AN INTEGRAL SOLAR WATER HEATER

by

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ABSTRACT

A novel design of a solar water heater in which the collector and storage tank are constructed as one unit is described. Tests indicated that the daytime collector performance was quite satisfactory and the night time losses were acceptable.

INTRODUCTION

The utilisation of solar energy for water heating is perhaps one of the simplest and most direct applications. Consequently considerable work has been carried out on the design, fabrication and testing of solar water heaters (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12).

The 'conventional' type of solar water heater (7) consists essentially of two elements viz, the solar collector and the hot water storage tank. Several variations of this basic combination have been designed, studied and some of them marketed successfully. Design and fabrication concepts have been towards producing the solar energy collector element more economically and towards greater efficiency of solar energy collection and storage.

In the conventional solar water heater, utilising separate solar energy collector and storage tank and employing the thermosyphon effect, the cold water outlet from the storage tank should be higher than the hot water outlet from the collector. This arrangement places a constraint on the use of these solar water heaters at localities of low latitude i.e. the tropics, where the sun at certain times of the year moves north or south of overhead. In these latitudes the storage tank should be placed so that at no time of the year does it cast a shadow on the collector surface. Consequently, the arrangement generally tends to be wasteful of space. Furthermore, the connecting pipework adds to the thermal and frictional losses.

The early Japanese simple water heaters (9) which were essentially solar hot boxes, were very neat packages, easy to assemble, erect and operate. In addition they do not suffer the disadvantage mentioned above though it is unlikely that this consideration formed any part of the design concepts at the high latitudes of Japan. These simple water heaters, however, suffer the severe disadvantage of negligible overnight thermal storage capacity, the heat being lost to the atmosphere during the nights.

It would appear that wider acceptance of solar water heaters may perhaps be expected provided the unit has the advantage of the simplicity of design of the simple Japanese type water heater combined with some significant overnight thermal storage capacity.

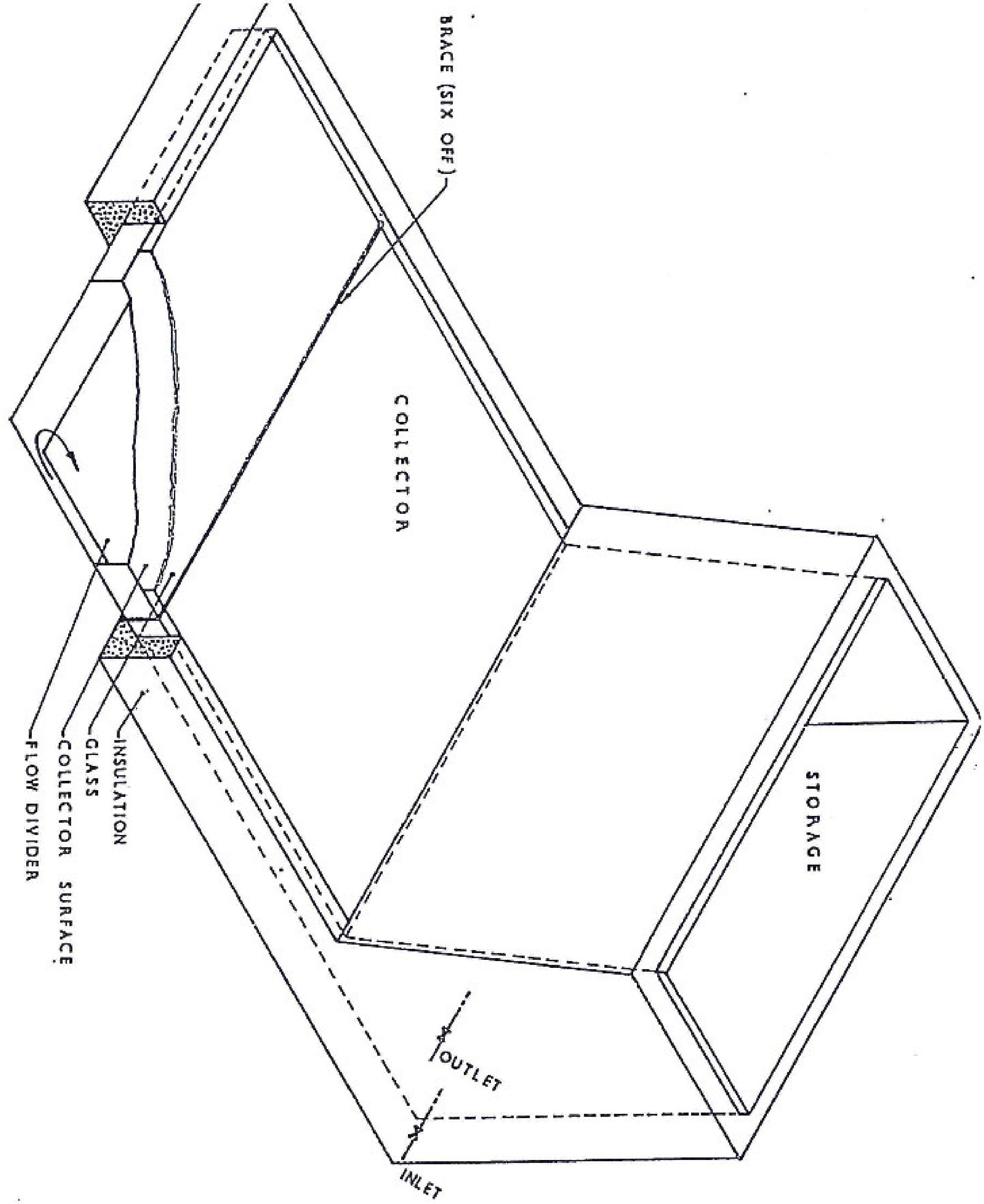
With these ideas in mind a solar water heater in which the collector element and storage are combined into one unit was built and tested. This paper presents the results of this study.

