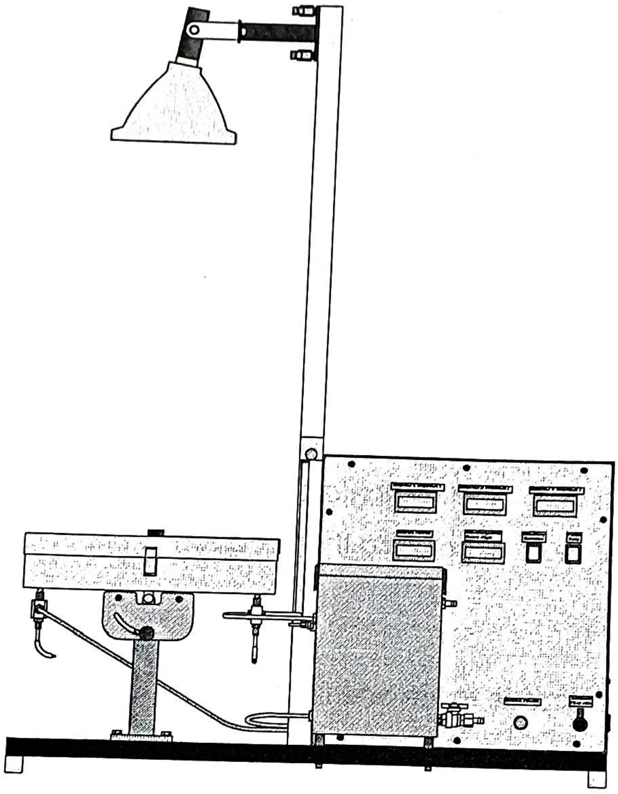
ET 202 **SOLAR ENERGY DEMONSTRATION**



Experiment Instructions

Please read and follow the safety regulations before the first installation!

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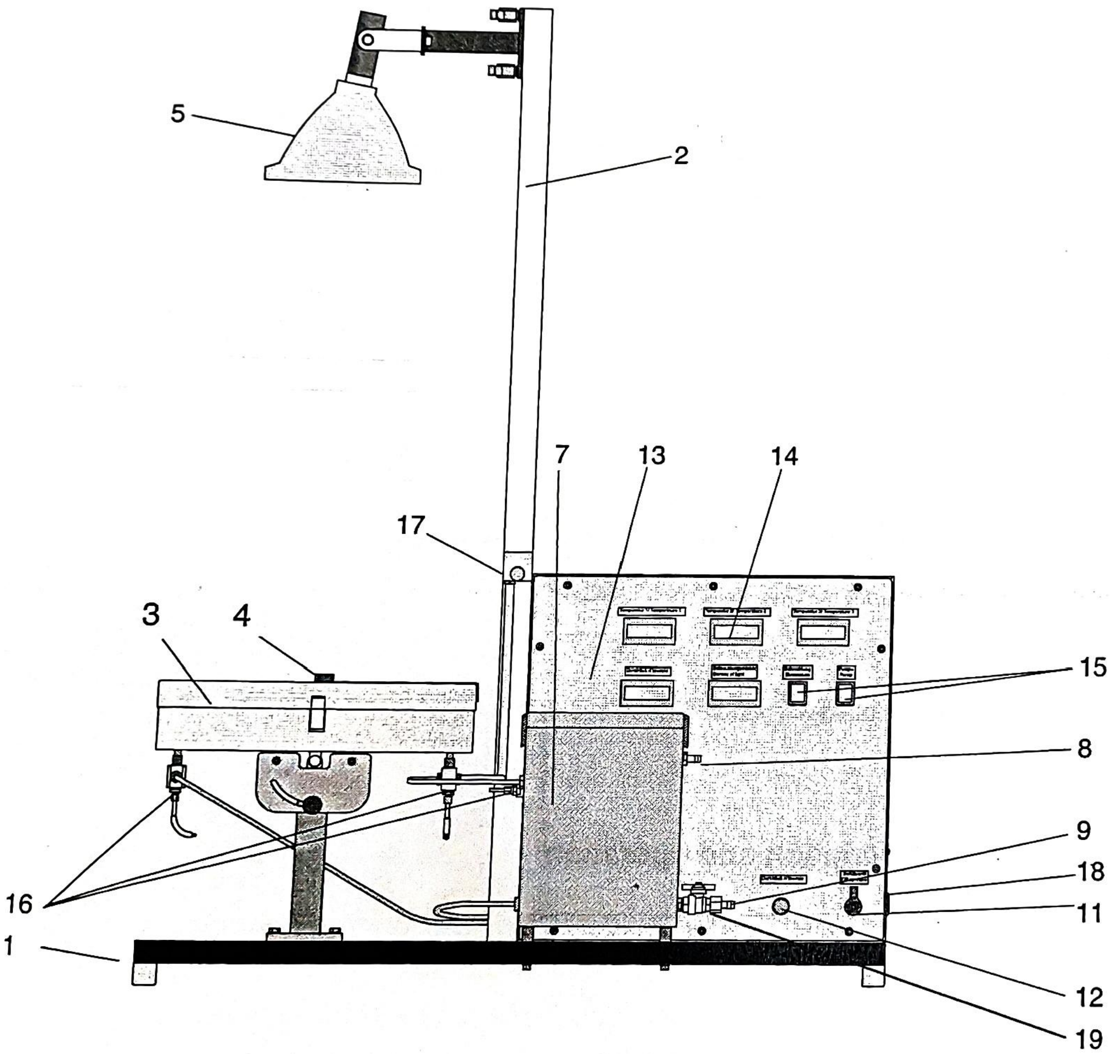
2 Description

