Heat

Heat transfer
Solar collector

LD Physics Leaflets

P2.2.2.2

Determining the efficiency of a solar collector as a function of the heat insulation

Objects of experiment

- Measuring the temperature characteristic of a solar collect with and without insulation.
- Estimation of the efficiency

Principles

A solar collector absorbs radiation energy and heats itself and the through putting water.

The efficiency η is the ratio of the heat energy absorbed by the water ΔQ and the radiation energy ΔE:

$$\eta = \frac{\Delta Q}{\Delta E}$$

Where the radiant energy is

$$\Delta E = \Phi \cdot \Delta t$$

with Φ : radiant power.

When the collector is warmer than the environment, it gives off energy by radiation, convection and conduction of heat to the environment. Due to these losses, the efficiency decreases.

A forced circulation is generated in the experiment with the help of a pump. The absorbed thermal energy of the whole system (collector, tubes and the reservoir) is distributed on the water, so that the temperature of the solar collector does not increase so much.

In the experiment the solar collector is used without and with insulation. Here, the temporal temperature characteristic of the water in the reservoir is measured.

Fig. 1: Set up

Kem 05-13

Apparatus

1 Solar collector 389 50

1 Flood light lamp 1000 W, with light shades.... 450 72

1 Water pump STE 2/50 579220
1 Variable extra-low voltage transformer S....... 521 35
1 Cable 100 cm, red/blue, pair.......................... 501 46

1 Mobile-CASSY 524 009A
1 NiCr-Ni-Adapter S, type K............................. 524 0673
2 Temperature sensor NiCr-Ni, 1,5 mm, Type K529 676

1 Steel tape measur, 2 m................................ 311 77
1 Stoppclock 313 17

2 Stand base V-shape, 20 cm 300 02
1 Stand rod 25 cm, 12 mm Ø........................... 300 41
1 Stand rod 47 cm, 12 mm Ø........................... 30042
1 Stand rod 75 cm, 12 mm Ø........................... 30043
3 Leybold multiclamp....................................... 301 01
1 Universal clamp 0...80 mm 666 555

1 Plastik beaker 590 06
1 Silicone tubing 5 mm Ø, 1 m......................... 604 431
1 Silicone tubing 6 mm Ø, 1 m......................... 604 432
1 Silicone tubing 8 mm Ø, 1 m......................... 604 434
1 Connector, straight, 6/8 mm Ø...................... 665 226

Setup

a) Water cycle

Set up the experiment as shown in Fig. 1. Use appropriate silicone tubings and connectors for the connection of the tubings with the nozzles.

- Connect the water pump so, that it pumps the water from the bottom through the solar collector, i.e. connect the output pump nozzle with the nozzle of the input chamber.
- Fix a temperature sensor directly at the output chamber of the solar collector with the help of the rubber stopper with 1.5-mm bore.
  This temperature measurement point is also used to prevent overheating of the solar collector. The water temperature must not exceed 60 °C
- Connect the nozzle of the output chamber with the input nozzle of the reservoir.
- Connect the output nozzle of the reservoir with the input of the water pump.
- Fill 1000 ml water into the reservoir.
- Lift the reservoir so that the water flows through the water pump into the solar collector and flows back into the reservoir at its input. All tubings must always remain without folding so that the water can flow without disturbance.
- Hang the reservoir on to the intended support rod.
- Switch on the power supply and run water pump with about 6 V observing the polarity.
- Make sure that the tubing system is now free of bubbles.

b) Measuring of temperatur

- Hold the second temperature sensor with the help of the universal clamp into the water of the reservoir.
- Connect the temperature sensors to the NiCr-Ni-adapter and the Mobile-CASSY.

c) Illumination

- Set up the flood light lamp on a stand base approximately 50 cm in front of the solar collector.
- Switch on the flood light lamp and align it so that the actual solar collector is illuminated. If necessary adjust the light shades slightly, so that the plastic housing is not illuminated.
- Switch off the flood light lamp and let cool down the solar collector.

Carrying out the experiment

a) Preparation

- Measure the temperature at switched water cycle and wait until the temperatures do not change anymore.

a) Measurement

- Reduce the voltage at the water pump so (to about 2.5 V), that only a small throughput speed is reached, i.e. only a small flow of water into the reservoir can be observed.
- Write down the temperature in the reservoir and observe the temperature in the output chamber.
- Simultaneous switch on the flood light lamp and start the stoppclock. Take a measuring value every minute.

