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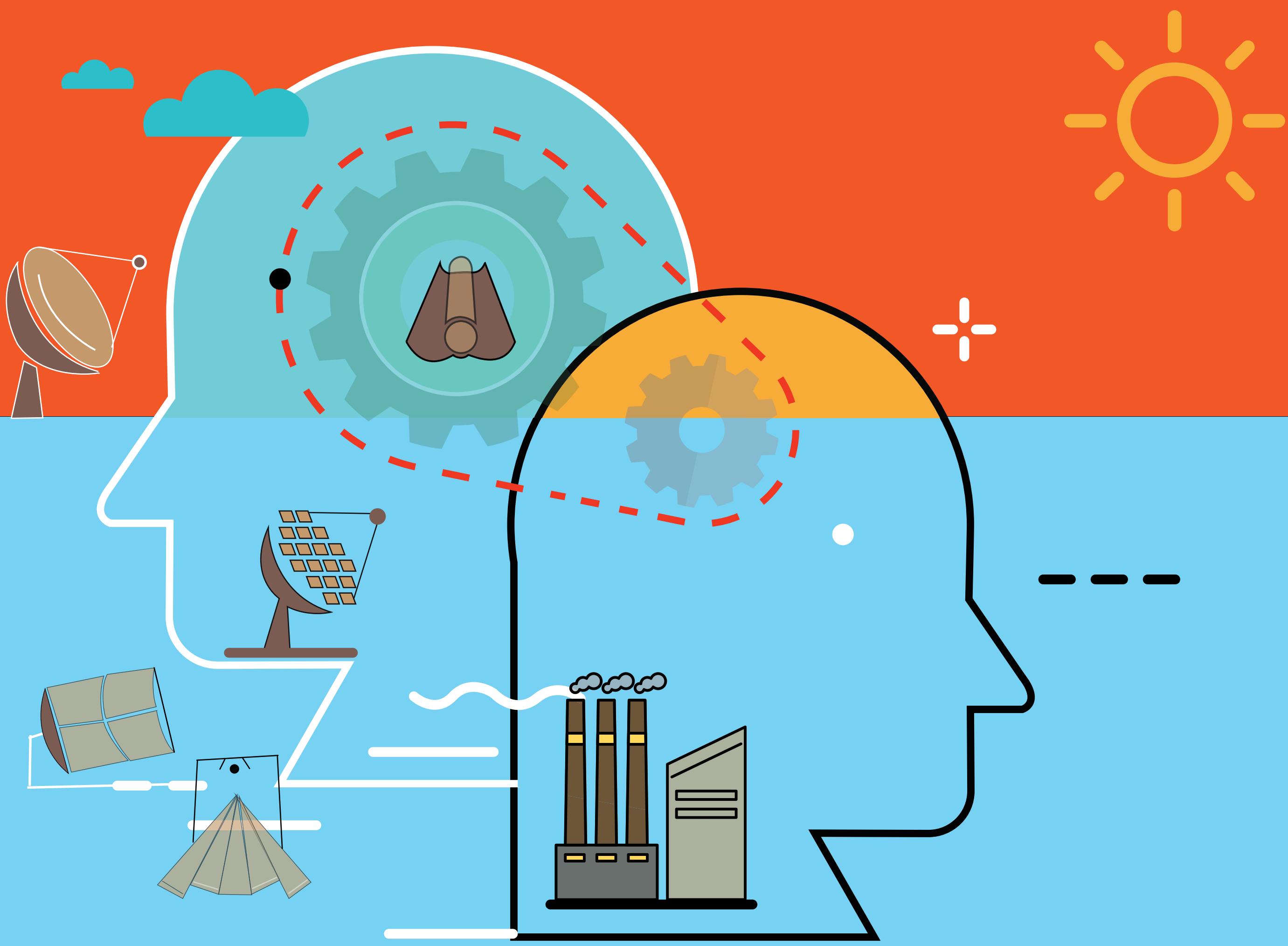

# Information Package for Concentrating Solar Thermal Technologies

INCLUSIVE AND SUSTAINABLE INDUSTRIAL DEVELOPMENT

# Executive Summary

This information package has been prepared as a part of MNRE-GEF-UNIDO project titled "Promoting Business Models for Increasing Penetration and Scaling Up of Solar Energy' that aims to complement support programme of MNRE on Concentrating Solar Thermal (CST). The overall objective of the project is to remove barriers associated with technology, increase awareness, and eventually increase the development of CST technologies. An increase in the deployment of these technologies aims to reduce fossil fuel consumption and greenhouse gas emissions. The aim of the assignment was to prepare an information package which includes technical details of different solar collector technologies, operation and maintenance guidelines, and other sector-specific information such as information about stakeholders, successful case studies, among others.

The technology information package has been prepared to serve as a guiding document for solar collector technologies being used in the CST sector of India. It may also serve for decision-making regarding appropriate solar collector technology in pre-installation stage as well as operation and maintenance manual for post-installation phase of CST systems.

The information package is further supported with a brief detail of technology provider and stakeholder associated with the CST sector in the country. It aims to initiate self-sustenance and replicate the phase of growth of these technologies, increase awareness, handholding, and capacity building of manpower in the CST sector. The focus has also been given to ensure that the information provided in the technology information package on CST is practiced.

## Project Background

The United Nations Industrial Development Organization (UNIDO) in cooperation with Ministry of New and Renewable Energy (MNRE), Government of India is implementing a Global Environment Facility (GEF) funded project on concentrating solar thermal applications in industries in India, targeting the medium–high temperature range (80–350°C) to satisfy both heating and cooling demand in the industrial sectors.

The overall objective of the project is to develop business models for promoting solar energy-based heating/cooling and, where feasible, tri-generation projects (combining power, heating, cooling) through different concentrating solar thermal technologies in industries and commercial. In addition, the project has helped to remove barriers associated with Concentrating Solar (CS) technology, its awareness, capacity building, market, and financial barriers.

## Main features of the project

- Provide financial support to CST installations in the industrial sector by offering the soft-loan facility with IREDA
- Support for improving manufacturing of CST technologies
- Provide technical support to beneficiaries to enable installation and integration of the most suited CST technology in industries
- Developing knowledge documents to facilitate better understanding of the projects
- Promotion of CST technologies as clean energy solutions for industrial sectors
- Capacity building to improve the manpower involved in the CST sector

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# Compound Parabolic Concentrators (CPCs)

## 1. Introduction

Compound parabolic concentrators (CPCs), as can be seen in Figure 1, are stationary solar collectors designed in the shape of two meeting parabolas to efficiently collect and concentrate solar radiation falling on the aperture parabolas.

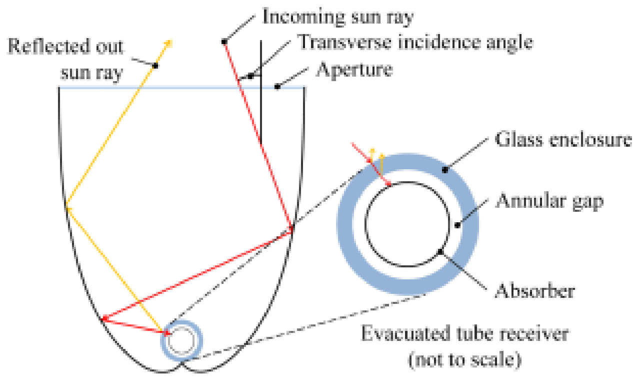
CPCs come under the category of non-imaging collectors (NICs) as they have multiple focal points for concentrating sun's radiation falling on the collector. Therefore, CPCs clearly do not produce defined images of the sun on the absorber. This is in contrast to imaging concentrators that produce an image of the sun by reflecting it on the receiver with a single focal point. NICs, instead distribute radiations from all parts of the concentrator onto all parts of the receiver as an example solar dish.

***Figure 1:*** Basic shape of CPCs showcasing two meeting parabolas and multiple focal points

## 2. Working Principle

The reflector part of the CPC collector is fixed on a tilted base, and the receiver part is placed aligning with the focal points of each reflector. The receiver part comprises an evacuated absorber tube with a glass cover as seen in Figure 2. Absorber tube is specially coated with solar radiation-absorbing coating also known as selective absorber coating and enclosed in a concentric glass cover. The tube is placed at the focal plane of two parabolic reflectors, and the gap between the tube and its cover is evacuated to reduce the convection losses.

***Figure 2:*** *A schematic of CPC collector*[1]




This arrangement enables CPCs to reflect all of the incident radiation, either beam or diffuse, intercepted over a wide range of incidence angles. It, therefore, makes this technology suited for regions that may have higher fraction of diffuse solar radiations or regions where Direct Normal Irradiance (DNI) is on lesser side. Moreover, fewer tracking adjustments have to be made with a high acceptance angle in case of CPCs.

The heat transfer fluid, which flows inside the receiver, collects the heat from absorber. These heat transfer fluids could be water or thermic fluids. The receivers are connected to each other by means of a header, where heated fluid is collected. CPC systems are commonly mounted in the E–W direction with the collector facing south in the Northern Hemisphere. The system is also kept inclined from the ground at an inclination angle of 'latitude of the place +/- 10⁰'.

The angle at which CPC is inclined from the horizontal is called tilt angle. Tilt angle has a direct effect on the overall performance of the CPC systems. Commonly, tilt is adjusted seasonally following the below arrangements:

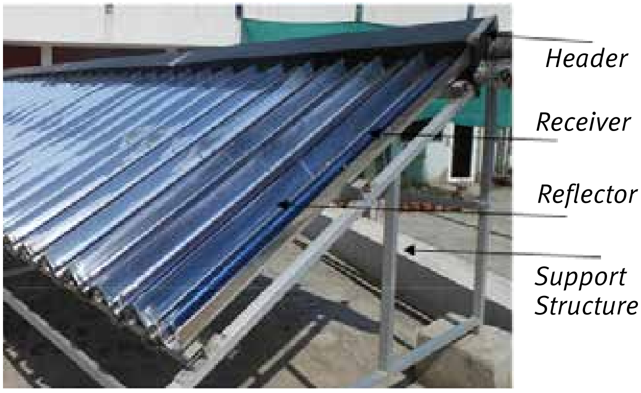
1 *Dabiri, Soroush. (2016). Introduction of solar collectors and energy and exergy analysis of a heliostat plant.*

- Maximum heat collection during summer (tilt angle = latitude angle - 10 degree)
- Maximum heat collection during winter (tilt angle = latitude angle + 10 degree)
- Maximum heat collection throughout the year (tilt angle = latitude angle)

## 3. Components of Compound Parabolic Concentrator

The major components of CPC collector include reflector, receiver, and supporting structure (Figure 3).

***Figure 3:*** *Major components of CPC collector system*




### 3.1. Reflector

Reflector focuses the incoming solar radiation on receiver. Usually, CPC reflectors are made up of a metal sheet with high reflectivity (90–95%). Specifications of a typical reflector are listed in Table 1.

***Table 1:*** *Specifications of reflector*

| Parameter | Specification |
|---|---|
| **Material and shape** | • Aluminum/Stainless steel sheet with high reflectivity<br>• Parabolic cross section |
| **Thickness** | 0.3–0.8 mm (typical) |
| **Coating** | Weather proof coating with high reflectivity |
| **Reflectivity** | 90–95% |
| **Durability** | At least 10 years |

### 3.2. Receiver

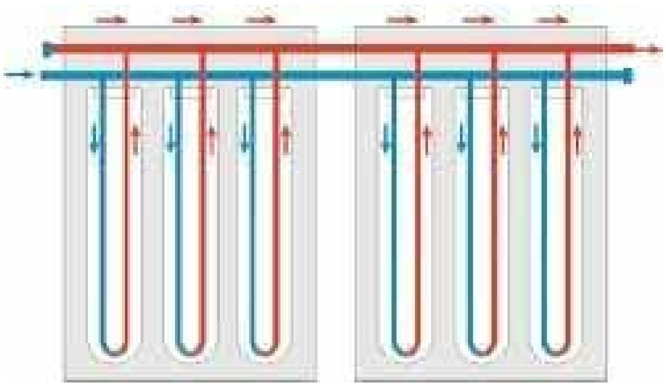
As mentioned in the previous section, "receiver" is a combined assembly of absorber tube and outer glass cover. The prime purpose of the receiver is to absorb as much of the concentrated solar radiation as possible, and convert it into thermal energy. Once converted into thermal energy, this heat is transferred into a fluid of some type (liquid or gas), that takes the heat from the receiver to the specific application. A cross-section view of the receiver is presented in Figure 4.

***Figure 4:*** *Cross-section view of CPC's receiver*


The other components of receiver are also listed in the below section

- **Absorber:** It is an inner part of the receiver kept under the evacuated tube, which absorbs the reflected radiation and converts it into thermal energy.
- **Copper tube:** A U-shaped copper tube (Figure 5) is the innermost part of the receiver and placed inside the absorber. One end of this tube serves as inlet (for cold fluid) while the other end as outlet (for hot fluid).

***Figure 5:*** *A schematic of copper tube with fluid flowing*



- **Copper tube holder:** It is a circular hollow pipe that holds the U-shaped tube. However, it is named as copper tube though, it could be of aluminium, keeping cost and operating temperature requirement in focus.
- **Inner glass tube:** It is a cylindrical glass pipe with a high heat absorption coating. It increases the overall absorptivity for solar radiation. It is also called as the absorber glass tube.
- **Outer glass tube:** This is the outermost glass tube and is thus tough and thick. The purpose of the outer glass tube is to maintain vacuum, which thereby reduces heat losses from the inner surface. Apart from this, it also provides safety to the inner glass tube by acting like a cover.

Specifications of a typical receiver are listed in Table 2.

***Table 2:*** *Receiver specifications*

| Specification | Unit | Value |
|---|---|---|
| **Tube length** | m | 1.5 and 1.8 |
| **Receiver absorptivity** | % | 92 |
| **1st degree heat loss factor (a1)** | kW/m²K | 0.749 |
| **2nd degree heat loss factor (a2)** | kW/m²K² | 0.005 |
| **Glass tube, (external diameter internal/wall thickness/tube length)** | mm | 47/36.2/1.6/ 1500 or 1800 |
| **Tube connection** | Parallel | |
| **Glass tube material** | Borosilicate glass 3.3mm thick | |
| **Absorber coating material** | Aluminium nitride/equiv | |
| **U-shaped tube material** | Copper | |

## 4. Key Features of Compound Parabolic Concentrator

- CPC is a proven technology as more than 25,000 m² of collector area is installed for heating and cooling applications in India.
- Leakage of fluid is not a concern in CPC system because of the absence of rotating parts and flexible joints.
- CPCs can be installed on rooftops of the buildings.
- They are best suitable for required temperatures up to 120°C.
- CPC has payback period of 4–5 years (refer to the case study).
- Absence of moving parts requires less maintenance.

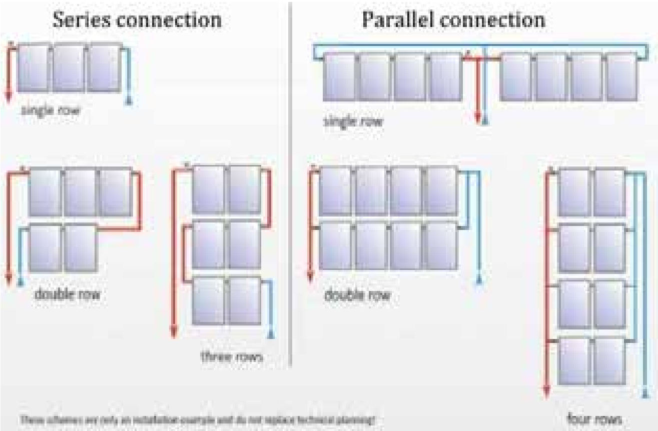
## 5. Applications

- CPC systems can be used for both heating and cooling applications in industries where the required temperatures lie in the range of 60°C to 120°C. CPCs are relatively low-cost CST technologies up to 120˚C temperature range use (refer the case study).
- CPCs are well suited for process heating applications in industrial sectors such as dairy, electroplating, automobile, textile, food, and beverages.
- This technology is also being used for pasteurization of milk in the dairy industry in India. Electroplating industry has also big scope of using CPCs for meeting the thermal energy requirements for processes such as cleaning and washing (40–60°C), plating (50–70°C), and post-plating/drying (70–80°C).
- The technology could be used in the engineering/ automobile industry for component washing, degreasing, metal treatment bath heating, and paint drying in the automobile sector.

## 6. Operation of CPC-based System

A CPC-based system can be connected in parallel as well as in series or combination based on the end-use requirements. A series connection increases the temperature while a parallel connection increases the flow rate. A schematic illustrating the different connections of CPC collectors is presented in Figure 6.

***Figure 6:*** *Series and parallel combination of the modules of a CPC*




Before initiating the operation (working) of CPC system checklist provided in Table 3 has to be followed and ensured.

***Table 3:*** *Checklist before initiating the operation*

| No | Equipment | Condition | Location |
|---|---|---|---|
| 1 | Reflector and receiver | Cleaned | Field |
| 2 | Pump-suction valve | Open | Field/pump house |
| 3 | Pump-discharge valve | Open | Field/pump house |
| 4 | Water level in expansion tank | Sufficient | Field |
| 5 | Nitrogen pressure in expansion tank | As per design | Field |
| 6 | Vent valves | Closed | Field |
| 7 | Drain valves | Closed | Field |
| 8 | Electricity (voltage and phase) | 440 V, 3 phases synchronized with pump | Control panel |

## 6.1. Start-up Procedure

1. Switch on the electric supply switch in the control panel.

2. Start the feed pump. Keep an eye on the water flow rate.

3. Keep a watch on the output temperature and pressure.

4. After achieving the desired temperature, open the output valve to let the heat transfer fluid flow towards the required process or application.

## 6.2. Shutdown Procedure

1. Take the most recent reading of the temperature, pressure, and flow indicators.

2. Cover all the collectors with tarpaulin.

3. Monitor the input and output temperature of the field.

4. Wait for the temperature to stabilize (inlet temperature [B] ~ outlet temperature [C]).

5. Switch off the pump and the control panel.

6. Close all the inlet and outlet valves of the solar field.

For long-term shutdown, drain all the water from the solar field. Afterwards, cover the solar field properly.

## 6.3. Maintenance and Precautions

1. Regular cleaning is a requisite.

2. Prevent reflectors from dents and scratches.

3. Prevent receiver from getting overheated. Never expose the receiver to the sun without a significant flow of water.

4. Always cover the collector with tarpaulin when not in use.

5. Check for leakages and verify that enough solar heat transfer fluid is in the system; furthermore, flush and clean the system with the help of the filling station as per the guidelines given by the supplier.

6. Ensure that all the connections and mounting elements are secured tightly.

7. Visually inspect all the collectors for probable defects.

8. Regularly check the expansion vessel and all the safety devices.

9. Regularly check the tanks for their reliability and security.

10. Replace the damaged tube as soon as possible as it can affect the output adversely.

11. Oil and grease the pump motor as per routine or as per the manufacturer's instructions.

## 6.4. Troubleshooting of Problems in a CPC-based System

*Table 4: Troubleshooting in a CPC*

| Problem | Possible cause | Solution |
|---|---|---|
| • Pump is operating good, but temperatures at flow and return are same<br>• Also, the pump is very hot | • There might be some air in the system and/or the valves are closed | • Check the pressure of the system. Flush the solar system completely and open all the valves |
| • Low heat gain in the system | • The insulation pipe might be faulty<br>• There could be high heat loss in the system<br>• The water circulation controller is bad | • Thoroughly check the system layout<br>• This includes collector connection, shading, pipe insulation, clock timer, and flow controller system |
| • The temperature at the collector is higher than that of the tank but the pump is not working<br>• There is no sound coming from the pump | • There is no power | • Check all the electrical connections and fuses to ensure uninterrupted power supply |

*contd...*

*Table 4 contd...*

| Problem | Possible cause | Solution |
|---|---|---|
| | • Either the controller is not working properly or the temperature difference is too large | • Check temperature sensor and controller<br>• Minimize the temperature difference |
| | • The maximum temperature is already achieved | • Check the temperature<br>• Correct the settings if needed |
| | • There might be some deposits in the bearing of the shaft of the pump that might be blocking it | |
| | • There might be some deposits in the bearing of the shaft of the pump that might be blocking it | • Try switching to the maximum rotation speed for a short interval<br>• If it does not work, unblock the rotator by putting the screwdriver into the slot and turning the blades of the pump manually |
| | • Broken pump | • Replace the pump |

## 7. Case Study

**Concentrating Solar Thermal System using Cocoon process at Uttarakhand Resham Federation Cooperation in Dehradun, Uttarakhand**

| | |
|---|---|
| **Location:** Selaqui, Dehradun | **Type of installation:** Compound Parabolic Concentrator |
| **Configuration:** 90 CPCs with 295.50 $m^2$ of collector area | **Supplier:** Ultra Conserve Pvt Ltd, Mumbai |
| **Application:** Pressurized hot water for cocoon process | **Year of installation:** May 2017 |

**Beneficiary details:** Central Silk Board is a statutory body under the Ministry of Textiles, Government of India established for the development of sericulture and silk industry in the country. The following are the four major types of silk of commercial importance, obtained from different species of silkworms, which in turn feed on a number of food plants. These are

- Mulberry
- Oak Tasar and Tropical Tasar
- Muga
- Eri

Uttarakhand Cooperative Resham Federation (UCRF) works under the aegis of the Department of Sericulture, Government of Uttarakhand. UCRF is engaged in the development of sericulture in the state. Presently, 22 silkworm-rearing cooperative societies, 10 reeling cooperative societies, 112 self-help groups, and 16 non-government organizations are functioning under the umbrella cover of the federation.

**Beneficiary details:** Uttarakhand Cooperative Resham Federation (UCRF)
Contact Person: Director
**Address:** Directorate of Sericulture, Premnagar, Dehradun – 248007
**Landline:** 0135-2773227/2774130

**System details:** The CPC is a specific type of solar collector with a reflector fabricated in the shape of two meeting parabolas. It belongs to the non-imaging collector family and is considered to be the collector in this class having the highest possible concentrating ratio. CPC collectors could operate up to 5 bar pressure and the maximum temperature of 140°C, but they are most efficient in the range of 80–120°C. This technology combines the high-efficiency-evacuated system plus solar radiation-concentrating system with copper U-tube aluminium fins for heat transfer.

**Timings and system application details:** The timing for operating the installed CST system from 8.00 AM to 4.30 PM with an average operating time in between 7–8 hours during the availability of the sunshine.
A closed loop with the solar collector array consisting of series and parallel connections with an expansion tank, a pump, and other accessories such as pressure and air release valve, pressure balancing valve, and so on, is formed closed loop with a Plate Heat Exchanger (PHE). The cold-water line passes through the PHE. The process of reeling with respect to converting silk cooked where the water at room temperature is heated up to 90ºC through CST system and further heated up to 120 ºC through woodfire boiler. They are saving more than 50% of wood consumption as well as to reduce GHG emission. CPC with PHE operating for 8 hours/day (during the sunny period) is a viable solution. Based on the actual data collected for 15 days in the month of May 2017, a total savings of 417 kg of wood was observed.

| | |
|---|---|
| **Thermal output:** 103,000 kcal/day | **Operating temperature and pressure:** 90°C at 1 bar |
| **Type of fuel saved:** Firewood | **Quantity of fuel saved:** 417 kg of wood saved per day |

**Percentage of heat provided by the CST system:** The total heat generates from ambient temperature to 90°C through CST system and further temperature rise up to 120°C through firewood, that is, the overall percentage using solar to generate heat is 75%.

| | |
|---|---|
| **Cost of system:** ₹ 6,230,000 | **Financial supports:** MNRE – ₹ 2,125,440 and UNDP – ₹ 708,000 |
| **Loan component:** NA | **Overall system performance:** Satisfactory |
| **IRR and payback with CFA :** 4.5 years | **IRR and payback without CFA:** 8.3 years |

**Carbon savings:** Biomass is considered as carbon neutral

**Beneficiary:** Uttarakhand Cooperative Resham Federation (UCRF),
Contact Person: Director
Address: Directorate of Sericulture, Premnagar,
Dehradun – 248 007, Uttarakhand
Landline: 0135-2773227/2774130

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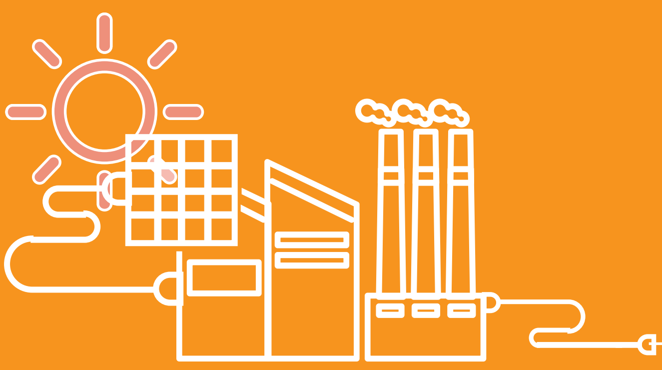


# Paraboulic Trough Concentrator

## 1. Introduction

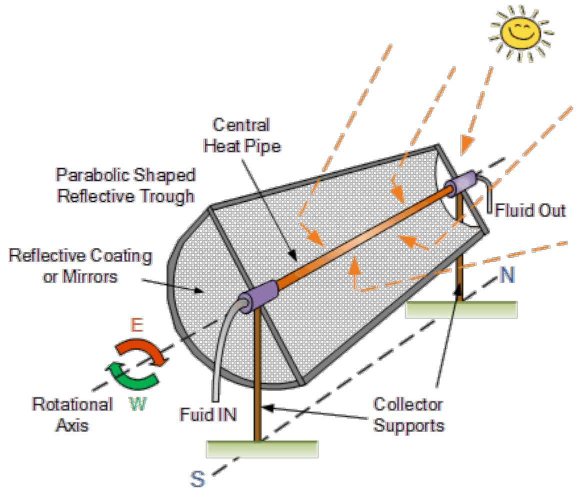
A parabolic trough concentrator (PTC) is a type of solar collector that is straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror (Figure 1). The sunlight, which enters the mirror parallel to its plane of symmetry, is focused along the focal line, where objects are positioned that are intended to be heated. PTCs are one of the earliest solar thermal power-generation technologies to be developed. The first use of PTC was reported in 1897 when Frank Shuman, an American engineer, built a small demonstration solar engine that works by reflecting solar energy onto square boxes filled with ether, which has a lower boiling point than water, and were fitted internally with black pipes, which in turn powered a steam engine.

***Figure 1:*** *Parabolic trough concentrator*

## 2. Working Principle

A parabolic trough focuses all the normal incident sunlight onto a metallic tubular or flat plate absorber placed along its length in the focal plane. The concentrator is usually rotated about one axis to track the apparent movement of the sun in the sky (Figure 2). Heat transfer fluid is passed through the receiver/absorber and the heated fluid is coupled to other modules in this system.

***Figure 2:*** *A schematic of parabolic trough concentrator*




The concentrator/reflector part of PTC is a shaped metal trough coated with a highly polished metal (usually aluminium) or metalized plastic, which not only acts as a reflecting surface but also protects the device from sunlight as well as rain and other elements. The incident sunlight is reflected onto the receiver, a metallic collector pipe that runs axially along the trough. The pipe is specially coated to increase the absorption of sunlight that falls on it and a glass casing reduces hear losses from the receiver due to convection. Sometimes, the space between the receiver and the glass envelope is evacuated and the ends are sealed to reduce the heat loss through convection. PTCs can also be connected on a common axis in series.

The parabolic trough solar concentrator is usually aligned with a north–south orientation because it enables one-axis tracking during the day from east to west. As an alternative, the parabolic trough can also be aligned with the east–west axis. However, in this case the cosine losses are much higher and thus may reduce the efficiency of solar energy collection.

# 3. Components of Parabolic Trough

The major components of a parabolic trough-based solar system include, concentrator/reflector, receiver, trough stand, and tracking system.

## 3.1 Concentrator/Reflector

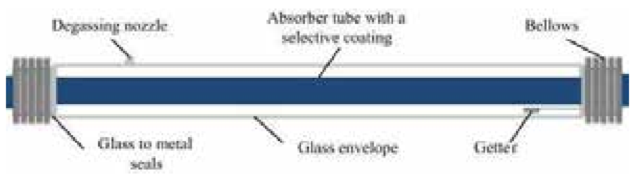
As mentioned earlier, the concentrator/reflector component of parabolic trough focuses the incident solar radiation onto the receiver. These reflectors can be of different material and may be made as a single-piece parabolic mirror or assembled with a number of smaller mirrors in parallel rows. Smaller modular mirrors require smaller machines to build the mirror, reducing cost. Cost is also reduced in case of the need of replacing a damaged mirror. However, aluminium sheets are also in use as reflector material. PTC reflector of different types are presented in Figure 3.

***Figure 3:*** *PTCs with different sizes and types of reflectors*

## 3.2 Receiver

The receiver is a tube positioned directly above the middle of the parabolic mirror and filled with a working fluid. It is a combined assembly of absorber tube and outer glass cover. The prime purpose of the receiver is to absorb as much of the concentrated solar radiation as possible, and convert it into thermal energy. Once converted into thermal energy, this heat is transferred into a fluid of some type that takes the heat from the receiver to the specific application. Inner part of the receiver is kept under evacuated tube, which absorbs the reflected radiation and converts it into thermal energy form (Figure 4).

***Figure 4:*** *Receiver of a parabolic trough concentrator*




## 3.3 Tracking system

The tracking subsystem acts as a support to the receiving subsystem. It maximizes the solar energy collection by keeping the receiver always facing the sun. Some tracking systems also track the sun as it changes its apparent position during the seasons. The PTC system along with a reflector and a receiver always tracks the apparent movement (east to west) of the sun throughout the day. A GPS system with step-up motor is used to synchronize the movement of the reflector with the sun. The mechanical component of the tracking system comprises a sprocket and a chain drive transmission mechanism driven by a stepper motor (Figure 5).

***Figure 5:*** *Tracking system of PTC*

# 4. Key Features of PTC Technology

- Parabolic trough is the most mature technology among all CSTs
- It is suitable for higher temperatures too
- It has low cosine losses
- It has the ability to incorporate thermal storage component to improve dispatch ability
- It can have indigenous fabrication
- It is available in different sizes

## 5. Applications

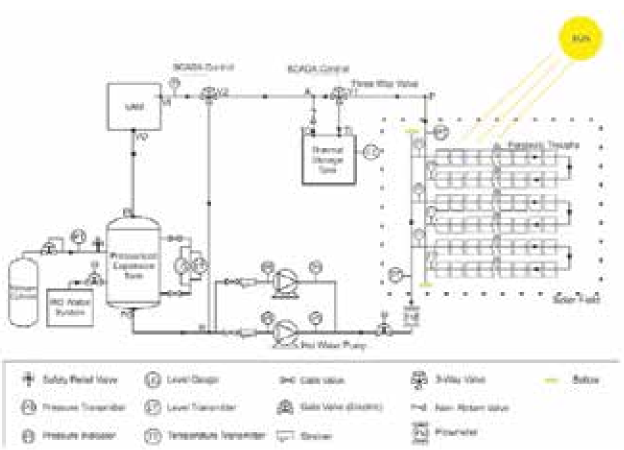
PTC has wide application from lower to intermediate temperature in industries. They are listed as follows:

- Petroleum and crude oil industry
- Food processing: drying, distillation and evaporation, and extraction
- Engineering/automobile industry: component washing, de-greasing, metal treatment bath heating, and paint drying
- Pulp and paper industry: kraft pulping, effluent treatment, and bleaching
- Hotels, hospitals, offices, and malls: air-conditioning, hot water for bathing and laundry
- Textile industry: mercerizing, drying, and finishing
- The industries where steam is required

## 6. Operation of PTC-based System

This section details the typical operating steps for a PTC-based system. It may be noted that, each manufacturer will provide steps that may differ slightly or considerably. The description provided here is for a general understanding. All the operational steps provided in the present document are corresponding to the PI diagram of a typical PTC-based process heating system (Figure 6). However, the steps may differ for other systems. Though, most of the steps presented here are generalized for a CST system.