2.1 Equipment layout



1 Trolley
2 Lamp tripod
3 Flat collector
4 Heliometer
5 Halogen lamp, adjustable height
6 Flow meter (not visible)
7 Hot water tank
8 Hot water tank overflow connection
9 Filler/drain valve for hot water
10 Circulating pump (not visible)
11 Filler valve in primary circuit
12 Regulator valve for setting the volumetric flow rate
13 Control cabinet
14 Digital displays for sensor measured values
15 Master switch for lamp and circulating pump
16 Temperature sensors
17 Air bleed hose
18 Computer interface
19 Ventilating valve (covered by item no. 9)

1 Introduction

The **ET 202 Solar Energy Demonstration System** is a fully functional model of a system for heating domestic hot water by converting solar energy (radiation energy) into heat. The natural solar radiation is replaced by an adjustable 1000W high power lamp.

An insulated **flat absorber** absorbs the radiation energy and provides for transfer to the heat transfer liquid (water).

A **circulating pump** provides circulation of the heat transfer liquid in the solar circuit. It pumps the heat transfer liquid through a **hot water tank** where the heat is given off to the water in the tank via an integrated heat exchanger. Additional heat can be dissipated using two **hose connections for tap water**.

The system is fitted with sensors to **record temperatures, luminous intensity and volumetric flow,** and the measured values from them are transferred to a **PC**. An associated software program performs an evaluation of these measured values and indicates the current states on the monitor of a connected PC. Digital displays on the unit also allow **use without a PC.**

The solar energy demonstration system allows **different angles of incidence and irradiances** to be investigated. To do this, the flat absorber can be adjusted to three different angles and the lamp to four positions.

In terms of teaching, the following **didactic objectives** can be achieved using the solar energy demonstration system:

- Familiarisation with the layout and function of a solar collector system
- Knowledge of heat transfer in solar collectors
- Setting up energy balances
- Determination of efficiencies

In addition, the use of the system provides the basic knowledge necessary for a discussion of alternative forms of energy and non-fossil fuels.

