INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR.704 - 33

Workshop on Materials Science and Physics of Non-Conventional Energy Sources

(30 August - 17 September 1993)

"Indoor Test Facility for Flat-Plate Collectors"

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INDOOR TEST FACILITY FOR SOLAR FLAT-PLATE COLLECTORS

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ABSTRACT

To determine the performance of solar collectors an indoor test facility is an indispensable requirement. ASHRAE Standard 93-97 specifies methods to test the collectors. Such a facility needs two major components; one is a versatile and efficient test stand, and the other is an array of lamps which will simulate solar irradiance. An excellent indoor test facility was established at the Solar Village near Riyadh, and the author presents here the description of the facility and its performance characteristics.

INTRODUCTION

As the energy collecting element, the solar collector is the single most important component of a solar system. Without the collector, the other elements of the system would serve no function. The past two decades have witnessed considerable research and development work in solar collector technology and a high degree of commercialization. Problems concerning materials, fabrication and poor efficiencies have been overcome and good quality collectors are currently available. In India there has been a great deal of activity in commercializing solar collectors for hot-water systems. In the author's hometown, Bangalore, there are about 25 manufacturers. A domestic solar hot water system with a 100 liter storage capacity costs about 18,000 Indian Rupees (U.S $600 approx.) The local government subsidy is around U.S $80. There is a significant and an encouraging trend to use solar energy for heating water in homes and industries. A typical commercial liquid collector, for residential houses, has an area of 2 sq.meters, copper or aluminium absorber plate with copper or aluminium tubes manifolded into headers, selective absorber (black chrome) surface occasionally, fiberglass and foam insulation, and single glass cover.

With a high degree of commercialization it becomes very important to have an accurate and repeatable standard test method. ASHRAE Standard 93-97 specifies methods to test solar collectors to determine their thermal performance, time constant, and the variation of efficiency with changes in the angle of incidence. In the United States there are organizations such as the Florida Solar Energy Center (FSEC), Tennessee Valley Authority (TVA), Solar Energy Rating and Certification Corporation (SRCC), and Air Conditioning and Refrigeration Institute (ARI), have developed procedures for rating solar collectors and hot water systems. These procedures are based on data

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generated from tests according to ASHRAE and ASTM Standards[1].

An indoor test facility has two major components: a collector test stand and a solar simulator. The test stand should be versatile and capable of accomodating a variety of collectors. The simulator should provide a spectral distribution that reasonably duplicates that of natural sunlight as defined by the standard air mass 1.5 solar spectrum.

TEST FACILITY AT THE SOLAR VILLAGE

An excellent test facility equipped with a large solar simulator, capable of accomodating solar collector area upto 6 m^2 and unit weight of 500 kg. has been in operation for quite some time at the Solar Village, a research station near Riyadh in Saudi Arabia. This is one of the projects taken up under the auspices of a program called SOLERAS, a joint cooperative research endeavour between the United States and Saudi Arabia. It is the authors opinion that this facility could become a nerve-centre for testing collectors for the whole of Middle East.

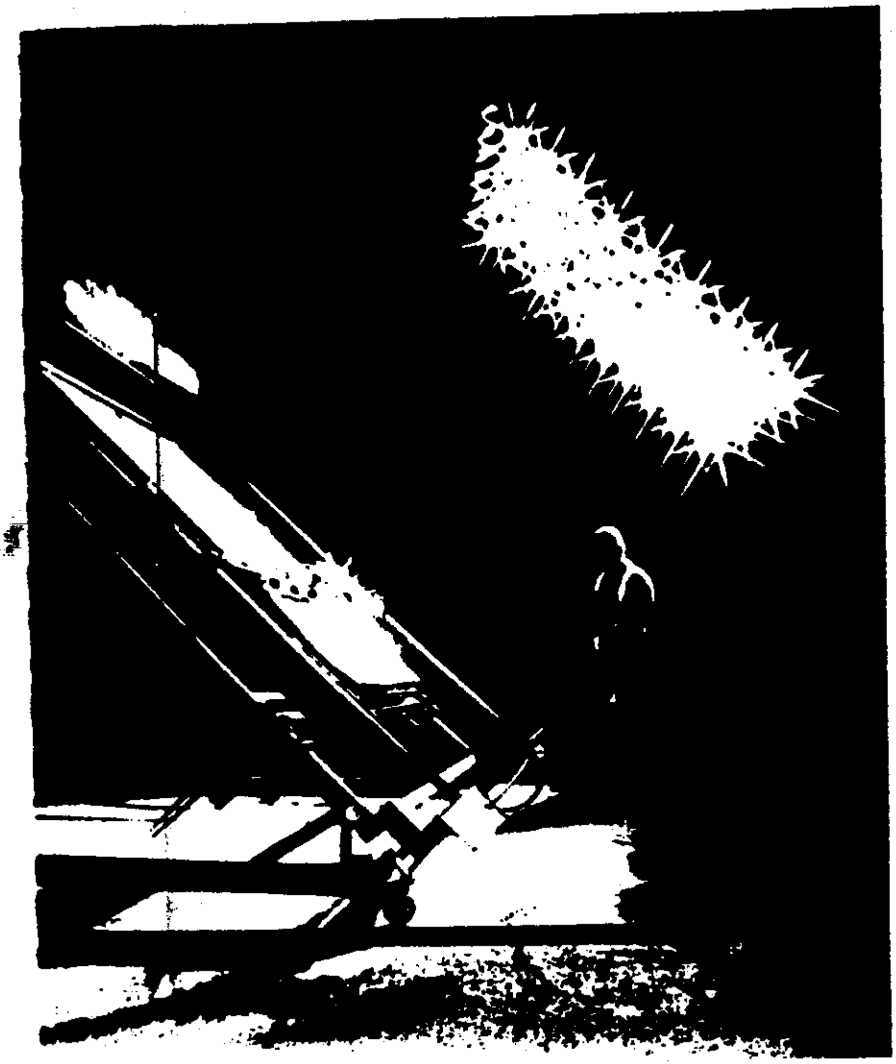
The installation consists of two large frames facing one another. One carries the solar panel to be tested, and the opposite frame carries a battery of 56 CSI lamps (each 1000 W capacity) in separate housings. Since the solar panel is tilted backwards, the array of lights is tilted forward at the same angle. The two frames are spaced from 8 to 12 meters apart. With a luminous output of 1000 W/m^2 and a high degree of uniformity, it is possible to obtain accurate tests of all types of solar panels.