***Figure 6:*** *Typical P&I diagram of a PTC-based system*



### 6.1. Start-up Sequence

There are two primary modes in which a system can be operated: (i) automatic, in which all actions are triggered automatically through pre-programmed logic; and (ii) manual, in which the user has to take certain or all actions for the system to start and shut down. Both the modes are described in Table 1.

***Table 1:*** *Start-up sequence*

| S. No | Manual mode | Automatic mode |
|---|---|---|
| 1 | • Check the water level in the expansion tank If the water level is less than 60%, then fill the tank with RO water from the makeup water tank to 80% water-level mark<br>• Turn on all MCBs in the solar-tracking control panel<br>• Turn AUTO/MANUAL switches into MANUAL mode | • Check the water level in the expansion tank. If the water level is less than 60%, then fill the tank with RO water from the makeup water tank to 80% water-level mark<br>• Turn on all MCBs in the solar-tracking control panel<br>• Turn AUTO/ MANUAL switches into AUTO mode |
| 2 | Check power supply from the grid:<br>1. Voltage in each phase<br>2. Ensure that it is not in reverse phase.<br>Check for proper opening of inlet/outlet valves for hot-water pump (when we have backup pumps). | Check power supply from the grid:<br>1. Voltage in each phase<br>2. Ensure that it is not in reverse phase.<br>Check for proper opening of inlet/outlet valves for hot-water pump (when we have backup pumps). |
| 3 | Opening valves: start computer with SCADA system<br>Go to 'Set Point & CV Operation Screen'<br>• Set the hot-water pump (HWP) speed so as to maintain the water flow rate in the circulation system to the minimum value specified in the manufacturer's manual (e.g. 1.5 $m^3/h$). The flow rate can be monitored in the P&I diagram | Opening valves: start computer with SCADA system<br>Go to 'Set Point & CV Operation Screen'<br>Start the process in auto mode. This action will open the valves automatically and control them according to the set parameters/ limits |

| S. No | Manual mode | Automatic mode |
|---|---|---|
| | • Open the gate valve for nitrogen line (to 100%)<br>• If the temperature of TST is higher than that of the circulating water, then open hot water inlet (3-way valve) to TST | |
| 4 | Start the tracking system<br>Go to ‘Tracking System Monitor’<br>• Check for tracking system alarms (for servo-amplifiers in each listed axis) on top<br>• Check for issues in sensor motors encoding and power supply<br>• Click ‘Enable’ for all the axis to start tracking | |
| 5 | Go to ‘Tracking System Configuration’<br>Press ‘Synchronize’ to update PLC time | |
| 6 | Focus fine-tuning<br>Inspect focus on each PT. Manual procedure for alignment should be followed if they are out of focus (can be done weekly during start up). Refer to STP 03 in the appendix. | Focus fine-tuning<br>Inspect focus on each PT. Manual procedure for alignment should be followed if they are out of focus (can be done weekly during start up). Refer to STP 03 in the appendix. |
| 7 | Check system parameters<br>• Go to the live P&I diagram<br>• Check the flow rate and hot-water temperature in the end-use application | Check system parameters<br>• Go to the live P&I diagram<br>• Check the flow rate and hot-water temperature in the end-use application |

| S. No | Manual mode | Automatic mode |
|---|---|---|
| 7 | • Check the minimum working temperature of hot water at the inlet of end-use application (e.g. 110–215°C).<br>• Check the average flow rate in the solar field (e.g. range 2–6 $m^3/h$) | • Check the minimum working temperature of hot water at the inlet of end-use application (e.g. 110–215°C).<br>• Check the average flow rate in the system |

## 6.2. Start-up Precautions

- If the thermic fluid is used in the circulation system, it should be initially heated up by 20 °C every hour till it reaches 100°C, so that all the moisture is removed from the thermic fluid.
- The PT should be kept in sleep position during rains/hailstorms to protect the aluminium collector sheet from damage.
- The backup expansion tank, when not in use, should be properly isolated with the gate valves completely closed.
- In Auto Mode System Control, the system follows the set parameters for each module in SCADA. These parameters are set with the help of the SCADA operations and maintenance manual and are dependent on the system rating and usage.
- If any set parameter for automatic mode is changed, observe the system for some time to study its effects on the system.
- Synchronize the PLC timings daily/weekly to prevent error in tracking by PLC due to time difference.
- Planned routine maintenance should be completed before starting up the system in the morning as it is cooled down at this stage.
- Use only RO water to feed the pressurized expansion tank, to prevent scaling in the system.

## 6.3. Operation of the Tracking System

- Whenever the fluid temperature increases above 215°C, the PTC defocuses to ±2°, and if the temperature crosses 220°C, the PTC completely defocuses to save the system from excessive heat.
- If the flow rate in the circulation system goes below 1.5 $m^3/h$, the system automatically defocuses the PTC.
- Seasonal effect causes a small error in the accuracy of the tracking system (error of around 3–4° quarterly). This effect is countered by changing the measurement bias for each axis on a monthly basis. This corrective measure is done manually.

## 6.4. Operation of the Circulation System

Pressure, temperature, and the flow rate will vary during normal operation. The range of normal values can be set in the SCADA system. As an example, the values are listed in Table 2.

***Table 2.*** *Example values for flow rate, pressure, and temperature*

| Point | Flow rate | Pressure | Temperature |
|---|---|---|---|
| | Acceptable range ($m^3/h$) | Acceptable range ($kg/cm^2$) | Acceptable range (°C) |
| *Solar field (PT)* | 2–6 | 2–15 | Up to 220 |
| Thermal storage tank inlet | 2–6 | - | Up to 220 |
| VAM inlet | 2–6 | - | 110–200 |
| Pressurized expansion tank | 2–6 | 28–29 | - |
| Hot-water pump | 2–6 | 2–15 | Up to 200 |

- *These parameters are system-dependent and change for different systems.*
- *To determine the minimum acceptable system pressure, refer to the steam table, where you can get the required pressure corresponding to the maximum hot-water temperature for which the system is designed.*

## 6.5. Error Control

The control mechanism is used to automatically rectify the error conditions described in Table 3.

***Table 3:*** *Error monitoring and control*

| | Module/(s) affecting the parameter | Error/(s) | Potential causes | System adjustment and control |
|---|---|---|---|---|
| Flow rate | Hot-water pump | Deviates from range 2–6 $m^3/h$ | The flow rate control is set in manual mode. | Can be controlled by changing the hot-water pump speed on SCADA system on 'Set Point and Operation' screen. |

*contd...*

*Table 3 contd...*

| | Module/(s) affecting the parameter | Error/(s) | Potential causes | System adjustment and control |
|---|---|---|---|---|
| Press-ure | Expans-ion tank | Increases beyond 32 $kg/cm^2$ | Safety relief valve failed to open | Adjust safety relief valve to open at 23.63 $kg/cm^2$ |
| | | Decreases below 26 $kg/cm^2$ | Not enough pressure in nitrogen cylinder, or a valve is not open. | Check for pressure in nitrogen cylinder to be at min. 26 $kg/cm^2$, and inlet valves connected to it |
| Tempe-rature | PT | Increases beyond 220°C) | Rise in solar radiation. | Defocus the PT to sleep position (-80°) |
| | | Decreases below 110°C | Not enough solar radiation | System turns OFF |

Safety note: It is dangerous for the system temperature to rise above a certain limit. The PT automatically defocuses by a certain angle (e.g. 10°) from its position.

## 6.6. Exceptions and Backup

**Power Failure**

In case of power failure, water stops circulating through the PT, and hence the temperature of the fluid at focus starts increasing, which can damage the receiver tubes. Hence, to prevent such damage in case of power failure, the PLC has a power backup system, which automatically defocuses the PT in case of power failure to prevent the receiver tubes from overheating.

**Storm/High Winds**

A 3-cup anemometer measures the wind velocity. The upper limit for wind is set to 15 m/s. Above this limit, the PT goes in stowing position (0°) to protect it from structural damage.

**Not Using System for Long Time**

- Turn the PT to sleeping position (east-facing direction/–80°).
- Give proper shading to cover electrical items like servomotors, electrical valves, and so on.
- Flush out water from the circulating system.
- Close the nitrogen cylinder valve.

## 6.7. Shutdown Sequence

Similar to the start-up sequence, the system has a different shutdown sequence for manual and automatic modes. Follow the set of actions according to the mode (manual or automatic) in which you are operating your system (Table 4).

***Table 4:*** *Shutdown steps for both the modes*

| No | Manual mode | Automatic mode |
|---|---|---|
| 1 | Tracking system<br>• Disable all the PTs to defocus them<br>• All the PTs will move to sleeping position (-80°) | Tracking system<br>Here T-End time period shows the time after which the PLC automatically shuts down the system |
| 2 | Pumps and valves<br>1. Close $N_2$ line to cylinder<br>2. Close hot water inlet to TST (close 3-way valve)<br>3. Shut down the hot-water pump by entering its value to 0. | Pumps and valves<br>Stop the process in auto mode |
| 3 | Save data Click 'Excel Export' to save monitored parameters for the day | |
| 4 | Wait for five minutes for the valve operation to complete. | Wait for five minutes for the valve operation to complete |
| 5 | Shut down the PC | Shut down the PC |
| 6 | Turn off all the MCBs in the solar panel | Turn off all the MCBs in the solar panel |

### 6.7.1. Shutdown Precautions

- Do not turn off MCBs on the days with strong wind, so that the PT can automatically move to homing.
- Position (0°), in the case of sudden storms.
- Turn PT to sleep position (-80°), if it is raining heavily.
- Wait for the tracking system to completely defocus the PTs to sleep position and electrical valves to complete their operation before completely shutting down the MCBs.
- Note that all the valves in the P&I diagram (on SCADA) are finally closed.
- Export and save data before you shut down the system.

# 7. Maintenance

## 7.1. Predictive Maintenance

Predictive maintenance involves inspecting the system for potential signs of failure. It should also include the study of the system data logs. The data log helps the trained service technician to identify and troubleshoot any potential problems within a system. You can contribute to a trouble- free and reliable performance of your solar system by regularly performing the following checks to determine whether maintenance is required or not:

### 7.1.1. Reflectors and Receivers

- Twice a month check for the misalignment of focus at the receiver tubes. Focus should not deviate more than ± 2° from the receiver tube.
- If focus of a complete PT axis connected to a tracking mechanism is out of acceptable limit, it can be tuned by changing the 'Tracking Measurement Bias' on SCADA. The bias value is determined by a hit and trial method.
- If focus of one or more PT(s) in an axis gets misaligned, it can be manually corrected. Loosen the couplings of the shaft driving the concerned PT, adjust/align that PT, and tighten back those couplings (check STP 03).
- Twice a year check for the broken glass tubes.
- Schedule to replace them if there are two broken glass tubes in a row.
- Schedule immediate replacement if there are three or more broken glass tubes in a row.
- Check STP 02 for replacement of the broken glass tubes.
- Annually, check for scaling at inner linings of the receiver tube.
- Scaling and its effect on the system's performance have to be visually determined.
- This maintenance task is generally outsourced because it is rarely performed and requires 'descale' systems and industrial descaling chemicals.

### 7.1.2. Circulation System

- Check for the functioning of dosing systems on a quarterly basis.
- Clean and rinse the pump.
- Check for screwed connections of piping and containers, and tighten if necessary.
- Carry out a visual inspection of pressure test.
- Check for pressure in the nitrogen cylinder on a quarterly basis.

- When pressure in the $N_2$ cylinder goes below 26 kg/cm², replace it.
- On a weekly basis, check for leakages in the system by looking for stagnant fluid on the ground. Perform this operation when you spot leakages in the circulation pipe.
- Identify the point of leakage and remove insulation for that component.
- Repair/replace the component with leakage.
- Leave the insulation material (mineral wool) open to dry off, and then put it back (see STP 05).

### 7.1.3. Tracking System

- Annually, inspect the proximity sensors. Place any obstacle in front of the proximity sensors and it should stop turning the PT; and if not, then:
    - Check for wiring connections in the proximity sensors.
    - Replace the proximity sensors as they might have been damaged due to rains/physical damage.
    - Check for electrical lines and components for visible damages (loose connections, damaged cables, and so on).
    - Check that the emergency alarms are not disabled (circuit breaker, fuses, alarm lights, and buzzers).

## 7.2. Preventive Scheduled Maintenance

Preventive scheduled maintenance is briefly explained in the following sub-sections

### 7.2.1. Daily, Weekly, or Monthly

The system requires some simple and small-scale activities for its general upkeep. The following tasks must be regularly performed when using the system:

- Clean the reflectors and the receiver tube on a weekly basis.
    - Add a few drops of shampoo to the water bucket and set the PT at -80°. Now splash the water on the PT, starting from the top, washing the loose dust down. Wipe off the remaining dust with a wet cotton towel.
    - Do not use plain water to wash reflectors.
- Use dry cloth for wiping
    - Clean the receiver tubes early in the morning before starting the system when the PT is defocused. You can use most of the window cleaners or a very soft cotton cloth to clean them carefully with soft hands, as these glass tubes are easily reachable.
- Dust off the pyrometer with a dry soft cloth on a weekly basis.
- Every month clean the screen in Y-strainers with a brush or by soaking it in a clean solution.
- Every month compensate for seasonal adjustment by adjusting the measurement bias on the SCADA screen.
- Twice a year, clean the RO system cartridge filler.

| Activity | Frequency | Description |
|---|---|---|
| Reflector and receiver washing | Weekly | Add a few drops of shampoo to the water bucket and set the PT at -80°. Now splash the water on the PT, starting from the top, washing the loose dust down. Wipe off the remaining dust with a wet cotton towel. |
| RO system cleaning | Twice a year | Clean the RO system cartridge filler |

### 7.2.2. Quarterly, Biannual, or Annual Maintenance

The following preventive maintenance must be undertaken as per schedule to avoid system failures for a trouble-free and reliable performance:

- Lubricate the moving parts in the system on a quarterly basis.
- Lubricate the top and bottom bearings (as shown in the figure in red circles) of the PT.
- The tracking unit (motor and gearbox) does not require lubrication.
- Lubrication should be done, especially after the rainy season.
- Twice a year, replace the water in the circulation system with fresh soft water from the RO system.

NOTE: If the thermic fluid is used in the circulation system, do not clean with water; either use compressed air or flush fluid from the tank to clean the piping system.

- Undertake structural painting and annual repair of PTs to improve the lifespan of the system.
- Calibrate the temperature transmitter, the pressure transmitter, the flow meter, and other gauges annually.
- Replace soft water resin in the RO water purifier annually.
- Every three years clean the pressurized expansion tanks.

## 7.3. Consumable Replacement

The following are the consumable components in the system, those may need standby stock:

- Nitrogen cylinder
- Resin for the RO water purifier
- Feedwater, if there is no water source near the PTC system
- Lubricant oil and grease

NOTE: Please refer to the manufacturer's manual for the recommended consumable item specifications.

## 7.4. Dos and Don'ts in Maintenance

### Dos

- Follow the maintenance schedule for all the components at the specified time intervals.
- The operator must maintain the log sheet regularly and the supervisor must review the log sheet readings regularly.
- Whenever maintenance is required in the thermal fluid circulation system, defocus the PT and keep on circulating the thermic fluid/hot water through the system till its temperature reaches below 50–60 °C.
- Then depressurize the system by venting nitrogen from the expansion tank by opening the vent valve.
- Switch off the circulation pump, close the water inlet/outlet valves, and then start the work.
- Open flanges when the system is cooled down to avoid burn injuries.
- Always use sunglasses while working in the solar field.

### Don'ts

- Do not leave the nitrogen valve open when the system is not in operation.
- Do not apply hand pressure on the PT collector reflecting surface while cleaning.
- Never tamper with the pressure relief valve and the safety relief valve without training and knowledge of the system.
- Do not clean the reflectors with dry cloth or paper.
- Do not clean the reflectors after 8.00 am and before 5.00 pm.
- Do not modify the system without a written approval from the manufacturer.
- Do not touch the receiver when focus is on the receiver.
- Do not walk in between the receiver and the reflector during operation.
- Do not use hard water for mirror cleaning, as it may form scaling on mirrors and thus reduce performance.
- Do not stop the water circulation when the water temperature has dropped below the level recommended by the manufacturer.
- A few process-related troubleshooting points are given below. Refer to the respective manual for troubleshooting of components as listed in Tables 5 and 6.

***Table 5:*** *Process-related troubleshooting*

| Observation | Probable cause | Action |
|---|---|---|
| Noise in circulation pump | Alignment of pump motor disturbed | Refer to pump/motor manual to realign the pump/motor |
| | Pressure of suction pump lower or equal to the saturation pressure of water at that temperature | Check the pressure of compressed air in the expansion tank; it must be above a certain kg/cm². Rectify as required |
| Pressure at pump fluctuating | Air entrapment in the water system | Open and close vent valves in the water piping, one at a time, to remove the trapped air |
| | Y-strainer is choked. | Clean the filter (refer to STP 01) |
| | The pump is cavitating due to hot water under pressure | Check the pressure of compressed air in the expansion tank; it must be above a certain limit (~3 kg/cm²) |

*__Table 6:__ Troubleshooting in PTC based system (Courtesy: Thermax Ltd.)*

| S. No | Symptoms | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| 1 | **System not starting in the morning** | Control panel not switched on | Control panel physically not started | | | Main switch to be switched on and ensure indicating lamps glow |
| | | | Problem in main distribution panel | | | Main distribution panel to be checked and correct the fault |
| | | Problem in incoming power for control panel | Physical damage to the incoming cable Short circuit at main distribution line | Incoming cable not routed properly | | Check/correct incoming supply to control panel and/or replace the cable, if required |
| | | | | Cable damage | | Check/correct/ replace the main distribution cable |
| | | Main MCCB not workingin controlpanel | MCCB tripped | Due to overload | | Check and replace the MCCB |
| | | | | Short circuit in control panel | | Check/correct the fault |
| | | | | Malfunctioning of the MCCB | | Repair/replace the MCCB |
| | | | | Short circuit in any of the motors or circuit | | Check and correct the fault |
| 2 | **Scattered focus** | Improperly fixed mirrors | Fixing arrangement not tightened properly | | | Check/adjust the alignment of mirrors |
| | | Mirrors not cleaned | No manpower available | | | Identify manpower from client end for reflector |
| | | | Procedure not followed | | | Follow process as per the O & M manual |
| | | | Soft water not available | | | Mirror to be cleaned only with soft water |
| | | | Proper tools not available | | | Hosepipe with nozzle, mopping brush, and wiper to be arranged for cleaning the mirrors |
| | | Low radiation | | | | No option |

*contd...*

*Table 6 contd...*

| S. No | Symptoms | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | Fine-tuning not done | Nut jam for fine adjustment | | | Make the adjustment nut-free and fine-tune the connection |
| | | Mirrors tainted | Bad quality of | | | Replace the mirrors with solar grade mirrors supplied by the manufacturer |
| | | | Protective coating | | | |
| | | | Domestic mirrors used | | | |
| | | | Corrosive weather/ coastal area | | | |
| 3 | **Auto forward not happening** | Problem in the contactor for forward motion | Carbon deposited on internal contacts | Loose contact | | Check/clean/ correct/replace the contactor with same specs and tighten the electrical terminations |
| | | Problem with the PLC | Program not functioning properly | Improper earthing to PLC panels | | Check/correct in coordination with PLC engineers, and provide separate instrument earthing for PLC panels |
| | | Problem in one of the limit switches | Limit switch damaged | Limit switch stuck up | | Check/replace/ repair the limit switch |
| | | Problem in gear motor | Winding burnt | Due to overload on motor | | Check/replace/ repair the gear motor |
| | | Problem in gearbox | Gearbox jam | No lubricant for gearbox | | Check/repair the gearbox |
| 4 | **Water pump not operating** | Problem in signals from Mobrey | Magnetic switch not functioning properly | | | Repair/replace the magnetic switch |
| | | | Float stuck up inside | | | Clear float |
| | | | Problem in electrical connection inside Mobrey | | | Check and correct the electric connections |
| | | Problem in contactor for water pump | Carbon deposit on internal contact | Loose contact | | Check/replace/ correct/clean the contactor |
| | | Problem in rotary switch for water pump | Internal contact burnt<br><br>Wiring not proper | Loose contact | | Check/replace the rotary switch |
| | | Problem in V-belt for pulleys | V belt worn out | | | Check tension/ replace V-belt |
| | | | Slippage of V-belt on pulley | | | Check tension/ replace V-belt |

*contd...*

*Table 6 contd...*

| S. No | Symptoms | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| 5 | **Focus not exactly at the centre of the receiver** | Reflector/ reflectors not tracking properly | No supply to AC motor from panel | Problem in wiring<br>Negligence during installation | | Check proper supply to panel and motor and/or rectify |
| | | | | Problem in contactor for AC motor | | Check contacts and replace if required |
| | | | Inadequate distance between the reflectors | Improper installation | | Take prior approval from engineering for any correction to be made |
| | | | | Inadequate layout size | | Take prior approval from engineering for any correction to be made |
| | | | Inadequate distance between the reflector and the receivers | Improper installation | | Take prior approval from engineering for any correction to be made |
| | | | | Improper layout size | | Take prior approval from engineering for any correction to be made |
| | | | Receiver inclination angle not as per requirement | Inclinometer not available during installation | | Angle to be checked with inclinometer |
| | | | | Negligence during installation | | Make alignment report and get it approved |
| | | Reflector movement is jammed | Undersizing of hole at channel | Back-bearing nut of rotating pipe is over tight | | Check the hole of the back-bearing channel and correct as per requirement |
| | | | Oversizing of bolt at rotating pipe | Top-bearing part is over tight and thus restricting the reflector's movement | | Check and loosen the top part |
| | | | Improper lubrication at top-part assembly | | | Ensure proper lubrication and free movement of the bolt |
| 6 | **Water pump not developing pressure** | Problem in NRV | Dead weight inside stuck up and not operating | | | Check/rectify/ replace NRV |
| | | | Direction of NRV not proper | | | Correct the direction as per requirement |
| | | Suction strainer choked | Excessive dust in water from piping | Water tank not cleaned | | Clean the water tank and flush the piping |

*contd...*

*Table 6 contd...*

| S . No | Symptoms | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | | Wire mesh of strainer clogged with permanent scale | Hard water getting used for operation | | Use only soft water to clean the strainer |
| | | Problem with the valve seat assembly | Wear and tear of the valve seat assembly | Hard water getting used for operation | Softener not available | Check/replace the valve seat assembly |
| | | | Spring tension not proper | In operation since long time | No breaks for regular maintenance | Adjust the spring tension. Replace if required |
| | | | Foreign particles inside the valve seat assembly | Strainer not cleaned | Maintenance not done properly | Clean the valve seat assembly properly during preventive maintenance |
| | | Problem in gland washer | Wear and tear of the gland washer | Wear and tear of the pump shaft | | Check shaft for smoothness. Replace gland washer if required |
| | | | Gland washer's rubber hardened | High temperature of inlet water | Strainer not cleaned | Maintain inlet temperature of the water within 70°C |
| | | | Water leakage from gland washer assembly | Foreign particles between shaft and gland rubber | | Clean the gland water and strainer |
| | | Faulty pressure gauge | Isolation valve closed | Negligence | | Open the isolation valve |
| | | | Spring tension lost | Overpressure | | Repair/replace the pressure gauge |
| | | No water in feedwater tank | Softener is not working | Resin property lost | | Replace resin/ replace softener |
| 7 | **Auto reverse not happening** | Problem in PLC | Program not functioning properly | Improper earthing to PLC panel | | Check/correct in coordination with the PLC engineer and provide separate instrument earthing for PLC panel |
| | | Problem in contactor for reverse motion | Carbon deposited on internal contacts | Loose contact | | Check/correct/ clean/replace contactor with the same specs and tighten the electrical termination |
| | | Problem in limit switch for reverse | Limit switch damaged | Limit switch stuck up | | Check/repair/ replace the limit switch |
| | | Problem in gear motor | Winding burnt | Due to overload on motor | Reflector movement jammed | Check/replace/ repair the gear motor |
| | | Problem in gearbox | Gearbox jammed | No lubrication for gearbox | | Check/repair gearbox |

*contd...*

*Table 6 contd...*

| S. No | Symptoms | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | | | Sprocket wheel teeth broken | Due to improper alignment | Make proper alignment |
| | | | | Bearing jam | Non-lubrication, rusting | Clean the bearing part, make proper lubrication, and ensure smooth movement |
| | | | | Gearbox shaft bend | Due to overload | Proper alignment to be done. Avoid the overload on shaft. Replace the shaft if required |

## 8. Case Study

### PTC-based CST System Used for Process Heat Application at SKF Ltd, Mysore, Karnataka

| | |
|---|---|
| **Location:** Mysore | **Type of installation:** PTC |
| **Configuration:** 256.4 $m^2$ (6.41 $m^2$ x 40 Nos.) | **Supplier:** Thermax Limited, Solar Division, Pune |
| **Application:** Process heat (metal phosphating) | **Year of installation:** January, 2013 |

**Beneficiary details:** SKF Sealing Solutions Business Unit is a wholly owned subsidiary of SKF AB, Sweden, and is a part of SKF Technologies (India) Pvt. Ltd. The SKF Seal Business accounts for 10% of SKF's global turnover and is their fastest-growing business division. The SKF Group decided to focus on Asia for SKF Sealing Solutions' upcoming developments. SKF Sealing Solutions India, Korea, and China, were thus formed. The manufacturing facility is located at KIADB Industrial area, Kadakola, Mysore.

The main processes in this plant are rubber-mixing plant, phosphating and cementing line, moulding presses, and finishing and assembly line.

**System details:** SKF Technologies (India) Pvt. Ltd., Mysore, has installed a PTC-based CST project for process heating application at their phosphating plant. The system consists of 40 parabolic troughs, each having 6.41 $m^2$ of collector area, totalling to 256.4 $m^2$. The system has been yielding pressurized hot water at 95°C (operational temperature required) and is integrated with the existing boiler being run on diesel. The hot water generated is being used for the purpose of metal phosphating in the plant.

**Timings and system application details:** The solar system is designed to run effectively from 8:30 am to 5:30 pm at Mysore based on the geographical location. The control mechanism helps the hot-water generator to seamlessly adjust its capacity in line with the solar output. The cumulative mitigation of fuel consumption achieved peaks at 15% of the total requirement and is only capped by the available rooftop area. The system is used for process heating and the quantity of fuel saved is 70 L of diesel per day.

| | |
|---|---|
| **Steam generation: -** | **Operating temperature:** 120°C |
| **Type of fuel saved:** HSD | **Quantity of fuel saved:** 12,000 L/year |

**Functionality and key issues of non-operation:** Operational

**Status of equipment:** System is functioning well

**O&M issues and beneficiary perception:** The system is functioning well, and so far no operational problems or breakdowns are noted. The system is properly maintained.

**Financials in detail:** The project cost was around ₹ 70 lakh. The project has received a direct government subsidy of nearly ₹ 14 lakh. The complete system enables fuel savings of about 12,000 L of diesel per year, which translates to nearly ₹ 5 lakh with all benefits considered and after factoring all overheads, and that amounts to a total payback period of around 5 years.

| | |
|---|---|
| **Cost of system:** ₹ 70 Lakh | **MNRE subsidy:** ₹ 14 Lakh |
| **Payback with subsidy:** 5 Years | **Overall system performance:** Good |

**Beneficiary contact:**
K. Venkatesh
DGM, Plant Engineering Services
SKF Technologies (India) Pvt. Ltd
Sealing Solutions.