THE INTEGRAL SOLAR WATER HEATER

The solar water heater is shown in Fig. 1. The unit was fabricated from 22 gauge galvanised iron sheets. The collector part consists essentially of a rectangular sectioned passage with a sheet of metal acting as a flow divider. The top of the collector is painted flat black and is covered with one pane of ordinary window glass (2 mm thick). Braces were placed at regular intervals across the width of the collector section to contain the bulging under the water pressure during operation.

The front of the storage section is raked back at an angle of 15^{o} to allow for the solar declination when placed on a tilted supporting frame. All surfaces other than the glass cover were insulated with a thickness of 4 cm of styrofoam. Provisions were made for the draw off of hot water, the supply of cold water, drain and overflow.

The nominal dimensions of the collector surface were 0.914 m x 1.22 m. The net collector area (allowing for glass



SCHEMATIC DIAGRAM OF INTEGRAL WATER HEATER

FIG. 1.

mounting and insulation) was 1.04 m^2. The filled capacity of the complete water heater up to the level at which the float valve cuts off the supply was 0.27 m^3 of which 0.07 m^3 was directly under the collector surface.

Several thermometers were placed at appropriate locations to measure the temperatures at various points in the heater. These were read every half hour.

RESULTS AND DISCUSSION

The solar water heater was filled with cold water overnight and temperature readings were commenced before dawn. Continuous readings were taken over four consecutive days (excepting nights) and the results over these four days are given in Figs. 2 to 5. In these figures the results are given for the variation in temperatures over the day and the cumulative insolation normal to the collector glass cover. The four temperature curves are the overall average temperature T_{ave}, the lowest temperature in the water heater T_{min} (obtained at the toe of the collector), the highest temperature T_{max} (obtained at the top of the storage sections) and the shaded atmospheric temperature T_a.

During the period of the tests, the local solar time lagged local standard time by about 4 to 8 minutes. The graphs therefore, though plotted in terms of local standard time, may be taken to be in terms of local solar time without significant error.