2.2 System diagram

and used to determine amount of heat absorbed

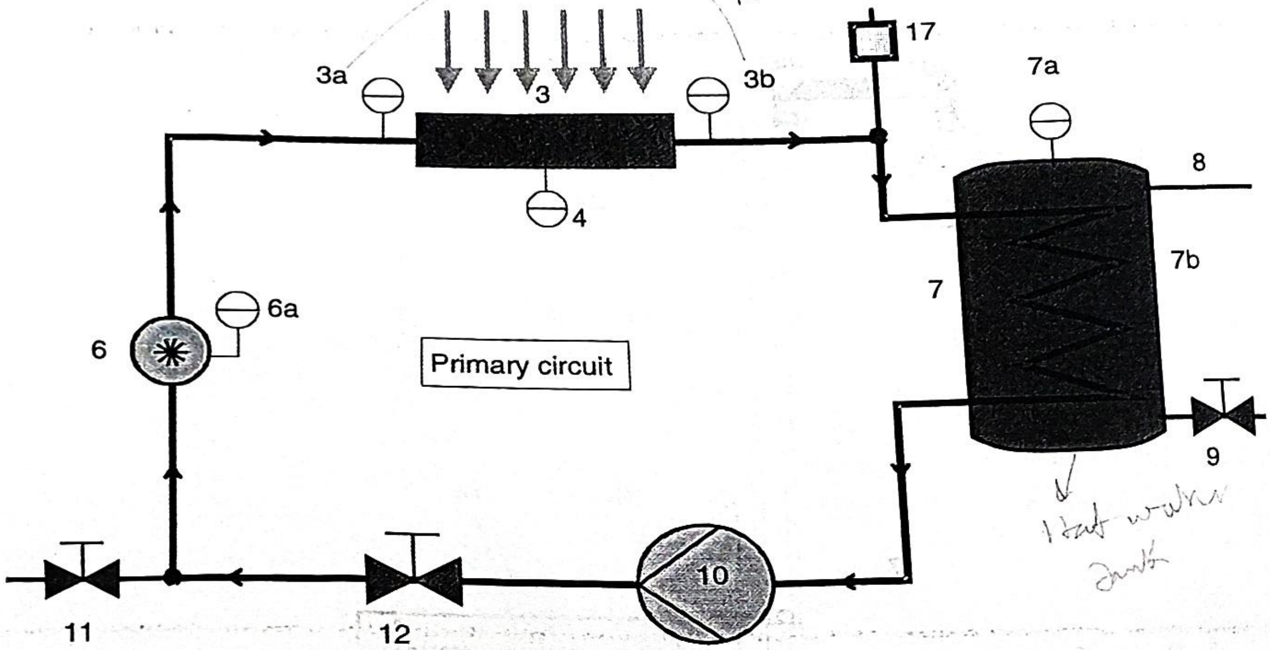


Fig. 2.1 System diagram of solar demonstration system

2.3 Function description and operation

(Fig. 2.1) The solar energy demonstration system is a fully functional model of a thermal solar absorption system. The solar radiation is replaced by a halogen lamp with a rating of 1000 W (5). The height of its position relative to the collector is continuously adjustable. The radiation falls onto a flat thermal collector (3) that converts part of the radiation energy into heat by absorption. The collector contains pipes with water flowing through them. The water dissipates the absorbed heat. This results in a temperature increase of the water between the collector feed and the collector return that is proportional to the irradiated power. Tem-

Dissipates → to slowly become less until it disappears;
↳ To make something weaker until it disappears

perature sensors on the collector feed (3a) and collector return (3b) are used to determine the amount of heat absorbed. The inclination of the collector (3) can be continuously adjusted. In this way the angle of incidence of the radiation from the lamp can be varied. The luminous intensity is measured using a heliometer (4). The heated water emerging at the collector return is fed into the hot water tank (7) and gives off its heat to the domestic water in the tank via a heat exchanger (7b). The temperature of the domestic hot water is measured using a temperature sensor (7a). An additional domestic water circuit (secondary circuit) that can be connected by a hose fitting (9) is used to dissipate additional heat if the water temperature in the tank rises too sharply. The domestic water is constantly exchanged.

NOTE! For the domestic water to be heated without exchanging, the water level in the hot water tank must be above the spiral pipe (7b).

The circulating pump (10) conveys the water further through the primary circuit. The flow rate in the primary circuit is adjusted using the regulator valve (12) and is recorded by a sensor (6a) at the impeller flow meter (6). The water in the primary circuit is pumped to the collector return (3a) and the circuit starts again.

2.4 Commissioning the system

- The primary circuit is filled with water and ventilated (Fig. 2.1):
  - Close all valves (19, 12, 11)
  - Connect the tap water connection to the filler valve (11)
  - Shift the air bleed hose (17) upwards until it leads straight upwards and is free of bubbles.
  - Open the ventilating valve (19)
  - Connect drain hose to hose connection of ventilating valve ?
  - Carefully open the filler valve (1/4 rotation), until approx. 75% of air bleed hose is filled with water