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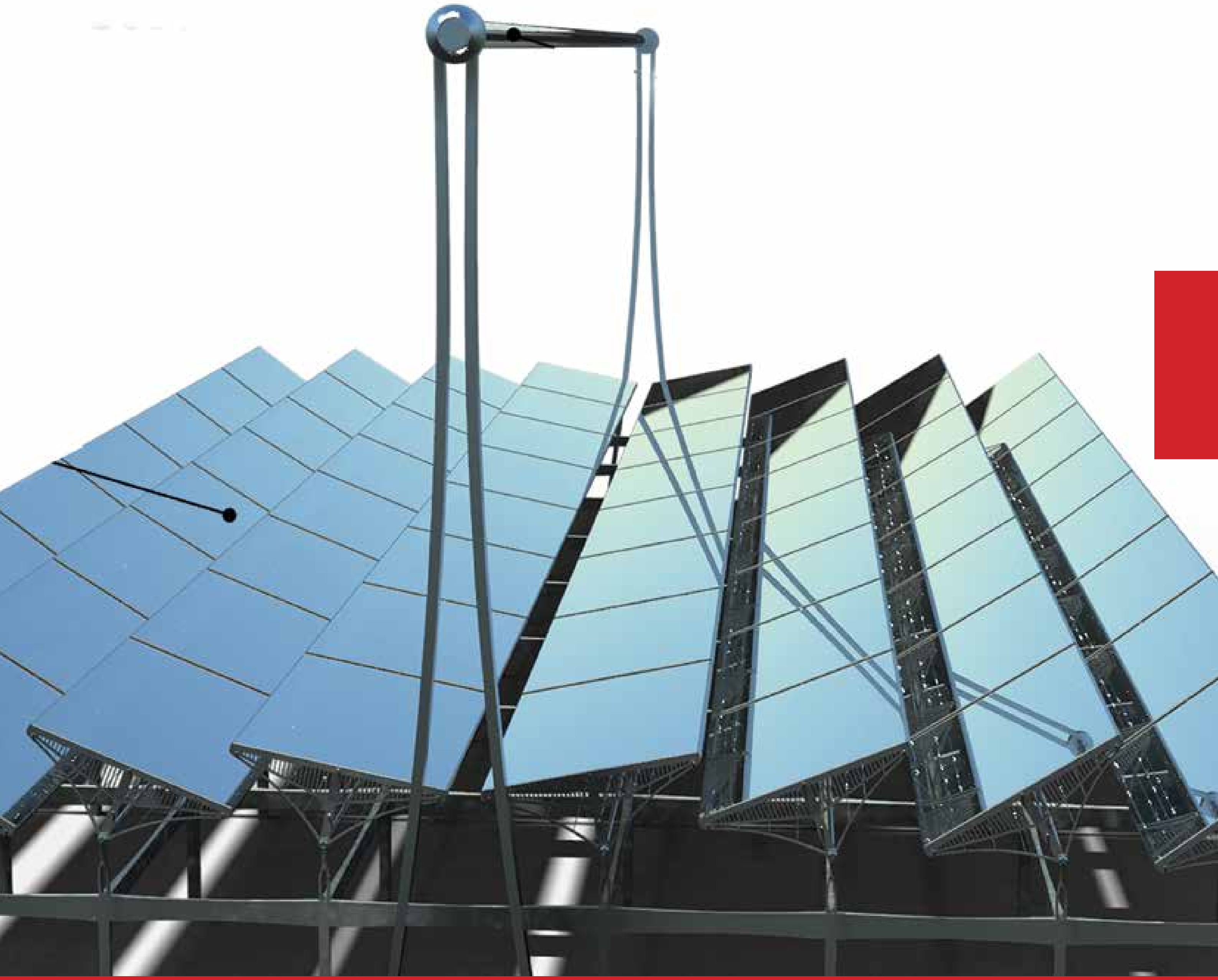
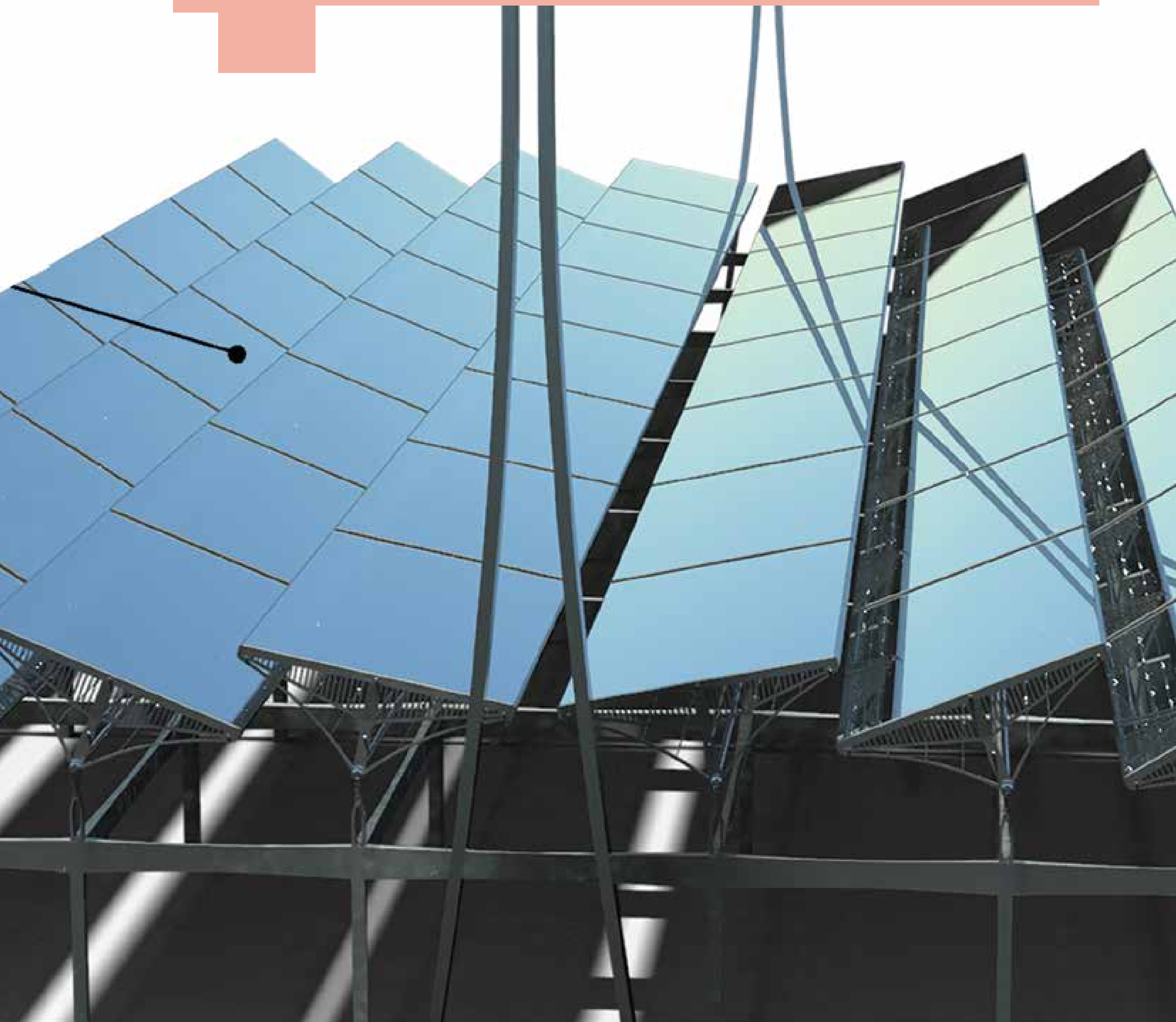


# 3

# Linear Fresnel Reflector (LFR)



## 1. Introduction

Linear Fresnel reflector (LFR) is a type of solar collector that captures the sun's energy with large mirrors that focus the sunlight onto a receiver tube (Figure 1). LFRs are made from strips of straight reflecting material, which could be highly polished reflecting metal and/or metal coated with a reflecting material, such as metallized plastic or glass mirrors, etc. The mirrors are arranged in a manner that emulates the contours of a parabolic trough to reflect the incident solar radiation to the focal line of a collector. These surfaces reflect the incident sunlight onto a metallic collector pipe (the receiver) that runs axially above the array of reflectors. Another type of Fresnel reflector is compact linear Fresnel reflector (CLFR). It is named for its similarity to a Fresnel lens, in which many small, thin lens fragments are combined to simulate a much thicker simple lens. These mirrors are capable of concentrating the sun's energy to approximately 30 times its normal intensity.

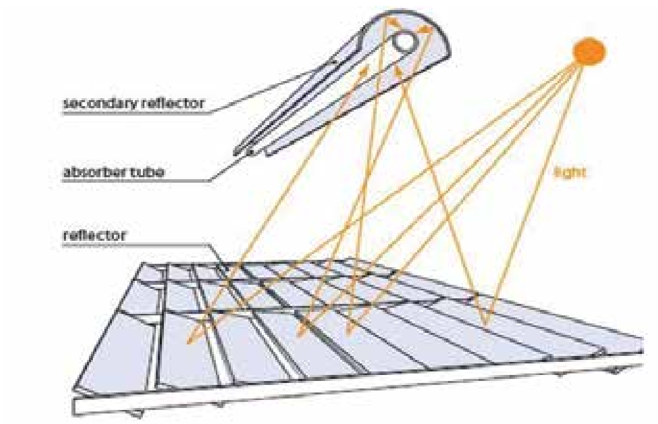
***Figure 1:*** *Linear Fresnel reflectors*

## 2. Working Principle

An LFR works by utilizing the Fresnel lens effect, which was first developed by French physicist Augustin-Jean Fresnel. The design allows the construction of lenses of large aperture and short focal length without the mass and volume of material that would be required by a lens of conventional design. This mirror-based system uses the same principle as a Fresnel lens uses for flat plane mirrors.

LFR systems produce a linear focus on a downward-facing fixed receiver mounted on a series of small towers as shown in Figure 2. Long rows of flat or slightly curved mirrors move independently on one axis to reflect or concentrate the sun's rays onto the stationary receiver. Somehow, it is similar to parabolic trough system but contains fixed receiver while mirrors track the apparent movement of the sun throughout the day.

***Figure 2:*** *A schematic of linear Fresnel reflector*




The LFR collectors can be oriented in two ways: with their axis in the north–south direction or in the east–west direction (in Northern Hemisphere).

Several LFRs can be connected in series on a common axis. The two common methods of mounting LFRs are with the focal axis:

- In a horizontal east–west direction, with continuous adjustment to ensure the least angle of incidence of the incident sunlight.
- In the horizontal north–south direction, with the troughs being moved to track the sun from east to west from morning to evening. These systems provide relatively larger quantities of heat but need a larger contiguous area. They are more robust and as efficient as PTCs.

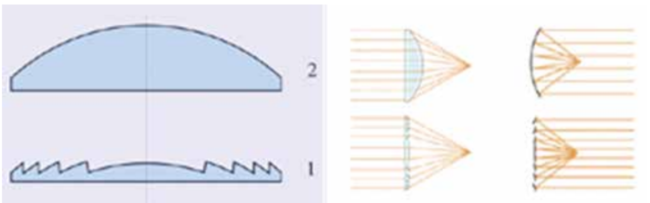
## 3. Components of Linear Fresnel Reflector

The major components of LFR include a linear reflective mirror, a receiver, and a tracking system.

### Linear Reflective Mirror

These mirrors act as a concentrator part of the LFR system (Figure 3), and constituted from Fresnel lens. Fresnel lens has multiple refracting planes designed to improve the concentration of light coming from many different angles onto a single point or line. This design allows a substantial reduction in the thickness, volume, and weight of the lens though it also reduces the quality of imaging. Giovanni Francia of Italy first applied it in 1960 for the development of linear and a two-axis-tracking Fresnel steam-generating system.

***Figure 3:*** *Fresnel mirror*

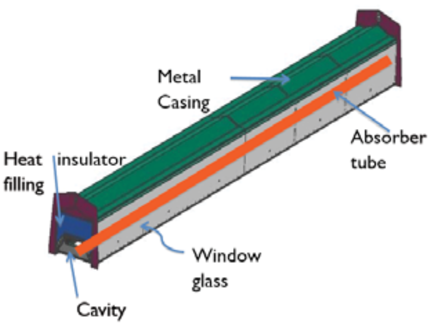



Mirrors are pasted on a corrugated sheet which is a wavy structure made up of GI or any other equivalent metal. The sheet gives a good support to the mirror and also protects the reflective paint of the mirror from corrosion. The corrugated sheet is supported by the mirror support structure (MSS) and fabricated with the GI hollow section.

### Receiver

The receiver consists of stainless steel absorber tube (Figure 4). Each receiver has a secondary reflector that directs beam radiation onto the receiver. The entire optical system is enclosed in a sealed glazed casing. The innermost part of the receiver is named as absorber. The concentrated energy is transferred through the absorber into a thermal fluid (oil, water, etc.). The absorber is specially coated to increase their absorption of the reflected solar radiation. The absorber is usually encased in a glass tube to reduce convective heat losses from the surface. Sometimes, to improve the insulation effect, the space between the absorber and the glass envelope is evacuated and the ends are sealed. However, the upper portion of the receiver is often insulated to prevent heat loss as the receiver is always kept downwards in the LFR system.

***Figure 4:*** *Receiver of the LFR system*

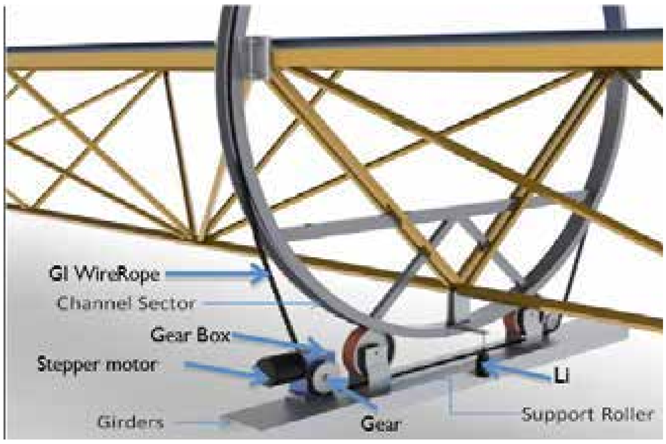



Insulated casing holds the absorber. This is low-iron casing filled with heat insulator and its inner side has an anti-reflective coating. The absorber tube is mounted in the cavity of the casing, and this cavity is further sealed with a glass-sheet (window glass) cover and silicon beading. The receiver is supported by steel A-frame structure that, in turn, is grouted to a concrete foundation. The wind arrestor (metal wire) reduces the wind load and provides support to the frame structure.

### Tracking System

The reflector of LFR system always tracks the apparent movement (east to west) of sun throughout the day. Tracking makes it possible to receive the maximum solar radiation at each time of operation. A GPS system with a step-up motor is used to synchronize the movement of reflector with the sun. The mechanical component of the tracking system comprises the sprocket and chain drive transmission mechanism driven by a stepper motor (Figure 5).

**Figure 5:** *Tracking system of LFR*




## 4. Key Features

- Feasibility of using lower cost flat or elastically curved mirrors with low cost of maintenance.
- Less structural requirements as the mirrors can be mounted close to the ground.
- The LFR system is structurally simpler and less expensive than other CST systems.
- Since the receiver is stationary, the possibility of leakage of heat transfer fluid is low.
- Cost reduction possibilities are higher as glass is the main material of use in LFR.
- Feasibility of increasing the size of the system without increasing the aperture width of constituent mirror elements.

## 5. Applications

LFR technology has broad application in the industries that require process steam and hot water at medium temperature range. For example, application of the LFR technology is found in the dairy and food processing industry. The relevant processes that require thermal energy in these industries are as follows:

- **Dairy**
  - — Storage of collected raw milk (cooling)
  - — Pasteurization of milk
  - — Cheese manufacturing
  - — Ice cream manufacturing (cooling)
  - — Cold storage (cooling)
- **Poultry, meat, and fish industry**
  - — Fish are thawed after storage (cooling)
  - — Drying of meat and fish products
  - — Rendering/dehydration of meat and poultry products
  - — Manufacturing of fish oil and fish meal
- **Vegetable oil manufacturing**
  - — Mechanical extraction of oil
  - — Chemical refining: degumming (oil is preheated)
  - — Chemical refining: soap stock heating
  - — Physical refining

Apart from the industries mentioned above, the LFR technology is applicable in:

- Textile industry: mercerizing, drying, and finishing
- Pulp and paper industry: kraft, pulping, efficient treatment, and bleaching
- Chemical process industry: drying, distillation and evaporation, extraction, and operations where the process temperature is less than 250°C
- Pharmaceutical and rubber industry.

# 6. Operation of LFR-based System

Operation of LFR-based system is almost similar to parabolic trough-based system. However, a few general steps are provided in the following subsections.

## 6.1. Checklist

Before initiating the operation (working) of a LFR system, the checklist provided in Table 1 has to be followed and ensured.

***Table 1:*** *Check list before initiating operation*

| S. No | Equipment | Condition | Location |
|---|---|---|---|
| 1 | Reflector and mirror | Reflector and mirror | Field |
| 2 | Pump-suction valve | Open | Field/pump house |
| 3 | Pump-discharge valve | Open | Field/pump house |
| 4 | Water level in expansion tank | Sufficient | Field |
| 5 | Nitrogen pressure in expansion tank | As per design | Field |
| 6 | Vent valves | Closed | Field |
| 7 | Drain valves | Closed | Field |
| 8 | Electricity (voltage and phase) | 440 V, 3 phases synchronized with pump | Control panel |

*contd...*

*Table 1: contd...*

## 6.2. Safety and Precaution During the Operation

### 6.2.1. General

- Pressurized steam or high-temperature (above 180°C) steam is explosive and, thus, should be avoided. The pressure of the fluid increases with the increase in temperature.
- Avoid looking at the reflector mirror with naked eyes.
- Always use sunglasses.
- Regularly monitor the pressure and temperature of the steam drum or boiler. It should be under the safe operating limit (normal limit: 45 kg/cm²). If pressure exceeds this limit, open the safety valve immediately.
- Only a technician with thorough knowledge of the system specifications should adjust the pressure -reducing valve and safety relief valve.
- In the steam drum, two safety relief valves (manual and automatic) are attached for additional safety.
- The pressure relief valve has to be set and tuned only by trained personnel.
- Adjust the safety relief valve.
- Always perform receiver maintenance when the receiver is at ambient temperature. Also, make sure that the plant is shut down.
- The system is pressurized, with the fluid/steam at a pressure much higher than the atmospheric pressure. Thus, on any opening/breakage/crack,

the fluid/steam can come out as a jet and may come in contact with the human body. This might result in burns.

- Pipes and other metal parts carrying the heated fluid/steam should be insulated, as any exposed area can pose burn hazards. Cover it with some temporary insulator (cotton, cloth, and so on) for the time being and flag it as danger.

# 7. Maintenance of LFR-based System

Necessary maintenance checks that need to be followed for smooth operation of LFR systems are listed in the following paragraphs.

## 7.1. Reflector

- Clean the mirrors once every three days using the DM water with less than 1 ppm.

If there is a lack of DM water supply for mirror cleaning at the supply points, then high-pressure pumps can be used. Ensure that the booster pump and the high-pressure pumps are functioning properly. Notify the manufacturer if either of the pumps does not function properly.

- The reflector mirror should be replaced whenever required to ensure that the reflectivity is always more than 90%.

## 7.2. Mirror Support Structure

- The galvanized steel elements of the MSS should be inspected once every 6 months for any damages and corrosion.

In case any corrosion of the steel elements is detected, the affected area should be cleaned and the zinc coating should be scrapped off with an emery paper. After scrapping, this area should be cleaned with an industrial detergent and repainted with a zinc-rich primer and aluminium paint or with a zinc-rich aerosol.

## 7.3. A-Frame

- Ensure that the legs of the A-frame, steel guy wires, bolted joints, and the welded joints are free from corrosion and external damages.

- The turn buckles of the guy wires should be kept properly oiled and greased. A routine check should be organized for the tightness of the guy wires once a year depending upon the climatic conditions.

- If the guy wire sags, ensure that its hooks and accessories and turn buckles are intact. Afterwards, tighten the turn buckle so that the guy wire does not sag and also ensure that the tightening does not deform the A-frame.

## 7.4. Receiver

In the case of low performance due to its low transmittance, clean the window glass.

- If you notice fade marks in the window glass, clean it using the DM water, that is, water with less than 1 ppm makes the window glass highly durable.

- If any of the beadings are found to be burnt out, the respective beadings have to be replaced with the new beadings.

- All the operations should be performed using a long boom crane which can reach the receiver from the service area of the solar field. Usually, it requires experienced technical support. Contact the manufacturer in case any problem pertaining to the receiver is detect

## 7.5. Electronic Tracking System

- The air filter in the panel should be changed once a year.

- The relay card contacts should be checked once every six months, and it should be changed if there is carbon formation between contacts. Inform the engineer/ manufacturer in case of a card problem.

- Periodical cleaning of the panel should be carried out with the help of the blower.

## 7.6. Mechanical Tracking System

- Ensure that the chains, sprockets, shafts in gearboxes, and rollers are kept properly greased and oiled using any branded oil. A routine check should be organized once every three months.

- The tension on the chains and wind-load-arresting wire ropes is to be maintained such that the chains and wire ropes do not hinder the rotation of the reflectors.

- In case there is a derailment of the chain from the sprockets, the chains should be loosened at the ends using the chain tension mechanism and they should be placed in position.

- If the reflector struggles to rotate, check for mechanical resistance caused by jamming of the rollers by foreign objects or mechanical failure of the tracking system. Clear the obstacles around the rotating parts/joints to facilitate the rotation of the reflector. If the roller gets jammed due to the wear and tear of the polyurethane coating on the roller, please notify the manufacturer.

- In case there is a mechanical deformation of the cam, notify the engineer/manufacturer since it would require adjustment and reset the alignment of the reflector.

## 7.7. Process and Instrumentation System

**Pump Maintenance**

- Follow the manufacturer's recommendations for lubrication. Tighten the packing gland as required. Look at the manual for individual pump maintenance.

**Pressure Relief Valves**

- Inspect the pressure relief valves annually. Operate the valves manually using the lift lever. Replace any valves that are frozen shut.

**Check Valves**

- Inspect the check valves annually. Open the valve to verify that there is no erosion or corrosion, the seat is not damaged, the valve operates freely (does not stick), and the flapper or plunger is not pitted and has not accumulated scale.
- Replace the valve in case of any problem.

**Manual Valves**

- Operate all manual valves, that is, open and close them once a year. This will prevent the valves from freezing up.

**Piping**

- Check all piping during visual inspection, that is, do a pipe-walk. Repair or replace torn/damaged/wet insulation. Wet insulation inside the insulating cover is sometimes hard to detect; however, puddling of the collector fluid under the piping is a definite indication of a leak.
- Remove the pipe covering for several feet on either side of the puddle; it should be enough to locate the leak and perform repair activity.
- Check and adjust pipe hangers annually to ensure that they are providing proper piping support.

## 7.8. Precautions during Maintenance

### 7.8.1. Pipeline and Equipment

- Flexible hosepipes are generally susceptible to leakages due to high pressure in the system. Therefore, maintain a safe distance from it.
- Wear gloves while removing insulation to avoid skin contact with hot surfaces.
- Ensure that the isolating valves are closed before working on any equipment.
- Remove steam completely through the vents before opening any equipment.
- If the fluid is to be flushed out by opening the pipe flanges or coupling, ensure that the majority of your body is above the pipeline.
- Stand away from the pipe while opening the drainage valves to avoid fluid spill over the body.

### 7.8.2. Steam Drum/Boiler

Historically, boilers were a source of many serious injuries and property destruction due to poorly understood engineering principles. Thin and brittle metal shells can rupture, while poorly welded or riveted seams could open up, leading to a violent eruption of the pressurized steam. When water is converted to steam, it expands to over 1000 times its original volume and travels down the steam pipes at over 100 kmph.

Some of the key points from a safety's viewpoint are as follows:

- The boiler temperature and pressure should not exceed the allowed limit. (See the steam table for applicable pressure.)
- Regular checkup of the boiler body is mandatory.

### 7.8.3. Receiver

- Always use a winch for receiver maintenance or repair.
- Always carry out receiver maintenance or repairs in the presence of the supervisor/manufacturer/engineer.
- Reflectors should be defocused completely before any maintenance work.
- The receiver temperature should be near the ambient temperature before repair/maintenance work.
- Drain the entire heat carrier (water or thermic fluid) before repairing the absorber tube.
- Do not start receiver maintenance without putting on gloves, helmet, and shoes.
- When working on the receiver at a height, ensure that the winch is working properly and a support for feet is available to avoid a fall.

### 7.8.4. Reflector

- Always use sunglasses while in the solar collector area.
- Do not forget to use gloves in addition to sunglasses while changing the reflector mirror.

### 7.8.5. Precautions during Operation

- Keep an eye on the temperature and pressure at every temperature transmitter (TT) and pressure transmitter (PT). It should not exceed the normal range.
- The header pipe stores steam at high pressure; hence, one should avoid going near by.
- Do not allow children/unauthorized persons/animals into the solar field.
- Keep distance from the safety relief valve when releasing steam.

### 7.8.6. Workforce Protective Equipment

- Hand gloves
- Industrial safety shoes
- Protective sunglasses

- While working on the receiver, always use a winch and make sure that the hands remain free from oil and grease.

### 7.8.7. Chemical-related Precautions

- Use only DM water or a branded thermic fluid as a heat carrier. Never use normal water in pipes

## 7.9. Troubleshooting of Problems in LFR System

- Problem mechanical systems are functioning properly but the reflectors are not tracking.

**Solution:** Check the panel devices and main power at the following points:

- **Feeder to main junction box**
  - Check the solar field (CLFR feeder) main power in switchyard to see whether it is switched on or off.
  - If it is off, inform the respective field in-charge.
- **Main junction box to field RTUs**
  - If the feeder is on, check the contactor.
  - If contactor is not picked up, check the pickup loop (see the instrumentation RTU panel wiring diagram).
- **Inside the field RTUs**
  - If the contactor is on, check power status in the main terminal block (Tag ID: P, N, G) with multi-metre
  - Switch off the main selector switch on the panel door if it is on.
- **Check the MCB's Position (32A, 6A MCBs)**
  - Check the main MCB's position, and if it is on, indication on the right door will show the power status.
  - Check the MSS MCB's position: if it is on, then the particular SMPS will get powered on; if not, check the MCB's condition.
  - Check the panel 24V SMPS MCB position: if it is on, the panel 24V SMPS will be powered on; otherwise, check the MCB's condition.

**a) Check the I/O modules power (24V SMPS)**

- Check the status of Module MCB: if it is in off position, change the position.
- If the panel 24V SMPS MCB is on, the modules automatically get powered on; otherwise, check the module SMPS and module MCB.

**b) Check the drive SMPS (48V SMPS)**

- If the MSS MCB is in perfect condition, then the particular drive SMPS will get powered on, otherwise check the SMPS by using multi-metre.
- Input: 230V, 50 Hz, single-phase output: 48v, direct current

**c) Check the driver (bi-polar stepper drive)**

If the SMPS is in perfect condition, check the stepper drive (fuse).

- ***Check the field devices***

**a) Check the stepper motor and cables**

- Ensure that the panel devices are in perfect condition (including SMPS and stepper drive). Check the stepper motor and cabling in the field.

**b) Check the feedback device I (encoder)**

- To check the encoder, first check the wiring, and then check the 24V DC power supply to the encoder on the junction (inside the cable tray).

**c) Check the feedback device II (limit switch)**

- To check the limit switch, check the continuity in junction, which is inside the cable tray when the limit switch is pressed.

## 8. Case Study

| Solar-Biomass Hybrid Desalination Plant, Tamil Nadu | |
|---|---|
| **Location:** Narippaiyur, Tamil Nadu | **Type of Installation:** Linear Fresnel Reflector |
| **Configuration:** 1404 $m^2$ collector area, 12 $m^3$ steam accumulator | **Supplier:** KGDS Renewable Energy Pvt. Ltd |
| **Application:** Steam generation for desalination of water | **Year of installation:** February, 2013 |
| **Beneficiary Details:** The Department of Science and Technology (DST) awarded KGDS Renewable Energy Private Limited with a prestigious project of national importance titled 'Design, Fabrication, Testing, and Installation of Solar Multi-Effect Distillation System for Providing Potable Water in Arid Rural Areas'. The National Institute of Ocean Technology (NIOT) played a major role in the development of this project. |  |

**System details:** The indigenously developed LFR steam-generating system consists of long parallel arrays of low-iron glass mirrors which concentrate the solar radiation falling onto a receiver placed at a specific height above the ground. The primary reflectors are equipped with a single-axis tracking system. Saturated or sub-cooled water from the steam drum is circulated through the absorber tubes housed inside a linear cavity receiver (LCR) using a recirculation pump. The concentrated solar radiation generates saturated steam–water mixture at a pressure of 21 bar. This steam–water mixture is passed to the steam drum where saturated steam is separated from saturated liquid. The saturated water in the steam drum is fed back to the LFR by the recirculation pump and the saturated steam is taken to the steam accumulator. The saturated steam enters the accumulator at a pressure of 21 bar. Steam from the accumulator is supplied to the MED-TVC system at a pressure of 5–7 bar.

**System application details:** The LFR delivers 800 kg/h of saturated steam at 21 bar. The saturated steam enters the accumulator at the same pressure and supplied to the MED-TVC system at a pressure of 5–7 bar. About 6000 kg/h of desalinated water having TDS less than 5 ppm is produced by the system.

| | |
|---|---|
| **Thermal Output:** 800 kg/h (steam) @ 21 bar | **Operating temperature and pressure:** 21 bar |
| **Type of fuel saved:** NA | **Quantity of fuel saved:** NA |

**Overall performance:** Satisfactory

**O&M issues and beneficiary perception:** The solar field can supply steam only during daytime. In order to achieve round-the-clock production of desalinated water, a 10 bar, 1 TPH biomass boiler is integrated with the solar MED system. The biomass boiler is fired using the locally available juliflora. The biomass boiler also helps the plant run in steady-state condition during periods of insufficient or intermittent solar radiation

**Beneficiary/supplier detail**

Dr Sathy Viswanathan
President, KGDS Renewable Energy Private Limited
Coimbatore, Tamil Nadu
Email: spv@kgisl.com

# 4

# Fixed Focus Elliptical (Scheffler) Dish

## 1. Introduction

The Scheffler dish is a paraboloidal mirror that is rotated about axes that pass through its centre of mass, but this does not coincide with the focus, which is outside the dish (Figure 1). If the reflector were a rigid paraboloid, the focus would move as the dish turns. To avoid this, the reflector is flexible, and is bent as it rotates so as to keep the focus stationary.  It concentrates sunlight in two dimensions to a 'point' or small area, allowing heat flow without a dedicated mechanism such as transfer fluid (Figure 1). The concentrating reflectors track the movement of the sun, reflecting the light of the sun and concentrating it on a fixed position.

The first well-functioning Scheffler reflector was built by Wolfgang Scheffler in 1986 at a mission station in north Kenya, which is still in use. Since then the technology has been continuously improving and passed to many locations throughout the world, with the number of dishes increasing every year.

***Figure 1:*** *Fixed focus elliptical (Scheffler) dish*

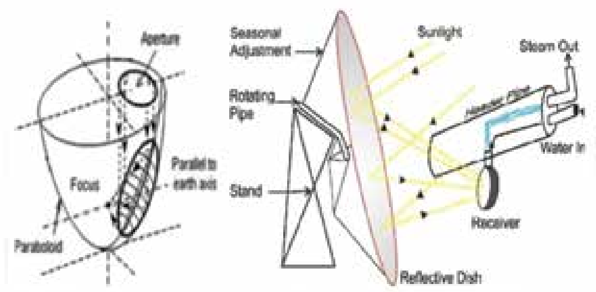
## 2. Working Principle

A fixed focus elliptical dish, or as it is called, a Scheffler concentrator, comprises of a large number of mirrors that move to reflect the sun's rays to a receiver, which is fixed and contains a working fluid to be heated. Water is usually used, which can be used as pressurized hot water or converted to steam. However, a suitable thermic fluid can also be used. A schematic of Scheffler dish is presented in Figure 2.

The Scheffler dish system works on the following principles:

- The parabolic reflective dish turns about north–south axis parallel to the earth's axis, tracking the sun's movement from morning (east) to evening (west), maintaining gravitational equilibrium of the dish.
- The parabolic reflector also performs change in inclination angle while staying directed to the sun in order to obtain sharp focal point.
- Focus lies at the axis of rotation. It remains at a fixed position, where concentrated heat is captured and transferred to water through the receiver to generate hot water or high-pressure steam.
- Water from header pipe passes to receiver (thermosyphon principle). At the receiver, the hot water or steam-generated water, collected in the header pipe, flows to the end-use application.

**Figure 2:** *Schematic representation of a fixed focus elliptical dish*




The sun is automatically tracked by the dish in the east–west direction from morning to evening using a single-axis tracking system. For the variations of the sun's position in north–south direction due to changing seasons, manual adjustments have to be made every few days. Scheffler dishes with automatic north–south tracking have also been recently introduced in India.

## 3. Components of Scheffler Dish

A system to generate heat from Scheffler dishes, consists of a number of sub-systems and components. However, it is easy to see what the entire system does by specifying just a few basic parameters. The key components in any Scheffler system are described below.

**Reflector or Concentrator**

Scheffler reflector as shown in Figure 3 is an assembly of parabolic-shaped reflector, made up of solar-grade reflecting mirrors.

**Figure 3:** *Reflector and receiver of Scheffler dish system*

**Receiver**

As shown in Figure 3, the receiver is placed at the focus of the dish, which absorbs concentrated sunlight to heat up water to generate steam. It works on thermosyphon principle, in which cold water sinks down from header to receiver, and hot water/steam comes up (lower relative density) and is then collected back in header pipe for storage.

**Header Pipe**

Storage tank contains water in the lower half and steam in the upper half. It also works as a buffer system, that is collects and stores steam generated by Scheffler system, which can be utilized as per requirement.

**Tracking Mechanism**

In Scheffler dish, with the sun's movement from east to west, the dish continuously turns about an axis, tracking the sun's radiation and maintaining the focus of collector on the receiver tube. The axis of daily rotation is located exactly in north–south direction, parallel to the earth's axis and runs through the centre of gravity of the reflector.

Scheffler dish tracking can generally be of two types:

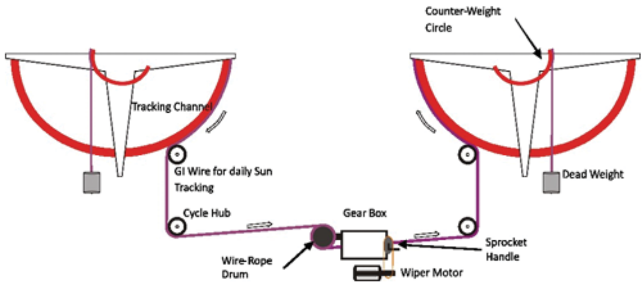
- Single-axis tracking: Automatic daily tracking but manual seasonal tracking
- Dual-axis tracking: Automatic daily tracking and automatic seasonal tracking

**1. Daily Tracking Mechanism (east to west)**

In order to compensate for west–east rotation of the earth, Scheffler dish moves from east to west by 1° every 4 minutes. Electronic timer is driving 12 Volt wiper motor, which accurately controls rotation of Scheffler dish, by pulse width modulation technique at fixed duty cycle.

