperature, F flow rate

	1	2	3	4	5
HL 320.01			X	X	X
HL 320.02		X			X
HL 320.03	X	X		X	X
HL 320.04	(X)	(X)		(X)	(X)
HL 320.05	X	X		X	X
HL 320.07		X	X	X	X
HL 320.08			X	X	X

Recomended combinations of the HL 320 modular system

Specification

[1] heat sink or heat source for the HL 320 modular system
[2] 3 selectable pipe lengths for heat transfer
[3] flow meters and temperature sensors for determining the heat flows
[4] tanks for hot or cold water
[5] connections for transmitting measurement data to an external controller

Technical data

Pipes
- lengths: 10m, 20m, 30m
- material: polyethylene
- wall thickness: 2mm
- outer diameter: 16mm
- operating pressure: max. 3bar

Tank
- volume: 200L

Measuring ranges
- temperature: 3x -50...180°C
- flow rate: 30...1000L/h

LxWxH: 1500x 800x1700mm
Weight: approx. 95kg

Scope of delivery

1 trainer
1 manual

HL 320.08
Fan heater / air heat exchanger

Description

- **trainer for the HL 320 “solar thermal energy and heat pump” modular system**
- **use as a heat source or heat sink**
- **axial fan with two speed settings**

Trainer consisting of a fan convector with piping, quick-release couplings and temperature sensors. The trainer may be used both to heat rooms and to absorb ambient heat from the outside air. It can thus be operated as either a heat sink or a heat source for a heat pump.

In the case of heating rooms, compared to traditional heating radiators, fan heaters offer the possibility of achieving a comparatively good transfer of heat to the room air, even at small dimensions. This advantage makes it possible to operate room heating with lower temperatures in the heating circuit. When combined with a heat pump, the fan heater therefore often represents a beneficial application both economically and in terms of energy, especially when renovating heating systems in old buildings.

When absorbing ambient heat to supply heat to a heat pump, air heat exchangers are often used when there is no access or difficulty accessing other heat sources such as groundwater or geothermal heat collectors. The disadvantage of the energy balance, particularly unfavourable in winter, in this case is contrasted with the advantage of lower initial investment costs.

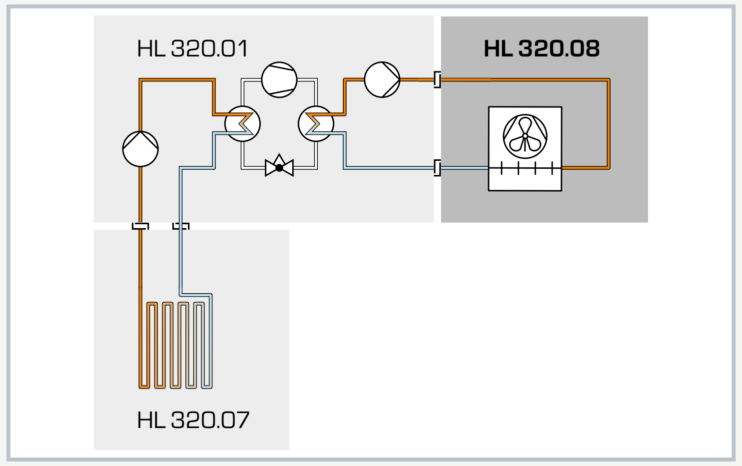
Carefully structured instructional materials have been created for the recommended modular combinations with the HL 320.08 module. As part of the documentation for the HL 320 modular system, these materials set out the basic principles and provide a step-by-step guide through the experiments.

Learning objectives / experiments

- use of a fan convector for heating and cooling rooms
- how the temperature difference between the heating feed and return affects the overall efficiency of a heating system
- operating conditions when used as an air heat exchanger in a heat pump system
- comparison of an air heat exchanger with other heat sources in a heat pump system

HL 320.08
Fan heater / air heat exchanger

1 junction box, 2 CAN-bus connecting sockets, 3 flow meter, 4 feed flow, 5 3-way mixing valve, 6 return flow, 7 temperature sensor feed flow, 8 fan convector, 9 vent valve



Inclusion of HL 320.08 in one possible configuration of the HL 320 modular system

	1	2	3	4	5
HL 320.01			x	x	x
HL 320.02		x			x
HL 320.03	x	x		x	x
HL 320.04	(x)	(x)		(x)	(x)
HL 320.05	x	x		x	x
HL 320.07		x	x	x	x
HL 320.08			x	x	x

Recomended combinations of the HL 320 modular system

Specification

[1] fan convector for connection to the HL 320 modular system
[2] axial fan with two selectable speed settings
[3] control by means of other controllers in the HL 320 system (CAN bus)
[4] temperature sensors for feed and return
[5] quick-release couplings with shut-off valves for connecting the pipes

Technical data

Fan
- speed: 900 / 1400min^{-1}
- flow rate: 683 / 1155m^{3}h^{-1}

Heat exchanger
- nominal cooling capacity: 2kW
- max. operating pressure: 10bar

Measuring ranges
- temperature:
  - 3x -50°C...180°C
- flow rate: 30...1000L/h

230V, 50Hz, 1 phase
230V, 60Hz, 1 phase
LxWxH: 1500x 800x1500mm
Weight: approx. 95kg

Scope of delivery

1 trainer
1 manual