DESIGN,DEVELOPMENT AND TESTING OF A PARABOLIC TROUGH SOLAR COLLECTOR

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CONTENTS

1.Introduction

This dissertation work was made an attempt to design, development and testing of a parabolic trough solar collector.

Objectives

Uncertainty over future sources of energy provides strong motivation to explore technologies that free systems from traditional energy inputs. The objective of this project is to investigate home built solar water heating systems that can be used in any climates.

A solar collector is a device for collecting solar radiation and transfers the energy to a fluid passing in contact with it. Utilization of solar energy requires solar collectors. These are general of two types:

(i) Non concentrating or flat plate type solar collector.

(ii) Concentrating (focusing) type solar collector.

(a) Parabolic trough collector (P.T.C)

(b) Mirror strip reflector

(c) Fresnel lens collector

(d) Flat plate collector with adjustable mirrors

(e) Compound parabolic concentrator (C.P.C.).

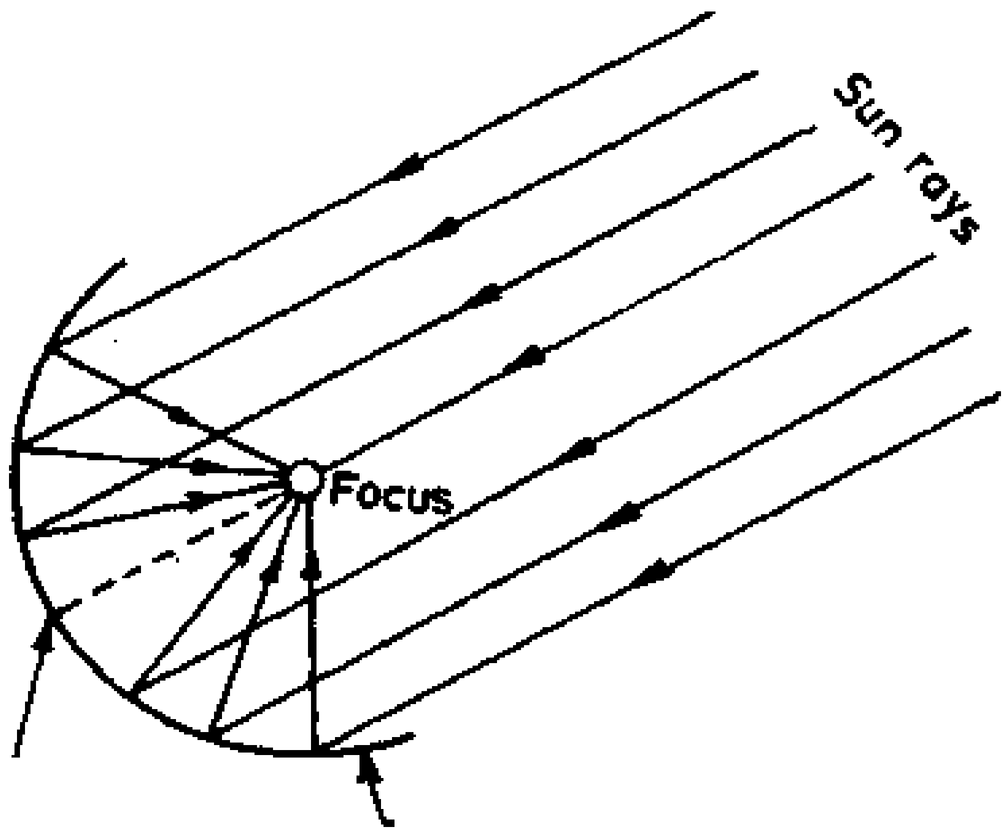


Fig. 1.1 Cross-section of parabolic-trough collector

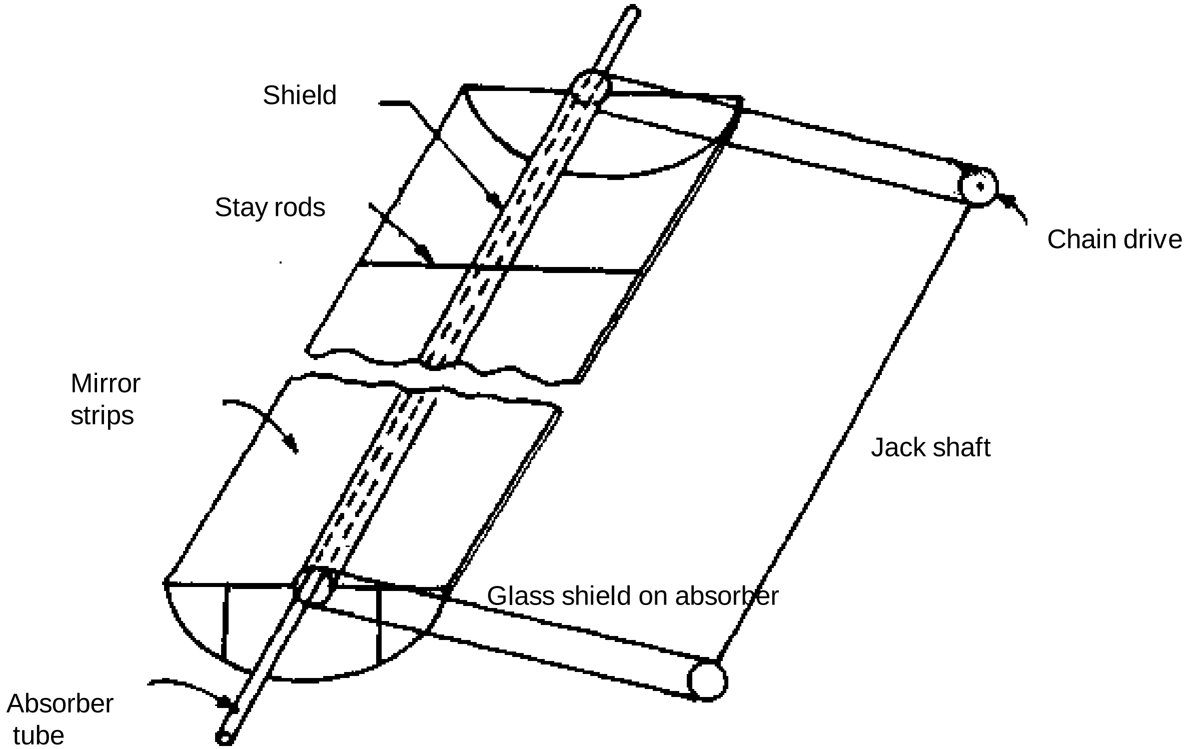


Fig. 1.2 A typical cylindrical parabolic system

Parabolic Trough Solar Collector: Description

The objective of the present work is to design, develop and investigate the performance of a PTC for hot water generation system. The cylindrical parabolic collector is also referred to as a parabolic trough collector or a linear parabolic collector. the basic elements making up a conventional collector are(1) the absorber tube located at the focal axis through which the liquid to be heatedflows,(2) the concentric transparent cover ,and (3) the parabolic concentrator .

HOW IT WORKS

Solar water heating, where heat from the Sun is used to heat water in glass panels on the roof.