Wiper motor thereafter rotates gearbox (minimum gear ratio 1:60), which transmits power to GI wire rope, connected through wire rope drum. This GI wire rope connects Scheffler dishes in a row to a common tracking wiper motor. The GI wire passes on C-Channel of rotating support of Scheffler through bicycle hub support as shown in Figure 4. GI wire pulls the reflectors in clockwise direction during the tracking period. To counter force from GI wire a dead weight (counter weight) is hung to rotary support on counter weight circle.

***Figure 4:*** *Daily tracking mechanism of Scheffler dish*




**2. Seasonal Tracking (north–south)**

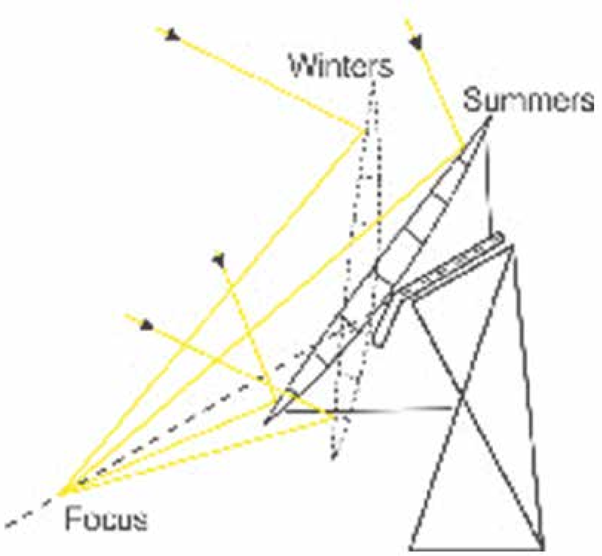
Seasonal tracking is done to change position of the reflector in north–south direction depending on the position of the sun (Figure 5). The mechanism providing lever and screws is mostly used, however the new system incorporates linear actuators.

- Very slow seasonal movement, that is 23.5° in three months
- Needs adjustment in 3–4 days
- In India, dishes are more vertical relative to ground during winters and flat in summers.

Seasonal adjustment is done by a telescopic bar at each end of the reflector. The following are the two ways of doing seasonal adjustment:

- Manual adjustment (as explained in STP 03)
- Automatic seasonal tracking with linear actuators to move dish up or down

***Figure 5:*** *Seasonal tracking of Scheffler dish*



## 4. Key Features

- Proven technology with a number of working installations for community cooking, air-conditioning, and other applications.
- After establishing structural load limits, these dishes can be installed on rooftops.
- Can be manufactured locally or at the site of installation.
- Relatively cheaper technology.
- Relatively lesser O&M requirement.

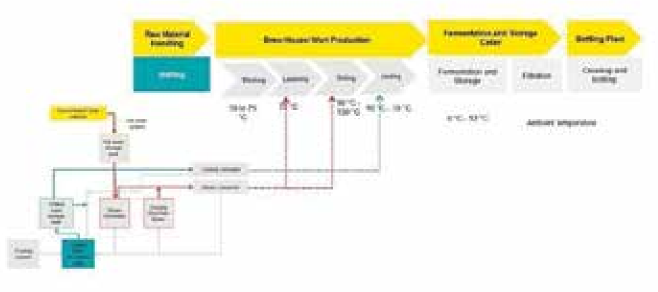
## 5. Applications

Scheffler systems can find application in the industries that require heat or steam below 150°C, for example, in beverage industry  heat demand of the following processes could be met with the Scheffler dish system:

- Mashing (50°C to 75°C)
- Lautering (75°C)
- Boiling (90°C to 100°C)
- Cooling (100°C to 9°C)
- Sterilization (80°C to 100°C)

An illustrative process flow diagram for beverages industry is also provided in Figure 6.

***Figure 6:*** *Process flow diagram of beverages industry where Scheffler dish could be integrated*



Other than this, Scheffler technology also finds its application in the electroplating sector, tobacco industry, and the desalination industry.

## 6. Operation of Scheffler Dish-based System

The steps involved in the operation of Scheffler dish-based system are described in the following paragraphs:

### 6.1. Setting of the Focus Correctly on the Receiver

- **Operation for PLC-Based Control Panel**
    - If by evening or earlier the dishes reach their extreme end, motors move dishes back to homing position automatically by sensing reverse limit switch.
    - Once the dish reaches to home position, it touches the forward limit switch, which automatically stops the entire system.
    - It is necessarily expected that positions of all dishes are properly and mechanically synchronized.
- **Operation for Timer-based Control Panel (Non-PLC based)**
    - Operator has to adjust the position of dish so that the sun focus is at the centre. Forward and reverse inching push buttons to be used to adjust the position as desired. Operator shall never use inching buttons while auto mode is on.
    - After adjustment of dish positions, again heating switch shall be put on.
    - Now depending on the timer on/off duration setting, the dish moves in forward direction in steps. 01 sec on and 18 sec off time is set. If required the setting can be changed on the timer.
    - This tracking shall continue for the whole day automatically. (Battery power is used for this purpose. Battery keeps on charging for the whole day if the panel is provided).
    - At the end of the day when dish motor reaches and touches the ‘full forward limit switch’, forward movement of the motor stops. Now the motor draws power from grid and starts reversing automatically. At this moment, the operator, being evening time, shall stop the heating by switching off the heating switch. The dishes shall reverse back to original position and touch ‘full reverse limit switch’ and stop.
    - On the second day, the same operation shall be repeated by the operator.
    - It is necessarily expected that positions of all the dishes are properly and mechanically synchronized.

In manual mode, the individual motors can be adjusted by using the push button on the push button station on the respective dish row.

### 6.2. Monitoring and Control

System parameters should be monitored regularly. An illustrative example of a monitoring table to be followed is shown in Table 1. It may be noted that the table is just for an illustration and actual values may vary on the basis of the manufacturer.

***Table 1:*** *System parameters for normal operation*

| System parameter | Value |
|---|---|
| Set maximum pressure in header pipe | 10 kg/cm$^2$ |
| Set minimum pressure at steam line | Depends on application |
| Water level in header pipe* | 75% water level |

*contd...*

*Table 1: contd...*

| System parameter | Value |
|---|---|
| Dry saturated steam generated for minimum solar radiation 450 $W/m^2$ | 5 kg/h |
| Set pressure limit at steam line near cooking vessel* | 2 $kg/cm^2$ |

- Monitor pressure at the point where steam is being utilized. It should be within the safe limit of the device which is utilizing that heat. Take readings of the operating parameters in a logbook. Some examples of the logbooks that could be used are shown in Appendix 2.
- If dish is moving too fast or too slow and the focus is out of place, follow STP 3, to adjust the timer.
- Monitor pressure in expansion tank. Safety relief valve should always go off to vent out excess steam.
- If the safety relief valve does not open after pressure crosses safe pressure limit, shut down the system and call maintenance.

## 6.3. Exceptions and Backup

**Power Failure**

Power backup is supplied along with system to run electronic timer during power cuts. In case backup power is also not working, manually defocus dishes to sleep mode so as to protect insulation near receiver from any damage due to concentrated heat. In case, not using system for long time/rainy season, then turn the dish to morning or evening position facing downwards.

- Give proper shading, cover items like timer (daily tracking device)/PLC, wiper motor, valves, gearbox, safety relief valve, pressure reducing valves, etc.
- Flush out water from the circulation system to turn off all the MCBs in the solar control panel.

## 6.4. Shutdown Sequence

There are different sets of action followed for different types of systems:

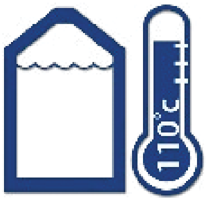
1. Electronic timers, Go-to timer and press shut down button: The dish starts turning in anti-clockwise direction. When the dish reaches sleep position release shut down button. Some timers have the option to automatically bring dishes to the morning position at a set time in the afternoon.
2. Electronic timers with automated tracking/PLCs: Electronic timers with pre-set time after which it automatically brings back dish to morning position
3. The dish can also be brought manually to a sleep position by rotating sprocket handle.

## 6.5. General Risks during Operation

Risks associated while working on Scheffler dish-based system are listed below and those risks that may cause system failure are listed in the following sub-sections:

### 6.5.1. Risks from High Temperature

- The fluid is at a temperature above 110°C, which is a scalding temperature. So any contact with fluid should be avoided.
- Pipes and other metal parts carrying fluid are at same temperature and are mostly insulated. However, at any exposed area near insulated hose pipes, the temperature can be high enough to cause skin burns.
- The area between the reflector and the receiver can be extremely hot.




### 6.5.2. Risks from High Pressure

- The system is pressurized, with fluid/steam at a pressure much higher than atmospheric pressure. Thus, on any opening/breakage/crack the fluid/steam can come out as a jet and may come in contact with and injure the human body.
- Regularly monitor pressure at header pipe. It should be under safe operating limit (normal limit: 10–11 $kg/cm^2$). If pressure in header pipe exceeds this limit, then call system maintenance.
- The pressure and safety relief valves should be set and tuned only by a trained person. Follow STP 04 to adjust the safety relief valve.
- Risks from concentrated sunlight.
- Concentrated sunlight seen at the reflector or receiver can severely damage the human eye.
- Make sure that focus cannot accidently fall on any ignitable material
- Never move or stand between the dish and the receiver, and if at all you are moving in this region, then keep close to the dish and away from the receiver.

### 6.5.3. Risks to Equipment

Risks to the equipment can occur from the following factors:

- Use of excessive force while handling levers or tightening.
- Placement of sensitive equipment such as temperature and pressure gauges near sources of high temperature and pressure.
- Gauges placed close to the receiver and not insulated to PVC conduit piping or any other non-metallic equipment placed behind the receiver.
- Control panel, water pump motor, and any other electrical equipment in the field should be properly grounded.
- For all the rotating equipment, safety guard and protective mesh are to be installed and well maintained.
- Control panel is to be installed at a suitable place to prevent direct exposure from rain/dust/sun light/heat.

## 6.6. Safety and Precaution during Operation

- Use of personal protective equipment (PPE)
- Hand gloves of appropriate thickness and insulation to protect against hot surfaces
- Industrial safety shoes while walking on site
- Protective sunglasses
- Fire extinguisher
- While working on height/sloping roof, use a foot support (scaffolding/firm roof-mounted platforms), safety harness/hand-grip rope

All valves and fittings should be as per Indian Boiler Regulation (IBR) specifications with test certification for each valve. During repair work, technician should follow IBR Regulations and specifications for tasks such as procuring material, welding and plumbing works near steam boilers and steam pipelines. Operator should refer to manufacturer's specifications for valve/fitting to be replaced.

# 7. Maintenance of Scheffler Dish-based System

Maintenance guideline of Scheffler-based system is provided in the following subsections:

## 7.1. Reflectors and Receivers

- Clean reflector dishes whenever the mirrors are dusty and reflectivity is reduced.
- Twice a year, check for broken mirrors. Schedule to replace them soon if there are five or less broken mirrors in a dish. Schedule immediate replacement (recommended) if there are five or more broken mirrors in a row.
- Every five years or whenever necessary check for mirror degradation as shown in Figure 7. Check that reflectivity of the mirrors should be more than 90%. Deterioration of mirrors affects the performance of the system. Replace blind mirrors (with reflectivity less than 80%).
- Annually, undertake structural painting and repair of the system to improve its life span.
- Twice a year, apply black coating on the receiver with paint as per the manufacturer's specification to improve the system's performance.

## 7.2. Circulation System

Annually, check for scaling at inner linings of the receiver and the header pipe. Scaling and its effect on the system's performance has to be visually determined as shown in Figure 7. This task is generally outsourced because it is rarely performed and requires descaling systems and industrial-grade descaling chemicals.

***Figure 7:*** *Scaling of inner lining of pipe*

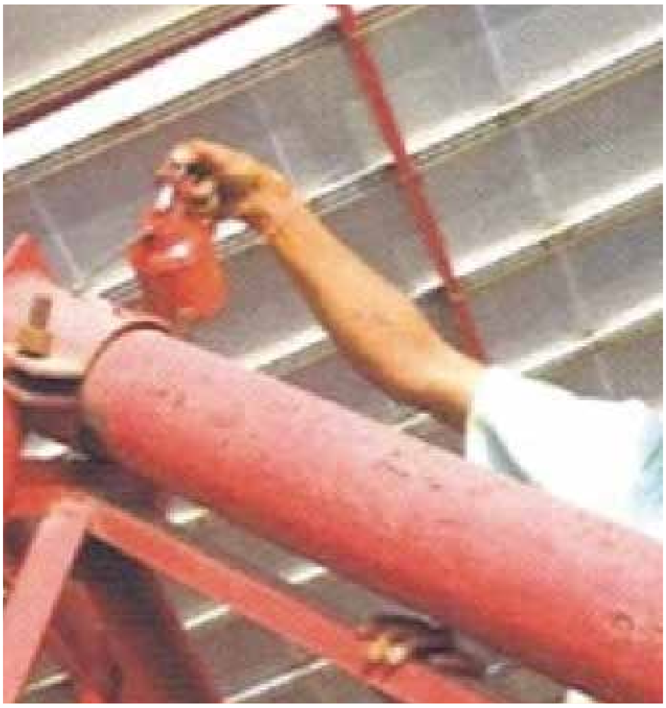
- Weekly check for leakages in the system. Due to high pressure in the system, it is susceptible to leakages especially at points like the rubber washer in the water-level indicator, flexible hose pipe. Perform this operation when you spot leakages in circulation pipe.
- Identify the point of leakage and remove insulation for that component. Repair/replace component with leakage. Leave insulation material (mineral wool) open to dry off, and then put it back.
- On the onset of monsoon, remove all the water from the header pipes. Open blind plugs connected at the bottom of steam pipelines. This will flush out rust and impurities from pipelines along with water from header pipe.
- After the monsoon, add fresh RO/DM water in circulation system and then start the system.
- Annually calibrate temperature transmitter, pressure transmitter, flow meter, and other gauges.

- Annually replace soft water resin (if applicable) in RO water purifier.
- Quarterly clean screen in Y-Strainers with brush or by soaking it in a clean solution.
- Twice a year clean RO system cartridge filler.

## 7.3. Tracking System

- Quarterly check that GI wire rope, which is tightly hung at the end points in the tracking system. GI rope can be tightened by U-clamps.

***Figure 8:*** *Greasing of moving parts*



- GI wire should be able to move freely about cycle hubs
- Quarterly check for the movement of cycle hubs
- Replace hubs that are deformed due to excessive weight
- Quarterly, grease and lubricate moving parts in the system as shown in Figure 8. Lubrication should be done especially after rainy season or lubricate brackets and screw of rotating pipe. Screws and levers in seasonal adjustment rods or cycle chain on gearbox.

## 7.4. Consumable Replacement

The following are the consumable parts in Scheffler system, and hence need standby stock:

1. Coating for receiver as per manufacturer's specifications
2. Resin for RO water purifier
3. Feed water if there is no water source near Scheffler solar system
4. Oil and grease
5. Mirrors (though not consumable, but some spare mirrors [around 25 mirrors per dish]) should be stocked as replacement for broken mirrors

## 7.5. Maintenance Dos and Don'ts

**Dos**

- Carry out maintenance as per the drawn maintenance schedule.
- Maintain the operation and maintenance log book every time as defined in the log format.
- For any maintenance work, ensure that power supply to control panel is switched off and dishes are defocused from the receiver.
- Follow all the requirements about safety as specified in the Chapter on Safety.
- Ensure all the settings (temperature and pressure) are as per the design criteria.

**Don'ts**

- Do not clean the mirrors with dry cloth or paper.
- Do not clean the mirror after 8.00 am and before 5.00 pm.
- Do not modify the system without written approval from the manufacturer.
- Do not touch the receiver when focus is on the receiver.
- Do not walk in between the receiver and the dish during operation.
- Do not stop water circulation till temperature drops to 60°C.
- Do not use hard water for mirror cleaning as it may form scaling on mirrors and thus reducing performance.

## 7.6. Troubleshooting of Problems in Scheffler-based System

Cause, reason, and possible troubleshooting for problems that occurred in Scheffler dish-based system are listed in Table 2.

*Table 2: Troubleshooting cause and solution in Scheffler dish-based system*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| 1 | **System not starting in the morning** | Control panel not switched on | Control panel physically not started | | | Main switch to be switched on and ensure indicating lamps glow |
| | | | Problem in main distribution panel | | | Main distribution panel to be checked and correct the fault |
| | | Problem in incoming power for control panel | Physical damage to the incoming cable | Incoming cable not routed properly | | Check/correct incoming supply to control panel and/or replace the cable, if required |
| | | | Short circuit at the main distribution line | Cable damage | | Check/correct/replace the main distribution |
| | | Main MCCB not working in control panel | MCCB tripped | Due to overload | | Check and replace MCCB |
| | | | | Short circuit in control panel | | Check/correct the fault |
| | | | | Malfunctioning of MCCB | | Repair/replace the MCCB |
| | | | | Short circuit in any of the motors or circuit | | Check and correct the fault |
| 2 | **Scattered focus** | Improperly fixed mirrors | Fixing arrangement not tightened properly | | | Check/adjusted alignment of mirrors |
| | | Mirrors not cleaned | No manpower available | | | Identify manpower from the client end for dish |
| | | | Procedure not followed | | | Follow the process as per the O&M Manual |
| | | | Soft water not available | | | Mirror to be cleaned only with soft water |
| | | | Proper tools not available | | | Hose pipe with nozzle, mopping brush, and wiper to be arranged for cleaning mirrors |
| | | Low radiation | | | | No option |
| | | Fine tuning not done | Jam nut for fine adjustment | | | Make the adjustment nut-free and fine-tune the connection |
| | | Mirrors tainted | Bad quality of protective coating | | | Replace mirrors with Thermax-supplied solar grade mirrors |
| | | | Domestic mirrors used | | | |

*contd...*

*Table 2: contd...*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | | Corrosive weather/coastal area | | | |
| 3 | **Auto forward not happening** | Problem in the contactor for forward motion | Carbon deposited on internal contacts | Loose contact | | Check/clean/correct/replace the contactor with same specs and tighten the electrical terminations |
| | | Problem with the PLC | Program not functioning properly | Improper earthing to PLC panels | | Check/correct in coordination with PLC engineers and provide separate instrument earthings for PLC panels |
| | | Problem in one of the limit switches | Limit switch damaged | Limit switch stuck up | | Check/replace/repair the limit switch |
| | | Problem in gear motor | Winding burnt | Due to overload on motor | | Check/replace/repair the gear motor |
| | | Problem in gear box | Gear box jam | No lubricant for gear box | | Check/repair the gear box |
| 4 | **Water pump not operating** | Problem in signals from Mobrey | Magnetic switch not functioning properly | | | Repair/replace the magnetic switch |
| | | | Float stuck-up inside | | | Clear the float |
| | | | Problem in electrical connection inside Mobrey | | | Check and correct the electric connections |
| | | Problem in contactor for water pump | Carbon deposited on internal contact | Loose contact | | Check/replace/correct/clean the contactor |
| | | Problem in rotary switch for water pump | Internal contact burnt | Loose contact | | Check/replace the rotary switch |
| | | | Wiring not proper | | | Correct the wiring as per wiring diagram |
| | | Problem in V-belt for pulleys | V-belt worn out | | | Check tension/replace V-belt |
| | | | Slippage of V-belt on pulley | | | Check tension/replace V-belt |
| 5 | **Focus not exactly at centre of receiver** | Dish/dishes not tracking properly | No supply to AC panel | Problem in wiring | | Check proper supply to the panel and motor and/or rectify |
| | | | | Problem in contactor for AC motor | | Check contacts and replace, if required |
| | | Improper alignment of tracking wheel with respect to gear box | Distortion in tracking wheel | | | Check and correct for any distortion in tracking |

*contd...*

*Table 2: contd...*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | | | Wire rope's locking arrangement loose | | Check and tight the locking arrangement |
| | | | Distortion in aluminium rectangular tube linkage | Overload on the linkage mechanism | Centre to centre distance in holes of aluminium rectangle is not as per the requirement | Check and correct the distance as per drawings, if required |
| | | | | | Back bearing nut of rotating pipe is overtight | Loose the back bearing nut and ensure free movement of the dish |
| | | | | | Top bearing part is overtight and thus restricting the dish movement | Loose the top part cover and ensure free movement of dish |
| | | | | Improper alignment of dishes | | Check and correct the alignment as per the procedure given in installation manual |
| | | | | Improper jointing of aluminium tubes | | Correct the joint and tight the nut and bolts for proper load distribution |
| | | | | Overload on the linkage mechanism due to high speed of wind | | Do not operate the system during high wind condition and tie dishes with reflector stand properly with ropes so as to avoid damages |
| | | | Inadequate distance between the dishes | Improper installation | | Take prior approval from engineers for any correction to be made |
| | | | | Inadequate layout size | | Take prior approval from engineers for any correction to be made |
| | | | Inadequate distance between the dish and the receivers | Improper installation | | Take prior approval from engineers for any correction to be made |
| | | | | Improper layout size | | Take prior approval from engineers for any correction to be made |
| | | | Receiver inclination angle not as per requirement | Inclinometer not available during installation | | Angle to be checked with inclinometer |
| | | | | Negligence during installation | | Make alignment report and get it approved |

*contd...*

*Table 2: contd...*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | Dish movement is jammed | Under sizing of hole at the channel | Back-bearing nut of rotating pipe is overtight | | Check hole of the back-bearing channel and correct as per requirement |
| | | | Oversizing of bolt at the rotating pipe | Top bearing part is overtight and thus restricting the dish movement | | Check and loosen the top part |
| | | | Improper lubrication at assembly top part | | | Ensure proper lubrication and free movement of bolt |
| | | Improper dish balancing | Balancing weight not installed | | | Check and correct balancing |
| | | Improper seasonal adjustment | Side rope not properly tight | | | Locking arrangement to be tightened properly |
| | | | Locking of adjustment levers not tight | | | Locking arrangement to be tightened properly |
| | | | Fine adjustment not done | Jam nut for fine adjustment | | Make the adjustment nut free and fine tune the connection |
| 6 | **Water pump not developing pressure** | Problem in NRV | Dead weight inside stuck up and not operating | | | Check/rectify/replace NRV |
| | | | Direction of NRV is improper | | | Correct the direction as per requirement |
| | | Suction strainer choked | Excessive dust in water from piping | Water tank not cleaned | | Clean the water tank and flush the piping |
| | | | Wire mesh of strainer clogged with permanent scale | Hard water getting used for operation | | Use only soft water to clean the strainer. Replace the water-treatment equipment, if required |
| | | Problem with the valve seat assembly | Wear and tear of valve seat assembly | Hard water getting used for operation | Softener not available | Check/replace valve seat assembly |
| | | | Spring tension is not proper | In operation since long time | No breaks for regular maintenance | Adjust/replace the spring tension |
| | | | Foreign particles inside the valve seat assembly | Strainer not cleaned | Maintenance not done properly | Clean the valve seat assembly properly during preventive maintenance |
| | | Problem in gland washer | Wear and tear of gland washer | Wear and tear of pump shaft | | Check shaft for smoothness, replace gland washer |

*contd...*

*Table 2: contd...*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | | Gland washer rubber hardened | High temperature of inlet water | | Maintain inlet temperature of the water within 70°C<br><br>Replace gland washer |
| | | | Water leakage form Gland washer assembly | Foreign particles between shaft and gland rubber | Strainer not cleaned | Clean the gland water and strainer |
| | | Faulty pressure gauge | Isolation valve closed | Negligence | | Open the isolation valve |
| | | | Spring tension lost | Over pressure | | Repair/replace the pressure gauge |
| | | No water in feed water tank | Softener is not working | Resin property lost | | Replace resin<br><br>Replace softener |
| 7 | **Pressure not developing in steam drum** | Low radiation | Cloudy weather, fogging | | | Wait for clear atmosphere |
| | | Focus not on receiver centre | As per above point no. 2 | As per above point no. 2 | As per above point no. 2 | As per above point no. 2 |
| | | No water steam drum | Pump not working | Level controller not functioning | | Check level controller and make the water pump operational. Repair, if required |
| | | | Level gauge functioning | Gauge glass valve choked | | Clean the gauge glass valve and ensure that the tube shows water level |
| | | | Operator negligence | | | At the start it should be a standard practice for steam drum filling |
| | | Scattered focus | As per above point no. 3 | As per above point no. 3 | As per above point no. 3 | As per above point no. 3 |
| | | Less focus intensity | Mirror tainting | | | Replace tainted mirror |
| | | | Low radiation | | | Wait for clear atmosphere |
| | | Faulty pressure gauge | Isolation valve closed | Negligence | | Open the isolation valve |
| | | | Spring tension lost | Overpressure | | Repair/replace the pressure gauge |
| 8 | **Steam continuously blowing from drum safety valve** | Problem in safety valve | Valve seat wear and tear | | | Check/replace the seat of safety valve |
| | | | Scale formation on valve seat | Hard water being used for operation | Softener not functioning properly | Recharge softener, clean the valve seat |
| | | | Spring tension lost | Overnighting of the spring | | Replace the safety valve spring |
| | | Restriction to steam flow | Main steam stop valve or isolation valve at application point closed | No utilization of generated quantity of steam at the process | | Open the valves and utilize the solar stream to the maximum possible extent |

*contd...*

*Table 2: contd...*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| | | | Problem in NRV in outlet line | NRV direction not as per requirement | Negligence during installation | Check/replace/rectify NRV |
| | | | | Flap/Dead weight inside got stuck up | Scale formed dust inside the NRV casing | Check and ensure free movement of flap/ dead weight steam flow |
| | | | Choked steam piping | Hard water being used for operation | Softener is not functioning properly due to operational negligence | Remove choking<br>Replace choked portion of piping |
| | | | | Thicker welding penetration inside the welding joint causing very small diameter | Improper welding or poor workmanship | Check/replace the choked portion<br>Welding to be done by skilled, experienced welder |
| 9 | **Drum pressure rising continuously** | Faulty pressure gauge | Spring tension lost | Over-pressurizing of steam | | Replace pressure gauge |
| | | Main steam stop valve closed | Negligence during operation | | | Open the valve and start utilizing the steam from solar |
| | | | No utilization of steam at the application point | | | Open the valve and start utilizing the steam from solar |
| | | Problem in outlet of the NRV | NRV direction not as per requirement | Negligence during installation | | Check/rectify/replace NRV |
| | | | Flap/dead weight inside got stuck up | Scale formed dust inside the NRV casing | | Check and ensure free movement of flap/dead weight for smooth steam flow |
| | | Underutilization of generated quantity of steam process | System is producing more steam than requirement | | | Solar steam shall be used to maximum possible extent |
| | | Choked steam piping | Hard water being used for operation | Softener not functioning properly due to operational negligence | | Remove choking/ replace choked portion piping |
| | | | Thicker welding penetration inside welding joints causing very small diameter to pass the steam | Improper welding and poor workmanship | | Check and replace the choked and welding to be done by skilled, experienced welder |

*contd...*

*Table 2: contd...*

| S. No | Symptom | Problem reasons (WHY-1) | Problem reasons (WHY-2) | Problem reasons (WHY-3) | Problem reasons (WHY-4) | Corrective action |
|---|---|---|---|---|---|---|
| **10** | **Auto reverse not happening** | Problem in PLC | Program not functioning properly | Improper earthings to PLC panel | | Check/correct in coordination with PLC engineer and provide separate instrument earthings for PLC panel |
| | | Problem in contactor for reverse motion | Carbon deposited on internal contacts | Loose contact | | Check/correct/clean/replace contactor with same specs and tighten the electrical termination |
| | | Problem to limit switch for reverse | Limit switch damaged | Limit switch stuck up | | Check/repair/replace the limit switch |
| | | Problem in gear motor | Winding burnt | Due to overload on motor | Dish movement jam | Check/replace/repair the gear motor |
| | | Problem in gear box | Gear box jam | No lubrication for gear box | | Check/repair the gear box |
| | | | | Sprocket wheel teeth broken | Due to improper alignment | Make proper alignment |
| | | | | Bearing jam | Non lubrication, rusting | Clean the bearing part, make proper lubrication, and ensure smoothness |
| | | | | Gear box shaft bend | Due to overload | Proper alignment to be done and avoid the overload on shaft. Replace the shaft, if required |

***Additional Troubleshooting Notes***

| Symptoms | Probable cause | Action |
|---|---|---|
| Noise in circulation pump | Alignment of pump motor disturbed | Refer to pump/motor manual to realign the pump/motor |
| | Pressure of suction pump lower or equal to saturation pressure of water at that temperature | Check pressure of compressed air in expansion tank; it must be above 3 kg/cm². Rectify as required |
| Pressure at pump fluctuating | Air entrapment in the water system | Open and close vent valves in the water piping, one at a time to remove trapped air |
| | Y-strainer is choked | Clean the filter (refer to STP 1) |
| | The pump is cavitating due to hot water under pressure | Check pressure of compressed air in expansion tank; it must be above 3 kg/cm². Rectify as required |
| Receiver is deforming from its shape  | Very less/no water in header pipe | Defocus the dish immediately<br>Fill water in header pipe<br>Set the focus of the dish back on the receiver |
| | Timer, which tracks the dish, not working properly | Refer to STP 3 to adjust/set focus of the dish on the centre of the receiver |
| | Power supply problem for the timer | Electric backup battery in the timer needs to be replaced |
| System not generating proper steam at expected rate | Refer to Annexure 3 | Refer to Annexure 3 |

## 7.7. Precautions During Operation and Maintenance

### 7.7.1. General

- Do not stand or walk between the dish and the receiver. If possible, the dishes should be completely defocused before any maintenance task near the receiver area.
- Always wear heavy duty sun goggles while inside the solar field. Avoid looking at the receiver or dish or focus with naked eyes.
- Always use safety helmet while moving inside the installation area.
- Use hand gloves while handling the mirror.
- Only authorized persons should enter inside the solar field.
- Do not touch bare receiver surface. It is kept un-insulated to absorb solar radiation.
- While setting focus never overforce adjustment lever excessively.
- Header pipe stores steam at high pressure, hence avoid going near that region.
- Keep distance from safety relief valve when releasing steam.
- Do not disturb tracking lever intentionally, and once system is set, do not disturb any settings at tracking mechanism, seasonal adjustment, gear box, etc.

### 7.2.2. While Handling Pipeline and Equipment

- Flexible hose pipes are generally susceptible to leakages due to high pressure in the system, hence maintain safe distance.
- Ensure isolating valves are closed to stop the flow of fluid before attending to a module or component.
- Drain hot fluid first through vents before opening any equipment to avoid any chance of contact.
- Loosen screws and connections only when the system is not under pressure. Wear gloves while removing insulation to avoid skin contact with hot surfaces.
- If the fluid is to be drained by opening the pipe flanges or coupling, ensure that most of the body part is above the pipeline.
- Stand away from the pipeline while opening the drainage valves to avoid fluid spill over the body.

### 7.7.3. While Handling Receiver and Header Pipe

Release steam completely by pressing handle on safety relief valve before opening any equipment, to reduce pressure in header pipe to atmospheric pressure.

### 7.7.4. While Working on the Scheffler Dish

- When working on the dish at a height, ensure that grip for hands and support for feet are available to avoid from falling.
- Dish is made up of glass and is not strong enough to support any load on its surface—ensure that other supports are available before undertaking any work with the dish.
- Close top/bottom needle valves of water-level gauge before removing glass tube to clean it from inside.
- Do not touch the receiver and header pipes as the system is hot.
- Valves connected with the header pipe do not require to be operated during day-to-day operation except for steam globe valve on steam line outlet from the header pipe.
- Dish should be defocused to morning position, otherwise it may fall on any nearby object and this concentrated heat can damage it.
- Reflected sunlight from the dish should not fall on the windows of nearby homes.

### 7.7.5. Chemicals Used and Health-related Precautions

**Use soft water**

- It is safe for use and has no health-related issues.
- Soft water can be safely released to atmosphere to control pressure in the system as water/steam has no toxic effect on environment.