Table 1 gives a summary of the overall performance of the water heater over the four consecutive days. The collection efficiencies based on the operation from 9 a.m. to 3 p.m. are roughly the same for the different starting temperatures.

	T_i °C	T_f °C	ΔT °C	QabsMJ	QinsMJ	Eff. %
Day 1	29.5	36.8	7.3	8.23	13.9	59.4
Day 2	34.1	43.8	9.7	10.95	17.0	58.5
Day 3	38.3	47.8	9.5	10.75	18.7	57.5
Day 4	41.2	49.7	8.5	9.60	16.1	59.5

TABLE 1: Performance of water heater for the period 9a.m. to 3p.m

T_i - Overall average Temperature at 9a.m.

T_f - Overall average Temperature at 3p.m.

Table 2 gives the overnight storage characteristics of the water heater for the three consecutive nights of the test. This is seen to greater effect in Fig. 6 where the dawn temperatures are shown against the temperature of the previous night for T_{ave}, T_{max} and T_{min}.

	T_{ave}			T_{max}			T_{min}		
	6 p.m.	6 a.m.	ΔT_{ave}	6 p.m.	6 a.m.	ΔT_{max}	6 p.m.	6 a.m.	ΔT_{min}
Night 1	37.5	32.5	5.0	37.8	35.8	2.0	36.5	30.5	6.0
Night 2	43.5	37.5	6.0	43.8	41.3	2.5	42.3	33.5	8.8
Night 3	48.2	40.5	7.7	48.8	6.1	2.7	48.0	36.3	11.7

TABLE 2: Overnight temperature drops during the period 6p.m. to 6a.m.

