

# Geothermal Energy

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2E a division of



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# Subject Areas

# Geothermal Energy



Subject Areas

Products

The effective use of geothermal energy requires a geothermal field with elevated temperature, effective heat transfer to the subsequent cycles and the efficient use of the energy. Depending on the temperature level of the source, geothermal energy can be used for heating only or for conversion to electricity with utilisation of the residual heat.

Both types of usage require heat exchangers to transfer the extracted heat to the subsequent cycles. The disadvantage of multiple cycles is the energy loss during heat transfer. The main advantage is a much longer service life of the system, since corrosive components are prevented. In geothermal systems, water circuits and refrigerant circuits with heat pumps are used for heating purposes. The water circuit is the more efficient option, since it does not require electrical energy for a heat pump. However, the temperature of the geothermal field must be higher.

The conversion into electricity, for example in steam turbines, requires higher temperatures again, which can be found in deep geothermal energy. The energy gained is used to operate a steam circuit with turbine and generator, which produces electricity.

## Heat exchangers

- WL 110**  
Heat Exchanger Supply Unit
- WL 110.01**  
Tubular Heat Exchanger
- WL 110.02**  
Plate Heat Exchanger
- WL 110.03**  
Shell & Tube Heat Exchanger
- WL 110.04**  
Jacketed Vessel with Stirrer & Coil
- WL 315C**  
Trainer for Various Heat Exchangers

## Shallow geothermal energy

- ET 101**  
Simple Compression Refrigeration Circuit
- ET 262**  
Geothermal Probe with Heatpipe Principle
- ET 264**  
Geothermal Energy with 2-Well System
- HL 320**  
Solar Thermal Energy and Heat Pump Modular System (Combination 3)

## Deep geothermal energy

- ET 850**  
Steam Generator
- ET 851**  
Axial Steam Turbine



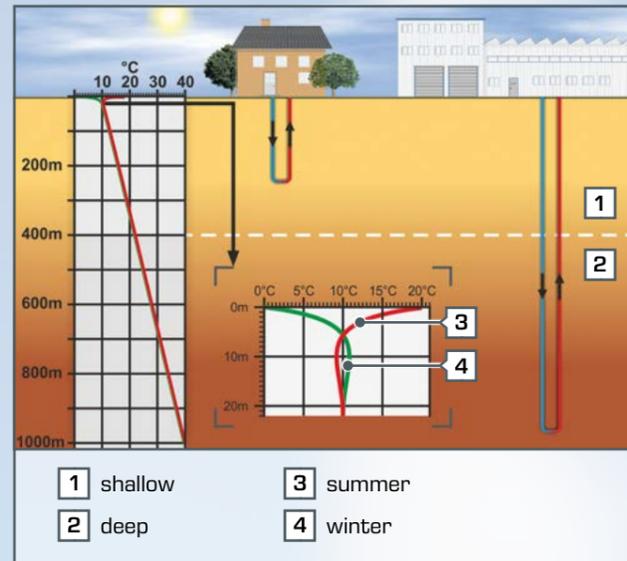
# Basic Knowledge Geothermal Energy



## Thermal energy from the ground

Geothermal energy refers to the use of thermal energy stored beneath the earth's surface. This thermal energy is usually available anywhere and at any time, which is a significant advantage compared to other renewable energies such as solar energy and wind power. Therefore, it makes sense to take advantage of this geothermal energy.

In the upper area of the earth's crust (about 0...20m) the temperature is determined by the climatic conditions at the earth's surface. Below this region, the temperature is constant over time and only depends on depth. On average, the temperature increases by 3°C for every 100m. For the most part, the thermal energy is the result of the decay of radioactive isotopes of uranium, thorium and potassium.



## Differentiating geothermal fields

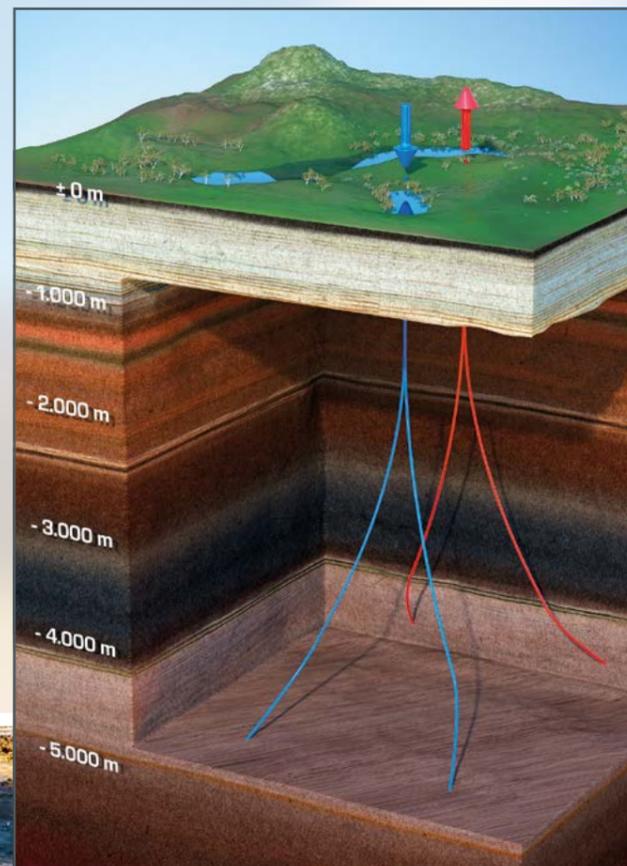
Usually when talking about geothermal energy a distinction is made between shallow geothermal energy and deep geothermal energy.

### Shallow geothermal energy

Shallow geothermal energy refers to the use of thermal energy stored in the upper area of the earth's crust (about 0...400m). Shallow geothermal energy is particularly useful for heating private households.

### Deep geothermal energy

Deep geothermal energy is when the thermal energy is stored in regions about 400...5000m below the surface. Since this requires deep drilling, this form of usage is significantly more cost-intensive than shallow geothermal energy. Therefore, deep geothermal energy is mainly suited to industrial applications.



## Using geothermal energy

Using geothermal energy requires interdisciplinary expertise in a variety of fields, such as mining, geology, mechanical engineering, plant engineering and civil engineering.

The use of geothermal energy also depends on the temperature of the geothermal field. If the temperature is low, the energy is used for heating and cooling. If a higher temperature is present, the energy is used to produce electricity.

In building services engineering, only low feed flow temperatures are required for underfloor heating, for example. Heat pumps are used in order to keep the drilling depth low. Therefore environments which are putatively too cold or too warm can also be used for cooling and heating purposes. Operating costs can therefore be reduced to operation of the heat pumps.

## Potential and outlook

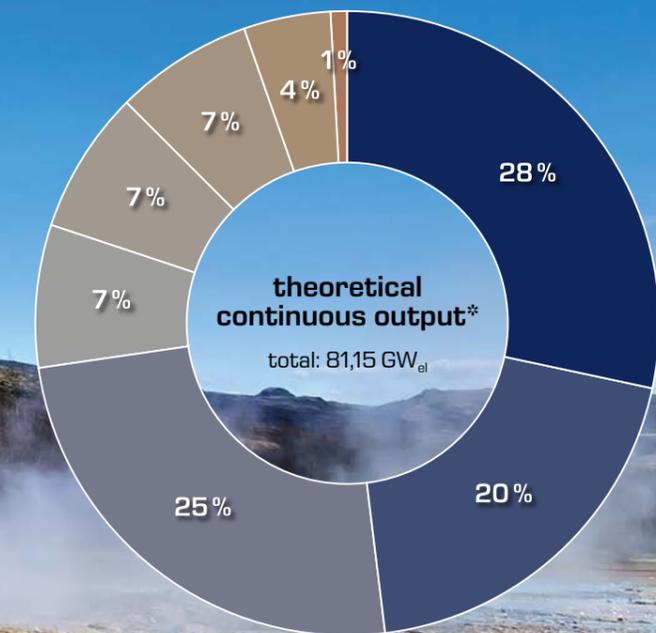
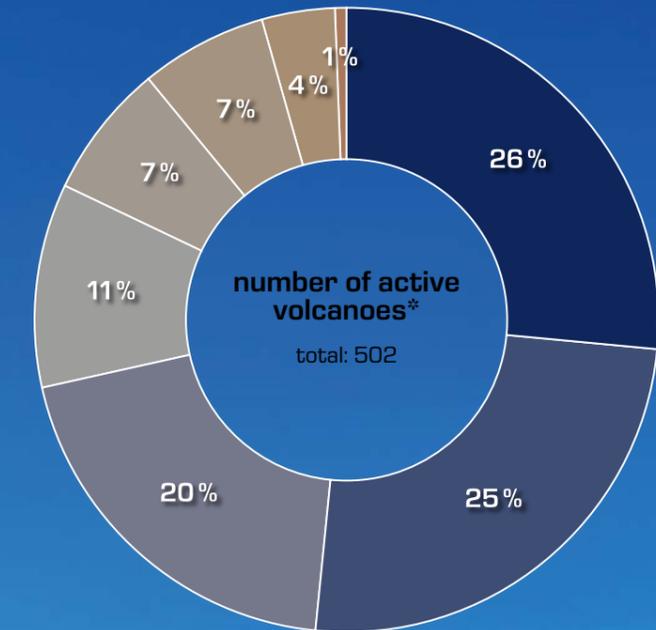
The potential for use of geothermal energy is divided according to the geothermal fields. For thermal anomalies with volcanic activity, a theoretical continuous electrical output of around 81 GW<sub>el</sub> has been determined in just 8 countries. As a comparison by size, the gross electricity consumption in Germany was around 600 TWh in 2013. This is equivalent to a continuous output of 68 GW<sub>el</sub>.

The global comparison shows that exploiting the theoretical continuous output of active volcanic regions alone could cover 4% of the global electricity demand. If other geothermal energy fields, both shallow and deep, are exploited as well, coverage of the global demand for heat and electricity is possible.



\*selected countries

Source: V. Steffansson:  
World geothermal assessment



# Basic Knowledge Heat Exchangers

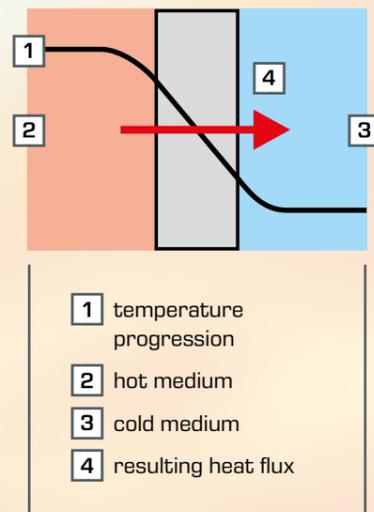


## Heat transfer

Essentially the role of heat exchangers is to transfer the heat of a flowing material to another flowing material with a lower starting temperature. The materials can be gaseous or liquid. The temperature difference between the two media as the driving differential is essential for heat transfer.

The entire transferred heat flux is directly dependent on the transference surface. This is why different wall geometries (e.g. fins) are used in order to increase the transference surface area.

