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14. Abstract/Notes

Based on a bilateral agreement on scientific and technological cooperation with West Germany, a collector test field has been established at the site of INPE/CNPq near the city of Atibaia (SP), Brazil. With the four installed test loops it is possible to test different kinds of solar collectors and collector banks in a temperature range from 30°C up to 250°C with a maximum power of 20 kW. The measurement equipment including a solar meteorological station meets all requirements to carry out collector test according to international standards. Three types of collector banks, flat-plate, booster mirror collectors (n~3) and parabolic trough collectors (n~12) with approximately 20 m^2 aperture area each are installed and under short and long term test. For typical applications, e.g. process heat in the range of 120°C up to 200°C, special experiments with outlet temperatures at fixed levels have been performed.

15. Remarks

This paper will be presented at the 1st Latin American Congress on Heat and Mass Transfer.

TEST STATION FOR SOLAR COLLECTORS IN LOW AND HIGH TEMPERATURE RANGE

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ABSTRACT

Based on a bilateral agreement on scientific and technological cooperation with West Germany, a collector test field has been established at the site of INPE/CNPq near the city of Atibaia (SP), Brazil. With the four installed test loops it is possible to test different kinds of solar collectors and collector banks in a temperature range from 30°C up to 250°C with a maximum power of 20 kW. The measurement equipment including a solar meteorological station meets all requirements to carry out collector tests according to international standards. Three types of collector banks, flat-plate, booster mirror collectors ($n \sim 3$) and parabolic trough collectors ($n \sim 12$) with approximately 20 m^2 aperture area each are installed and under short and long term test. For typical applications, e.g. process heat in the range of 120°C up to 200°C, special experiments with outlet temperatures at fixed levels have been performed.

INTRODUCTION

Solar energy is an important energy resource in the future, especially for countries with high irradiation, if economic solar systems can be developed.

One of the key component of solar systems is the solar collector which converts solar radiation into heat at certain temperature levels. For the application of a special collector one needs to know its technical characteristics.(Ashrae (1978), BSE (1979), Duffie et al.(1979))

A collector has to be tested according to international standards. A CNPq-KFA bilateral project was aimed to install test loops to examine different kinds of collectors in a temperature range from 30°C up to 250°C. To cover this scope, four loops with appropriate measurement equipment and a small meteorological station had been put in operation at the site of INPE/CNPq near Atibaia, São Paulo. Three loops are connected to collector banks delivered from Germany and one loop is used to test commercial collectors from Brazilian companies. Beyond this, a high temperature collector (250°C) has been developed by the University of São Paulo.

TEST SITE

The location of the test station was chosen at the Radio Observatory of INPE/CNPq near Atibaia. This choice was made on the basis of the following favourable characteristics:

- The locality has a particular climate which favours clear sky conditions (approximately 200 days of bright sunshine per year).
- The electric and mechanic workshop of the observatory could be used.
- The installed emergency power supply gives the necessary safety for the electric powered tracking systems of the concentrating collectors.

TESTLOOPS

The testloops are designed to cover the conditions of international standards (ASHRAE 93-77, DIN 4757) for collector tests. Beyond these requirements, it should be possible to run the collector banks in long term test. The construction (Fig. 1) matches the following specifications:

- Adjustable collector field inlet temperature: 30 to 100°C, ± 0.3K stability.
- Maximum collector field outlet temperature: 250°C.
- Adjustable mass flow rate: 0.014 to 0.22 kg/s, ± 1% stability.
- Maximum pressure: 3 bar.
- Working fluid: organic heat transfer liquid.

The design of the flow control, temperature control and the selection of instruments for flow and temperature measurement are based on the experience in construction of different kinds of test loops. The critical temperature regulation of the collector inlet is controlled by a PI-regulator contacting two temperature sensors (PT 100, 1/3 DIN) and operating an electro-pneumatic threeway-valve. The flow is controlled by a P-regulator while it is measured by a displace flow meter.

MEASUREMENT EQUIPMENT

The established measurement and control devices are integrated into one cabinet as a central control and switch board, which contains:

- two 12 point recorders with appropriate amplifiers recording the collector data;

- one 6-channel line recorder to collect the meteorological data like global solar irradiance in the horizontal plane, the direct solar irradiance, the dry and wet bulb air temperature, the wind velocity and the wind direction;
- eight amplifiers to measure directly temperature differences with PT-100 in fourwire technique;
- display of the volume flow of all four loops;
- regulation system for temperature control;
- distribution system for compressed air;
- switchboard for the instruments, pumps, heaters.

