Parabolic Trough based Solar System
Operations & Maintenance Manual

UNDP-GEF Project on Concentrated Solar Heat
Ministry of New & Renewable Energy
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Contents

Acknowledgement 3
About This Manual 5
1.0 General Description 6
2.0 How a Parabolic Trough Works 7
3.0 Specifications
   3.1 Interpreting System Specification 7
   3.2 Interpreting Sub-System Specifications 8
   3.3 Interpreting Components Specifications 10
4.0 How Tracking Works 16
5.0 How the Control System Works 17
6.0 How the Circulation System Works 18
7.0 Safety Information
   7.1 General Safety Risks and Precautions 19
   7.2 Use of Personal Protective Equipment (PPE) 20
   7.3 Precautions During Operation and Maintenance 20
   7.4 Chemicals used and health related precautions 21
   7.5 IBR (Indian Boiler Regulations) Safety Regulations 21
8.0 Operating the System 22
   8.1 Start-up Sequence 22
   8.2 Start-up Precautions 24
   8.3 Normal Operation, Monitoring and Error Control 24
   8.4 Error Control 25
   8.5 Exceptions and Backup 26
   8.6 Shutdown Sequence 26
   8.7 Shutdown Precautions 27
9.0 Maintenance
   9.1 Predictive Maintenance 27
   9.2 Preventive Scheduled Maintenance 28
   9.3 Maintenance Do's & Don'ts 29
10.0 Troubleshooting 30
Appendix 1: Daily Maintenance Record Form 34
Standard Task Procedure 01: Cleaning of Y-Strainer 35
Standard Task Procedure 02: Replacement of Broken Glass Tube from Receiver Pipe 37
Standard Task Procedure 03: Set of focus of PT at Receiver Tube in an Axis 38
Standard Task Procedure 04: Removing Air Bubbles from Circulation System 40
Standard Task Procedure 05: Removing Insulation for Repair 42
Standard Task Procedure 06: Replacing Broken/ Sun-Damaged Mirrors 44
Standard Task Procedure 07: Descaling of Pipelines 46
Standard Task Procedure 08: Calibration of Temperature Transmitter 48
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About This Manual

This document describes the working of parabolic trough solar concentrating systems, and the procedures needed to operate and maintain them successfully. The document is intended primarily for instructors, supervisors and engineers to train the site level technicians.

The document maintains a focus on the practical day-to-day tasks of operating a parabolic trough system. The design of the system and the engineering considerations behind its operation are not covered unless they have a direct bearing on operational decisions.

Please note that the manual presents generalized information that is not specific to any specific manufacturer. It prepares the student to quickly learn the specifics of a particular system during onboarding and deployment on an installed site.
1.0 General Description

Heat from sun’s rays can be harnessed to provide heat to a variety of applications such as cooking, air conditioning and generating electricity. But in general, Sun’s rays are too diffuse to be of direct use in these applications. So solar concentrators are used to collect and concentrate sun’s rays to heat up a working fluid to the required temperature.

Parabolic Troughs (PTs) are a class of solar concentrators that are curved as a parabola and placed in a straight line as shown in Figure 1.

![Figure 1: Solar Parabolic Troughs](image)

Some of the common applications where parabolic trough systems are used are:

1. Boiler feed water preheating
2. Air conditioning
3. Milk pasteurization
4. Industrial process heat
5. Power generation
2.0 How a Parabolic Trough Works

Reflectors are parabolic in shape, such that they concentrate solar radiation over a line focus as shown in Figure 2. The trough is positioned such that its aperture plane is perpendicular to the sun’s rays. It tracks the sun in a single axis to transfer energy to fluid circulating through receiver pipe.

![Diagram of a Parabolic Trough Reflector]

Figure 2: Parabolic Trough Reflector

3.0 Specifications

3.1 Interpreting System Specification

A system to generate heat from parabolic troughs 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. Table 1 below shows the specification of a particular trough system as an example. Please note that the format for technical specifications will vary by manufacturer.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Specification</th>
<th>Example Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nominal Rating</td>
<td>2 kW (Aperture Area: 6 m²)</td>
<td>The heat output provided on a clear sunny day</td>
</tr>
<tr>
<td>2</td>
<td>Basic Module</td>
<td>Parabolic concentrator with coated receiver tubes encased in glass tubes</td>
<td>The basic unit for collecting, concentrating and capturing sun’s heat</td>
</tr>
<tr>
<td>3</td>
<td>Working Fluid</td>
<td>Water/oil</td>
<td>The fluid through which heat from the sun is transferred to the end application</td>
</tr>
<tr>
<td>4</td>
<td>System Temperature Range</td>
<td>120°C-220°C</td>
<td>The temperature range at which the working fluid operates</td>
</tr>
<tr>
<td>5</td>
<td>End Use Application</td>
<td>Cooling/cooking/laundry</td>
<td>The final use to which the system is put</td>
</tr>
</tbody>
</table>
3.2 Interpreting Sub-System Specifications

Figure 3: Solar Parabolic Troughs Block Diagram

From Figure 3 it can be seen that the entire system can be thought of as made up of subsystems each performing a core function.

The receiving subsystem collects solar radiation in the solar field from parabola shaped reflecting collectors and transfers it to working fluid such as water or oil.

The tracking subsystem acts as a support to the receiving subsystem. It maximizes the solar energy captured by moving solar collectors towards the sun for complete day. Some tracking systems also track the sun as it changes its position during the seasons.

The circulation subsystem carries fluid and transfers the heat received by it to the end use application. Fluid has to circulate in the system at a certain rate to quickly and efficiently transfer the received heat from solar field to end use application. Circulation subsystem has a number of components such as pipes, pumps and valves to control fluid flow and temperature.

The thermal storage subsystem is a part of the circulation system. It extracts heat from the circulating fluid when the temperature becomes too high. When the temperature is too low, it supplies stored heat to the fluid.

Finally, the control mechanism is the brain behind tracking and circulation system. It sends signals to these systems to control the tracking of the receiver and the pressure and flow rate of the circulating fluid.