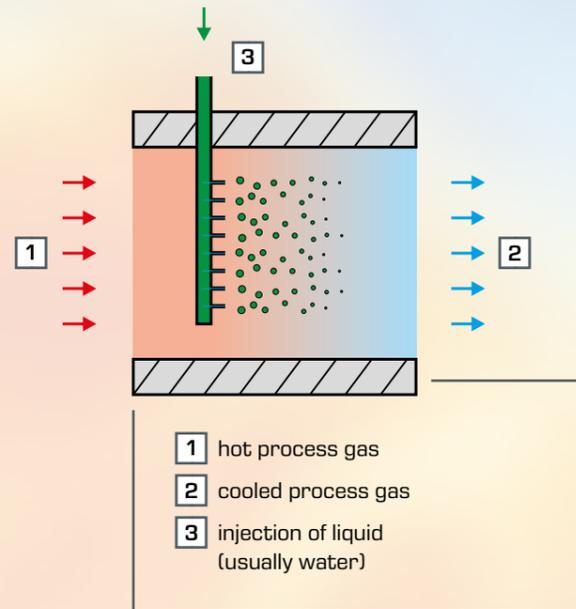
Heat transfer is divided into three stages: Heat transfer from the warmer medium to the wall, heat conduction through the wall and heat transfer from the wall to the colder medium.



The heat transfer from the medium to the wall or from the wall to the medium is dependent upon the material type, the flow velocity and the aggregate states of the media, amongst other things. The heat conduction on the wall depends on the wall thickness and the wall material.

## Type of contact between the media involved

If water is injected into a production process for cooling, this is known as direct heat transfer. There is no separation of the coolant and the product. The direct injection of water is used for example in the steel industry for intercooling or in wet cooling towers in the power station sector.

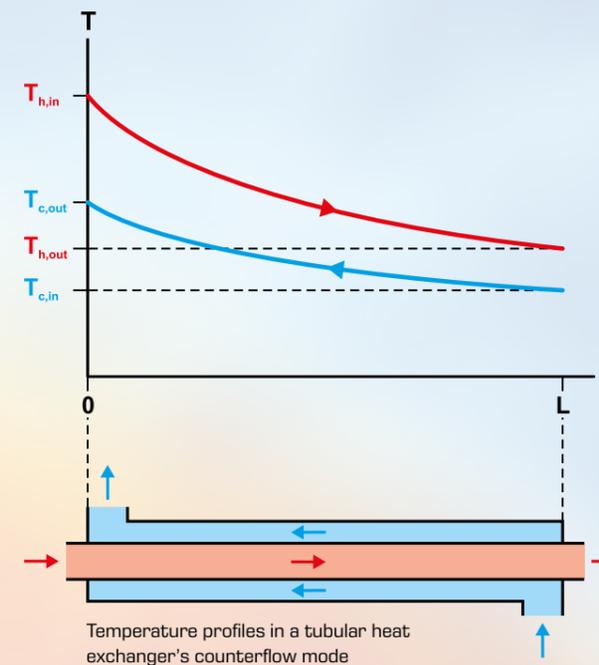


In contrast to direct heat transfer, the transfer of heat in spatially separated media is known as indirect transfer. The two materials are separated by a heat-permeable wall. The most well-known heat exchanger with indirect heat transfer is the domestic radiator.

Semi-indirect heat transfer is a special case which is used especially for heat storage. This mixed form is achieved by usage separated by time. During the day, heat storage is charged by a solar thermal system and during the night the thermal energy is discharged to heat rooms or as hot water.

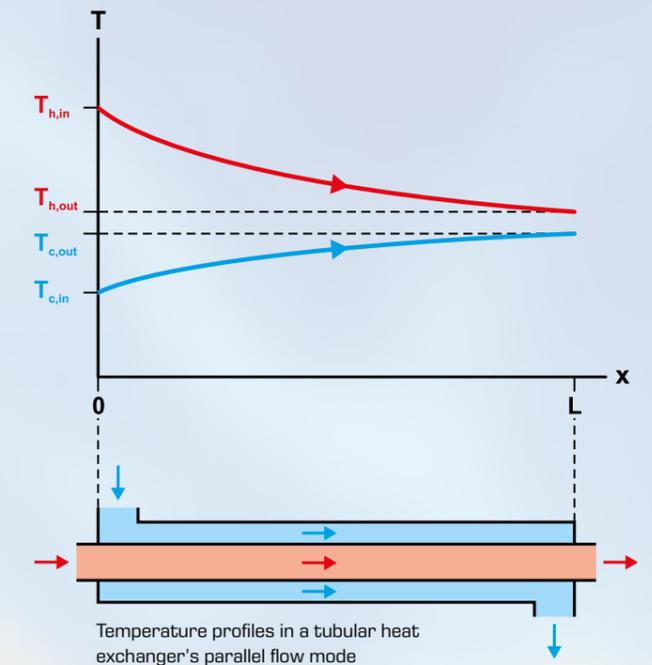
## Flow conditions

The possible flow conditions of indirect heat exchangers are counterflow, parallel flow, cross flow or combinations thereof. One example of a combination is cross counter flow, which is commonly used in shell and tube heat exchangers. If the space available is limited, plate heat exchangers are often used. These are operated in counterflow.



In counterflow mode, the cold medium exits at the input of the hot medium. If the heat exchanger is well designed, it is possible to achieve a higher outlet temperature on the cold side than on the hot side.

This is not possible when operating the heat exchanger in parallel flow. The maximum outlet temperature of the cold side can be equal to the outlet temperature of the hot side. The media flow next to each other in parallel.



The third variant is cross flow, which is used in particular for the precise temperature control of a temperature-sensitive product.

In order to use the advantages of all flow conditions, combinations of the basic forms are common. For example, a multiple-channel shell and tube heat exchanger can be used for quick and safe temperature control of large quantities of aggressive chemicals.

# WL 110-Series Modular Heat Exchangers



## Experiments on the fundamentals of heat transfer

Clear, simple, reliable, learning progress monitoring

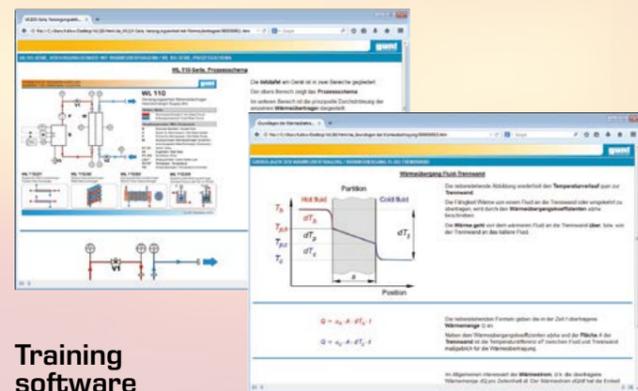


## Didactic advantages

Ideally suited for student-led experiments

A small group of 2-3 students can easily and independently conduct a variety of experiments. The lecturer can present characteristic aspects of the heat exchanger using software for data acquisition and a projector connected to the computer. The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments.

Supply unit for heat exchangers WL 110 with WL 110.03 Shell and Tube Heat Exchanger



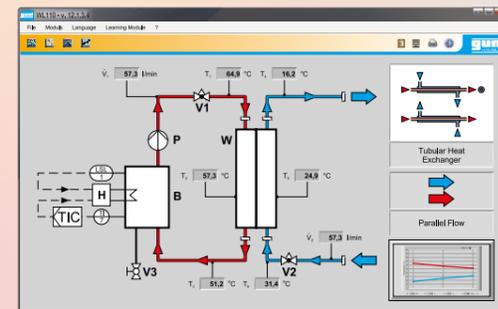
## Training software

Our training software, specially developed for this equipment series, provides a multimedia-based and interactive course of study on the fundamentals of heat transfer and on operating the WL 110 series. Didactically thought-out test questions at the end of the course allow you to review students' learning progress directly on the PC.



## WL 110.20 Water Chiller for WL 110

The cold water required for all experiments is usually provided by the laboratory supply. If the ambient temperature of the laboratory is too high, we recommend using the water chiller to obtain meaningful experimental conditions. Hot water is also needed for the experiments. It is provided by the WL 110 supply unit.



## Software

The software for WL 110 has the following main features:

- measurement of temperatures and flow rates
- operation in parallel flow or counterflow
- calculation of the mean heat transfer coefficient
- calculation of the heat fluxes

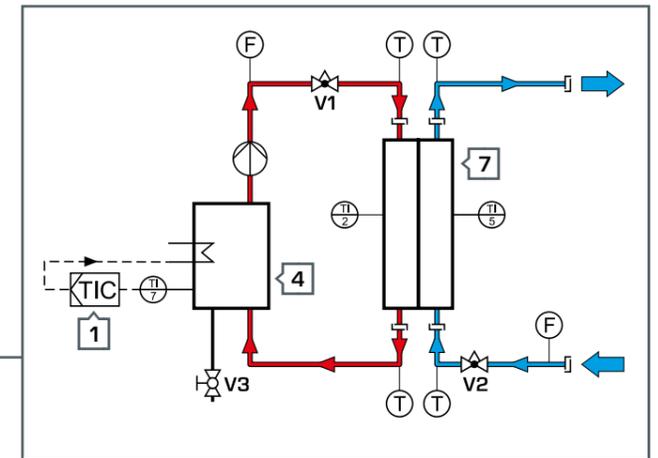
## Learning objectives

- function and operational behaviour and different heat exchangers
- plotting temperature curves
  - ▶ in parallel flow mode
  - ▶ in counterflow mode
- calculation of the mean heat transfer coefficient
- comparison of different heat exchanger types

# WL 110 Heat Exchanger Supply Unit



- 1 temperature controller
- 2 temperature displays
- 3 flow rate displays
- 4 tank for hot water
- 5 process schematic
- 6 connections for cold water circuit
- 7 jacketed vessel with stirrer and coil (or other accessory)

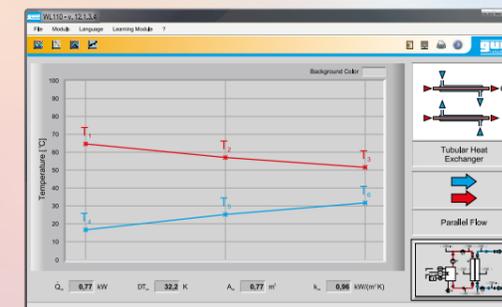


All measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included. The mean overall heat transfer coefficients are determined as typical characteristic variables in experiments.

Using the WL 110 supply unit you can operate the following four basic types of heat exchanger:

- Tubular Heat Exchanger (WL 110.01)
- Plate Heat Exchanger (WL 110.02)
- Shell & Tube Heat Exchanger (WL 110.03)
- Jacketed Vessel with Stirrer & Coil (WL 110.04)

Water is used as the medium. The heat exchanger being studied is connected to the supply unit. The hot water flows through the heat exchanger and emits some of its thermal energy to the cold water. By rearranging the water connections, you can easily change the flow direction in order to achieve parallel flow and counterflow.



Software screenshot with WL 110.02 in parallel flow mode

- representation of the process media temperature profiles along the heat exchanger
- calculation of the mean heat transfer coefficient
- calculation of the heat fluxes
- display of the characteristic values of the heat exchanger
- selection and display of the current operating mode and of the heat exchanger

## Learning objectives

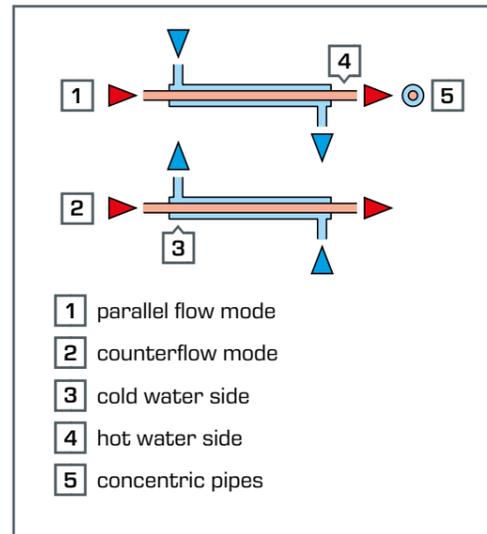
- in conjunction with a heat exchanger:
  - plotting temperature profiles
  - determining overall heat transfer coefficient
  - comparing different heat exchanger types



## WL 110.01 Tubular Heat Exchanger



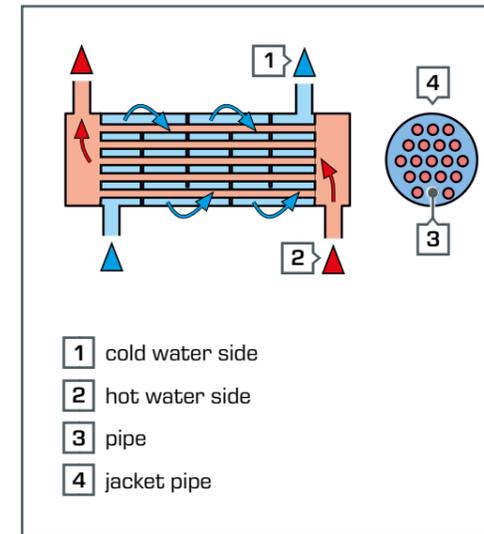
Tubular heat exchangers are the simplest type of heat exchanger and are preferably used when heat is transferred at high pressure differences or between highly viscous media (e.g. sewage sludge). One advantage is that the pipe space is flowed through evenly and is free of flow dead zones.



