A COMPARISON OF EFFICIENCIES SIMILARLY BUILT CORRUGATED STEEL SOLAR COLLECTOR AND A COPPER FLAT PLATE SOLAR COLLECTOR

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Training in Alternative Energy Technologies

Session 7

June 1983

I. ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to the U.S. Agency for International Development and the University of Florida for having made it possible to attend the seventh session of the Alternative Energy Technologies program. He extends his gratitude to Drs. E. Farber, R. Pagano, M. Bush and Mr. L. Laketek, for their continuous teaching support and encouragement throughout the session.

I wish to express special thanks to Mr. L. Laketek and Mr. V. Chesney who guided the tests of this project.

II. INTRODUCTION

The renewed interest in solar collectors, as a response to rising energy costs, has produced a wide range of models and designs which are now available in the market place. The need to test the performance of these collectors established the necessity for standardized procedures. These now exist and are used in many testing facilities, both in the U.S. and abroad. Therefore, the theoretical considerations in which the tests are based will not be discussed here.

The basic aim of this project was to test the efficiency of the solar collector at two constant flow rates while changing the inlet temperature from 32° to 60°C.

It is widely known that corrugated copper and copper tubes (pipes) are widely available even in the more remote areas of most countries; while it is also known that copper materials are not only more expensive but more difficult to find, especially in areas far from the main cities.

Therefore, this project, as previously stated, aimed to show the best case of the efficiency to make its use attractive in some countries.

III. CONSTRUCTION

A flat plate collector was built from corrugated copper flat plate and copper tubes (pipes). The dimensions of it are as follows:

The length	97 7/8"
The width	47 7/8"
The depth	3 3/4"
The glass cover (special thick glass)	3/16"
The weight	161 lb.
Temperature application	32°-160°F
Fluid capacity	.79 gallon
Aperture area	29.8 ft^2
Pressure drop at 0.03	GPM/sq. ft. = 0.6 ft.

While constructing the collector, the black paint was mostly off, so we repainted it, then we fixed the collector and also fixed teh thermocouples as shown.

Number	Place
1,2,3	On the absorber plate
4	On the lower side
5	On the right side
6	On the upper side
7	On the left side
8	Above the glass cover
9	Under the bottom
10	Throw open cover to measure the ambient temperature

This arrangement was followed in aranging the channels as well (see Table 1).

IV. DATA ACQUISITION, CONVERSION AND RESULTS

The tests on the collector were done according to ASHRAE Standard Test 93-77. The location: in the energy park by using the earg test (See Figure 1.) The earg test has the following devices:

1. The heat exchanger	To freeze the water in the storage tank
2. The flow calibration facility	To adjust the flow rate through the sytem
3. The storage tank	To store the hot water
4. The pump	To pump liquid through the system
5. The electric heater	To heat the water and to control the water temperature
6. The flow meter	To measure the value of the flow rate