Table 2 below shows a sample specification that describes each subsystem in more detail. Please note that actual specifications will vary by manufacturer. The following is provided as an illustrative example only.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Sub-system</th>
<th>Example Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Receiving subsystem</td>
<td>Collects and reflects Sun’s heat in a line focus</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Parabolic trough reflecting surface</td>
<td>Reflectors with aluminium sheet or mirror</td>
<td>Arrangement of troughs typically consisting of distinct modules connected to a common shaft</td>
</tr>
<tr>
<td></td>
<td>Total Collector Area</td>
<td>288m²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of collector modules</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of collectors per row</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of rows</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Area of each module</td>
<td>6m²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Module power</td>
<td>2 kW</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Receiver Tubes</td>
<td>Coated receiver tubes enclosed in glass</td>
<td>Carries the fluid that captures the heat</td>
</tr>
<tr>
<td></td>
<td>Fluid Inlet Temperature (nominal)</td>
<td>110°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fluid Outlet Temperature (nominal)</td>
<td>220°C</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tracking subsystem</td>
<td>Moves East-West Fixed North-South</td>
<td>The direction in which the solar collectors move to track the sun’s rays</td>
</tr>
<tr>
<td></td>
<td>Control system</td>
<td>Programmable Logic Controller (PLC) or Manual</td>
<td>PLC can be programmed to move the trough at fixed times</td>
</tr>
<tr>
<td></td>
<td>Drive mechanism</td>
<td>Servo or Stepper motor</td>
<td>Can turn PT in clockwise/anticlockwise direction</td>
</tr>
<tr>
<td></td>
<td>Axis</td>
<td>Single</td>
<td>Single axis tracks the sun daily from east to west.</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Sub-system</td>
<td>Example Specification</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------</td>
<td>------------------------------------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>Circulation Subsystem</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fluid composition</td>
<td>RO water or steam or thermic oil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operating pressure</td>
<td>10 Kg/cm²</td>
<td>Pressure at which fluid is supplied to the application</td>
</tr>
<tr>
<td></td>
<td>Operating temperature</td>
<td>220°C</td>
<td>Temperature at which fluid is supplied to the application</td>
</tr>
<tr>
<td></td>
<td>Average flow rate</td>
<td>5 m³/hour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flow rate control</td>
<td>Hot water pump</td>
<td>Flow rate is controlled by varying the speed of the hot water pump</td>
</tr>
<tr>
<td></td>
<td>Flow Rate Control Logic</td>
<td>Hot water pump speed control by controlling input voltage in percentage (Input Range: 0-100)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Balancing system</td>
<td>Nitrogen topped pressurized tank</td>
<td>It keeps the system in balance by storing excess water. Nitrogen is used to maintain pressure</td>
</tr>
<tr>
<td>4</td>
<td>Thermal Storage subsystem</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phase change material</td>
<td>Salt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum energy storage</td>
<td>60 kWh</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Control subsystem</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Input type</td>
<td>HMI or SCADA (Supervisory Control and Data Acquisition)</td>
<td>The mechanism could be HMI or SCADA based which uses a Programmable Logic Controller (PLC) to automatically control the tracking and circulation system</td>
</tr>
</tbody>
</table>

3.3 Interpreting Components Specifications

P&I Diagram

A P&I (Piping and Instrumentation) diagram as shown in Figure 4 below provides a full system view of the components in a typical system and the flow of fluid through the system. Interpretation of this diagram is useful to diagnose and rectify problems.
The detailed component specifications are provided in Table 3 below. This information is particularly useful to store and retrieve replacement parts. The component specifications will vary greatly based on the individual system. The pictures and values provided in Table 3 below are illustrative examples only.

**Parabolic Trough (Figure 5)**
- Parabolic reflector, made up of solar grade reflecting mirrors
- Concentrate sunlight in a line focus throughout the day
**Receiver Tube**
- Coated tube encased in glass tubes, in which circulating fluid is continuously flowing
- Collects concentrated sunlight over a line focus

**Expansion Tank**
- Maintains the pressure of circulating water in the closed system, allowing water to expand with rising temperature
- Pressure is maintained by adding nitrogen, which also eliminates corrosion by inhibiting exposure of water vapor to oxygen
- Minimizes pressure surge (to reduce water hammering effect) to save pipeline from damage

**Hot Water Pump**
- Pumps water to the Solar Field, and maintain water flow rate in the circulation system
- Flow rate of water circulating in closed system is maintained/controlled through the SCADA system
- Only moving module in parabolic trough arrangement with substantial wear & tear, hence generally comes with a standby backup pump connected in parallel

**Thermal Storage Tank**
- Uses buffering technique, i.e. it store excess heat generated by the Solar field, which can be utilized next day in the morning to reduce warm up/ start up time period of the system
- Stores Phase Change Material which can transform from solid to liquid state while storing Heat, and vice-versa to loose heat gained by it

**Dosing System (Optional)**
- The feed water needs to be treated with chemical to avoid scaling inside the circulation systems. Dosing Systems add controlled volume of concentrated chemicals to feed water.
- It can also be coupled with an additional feature of cooling tower chemical dosing.

**Safety Relief Valve**
- When excess pressure (due to steam) is generated in header pipe, Safety Relief Valve automatically releases it to atmosphere/ isolated tank
- Can be set/adjusted to a Safe Pressure limit for circulation system
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Component</th>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tracking System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Motor and gearbox</td>
<td>Drives the shafts that changes the orientation of the parabolic troughs to track the sun</td>
<td>Gearbox: Make: Gear Ratio: Servomotor OR Stepper-motor Make: Model: RPM:</td>
</tr>
<tr>
<td>2</td>
<td>Limit Switches</td>
<td>Proximity switches to detect and limit trough position at two extreme ends</td>
<td>Make: Supply voltage: ___V Current: ___mA Maximum Operating Distance: ___mm</td>
</tr>
<tr>
<td>3</td>
<td>PLC</td>
<td>Microcontroller chip that controls the circulation and tracking systems based on pre-programmed logic</td>
<td>Input: From SCADA and/or HMI (Human Machine Interface) Output: Controls tracking motors, fluid valves and fluid pumps</td>
</tr>
<tr>
<td>4</td>
<td>Solar radiation sensor</td>
<td>To monitor and log solar radiation received, for monitoring system's efficiency</td>
<td>Thermopile Range: 0 to ___ W/sq. meter Output: 0 to ___ mV</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Component</td>
<td>Description</td>
<td>Specification</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5</td>
<td>Wind speed sensor</td>
<td>To detect storms, when the wind velocity exceeds a certain speed, parabolic trough should go to the stowing position (0 degree)</td>
<td>3 cup anemometer Wind Range: 0 to ___ meters/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Circulation System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Hot water pump</td>
<td>Hot water circulating pump</td>
<td>Make:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Voltage: ___ Volts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Current: ___ Amps</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Speed: ___ RPM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Head: ___ bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Capacity: ___ litres of water per second</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max Water Temp: ___C</td>
</tr>
<tr>
<td>7</td>
<td>Balancing tank</td>
<td>Used for balancing storage of circulating fluid to keep the system pressure stable</td>
<td>Capacity: ___ litres</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum recommended water level indicator: ___ %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum recommended nitrogen pressure: ___ bar</td>
</tr>
<tr>
<td>8</td>
<td>Nitrogen tank</td>
<td>To maintain pressure in the balancing tank</td>
<td>Capacity: ___</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Component</td>
<td>Description</td>
<td>Specification</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
<td>------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 9      | Valves     | Used for flow control  | Valve pressure rating: __ bar  
Max temperature: __ C  
Material: CS or Stainless steel  
Manual or Automatic (controlled by PLC)  
End connection used: Flange or thread end  
Open bonnet (for water and steam) or closed bonnet (for thermic oil) |
| 10     | Flow meter | Digital or Analog  
Range: 0 to __m³/h  
Inlet water temperature range: __ C to __ C  
Inlet pressure range: __ bar to __ bar |
| 11     | Pressure gauge | Measurement of pressure at a point in the system | Range: 0 to __ kg/cm² |
| 12     | Temperature gauge | Measurement of temperature at a point in the system | Range: 0 to __ C |
Module Specification
Please note that actual specifications will vary by manufacturer. The following is provided as an illustrative example only.