## WL 110.03 Shell & Tube Heat Exchanger



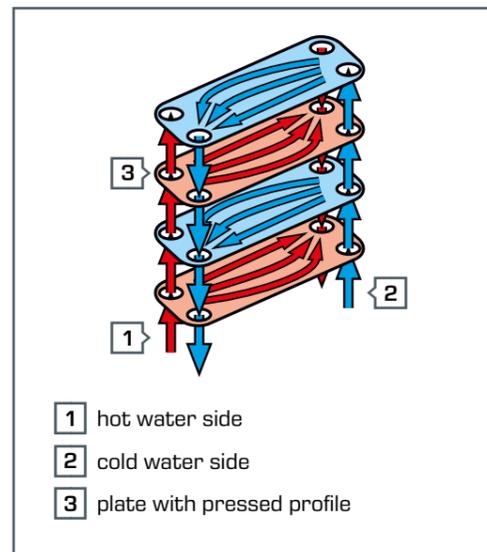
Shell & tube heat exchangers are a widely-used design. The advantages of this design are the large heat transfer area and the compact size. Shell and tube heat exchangers are used in the chemical and pharmaceutical industry, in refining and process engineering plants.



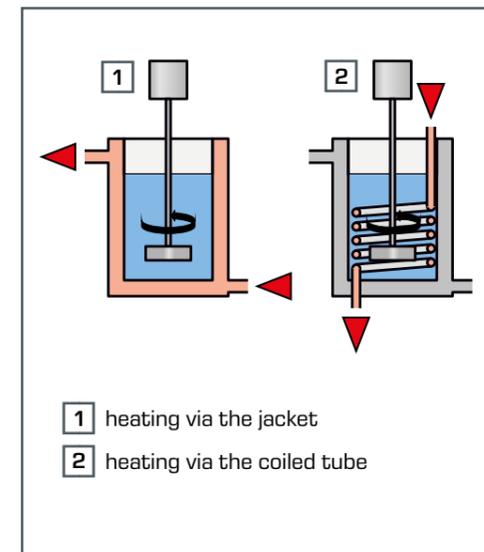
## WL 110.02 Plate Heat Exchanger



Plate heat exchangers are mainly characterised by their compact design, in which the entire medium is used for heat transfer. The profile pressed onto the plates forms narrow flow chambers in which extensive turbulence occurs. The turbulent flow enables an effective heat transfer at low flow quantities and also has a self-cleaning effect. Plate heat exchangers are used for example in the food industry, marine engineering, refrigeration technology and in domestic engineering.



## WL 110.04 Jacketed Vessel with Stirrer & Coil



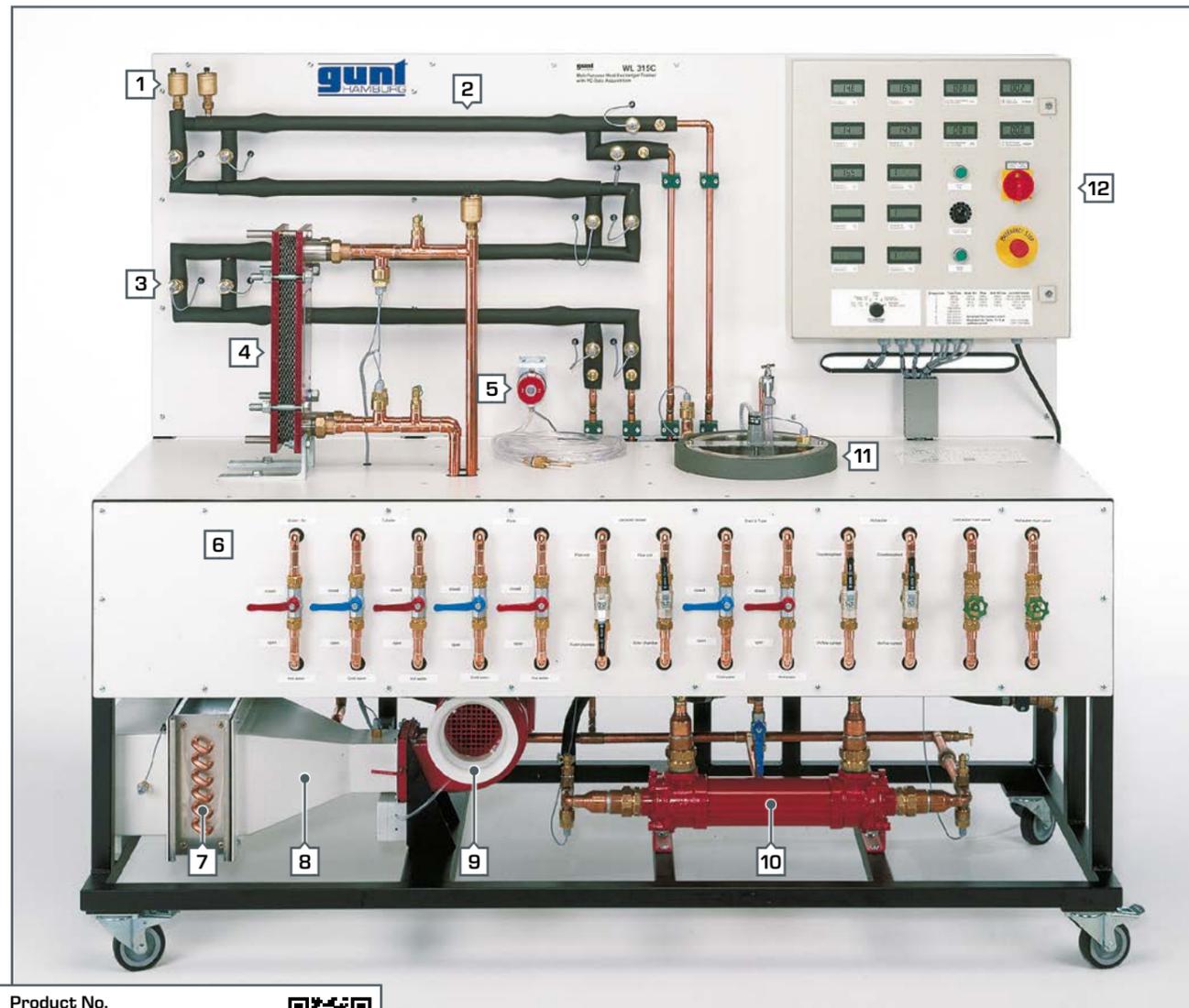
Simple stirrer tanks are widely used in process engineering. These are often fitted with a double jacket or a coiled tube for cooling or heating. Stirring machines are used for better mixing of the tank contents and for an even temperature distribution.

# WL 315C Trainer for Various Heat Exchangers

In practice different heat exchanger types are used depending on the requirements. You can investigate and compare five different heat exchanger designs with the WL 315C trainer. Heat transfer in different heat exchangers takes place with different fluids according to the counterflow or parallel flow principle. The heat exchanger being studied is selected at the switch cabinet. Valves are used to switch between parallel flow and counterflow. You can also adjust the flow rate in the hot water or cold water circuit by means of valves. The hot water flows through

the heat exchanger and emits some of its thermal energy to the cold water. The trainer is equipped with sensors for temperatures and differential pressures. The flow rate is measured by an electromagnetic flow meter. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

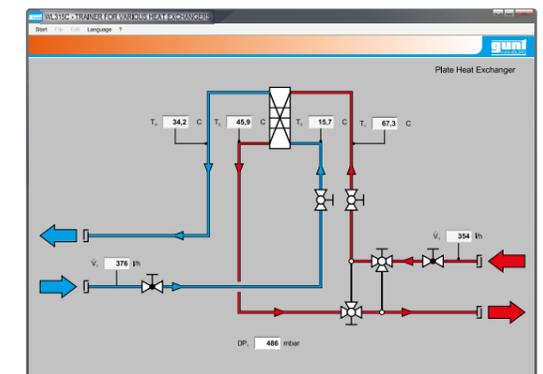
Using the hot water supply (WL 312.10) and the cold water supply (WL 312.11), you can operate WL 315C as an independent system with closed water circuit. An optionally available steam/water heat exchanger (WL 315.01) and an electrical steam generator (WL 315.02) complement the scope of experiments.



The software for WL 315C measures the following variables:

- temperature profiles along the heat exchanger
- inlet and outlet temperatures
- flow rate of the hot and cold water
- pressure loss across the heat exchange

Using the software you can also determine the mean overall heat transfer coefficients of the various heat exchangers. A separate view lists the physical properties of the heat transfer fluid and calculates the characteristic values with the measurement data.



- 1 ventilator
- 2 tubular heat exchanger
- 3 temperature sensor
- 4 plate heat exchanger
- 5 pressure sensor
- 6 adjusting valves
- 7 finned tube heat exchanger
- 8 flow channel
- 9 fan
- 10 shell and tube heat exchanger
- 11 jacketed vessel with stirrer and coil
- 12 switch cabinet

## Learning objectives

- familiarisation with heat transfer processes
  - ▶ heat transfer
  - ▶ heat conduction
- measuring of relevant temperatures and flow rates
- determination of the overall heat transfer coefficient
- preparation of temperature curves for the various types of heat exchanger
  - ▶ parallel flow
  - ▶ counterflow
  - ▶ cross parallel flow
  - ▶ cross counter flow
- comparison of various types of heat exchanger
  - ▶ plate heat exchanger
  - ▶ tubular heat exchanger
  - ▶ shell and tube heat exchanger
  - ▶ finned cross-flow heat exchanger
  - ▶ jacketed vessel with stirrer

Product No.  
060.315C0  
More details and technical data:  
[gunt.de/static/s4642\\_1.php](http://gunt.de/static/s4642_1.php)



# Basic Knowledge Shallow Geothermal Energy



## Fundamental principle

Shallow geothermal energy is based on the same fundamental principle as solar thermal energy. However, in this case it is the ground which is acting as a heat source, not the sun. There is an underground pipe system in which a liquid heat transfer medium circulates. This medium heats up under the ground and

transfers the stored heat to a heat pump in the house. The heat pump raises the heat transfer medium to a higher and thus usable temperature (thermodynamic cycle).

