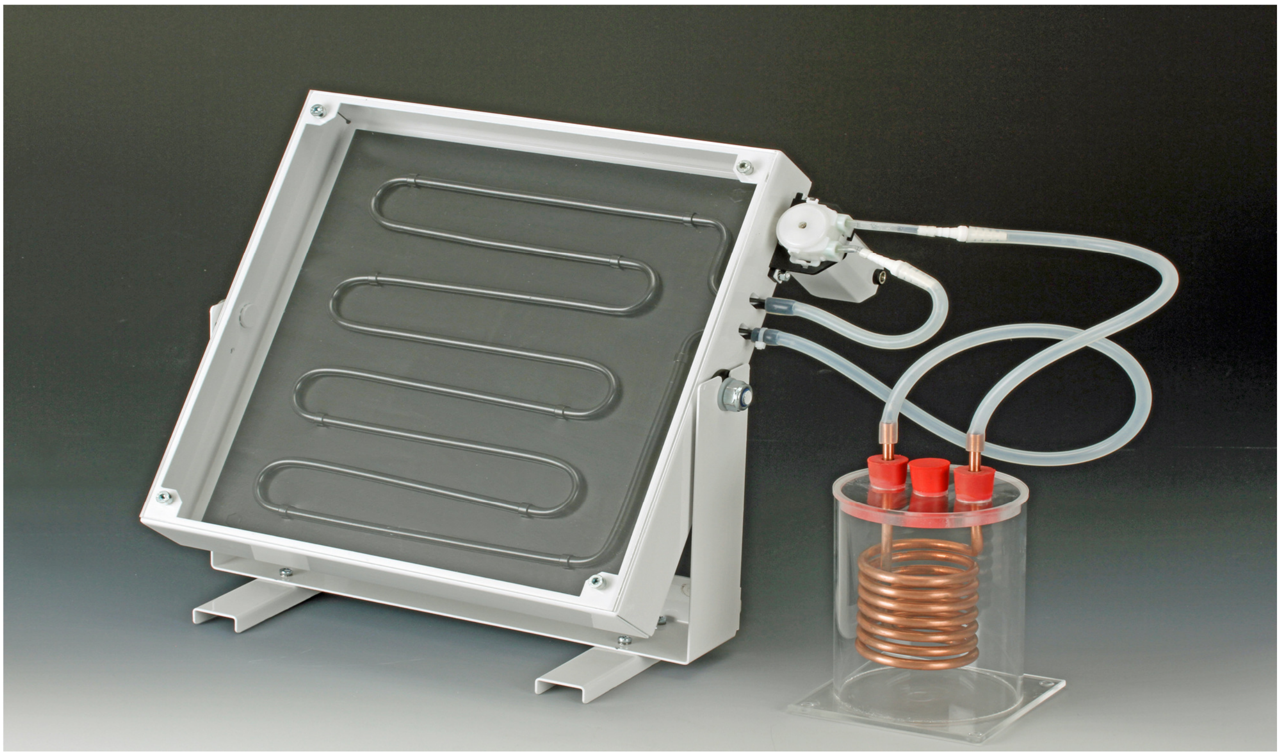
Solar thermal collector 503720



The solar thermal collector is used to demonstrate how solar energy can be converted into heat energy. The set-up includes heat pump and reservoir with heat exchanger (copper coil). The reservoir can illustrate how the water heater in a house works or if used without water to illustrate how a radiator heats up a room.

Function

Solar radiation is absorbed by the black absorber plate, which consists of a metal plate with attached copper pipes. The back of the collector is insulated from the absorber. Mounted on the front is a transparent acrylic plate, which reduces heat loss by convection.

The black copper pipe mounted on the collector is connected with plastic tubing to the pump and copper coil in the reservoir. The pump circulates water through the pipe and tubes and transports thermal energy from the absorber to the reservoir.

A thermometer can measure the temperature in the reservoir. When the amount of water in the reservoir is known, the heat input can be calculated from the temperature rise (see example below). The storage tank includes two different rubber stoppers: One with a large hole for ordinary thermometers and one with a small hole for a digital thermometer or a temperature sensor for data logging.