    which is this

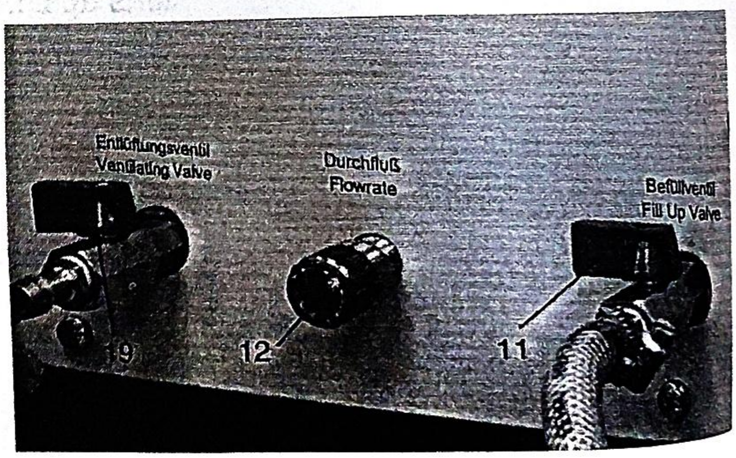
  - Close ventilating valve and filler valve

    what is this

  - Switch on the pump for approx. 30 seconds
  - Open flow valve for approx. five minutes to release any residual air remaining in the system via the air bleed hose (17)

    what is this

  - The primary circuit is filled with water and ventilated
  - Finally the the tap water connection to filler valve (11) and the drain hose at ventilating valve (19) are to be disconnected



4 Theory and experiments

4.1 Thermal collector

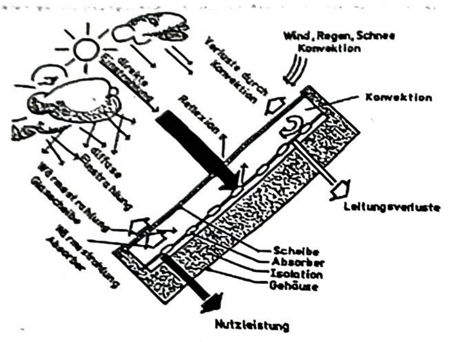


Fig. 4.1 Flat thermal collector

Fig. 4.1 shows the principle of a flat thermal collector. Direct and diffused sunlight from the surroundings comes into contact with an absorber, where it is converted into heat. To achieve the maximum possible temperatures and efficiency, the absorber is thermally insulated from the surroundings. To be able to absorb a large amount of sunlight, the thermal insulation must be transparent, at least on the front. The heat generated is fed to a consumer using a system with a liquid or gaseous heat transfer medium.

4.2 Collector efficiency

The collector efficiency is determined by the available **irradiance P_S** from the sun (in this case the lamp) and the **effective power P_N** dissipated via the heat transfer liquid in the primary circuit:

$$\eta = \frac{P_N}{P_S} \tag{4.3}$$

The effective power is reduced by radiation losses reducing the collector efficiency.

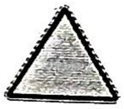
The irradiance PS is given by the collector surface area AK and the radiation per unit area E (luminous intensity) in W/m²:

$$P_S = A_K \cdot E \tag{4.4}$$

The **effective power P_N** is determined from the **temperature difference** between the collector feed and return ($T_2 - T_1$), the **mass flow rate of the heat transfer medium** $\dot{m}$ and the **specific heat capacity c_p** of the heat transfer medium (c_p, water = 4.2 kJ/kgK):

$$P_N = \dot{m} \cdot c_p \cdot (T_2 - T_1) \tag{4.5}$$

- Notes on plotting measured values:
  - The radiation per unit area E is measured using a heliometer in $^W/_{m^2}$. The measurement should be made under the lamp exactly in the centre of the collector surface to obtain correct measured results.



  - **CAUTION!** The heliometer only delivers the correct measured results for artificial light. When using sunlight, the value specified on the display must be multiplied by the correction factor of **1.65**.
  - Due to the large thermal inertia of the collector system, it is necessary to wait for around 20 min until a steady state condition has been reached before the measured results are read and evaluated.
  - For the same reason, it may occur that collector efficiencies greater than 1 are indicated temporarily, something that is not physically possible. After waiting until the steady state condition is reached, the correct measured value is displayed.
  - The measuring accuracy improves as the temperature difference T_2 - T_1 increases. It is therefore recommended that the heat transfer medium flow rate is limited to around 6-7 l/h.