Table 3: Example Module Specification

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Module Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Surface Area of Collector (m²)</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Dimension &amp; Shape</td>
<td>Parabolic</td>
</tr>
<tr>
<td>3</td>
<td>Reflectivity</td>
<td>92 %</td>
</tr>
<tr>
<td>4</td>
<td>Thermal output Capacity</td>
<td>2 kW</td>
</tr>
<tr>
<td>5</td>
<td>Thermal Efficiency (depends on location)</td>
<td>45 %</td>
</tr>
<tr>
<td>6</td>
<td>Area Required (m²)</td>
<td>10</td>
</tr>
</tbody>
</table>

4.0 How Tracking Works

In parabolic trough, collector concentrate sunlight on receiver tube forming a line focus. With sun’s movement from east to west, collector continuously turns about an axis, tracking sun’s radiation and maintaining the focus of collector on receiver tube. The picture below (Figure 6) illustrates this concept:

![Figure 6: Parabolic Trough tracking Sun’s movement from Morning to Evening](image)

Tracking sunlight from morning (east) to evening (west) helps to get the maximum utilization of the sun’s rays by having the parabola perpendicular to the sun for 8-9 hours per day.
The trough can thus said to be in its ‘morning or sleeping position’ at the start of the day. It moves to its ‘noon or homing position’ when the sun is directly overhead. By the end of the day, it moves to its ‘evening position’ while following the sun all the way.

There are 3 important questions to ask when observing the tracking system of a PT assembly:

**What is the control logic?**

The control logic is the formula used to calculate the best position to capture maximum solar energy. The position may be calculated just once using the latitude and time of the year. Or it may be calculated continuously based on input from a sensor that detects the sun’s position.

**What is the drive mechanism?**

The mechanism to cause and transmit the motion to the PTs could electrical or hydraulic. In electrical, there could be a servo or stepper motor connected to some combination of linear actuator, swivel drive and worm gear or planetary gears. The hydraulic system will use hydraulic cylinders to position the troughs.

**What are the sensing devices used?**

One or more of the following sensing devices may be used as input to the control logic:

- Pyranometer to measure light intensity
- Temperature, pressure and humidity sensors to maximize efficiency
- Limit switches to sense the motion of the PTs
- Wind speed sensors to protect the PTs against high winds

### 5.0 How the Control System Works

Most parabolic trough systems are controlled through a computer software interface called Supervisory Control and Data Acquisition (SCADA). The control system is like the brain of the system and instructs all the other systems. The control diagram below (Figure 7) shows the flow of information to control the tracking system. Input is received through the SCADA and passed to the PLC. The PLC applies the control logic and passes instruction to the actuators and motors. A similar flow will occur to control the circulation system.

![Supervisory Control and Data Acquisition (SCADA) System](image)

- Controls and monitors the servomotor’s movement to track sunlight and ensure concentration at the collector tube
6.0 How the Circulation System Works

The primary function of the working fluid is to transfer the heat captured from the sun to the end use application. The working fluid could be water, steam or oil.

Please refer to the P&I diagram shown in Figure 4. In the example system, water in the expansion tank is pumped to the solar field through the hot water pump to collect heat. Hot water outlet from the solar field then passes through 3-Way Valve (V1), which selects where to direct hot water flow in the system.

- In the morning, when system starts, 3-Way Valve V1 opens up completely (100%), so that hot water coming from parabolic troughs follows through path P (outlet from Solar field) - V1 (3-way valve 1) – TI (TST Inlet) – TO (TST Outlet) – A – V2 (3-way valve 2), thus collecting heat from Thermal Storage Tank (TST). This reduces warm-up time of the system. When temperature of water flowing through this path comes in equilibrium with the temperature of PCM in TST, this 3-Way Valve (V1) completely closes and water flows directly through path P – V1 – A – V2.

- To optimize the efficiency of this system, VAM utilizes incoming heat from the solar field only when the temperature of incoming hot water exceeds 110°C.
  - When temperature of incoming hot water at Valve V2 is less than 110°C, water flows through path A – V2 – B
  - When temperature of incoming hot water at Valve V2 exceeds 110°C, water starts flowing through path A – V2 – VI (VAM Inlet) – VO (VAM Outlet) – PI (Expansion Tank Inlet) – PO (Expansion Tank Outlet) – B to feed VAM with heat energy required to power the cooling system.

- When the temperature of hot water at outlet from solar field reaches the upper limit of set temperature (215°C), valve V1 directs the hot water to TST to collect & store buffer heat coming from solar field and water starts flowing in route P - VI – TI – TO – A – V2

When you click “START Process” on SCADA’s Operations Screen, the SCADA calculates degree of rotation required to rotate each parabolic trough axis from Sleeping Position to set Tracking Position based on current system timing. Then it sends accommand to the PLC, which operates servomotors on each axis at their peak rating (2000 rpm), till the PTs starts focusing concentrated sunlight accurately on Receiver Tube.

In Automatic Mode, to track PT, SCADA takes input from “Tracking System Configuration” to which an operator has limited access. These parameters are generally set by system manufacturer and remain unchanged.

For accurate tracking of the PT, Servomotors are used, which give position feedback to PLC to control its position & movement.
7.0 Safety Information

An understanding of safety involves three aspects:

- A general awareness of safety risks on the site
- Knowledge of protective equipment that should be available on-site and the specific scenarios when they should be used
- Safety precautions that should be followed for every activity that is undertaken on-site

This section provides general coverage of all of the above aspects. In addition, the safety risks and precautions related to every task can be found in the Standard Task Procedures in the annexure.