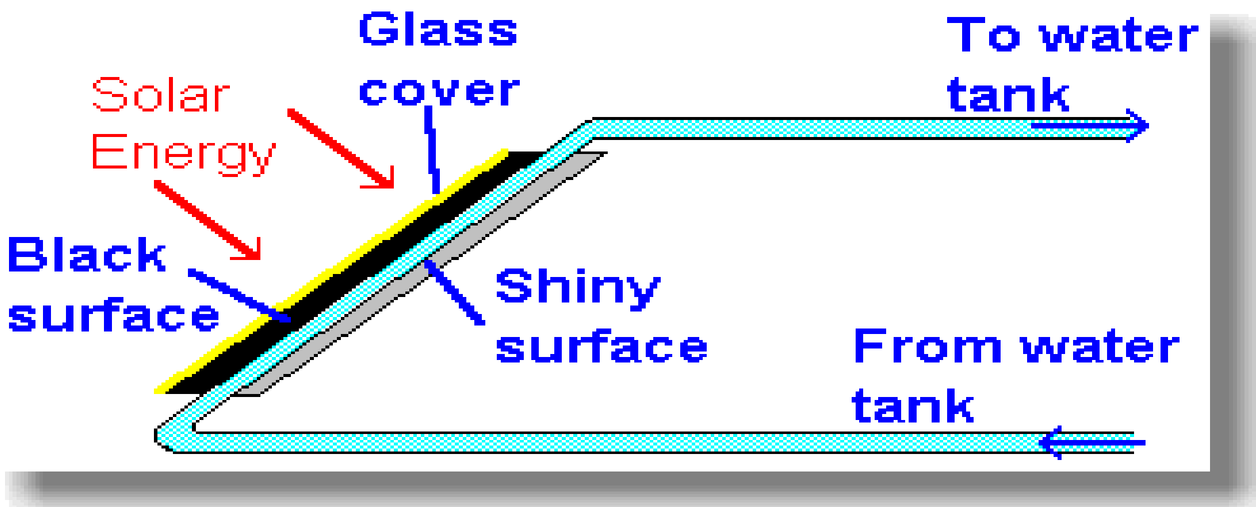
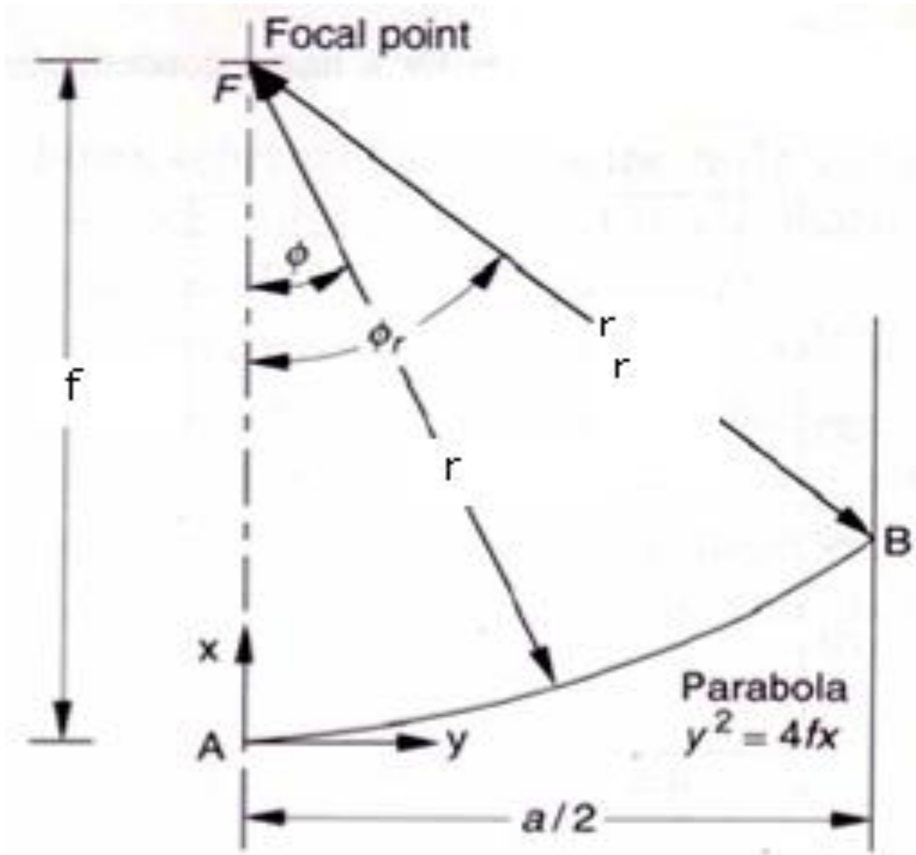


Fig. working principle

This means householders don't need to use so much gas or electricity to heat water at home.

2.DESIGN OF PARABOLIC TROUGH SOLAR COLLECTOR



2.1 Generation of the Parabolic Reflectors

2.1 Generation of the Parabolic Reflectors

Parabolic trough collector needs the parabolic reflector having two dimensional parabolic profile. To understand how these collectors operate, it is necessary to describe the optical properties of the concentrators and the images (the distribution of solar radiation flux across the focus) they produce. This section treats the geometry of reflectors and the width of the images they produce. The equation of the parabola, in terms of the coordinate system shown, is

$$y^2 = 4fx$$

For concentration ratio the equation is

$$C.R = \frac{(a - D)}{\pi D}$$

Perhaps the most important advantage is the enhanced thermal efficiency and therefore this is analyzed further. The thermal efficiency of a PTC is defined as the ratio of the useful energy delivered to the energy incident at the concentrator aperture. This may be calculated from anenergy balance on the receiver which is given by in terms of the heat removal factor,

...(1)

$$n = F_R\left(n_o - \frac{T_i - T_a}{I \times CR}\right)$$

...(2)

From both equations, it can be realized that the efficiency of a PTC depends on the optical efficiency (no) which is determined by the optical properties of the various materials used in the construction of the collector and the magnitude of the heat losses ,determined by the second termin eqn (1). The advantage of the PTCs is that, in the second term, the heat losses are inversely proportional to the concentration ratio (CR).