## Technical implementations

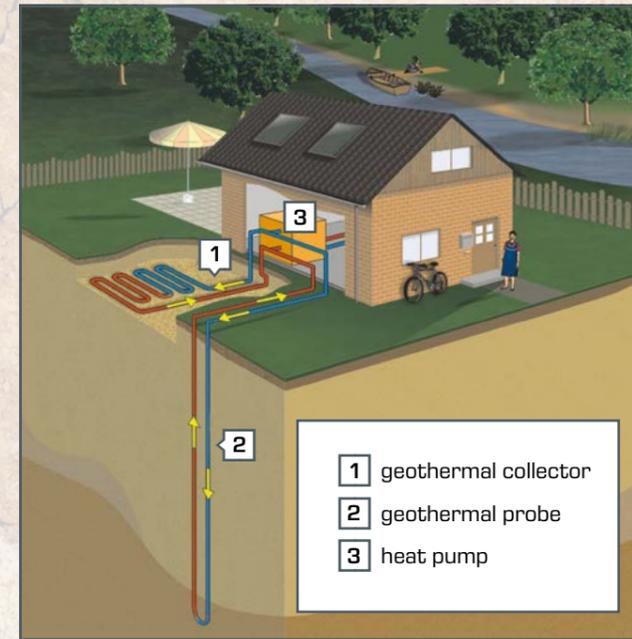
There are various options for using the thermal energy of the earth's surface. The technical implementation is dependent upon the local conditions, the desired power and the combination with other energy systems. In the field of shallow geothermal energy, a distinction is firstly made between open and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

zontally in the ground. This pipe is located at a depth of about 1...2m. Geothermal probes are oriented vertically and can reach down to a depth of about 100m under the ground. Well systems use the thermal energy of the groundwater by means of two wells. Feed-in occurs with the source well and return occurs with the sink well against the direction of flow.

## Heat exchangers and heat pumps

Geothermal collectors, geothermal probes and well systems function as heat exchangers in shallow geothermal energy and therefore represent the drive power of the thermodynamic cycle of heat pumps. The cyclic processes illustrate the economic use of geothermal heat for heating purposes, even with source temperatures which are actually too low.

In addition to operation with water as the heat transfer medium, refrigerant is also used. Heat pipe systems of the geothermal probe type use the large quantity of energy in evaporation and condensation for an effective transfer of energy.



## Resource-efficient heating

Geothermal energy can be used effectively even at shallow depths of up to 100m. Shallow geothermal energy is mainly suited to providing heat in private households and small industrial companies.

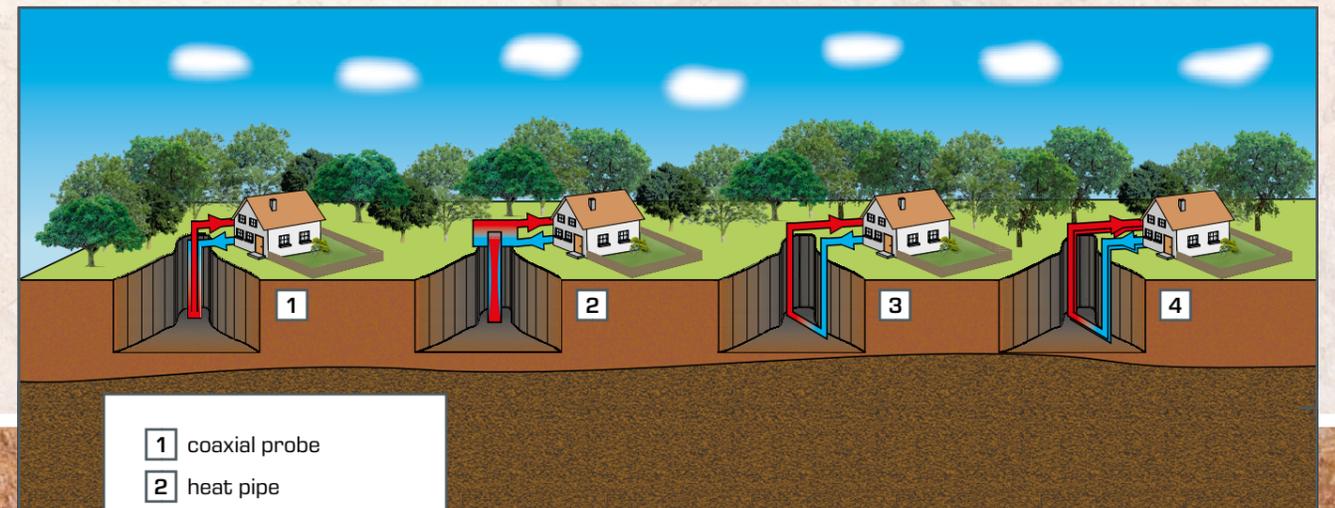
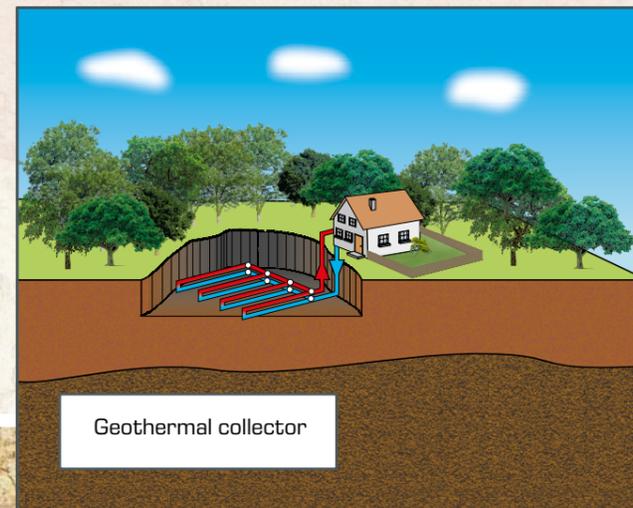
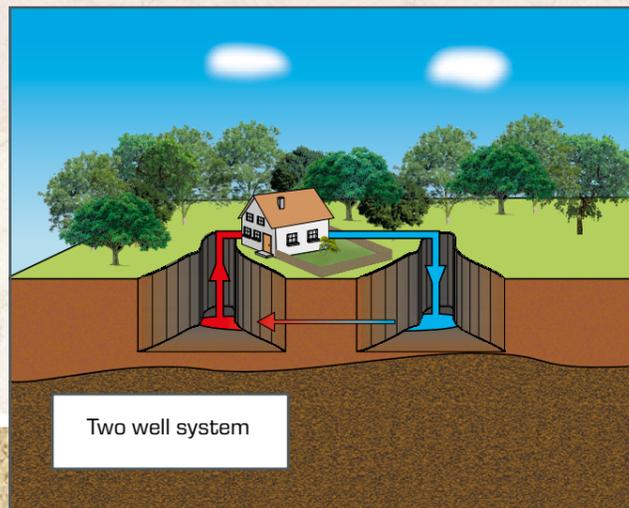
By using heat pumps, heating and operating costs can be reduced to the electrical consumption of the circulation pumps.

It is also possible to combine different usage types. If open areas are available a collector can be used in conjunction with a geothermal probe, for example.

## Geothermal probes

Different designs, which offer different benefits, are available for geothermal probes. The U-shaped probe and the dual U-shaped probe are already widely used, for example embedded

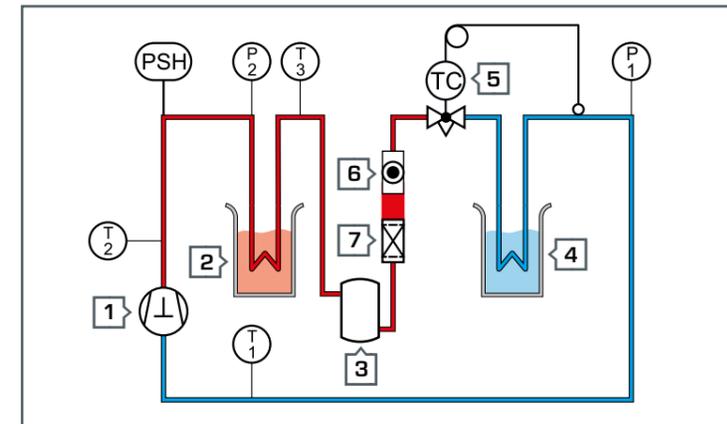
in piled foundations. Heat can therefore be supplied with geothermal heat with little additional investment.



# ET 101 Simple Compression Refrigeration Circuit

This experimental unit allows you to explain the structure and function of a heat pump using a simple compression refrigeration circuit, and tangibly demonstrate it to your students.

It is necessary to use heat pumps in the field of shallow geothermal energy in order to raise the thermal energy extracted from the ground to a usable energy level. The energy in the ground is transmitted to a heat transfer medium, usually water, and thus can be used for heating.

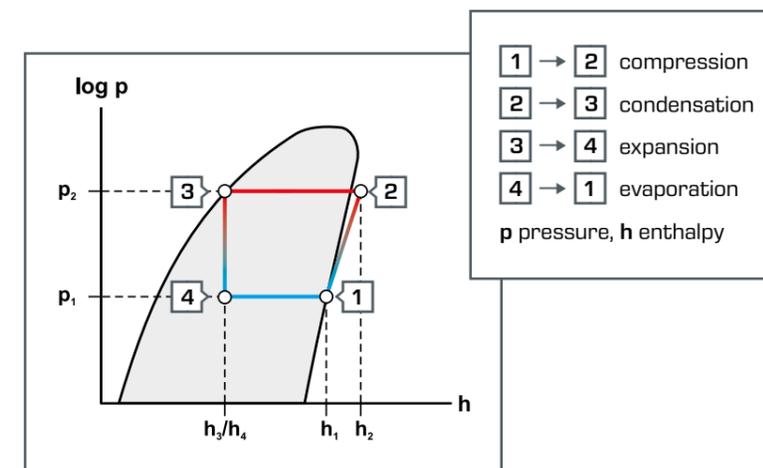


- |              |                   |
|--------------|-------------------|
| 1 compressor | 5 expansion valve |
| 2 condenser  | 6 sight glass     |
| 3 collector  | 7 filter/dryer    |
| 4 evaporator |                   |
- P** pressure, **PSH** pressure switch, **T** temperature

ET 101 contains all components necessary to operate a heat pump. The use of commercially available components from the field of refrigeration engineering ensures a high level of practically-oriented recognition value.

All variables necessary for the process are displayed analogously at the respective measurement locations.

Knowledge about this cycle is an indispensable part of training for engineering students and specialists in the field of energy technology.



The energy for compression is applied electrically. The energy required for evaporation is extracted from the ground and, after compression at a higher pressure, is used for underfloor heating for example.