The sensors in the loops and at the meteorological tower are:

- resistance thermometers PT 100 1/3 DIN for temperature measurement;
- pyranometers for the global solar irradiance horizontal and in the plane of the collectors;
- phyrheliometer tracking for the direct irradiance;
- psychrometer for the dry and wet bulb air temperature;
- three cup anemometer and wind vane for wind velocity and direction.

INSTALLED COLLECTORS

Three types of commercially fabricated collectors have been proposed and selected by the German side:

- A double-glazed flat-plate collector with selective aluminium rollbond absorber. Six collectors are connected in series. The total aperture area is 6.66 m^2. Temperature range up to 120^oC.
- A tracking low concentrating collector (n~3) consisting of a single glazed selective flat-plate collector with booster mirrors. The whole

unit is composed of four collectors which could be connected either in parallel or in series. The total aperture area is 20.16 m^2. Temperature range up to 150°C.

- A tracking, linear concentrating collector (n~12) consisting of parabolic troughs in polar axis orientation. Eight troughs are connected in series. The total aperture are is 25 m^2. Temperature range up to 200°C.

The Brazilian side has installed commercial flat-plate collectors for short term tests. The developed high temperature collector (250°C) with approximately 15 m^2 aperture area consisting of tracking mirror stripes with a small flat-plate absorber in the focus is ready for final tests.

RESULTS

After the start-up phase efficiency curves have been measured according to international standards (Figs. 2, 3). It should be noted that the collector modules are interconnected in series. Neglecting a possible manufacturing scatter of collector modules, the data points represent testing of the same collector type at different temperatures under identical weather conditions.

Whilst the parabolic-trough collector type meets the expected performance, there have been difficulties with the flat-plate collectors and the booster-mirror collectors. In contrast to efficiency curves supplied by the manufacturer, the flat-plate collector has higher thermal losses than expected, probably due to high thermal losses in the backside insulation (soaked material) and deteriorated absorber surfaces. These conclusions are supported by DIN-type measurements in Germany. Similar disappointing observations were made with the booster-mirror collector.

Particular effort was undertaken to test the parabolic-trough collector under typical working conditions used for process heat production. The temperature regulation system of the loop was changed in order to keep a constant temperature at the outlet of the collector bank. Since the energy output is variable, conditioned by the fluctuating solar radiation, the PI regulator takes over the control of the volume flow correlated with the outlet temperature. Normally in the start-up phase the volume flow is zero, that is the throttle valve is completely closed. This leads to an overheating of the collector because the temperature measurement in the remaining standing fluid is inert. This undesired condition is prevented with a bypass to the throttle valve obtaining a minimum volume flow of approximately 0.01 kg/s through the collector field. The time constant and dead time of the system were measured in preliminary investigations for a proper adjustment of the regulator.

Figure 4 shows a typical start-up phase and operation at fluctuating solar radiation. Same experiments had been carried out at fixed temperature levels in a range from 120^{o}C up to 210^{o}C. For instance, a total energy output of 43.6 kWh at 112 kWh direct irradiation was measured at 135^{o}C outlet temperature over seven hours (25 m^2 aperture area, n~12).

CONCLUSIONS

The described test station for solar collectors, the first in Brazil operating at high temperatures, offers the possibility to test different kinds of collectors under certain working conditions. The collector fields delivered from Germany and several flat-plate collectors from Brazil have been tested according to international standards. With the parabolic-trough collector bank measurements have been carried out under conditions for solar systems producing process heat. The developed high-temperature loops with the appropriate measurement devices and regulation system turned out to be well designed for further experiments. The examination of the Brazilian collectors has lead to a close cooperation between industry and the scientists of the test site for the further development of new collectors.

LIST OF SYMBOLS

n = concentrating factor

T_* = reduced temperature (dimensionless)

Tm = average temperature of fluid in collector (^oC)

Ta = ambient temperature (^oC)

I = incident radiation (w/m^2)

U_o = normalized coefficient

η = instantaneous efficiency (dimensionless)