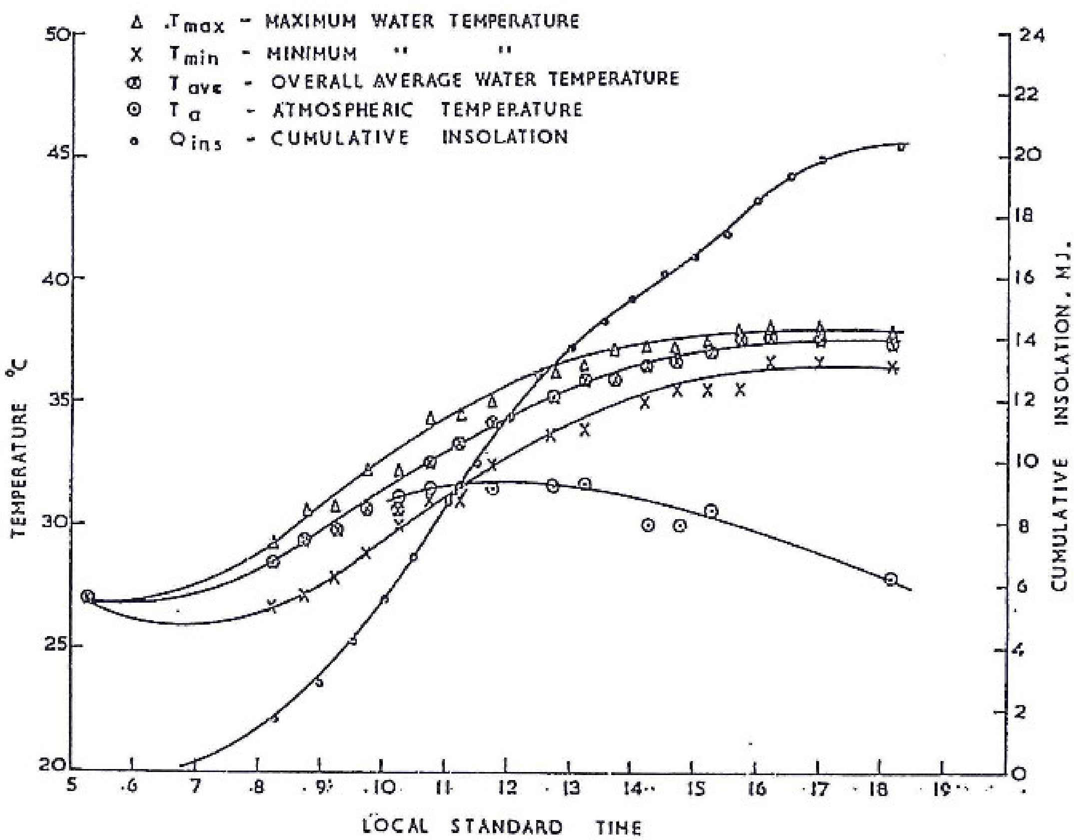


FIG 2 TEMPERATURE & INSOLATION OVER DAY 1

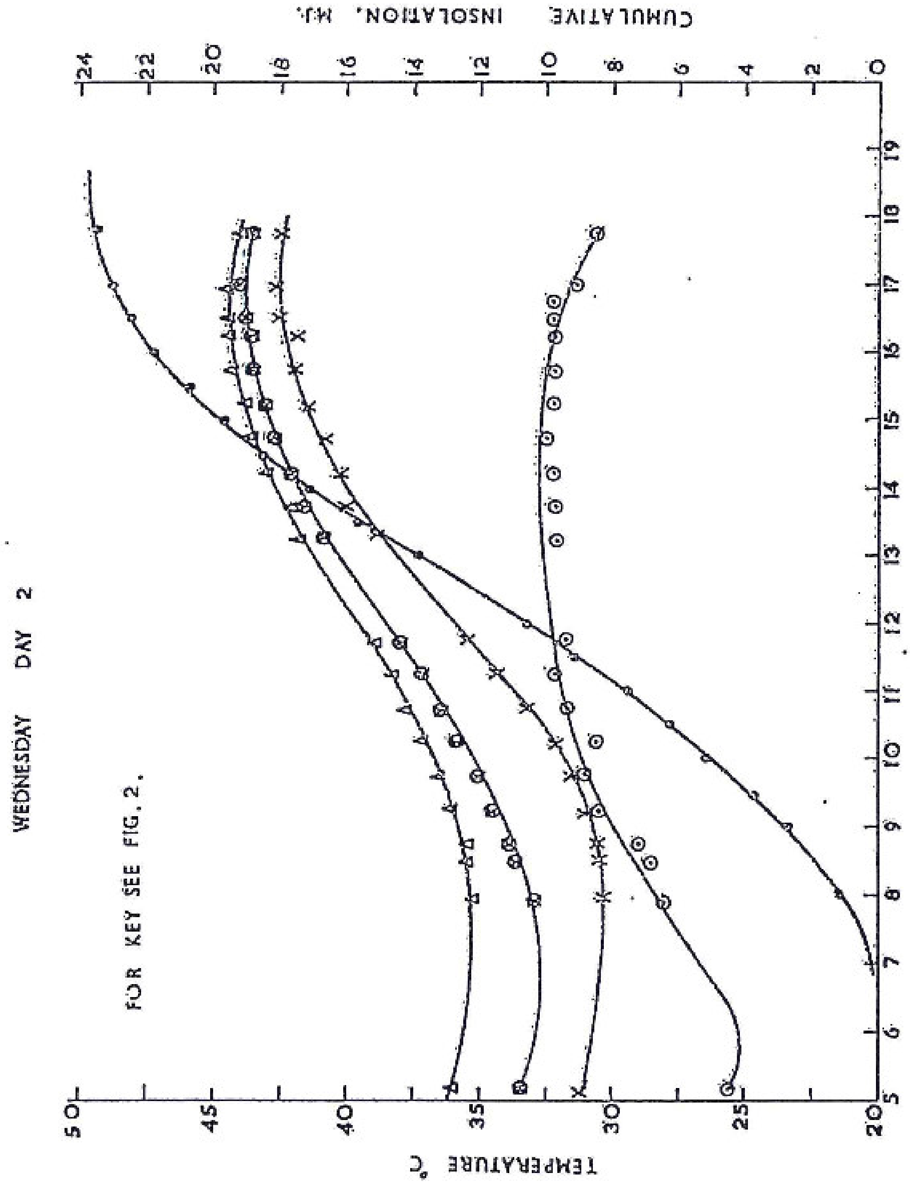

WEDNESDAY DAY 2
FOR KEY SEE FIG. 2.
TEMPERATURE °C
CUMULATIVE INSOLATION, MJ.
LOCAL STANDARD TIME

Fig. 3.