**Thermic fluid precautions**

- Maintain good ventilation around equipment area to provide quick cooling of any leaks. This will also disperse any unreacted vapours.
- Safety relief valve should be connected to a vessel to discharge thermic fluid safely, as fluid may be toxic and unsafe for release to environment.

### 7.7.6. Indian Boiler Regulations Safety Regulations

- Steam boilers exceeding 22.75 L capacity, steam pipelines where steam pressure exceeds 3.5 kg/cm² come under the scanner of IBR regulations.

## 8. Case Study

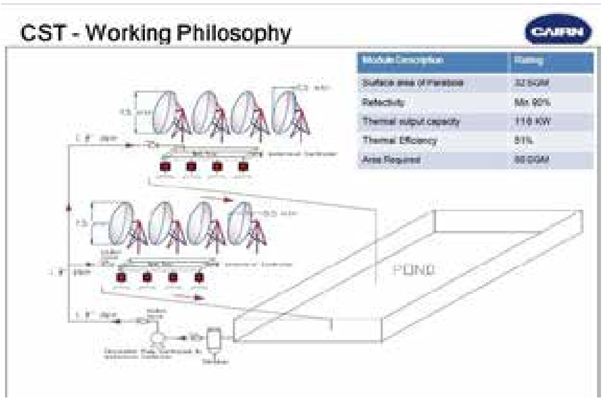
### Cairn India (P) Ltd using Scheffler-based CST system for waste water evaporation

| | |
|---|---|
| **Location:** Barmer, Rajasthan | **Type of Installation:** Scheffler Dish |
| **Configuration:** 8 Nos of parabolas of 32 $m^2$ with collector area of 256 $m^2$ | **Supplier:** Taylormade Solar Solution Pvt Ltd., Ahmedabad |
| **Application:** Waste water evaporation | **Year of Installation:** April 2015 |

**Beneficiary details:** Cairn India is a part of the Vedanta Group that operates ~27% of India's domestic crude oil production. While exploration, several thousands of gallons of wastewater is generated which is contaminated with oil and minerals and cannot be thrown in the desert or river basins, this was a major issue and they needed a solution for speedy thermal evaporation. They, however, make use of solar ponds to evaporate this water.

**System details:** Scheffler-based CST system was installed at Barmer site in Rajasthan, using eight of Scheffler dishes each of 32 $m^2$ with collector area of total 256 $m^2$. The system is installed in CIL at Mangala for evaporating 10,000 L of waste water per day. The system was commissioned in April 2015 by M/s Taylor made Solution, Ahmedabad.

**Timings and system application details:** The wastewater is electrically pumped on a metal open tray coated with marine grade paint. The water is further made to fall on the receivers of the concentrated solar thermal that have temperatures in excess of 100°C. The falling water on the receivers will start evaporating and the rest of the water, which will not evaporate, is heated up. The heated water is sent in the nearby solar pond and the cycle is repeated continuously.




To control the flow of water, a level indicator with a controller is installed, to make the process completely automatic. The project is running without any problems since its inception, and following the successful pilot, Cairn India is planning for bigger size projects.

| | |
|---|---|
| **Steam generation:** NA | **Operating temperature:** 100°C |
| **Type of fuel saved:** - | **Quantity of fuel saved:** - |

**Functionality and key issues of non-operation:** Operational

**Status of equipment:** System is functioning good

**O&M Issues and beneficiary perception:** The system is functioning well and so far no operational problems or breakdowns are noted. The system is properly maintained.

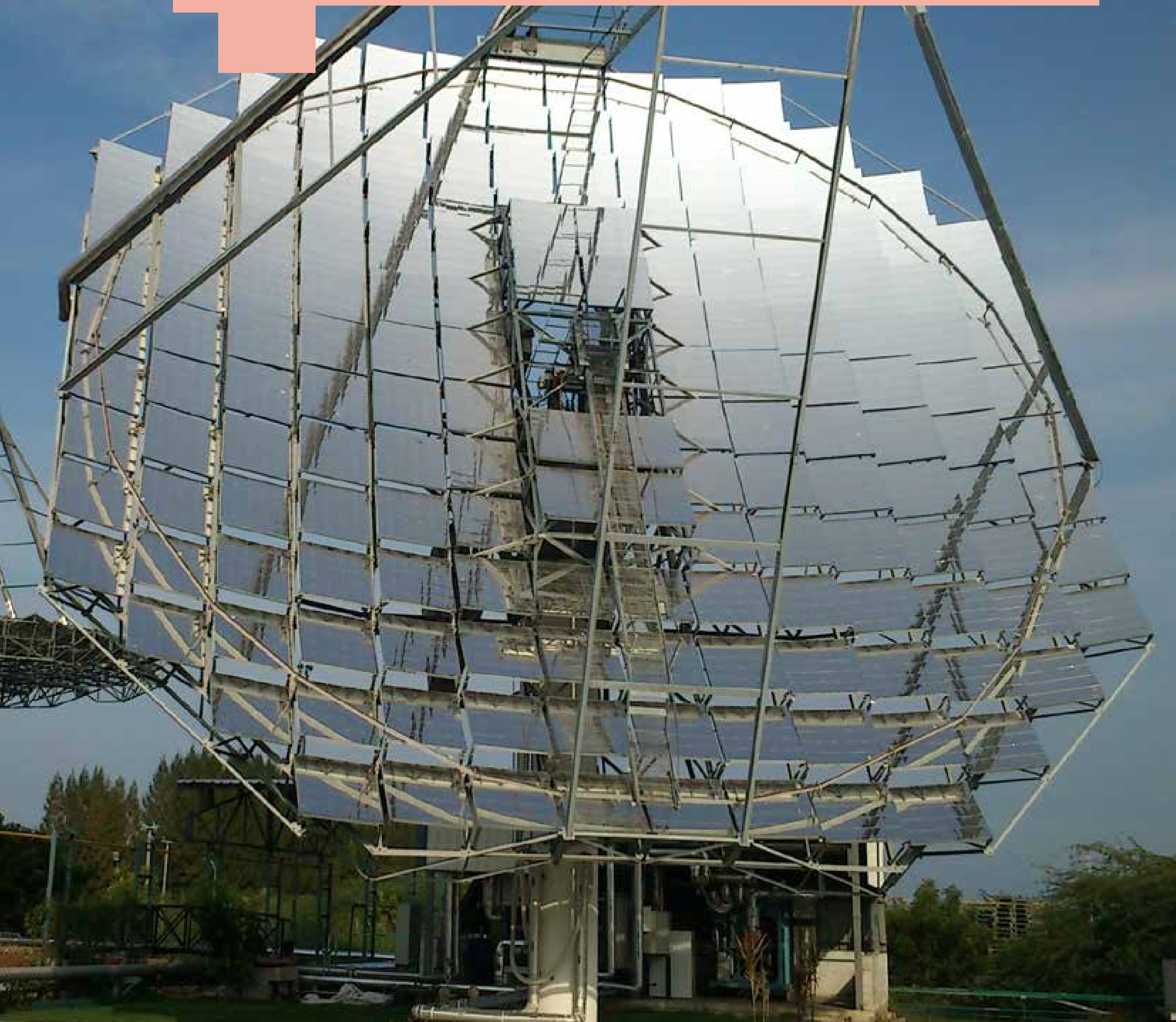
**Financials in detail:** The total investment in this pilot project was little over ₹ 60 lakh and was self-funded. The applicable capital subsidy from the Ministry of New and Renewable Energy (MNRE) has helped in improving the economics. Cairn India is one of the largest independent oil and gas exploration and production companies in India with a market capitalization of ~ US$ 7 billion.

| | |
|---|---|
| **Cost of system:** ₹ 60 lakh | **MNRE subsidy:** ₹ 13.82 lakh |
| **Payback with subsidy:** NA | |

**Overall system performance:** Good

5

# Fresnel Paraboloid Concentrator (ARUN Dish)



## 1. Introduction

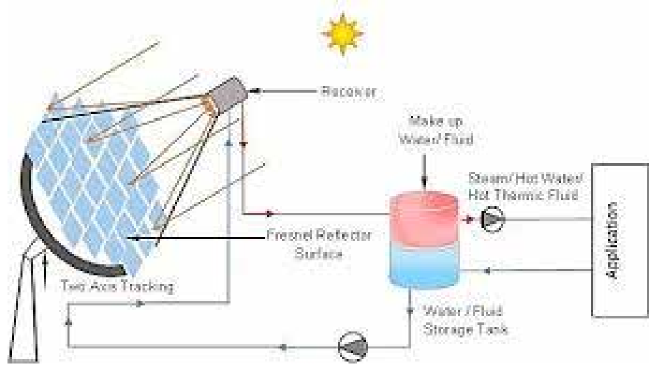
The ARUN dish, as can be seen in Figure 1, is a Fresnel paraboloid solar concentrator with a point focus. It can handle various heat transfer fluids including steam, hot oil, hot water or even hot air at temperatures up to 350 °C and pressures up to 25 bar. The low area required for installation makes it ideal for industries with space constraints. ARUN is also India's first IBR (Indian Boiler Regulations)-approved solar boiler.

***Figure 1:*** *ARUN dish*

## 2. Working Principle

ARUN dish technology is based on the basic principles behind a magnifying glass and a sunflower. Similar to how a magnifying glass concentrates sunlight at a single point with the help of parabolic lenses, ARUN uses an ingenious, Fresnel mirror arrangement scheme to get a three-dimensional parabola effect (Figure 2).

***Figure 2:*** *Schematic showing the working of ARUN dish*

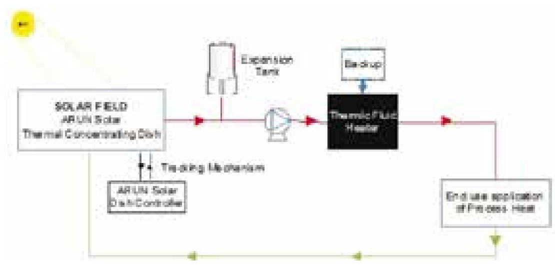



Like a sunflower, ARUN automatically tracks the sun from sunrise to sunset on both east–west and north–south axes in order to intercept maximum sunlight throughout the year, irrespective of the installation location. The ARUN dish is mounted on a single column, thus occupying ground area of less than 3 m x 3 m. It can be operated with various thermic media including steam, water, hot oil, hot air, etc. and reach temperatures and pressures of up to 350°C or 25 bars, respectively. Its dual-axis, completely automated tracking, which is based on both chronological tracking and a light-sensing tracking mechanism, ensures high tracking accuracy.

## 3. Components of ARUN Dish

As shown in Figure 3, the entire system is split into subsystems, each performing a core function in the overall operation.

***Figure 3:*** *Components of ARUN dish-based system*

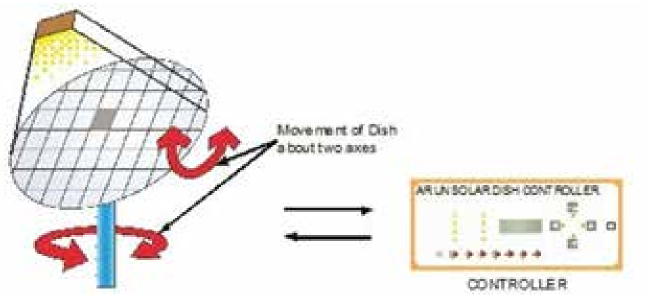


The concentrator subsystem collects solar radiation in the solar field from paraboloid-reflecting collectors and transfers it to a working fluid, such as water or oil. As shown in Figure 4, the collector is essentially made up of reflective mirrors which concentrate the sun's light at a fixed-point focus. The receiver is placed at the focus of the dish (Figure 4), to absorb and transfer concentrated heat to the fluid flowing continuously through it.

***Figure 4:*** *Collector and receiver of ARUN dish*

The tracking subsystem supports the receiving subsystem: it maximizes the solar energy captured by moving the solar collectors towards the sun throughout the day and across the seasons.

***Figure 5:*** *ARUN dish tracking system*




The circulation sub-system carries fluid and transfers the heat received to the end-use application. The fluid circulates in the system at a certain desired rate in order to quickly and efficiently transfer the heat received from the solar field to the end-use application. The circulation sub-system has a number of components such as pipes, pumps, and valves to control fluid flow and temperature.

Finally, the control mechanism is the brain behind the tracking and circulation systems. It sends signals to these systems to control the tracking of the receiver, based on pressure and temperature of the circulating fluid. Table 1 shows a sample specification that describes each subsystem in more detail (the values provided are examples only).

***Table 1:*** *Component-wise description of ARUN dish-based system*

| S. No. | Sub-system | Example specification | Description |
|---|---|---|---|
| 1 | **Receiving sub-system** | | Collects and reflects the sun's heat in a line focus |
| 1.1 | Fresnel paraboloid dish reflecting surface | Reflecting mirrors | Solar heat capturing capacity of each dish |
| | Total collector area | ARUN 160: 169 m² <br> ARUN 100: 104 m² <br> ARUN 30: 34 m² | |
| | Dish energy output (clear sunshine) | ARUN 160: 6 Lkcal/day <br> ARUN 100: 4 Lkcal/day <br> ARUN 30: 1 Lkcal/day | |
| 1.2 | Receiver | Inverted cavity type MS receiver | Carries the fluid that captures heat |
| | Fluid outlet temperature (nominal) | 300°C(as per required application) | After heat collection |
| 2 | **Tracking sub-system** | Moves east–west and north–south | The direction in which the dish moves to track the sun's rays |
| | Tracking | Chronological/ light sensing tracking | Tracking motors moves at preset time intervals/ sensing direction of sunlight and following it |
| | Control system | Programmable logic controller/ microprocessor based | System stores program to track the dish |
| | Drive mechanism | Suitable drive mechanism with electric motor | Can turn dish about its horizontal and vertical axis |
| | Axis | Dual | Tracks in both the axes together continuously when the system is working |

contd...

*Table 1 contd...*

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*Table 1 contd...*

| S. No. | Sub-system | Example specification | Description |
|---|---|---|---|
| 3 | **Circulation sub-system** | | |
| | Fluid composition | RO water or steam or thermic oil | |
| | Operating pressure | Up to 20 bar (as per application) | Pressure at which fluid is supplied to the application |
| | Operating temperature | Up to 300°C (as per application) | Temperature at which fluid is supplied to the application |
| | Average flow rate | As per requirement | |
| | Flow rate control | Hot water pump | Fixed flow/ variable flow rate if required |
| | Flow rate control logic (if required) | Input range: 0–100% | Can be provided if required |
| 4 | **Thermal storage sub-system** | | |
| | Steam accumulator (if required) | | Stores excess steam which can be utilized during non-solar hours |
| | Expansion tank | | Stores hot water/oil |
| | Molten salt system (if required) | | Collects and stores excess heat which can be utilized later on when required |
| 5 | **Control sub-system** | | |
| | Input type | ARUN solar controller | To monitor and control tracking of ARUN dish |

## 4. Key Features

- Indigenous technology which is simple in design and structure
- Dual axis tracking enables maximal utilization of solar energy
- Available in different sizes (160 m², 100 m², and 30 m²)
- Can be used in industries which require heat up to 350˚C
- Requires less space for installation, and is therefore ideal for industries with space constraints.
- Approved by Indian Boiler Regulations.

## 5. Applications

The following are some of the common application areas where ARUN systems can be used:

- Milk pasteurization and CIP
- Steam cooking
- Baking and frying (using hot oil)
- Cooling
- Desalination/effluent drying
- Process heating
- Power generation
- Laundry
- Hot air for powder coating/paint curing

## 6. Operation of ARUN Dish-based System

This section details the typical steps for operating an ARUN Dish. Please note that some sites may require steps that differ slightly or considerably and the reader is advised to refer to the manufacturer's manual for the site. The description provided here is for a general understanding.

### 6.1. Start-up Sequence

On starting ARUN dish, actions are triggered automatically through pre-programmed logic.

Attend to the following sets of actions and operations to start the ARUN dish:

- Before starting the system, mirrors should be cleaned properly
- Before removing the parking, check that the mirror access ladder (cleaning ladder) is parked and locked in its south position (with respect to the dish)
- Switch on the clutch (by switching on the respective MCB in tile electrical panel)
- Now remove the entire dish parking struts and engage them with parking locks provided so that they will not hinder the movement of the dish along any axis. Please note that clutch should be turned on before removing the parking
- After removing the parking, put the 'PARKING REMOVED' switch on the panel to 'YES'.
- Check the day, date, and time on the display panel of the controller. Change the settings to correct IST if required

- Go to DD7 of the controller and check that 'LLL Sensing is on'.
- Now with the arrow keys on the controller go to input status and check the following conditions before the start of the dish:
  - Select the auto mode by auto/manual selector and switch on the controller.
  - Now by arrow keys go to select mode (a password is prompted, which is '000').
  - Select initialize mode to start the dish. The dish will go through 'Initialize and Align' mode before it starts tracking the sun in sensor mode.
  - By default, dish will track on sensor mode. To set the tracking on counts select track-on-count mode
  - Dish receiver fluid temperature readings can be noted from the controller.
  - Dish will continue in tracking mode throughout the day until senset.

## 6.2. Start-up Precautions

The following field checks/precautions must be performed every time when starting the system:

- If thermic fluid is used in circulation system, it should be initially (first fill) heated up by 20°C per hour till it reaches 100°C, so that all the moisture gets removed from the thermic fluid.
  - Check that all the inlet and outlet valves for makeup water tank, steam accumulator, and cold-water pumps are always open, and that the makeup tank is completely filled with water.
  - Check the level of water in the steam accumulator. It should be below high level and above low level.
  - Check that the inlet/outlet valves to the dish are also open.
  - Also check whether all drains and vents are closed.
  - Initially keep the bypass valve for steam trap open, so that all the air and condensate is removed. Make sure that once the air and condensate is removed completely, the by-pass valve is closed.
  - Switch on all the MCBs of the main panel and the local panels.

## 6.3. Normal Operation, Monitoring, and Error Control

The system requires little intervention when in operation. However, periodic monitoring is essential. Monitor the control panel for alarms and process parameters. The description below is for an example system and each system could vary in its operation, monitoring, and control parameters.

The following are the automatic control actions that take place in normal operation:

- Tracking of the sun's movement by the ARUN dish to optimize the performance of the system.
- Maintenance of the pressure and tmperature of the fluid circulating in the system.

The values provided in Table 2 are for a sample system. The actual values for a system should be determined from the manufacturer's manual. Pressure, temperature, and flow rate will vary during normal operation depending on the type of application. The range of normal values can be set in ARUN dish controller.

**Table 2:** *Example values for flow rate, pressure and temperature*

| Point | Flow rate | Pressure | Temperature |
|---|---|---|---|
| | Acceptable range ($m^3/h$) | Acceptable range ($kg/cm^2$) | Acceptable range (°C) |
| Solar field (ARUN dish) | 2500 | 12–15 | 160–350 |
| Thermal storage tank inlet | 2500 | 12–15 | 160–210 |
| Pressurized expansion tank | | 10 | - |
| Hot-water pump | 2500 | 10–12 | Upto 160 |

**These parameters are system dependent and change for different systems*

**To determine minimum acceptable system pressure, refer to steam table, where you can get required pressure corresponding to maximum hot water temperature for which the system is designed.*

The control mechanism is used to automatically rectify the error conditions described in Table 3:

***Table 3:*** *Error monitoring and control*

| | Module/(s) affecting the parameter | Error/(s) | Potential causes | System adjustment and control |
|---|---|---|---|---|
| Flow rate<br>(if applicable) | Hot-water pump | Deviates from set flow rate range | Air bubbles in system/blockage in pipes | Can be controlled by changing hot-water pump speed on SCADA system<br>(if provided for the system) on 'Set Point and Operation' screen |
| Pressure | Expansion tank | Increases beyond set pressure limit | Excessive pressure at start up | Release excessive pressure, else defocus the dish, correct the situation, and restart |
| Temperature | ARUN dish | Increases beyond set temperature range | Low flow, steam formation due to low pressure in expansion tank, low system load | Correct the respective causes or defocus the dish, correct the situation and restart |

## 6.4. Exceptions and Backup

- Exceeding set temperatures
    - When the temperature of the thermic fluid crosses the set temperature limits, the ARUN dish automatically defocuses from the receiver
- Power failure
    - Tracking System has a ~ 45-minute power backup UPS to handle power cuts preventing defocusing of the dish during power cuts).
- Storm/high winds
    - A three-cup anemometer measures the wind velocity. Upper limit for wind is set to 10 m/s. Above this limit, ARUN dish goes into parking position to protect it from structural damage.
- Not using system for long time
    - Keep the dish secured in parking position
    - If the circulation system contains water, and atmospheric temperature reaches below freezing temperature, drain out the water
    - If the circulation system contains oil and atmospheric temperature reaches below the pour point of oil, drain out the oil into appropriate storage.

## 6.5. Shutdown Sequence

Attend to the following set of actions to shutdown ARUN dish system:

1. When the dish reaches near the sunset position, it will automatically enter the parking mode and the dish will be brought to parking position. One can also select 'parking mode' for the same operation.
2. When it gets into the parking position on both the axes (sensed from the parking proximity switches), the dish will stop. This can be seen on the controller (when its LED glows green) or in input status.
3. Now engage all the parking struts. (If parking struts do not match properly then move the dish forward/ reverse by selecting manual mode (refer to manual mode selection instructions to operate the dish in manual mode).
4. Now switch off circulating and make up water pumps.
5. Switch off the main electrical panel.
6. Record the flow meter reading to know the quantity of steam delivered
7. Close the outlet valve on the steam delivery line.
8. At the end, open the by-pass valve of steam trap to avoid vacuum formation

### 6.5.1. Shutdown Sequence in Manual Mode

1. Repeat steps 1–7 of above section
2. Now select manual mode by auto/manual selector switch on the controller.
3. Use FWD-REV push buttons on the controller to rotate the dish as desired.
4. There are two sets of FWD-REV buttons on the controller for each axis, respectively.
5. Press both the buttons simultaneously to stop the motor

NOTE: FWD for vertical motor: towards west, REV for vertical motor: towards east, FWD for horizontal motor: towards south, REV for horizontal motor: towards north

## 6.6. General Precautions during Operation

Precautions to be followed during operation (which are also applicable in maintenance) are listed in the following subsections

### 6.6.1. Pipe Line and Equipment

- Ensure isolating valves are closed to stop the flow of fluid before attending to a module/component
- Drain hot fluid first through drain valve and depressurize through vent valves before opening any equipment to avoid any chance of contact
- Wear hand gloves while removing insulation to avoid skin contact with hot surfaces
- Loosen screws and connections only when the system is not under pressure
- Whenever fluid is to be drained by opening flanges or coupling before opening drainage valves, stand slightly away from the pipe to avoid fluid spills from hitting you

### 6.6.2. Collector and Receiver

- Reflection from collector surface could be intense and can cause harm to your eyes. Protective filtered goggles should be worn while working on reflective surfaces in the sun

### 6.6.3. Expansion Tank

- Close top/bottom needle valves of level gauge before removing level gauge to prevent contact with hot fluid
- It generally stores liquids at high pressure, hence a safe distance must be maintained from vent (outlet), to control expansion tank pressure
- If the insulation of tanks is to be removed, then always use gloves to remove glass wool, as it is an irritant to the skin and can cause severe itching on your hand
- Thermal storage tank has a phase change material, which melts and turns fluid at a certain temperature. Take care to avoid any contact with it.

### 6.6.4. Chemicals Used and Health-related Precautions

**Soft Water**

- May have been treated for specific purpose
- Safety relief valve should be in upright position at a height away from the reach of system operator

**Thermic Fluid**

- Thermic fluid may be pressurized and working at high temperature ranges, hence precaution needs to be taken while operating and maintaining the system, as any human contact with the hot system's thermic fluid can cause fatal injuries
- Maintain good ventilation around equipment area to provide quick cooling of any leaks, and disperse any unreacted vapors
- Safety relief valve should be connected to a vessel to discharge thermic fluid safely, as fluid may be toxic and unsafe for release into the environment

The guidelines are also listed in Table 4.

***Table 4:*** *Safety guidelines based on the heat transfer fluid*

| S No. | | Steam systems | Thermal fluid systems |
|---|---|---|---|
| 1 | System pressure | Steam systems are high pressure-fired systems, hence require engineer's supervision | Most thermic fluid systems generally operate at low/medium pressure, hence do not require constant engineer's supervision |
| 2 | Corrosion | Air in combination with hot water and salts can cause corrosion, nitrogen gas used to maintain pressure and suppress the effect of corrosion | Non-corrosive fluids, providing high degree of metal finish protection as provided by lubricating oils |
| 3 | Maintenance | Require frequent maintenance, but easier to maintain | Require minimal maintenance |
| 4 | Environmental safety | Water is relatively safer, and is widely used in domestic kitchen application | Cannot be directly discharged into sewers, but can be processed and recycled to reuse |
| 5 | Safety | These systems are safer for use in low temperature range. Steam has no toxic property | These systems are safer for use in high temperature range<br><br>Inorganic thermic fluids may have toxic properties |

### 6.6.5. Indian Boiler Regulations Safety Regulations

Steam boilers exceeding 22.75 L capacity and steam pipelines where steam pressure exceeds 3.5 kg/cm² come under the IBR regulations.

All valves and fittings should be as per IBR specifications with test certification for each valve. During repair work, technician should follow IBR regulations and specifications for tasks such as material procurement, welding and plumbing works near steam boilers and steam pipelines. Operator should refer to manufacturer's specifications for valve/fitting replacement.

# 7. Maintenance of ARUN Dish-based System

Maintenance guidelines/schedule of ARUN dish-based system are listed in the following subsections

## 7.1. Predictive Maintenance

The system is designed to provide easy isolation for maintenance or emergency repairs. To isolate any module, close down respective gate valves and do the maintenance.

For trouble-free and reliable performance of the system, the ensuing checks should be followed. These steps help in determining whether maintenance is required or not

- Annually, check for scaling on the inner linings of the circulation system.
  1. Scaling and its effect on the system's performance have to be visually determined
  2. This maintenance task is generally outsourced because it is rarely performed and requires de-scaler systems and industrial descaling chemicals
- Quarterly, check for pressure in the nitrogen cylinder. Whenever pressure in the $N_2$ cylinder drops below 26 kg/cm², replace it
- Weekly, check for leakages in the system. Perform this operation when you spot leakages in the circulation line
  1. Identify the point of leakage and remove insulation for that component
  2. Repair/replace component with leakage
  3. Leave insulation material (mineral wool) open to dry off, and then put it back
- Annually, inspect sensors in the system
  1. Level transmitter (ultrasonic/DP type): Check connection and tightness of wiring. Clean level transmitter
  2. RTD and thermowell: Check connection and tightness of wiring. Check oil and fill if required
  3. Pressure/temperature transmitter: Check connection and tightness of wiring
- Annually, check the pressure at output of safety relief valve and adjust it to the required set pressure
- Half yearly, inspect solenoid valves
  1. Check their operation, overheating during operations
  2. Clean the valves
- Weekly, check dish tracking mechanism-dish motors, gear box, sprockets, shafts, bushes
  1. Check oiling and greasing
  2. Check for vibration and noise
  3. Check for heating problem and tighten loose parts
  4. Replace bearing if required
- Monthly check for functioning of dosing systems
  1. Check for leakage of hazardous substances
  2. Clean and rinse the pump
  3. Check for screwed connections of piping and containers, and tighten if necessary
  4. Carry out a visual inspection of pressure test
  5. Check for electrical lines and components for visible damages (loose connections, damaged cables, etc.)

## 7.2. Preventive Maintenance

Preventive maintenance in the ARUN dishes improves the efficiency and reliability of the system. The maintenance period is based on measured values from the solar system data log, which helps the trained service technicians identify and troubleshoot potential problems within a system.

The following preventive maintenance must be undertaken as per schedule to avoid system failures and to get trouble-free and reliable performance:

- Weekly lubricate chain block pulley with grease/oil, but not too much as that will attract dust. Lubrication should especially be done after the rainy season
- Monthly replace the water in the circulation system with fresh soft water from RO system

Note: If thermic fluid/oil is used in circulation system do not clean with water; either use compressed air, or flush the fluid from the tank to clean the piping system

- Annually, undertake structural painting and repair of the dish to improve the life span of the system
- Annually, replace soft water resin in RO water purifier
- Every three years, clean the pressurized expansion tanks

### 7.2.1. Consumable Replacement

The following are the consumable parts in the system which need standby stock:

- Nitrogen cylinder (optional)
- Gaskets (size as per manufacturer's specifications)
- Teflon tape
- Lubricant oil and grease

Note: Please refer to manufacturer's manual for recommended consumable item specifications.

## 7.3. Routine Maintenance

The system requires some simple and small-scale activities for general upkeep. The following tasks must be regularly performed when using the system:

- Weekly, clean the ARUN dish system.
    - Use parking locks to lock the ladder.
    - Climb up and use the sprayer to wipe off dust.
    - Clean the dish early in morning before starting the system.
- Weekly, dust off the pyrometer with a dry soft cloth.
- Monthly, clean the screen in the Y-Strainers with brush or by soaking it in a clean solution.
- Twice a year, clean the RO system cartridge filler.

## 7.4. Dos and Don'ts in Maintenance

- Whenever maintenance is required in a thermal fluid circulation system, defocus the ARUN dish and keep on circulating thermic fluid/hot water through the system till its temperature comes below 50°C.
- After this, depressurize the system by venting nitrogen from the expansion tank by opening the vent valve. Switch off the circulation pump, close water inlet/outlet valves and then start the work.
- Open the flanges once the system is cooled down so that burn injuries are avoided.
- Operator must maintain log sheet regularly and supervisor must review the log sheet readings regularly.
- Follow maintenance schedule for all components at specified time intervals
- Always use sunglasses while working in the solar field
- Never tamper with pressure relief valve and safety relief valve without training and knowledge of the system

## 7.5. Troubleshooting of Problems in ARUN Dish-based System

A few process related troubleshooting points are given in Table 5. Refer to respective manual for troubleshooting of components:

***Table 5:** Troubleshooting of problems in ARUN dish-based system*

| Observation | Probable cause | Action |
|---|---|---|
| Noise in circulation pump | Alignment of pump motor disturbed | Refer to pump/motor manual to realign the pump/motor |
| | Pressure of suction pump lower or equal to saturation pressure of water at that temperature | Check pressure of compressed air in expansion tank; it must be above 3 kg/cm². Rectify as required |
| Pressure at pump fluctuating | Air entrapment in the water system | Open and close vent valves in the water piping, one at a time to remove trapped air |
| | Y-strainer is choked | Clean the filter |
| | The pump is cavitating due to hot water under pressure | Check pressure of compressed air in expansion tank; it must be above 3 kg/cm². Rectify as required |
| System temperature has shot up above the safety limit | Power supply of the panel tripped causing water circulation system to stop | Correct system fault and restart the pump at earliest |
| | | Release pressure in the system at earliest |
| | | Circulate water at higher flow rate until temperature drops down to normal level |

## 8. Case Study

| Solar System for Process Heat by using Arun Dishes at M/S. Mahananda Dairy, MIDC, Kalam Road, Latur | |
|---|---|
| **Location:** Latur Maharashtra | **Type of Installation:** Arun Dish |
| **Configuration:** 160 m² (160 m² x 01 No) | **Supplier:** Clique Solar |
| **Application:** Process heating | **Year of Installation:** August 2006 |

**Beneficiary details:** Mahanand Dairy is the largest cow milk packing and distributing dairy in Asia. Mahanand Dairy is always related to any breakthrough or advent in the Milk Production and Dairy Technology in India. Mahananda has launched Mahanand Parijatak Scheme. The establishment has implemented 168 m² capacity concentrated solar project for the purpose of heating application. The plant is installed at manufacturing company within the premises.