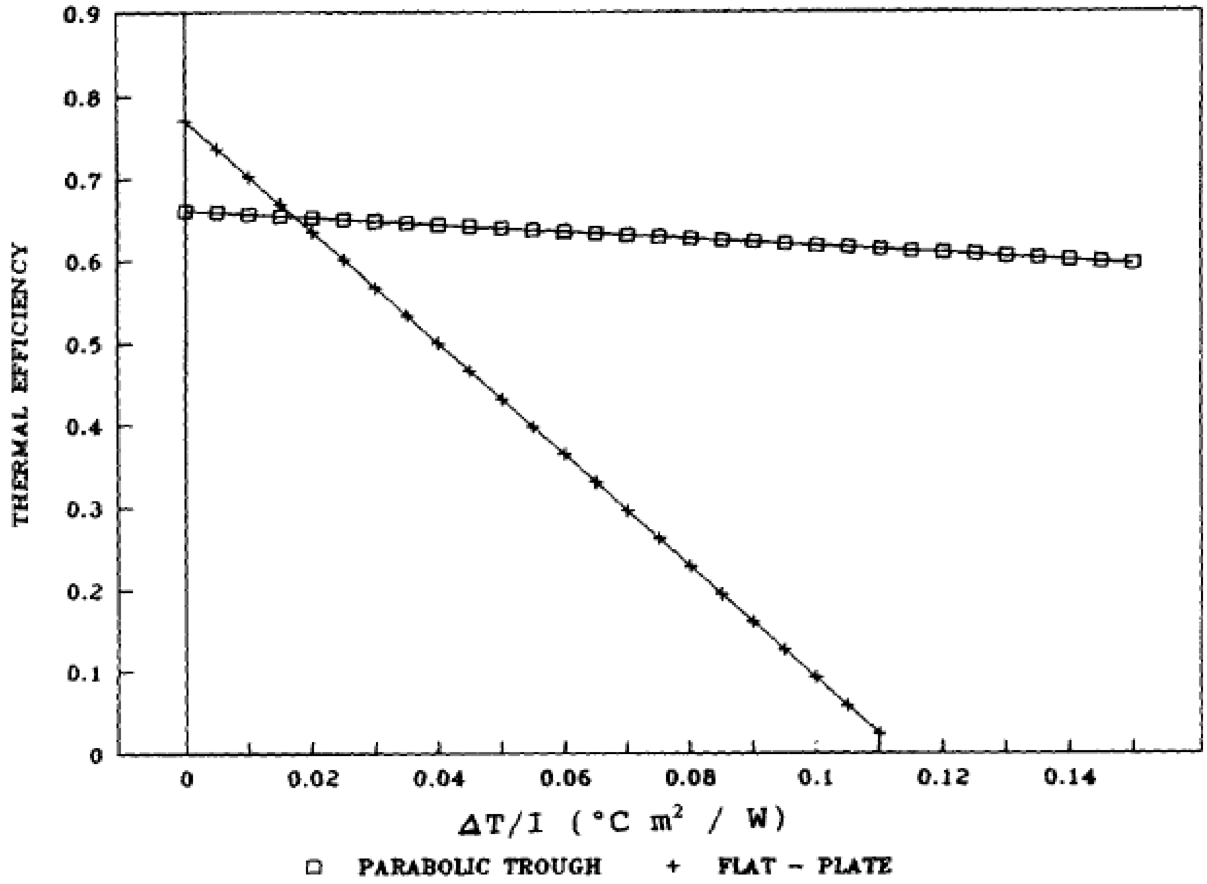
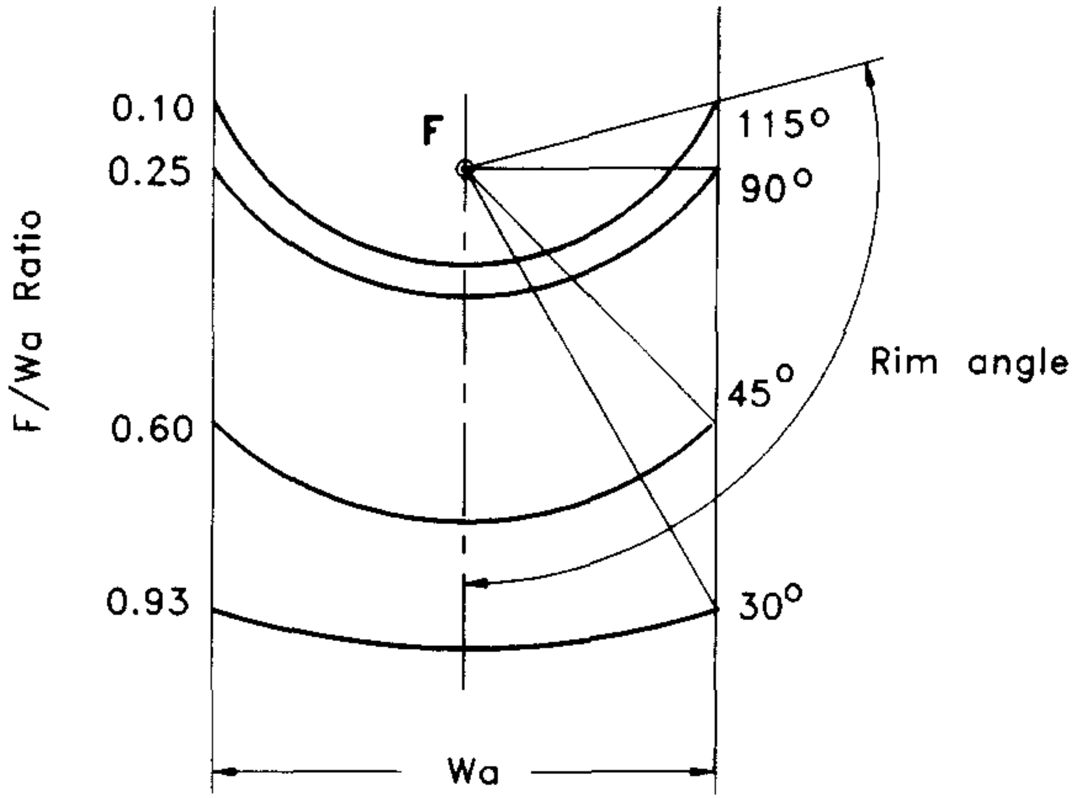