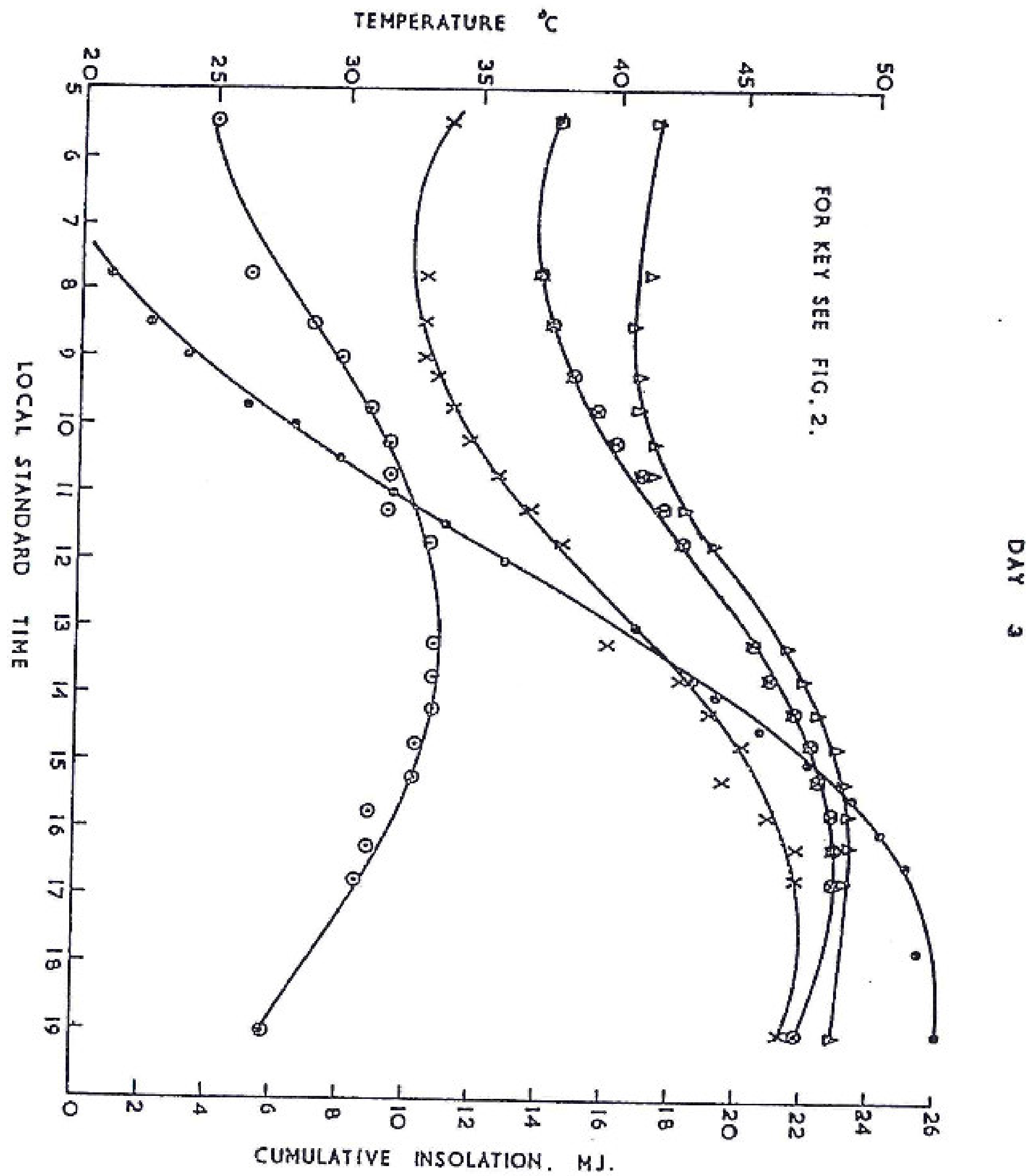