**System details:** Mahananda Dairy, Latur has implemented the Arun Technology-based system for process heat. The total system has 160 m² of collector area. Prior to the implementation of the CST system the establishment was using fossil fuel (furnace oil) for its end-use consumption. The system is integrated with CST and boiler (furnace oil) to meet their requirement. The project is set up at a cost of ₹ 52 Lakh and availed the MNRE grant of ₹ 19 Lakh.

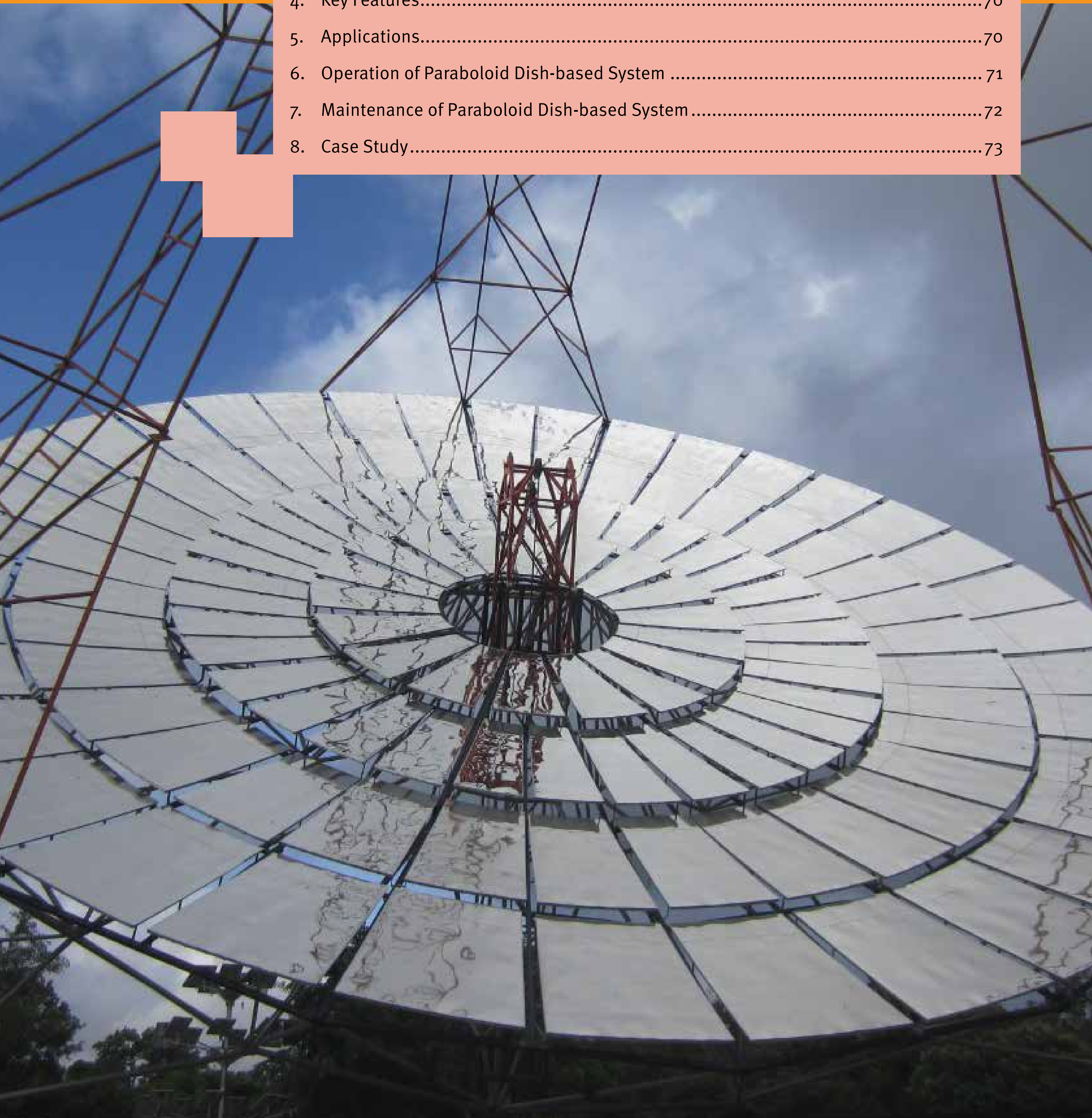
**Application details:** This existing system is an integrated system [CST+ boiler (furnace oil)]. The plant is utilizing the CST system for about 6 hours per day. This technology is used for generating the steam and is being used for pasteurization of milk about 20,000 per day. The system is operating properly and has benefited the company in terms of saving around 100 L per day. The system is currently functioning well. The system is used for approximately 8 hours per day and around 270 days in a year

| | |
|---|---|
| **Steam generation:** 18 kg/cm² | **Operating temperature and pressure:** 120˚C and 2 kg/cm² |
| **Type of fuel saved:** Furnance oil quantity of fuel saved: 73 L/day | **Status of equipment:** System components are in good condition |
| **Cost of system:** ₹ 52 Lakh | **MNRE subsidy:** ₹19 Lakh |
| **Payback with subsidy:** 3.3. Years | **Overall performance:** Good |

**Beneficiary vontact:**
Mr. Arun Ghodake,
Plant Manger
Mobile no: +91 9619662456

6

# Paraboloid Dish Concentrator



## 1. Introduction

Paraboloid-dish solar concentrators (Figure 1) are two-axis solar tracking systems that concentrate the solar radiations toward the thermal receiver located on the focal point of the dish collector. Usually, one or more paraboloid dishes concentrate solar energy at a single focal point, similar to the way a reflecting telescope focuses starlight, or a dish antenna focuses radio waves. This geometry may be used in solar furnaces and solar power plants.

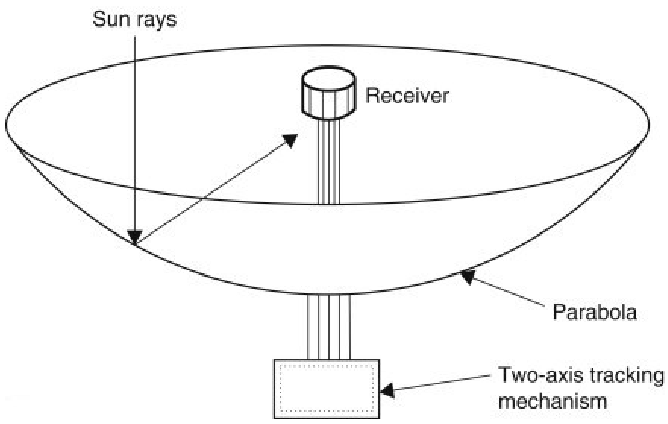
***Figure 1:*** *Solar paraboloid dish concentrator*

The parabolic shape means that incoming light rays, which are parallel to the dish's axis will be reflected toward the focus, no matter where on the dish they arrive. Since light rays arriving from the sun are almost parallel at the earth's surface, aligning the dish with its axis pointing at the sun allows almost all incoming radiation to be reflected towards the focal point of the dish. Most losses in such collectors are due to imperfections in the paraboloid shape and imperfect reflection. Losses due to atmospheric scattering are generally minimal. However, on a hazy or foggy day, light is diffused in all directions through the atmosphere, which reduces the efficiency of a paraboloid dish significantly.

## 2. Working Principle

The paraboloid dish (Figure 2) tracks the sun in two axes and concentrates the incoming solar radiation onto a receiver located at the focal point of the dish.

***Figure 2:*** *A schematic of paraboloid dish concentrator*




The receiver absorbs the concentrated solar radiation and converts it into thermal energy, which is further transferred to a heat-transfer fluid circulating in the loop. The thermal energy can be used for process heating applications or could even be converted into electricity using an engine–generator coupled directly to the receiver or transported through pipes to a central power conversion system. Paraboloid dishes are often called distributed receiver systems as each dish act as an identical source for generating heat or power.

## 3. Components of Paraboloid Dish System

A typical paraboloid dish-based system consists of three main components: concentrator/reflector, receiver, and tracking system.

**Concentrator/Reflector**

A concentrator or reflector (Figure 3) consists of a set of paraboloid dish-shaped mirrors, which are mounted on a structure. The concentrator of paraboloid dish could be of different designs; however, principle remains the same. In some designs, highly reflective aluminum-coated sheets are used in place of a mirror.

***Figure 3:*** *Paraboloid dish concentrators and receiver*

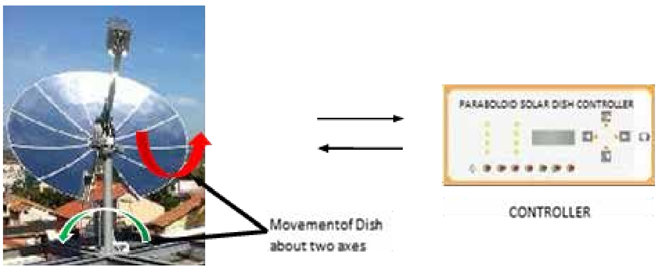
### Receiver

The receiver of a paraboloid dish usually has a cavity structure (Figure 3). This cavity is specially designed to reduce heat losses due to convection and radiation. The receiver is held in a fixed position relative to the reflectors using a suitable structure, and is insulated from the inside. The sun is tracked by movement of the entire array of mirrors and the receiver. A small aperture in the cavity allows efficient absorption of energy, which results in low losses. To increase its absorption, the inside area of the cavity usually is specially coated. Often, there are mechanisms present to prevent or reduce heat losses from the receiver due to convection. The dish structure must fully track the sun to reflect the beam into the thermal receiver. For this purpose, tracking mechanisms similar to the ones described in the previous section are employed in double, so the collector is tracked in two axes.

### Tracking System

To ensure the tracking of the sun throughout the year, the dish and the receiver assembly has to be moved while making adjustments, and thus, these systems need light structures. To track the sun in two directions (that is, elevation and azimuth), a dual-axis tracking system is deployed to capture the maximum sun rays by tracking the movement of the sun. One axis is the azimuth, which allows the paraboloid dish to move east–west, while the other axis is the elevation and allows the dish to turn up and down. The result of this mechanism provides the dish extensive freedom of movement (Figure 4).

***Figure 4:*** *Tracking of Paraboloid dish-based system*




The dish tracking the sun from morning (east) to evening (west) helps get the maximum utilization of the sun's rays by keeping the dish perpendicular to the sun for about 10 hours (useful radiation) per day. The dish goes to 'morning position' at the start of the day when it is started from parking, and starts moving to the west in direction with sun's movement. By the end of the day, it moves to its 'evening position' while following the sun all the way. At the end of the day it goes back to parking position.

The whole process is controlled by a controller. The control system is like the brain of the system and instructs all the other systems. Figure 4 shows the flow of information to control the tracking system. Paraboloid solar dish controller based on a control logic reads current coordinates of the dish (as input) and runs the tracking motors precisely to track the dish towards the sun.

## 4. Key Features

- Suitable for retrofiring in congested layouts because they can be mounted non-contiguously wherever space permits.
- Paraboloid dishes have high efficiencies throughout the year.
- Paraboloid dishes are a proven technology with a number of working installations abroad for process heating, and other applications. There are few installations in India.
- Paraboloid dishes have a small footprint due to the pole mount.
- These dishes can be installed on rooftops after proper strengthening of the structure and analysis.
- Operating temperatures are high due to high concentration ratio and relatively low losses from the receiver, often as high as 350°C. The use of thermic fluids allows high temperature operation at low pressures.

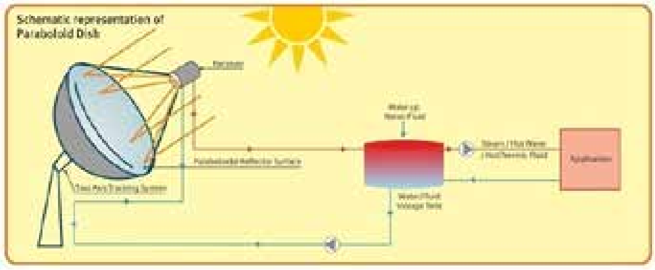
## 5. Applications

Paraboloid dish technology can be applied in:

- Pharmaceutical sector: Distillation, evaporation, drying, crystallization, sterilization, granulation for drying, finishing
- Pulp and paper industry: Kraft pulping, effluent treatment, bleaching
- Textile Industry: Mercerizing, drying, finishing
- Food processing: Drying, distillation and evaporation, extraction
- Engineering/automobile industry: Component, washing, de-greasing, metal treatment bath heating, paint drying
- Tobacco and rubber industries

A schematic presentation of a paraboloid trough system deployed in the industry is illustrated in Figure 5.

***Figure 5:*** *A schematic of paraboloid dish-based system integrated in an industry*




# 6. Operation of Paraboloid Dish-based System

This section details the typical steps for operating a paraboloid dish. Please note that steps may differ slightly or considerably, and the reader is advised to refer to the manufacturer's manual for the site. The description provided here is for a general understanding.

## 6.1. Start-up Sequence

On starting the paraboloid dish, actions are triggered automatically through pre-programmed logic.

Perform the following sets of actions and operations to start a paraboloid dish:

1. Before starting the system, the reflective surfaces should be cleaned properly.
2. Before removing the parking, check that the mirror access ladder (cleaning ladder) is parked and locked in its south position (with respect to dish).
3. Now remove the entire dish-parking struts and engage them with the parking locks provided so that they will not hinder the movement of the dish along any axis. Please note that clutch should be turned on before removing the parking.
4. After removing the parking put the 'Parking Removed' switch on the panel to 'YES'.
5. Select auto mode by auto/manual selector to switch on the controller.
6. Select initialize mode to start the dish. The dish will go through initialize and align mode before it starts tracking the sun in sensor mode.
7. By default, dish will start tracking the sun automatically (on sensor mode).
8. Note the dish receiver fluid temperature reading from the controller.
9. Dish will continue in tracking mode throughout the day until sunset time is reached.

## 6.2. Start-up Precautions

The following field checks/precautions must be performed/taken every time when starting the system:

- If thermic fluid is used in circulation system, it should be initially (first fill) heated up by 20°C per hour till it reaches 100°C, so that all moisture is removed from the thermic fluid.
- Check the level of water in steam accumulator. It should be below the high level and above low level.
- Check that the inlet/outlet valves to the dish are also open.
- Ensure that all drains and vents are closed.

## 6.3. Normal Operation, Monitoring and Error Control

The system requires little intervention when in operation. However, periodic monitoring is essential.

- Regularly monitor the control panel for alarms, and process parameters.
- Regularly cross-check the tracking system of the paraboloid dish for sun's movement to optimize the performance of the system.
- It is extremely important to maintain the pressure and temperature of the fluid circulating in the system.

## 6.4. Shutdown Sequence

Follow the ensuing sets of actions to shutdown paraboloid dish solar system:

1. When the dish reaches near sunset position, it will automatically enter the parking mode and the dish will be brought to parking position. One can also select 'Parking Mode' for the same operation.
2. When it gets into parking position on both the axes (sensed from the parking proximity switches), the dish will stop.

   This can be seen on the controller when its LED glows green.
3. Now engage all the parking struts.
4. Now switch off the circulation system and make up water pumps.
5. Switch off the main electrical panel.
6. Record the flow meter reading to know the quantity of steam delivered.
7. Close the outlet valve on the steam delivery line.
8. At the end, open the by-pass valve of steam trap to avoid vacuum formation.

### 6.4.1. System is Not Used for Long Time

- Keep the dish secured in parking position
- If circulation system contains water/thermic oil and atmospheric temperature reaches below freezing temperature/pour point, drain out water/thermic oil.

# 7. Maintenance of Paraboloid Trough-based System

The system requires some simple and small-scale activities for general upkeep of the system. The following tasks must be regularly performed when using the system:

**Weekly**

- Clean paraboloid dish system
- Use parking locks to lock the ladder
- Use sprayer to wipe off dust
- Clean the dish every morning before starting the system

## 7.1. Troubleshooting of Problems in Paraboloid Dish-based System

A few process-related troubleshooting points are given in Table 1. You can also refer to respective manual of each component for troubleshooting:

***Table 1:*** *Troubleshooting of problems in paraboloid dish system*

| Observation | Probable cause | Action |
|---|---|---|
| System temperature is above safety limit | Power supply of the control panel is tripped causing water circulation system to stop | Correct the system fault<br><br>Restart the pump at earliest |
| | | Release pressure in the system at earliest |
| | | Circulate water at higher flow rate until temperature drops to normal level |
| Noise in circulation pump | Alignment of pump motor disturbed | Refer to pump/motor manual to realign the pump/motor |
| | Pressure of suction pump lower or equal to saturation pressure of water at that temperature | Check pressure of compressed air in expansion tank<br><br>Rectify as required |

*Note: Safety and precaution while working on paraboloid dish system are almost similar to ARUN dish-based system and the same module can be referred to for this*

## 8. Case Study

**Paraboloid dishes based CST System used for Medicine preparation and Sludge Drying at Unique Biotech Ltd, Hyderabad, Telangana**

| | |
|---|---|
| **Location:** Hyderabad, Telangana | **Type of installation:** Paraboloid Dishes |
| **Configuration:** 540 m² (90 m² x 5 Nos.) | **Supplier:** Megawatt Solar Solution (P) Ltd, Noida |
| **Application:** Process heating | **Year of installation:** August, 2014 |

**Beneficiary details:** Unique Biotech Ltd (UBL) is a world class, dedicated, and a well laid out large-scale fermentation facility established in 2001 for probiotics, enzymes, and nutraceuticals with state-of-the-art equipment in Genome Valley, Hyderabad. Unique Biotech is working towards developing disease-specific probiotic solutions.

**Paraboloid dish system details:** Paraboloid dish-based CST system uses thermic oil as a heating medium and transfers heat to water with the help of a shell tube-type heat exchanger. The system consists of automated dual axis tracking and is integrated with the existing system, without any undeterred impact on the process. CST system is used for drug manufacturing, the dishes are connected in parallel configurations and thermic oil transfers heat to water with the help of heat exchanger.

**Application detail:** The fully automated system is working efficiently and its performance is regularly monitored with the help of PLC monitors. The control mechanism helps the hot-water generator seamlessly adjust its capacity in line with the solar output. Hot water (around 90°C) gets stored in insulated storage tanks of 30 kL, which can be used either for boiler feed-water heating or directly into the process. Hot water requirement for drug manufacturing—around 30,000 L/day—is being fulfilled by the CST system, which is saving around 200 kg of furnace oil per day. In other words, 9,000 tonne $CO_2$ emission will be saved over the project's lifetime.

| | |
|---|---|
| **Type of fuel saved:** Furnance oil | **Status of equipment:** System is functioning good |
| **Quantity of fuel saved:** 200 kg/day | |
| **Cost of system:** ₹ 130 Lakh | **MNRE subsidy:** ₹ 32.40 Lakh |
| **Payback with subsidy:** 5 Years | **Overall performance:** Good |

**Beneficiary Contact:**

M. Jawahar Babu, Director
Unique Biotech Limited
Plot No.2, Phase-II, Alexandria Knowledge Park, Genome Velley
Shameerpet, Hyderabad

# 7

# Thermal Efficiency and Yield of Concentrating Solar Thermal Systems at Different Locations in India

## 1. Introduction

This report has been compiled to show the thermal efficiency and yield of four different concentrating solar thermal (CST) technologies at different locations in India. The five sites have been chosen to give results that are relevant to a large amount of the country.

The concentrating solar thermal technologies covered in this study are: compound parabolic collector (CPC), linear Fresnel reflector (LFR), paraboloid dish collector (PDC) and parabolic trough collector (PTC). Each of these collector types have been modelled and their performance simulated at various temperatures at all the sites. The thermal output and efficiency of each collector type has then been derived from these results.

### 1.1. Definition of Thermal Efficiency

In order to make a comparison regarding the efficiency of the different CST technologies, the thermal energy absorbed by each type of collector and the collector's thermal losses have been calculated for each of the different locations. By subtracting the thermal losses from the thermal energy absorbed, the total thermal energy available from the collector (also called thermal yield) has been calculated. Then, by relating the actual thermal yield to the theoretical amount of the thermal energy that could be collected (solar radiation x aperture area), the thermal efficiency of the specific type of collector has been determined.

In the case of collectors that use tracking systems to follow sun throughout the day (that is the LFR, PDC and PTC), direct normal solar irradiance is used in the efficiency calculation. In contrast, the efficiency of the compound parabolic collector is calculated using both global and diffuse irradiance.

The performance simulations used to produce the data for the comparisons give, as an output, the yield and thermal loss data on an hourly basis over a complete year. This is then used to calculate the average annual yield or average annual thermal efficiency.

In order to ensure the best possible comparison between collector types, only the performance of each collector itself has been considered. Other factors, such as solar field losses or boiler efficiency (that are specific to an actual installation), have not been taken into account.

**It should be noted that these factors will typically result in the energy that is actually being delivered to the process being between 5% and 10% lower than that which is measured at the output of the collector. In the case of solar fields constructed using large numbers of PDCs, the losses could exceed these values.**

## 2. Sites

To be able compare the effects of latitude and differing solar radiation, five sites throughout India have been chosen. These are shown in Figure 1.

**Jaipur**

Lat.: 26.95° DNI: 4.85 kWh/m$^2$/day = 1772 kWh/m$^2$/a

DHI: 2.26 kWh/m$^2$/day = 826 kWh/m$^2$/a

**Bhopal**

Lat.: 23.25° DNI: 4.69 kWh/m$^2$/day = 1712 kWh/m$^2$/a

DHI: 2.25 kWh/m$^2$/day = 820 kWh/m$^2$/a

**Kolkata**

Lat.: 22.55° DNI: 3.58 kWh/m$^2$/day = 1308 kWh/m$^2$/a

DHI: 2.42 kWh/m$^2$/day = 883 kWh/m$^2$/a

**Pune**

Lat.: 18.55° DNI: 4.76 kWh/m$^2$/day = 1739 kWh/m$^2$/a

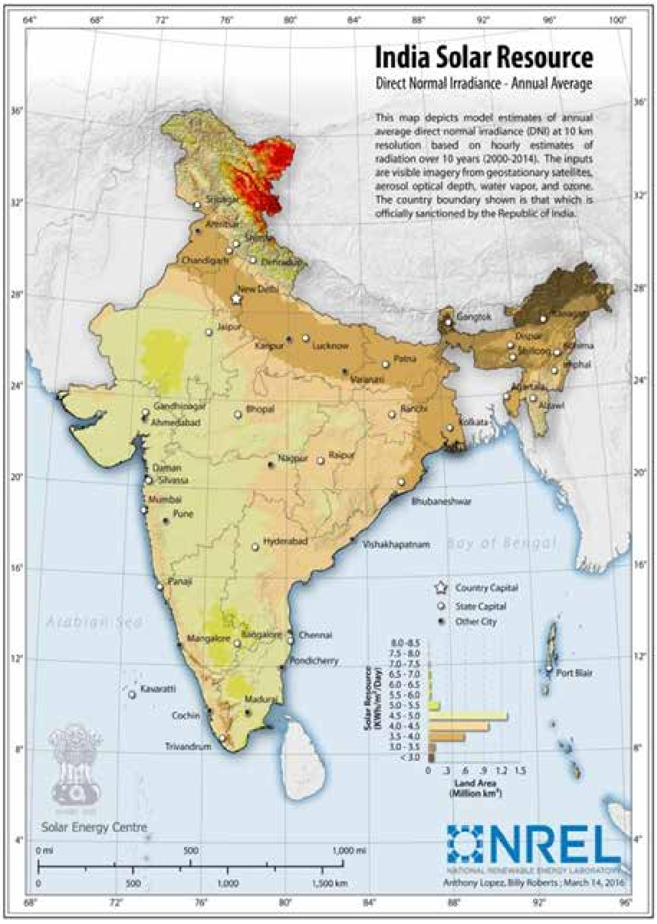
DHI: 2.26 kWh/m$^2$/day = 824 kWh/m$^2$/a

**Madurai**

Lat.: 9.95° DNI: 5.10 kWh/m$^2$/day = 1863 kWh/m$^2$/a

DHI: 2.17 kWh/m$^2$/day = 790 kWh/m$^2$/a

*Figure 1: NREL solar resource map of India*




## 3. CST Technologies

When comparing the four different technologies, there is a risk of comparisons being made between products that are at different stages of development. To try and reduce this risk, performance data from solar collectors and their components that are already on the market has been used whenever possible.

The state-of-the-art collectors selected have been used in utility-scale applications and are, therefore, market-ready, tested, verified and available. The possible exception to this is the PDC, where a high-efficiency tubular cavity receiver has been used in the model, even though, to date, the results have only been proven in scientific projects and not in large-scale industrial applications.

The four CST technologies evaluated in this study are:

- Parabolic Dish Collector
- Linear Fresnel Reflector
- Parabolic Trough Collector
- Compound Parabolic Collector

**It should be noted that the performance data given in this report assumes state-of-the-art technology, manufacturing, installation and operation. In the case that these conditions are not met, significant reductions in performance can occur.**

### 3.1. Collector Parameters

In order to model the thermal yield from each CST technology, a nominal mirror area of 5000 m² has been taken for the solar field; this has then been adjusted slightly to reflect the actual collector sizes available for the relevant technology. A solar field of this size not only allows a realistic simulation to be carried out, but also is a representative of a typical mid-range (2.5$MW_{thermal}$ – 3$MW_{thermal}$) application.

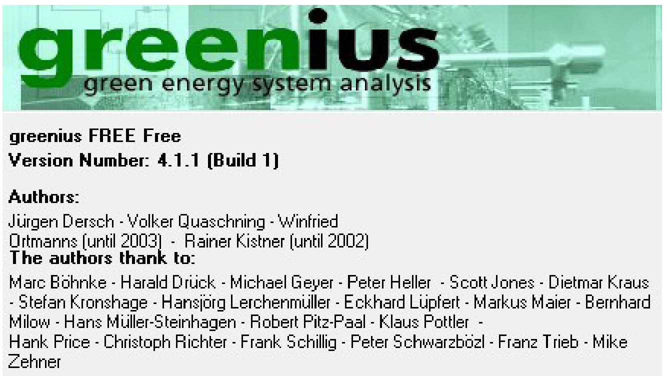
The thermal losses that have been used in the simulation are based on the average temperature of a heat transfer fluid (HTF) being heated in the collector such that its temperature increases by 50°C, that is the temperature used in the simulation is 25°C lower than the output temperature of the collector.

A soiling factor of 97% has been considered for all technologies, as has an availability of 100%, that is uninterrupted daytime operation.

### 3.2. Simulation Tools

The yield of the collectors has been determined using the Greenius simulation software (Figure 2). Developed by the German Aerospace Centre (DLR), Greenius is a powerful simulation environment for the calculation and analysis of renewable power projects, such as concentrating solar thermal systems. This program offers a combination of detailed technical and economic calculations and model the system's thermodynamic performance, and provide the financial data needed for project planning of renewable power projects.

*Figure 2: Greenius simulation software*




Greenius was developed at the German Aerospace Centre (DLR). Dr. Rainer Kistner, Winfried Ortmanns, Dr. Volker Quaschning, Dr. Jürgen Dersch and Simon Dieckmann belonged to the development team. Development, distribution and service are made under the license of DLR. For this calculation, the Version Number 4.3.1 has been used.

In addition to the Greenius simulations, the parabolic dish and Fresnel collectors have also been modelled and run in the System Advisor Model (SAM) program from NREL. SAM makes performance predictions based on system design parameters that are specified as inputs to the model. The software is reputable in the renewable energy sector and is often used for simulation purposes.

To simulate and reflect the real metrological conditions on site, a weather reference year called the typical metrological year (TMY) has been used as the basis of the calculation. To produce the TMY, key weather data from the last 15 years, which is available as a result of a joint MNRE/NREL project, has been used.

In order to verify that the SAM and Greenius simulation results are comparable, both sets of linear Fresnel simulations have been compared. The results of this comparison are given in Chapter 6.

## 3.3. Collector Types

### 3.3.1. Parabolic Dish Collector

**Concentrator**

| | |
|---|---|
| Single size: | 87.7m² |
| Amount: | 57 (Array of 3 m × 19 m –15 m × 15 m grid) |
| Total mirror area: | 4999 m² |
| Focal length: | 7.45 m |
| Reflectance | 94% |
| Shading: | 99% |
| Intercept factor: | 99.5% |

**Receiver**

| | |
|---|---|
| Aperture diameter: | 0.2 m |
| Absorptance: | 90% |
| Receiver efficiency: | max. 95% |

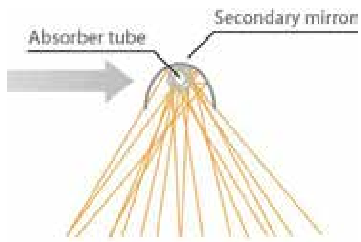
### 3.3.2. Linear Fresnel Reflector

**Concentrator**

| | |
|---|---|
| Size module: | 22 m² |
| Length module: | 4.06 m |
| Row: | 16 modules |
| Loop area: | 704 m² (effective) |
| Field area: | 4928 m² (7 loops) |
| Reflectance: | 95% |
| Intercept factor: | 100% |
| Optical efficiency: | max. 66.3% (5° transversal zenith angle) |
| | nom. 63.5% |

**Receiver (evacuated)**

| | |
|---|---|
| Absorber outer diameter: | 0.7 m |
| Receiver height: | 4 m (above primary reflector) |
| Absorptance: | 96% |
| Envelope transmittance: | 97% |
| Bellows shading: | 96.7% |




### 3.3.3. Parabolic Trough Collector

**Concentrator**

| | |
|---|---|
| Size module: | 36 m² |
| Length module: | 12 m |
| Row: | 8 Modules |
| Loop area: | 556.3m² |
| Field area: | 5,007m² (9 loops) |
| Reflectance: | 94% |
| Intercept factor: | 97.5% |
| Optical efficiency: | max. 79.7% |

**Receiver (evacuated)**

| | |
|---|---|
| Absorber outer diameter: | 0.38 m |
| Absorptance: | 95% |
| Envelope transmittance: | 95% |
| Bellows shading: | 96.4% |

### 3.3.4. Compound Parabolic Collector

**Concentrator**

| | |
|---|---|
| Size module: | 4.5 m² |
| Length module: | 2,4 m |
| Row: | 20 modules |
| Loop area: | 90.0 m² |
| Field area: | 4995 m² (c. 55 loops) |
| Reflectance: | 85% |
| Intercept factor: | 100% (Diffuse 90%) |
| Optical efficiency: | max. 68.8 % |
| Inclination angle: | Determined for each site |

**Receiver (evacuated)**

| | |
|---|---|
| Absorptance: | 95% |
| Envelope transmittance: | 90% |

## 4. Result

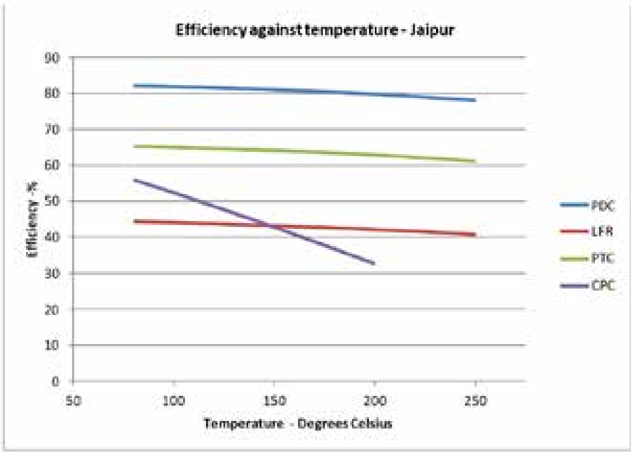
A standardised output table has been compiled for each of the locations. This table includes the main parameters for the location (latitude and solar irradiance) and then the average annual efficiency (%) and daily yield (measured in kWh/m²) for each technology, over a range of temperatures.