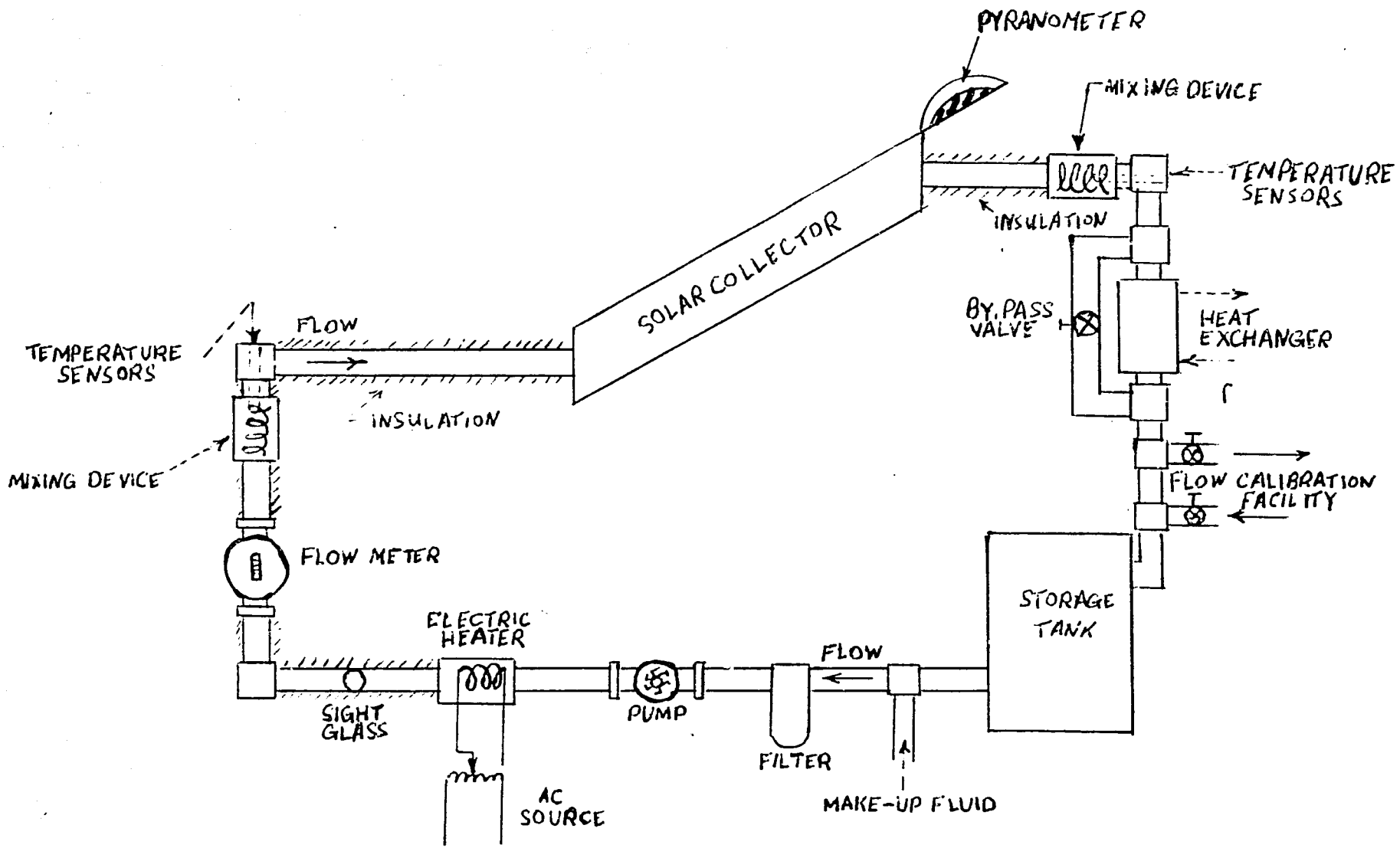


Fig. 1 Closed-Loop Testing Configuration for the Solar Collector when Transfer Fluid is Liquid.

7. The mixing device — To mix the water so it will all be at the same temperature

The thermocouples go through the channels to the recorder to record the measurements every five minutes.

Table 1.

The Channel No.	The Value of:
800	The pyranometer to measure the value of the insolation in m.v.
801	The Delta temperture in m.v.
803,4,5	The average temperature of the flat plate in °F
806	The temperature of the lower side in °F
807	The temperature of the right side in °F
808	The temperature of the upper side in °F
809	The temperature of the left side in °F
810	The temperature of the outer surface of the glass in °F
811	The temperature of the bottom surface in °F
813	The ambient temperature in °F
815	The inlet temperature in °F
825	The outlet temperature in °F

The Test Process

1. Adjust the flow rate at higher main value in GPM or flow meter.

2. Adjust the inlet temperature of water to equal the ambient temperature.

3. Adjust the orientation of the collector tube to face directly with the sun and measure the θ angle.

4. Change the orientation and take a measure every five minutes.

5. Change the inlet temperature of the water by raising it until it reaches 60°C.

6. Collect the data that you have.

The Calculations

1. Calculate the efficiency and $\frac{\Delta T}{I}$ every five minutes.

2. Calculate the slope of the curve by using the values of the efficiencies and $\frac{\Delta T}{I}$

3. The equations used in the calculations are as follows:

$$Q_U = Q_{in} - Q_L$$

Q = Useful energy gained from the collector

$$\eta\% = \frac{\dot{m} \times C_p \times \Delta T}{I \times A_c}$$

$\dot{m}$ = the mass flow rate in IB/hr

C_p = the specific heat Btu/IB.F°

ΔT = the difference between the inlet temperature and the outlet temperature in °F.

I = the solar radiation in $W \cdot m^{-2}$ or $Btu/hr.ft^2$

A_c = the area of the collector in (ft^2)