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CAPTIONS TO FIGURES

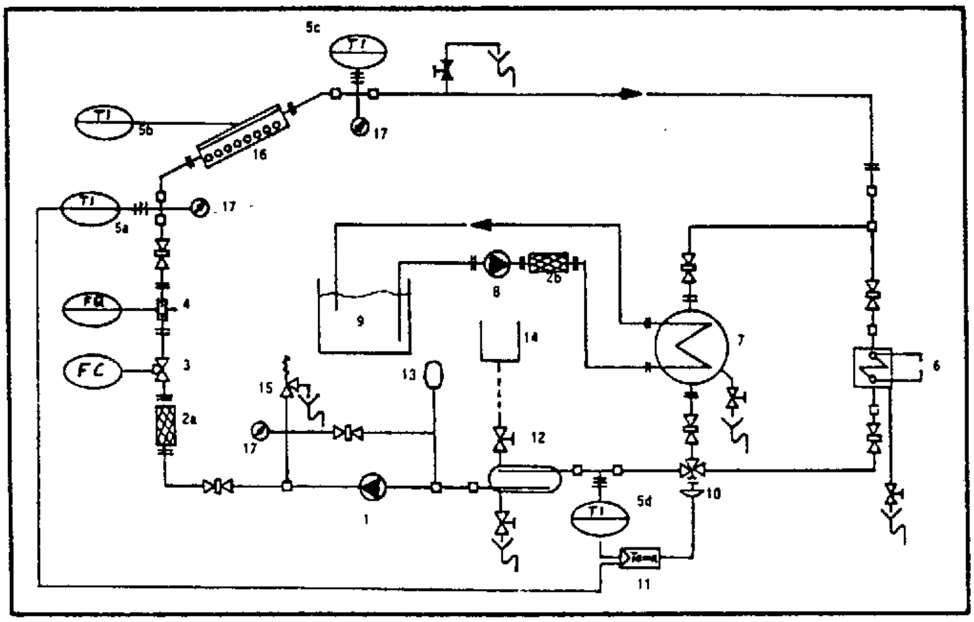
Fig. 1 - Scheme of the high-temperature collector test loop.

1) circuit pump; 2) filter; 3) flow-Controller; 4) flow-meter; 5) thermometer; 6) regulated heater; 7) heat-exchanger; 8) water pump; 9) lake; 10) three-way-valve; 11) temperature controller; 12) mixing tank; 13) compensation tank; 14) hopper; 15) safety valve; 16) collector field; 17) pressure gauge.

Fig. 2 - Instantaneous-efficiency data of the flat-plate collector.

Fig. 3 - Instantaneous-efficiency data of the parabolic-trough collector and booster-mirror collector. The efficiency is related to the direct radiation, and to the global radiation in the plane of the collector, respectively.

Fig. 4 - Start-up phase and operation of the parabolic-trough collector at fixed outlet temperature.



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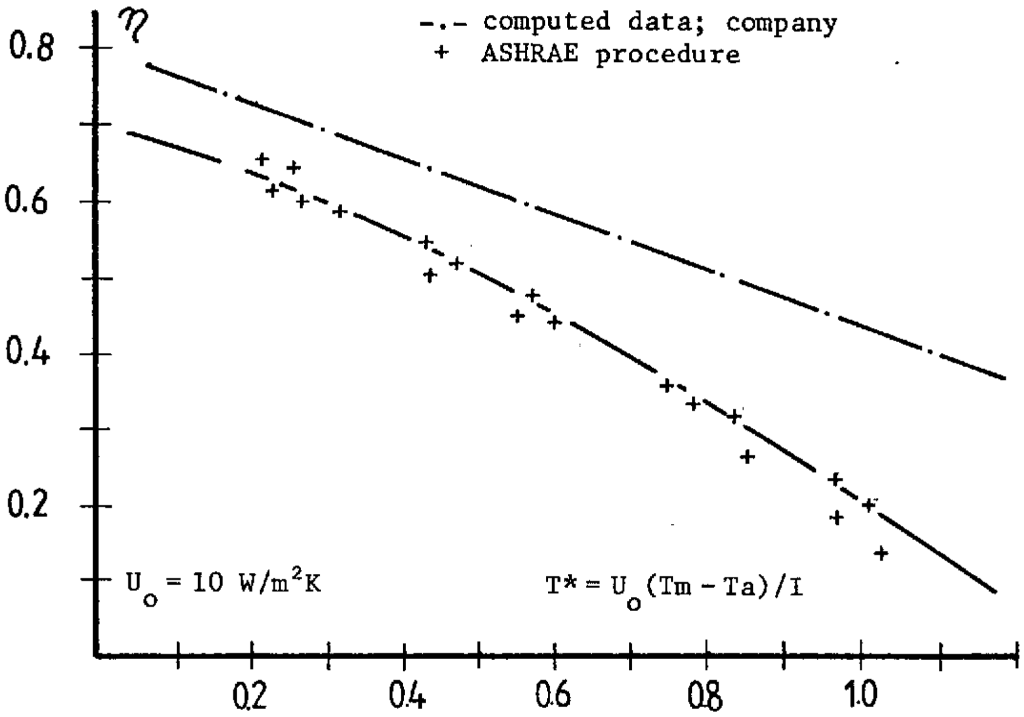