NOTE: This is a generalized discussion of safety aspects on CST systems. By no means is this a comprehensive treatment of all safety risks and precautions. For a more complete understanding of safety, please refer to the manufacturer manual or OSHA guidelines.

7.1 General Safety Risks and Precautions

Human Safety

Risks from High Temperature

- The fluid is at a temperature above 110°C, which is 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 receiver can be extremely hot

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/cm²). If pressure in header pipe exceeds this limit call system maintenance
- The pressure and safety relief valves should be set and tuned only by a trained person. Follow STP04 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 reflector and the receiver, and if at all you are moving in this region keep closer to reflector and away from receiver

Risks from Heights

- Catwalk, railings, ladders provided should all be in place and inspected periodically

Equipment Safety

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 heat. For example:
  - Temperature and pressure gauges placed close to the receiver and not insulated
• PVC conduit piping or any other non-metallic equipment placed behind the receiver
• Control panel, water pump motor, any other electrical equipment in the field should be properly grounded
• For all 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

7.2 Use of Personal Protective Equipment (PPE)
Note: Please refer to the manufacturer's manual for the specific make and grade of each piece of equipment to be used

• 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
  ▪ Foot support (scaffolding / firm roof mounted platforms)
  ▪ Safety harness/ Hand-grip rope

7.3 Precautions During Operation and Maintenance

General
• Do not stand or walk between reflector and receiver. If possible, the reflectors should be completely defocused before any maintenance task near receiver area
• Wear heavy duty sun goggles always while in side the solar field. Avoid looking at receiver or reflector or focus with naked eyes.
• Use always 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 over force 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, gearbox, etc.

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 fluid is to be drained by opening the pipe flanges or coupling, ensure:
   Most of body part is above the pipeline
   Stand away from pipe-line while opening drainage valves to avoid fluid spill over the body

While Handling Receiver & 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

While Working on the Reflectors
• When working on the reflectors at a height, ensure that grip for hands and support for feet is available to avoid from falling
• Close top/bottom needle valves of water level gauge before removing glass tube to clean it from the inside

While Working on the Expansion Tank and Thermal Storage Tank
• Close top/bottom needle valves of level gauge before removing glass tube to prevent hot fluid-contact
• It generally stores liquid at high pressure, and hence a safe distance must be maintained from vent (outlet), used 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

7.4 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 vapors
• 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

7.5 IBR (Indian Boiler Regulation) Safety Regulations
• Steam boilers exceeding 22.75 Liters capacity, steam pipelines where steam pressure exceeds 3.5 Kg/cm² come under the scanner of IBR regulations.
• All valves & fittings should be as per IBR specifications with test certification for each valve. During repair work technician should follow IBR Regulations & specifications for tasks such as procuring material, welding & plumbing works near Steam Boilers & Steam Pipelines. Operator should refer to manufacturer’s specifications for valve/fitting to be replaced.
8.0 Operating the System

This section details the typical operating steps for a PT system. Please note that each manufacturer will provide steps that may differ slightly or considerably. The description provided here is for a general understanding.

8.1 Start-up Sequence

There are two primary modes in which a system can be operated:

- Automatic, in which all actions are triggered automatically through pre-programmed logic
- Manual, in which the user has to take certain or all actions for the system to start and shutdown

In manual mode, user has to go to SCADA control panel and manually start different parts of the system. In automatic mode, parameters and limits are set for each Module in SCADA so that whenever the system is started in automatic mode it executes predefined set of actions.

In Manual mode, regular human intervention is required to observe and control system parameters, whereas in Automatic mode, system follows set limit ranges and takes corrective measures automatically. In Automatic mode only System Alarms have to be addressed by the operator.

The table below details the start-up sequence for an example system.

<table>
<thead>
<tr>
<th>Step</th>
<th>Manual Mode</th>
<th>Automatic Mode</th>
</tr>
</thead>
</table>
| 1    | • Check Water Level in Expansion Tank. If water level is less than 60%, then fill tank with RO water from makeup water tank to 80% water level mark.  
• Turn on all MCBs in Solar Tracking Control Panel  
• Turn AUTO/MANUAL switches into MANUAL mode | • Check Water Level in Expansion Tank. If water level is less than 60%, then fill tank with RO water from makeup water tank to 80% water level mark.  
• Turn on all MCBs in Solar Tracking Control Panel  
• Turn AUTO/MANUAL switches into AUTO mode |
| 2    | Check power supply from the grid:  
a) Voltage in each phase  
b) Ensure that it is not in reverse phase  
Check for proper opening of Inlet/Outlet valves for hot water pump (when we have backup pumps) | Check power supply from the grid:  
a) Voltage in each phase  
b) Ensure that it is not in reverse phase  
Check for proper opening of Inlet/Outlet valves for hot water pump (when we have backup pumps) |
<table>
<thead>
<tr>
<th>Step</th>
<th>Manual Mode</th>
<th>Automatic Mode</th>
</tr>
</thead>
</table>
| 3 | **Opening Valves:** Start computer with SCADA system  
Go to ‘Set Point & CV Operation Screen’  
• Set Hot Water Pump speed (HWP) so as to maintain water flow rate in circulation system to the minimum value specified in the manufacturer manual (e.g. 1.5 m³/hr). Flow rate can be monitored in the P&I diagram  
• Open Gate Valve for Nitrogen line (to 100 %)  
• If temperature of TST is higher than that of circulating water, then open hot water inlet (3-Way Valve) to TST | **Opening Valves:** Start computer with SCADA system  
Go to ‘Set Point & CV Operation Screen’  
Start the process in Auto mode. This action will open the valves automatically, and control them according to set parameters/limits |
| 4 | **Start Tracking System**  
Go to ‘Tracking System Monitor’  
• Check for Tracking System Alarms (for Servo-amplifiers in each listed axis) on top  
• Check for issues in sensors motors, encoding and power supply  
• Click “Enable” for all the axis to start tracking |  |
| 5 | **Go to ‘Tracking System Configuration’**  
Press “Synchronize” to update PLC time |  |
| 6 | **Focus Fine Tuning**  
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 STP03 in the appendix | **Focus Fine Tuning**  
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 STP03 in the appendix |
| 7 | **Check System Parameters**  
• Go to the live P&I diagram  
• Check flow rate and hot water temperature into the end use application  
• Check minimum working temperature of hot water at inlet of end use application (e.g. 110 - 215 °C)  
• Check the average flow rate in the solar field (e.g. range 2-6 m³/hr) | **Check System Parameters**  
• Go to the live P&I diagram  
• Check flow rate and hot water temperature into the end use application  
• Check minimum working temperature of hot water at inlet of end use application (e.g. 110 - 215 °C)  
• Check the average flow rate in the solar field (e.g. range 2-6 m³/hr) |
8.2 Start-up Precautions