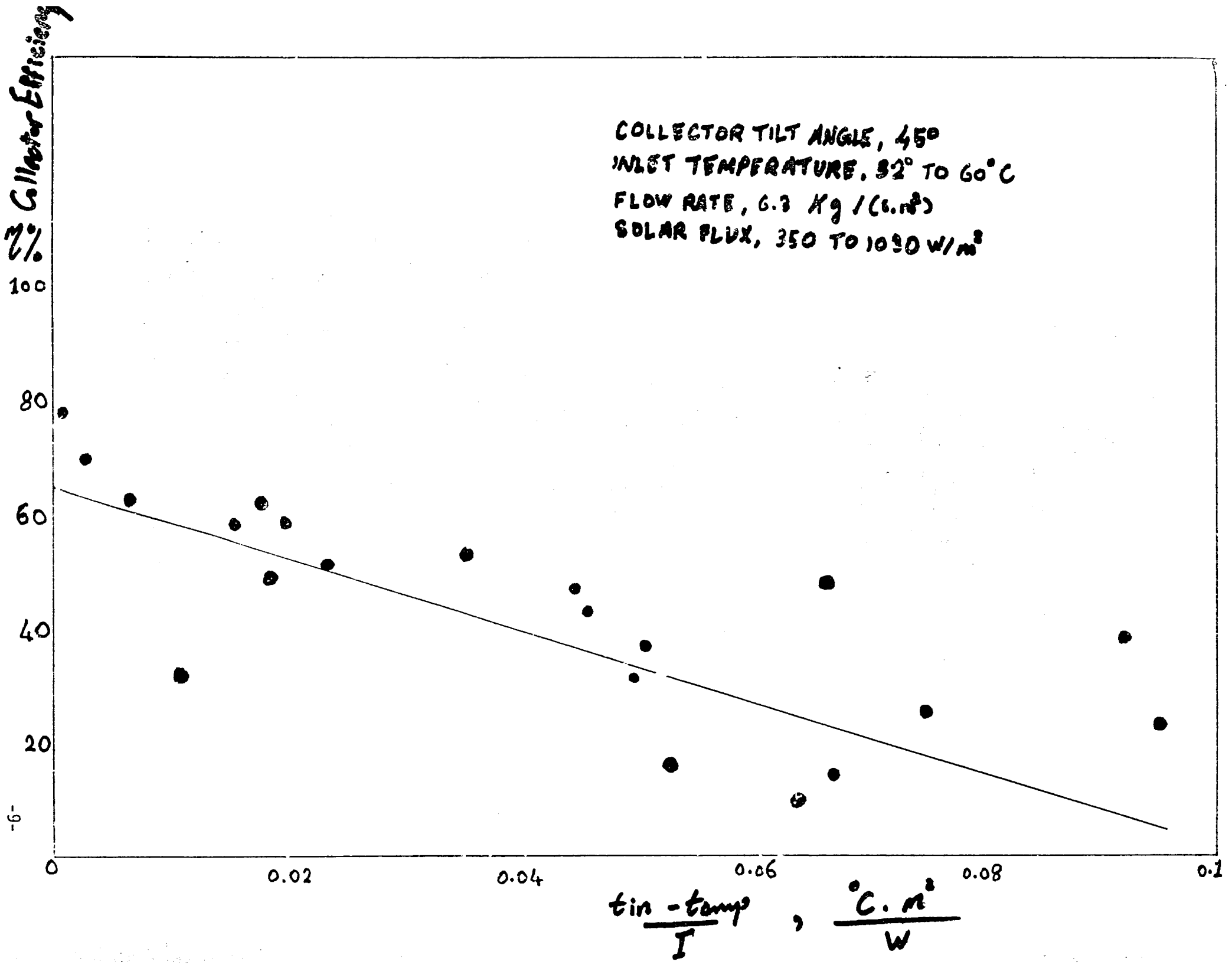
$$\frac{\Delta\ (m \cdot v)}{4} \times \frac{T_1\ (°F) - T_2\ (°F)}{T_1\ (m \cdot v) - T_2\ (m \cdot v)} = \Delta T\ (°F)$$

$$\frac{I\ (m \cdot v) \times 10^{-6}}{11.05 \times 10^{-3}} = I\ w \cdot m^2$$

$$\frac{I\ w \cdot m^{-2}}{3.154} = I\ (Btu/Ft^2\text{-}hr)$$

Data of Solar Collector Testing

Time	$\theta°$	Temperature °F	$\frac{\Delta T}{I}$, $\frac{K.m}{W}$	η%
9:35	13	85.7	0.003	70.15
9:45	10	86.0	0.0029	69.33
10:00	8	86.6	0.007	63.08
10:10	5	87.2	0.0096	77.96
10:30	2	88.2	0.015	58.7
10:30	0	88.9	0.0153	58.64
10:40	2	88.6	0.0178	62.12
10:50	3	89.3	0.0186	49.34
11:00	7.5	89.4	0.024	50.77
11:10	9	89.8	0.02	59.2
11:15	10	91.5	0.023	50.74
11:20	10	89	0.0335	53.46
11:25	11	88.3	0.092	38.32
11:30	12	89	0.0668	14.66
11:40	13	88.3	0.095	23.48
11:50	15	87.1	0.0497	31.54
12:00	16	87	0.036	59.57
12:05	18	89.3	0.0664	48.2
12:10	19	89.3	0.075	25.78
12:15	19	90	0.053	15.82
12:20	19	88.2	0.11	31.95
12:35	20	85.5	0.0162	56.71
12:40	20	88.5	0.06	7.68
12:45	20	94.3	0.045	46.59
12:50	21	94.1	0.051	36.98
12:55	22	93.4	0.046	43
15:20	22			


COLLECTOR TILT ANGLE, 45°
INLET TEMPERATURE, 32° TO 60°C
FLOW RATE, 6.3 Kg/(s.m²)
SOLAR FLUX, 350 TO 1090 W/m²
% Collector Efficiency
100
80
60
40
20
0
0.02
0.04
0.06
0.08
0.1
tin - tamp / I , °C.m² / W