## Learning objectives

- fundamentals of a compression refrigeration circuit
- key components of a refrigeration system
  - ▶ compressor
  - ▶ evaporator
  - ▶ condenser
  - ▶ expansion element
- relationship between the pressure and boiling point of a liquid
- operation of a refrigeration system / heat pump
- developing a basic understanding of the thermodynamic cycle
- simple energy balance

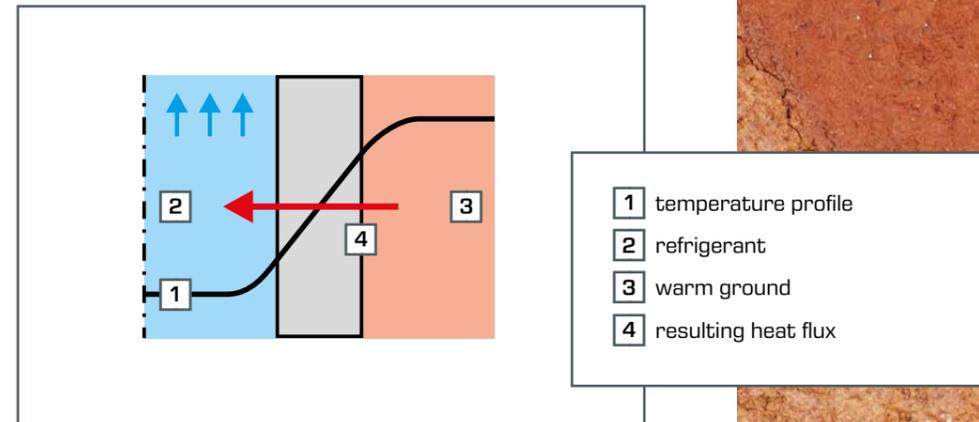
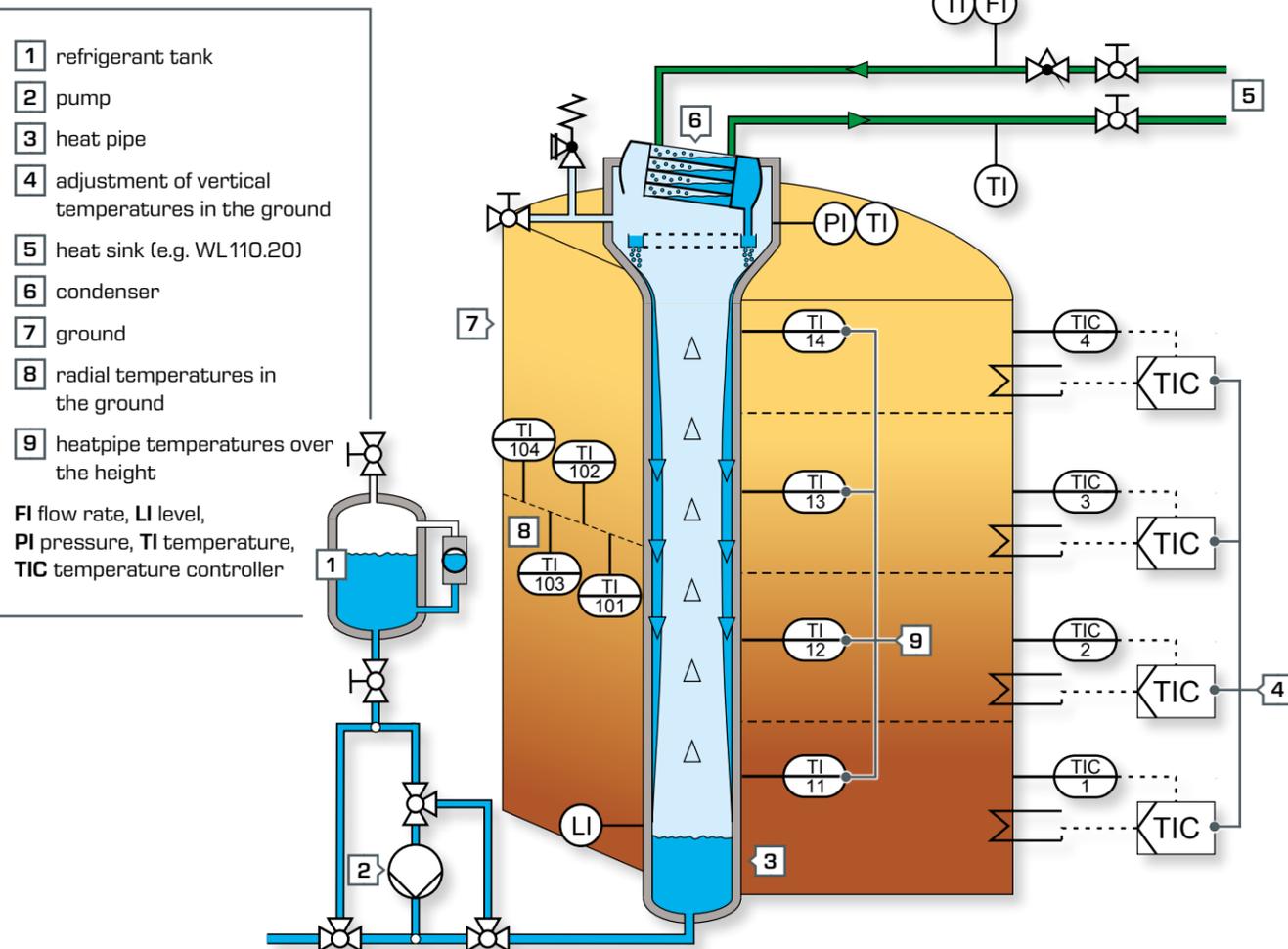
Product No.  
061.10100  
More details and technical data:  
[gunt.de/static/s3594\\_1.php](http://gunt.de/static/s3594_1.php)



# ET 262 Geothermal Probe with Heatpipe Principle

Our ET 262 trainer provides you with a geothermal probe with refrigerant. You can make various adjustments, thereby configuring various operating conditions. For example, these include the thermal load and heat conduction within the fill material as a function of humidity.

The trainer consists of the geothermal probe, the surrounding ground, the condenser for heat dissipation and a filling and draining system for the refrigerant. The geothermal probe is partially transparent, so that the evaporation and condensation of the refrigerant can be observed.



The surrounding ground is represented by gravel with different moisture and grain size, so that the different thermal resistances can be studied. The change is illustrated partly by the radial temperature profile and partly by the water temperatures in the condenser feed and return. As an additional option, you can adjust the vertical temperature profile of the ground in four zones to study condensation before heat dissipation.

#### The software for ET 262 measures the following variables

- radial temperature profile
- axial temperature profile of the ground
- axial temperature profile of the heatpipe
- feed and return temperature of the condenser

The vertical temperature profile superimposed from the outside results in the operating fluid evaporating in the heatpipe. After condensation it flows back for re-evaporation along the inner wall of the probe. This creates a closed circuit.

Learning objectives	
■	investigation of the radial temperature profile
■	variation of the thermal load
■	variation of the quantity of operating fluid contained
■	overlay of a vertical temperature profile
■	investigation of the vertical temperature profile



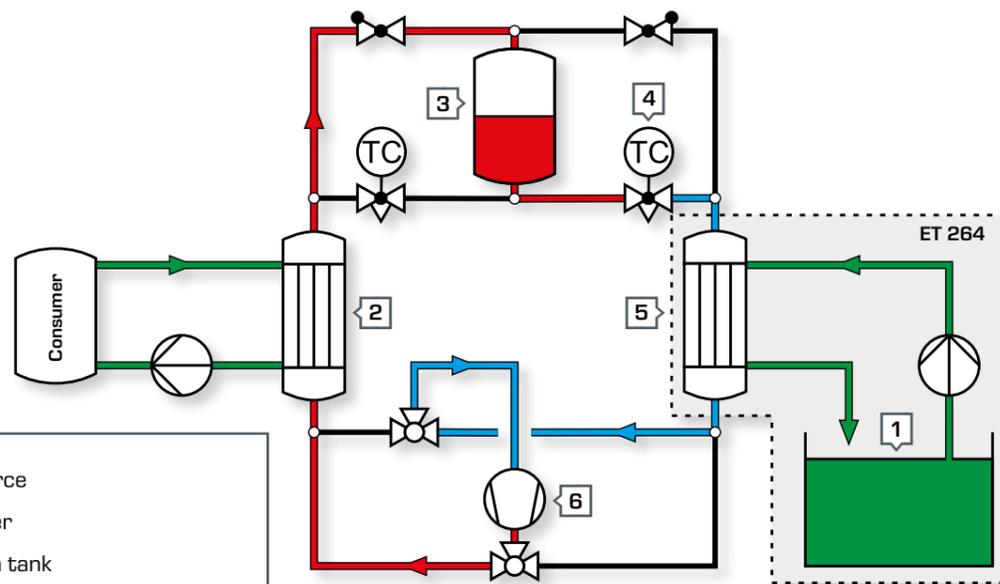
# ET 264 Geothermal Energy with 2-Well System

The trainer ET 264 offers you a dual well system with source and sink wells. ET 264 illustrates the installation in the ground with the characteristic parameters and requires, for example, WL 110.20 as a cold water substitute. The combination for domestic engineering with heat pumps is presented by the HL 320 series.

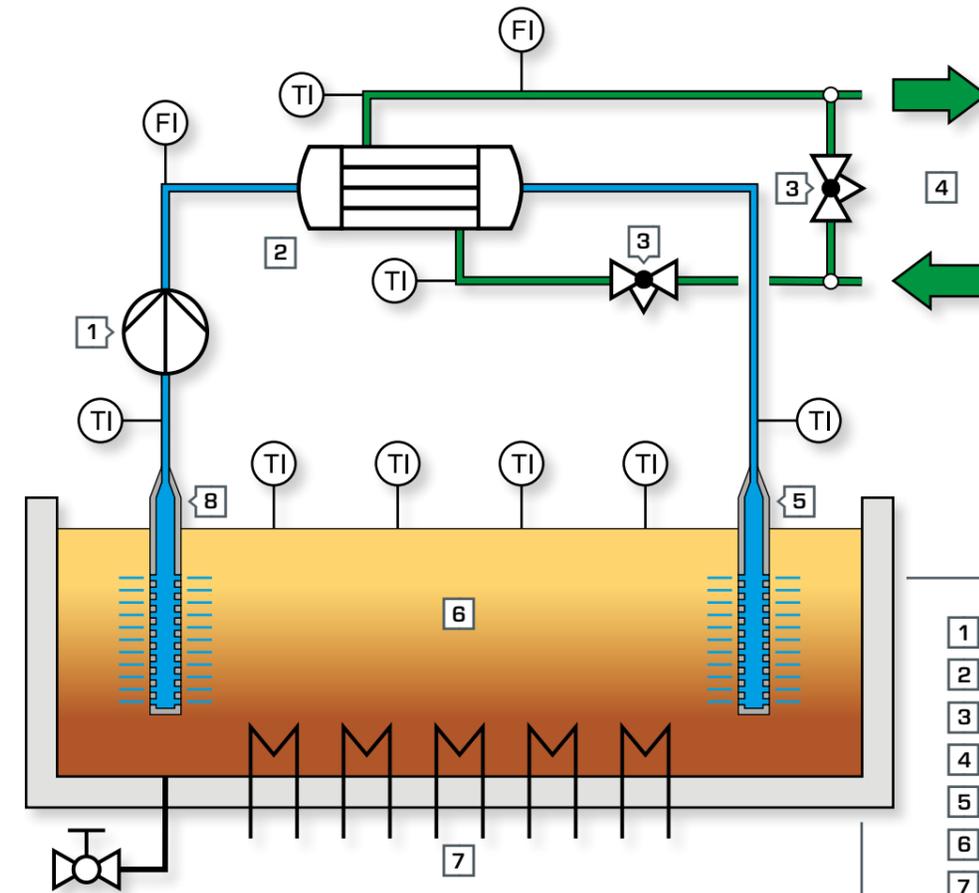
The energy dissipated via the heat exchanger is used in domestic engineering, for example to operate a heat pump (HL 320.01). In order to increase the system's operating efficiency, cooling operation is also possible. The usual water temperatures of around 7...12°C can be used directly in this case. You only need

to circulate the heat exchanger, so the additional installation of air conditioning units with very high energy consumption can be avoided.

Using the ET 264 trainer you can investigate the steady-state operation of an open system for using shallow geothermal energy. The temperature and flow rate measurements allow you to establish the energy balance and the amount of heat that can be dissipated in relation to the ground temperature. To expand the range of possible experiments, you can set different temperatures in the ground and use different materials.