- If thermic fluid is used in circulation system, it should be initially heated up by 20 C per hour till it reaches 100 C, so that all moisture is removed from the thermic fluid
- PT should be kept in sleep position during rains/hailstorms to protect aluminum collector sheet from being damaged
- Backup expansion tank, when not in use, should be properly isolated with Gate Valves completely closed
- In Auto Mode System Control, system follows set parameters for each module in SCADA. These parameters are set with the help of the SCADA operations and maintenance manual and dependent on system rating and usage
- If any set parameter for automatic mode is changed, observe system for some time to study its effects on the system
- Synchronize 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 morning as the system is cooled down at this stage
- Use only RO water to feed pressurized expansion tank, to prevent scaling in the system

8.3 Normal Operation, Monitoring and Error Control

The system requires little intervention when in operation. However, periodic monitoring is essential. Monitor the SCADA for alarms, and process parameters. The description below is for an example system and each system could vary in its operation, monitoring control parameters. The following are the automatic control actions that take place during normal operation:

Operation of Thermal Storage System

Both 3-Way Valves operate (ON/OFF) work as explained below to optimize the performance of the system. The values provided in the table below are for a particular example system. The actual values will vary for each manufacturer.

<table>
<thead>
<tr>
<th>State of 3-way valve 1</th>
<th>Temperature of Thermic Fluid (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>&lt; temperature of Phase Change Material in TST</td>
</tr>
<tr>
<td>OFF</td>
<td>110 – 215</td>
</tr>
<tr>
<td>ON</td>
<td>&gt;= 215</td>
</tr>
</tbody>
</table>

3-way valve 2 operates as follows:

<table>
<thead>
<tr>
<th>State of 3-way valve 2</th>
<th>Temperature of Thermic Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>&lt; 110</td>
</tr>
<tr>
<td>OFF</td>
<td>&gt;= 110</td>
</tr>
</tbody>
</table>
Operation of the Tracking System

- Whenever fluid temperature increases above 215°C, PT defocusses to ± 2°, and if temp. crosses 220°C, PT completely defocusses to save system from excessive heat.
- If Flow Rate in circulation system goes below 1.5 m³/hr, the system automatically defocus the PT.
- Seasonal effect causes small error in accuracy of Tracking System (error of around 3-4 quarterly). This effect is countered by changing Measurement Bias for each axis, monthly. This corrective measure is done manually.

Operation of the Circulation System
Pressure, temperature and flow rate will vary during normal operation. The range of normal values can be set in the SCADA system.

Example values for flow rate, pressure and temperature

<table>
<thead>
<tr>
<th>Point</th>
<th>Flow Rate</th>
<th>Pressure</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acceptable Range (m³/hr)</td>
<td>Acceptable Range (Kg/cm²)</td>
<td>Acceptable Range (°C)</td>
</tr>
<tr>
<td>Solar Field (Parabolic Trough)</td>
<td>2 - 6</td>
<td>2 – 15</td>
<td>Upto 220</td>
</tr>
<tr>
<td>Thermal Storage Tank Inlet</td>
<td>2 - 6</td>
<td>–</td>
<td>Upto 220</td>
</tr>
<tr>
<td>VAM Inlet</td>
<td>2 - 6</td>
<td>–</td>
<td>110 – 200</td>
</tr>
<tr>
<td>Pressurized Expansion Tank</td>
<td>2 - 6</td>
<td>28 – 29</td>
<td>–</td>
</tr>
<tr>
<td>Hot Water Pump</td>
<td>2 - 6</td>
<td>2-15</td>
<td>Upto 200</td>
</tr>
</tbody>
</table>

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

8.4 Error Control
The control mechanism is used to automatically rectify error conditions described below:

<table>
<thead>
<tr>
<th>Module/(s) Affecting the Parameter</th>
<th>Error/(s)</th>
<th>Potential Causes</th>
<th>System Adjustment and Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate</td>
<td>Hot Water Pump</td>
<td>Deviates from range 2 - 6 m³/hr.</td>
<td>Flow rate control is set in Manual mode</td>
</tr>
</tbody>
</table>
Safety Note: It is dangerous for the system temperature to rise above a certain limit. The PT automatically defocusses by a certain angle (e.g. 10°) from its position.

### 8.5 Exceptions and Backup

#### Power Failure

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

#### Storm / High Winds

3 Cup Anemometer measures the wind velocity. Upper limit for wind is set to 15 m/s. Above this limit, 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 cover electrical items like servomotors, electrical valves, etc.
- Flush out water from the circulating system
- Close nitrogen cylinder valve

### 8.6 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:
### Step Manual Mode | Automatic Mode
---|---
1. **Tracking System**<br>• Disable all PT’s to defocus them<br>• All the parabolic troughs will move to sleeping position (-80°) | Tracking System<br>Here T-End time period shows time after which PLC automatically shuts down the system
2. **Pumps and Valves**<br>a) Close N2 line to cylinder<br>b) Close hot water inlet to TST (close 3 way valve)<br>c) Shutdown Hot Water Pump by entering its value to 0 | Pumps and Valves<br>Stop the Process in Auto Mode
3. **Save Data**<br>Click “Excel Export” to save monitored parameters for the day | 
4. **Wait for five minutes for valve operation to complete** | Wait for five minutes for valve operation to complete
5. **Shutdown the PC** | Shutdown the PC
6. **Turn off all the MCBs in solar panel** | Turn off all the MCBs in solar panel

### 8.7 Shutdown Precautions
- Don’t turn OFF MCBs on the days with strong wind, so that PT can automatically move to Homing Position (0°), in case of sudden storms
- Turn PT to Sleep Position (-80°), if it is raining heavily
- Wait for Tracking System to completely defocus the PTs to sleep position & electrical valves to complete their operation before completely shutting down MCBs
- Note that all valves on P&I diagram (on SCADA) are finally closed
- Export and save data before you shut down the system

### 9.0 Maintenance

#### 9.1 Predictive Maintenance
Predictive maintenance involves inspecting the system for potential signs of failure. It should also include study of the system data logs. The data log helps the trained service technician to identify and troubleshoot any potential problems with in a system.

You can contribute to trouble-free and reliable performance of your solar system by regularly performing following checks to determine whether maintenance is required or not:

**Reflectors and Receivers**
- Twice a month, check for misalignment of focus at Receiver Tubes. Focus should not deviate more than ± 2° from 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 hit & 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 STP03)

• Twice a year, check for 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 STP02 for replacement of broken glass tubes.