Figure: 3.2 Typical collector performance curves.

The standard collector-performance behavior can be described as a straight line graph. The slope and intercept of this line are then quoted as performance indicators. Therefore eqn (2) can be written as

$$n = I_n - S\left(\frac{\Delta T}{I}\right)$$

Optimization of the rim angle



3.2.3 .Selection of the receiver diameter

The receiver diameter determines the intercept factor and consequently the optical efficiency. The intercept factor is the ratio of the energy intercepted by the receiver to the total energy reflected by the focusing device Its value depends on the size of the receiver, the surface angle errors of the parabolic mirror, and the solar beam spread. According to Guven and Bannerot [36] these errors, or imperfections, are of two types, namely random and non-random.

Table 3.3 Intercept Factors for Various Receiver Diameters

Receiver diameter (mm)	*CR*	*Intercept factor*
6	42·44	0·80
9	28·29	0·94
12	21·22	0·98
15	16·98	0·99
18	14·15	1·00
21	12·13	1·00

Table 3.4 Thermal Efficiency as a Function of Receiver Diameter

Receiver diameter (mm)	*Optical efficiency*	*Thermal efficiency*
6	0·529	0·496
9	0·618	0·568
12	0·648	0·582
15	0·661	0·579
18	0·661	0·562
21	0·661	0·545

3.DEVELOPMENT OF PARABOLIC TROUGH SOLAR COLLECTOR

3.1 INPUT DATA

LENGTH OF PARABOLA (L)	= 2 meter
WIDTH OF PARABOLA (W)	= 1 meter
COLLECTING AREA (AC)	= 2 $meter^2$
RIM ANGLE (θR)	= 45º
ABSORBING FLUID	= Water

3.2 DERIVED DATA:

FOCAL LENGTH	= 250 mm
PARABOLA HEIGHT	= 250 mm
DIAMETER OF RECEIVER TUBE	= 12 mm
CONCENTRATION RATIO	= 52.76
REFLECTING MATERIAL	= ALMINIUM SHEET
STRUSS MATERIAL	= MILD STEEL
RECEIVER TUBE MATERIAL	= COPPER
COATING	= BLACK PAINT (WITHOUT SHINING)
SUPPORTING STRUCTURE MATERIAL	= MILD STEEL

3.3 Parabola construction

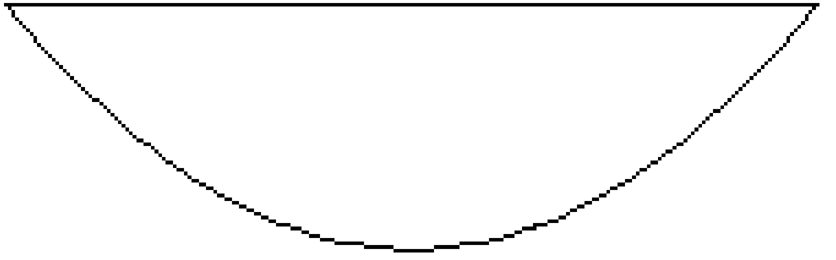


Figure 3.1 generated curve of parabola

The accuracy of the parabola plays important role in the performance of the collector. the surface imperfection (measured as the standard deviation of the surface errors) affect the intercept factor and consequently the efficiency of the collector. from this it must be realized that parabolic surface must be constructed as accurately as possible.