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



- 1 centrifugal pump
- 2 centrifugal pump
- 3 cooling water metering valve
- 4 heat sink (e.g. WL 110.20)
- 5 sink well
- 6 ground
- 7 temperature overlay
- 8 source well
- FI flow rate, TI temperature

### Features:

- trainer to replicate operation of a dual well system
- controlled electrical heating
- temperature and flow rate measurement for the cooling medium
- open circuit
- GUNT software for data acquisition via USB under Windows 7 or Windows 8

### Learning objectives

- steady-state operation of an open system
- determining the amount of usable heat
- energy balance
- determining the possible flow rate



# HL 320 Solar Thermal Energy and Heat Pump Modular System

## Combination 3



The HL 320 modular system allows you to conduct experiments on the topics of geothermal and solar thermal energy in a modern heating system. In combination 3, the following modules are combined to create a system:

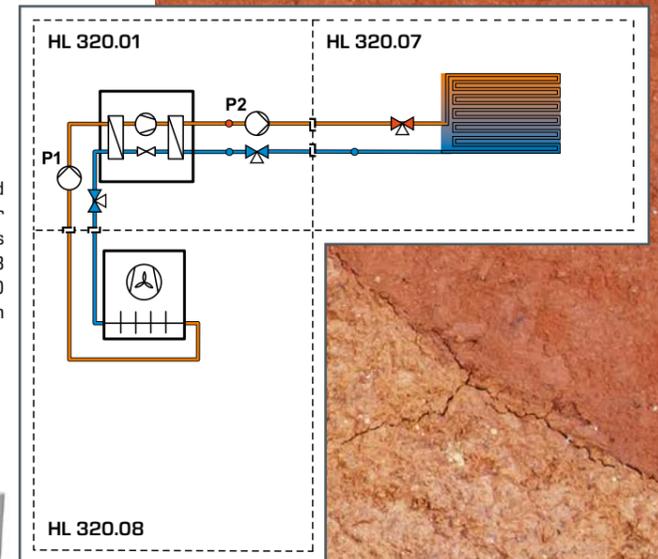
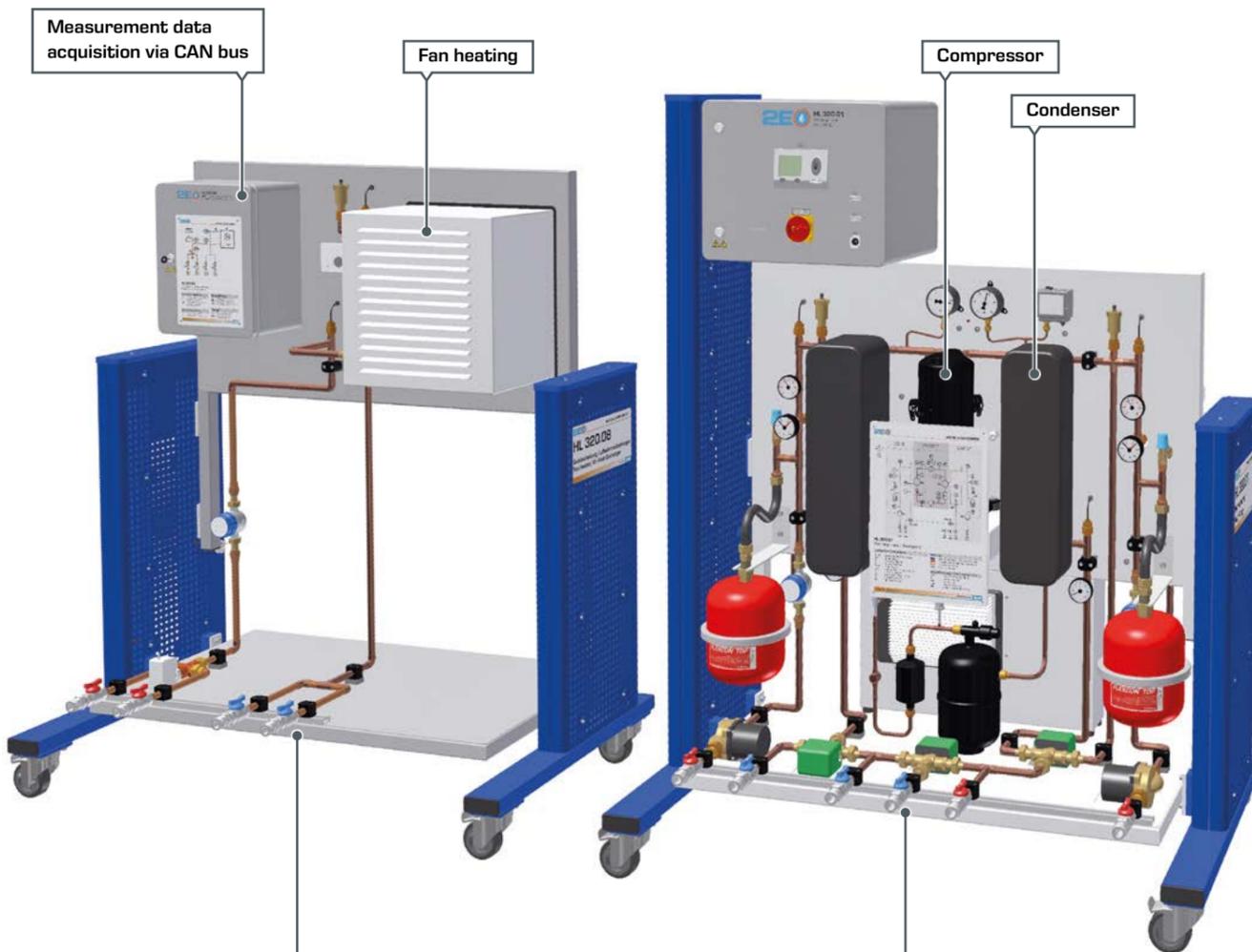
**HL 320.01** Heat Pump

**HL 320.07** Underfloor Heating/Geothermal Energy Absorber

**HL 320.08** Fan Heater/Air Heat Exchanger

Sensors for temperature and flow rate are included at all necessary points to draw up an energy balance of the energy flows. The measured values of all modules are transferred to the heat pump module controller via a shared data line (CAN bus) and logged by an integrated data logger. Data can be exchanged with a PC via a network connection.

Combination 3 allows targeted experiments on a heating system based on a heat pump. HL 320.07 is used as a heat source for investigations on a system for the use of shallow geothermal energy, i.e. operated as a geothermal energy absorber.



**HL 320.08**  
Fan Heater / Air Heat Exchanger

Product No.  
065.32008  
More details and technical data:  
[gunt.de/static/s5362\\_1.php](http://gunt.de/static/s5362_1.php)



**HL 320.01**  
Heat Pump

Product No.  
065.32001  
More details and technical data:  
[gunt.de/static/s5360\\_1.php](http://gunt.de/static/s5360_1.php)



**HL 320.07** Underfloor Heating /  
Geothermal Energy Absorber

Product No.  
065.32007  
More details and technical data:  
[gunt.de/static/s5291\\_1.php](http://gunt.de/static/s5291_1.php)



### Learning objectives

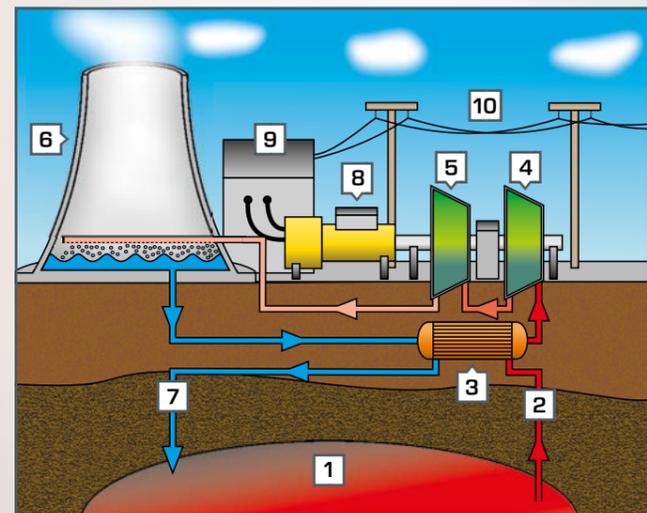
- function and design of a heat pump
- comparison of different heat sources
- factors influencing the COP (coefficient of performance)
- parameterisation of a heat pump controller

# Basic Knowledge Deep Geothermal Energy



## Fundamental principle

Deep geothermal energy, like shallow geothermal energy, is also based on the fundamental principle of solar thermal energy. The difference is that the ground, and not the sun, is used as a heat source. Unlike shallow geothermal energy, the earth's heat can be used directly. Depending on the temperature level of the geothermal field, there is either direct conversion to electricity or direct use for heating purposes.



- 1 heat reservoir
- 2 transport
- 3 steam generator
- 4 first turbine stage
- 5 second turbine stage
- 6 cooling tower
- 7 return
- 8 generator
- 9 transformer
- 10 public power grid

## Differentiating geothermal fields

There are different ways of distinguishing between the various geothermal fields attributed to deep geothermal energy. Criteria for the different deposits include the necessary drilling depth, the origin of the geothermal energy, the type of usage or the temperature level. From the point of view of technical usage of the geothermal energy, distinction by temperature level of the geothermal field is usually chosen. In this case, distinction is made between two different types of deposits.

The highest temperatures occur in areas known as thermal anomalies. These are mainly active or formerly active volcanic regions, but may also occur without volcanism. The deposits are referred to as high enthalpy deposits. The advantages of these deposits are direct conversion of the hot steam and low depth. The deeper the borehole, the warmer the earth. Thermal anomalies with comparable temperatures are usually reached at depths of 4000 – 5000m. These deposits no longer have the advantage of lower drilling costs.

Low enthalpy deposits are somewhat colder. It is only profitable to operate a geothermal energy source with low temperature level when using the heat for heating purposes. Converting the geothermal energy of these deposits into electricity is only carried out in special cases. In these cases, closed Organic Rankine Cycle (ORC) systems are employed in order to use temperatures from 80°C onwards for electrical purposes.

There are several technical solutions available to exploit both deposit types. The following systems are differentiated by the pressure and temperature conditions, any gases contained in the deposits, or by the quantity of water:

- hydrothermal systems
- petrothermal systems
- deep geothermal probes
- geothermal energy from tunnels
- geothermal energy from mining installations

## Technical implementation

Apart from deep geothermal probes, these are open systems which are designed as dual well systems for environmental reasons. A power station site is equipped with up to four boreholes. After pumping and using the hot water or steam, the cold working medium is pumped back into the holes. Doing so does not reduce the operating pressure, and the efficiency and capacity remain largely unaffected.

## Outlook

At present, an electrical output of 10 GW<sub>el</sub> is installed worldwide. Using currently available technology for hydrothermal systems, this could be increased to 70 GW<sub>el</sub> by 2050.

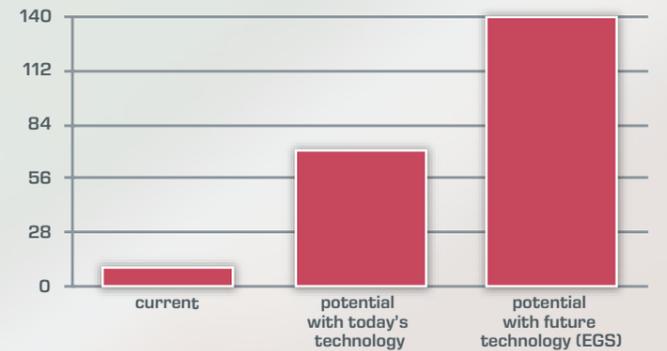
Including Enhanced Geothermal Systems (EGS), i.e. petrothermal systems, it could even be possible to reach 140 GW<sub>el</sub>. However, these systems are not yet state of the art.