A unique feature of the collector test stand is the construction of a test pit which has a lift platform. The platform provides a vertical movement for the test stand, which has a 0 to 90 degrees tilt adjustment, and a flux mapper attached to it. The flux mapper enables the operator to ensure a uniform incidence of light on the collector. Ten WMO (World Meteorological Organization) black body radiometers measure the irradiance level. The solar simulator is provided with 56 CSI (Compact Source Iodide) lamps. Each lamp's illuminance can be individually controlled. An irradiance intensity as high as 1353 W/m^2 can be achieved. Spectral quality of irradiance complies with ASHRAE Standard 93.

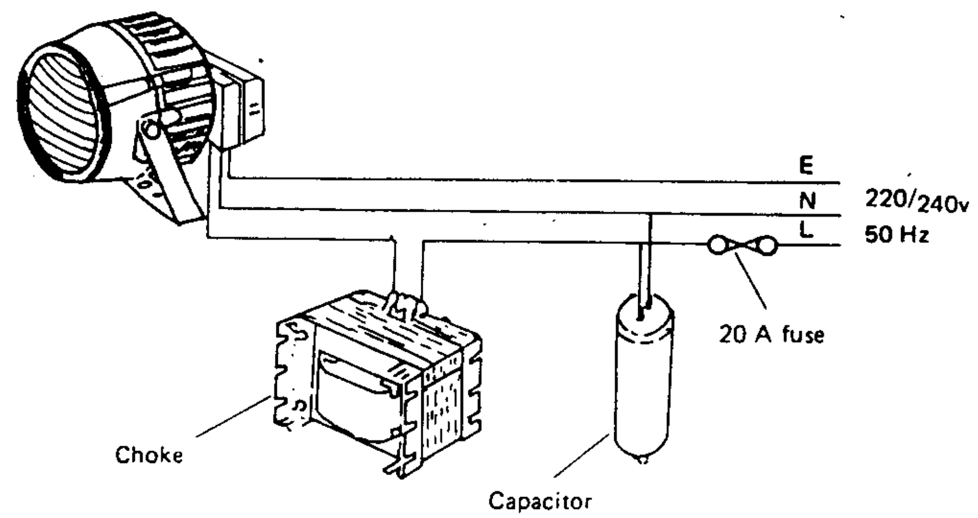
The test stand and the simulator were supplied by the DSET Laboratories,Inc., Phoenix, Arizona,USA. This is an internationally known materials weathering and solar device testing facility.