3.4 Receiver Construction

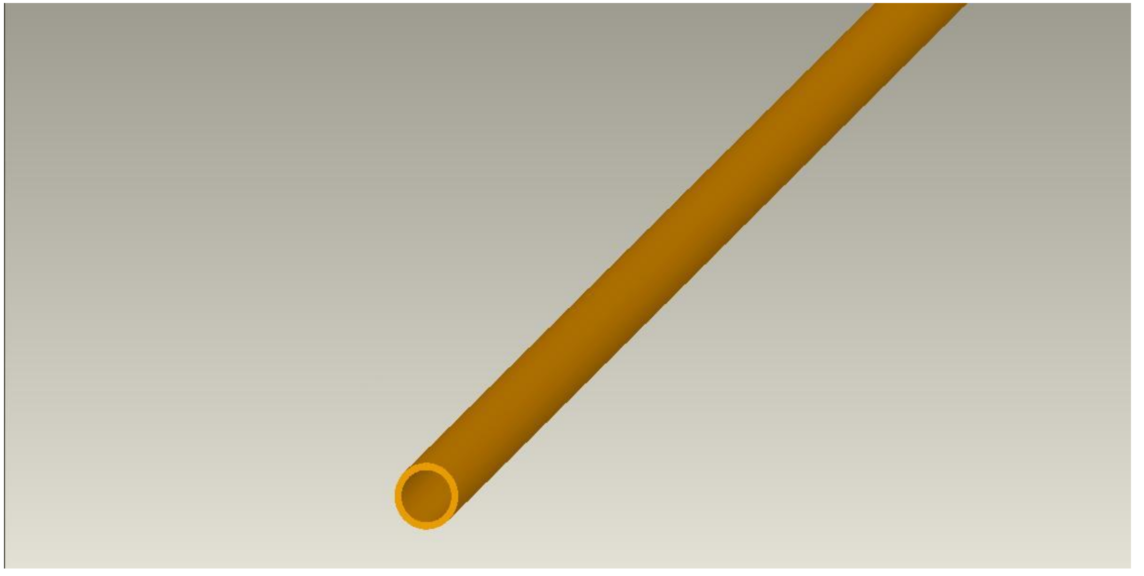


Figure: 3.2 Receiver tube

The receiver is made from the copper pipe. We find size of the receiver diameter according to equation (as in design chapter 2).the copper tube has high absorptance (0.96) and low emittance (0.08) of solar radiation.

3.5 Torque tube:

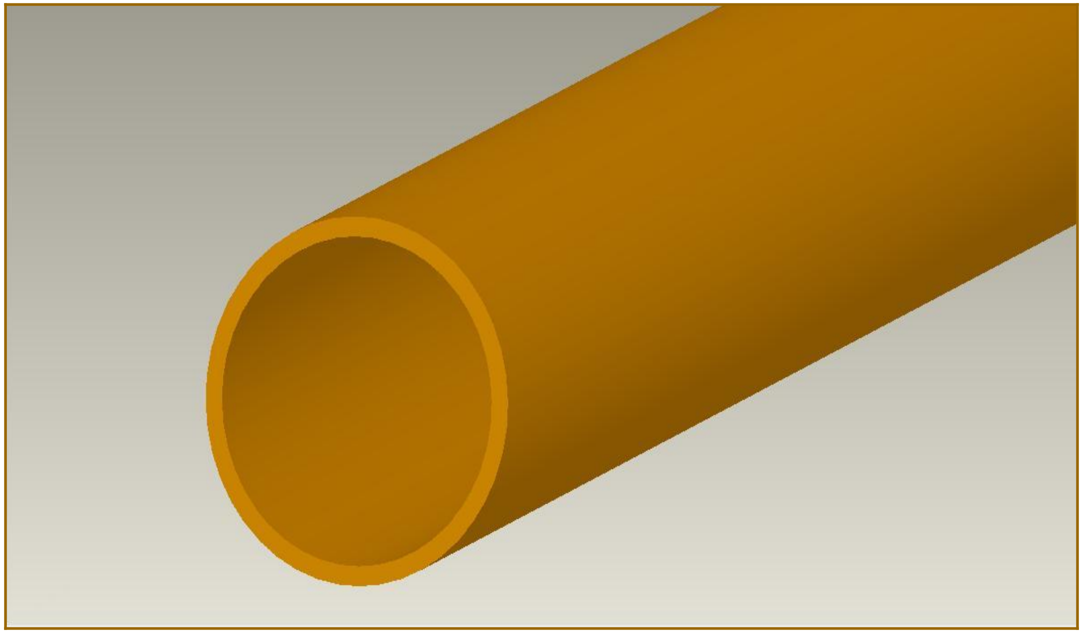


Figure: 3.3 Torque tube:

Torque tube has a length of 2.30 meter and it is passes through the holes of the middle of the frame. the material of the torque tube is mild steel.