For this study it is assumed that the CPC collector can operate to 200°C although the very poor efficiency and design limitations would mean it is relatively unlikely that this technology would ever be used at this temperature. Similarly, the yields from the PDC, LFR and PTC have been calculated for an output temperature of 80°C, whereas it is unlikely that these technologies would be used at such a low temperature.

## 4.1. Results by Location

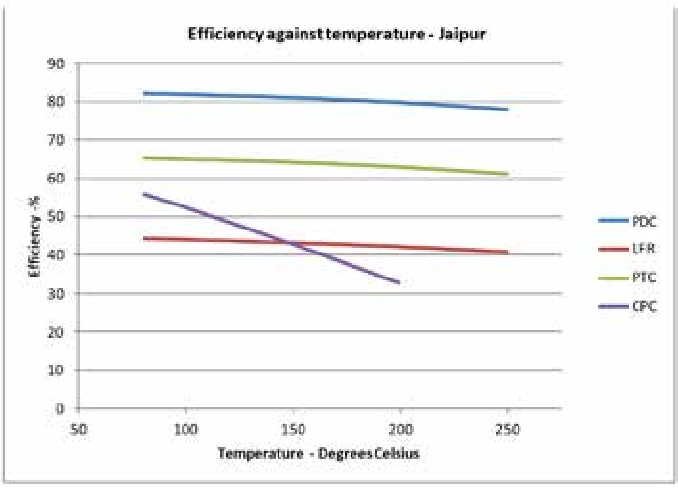
### 4.1.1. Results – Jaipur

| Location | Jaipur | | Average annual thermal efficiencies (%) and thermal output (yield) (kWh/m².day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | 26.95 | | CST Tech. | 80°C | | 100°C | | 150°C | | 200°C | | 250°C | |
| Average irradiance kWh/m².Day – Year | | | | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield |
| | | | PDC | 82.08 | 3.98 | 81.80 | 3.97 | 80.98 | 3.93 | 79.76 | 3.87 | 78.01 | 3.79 |
| DNI | GHI | Diff. | LFR | 44.33 | 2.15 | 44.01 | 2.14 | 43.17 | 2.10 | 42.16 | 2.05 | 40.81 | 1.98 |
| 4.85 | 5.54 | 2.26 | PTC | 65.19 | 3.16 | 64.92 | 3.15 | 64.09 | 3.11 | 62.88 | 3.05 | 61.14 | 2.97 |
| 1772 | 2021 | 826 | CPC | 55.97 | 3.39 | 52.38 | 3.17 | 42.81 | 2.59 | 32.66 | 1.98 | - | - |



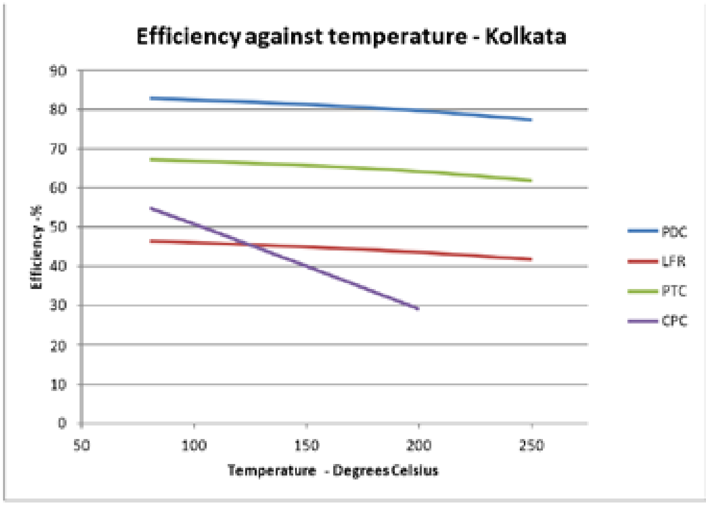

### 4.1.2. Results - Bhopal

| Location | Bhopal | | Average annual thermal efficiencies (%) and thermal output (yield) (kWh/m².day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | 23.25 | | CST Tech. | 80°C | | 100°C | | 150°C | | 200°C | | 250°C | |
| Average irradiance kWh/m².Day - Year | | | | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield |
| | | | PDC | 80.99 | 3.80 | 80.71 | 3.97 | 79.87 | 3.75 | 78.87 | 3.69 | 76.91 | 3.61 |
| DNI | GHI | Diff. | LFR | 45.30 | 2.12 | 44.98 | 2.11 | 44.11 | 2.07 | 44.11 | 2.02 | 41.71 | 1.96 |
| 4.69 | 5.47 | 2.25 | PTC | 66.33 | 3.11 | 66.05 | 3.10 | 65.20 | 3.06 | 65.20 | 3.00 | 62.24 | 2.92 |
| 1712 | 1997 | 821 | CPC | 56.11 | 3.32 | 52.43 | 3.10 | 42.66 | 2.52 | 42.66 | 1.92 | - | - |



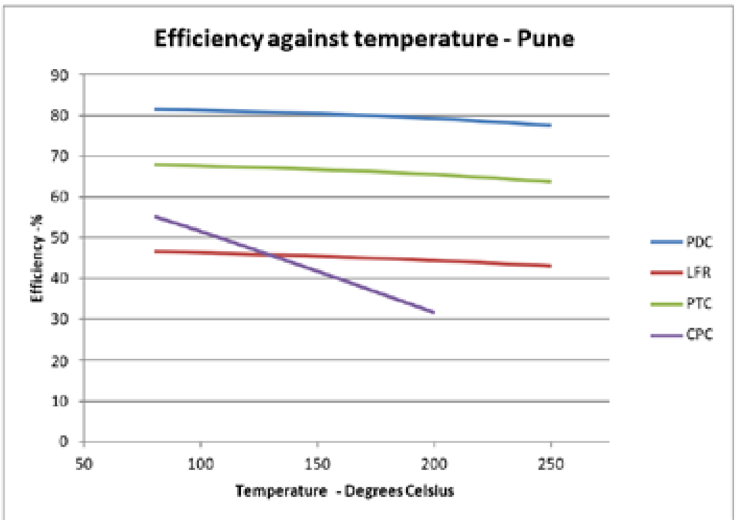
### 4.1.3. Results - Kolkata

| Location | Kolkata | | Average annual thermal efficiencies (%) and thermal output (yield) (kWh/$m^2$.day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | 22.55 | | CST Tech. | 80°C | | 100°C | | 150°C | | 200°C | | 250°C | |
| Average irradiance kWh/$m^2$.Day - Year | | | | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield |
| | | | PDC | 82.77 | 2.97 | 82.41 | 2.95 | 81.31 | 2.91 | 79.73 | 2.86 | 77.48 | 2.78 |
| DNI | GHI | Diff. | LFR | 46.51 | 1.67 | 46.08 | 1.65 | 44.96 | 1.61 | 43.61 | 1.56 | 41.83 | 1.50 |
| 3.58 | 4.96 | 2.42 | PTC | 67.25 | 2.41 | 66.88 | 2.40 | 65.79 | 2.36 | 64.21 | 2.30 | 61.98 | 2.22 |
| 1308 | 1812 | 883 | CPC | 54.85 | 2.91 | 50.77 | 2.69 | 40.06 | 2.12 | 29.19 | 1.55 | - | - |



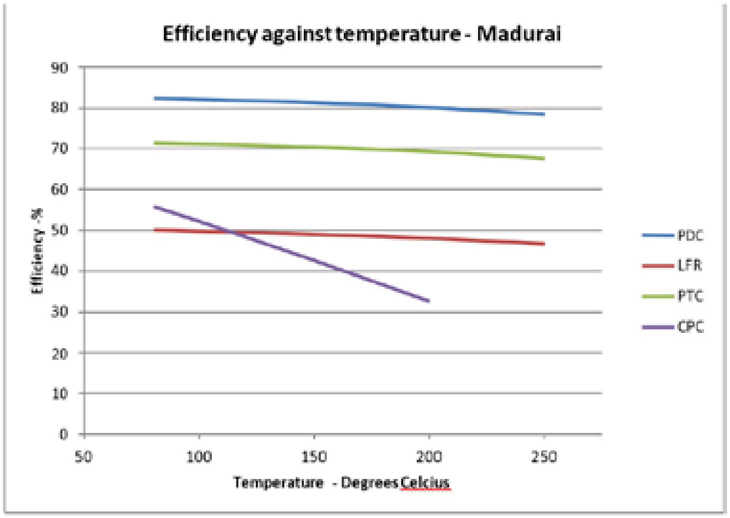

### 4.1.4. Results - Pune

| Location | Pune | | Average annual thermal efficiencies (%) and thermal output (yield) (kWh/$m^2$.day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | 18.55 | | CST Tech. | 80°C | | 100°C | | 150°C | | 200°C | | 250°C | |
| Average irradiance kWh/$m^2$.Day - Year | | | | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield |
| | | | PDC | 81.64 | 3.89 | 81.36 | 3.88 | 80.52 | 3.84 | 79.27 | 3.78 | 77.49 | 3.69 |
| DNI | GHI | Diff. | LFR | 46.68 | 2.22 | 46.35 | 2.21 | 45.49 | 2.17 | 44.46 | 2.12 | 43.08 | 2.05 |
| 4.76 | 5.61 | 2.26 | PTC | 68.00 | 3.24 | 67.72 | 3.23 | 66.86 | 3.19 | 65.61 | 3.13 | 63.84 | 3.04 |
| 1739 | 2046 | 824 | CPC | 55.20 | 3.28 | 51.52 | 3.06 | 41.71 | 2.47 | 31.59 | 1.87 | - | - |



## 4.1.5. Results - Madurai

| Location | Madurai | | Average annual thermal efficiencies (%) and thermal output (yield) (kWh/m$^2$.day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | 9.95 | | CST Tech. | 80°C | | 100°C | | 150°C | | 200°C | | 250°C | |
| Average irradiance kWh/ m$^2$.Day - Year | | | | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield | Eff. | Yield |
| | | | PDC | 82.40 | 4.21 | 82.14 | 4.19 | 81.35 | 4.15 | 80.19 | 4.09 | 78.52 | 4.01 |
| DNI | GHI | Diff. | LFR | 50.16 | 2.56 | 49.85 | 2.54 | 49.06 | 2.50 | 48.10 | 2.46 | 46.81 | 2.39 |
| 5.10 | 5.96 | 2.17 | PTC | 71.60 | 3.65 | 71.34 | 3.64 | 70.55 | 3.60 | 69.40 | 3.54 | 67.73 | 3.46 |
| 1863 | 2175 | 790 | CPC | 55.87 | 3.337 | 52.21 | 3.15 | 42.60 | 2.57 | 32.57 | 1.96 | - | - |




## 4.2. Results - Thermal Yield

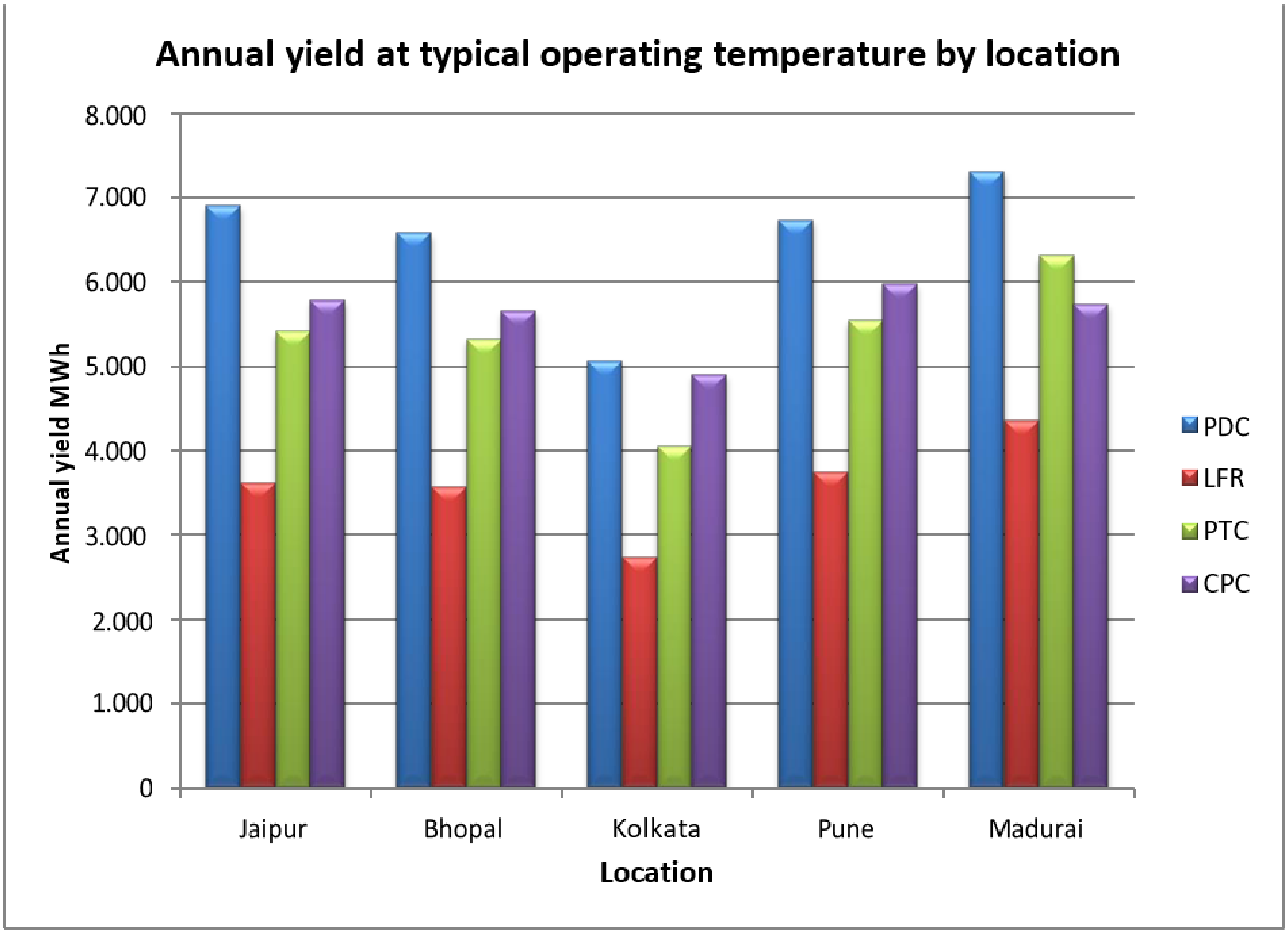
In order to provide a better visualisation of the annual energy yield that can be expected from a system with an aperture area of circa 5000m$^2$, tables and graphs showing the output of each type of collector at each site are given below. However, when making such a comparison, the issue of the very different typical operating temperature of the CPC when compared to the other types of collectors arises. In order to solve this, two sets of data have been prepared.

The first data set (Table 1, Figure 2) gives the yield at typical operating temperatures, namely 250°C for the PDC, LFR and PBC collectors and 100°C for CPC. Whilst this gives a good idea of the type of yields that can be expected, it is not a valid comparison between the technologies due to the advantage given to the CPC system by its lower operating temperature.

***Table 1:*** *Annual yield at typical operating temperatures*

| Annual yield (MWh) at typical operating temperature by location | | | | | |
|---|---|---|---|---|---|
| | Jaipur | Bhopal | Kolkata | Pune | Madurai |
| PDC | 6911 | 6583 | 5067 | 6736 | 7315 |
| LFR | 3617 | 3573 | 2737 | 3747 | 4363 |
| PTC | 5416 | 5328 | 4056 | 5551 | 6310 |
| CPC | 5794 | 5657 | 4912 | 5977 | 5747 |

***Figure 2:*** *Annual yield at typical operating temperature by location*



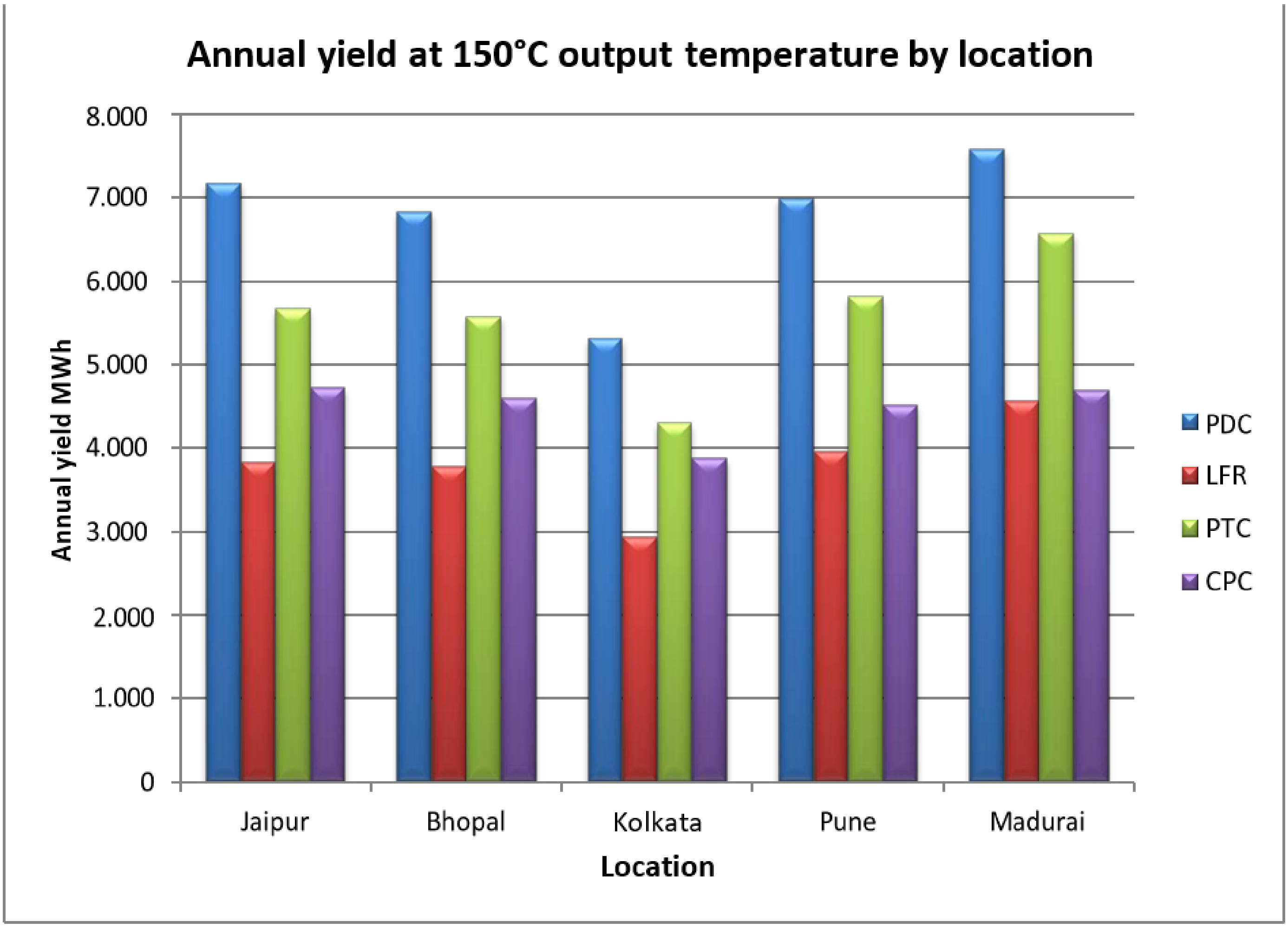

To make a more meaningful comparison between performances possible, a second set of data (Table 2, Figure 3) has been produced using the same temperature (150°C) for all technologies.

The temperature chosen is at the lower end of the likely usage range for the three tracked collectors and is at the upper end of the temperatures normally seen by CPC collectors, however, by using this value the performance of the systems can be compared against a single temperature datum.

***Table 2:*** *Annual yield at 150°C*

| | Annual yield (MWh) at typical operating temperature by location | | | | |
|---|---|---|---|---|---|
| | Jaipur | Bhopal | Kolkata | Pune | Madurai |
| PDC | 7173 | 6837 | 5318 | 6999 | 7578 |
| LFR | 3825 | 3777 | 2940 | 3955 | 4570 |
| PTC | 5678 | 5582 | 4304 | 5813 | 6573 |
| CPC | 4735 | 4603 | 3875 | 4517 | 4690 |

***Figure 3:*** *Annual yield at 150°C*




## 4.3. Peak Thermal Power

The peak thermal power of each of the concentrating solar thermal technologies at a DNI of 850W/m² (no incidence angle considered, clean mirror and receiver surfaces) is as follows.

| | | |
|---|---|---|
| Parabolic dish: | @250°C | ca. 3.6 $MW_{th}$ |
| Fresnel: | @250°C | ca. 2.6 $MW_{th}$ |
| Parabolic trough: | @250°C | ca. 3.3 $MW_{th}$ |
| CPC: | @100°C | ca. 2.5 $MW_{th}$ |

As discussed in section 4.2 the peak simulation is based on a collector of 5000m² under typical operating temperatures.

## 4.4. The Effects of Latitude

The effects of latitude on collector average annual thermal efficiencies at 150°C are shown in Table 3.

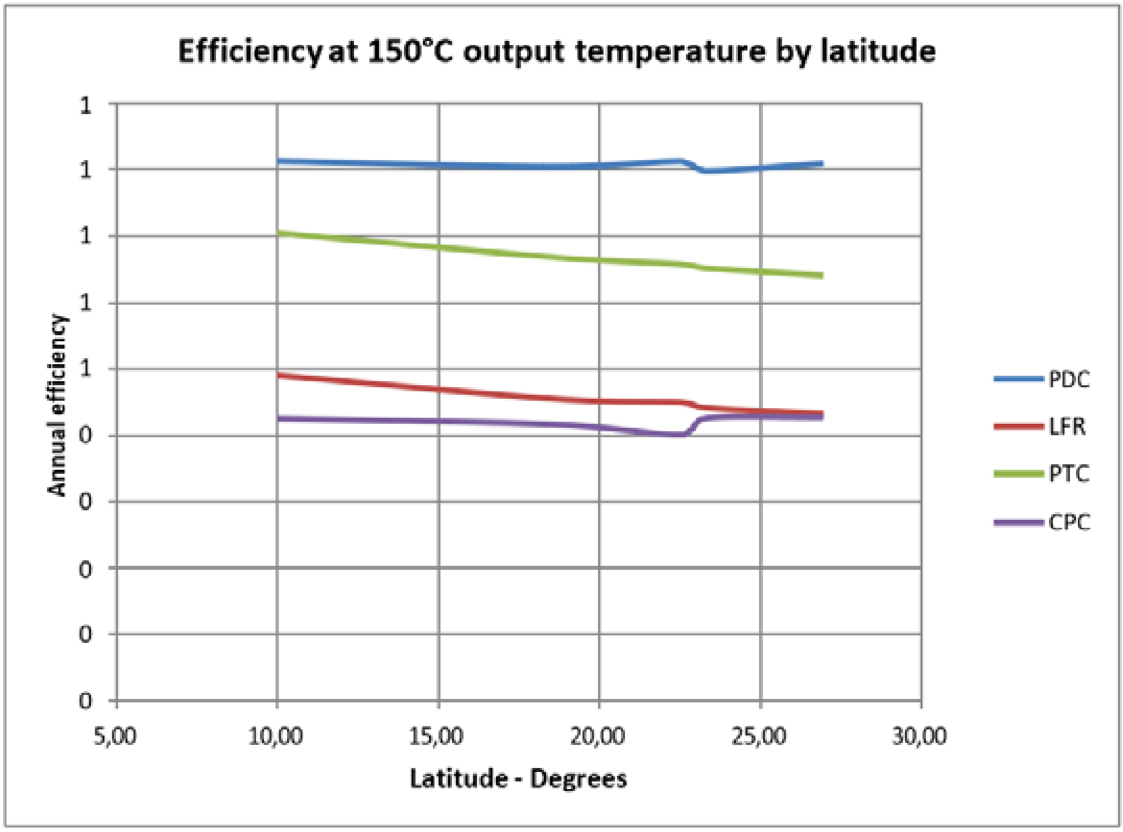
***Table 3:*** *Collector efficiency at 150°C output temperature by latitude*

| Collector efficiency at 150°C output temperature by latitude | | | | | |
|---|---|---|---|---|---|
| Latitude | 26.95°N | 23.25°N | 22.55°N | 18.55°N | 9.95°N |
| PDC | 80.98% | 79.87% | 81.31% | 80.52% | 81.35% |
| LFR | 43.17% | 44.11% | 44.96% | 45.49% | 49.06% |
| PTC | 64.09% | 65.20% | 65.79% | 66.86% | 70.55% |
| CPC | 42.81% | 42.66% | 40.06% | 41.71% | 42.60% |

Figure 4 shows the variation of annual thermal efficiency with respect to latitude. It also highlights the difference in the thermal efficiency of the four CST technologies that have been modelled.

What is evident from the graph (Figure 4) is the effect of latitude on the two linear solar collectors (LFR and PTC), which show a reduction in efficiency as the latitude increases. In addition to this, an effect can be seen due to the different meteorological conditions found in Kolkata, where the distribution of irradiance throughout the year affects the trend line for both the tracked and the non-tracked collectors albeit in different ways.

***Figure 4:*** *Efficiency at 150°C output temperature by latitude*




## 4.5. Efficiency and Thermal Output Over the Day

The final two graphs (Figures 5 and 6) show the daily distribution of efficiency and specific output over a typical day (1st April used) in Pune. As is typical for India in springtime, there is clear weather with no breaks in the sunshine.

Figure 5 shows the tracked collectors rapidly reaching a stable efficiency, with the fixed CPC taking longer to 'get started' due to its fixed (non-tracking) installation combined with its higher mass of working fluid in the collector.

In Figure 6 (specific output graph), we can see the very high output of the CPC towards noon. This is due to its relatively high efficiency with the sun overhead and its ability to make use of both direct and diffuse irradiance. Its performance relative to the other collectors is further enhanced due to the 100°C operating temperature as opposed to 250°C for the other collectors.

***Figure 5:*** *DNI, GHI and collector efficiency over a typical day (01 April)*

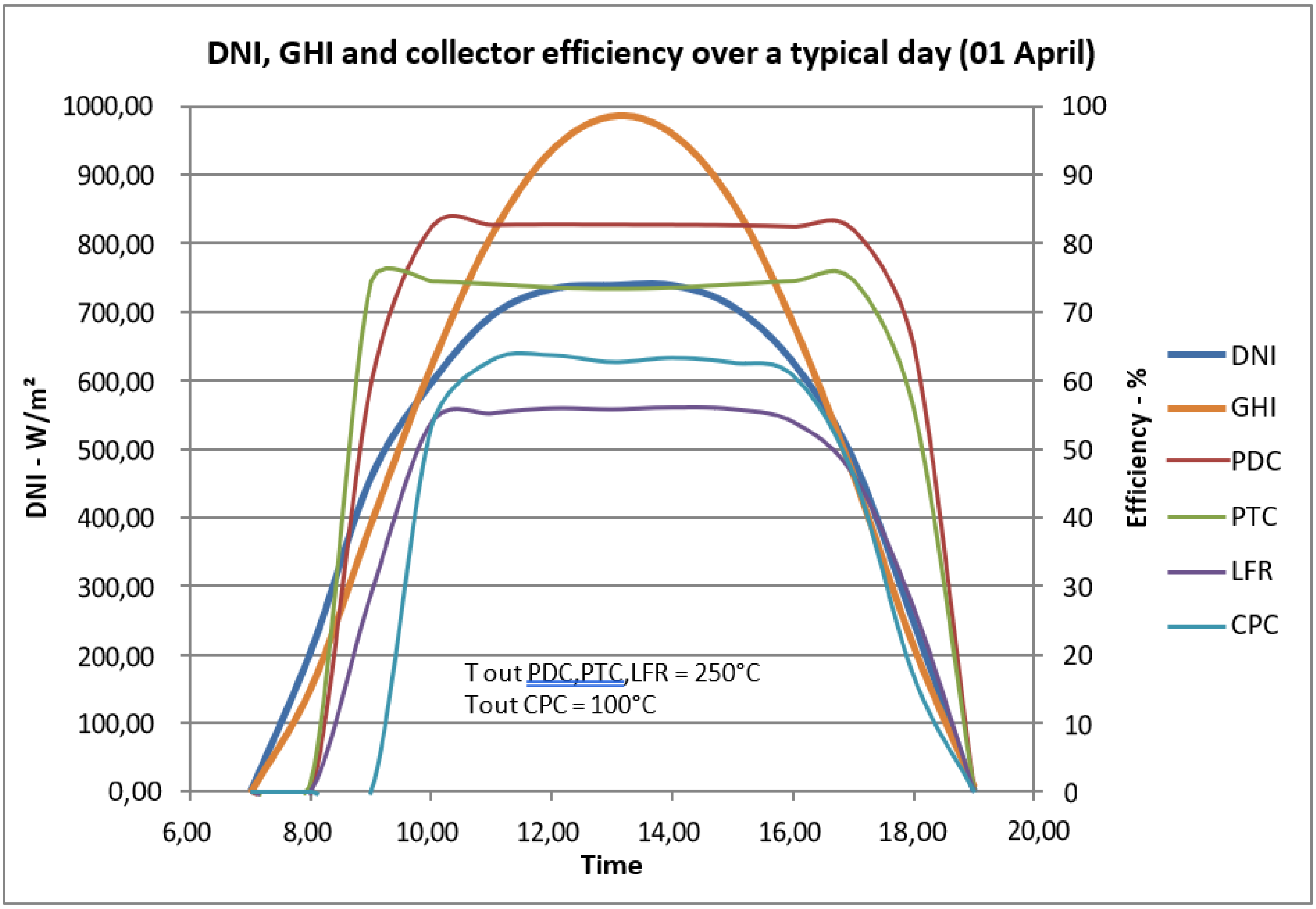
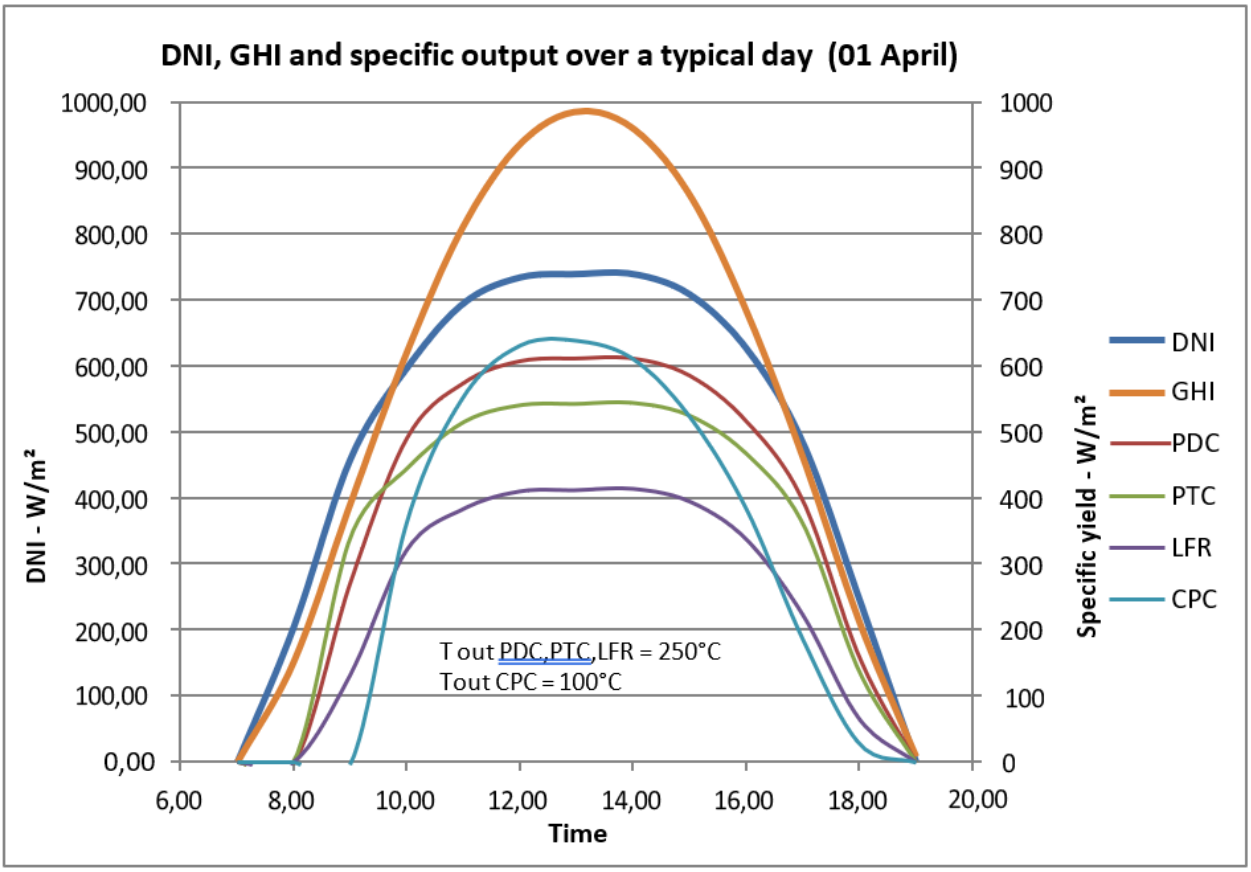



***Figure 6:*** *DNI, GHI and specific output over a typical day (01 April)*



## 5. Conclusion

From the efficiency against temperature results, it can be seen that regardless of which site is taken, the parabolic dish has the highest annual efficiency, followed by the parabolic trough. Whilst having lower efficiency than the parabolic trough, the compound parabolic collector has higher efficiency than the linear Fresnel linear reflector at temperatures below circa 120°C (exact crossover point dependent on latitude).

