SOLAR THERMAL DEVICE WITH BUILT-IN FERRO-CERAMIC STORAGE SYSTEM

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ABSTRACT

The present paper discusses the unique design and the experimental performance of a low cost, portable, solar thermal device, which may be used for obtaining hot water. The radiation energy is stored in non-reactive, Ferro-ceramic materials, which can provide sensible thermal energy in absence of radiation source. The beauty of this device is that it receives the radiation not only from the top side but also from three sides of the central core and it is also heated up from lower sides of the collector and thus increases the thermal efficiency and reduces the heating time.

The ferro ceramic materials are chosen because of their high thermal masses stability at high temperature and the thermal retention property of the accumulated thermal energy increases every day till it reaches to thermodynamical equilibrium. This device is of modular type and it can be used in parallel and in series direction according to the needs of the consumers in any sectors either in small domestic sector or in big industrial sector.

Introduction

There are two major problems in optimal utilization of solar energy, one is its low flux density and other is its irregular availability. Therefore, multi-dimensional researches are being done in all parts of the world to overcome these difficulties by designing different types of solar concentrators and developing various types of thermal storage systems.\textsuperscript{1,2,3}

It is well known that solar energy is naturally stored, retained and radiated in different quantum in the same period of time in different ways in materials available in the world. The major characteristics of these materials for the thermal energy storage depend on (1) its specific heat (2) density (3) temperature range (4) thermal stability (5) thermal retention capacity and (6) heat transfer characteristics. It has been reported by several investigators that Ferro-ceramic materials having proper combination conducting ferrous material and non-conducting thermal retentive ceramic materials have proved an efficient sensible heat

Keywords: direct absorption, thermal mass, storage, modular type.
storage system because of its high specific heat, high density, high thermal stability, high thermal retention capacity and high heat transfer capability for higher temperature range\textsuperscript{4,5,6,7}.

The present paper discusses a multi-purpose solar thermal device, which may be used for cooking and obtaining hot air and hot water simultaneously. The beauty of this device is that it contains a Ferro-ceramic thermal storage system which can provide a fairly stable thermal energy in absence of solar radiation. This device can be used as a module to provide demands of every sector successfully.

**Design and Construction**

Figure 1(a) shows the photograph and Figure 1(b) shows the line diagram of the Multipurpose solar thermal device and it has following seven parts:

(i) A central tetragonal metallic core painted with non-reflecting black paint and filled with ferro-ceramic material.

(ii) A highly conducting metallic heat exchanger fitted inside the central core which is submerged in non-reactive radiation storing ferro-ceramic material.
(iii) Double transparent windows are jacketted around the three sides of the central core.

(iv) There are three, folding type radiation boosters of reflecting mirrors attached outside the transparent window. The purpose of these reflecting booster.

(v) is to act as radiation concentrator and to provide addition thermal energy to the central tetragonal core from three sides.

(vi) A non-reflecting black painted tray is fixed on the top side of the central core. The tray is covered with air tight transparent glass window. The tray is used as solar cooker with four cooking boxes. The tray-cover is attached with a moveable reflecting booster with proper stand.

(vii) Perforated hot air outlet and window in the central core.

(viii) A rear side air tight non conducting door. The inlet and outlet of the heat exchanger are fitted on this side of the core. This side is sealed with non conducting, air tight. The door has a outlet for hot air.

Results and Discussion

Figure 2 shows the thermal performance of the device due to direct absorption of solar radiation, studied for 24 hours cycle and the temperature gained by the working fluid at the interval of two hours. It has been observed that, the daily thermal storage characteristic rapidly increases up to 1.0 pm and remains constant up to 3.30 pm and then decrease slowly.
to a minimum temperature at early next morning, inspite of taking all precautionary measures to check thermal losses due to conduction, convection and radiation. It may be observed that the residual temperature of the ferro-ceramic materials, in the next morning is quite high than the temperature of the previous morning as this increase in temperature is due to thermal retention capacity of the Ferro-ceramic materials.

![Graph showing thermal performance characteristic](Image)

**Fig. 2 The Thermal Performance Characteristic**

It has been further found that the stored thermal energy gradually increases due to accumulation of the residual energy. It is further observed that after few days the device reaches to a dynamical thermal-equilibrium and a plateau of temperature is obtained.

Figure 3(a) represents the variation of the accumulated temperature gain of central core in the early morning with continued time series of bright sunny days. It may be observed that the temperature of the central core is gradually increasing with respect to the temperature in the previous morning. It is found that the temperature gain is higher than that of the previous morning. This stored thermal energy is mainly due to thermal retention property of the ferro-ceramic materials used and the precaution has been taken to check the thermal losses from conduction, convection and radiation. It is observed that the slope of the curve slowly increases and after few days a plateau is obtained. If the bright sun is exposed to the device regularly, the temperature gain increases to a quite appreciable value and sufficient thermal energy can be extracted early morning.

Figure 3(b) shows the accumulated temperature gain at mid day when the value of temperature is at maximum. It may be observed that the maximum temperature gain increases gradually every day. This increase in maximum temperature on any particular day is due to the stored initial temperature in the early morning on that day. It is further observed
Fig 3. Shows the accumulated temperature gain (a) in the early morning (b) at midday.

Fig 4. Array of Modules.
that after few days the maximum temperature gain also becomes constant. This plateau of temperature gain is obtained due to thermodynamical equilibrium when the thermal energy gain becomes the thermal losses due to the several sources.

Figure 4 shows the array of module connected in series to provide high thermal energy output. The arrays can be arranged in series or in parallel depending on the need of the consumers.

Conclusions

The multi-purpose solar thermal device has a unique design where the radiation comes to the central core from different direction. It is a low cost, portable, and can be used for cooking, obtaining hot air and hot water simultaneously. The beauty of this device is that it has a direct absorption receiver, flat solar booster as well as a sensible solar energy storage system having nonreactive high thermal mass of Ferro-ceramic materials, which can provide thermal energy in absence of solar radiation. The solar energy is obtained not only from the top side but also from three sides of the central core. This is the first solar device which is heated up from lower sides of the radiation collector and thus increases the thermal efficiency and reduces the heating time. The stored energy in core is due to thermal retention property of the ferro ceramic material. The accumulated thermal energy increases every day till it reaches to thermodynamical equilibrium.

The beauty of this device is that it is of modular type and the modules can be used in parallel and in series direction according to the needs of the consumers in any sectors either in small domestic sector or in big industrial sector. The advantage of this device is that it is of modular type, portable, highly efficient, low cost, requires small installation space, and can serve as tracking system. It may be observed that the working fluid used is always inside the copper heat exchanger and extract the accumulated thermal energy and thus minimises the chances of corrosion.

REFERENCES