• Annually, check for scaling at inner linings of Receiver Tube.
  • Scaling & its effect on system’s performance has to be visually determined.
  • This maintenance task is generally outsourced because it is rarely performed and requires ‘descaler’ systems and industrial descaling chemicals.

**Circulation System**

• Quarterly check for functioning of Dosing Systems
  • Clean and rinse the Pump
  • Check for screwed connections of piping & containers, and tighten if necessary
  • Carry out a visual inspection of pressure test

• Quarterly, check for pressure at nitrogen cylinder
  • When pressure in N₂ cylinder reduces below 26 Kg/cm² replace it

• Weekly, check for leakages in the system by looking for stagnant fluid on the ground. 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 (See STP05)

**Tracking System**

• Annually, inspect Proximity Sensors. Place any obstacle in front of Proximity Sensors and it should stop turning PT, and if not then:
  • Check for wirings connections in Proximity Sensors
  • Replace 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, etc.)
  • Check Emergency Alarms shouldn’t be disabled (circuit breaker, fuses, alarm lights & buzzers)

9.2 Preventive Scheduled Maintenance

**Daily, Weekly or Monthly**

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 reflectors & Receiver Tube
  • Add few drops of shampoo to water bucket and set parabolic trough at -80°. Now splash the water on PT, starting from the top, washing loose dust down. Wipe off the remaining dust with wet cotton towel.
  • Don’t: a) Use plain water to wash reflectors
    b) Use dry cloth for wiping
• Clean Receiver Tubes in early morning before starting the system when 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.

• Weekly, dust off the Pyrometer with a dry soft cloth

• Monthly, clean Screen in Y-Strainers with brush or by soaking it in a clean solution

• Monthly, compensate for seasonal adjustment by adjusting measurement bias on SCADA screen

• Twice a year, clean RO system Cartridge Filler

Quarterly, Bi-annual or Annual Maintenance
Following preventive maintenance must be undertaken as per schedule to avoid system failures to get trouble-free and reliable performance:

• Quarterly, lubricate moving parts in the system
  • Lubricate top and bottom bearings (as shown in figure in red circles) of PT
  • Tracking unit (motor, gearbox) does not require lubrication
  • Lubrication should be done specially after rainy season

• Twice a year, replace water in circulation system with fresh soft water from RO system

• Note: If thermic fluid is used in circulation system don’t clean with water; either use compressed air, or flush fluid from the tank to clean piping system

• Annually, undertake structural painting & repair of PTs to improve life span of the system

• Annually, calibrate Temperature Transmitter, Pressure Transmitter, Flow meter and other gauges

• Annually, replace soft water resin in RO water purifier

• In every three years, clean pressurized Expansion Tanks

Consumable Replacement
Following are the consumable parts in the system, which need standby stock:

• Nitrogen cylinder
• Resin for RO water purifier
• Feed water if there is no water source near PT system
• Lubricant Oil & Grease

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

9.3 Maintenance Do’s & Don’ts

Do’s

• Follow maintenance schedule for all components at specified time intervals

• Operator must maintain log sheet regularly and supervisor must review the log sheet readings regularly

• Whenever maintenance is required in thermal fluid circulation system, defocus the parabolic trough and keep on circulating thermic fluid/hot water through the system till its temperature comes below 50 °C - 60 °C. Then depressurize the system by venting nitrogen from expansion tank.
tank by opening vent valve. Switch OFF the circulation pump, close water inlet/outlet valves and then start the work.

- Open flanges when the system is cooled down so that burns injuries are avoided.
- Always use sunglasses while working in the Solar Field

**Don’ts**

- Don’t leave nitrogen valve open when system is not in operation
- Don’t apply hand pressure on PT collector reflecting surface while cleaning
- Never tamper with Pressure Relief Valve & Safety Relief Valve without training & knowledge of the system
  - Do not clean the reflectors with dry cloth or with paper
  - Do not clean the reflectors after 8.00 am & before 5.00 pm
  - Do not modify the system unless written approval from the manufacturer
  - Do not touch the Receiver when focus is on the receiver
  - Do not walk in between receiver and reflector during operation
  - Do not use hard water for mirror cleaning as it may form scaling on mirrors and thus reducing performance
  - Do not stop water circulation when the temperature of the water has dropped below the manufacturer recommended level