## Converting thermal energy into kinetic energy

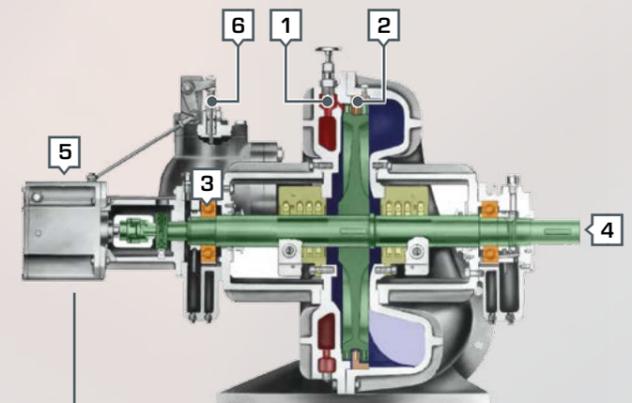
It is necessary to use steam turbines in the field of deep geothermal energy in order to convert the thermal energy extracted from the ground into electricity. The steam turbine converts the energy of the steam from the ground into rotational kinetic energy. A generator then produces electric current from the kinetic energy of this rotation.

A typical industrial steam turbine is the impulse turbine, shown in cross section, with a Curtis wheel. The turbine is designed to drive generators directly and does not have any gearing.

Globally installed power in gigawatts



Source: Bertani 2010 Geothermal Power Generation in the World



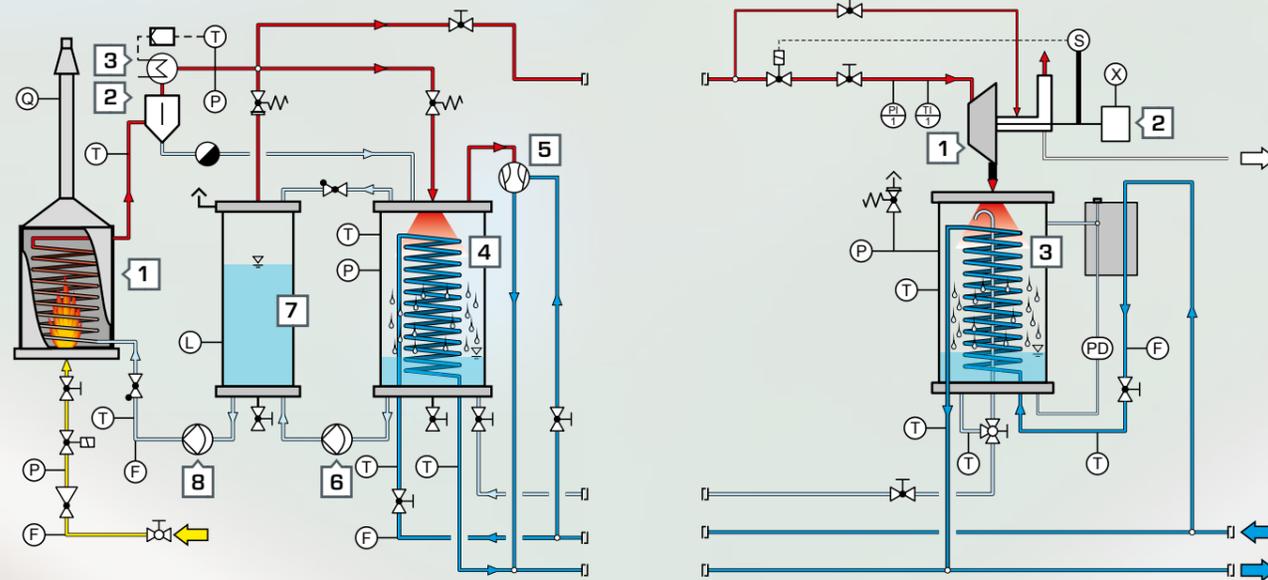
- 1 nozzle
- 2 deflection in the impeller
- 3 roller bearing
- 4 impeller shaft
- 5 speed controller
- 6 flow control valve

# ET 850 & ET 851 Steam Generator and Axial Steam Turbine



The combination of the ET 850 Steam Generator and ET 851 Axial Steam Turbine from GUNT give you the opportunity to set up a real steam power station at a laboratory scale.

As the process diagram shows, the system includes all the key components of a real large-scale system: pass-through water tube boiler with superheater, condenser with water jet pump for vacuum operation, feedwater tank, condensate and feedwater pumps, steam turbine with dynamometer, shaft sealing with labyrinth and sealing steam and many more. The operating behaviour is also similar to a real system. In this way accurate matching of steam generator, turbine, condenser and superheater can be demonstrated and practised. The data acquisition software relieves students of routine tasks and gives a quick overview.


**ET 850**

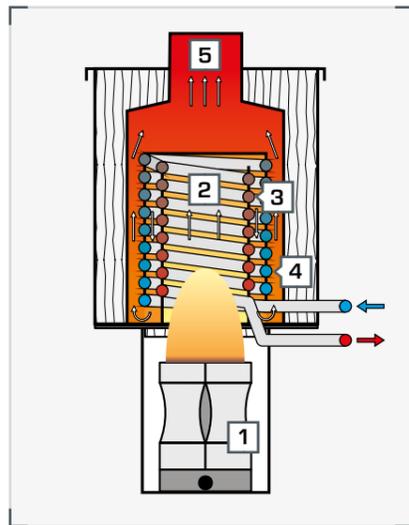
- 1** steam boiler
- 2** water separator
- 3** superheating
- 4** condenser
- 5** water jet pump
- 6** condensate pump
- 7** feedwater tank
- 8** feedwater pump

**ET 851**

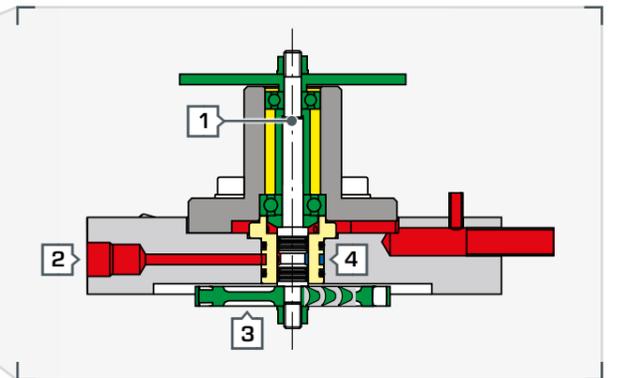
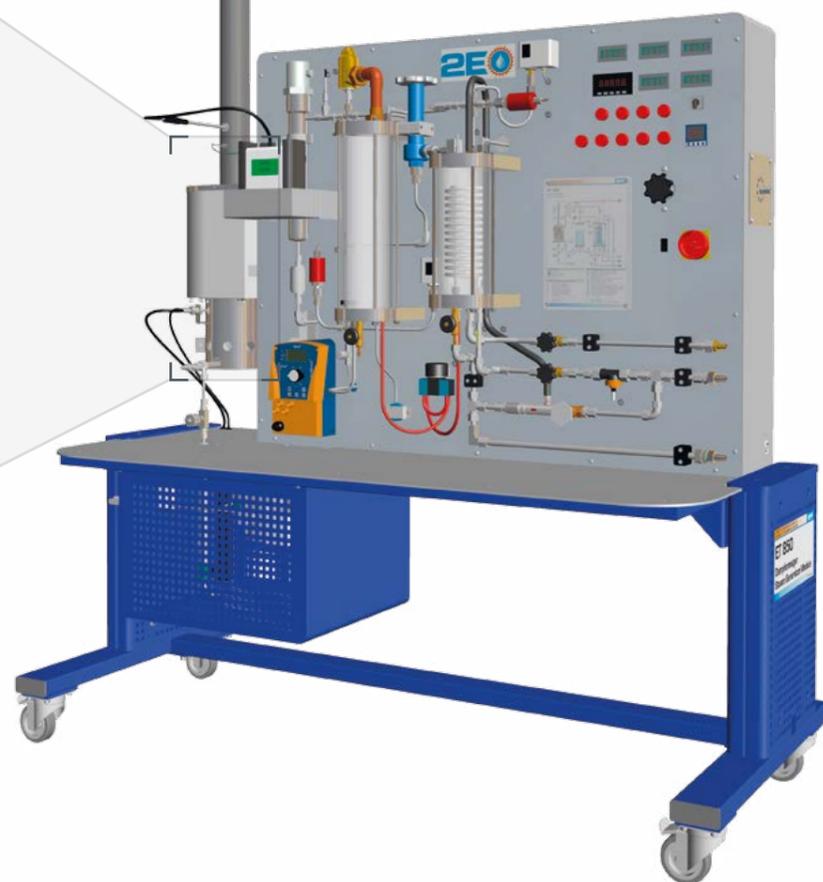
- 1** turbine
- 2** brake
- 3** condenser

**Measuring points**

F flow rate, P pressure, PD differential pressure, Q exhaust gas analysis, S speed, T temperature, X torque



- 1** burner
- 2** 1<sup>st</sup> draw
- 3** 2<sup>nd</sup> draw
- 4** 3<sup>rd</sup> draw
- 5** exhaust gas



- 1** turbine shaft
- 2** sealing steam inlet
- 3** impeller
- 4** labyrinth seal

# ET 850 Steam Generator

A steam generator creates steam which is then used for heat power plants or to drive machinery. The steam generator and steam consumer together form a steam power plant. Steam power plants work according to the steam power process, which even today is still one of the most important industrial cyclic processes. Steam power plants are mainly used to generate electricity. The ET 850 Steam Generator, together with the ET 851 Axial Steam Turbine, forms a complete laboratory-scale steam power plant. The ET 850 trainer teaches

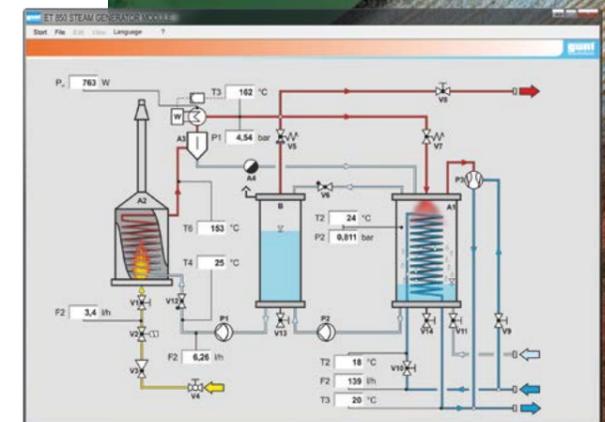
students the components and operating principle of a steam generator. Students can study the characteristic values of the plant. The diverse safety devices of the steam generator can be tested and inspected using various monitoring systems.

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

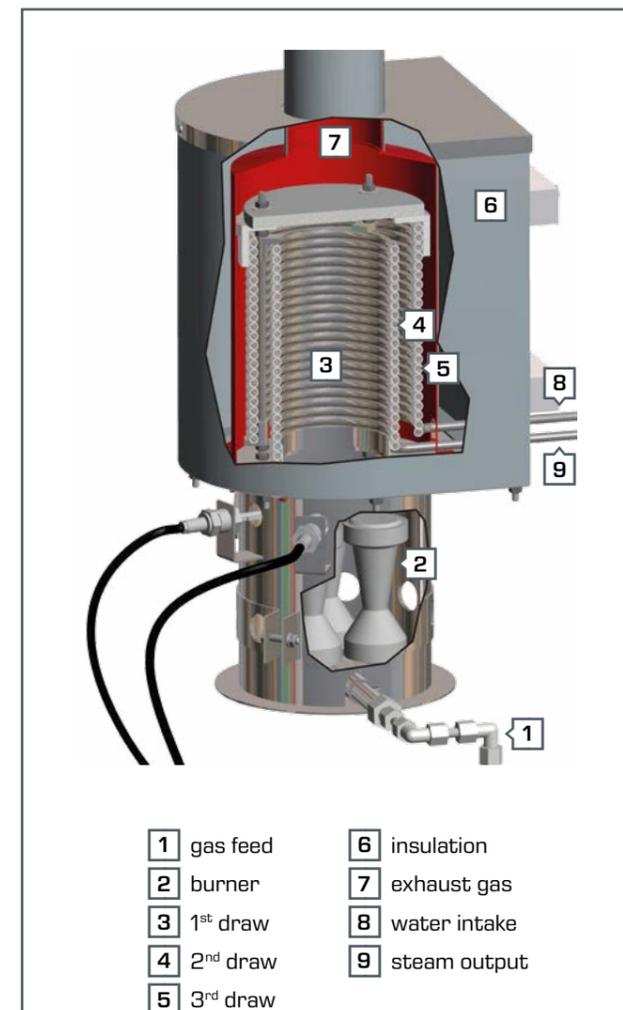
The steam generator is designed and pressure tested according to the "Technical Regulations for Steam" (TRD, german: Technischen Regeln Dampf) and has all the safety valves prescribed by law.