Fig. 2- Instantaneous-efficiency data of the flat-plate collector

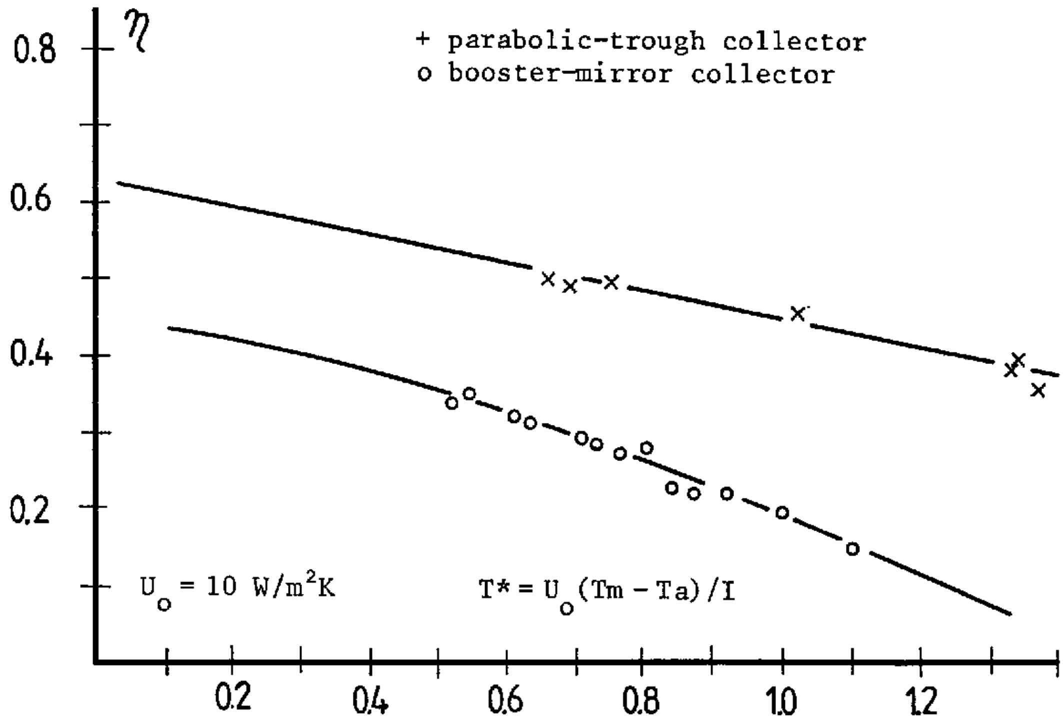

Fig. 3- Instantaneous-efficiency data of the parabolic-trough collector and booster-mirror collector.

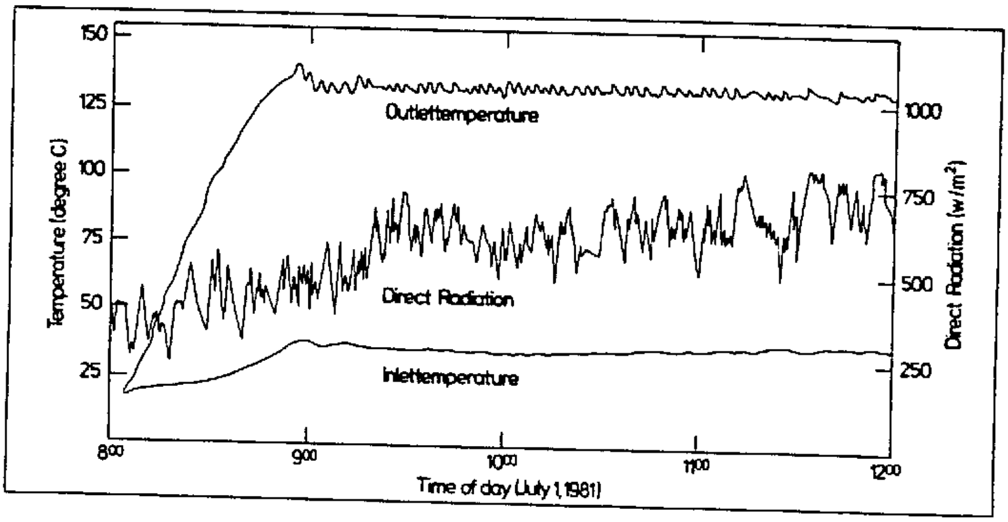

Fig. 4- Start-up phase and operation of the parabolic-trough collector at fixed outlet temperature