Safety note

The water temperature must not exceed 60 °C !

- Stop the measurement after 30 minutes.

Note: For longer measuring times note the maximum allowed temperature.

- Replace water to cold water. Make sure that the same amount of water is taken. The experiments should be started with the same initial temperature as possible.
- Mount the insulation plate in front of the solar collector.
- Repeat the experiment.

Measuring examples

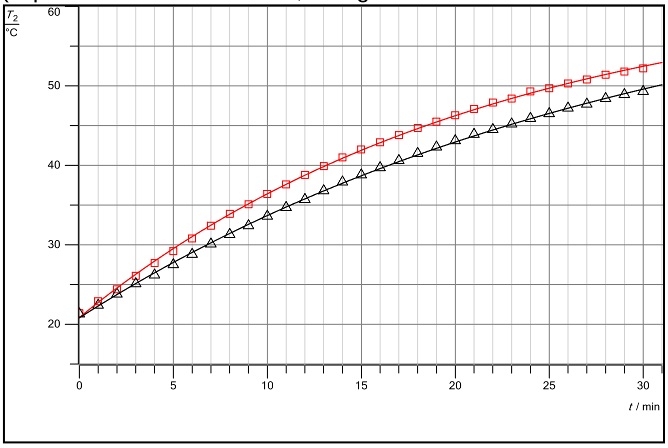
Table 1: Temperature characteristic of water in the reservoir

	insulation	
	without	with
time	Temperature oft he reservoir	
$\frac{t}{\text{min}}$	$\frac{T_1}{°C}$	$\frac{T_2}{°C}$
0	21.4	21.3
1	22.9	22.4
2	24.4	23.8
3	26.1	25.1
4	27.7	26.2
5	29.2	27.5
6	30.8	28.8
7	32.4	30.1
8	33.9	31.3
9	35.1	32.4
10	36.4	33.6
11	37.6	34.7
12	38.8	35.7
13	39.9	36.8
14	41.0	37.9
15	42.0	38.8
16	42.9	39.7
17	43.8	40.6
18	44.7	41.5
19	45.5	42.3
20	46.3	43.1
21	47.1	43.9
22	47.9	44.5
23	48.4	45.2
24	49.3	45.9
25	49.7	46.5
26	50.3	47.2
27	50.8	47.7
28	51.4	48.4
29	51.8	48.9
30	52.2	49.3

The difference of the Temperatures between the output chamber of the solar collector and the reservoir: app. 2 K

Evaluation

Diagram 1: Temperature as function of the time
(Squares: without insulation, triangles with insulation



The diagram clearly shows that the temperature rises more quickly without insulation. With the insulation a part of the radiant energy is reflected, i.e. the actual radiation onto the solar collector is lower.

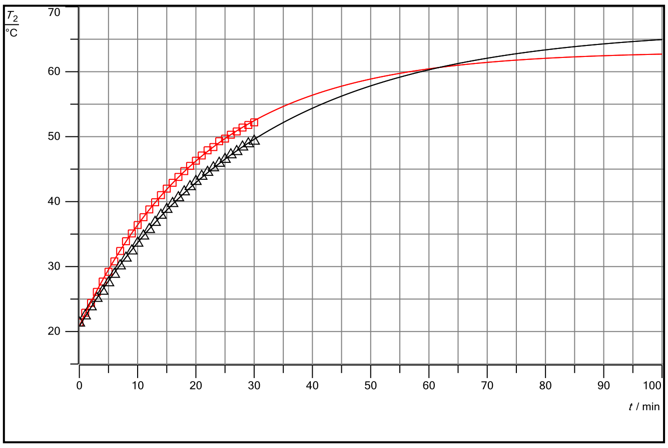
The curves in the investigated period are not linearly, but run according to a function

$$T(t) = T_{End} - a \cdot e^{\frac{-t}{b}}$$

exponential, i.e. the temperature-increase decreases with increasing temperature of the water, since an increasing part of the heat energy is lost.

By calculation of the measured values and an extrapolation it is clear that the theoretically possible temperature T_{End} is higher wit insulation than without insulation, although the radiant power at the absorber is lower.

Diagram 2: Calculated curves with the measured values



Note: The presentation of this effect could be amplified by additional cooling, e.g. with a fan.

Above the intersection of the two curves, the heat losses are smaller with insulation. By acting as a heat cover, the efficiency is increased.

Real solar collector systems use special non-reflective glasses.