SOLAR SIMULATOR LAMP ARRAY

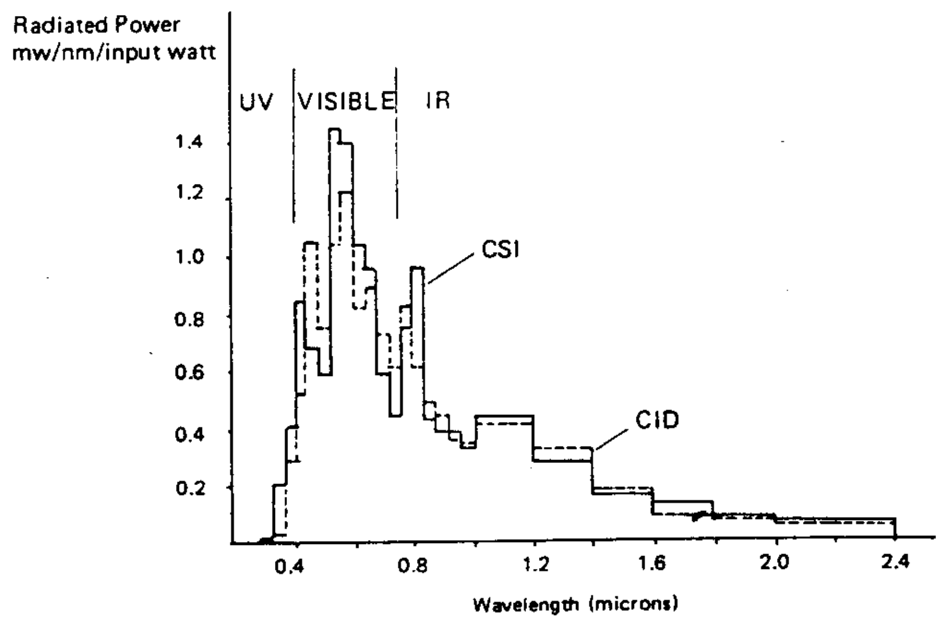
Lamps which have been used for solar simulator studies include tungsten halogen, compact source zenon and metal halide designs. By the use of suitable filters, the spectra of such lamps can be modified to approximate to that of sunlight. However, it has been widely accepted that the Compact Source Iodide lamps, in the sealed beam envelope give not only satisfactory match to the solar spectrum without the need for a filter, but also produces a convenient narrow beam of intense light [2]. Other advantages of CSI lamps include long life, built-in and sealed reflector, ease of elecrical control, and relatively low cost.



COLLECTOR TEST STAND AND SOLAR SIMULATOR LOCATED IN A TEMPERATURE CONTROLLED ROOM. THE SOLAR PANEL IS TILTED BACKWARDS AND THE ARRAY OF LIGHTS IS TILTED FORWARD AT THE SAME ANGLE. A WIND BENCH SIMULATES WIND VELOCITY. THE TEST STAND IS FULLY INSTRUMENTED TO MEASURE ALL THE PARAMETERS REQUIRED TO DETERMINE THE THERMAL PERFORMANCE, TIME CONSTANT AND INCIDENT ANGLE MODIFIER.



BASIC LAMP CIRCUIT. THE CSI LAMP PROVIDES A GOOD BALANCE IN ITS SPECTRAL QUALITIES, CLOSELY MATCHING THAT OF SUNLIGHT. THE LAMP OPERATES FROM THE NORMAL 240 VOLTS A.C.SUPPLY,WITH A SERIES CHOKE AND IGNITOR. IT IS SIMPLE TO INSTALL AND ECONOMICAL TO OPERATE.



SPECTRAL DISTRIBUTION OF CSI LAMPS SHOWS GOOD SPECTRAL BALANCE. SINCE THE SEALED BEAM TYPE ENCLOSES THE QUARTZ ARC TUBE,RADIATION BELOW 320 nm AND ANY OZONE RADIATION, HOWEVER SMALL,IS EXCLUDED. THE AMOUNT OF SOLAR RADIATION BELOW 300nm REACHING THE EARTH'S SURFACE IS SMALL. IN THE VISIBLE REGION 400-700nm A HIGH EFFICIENCY IN POWER CONSUMPTION IS OBSERVED. IN THE 780-3000 nm REGION,THE LAMP PROVIDES MUCH IMPROVED BALANCE WITH THAT OF SOLAR RADIATION.

However it is to be noted that true simulation is not possible and hence some standards have to be applied. ASHRAE has set up the standards for a solar simulator, and they are summarized here:

Band	Air Mass 2 Per cent energy in band	Maximum deviation of solar simulator in percentage
0.3 - 0.4	2.7	15
0.4- 0.7	44.4	9
0.7 - 1.0	28.6	3
1.0 - ∞	24.3	10

During operation at the Solar Village, it was found that the CSI lamps gave satisfactory performance. Only a few lamps had to be replaced due to failure.

COLLECTOR THERMAL PERFORMANCE

The thermal performance of a solar collector is determined by establishing an efficiency curve from the instantaneous efficiencies obtained for a combination of values of incident solar radiation, ambient temperature, and inlet fluid temperature. Measurements are made according to the standards, of the fluid flow rate, the temperature of the fluid at the inlet and at the outlet, the incident solar radiation, the ambient temperature, and the wind speed.

ASHRAE 93-77 specifies methods to determine the time constant of a collector and its incident angle modifier. The time constant determines the time response of a collector in order to evaluate its transient behaviour and to select the proper time intervals for the quasi-steady state or steady-state efficiency tests.

CONCLUSION

The thermal performance of several flat-plate collectors was determined at the Solar Village and it was found that the test facility indicated that there was a good match between the test stand and the simulator, and that collectors could be tested with ease, reliability and effectiveness.

REFERENCES

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