The collector has a hole at the top to access the copper pipe with a thermometer thus allowing monitoring of the temperature rise of the copper pipe. The absorber temperature is very sensitive to variations in solar radiation and the solar thermal collector can be set at different angles to ensure the highest possible solar intensity. If you are using a halogen lamp as light source, the same principle applies.

Filling the piping

1. From the copper coil, remove the tube that ends in the lower pipe stub at the collector.
2. Pour water into a beaker and place the end of the tube under the surface.
   (See photo.)
3. Start the pump; now water flows through the tube, the pipe on the absorber and the copper coil.
4. When water flows out of the coil, the system is filled.
5. Turn off the pump and reconnect the tube to the copper coil.

Final preparations

Fill the approx. 0.6 L water into the storage tank.

Usually you want to know the amount of water in the tank more precisely. That can be found using a graduated cylinder when filling or by weighing the tank before and after filling.

Put the lid with the coil back in place.

Place a thermometer or a temperature sensor in a suitable cork and insert it in the centre hole in the lid.

The system is now ready for operation.

Volume of the piping

If you want to determine the amount of water in the closed circuit, it can be found like this – after all measurements are done:

1. Weigh an empty beaker (100 mL – 250 mL).
2. Stop the pump. From the copper coil, re-move the tube that ends in the lower pipe stub at the collector.
   (Let the end of the tube point upwards.)
3. Place the open end of the copper coil over the beaker and let the pump run until the water stops flowing out.
4. Weigh the beaker with water. Subtract the two masses.

Experiments with the solar collector

The piping is filled as described, and the pump is switched on via the supplied adapter.

The storage tank is filled with 0.6 L water.

The initial temperature is measured and recorded. The following data was obtained by using a halogen-lamp. The radiation intensity was measured by a pyranometer to 850 W / m2. The area of the absorber is 0.0756 m2.

The measured values in the table to the right were obtained with a digital thermometer (not included).

The energy conversion efficiency of the solar thermal collector can now be calculated:

$Q_{In} = \Phi \cdot A \cdot t = 850\ \text{W/m}^2 \cdot 0.0756\ \text{m}^2 \cdot 1800\ \text{s} = 115.7\ \text{kJ}$

$Q_{Water} = c_v \cdot m_v \cdot \Delta T = 4.18\ \text{kJ/(kg·K)} \cdot 0.6\ \text{kg} \cdot 17.9\ \text{K} = 44.9\ \text{kJ}$

$\eta = Q_{Water}/Q_{In} = 44.9\ \text{kJ}/115.7\ \text{kJ} = 0.39 = 39\ \%$

These calculations consider only heating of the water in the tank as “useful”.

The water circulating in the tubes and pipes as well as the absorber plate and the copper spiral are also heated. The heat capacity of the metal parts are listed under *Specifications,* in case you need to go into details with the energy of these.

Time / min	T_{Res} / °C
0	19.5
2	20.2
4	21.5
6	22.8
8	24.3
10	25.7
12	27.0
14	28.4
16	29.6
18	30.9
20	32.1
22	33.2
24	34.4
26	35.5
28	36.5
30	37.4

Maintenance

A peristaltic pump leads the water through the system. In the pump, the plastic tube is bend around a wheel with three rollers, that squeeze the tube. Hence, when the motor turns the wheel, the water will be moved through the system. At some point the tube needs changing, which is easily achieved. First loosen the two fittings that holds the pump head, which now easily can be removed. Second, change the tube in the pump head. Third, push the head back in place on the metal axle. The pump now works again.


Loosen head


Head removed


Motor axle

Specifications

Solar thermal collector

Absorber area: 27.0 cm x 28.0 cm = 756 cm^2

Heat capacity of absorber and Cu pipe: 377 J/K

Reservoir

Material: acrylic plastic of thickness 3 mm (sides) and 4 mm (bottom)

Internal diameter: 94 mm

Heat capacity of copper coil: 83 J/K

Water circuit

Tubes and pipes holds around 50 to 55 mL

Adapter for the pump: 12 V DC and 1,5 A

Accessories – not included

- Sunlight or halogen lamp (e.g. 280130 or 280135)
- Magnetic stirrer (e.g. 064067)
- Pyranometer (e.g. 489020 / 489025)
- Digital thermometer (e.g. 062100)