Example measured values:

Angle of incidence 0°

Collector surface area l = 0.32 m

b = 0.34 m

$$A_{K,60°} = 0{,}32m \cdot 0{,}34m = 0{,}1088m^2$$

Luminous intensity $E = 2090\dfrac{W}{m^2}$ (displayed)

Heat transfer medium flow rate $\dot{m} = 6{,}0\dfrac{l}{h} = 0{,}00166\dfrac{kg}{s}$

Specific heat capacity $c_p = 4200\dfrac{J}{kg \cdot K}$

Temperature difference at collector

$$\Delta T = T_2 - T_1 = 24{,}1 - 13{,}0 = 11{,}1K$$

For the irradiance, this gives

Area × luminous intensity

$$P_S = 0{,}1088m^2 \times 2090\frac{W}{m^2} = 227.39\,W$$

The effective power is

$\dot{m}\, c_p\, (\Delta T)$

$$P_N = 0{,}00166\frac{kg}{s} \cdot 4200\frac{J}{kg \cdot K} \cdot 11{,}1K = 77{,}70\,W$$

The collector efficiency is calculated as

$$\eta = \frac{P_N}{P_S} = \frac{77{,}70}{227{,}39} = 34{,}1\%.$$

4.3 Discussion material for use of solar energy

4.3.1 Development of global energy consumption

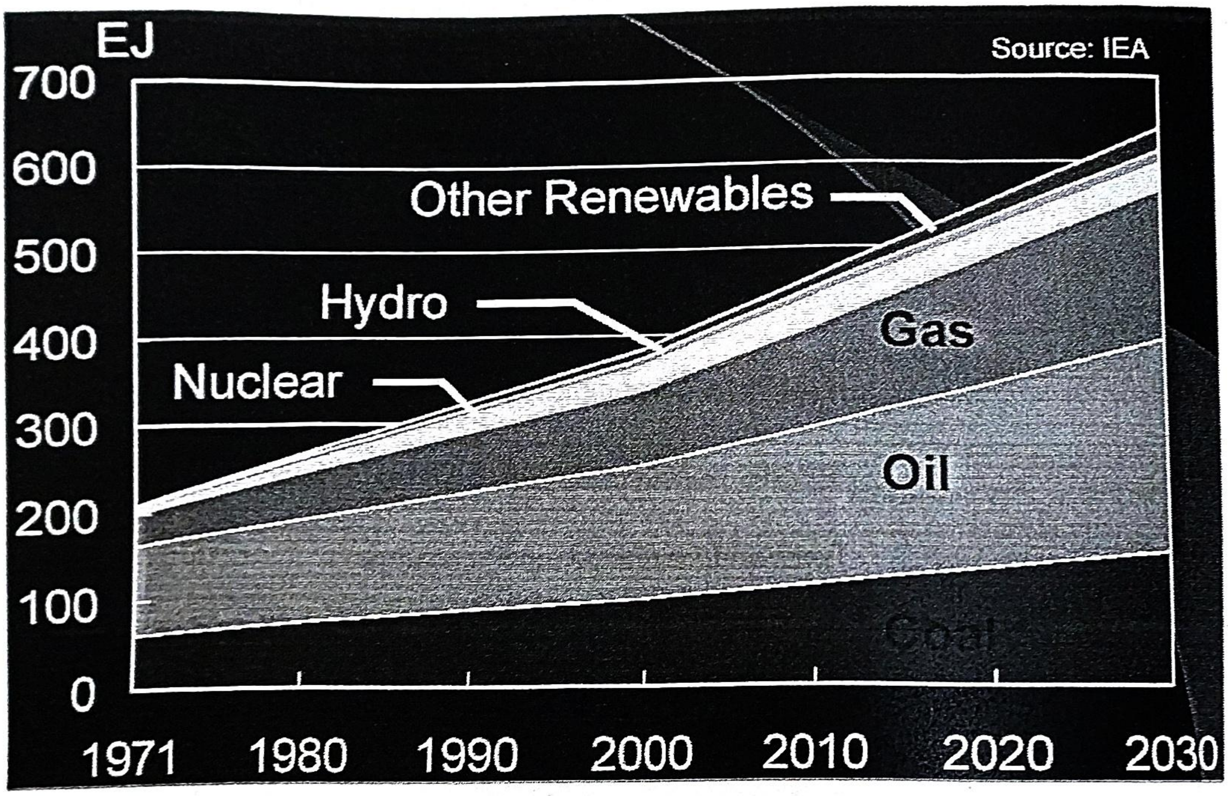


Fig. 4.2 Development of global energy consumption /1/

4.3.2 Limited reserves of fossil fuels

Fuels	Reserves (years)
Coal	80-100
Crude oil	20-55
Natural gas	40
Uranium	90

(from \1\)