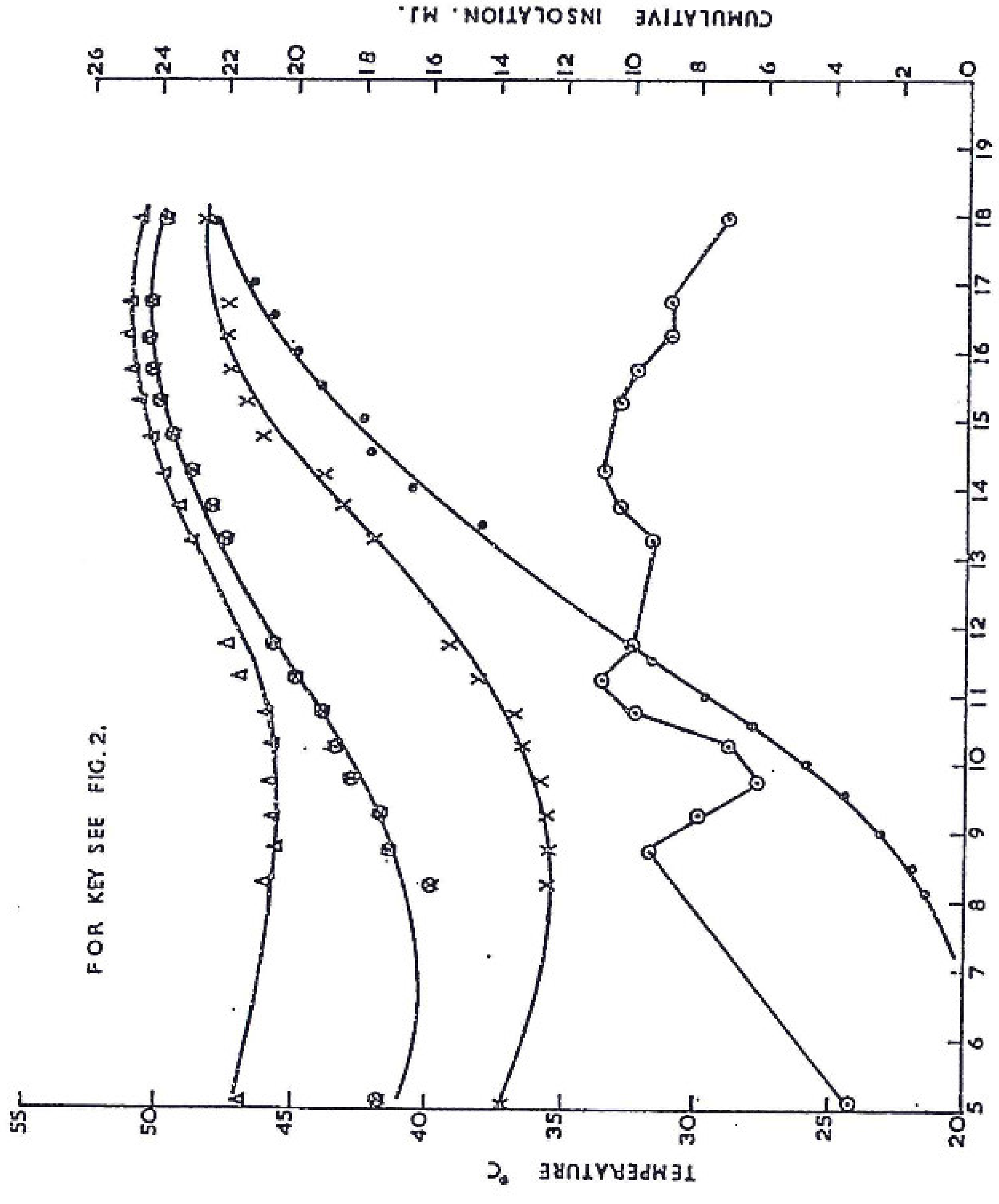