### Software

Sensors record temperatures, pressures and flow rates at all relevant points. The software allows measurement data to be clearly displayed on the PC. Time dependencies can be recorded and saved. A spreadsheet program (e.g. MS Excel) can be used to analyse the stored data.



Product No.  
061.85000  
More details and technical data:  
[gunt.de/static/s3484\\_1.php](http://gunt.de/static/s3484_1.php)



### Learning objectives

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

# ET 851 Axial Steam Turbine

The ET 851 trainer provides you with an axial steam turbine with eddy current brake, condenser, piping, instrumentation and safety devices. All the relevant measured values such as temperatures, pressures and flow rates are recorded and displayed digitally. User-friendly software enables you to easily process the measured values further using a PC.

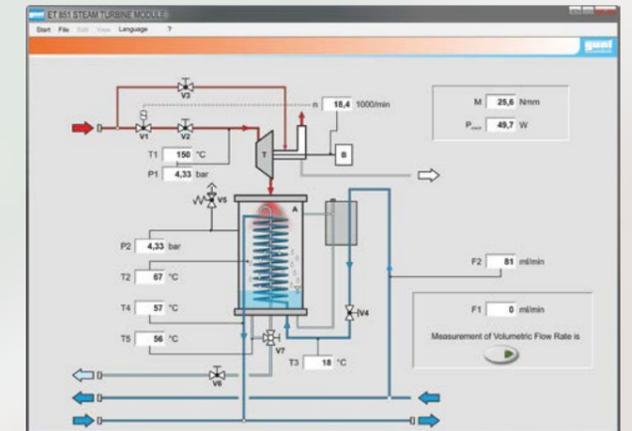
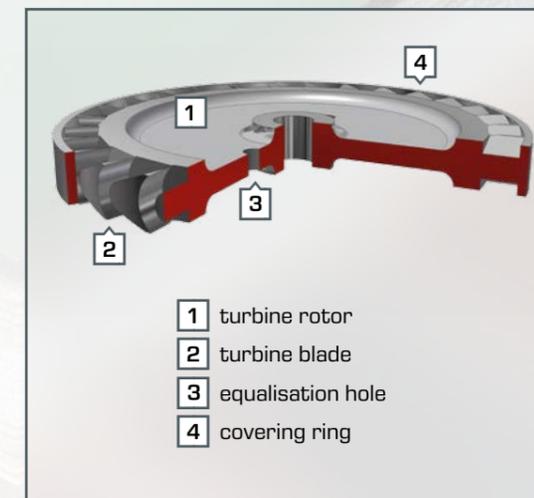
ET 851 is optimally adapted to the ET 850 Steam Generator. It is therefore possible to operate and investigate the steam turbine in a closed steam circuit.

Knowledge about the steam turbine process is an indispensable part of training for engineering students and specialists in the field of energy engineering.

The ET 851 experimental unit is a single-stage axial impulse turbine with a vertical axis. The steam required must be generated externally (e.g. via the ET 850 Steam Generator). The turbine can be operated with saturated steam or superheated steam. The steam is expanded in the turbine and condensed via the water-cooled condenser. Load is applied to the turbine via an eddy current brake. The turbine has a non-contact labyrinth seal on the shaft with sealing steam circuit. The turbine is fitted with various safety devices in order to prevent damage such as excessively high speed or overpressure in the system.



- 1 turbine
- 2 brake
- 3 condenser
- 4 water supply
- 5 main steam valve
- 6 sealing steam valve



### Software

Sensors record temperatures, pressures and flow rates at all relevant points. Turbine speed and torque are measured electronically at the eddy current brake. The measured values can be read on digital displays. At the same time, the measured values can also be transmitted directly to a PC via USB. The data acquisition software is included.

### Learning objectives

- principle of operation of a steam turbine
- steam consumption of the turbine
- turbine output at different settings
- investigation of the losses occurring in different turbine components
- power and torque curve
- overall efficiency compared to the theoretical efficiency

Product No.  
061.85100  
More details and technical data:  
[gunt.de/static/s3483\\_1.php](http://gunt.de/static/s3483_1.php)



## Energy

**Solar energy:**  
solar cooling

**ET 256**  
Cooling with solar electricity

Compression refrigeration system for operation with solar current from ET 250



Order No.: 061.25600


**ET 250**  
Solar module measurements

Determining the characteristic parameters of a photovoltaic system

Order No.: 061.25600


**ET 352.01**  
Solar heat for cold production

Solar thermal operation of a vapour jet compressor

Order No.: 061.35201


**ET 352**  
Vapour jet compressor in refrigeration

Investigation of cold production using thermal energy. Transparent condenser and evaporator allow the view into the inner workings.

Order No.: 061.35200


**HL 313**  
Domestic water heating with flat collector

Demonstration of the conversion of the sun's radiation energy into heat and the storing of that heat

Order No.: 065.31300



## Energy

**Geothermal energy:**  
heat exchangers

**WL 110**  
Heat exchanger supply unit

Measuring the transfer characteristics of four different heat exchanger models

Order No.: 060.11000


**WL 110.01**  
Tubular heat exchanger

Transparent heat exchanger with additional temperature measuring point after half of the transfer section; parallel flow and counterflow operation

Order No.: 060.11001


**WL 110.02**  
Plate heat exchanger

Typical plate heat exchanger in parallel flow and counterflow operation

Order No.: 060.11002


**WL 110.03**  
Shell & tube heat exchanger

Transparent shell and tube heat exchanger in cross parallel flow and cross counterflow operation

Order No.: 060.11003


**WL 110.04**  
Stirred tank with double jacket and coil

Heating using jacket or coiled tube; stirrer for improved mixing of medium

Order No.: 060.11004


**WL 315C**  
Comparison of various heat exchangers

Comparison of plate heat exchanger, tubular heat exchanger, shell and tube heat exchanger, finned cross-flow heat exchanger, and stirred tank with double jacket and coiled tube

Order No.: 060.315C0



## Energy

**Geothermal energy:**  
shallow geothermal energy

**ET 101**
**Simple compression refrigeration circuit**

Demonstration of a heat pump: cooling and heating of the heat exchangers directly tangible

Order No.: 061.10100


**ET 262**
**Geothermal probe with heat pipe principle**

Transparent components allow observing how the state of the heat transfer medium changes

Order No.: 061.26200


**ET 264**
**Geothermal energy with two-well system**

Use of geothermal energy in an open system without thermal repercussion

Order No.: 061.26400


**HL 320.01**  
Heat pump

Heat pump for operation with different sources

Order No.: 065.32001


**HL 320.07**
**Underfloor heating / geothermal energy absorber**

Can be used as heat sink or heat source

Order No.: 065.32007


**HL 320.08**
**Fan heater / air heat exchanger**

Can be used as heat sink or heat source

Order No.: 065.32008



## Energy

**Geothermal energy:**  
deep geothermal energy

**ET 851**
**Axial steam turbine**

Single-stage steam turbine with power output measurement; steam supply from ET 850

Order No.: 061.85100


**ET 850**
**Steam generator**

Laboratory scale gas-fired steam generator for wet or superheated steam; integrated condenser

Order No.: 061.85000



## Energy

**Wind power:**  
fundamentals of wind energy technology

**ET 222**
**Wind power drive train**

Experiments on conversion of rotational energy into electrical energy



Order No.: 061.22200

**ET 210**
**Fundamentals of wind power plants**

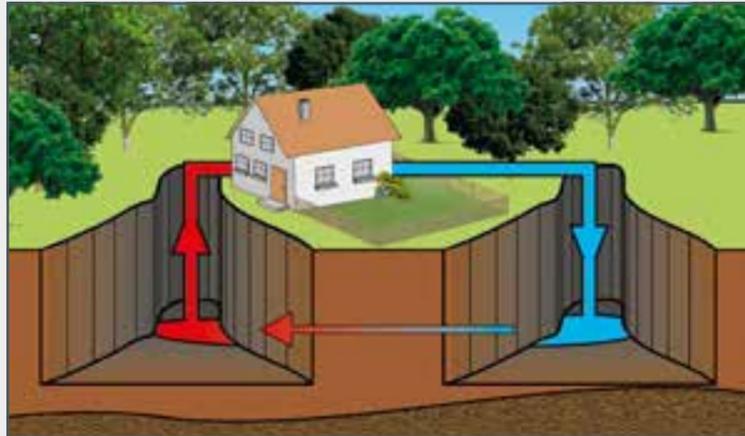
Wind power plant with rotor blade adjustment and yaw angle adjustment

Order No.: 061.21000



# Geothermal energy

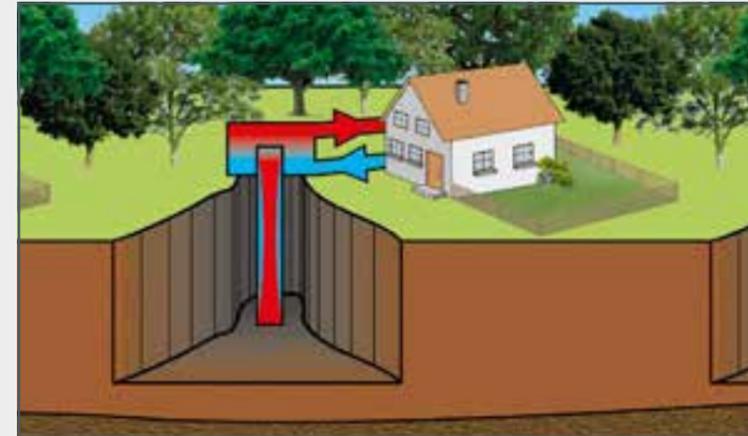
## Dual well system



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.

Groundwater is pumped from a well to the surface. After thermal use the groundwater is returned to the soil via a discharge well to conserve the groundwater reservoir. A sufficient distance between the well and discharge well prevents a hydraulic short cut.

## Geothermal probes



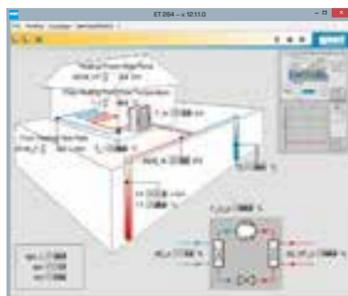
Geothermal probes are heat exchangers that are inserted vertically or at an angle into the ground. In most cases, these consist of plastic pipes inserted into boreholes. The probes can be designed in different ways. Geothermal probes are a closed geothermal system with thermal retroaction on the ground.

Probe with heat pipe principle

### ET 264 Geothermal energy with two-well system

Use of geothermal energy in an open system without thermal repercussion

- 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 262 Geothermal probe with heat pipe principle

Transparent components allow observing how the state of the heat transfer medium changes

- operating behaviour of a geothermal probe with heat pipe principle
- fundamentals of geothermal energy
- 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