3.6 Description of the frame:

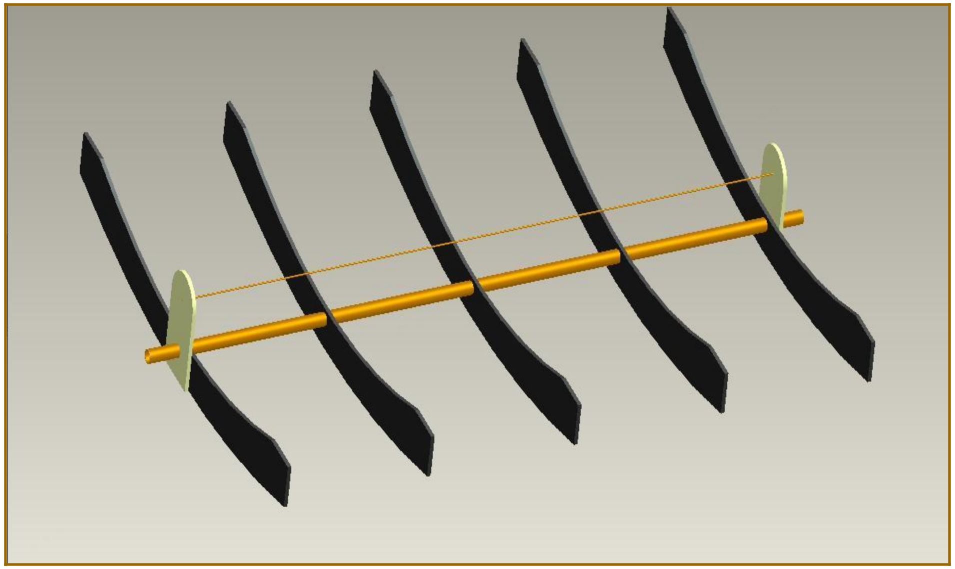


Figure 3.4 Frame structure

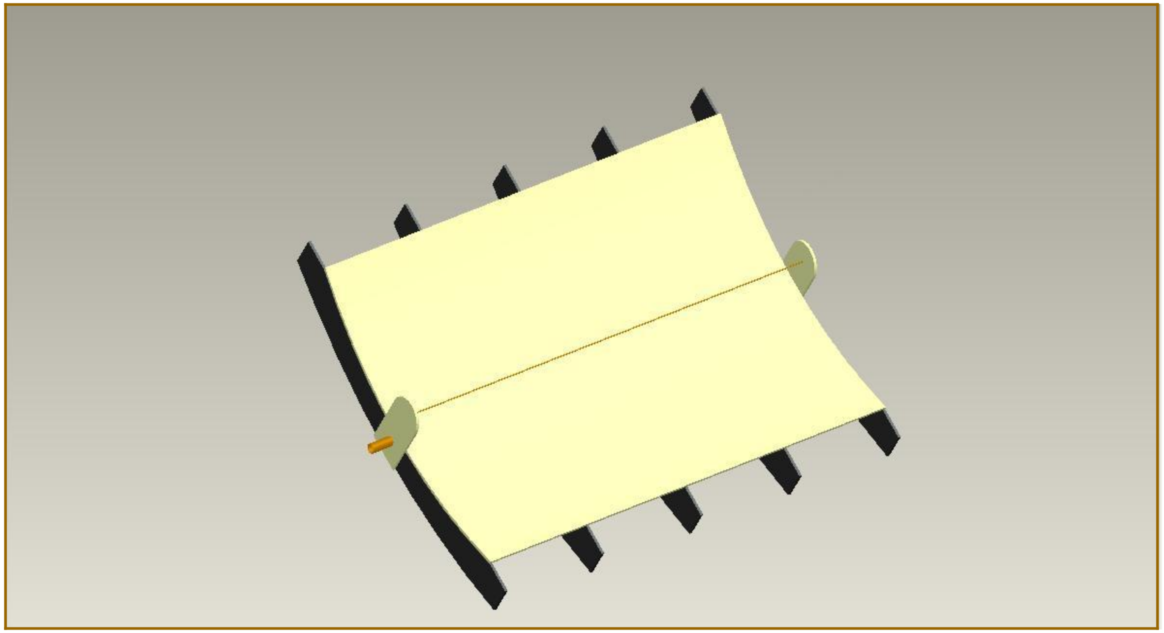


Figure: 3.5 Frame structure with aluminum sheet.