### 10.0 Troubleshooting

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

<table>
<thead>
<tr>
<th>Observation</th>
<th>Probable Cause</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise in circulation pump</td>
<td>Alignment of pump motor disturbed</td>
<td>Refer to Pump/motor manual to realign the pump/motor</td>
</tr>
<tr>
<td></td>
<td>Pressure of suction pump lower or equal to saturation pressure of water at that temperature</td>
<td>Check pressure of compressed air in expansion tank; It must be above a certain Kg/cm². Rectify as required</td>
</tr>
<tr>
<td>Pressure at Pump fluctuating</td>
<td>Air entrapment in the water system</td>
<td>Open and close vent valves in the water piping, one at a time to remove trapped air</td>
</tr>
<tr>
<td></td>
<td>Y-strainer is choked</td>
<td>Clean the filter (Refer to STP01)</td>
</tr>
<tr>
<td></td>
<td>The pump is cavitating due to hot water under pressure</td>
<td>Check pressure of compressed air in expansion tank; It must be above a certain limit (~3Kg/cm²)</td>
</tr>
<tr>
<td>Symptom</td>
<td>Problem reasons (WHY-1)</td>
<td>Problem reasons (WHY-2)</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>1</td>
<td>1. Control Panel not switched on</td>
<td>1. Control Panel physically not Started</td>
</tr>
<tr>
<td></td>
<td>1. Problem in incoming power for control Panel</td>
<td>1. Physical damage to the incoming cable</td>
</tr>
<tr>
<td></td>
<td>2. Problem in incoming power for control Panel</td>
<td>2. Short circuit at main distribution line</td>
</tr>
<tr>
<td></td>
<td>3. Main MCCB not working in Control Panel</td>
<td>3. MCCB Tripped Due to overload</td>
</tr>
<tr>
<td>2</td>
<td>1. Improperly fixed mirrors</td>
<td>1. Fixing arrangement not tightened properly</td>
</tr>
<tr>
<td></td>
<td>4. Mirrors not cleaned</td>
<td>4. Soft water not available</td>
</tr>
<tr>
<td></td>
<td>5. Mirrors not cleaned</td>
<td>5. Proper tools not available</td>
</tr>
<tr>
<td>3</td>
<td>1. Problem in the contactor for forward motion</td>
<td>1. Carbon deposited on internal contacts</td>
</tr>
<tr>
<td></td>
<td>2. Problem with the PLC</td>
<td>2. Program not functioning properly</td>
</tr>
<tr>
<td>Symptom</td>
<td>Problem reasons (WHY-1)</td>
<td>Problem reasons (WHY-2)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>4 Water Pump not operating</td>
<td>1. Problem in signals from Mobrey</td>
<td>Magnetic switch not functioning properly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Float stuck up inside</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem in electrical connection inside Mobrey</td>
</tr>
<tr>
<td></td>
<td>2. Problem in contactor for water pump</td>
<td>Carbon deposit on internal contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Problem in rotary switch for water pump</td>
<td>Internal contact burnt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wiring not proper</td>
</tr>
<tr>
<td></td>
<td>4. Problem in V-belt for pulleys</td>
<td>V belt worn out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slippage of V belt on Pulley</td>
</tr>
<tr>
<td>5 Focus not exactly at center of receiver</td>
<td>1. Reflector/ Reflectors not tracking properly</td>
<td>No supply to AC motor from Panel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem in contactor for AC motor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadequate distance between reflectors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadequate layout size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadequate distance between reflector&amp; receivers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improper Layout size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Receiver inclination angel not as per requirement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Negligence during installation</td>
</tr>
<tr>
<td></td>
<td>2. Reflector movement is jammed</td>
<td>Under sizing of hole at channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oversizing of bolt at rotating pipe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improper lubrication at top part assembly</td>
</tr>
<tr>
<td>Symptom</td>
<td>Problem reasons (WHY-1)</td>
<td>Problem reasons (WHY-2)</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>6 Water pump not developing pressure</td>
<td>Dead weight inside stuck up and not operating</td>
<td>Direction of NRV not Proper</td>
</tr>
<tr>
<td>2. Suction strainer choked</td>
<td>Excessive dust in water from piping</td>
<td>Water tank not cleaned</td>
</tr>
<tr>
<td>3. Problem with the valve seat assembly</td>
<td>Wear and tear of valve seat assembly</td>
<td>Hard water getting used for operation</td>
</tr>
<tr>
<td>4. Problem in gland washer</td>
<td>Wear and tear of Gland washer</td>
<td>Wear and tear of pump shaft</td>
</tr>
<tr>
<td>5. Faulty pressure gauge</td>
<td>Isolation valve closed</td>
<td>Negligence</td>
</tr>
<tr>
<td>6. No Water in feed water tank</td>
<td>Softener is not working</td>
<td>Resin property lost</td>
</tr>
<tr>
<td>7 Auto reverse not happening</td>
<td>Program not functioning properly</td>
<td>Improper earthing to PLC panel</td>
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<tr>
<td>2. Problem in contactor for reverse motion</td>
<td>Carbon deposited on internal contacts</td>
<td>Loose contact</td>
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<tr>
<td>3. Problem to limit switch for reverse</td>
<td>Limit switch damaged</td>
<td>Limit switch stuck up</td>
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<tr>
<td>4. Problem in gear motor</td>
<td>Winding burnt</td>
<td>Due to overload on motor</td>
</tr>
<tr>
<td>5. Problem in Gear Box</td>
<td>Gear box jam</td>
<td>No Lubricantion for Gear Box</td>
</tr>
<tr>
<td></td>
<td>Sprocket wheel teeth broken</td>
<td>Due to improper alignment</td>
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<tr>
<td></td>
<td>Bearing Jam</td>
<td>Non lubrication, rusting</td>
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<td>Gear box shaft bend</td>
<td>Due to overload</td>
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## Appendix 1: Daily Maintenance Record Form

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(‘X’ indicates scheduled maintenance tasks)
**Standard Task Procedure 01**  
**Cleaning of Y-Strainer**  

**Responsible Person:** Technician  
**Effective Date:** 2013-09-05  
**Revision:** 001

This Standard Task Procedures is used:

1. As a learning aid  
2. To assess competence  
3. As a job aid while performing the function  
4. To conduct a Planned Task Observation

### Preparation

<table>
<thead>
<tr>
<th>Preparation</th>
<th>✓/✗</th>
<th>✓/✗</th>
</tr>
</thead>
</table>

**Equipment/tools:** Spanner, Brush  
**Material:** Cloth, Bucket

**Other prerequisites:**

### Pre-operational checks

<table>
<thead>
<tr>
<th>Criteria</th>
<th>✓/✗</th>
</tr>
</thead>
</table>

1. Check state of system  
   - Should not be in working condition

2. Check circulating fluid temperature  
   - Should be at workable temperature

### Step

<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
</tr>
</thead>
</table>

1. **Close isolating gate valve**  
   - Close isolating gate valves connected just before and after Y-Strainer.

2. **Opening strainer**  
   1. Remove insulation from Y-Strainer.
   2. Loosen nuts and bolts from cover with a spanner of suitable size.

3. **Collecting sludge in a bucket**  
   - Place a bucket under strainer to collect oil. Circulating liquid along with dirt will flow down to the bucket. When no more circulating fluid is coming out, remove filter (screen) from inside the strainer.

### CAUTION!

**Risk for hand! Wear hand gloves. Check that temperature of circulating liquid is safe to handle before touching it.**
<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
</tr>
</thead>
</table>
| 1. Cleaning of Filter | 1. When no more circulating fluid is coming out, remove filter (Screen) from inside the strainer.  
2. Clean filter with pressurized water and brush.  
3. Take out sludge from inner side of strainer. |
| 2. Closing back Y-Strainer after cleaning | Place back filter after cleaning and tightly close cover with bolts. Put back insulation. Open back isolating gate valve. Start the liquid circulation system. Remove air in strainer through air-vent located at a height near outlet of strainer. After air is removed close back air vent. |

**CAUTION!**

Keep your face and body away from circulating fluid

Risk of Body injury

Wear Gloves
Standard Task Procedure 02
Replacement of Broken Glass Tube from Receiver Pipe

Responsible Person: Technician

Effective Date: 2013-09-05  
Revision: 001

This Standard Task Procedures is used:

1. As a learning aid  
2. To assess competence  
3. As a job aid while performing the function  
4. To conduct a Planned Task Observation

<table>
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<th>Preparation</th>
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<th>✓/✗</th>
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</thead>
<tbody>
<tr>
<td>Equipment/tools: Wrench, Screw Driver, Nose Plier</td>
<td>✓/✗</td>
<td>✓/✗</td>
</tr>
<tr>
<td>Material: Receiver Glass Tube, Wire Mesh, Plumbing Tape</td>
<td>✓/✗</td>
<td>✓/✗</td>
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<tr>
<td>Safety Equipment:</td>
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<tr>
<td>Other prerequisites:</td>
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Documentation to be completed

Submitted to

By when

a. Operations Log sheet  
Supervisor  
In six months

Pre-operational checks

Criteria

Check state of system

Should not be in working condition

<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓/✗</td>
<td>✓/✗</td>
</tr>
</tbody>
</table>

**Broken glass tubes in a PT axis are taken out from sideways. For this first remove hose pipe connected to that receiver tube.**

1. Remove hose pipe from receiver tube
   - Open wire mesh with nose plier wearing hand gloves. Remove insulation from hose pipe only near Face Seal Braze Nut (pointed in fig. below).
   - Open brazen nut with wrench. Hold receiver tube with gloves to avoid any damage while opening it during this operation.