DAY 3
FOR KEY SEE FIG. 2.
TEMPERATURE °C
20
25
30
35
40
45
50
LOCAL STANDARD TIME
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
CUMULATIVE INSOLATION. MJ.
0
2
4
6
8
10
12
14
16
18
20
22
24
26

FIG. 4.



FOR KEY SEE FIG.2.
TEMPERATURE °C
LOCAL STANDARD TIME
CUMULATIVE INSOLATION, MJ.

Fig. 5.

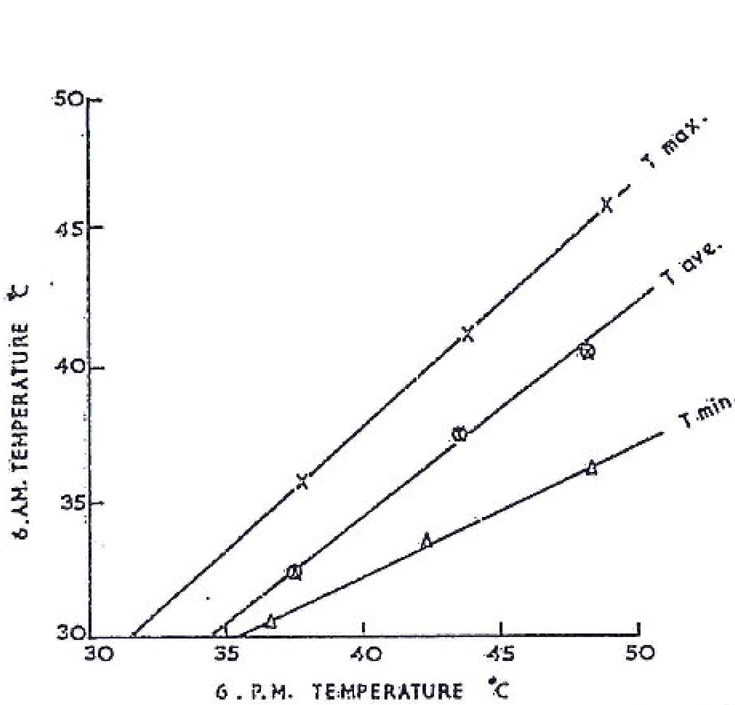


FIG. 6. OVERNIGHT TEMPERATURE DROP

The object of the present programme of work was the establishment of the feasibility of two basic concepts viz (a) the workability of an integral solar water heater in which the heater/collector element forms an integral part of the storage system or vice versa and (b) that such a system could be designed to have a reasonable overnight storage capacity.

The workability of the design is clearly seen from Figs. 2 to 5. It is also evident that the final equilibrium temperature of this particular unit is about 52°C. Estimates indicate that this temperature could be raised to about 55 - 60°C with adequate bottom and side insulation.

During construction and initial testing it was found that the bulging of the top of the collector plate under the hydrostatic water pressure reduced the clearance between the glass cover and the blackened plate to almost zero, necessitating repositioning the glass cover at a greater initial distance (5.1 cm). This will increase the cover

(11) Gopffarth, W.H. et al "Performance correlation of horizontal plastic solar water heaters". Jl. Solar Energy Vol. 12, No. 2, p. 183, 1968.

(12) Vincze, S.A. "A high speed cylindrical solar - water heater". Solar Energy, Vol. 13, No. 3, p. 339, 1971.