What can also be seen from the results is that as the latitude increases, the average annual performance of the linear systems (PTC and LFR) reduces, with at least a 5% decrease in performance between a system located in the southernmost parts of India and one located in the north. This reduction is due to the "cosine effect" caused by the sun being lower in the sky especially in winter (northern hemisphere) and as a result the sun's rays tend to shine "along" the axis of the linear collector rather than arriving perpendicular (i.e., at a 90° angle) to it.

The compound parabolic collector does not show a significant dependency on latitude, although the effects of different weather conditions, can be seen (especially in Kolkata).

The parabolic dish collector shows a different trend, with the thermal efficiency slightly increasing at higher latitudes. As the dish tracks the sun about two axes, it is not subject to the "cosine effects" that affect the single axis linear collectors. However, changes in the DNI distribution over the year at different sites are sufficient to give rise to changes in efficiency with location.

## 6. Comparison between Simulation Software Types

To demonstrate that the two types of simulation software used are able to produce comparable results, a cross check has been carried by running the Fresnel technology simulation in both SAM and Greenius.

The Greenius model for linear Fresnel is expected to be very accurate, as the modelled collector is implemented into the system's distinct library and the values have been agreed with the system supplier. Therefore the collector specific properties are considered in the model- the IAM, especially, is based on the specific linear Fresnel collector. In the SAM Model a general, more standard IAM is used to calculate the output as the specific IAM is not provided.

The results obtained using the Greenius simulation for linear Fresnel and the difference to the SAM results are shown in Table 4 for efficiency @ 250°C

***Table 4:*** *Comparison Simulation of Fresnel technology at 250°C*

| | Madurai | Pune | Kolkata | Bhopal | Jaipur |
|---|---|---|---|---|---|
| LFR | 46.8% | 43.08% | 41.8% | 41.7% | 40.8% |
| Δn | +0.8% | -1.1% | +0.1% | -1.2% | 1.6% |

The results show that a simulation provides an accurate value (repeatable with different simulation tools).

# 7. Annexure I

## 7.A. Empaneled Channel Partners of CST in India

| Sl. No | Name and Address | Technology |
|---|---|---|
| 1 | M/s. Unisun Technologies Pvt. Ltd.,<br>Regus Eversun Business Centre,<br>Manyata Embassy Business Park,<br>Ground Floor, El Block, Beech Building, Outer Ring Road, Bengaluru - 560 045.<br>Karnataka State, India.<br>Direct line: +91 (80) 4276 4565<br>E-mail: info@unisun.net<br>Website: www.unisun.net | Single Axis Tracked Scheffler Dishes |
| 2 | M/s. Thermax Limited, Solar Division,<br>4th Floor, Energy House, D Il Block,<br>Plot No. 38 & 39 MIDC, Chinchwad Pune— 411 019<br>Ph : (020) 67308880/ 67308991/<br>66051200/ 25542122<br>Fax : (020) 66126612/ 6700 | • Parabolic Trough Collectors (Single Axis)<br>• Scheffler Dishes (Both Single Axis and Double Axis Tracked).<br>• Non- imaging concentrating system |
| 3 | M/s. Clique Solar, A-601, First Floor,<br>Lancelot, Near Kalyan Jewelers,<br>S. V. Road, Near Kora Kendra Flyover,<br>Borivali (West), Mumbai — 400 092,<br>E-mail: adh@cliquesolar.comt<br>Website: www.cliquesolar.com | Double Axis Tracked Fresnel Reflector based Dishes |
| 4 | M/s. Megawatt Solutions Pvt. Ltd.<br>T-93, Floor, Gautam Nagar, Yousuf Sarai Commercial Complex, New Delhi110049<br>Email: smalik@megawattsolutions.in<br>info@megawattsolutions.in<br>Website:http://megawattsolutions.in | Double Axis Tracked Paraboloid<br>Dishes |
| 5 | M/s. Taylormade Renewables Ltd.,<br>705, Kerala G.I.D.C., Taluka Bavlm Dist. Ahmedabad, Gujarat — 382 220.<br>Mail: dharam@tss-india.com<br>Website: www.tss-india.com | Single Axis Tracked Scheffler Dishes |
| 6 | M/s. Ultra Conserve Pvt. Ltd.,<br>25 Gaurav Industrial Estate, Bharat Coal<br>Compound, Bail Bazar, Kurla-West, Mumbai-400 070, www.conserve.co.in | • Parabolic Trough Collectors (Single Axis)<br>• Non-imaging Concentrating System |
| 7 | M/S. Leveragenet Solutions Pvt. Ltd.<br>Suite 21, Bldg 2, New Lakshmi Narayan<br>Park Society, Koregoan Rd., Koregoan<br>Park, Pune, Maharashtra 41 10001 ,<br>Mr. Umesh Choori<br>Mob: 09975591062<br>Ph: 020- 30560130,<br>E-mail: contact@energy-guru.com | Parabolic Trough<br>Collectors<br>(Single Axis) |

| Sl. No | Name and Address | Technology |
|---|---|---|
| 8 | M/S. Forbes Solar Pvt. Ltd<br>P B # 29, Mumbai-Pune Rd., Kasarwadi,<br>Pune 411 034<br>Mr. N.Iyer<br>Ph : 91 (0) 20-27145595 / 39858555<br>Fax : 91 (0) 20-27147413<br>Website: www.forbesmarshall.com<br>E-mail : ccmidc@forbesmarshall.com | Concentrator Dish (Dual Axis) |
| 9 | M/s. Sunbest<br>Manufacturers of Solar Products 238/10, Nehruji Road, Valli Nagar,<br>Theni- 625531, Tamil Nadu<br>Dr. C Palaniappan<br>Mb: 91-9994094400<br>Ph: 04546-255272<br>Fax: 04546-255271<br>Email: info@sunbest.in | Non-imaging<br>Concentrating System |
| 10 | M/S. Green Life Solutions Pvt. Ltd.,<br>F-501, Shiv Height, Beltarodi, Nagpur440034,<br>Mr. Amit Deotale, Mr. Sudhir Sarawat<br>Ph: 0712-2289548,<br>Mob:7507500122<br>Email: amit@greenlifesolution.in info@greenlifesolution.in www.greenlifesolution.in | Double Axis Tracked Parabolic Dishes |
| 11 | M/S. A.T.E Enterprises Pvt. Ltd.<br>T-126, T Block, MIDC, Bhosari, Pune<br>Maharashtra-411026<br>Dr. Prasanna Rao Dontula<br>Mob: +91 98808 21732<br>Ph: +91 80 2535 8661<br>Email id: p_dontula@ateindia.com | • Double Axis Paraboloid Dishes<br>• Non -Imaging Concentrating System |

## 7.B. Manufacturers/ Suppliers of CST in India

| Sl. No | Name and Address | Technology |
|---|---|---|
| 1 | M/s. Unisun Technologies Pvt. Ltd.,<br>Regus Eversun Business Centre,<br>Manyata Embassy Business Park,<br>Ground Floor, El Block, Beech Building,<br>Outer Ring Road, Bengaluru - 560 045.<br>Karnataka State, India.<br>Board line: +91 (80) 4276 4567<br>Website: www.unisun.net | Single Axis<br>Tracked Scheffler<br>Dishes |

| Sl. No | Name and Address | Technology |
|---|---|---|
| 2 | Ws. Thermax Limited,<br>C & H Heating -Solar, Eco House, D-13,<br>MIDC Industrial Area, R D Aga Road,<br>Chinchwad, Pune, India - 41 1019<br>Website: www.thermaxglobal.com | a. Parabolic Trough Collectors (Single Axis)<br>b. Scheffler Dishes (Both Single Axis and Double Axis Tracked).<br>c. Non- Imaging Concentrating System |
| 3 | M/s. Clique Solar,<br>A-601, First Floor, Lancelot, Near Kalyan<br>Jewelers, S. V. Road, Near Kora Kendra Flyover, Borivali (West), Mumbai — 400 092,<br>Website: www.cliquesolar.com | Double Axis<br>Tracked Fresnel<br>Reflector based<br>Dishes |
| 4 | M/s. Megawatt Solutions Private Limited<br>T-93, 4th Floor, Gautam Nagar, Yousuf<br>Sarai Commercial Complex, New<br>Delhi-110049<br>info@megawattsolutions.in<br>Website: http://megawattsolutions.in | Double Axis<br>Tracked Paraboloid<br>Dishes |
| 5 | M/s. Taylormade Renewables Ltd.,<br>705, Kerala G.I.D.C., Taluka Bavla,<br>Dist. Ahmedabad, Gujarat - 382 220.<br>Tel: 079-40035875, 40040888<br>Website: www.tss-india.com | Single Axis<br>Tracked Scheffler<br>Dishes |
| 6 | M/s. Ultra Conserve Pvt. Ltd.,<br>25 Gaurav Indl. Estate, Bharat Coal<br>Compound, Bail Bazar, Kurla-West,<br>Mumbai-400070,<br>Ph: 022-25145602,<br>Website: www.conserve.co.in | a. Parabolic Trough Collectors (Single Axis)<br>b. Non-imaging Concentrating System |
| 7 | M/s. Bhagawati International Ltd.<br>A-27 B, Sector-16, NOIDA- 201 301<br>Tel: 91-120-4749901,<br>Fax:91-120-4749919/ 011-29230698<br>Website: www.tarasolar.in | Single Axis<br>Tracked Scheffler<br>Dishes |
| 8 | Ws. K energy<br>5, Haider building, outside sojati gate,<br>Jodhpur - 342001, Rajasthan<br>Ph.: 0291 3269045, 3260432,<br>Fax: 0291 2630432,<br>E mail: info@kenergy.co.in | Single Axis<br>Tracked Scheffler<br>Dishes |
| 9 | M/s. Leveragenet Solutions Pvt. Ltd.<br>Suite 21, Bldg 2, New Lakshmi Narayan<br>Park Society, Koregoan Rd., Koregoan Park,<br>Pune, Maharashtra 4110001 ,<br>Ph: 020- 30560130,<br>E-mail: contact@energy-guru.com | Parabolic Trough<br>Collectors<br>(Single Axis) |

| Sl. No | Name and Address | Technology |
|---|---|---|
| 10 | M/s. Forbes solar Pvt. Ltd.<br>P B # 29, Mumbai-Pune Rd., Kasarwadi,<br>Pune 411 034,<br>Ph : 91 (0) 20-27145595 / 39858555<br>Fax : 91 (0) 20-27147413<br>Website: www.forbesmarshall.com.<br>E-mail : ccmidc@forbesmarshall.com | Concentrator Dish (Dual Axis) |
| 11 | M/s. Empereal-KGDS Renewable Energy<br>Private Limited<br>366, Thudiyalur Road, KG Campus,<br>Saravanampatti, Coimbatore- 641 035<br>Ph : 0422 - 661 9917<br>Fax : 0422-266 8325<br>E-mail: spv@kgisl.com<br>Website : http://solar.kgisl.com | Single Axis Tracked<br>Linear Fresnel<br>Reflector based Systems |
| 12 | M/s. Oorja Energy Engg. Services Hyd Pvt.<br>Ltd., Plot No. 30, Lane 14, Phase 11, IDA,<br>Cherlapally, Hyderabad - 500051 | Single Axis Paraboli Trough Collectors |
| 13 | M/s. Greenera Energy India Pvt. Ltd.<br>No.32, KV Nagar,<br>Opp. To Cheran Maa Nagar,<br>Vilankuruchi main Road Coimbatore 641035 ,<br>Tamil Nadu<br>www.greeneraindia.com | Parabolic Trough<br>Collectors<br>(Single Axis) |
| 14 | M/s. A.T.E Enterprises Pvt. Ltd.<br>T-126, T Block, MIDC, Bhosari, Pune<br>Maharashtra-411026<br>Ph: +91 80 2535 8661 | a. Double axis Paraboloid Dishes<br>b. Non-Imaging Concentrating System |
| 15 | M/s. Jayanthi Plastics (Stellar Energy)<br>5/168, Velappgoundan Valasu<br>Villiarasampati (PO) Nasiyanoor Road<br>Erode 638107<br>Ph: 04242411421 | |
| 16 | M/s. Sunbest<br>238/10, Nehruhi Road, Valli Nagar,<br>Theni 625531, Tamil Nadu<br>Ph: 04546-255272<br>Fax: 04546-255271<br>Email: info@sunbest.in | Non-Imaging<br>Concentrating<br>System |

| Sl. No | Name and Address | Technology |
|---|---|---|
| 17 | M/s. GreenLife Solutions Pvt. Ltd.,<br>F-501, Shiv Height, Beltarodi,<br>Nagpur-440034<br>Ph: 0712-2289548,<br>info@greenlifesolution.in<br>www.greenlifesolution.in | Double Axis<br>Paraboloid Dishes |
| 18 | Ws. Solar Alternatives & Associated Programmes (SAAP), St. Mary's Church<br>Compound, Phulwarisharif PO,<br>Patna-801505, Bihar<br>Ph: 0612-2555787<br>Email: mail@solarvihar.com | Single Axis<br>Tracked Scheffler<br>Dishes |
| 19 | Ws. Enersun Power Tech Pvt. Ltd.<br>Chandermukhi Basement, Nariman Point,<br>Mumbai, Maharashtra-400021<br>Ph:022-4910444,<br>Fax:02222853752 | Curved Linear Fresnel reflector |
| 20 | M/s. VSM Solar Pvt. Ltd.<br>No.43, 4Th Phase, KIADB Industrial Area, Bommasandhra, Anekal Taluk, Bangalore560099,<br>Email: vsmsolar@gmail.com | Non-Imaging<br>Concentrating<br>Systems |
| 21 | M/s. Thermosol Glass Pvt. Ltd.,<br>Cargo House, Opp. Gandhi Ashram Road,<br>Ahmedabad-380027,<br>Ph. +917927556142, / 9687688381<br>Fax: +91 7927556139,<br>Email: enquiry@thermosolglass.com info@ thermosolglass.com<br>Website: www.thermosolglass.com | Solar Grade<br>Tempered Glass<br>Parabolic Trough<br>Collector<br>(Single axis) |
| 22 | M/s. Quadsun Solar Pvt. Ltd.,<br>5 Padmini Enclave, Hauz Khas,<br>New Delhi-110016<br>info@quadsunsolar.com www.quadsunsolar.com | Double axis<br>Paraboloid Dishes |
| 23 | M/s. Solwedish Solar Pvt. Ltd. (SSPL),<br>Villa- 5, Ashoka-A-la-Maison, Dhulapally,<br>Secunderabad - 500014 (Telangana),<br>Email: works.hyd@solwedish.com<br>Website: solwedish.com | Dual Axis Dish Concentrator |
| 24 | M/s. ARS Glass Tech Pvt. Ltd.<br>327 B-Wing, Monalisa Commercial<br>Complex, Manjalpur, Vadodara-390 01 1, Gujarat,<br>Ph: +91-265-3262759 | Solar Grade Mirror |

| Sl. No | Name and Address | Technology |
|---|---|---|
| 25 | M/s. Apollo Power Systems Pvt. Ltd.<br>#31, 1 st floor, 1 st Main Road,<br>Chamarajpet, Bangalore — 560018,Karnataka<br>Tel: +91-80-26500022, +91-80-26981515,<br>Email: infoblr@apollopgwersystems.com<br>Website: www.apollopowersvstems.com | Dual Axis<br>Paraboloid Dishes |
| 26 | M/s. Luit Renewable Pvt. Ltd.<br>C-6/13, Lawrence Road Industrial Area,<br>Delhi 110 035,<br>Website: www.luitrenewable.org | Parabolic Trough<br>Collector (Single Axis) |
| 27 | M/s. Soft Tech Renewable Energy<br>#1618, Sector-32A, Chd. Road<br>Ludhiana Punjab -141003<br>Tel: +91-8427122990,<br>Mob. +91-8699500011 | Single Axis<br>Tracked Scheffler<br>Dishes |
| 28 | M/s. Sahajanand Laser Technology Ltd.<br>E-30, Electronics Estate, GIDC Sector-26,<br>Gandhinagar, Gujarat, India- 382 028<br>Website: www.sltl.com | Parabolic Trough Collector(PTC) |
| 29 | Ws. Zodiac Energy Pvt. Ltd.<br>A-1204, Siddhi Vinayak Towers Near DCP Office Beside Kataria Auto Makarba, S. G.<br>Highway Ahmedabad-380051 Gujarat, India<br>Ph: +91 79 29704116/ 79 66170307<br>Website: http://www.zodiacenergy.com | Parabolic Trough Collector(PTC) |
| 30 | M/s. Vcare Engineering Pvt. Ltd.<br>Ground Floor, Synergy house Il, Alembic Road, Subhanpur, Vadodara-390023, Gujarat.<br>(901-902 Gunjan Tower, Alembic Road,<br>Subhanpur, Vadodara- 390023 Gujarat, India)<br>Email: info@vcare-global.com Web; https://vcare-global.com | Compound Parabolic Collector (CPC) |
| 31 | M/s. 3 EN Clean Tech Pvt. Ltd.<br>Plot No. 87, 6th Main Road Belur Industrial Area, Dharwad Karnataka.<br>Tel: 0836-2486686 | a. Single Axis Scheffler Dishes<br>b. 28 Sq.m Moving Focus Dish |
| 32 | M/s. Emsol Innovations Pvt. Ltd.<br>603-B, Brentwood, 5/63 Rajiv Gandhi Salai,<br>Egattur Kelambakkam, Chennai 603103,<br>Tamil Nadu<br>(GA2 Sampoorna Appt,<br>167 LB Road, Thiruvanmiyur,<br>Chennai 600 041, INDIA.)<br>Website: http:((www.emsolin.com | Cross Compound<br>Parabolic<br>Concentrator |

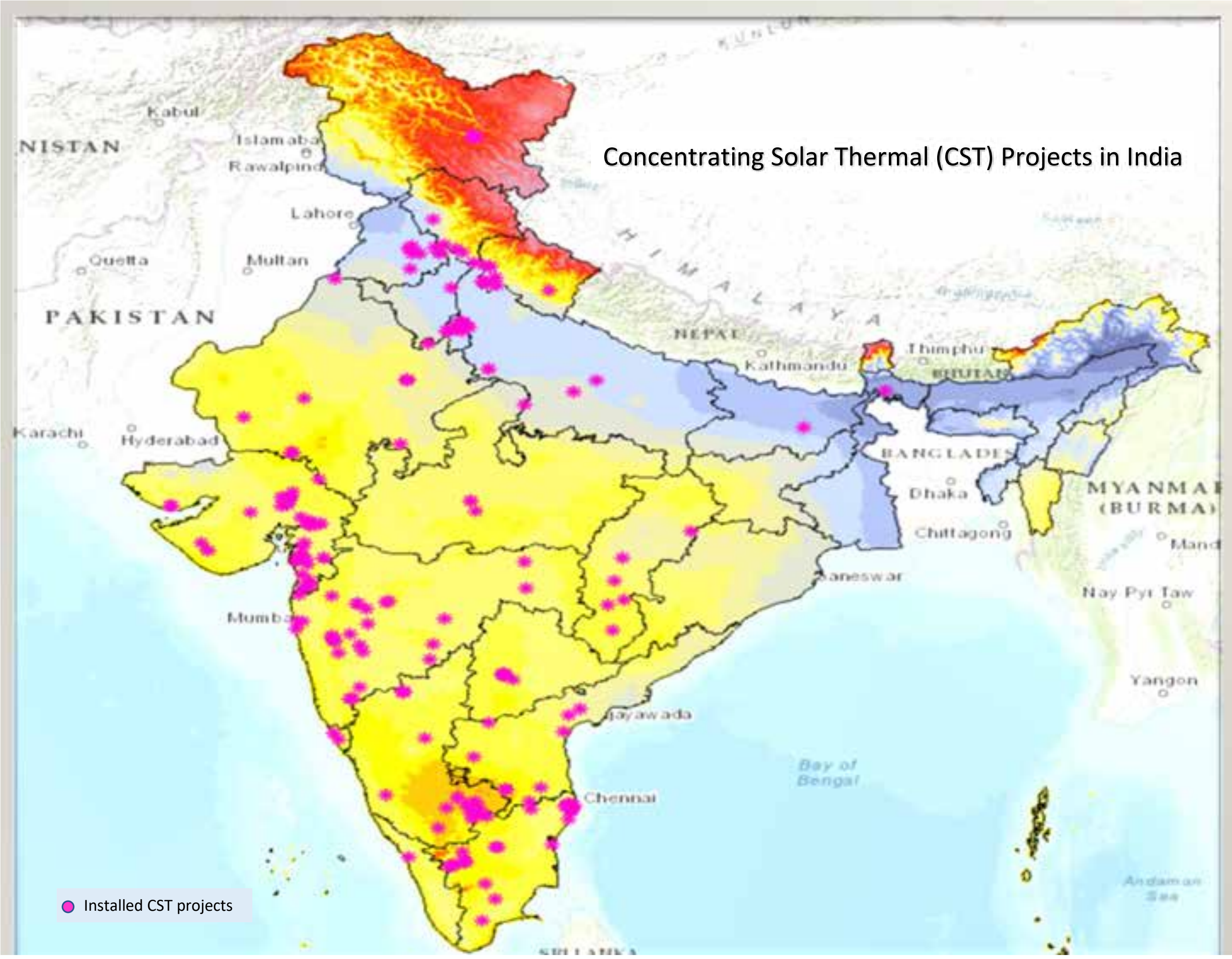
| Sl. No | Name and Address | Technology |
|---|---|---|
| 33 | M/s. Pasumai Aatral Pvt. Ltd.<br>Plot No. 3, yd street, 2/841, Krishnaveni<br>Ammal Nagar, Iyyappanthangal, Chennai 600 056,<br>Tamil Nadu, India | Dual Axis<br>Paraboloid Dishes |

## 7.C. Updated list of empaneled Entrepreneurs

| Sl. No | Name and Address |
|---|---|
| 1 | LANASOL Energy Solutions Pvt. Ltd, #242/a, Badri Sadan, 5th Cross, KG Nagar, Bangalore, Karnataka-560019,<br>Tel:080-26607666, E-mail: info@lanasol.com |
| 2 | M/s. Prorener Engineering Consultants Pvt. Ltd.<br>401, Aprirose-2 , B/H. Parimal garden, Ambawadi-38006.<br>Tel: 917940034673 (79)/ 7486849477<br>Email:operations@prorener.com. |
| 3 | M/s. Ashman Solar Solution Pvt. Ltd.<br>13/3 TTK road , 2nd cross street, Alwarpet,<br>Chennai-600 018 Tel: 9841843417 |
| 4 | M/s. SAFCONx Pvt. Ltd.<br>Radhalayam, Angadical puthencavu . P.O, Chengannur Alappuzha, Kerala-689123.<br>Email: info.safconx mail.com |
| 5 | M/s. Swathi Sunsource Power Pvt. Ltd.<br>Plot no. I to 113, Industrial park, Penukonda District, Anantpur , Andhra Pradesh<br>Contact Person: Ravi Kapoor<br>Mb: 918041480539<br>Ph: +91-22-28444400/ 01/ 02/ 03/ 04/ 05<br>Email: info@swathisunsource.com |
| 6 | M/s. Soft Tech Renewable Energies,<br>#1618, Sec - 32A, Chd.Road, Ludiana<br>Ph:0161 - 5088885, M: 8427122990, 8699500011<br>Email: softtechre mail.com |
| 7 | M/s. Heat ray Solar Pvt. Ltd.,<br>108, Prabhadevi Unique Industrial Premises Co-op Society Limited,<br>Veer Savarkar Marg, Prabhadevi, Mumbai — 400 025 |
| 8 | M/S. Suren Power Pvt. Ltd.<br>No. 1/507, Avinasi Road, Neelambur, Coimbatore-641062 |

# 8. Annexure II

## 8.A. CST Project Map



## 9. Annexure III

# MNRE-GEF-UNIDO Project

## Promoting Business Models for Increasing Penetration and Scaling up of Solar Energy

**Sustainable Development Goal 9:**

Industry, Innovation and Infrastructure

**Project Targets:**

- CST based systems installed with 45,000 $m^2$ of collector area
- 83,000 tonnes of direct $CO_2$ emission reduction

**Relevant India Development Goal:**

JNNSM target of achieving 20 million square meters of solar collector area by 2022.

### Background

Solar heating and cooling applications for industrial processes present a niche market. Analysis of solar sector in India and review of existing barriers to promote solar energy use in industrial sectors carried out during the project preparation phase have shown strong relevance of the GEF-UNIDO project, and complementarity to ongoing and planned national and international programmes to promote and support increased solar energy use for industrial heat in India – the driving solar support initiative in India has been the Jawaharlal Nehru National Solar Mission (JNNSM) of the Ministry of New and Renewable Energy (MNRE), Government of India .

The project has been conceived aiming to contribute to the GEF Climate Change Strategic Objective namely, promoting investment in Renewable Energy (RE) technologies by transforming the market for solar energy for industrial heat applications in India through investment, market demonstration, development of appropriate financial instruments, development of technical specifications, capacity building and contributions to establish a favorable policy and regulatory environment.

The project will therefore assist in the commercialization of solar heat technologies, avoid GHG emissions and help India in its transformation towards low carbon development.

### Major Outputs Envisaged from the Project

1) Systems based on Concentrating Solar Thermal (CST) technologies are installed with 45,000 $m^2$ of solar collector area through demonstration projects resulting in saving of 39,200 tonnes of $CO_2$ emission.

2) Knowledge documents & standardization of performance measurement developed with barriers removed for large scale promotion of CST Technology.

### Project Information

**Area:** Energy

**Implementing Partners:**

- Ministry of New and Renewable Energy (MNRE), Government of India
- Indian Renewable Energy Development Agency
- National Institute of Solar Energy

**Location(s):**

National-level

### Main features of the project

- ❖ Promotion of CST technologies as clean energy solutions for industrial sectors
- ❖ Provide financial support to CST installations in the industrial sector by offering the soft-loan facility with IREDA.
- ❖ Support for improving manufacturing of CST technologies
- ❖ Provide technical support to beneficiaries to enable installation & integration of the most suited CST technology in industries.
- ❖ Developing knowledge documents to facilitate better understanding of the projects.
- ❖ Capacity building to improve the manpower involved in the CST sector.

## Objectives

The GEF-UNIDO's project is designed to complement MNRE's support programme by helping to remove barriers associated with CST technology, its awareness, capacity building, market and financial barriers. The duration of the project is from January 2015 to December 2019 (being extended till December 2020).

In addition, the initiative aims to provide technology application information packages and standardization of CST performance measurement.

## Target technologies for Solar Heating and Solar Cooling

Different concentrating technologies have been developed or are currently under development for various commercial and industrial applications.

For industrial processes where temperatures above 80°C are required, concentrating solar collectors such as parabolic trough or dish collectors, non-imaging concentrators or a Linear Fresnel system are required to be used.

The analysis of various industrial processes shows that solar concentrators could be technically and commercially viable in many industries. The industries showing good potential for implementation of solar concentrators are food processing, paper and pulp, fertilizer, breweries, electroplating, pharmaceutical, textiles, refineries, rubber and desalination sectors.

UNIDO invites industry units to install CST systems for the supply of heat at medium and high temperatures and to avail the financial incentives from the UNIDO project on a first-come-first-serve basis

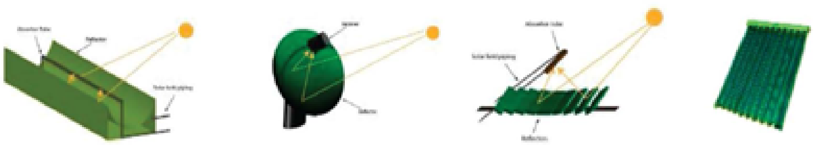
## Expected Payback

The project payback usually depends on the cost of the substituted fuel. It ranges from 3–4 years for process heat applications if the substituted fuel is Furnace Oil, Diesel, or PNG. The payback may be slightly longer (5–7 years) to substitute solid fuels such as Coal, Biomass, and Wood. The longer payback period is also seen in cooling applications.

## Implementation Arrangement

The project strategy builds on the existing favorable framework for solar thermal in India. Factors in favor of the project include the high commitment by the government to the development of its solar thermal industry, and significant interest by the industrial sector to reduce its reliance on fossil fuels.

Primary target beneficiaries of the project are energy policy-making and implementing institutions, primarily MNRE, MSME, IREDA, industrial unit owners (end beneficiaries), CS manufacturers, designers, installers, training institutes, energy professionals and service providers and the financial sector.



## UNIDO-IREDA SOFT-LOAN SCHEME

UNIDO has partnered with IREDA (Indian Renewable Energy Development Agency) to develop and implement an innovative finance/loan scheme to further promote the deployment of CST projects in India for heating and cooling applications in selected industrial sectors to reduce energy consumption and Greenhouse Gas (GHG) emissions. The highlights of the currently available financial incentives are as follows.

- ✓ The beneficiary's or project developer's contribution would be 25%.
- ✓ The financial incentives provided for CST installation include CFA (Central Financial Assistance) from MNRE at 30% of the benchmark solar project cost, and tax benefit from the government (depreciation benefit).
- ✓ Additional support is available from UNIDO project in terms of technical feasibility and soft loan from IREDA.
- ✓ Bridge loan against subsidy and at normal interest rate would be available.
- ✓ Support is available also for improving the manufacturing of CST system/components.

Loan for the CST project would be provided at an interest subvention of 5% from the current rates using funds under the project.

Both the loan and MNRE subsidy would be bundled in form a financial package by IREDA.

Eligibility of an entity willing to apply for financial assistance from IREDA would be checked according to IREDA's guidelines to set up a solar thermal heating/ cooling/ tri-generation project.

The project developers and beneficiaries may contact UNIDO for further information on the loan scheme and the technical support available from UNIDO for CST projects for industry process heat applications.

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**MNRE-GEF-UNIDO CST Project**
https://open.unido.org/projects/IN/projects/130149

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