3.7 Tracking Mechanism: Manual

3.8 Experimental Setup and Instrumentation

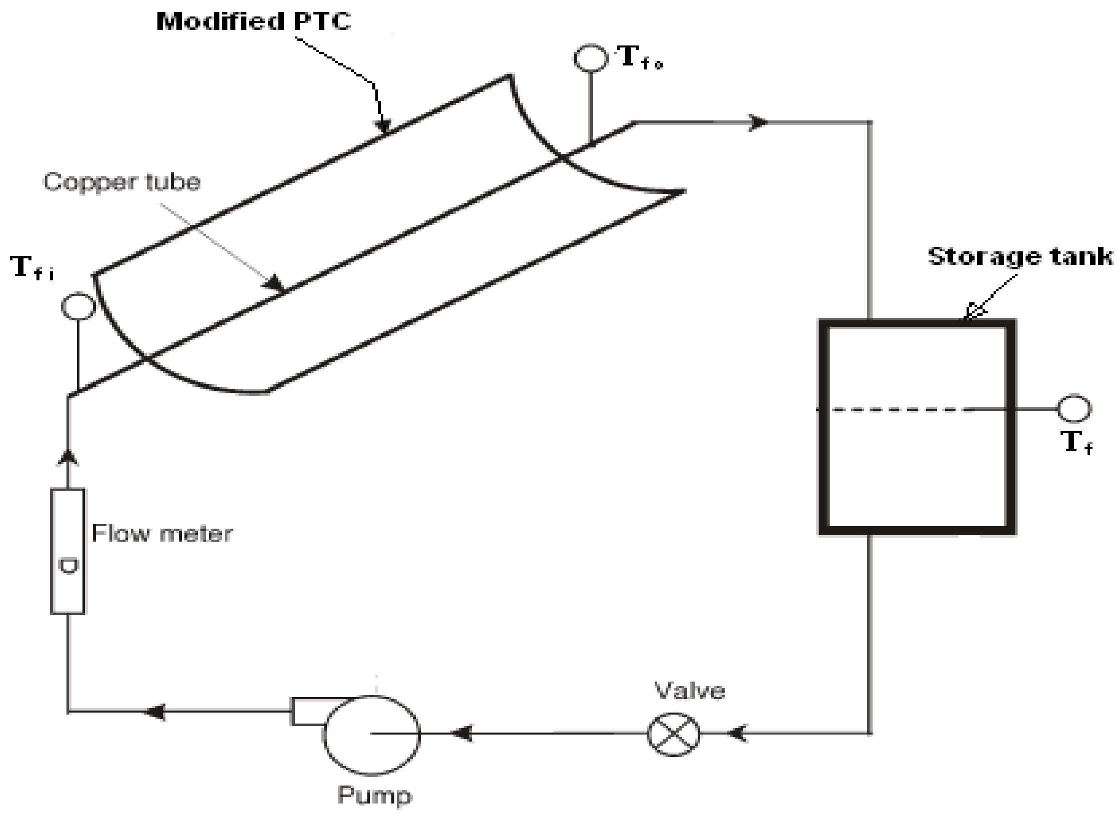


Fig. 3.6 Line Diagram for Experimental setup for PTC

Fig. 3.7 Flow Control Valve

Fig. 3.8 Surya Mapi

❑Conclusion

Design and development of Parabolic Trough Collector and subsequent experimental work carried out on this setup during the course of this work leads to the following clear conclusions:

(a) Initially the thermal efficiency is increasing with fluid temperature. After the fluid temperature around 42 C to 45 C, the thermal efficiency again decreases. This is due to higher convection losses at more temperature difference between fluid and ambient.

(b) The maximum thermal efficiency is ranging in between 20 to 22%.

(c) The average performance characteristics of the present Parabolic Trough Collector can be written as: $\eta_{thermal} = 0.353 - 0.0254 (\Delta T/I)$

(d) The performance characteristics of the parabolic trough solar collector are matching with the standard characteristics. The optical efficiency is varying in the range of 32% to 41%

❑ Scope of the future work

Parabolic Trough Solar Collector has been designed and developed during this course work. Due to time constrain, the testing and performance evaluation of the same was not carried out for a long period of time.

The following are the future scope:

(1) Test with thermic fluid

(2) Automatic tracking mechanism.

(3) Second axis tracking.

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