2. Replacing broken glass tubes
   - Open and take out Ring Clips, which hold the receiver tubes at focus
   - Start taking out glass tubes gently and carefully from sideways
   - Replace broken glass tube with new ones

3. Connect hose pipe to receiver tube
   - Fix ring clips back to PT receiver tube. Connect hose pipe with receiver tube, and tightly seal brazen nut with plumbing tape.
   - Close back insulation of Hose Pipe. If wire mesh is breaking due to rust, use new mesh.
   - Undertake task to remove air bubbles from receiver tube which have entered circulation system while performing this operation.

**CAUTION!**

Risk for hand! Wear hand gloves. Check that temperature of receiver tube is safe to handle before touching receiver tube.

Risk for eye! Always wear dark sunglasses
Standard Task Procedure 03
Set of focus of PT at Receiver Tube in an Axis

Responsible Person: Technician

Effective Date: 2013-09-24
Revision: 001

This Standard Task Procedures is used:
1. As a learning aid
2. To assess competence
3. As a job aid while performing the function
4. To conduct a Planned Task Observation

Preparation
- Equipment/tools: Wrench, Screw, Driver, Nose Plier
- Material: Wrench
- Safety Equipment: Other prerequisites:
- Documentation to be completed
  - Submitted to: Supervisor
  - By when: In three months

Check state of system
- Criteria: Should not be in working condition

Pre-operational checks
- Criteria: Operating/Safety/Quality

Correcting focus when all parabolic troughs in an axis are misaligned

If focus of PT’s on receiver tubes is deviated from the center of receiver tube by more than 2°, then:

- If focus of PT is above the center of receiver, then go to “Tracking System Monitor” on SCADA Screen, and keep on increasing measurement bias by -0.5, till the focus of PT reaches center of receiver tube.

- If focus of PT is below the center of receiver, then go to “Tracking System Monitor” on SCADA Screen, and keep on increasing measurement bias by 0.5, till the focus of PT reaches center of receiver tube.
Correcting focus of PT’s, when one or more PT’s get misaligned

1. Adjusting focus of a PT in an axis

As in the above picture focus of PT 1 & PT 2 is lying properly on receiver tube, but focus of PT 3 which is on the same axis is not falling completely on the receiver tube. To adjust its focus, loosen couplings A & B on sideways of PT 3 to turn collector of PT 3 freely about its axis.

2. Loosening the couplings

Loosen nuts of couplings diagonally in fashion 1 -> 2 -> 3 -> 4 with a wrench as shown in figure.

3. Adjusting focus of misaligned PT on receiver tube manually

Manually turn PT 1, to adjust its focus to be aligned with other PT’s on the same axis.

4. Tighten back couplings

Tighten back couplings to the tracking shaft.

Now focus of all parabolic troughs in an axis must be aligned and lying completely on receiver tubes.

CAUTION!

Risk for eye! Always wear dark sunglasses, as collector can reflect back sunlight to your eyes.
Standard Task Procedure 04
Removing Air Bubbles from Circulation System

Responsible Person: Technician
Effective Date: 2013-10-11
Revision: 001

This Standard Task Procedures is used:
1. As a learning aid
2. To assess competence
3. As a job aid while performing the function
4. To conduct a Planned Task Observation

<table>
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<td>Material:</td>
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<td>Safety Equipment:</td>
<td>Other prerequisites:</td>
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- Documentation to be completed
- Submitted to
- By when

a. Operations Log sheet
   Supervisor
   Monthly

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<th>Pre-operational checks</th>
<th>Criteria</th>
<th>✓/✗</th>
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<tbody>
<tr>
<td>a. Check state of system</td>
<td>Should not be in working condition</td>
<td></td>
</tr>
<tr>
<td>b. Check circulating fluid temperature</td>
<td>Should be at workable temperature</td>
<td></td>
</tr>
</tbody>
</table>

Step | Criteria: Operating/Safety/Quality | ✓/✗ |
| Detecting receiver tube containing air bubbles | Monitor temperature at axis of parabolic troughs at outlet points. |

PT Axis with relatively higher temperature (Axis 1) or one or more axis with non-linearly increasing temperature at outlet indicates it/they contain air bubbles.
## Removing air bubbles

1. Open control valve for air vent for respective receiver tube axis, keeping hot water pumps in running position. Air vent is generally located near outlet of axis.

   ![air vent diagram](image)

2. Monitor air vent. Air, or bubbling water gushing out through air vents. Note: While performing this operation keep monitoring water level in pressurized expansion tank as water level in expansion tank should always be more than 80%.

3. When water continuously starts gushing out close the vent as it is an indicator that there is no more air in circulation system. Now after complete air in the system has escaped through air vents, you can close air vents.

### CAUTION!

Maintain safe distance from Air Vents.
# Standard Task Procedure 05
## Removing Insulation for Repair

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<th>Responsible Person: Technician</th>
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<td>Revision: 001</td>
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This Standard Task Procedures is used:
- 1. As a learning aid
- 2. To assess competence
- 3. As a job aid while performing the function
- 4. To conduct a Planned Task Observation

### Preparation

<table>
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<tr>
<th>Equipment/tools: Screw Driver, Wire Cutter</th>
<th>Material: Cloth</th>
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<td>Safety Equipment:</td>
<td>Other prerequisites:</td>
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### Documentation to be completed

| a. Operations Log sheet | Submitted to: Supervisor | By when: Monthly, before following Tuesday |

### Pre-operational checks

| Check state of system | Criteria: Should not be in working condition |

### Step

<table>
<thead>
<tr>
<th>Criteria: Operating/Safety/Quality</th>
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</table>

**Prepare for Startup**

1. **Open Aluminum/SS sheet**

   Open screws of the Insulation line to be opened and take out Aluminium/SS sheet.
2. **Remove wire mesh and insulating material**

   Untie wire mesh to loosen glass wool from the pipe. Use wire cutter to remove wire mesh if required.

   Remove insulating material for inspecting pipeline.

3. **Maintenance operation on pipeline/equipment**

   Perform required maintenance operation on the pipe/component (repair/replacement). Use wire cutter to remove wire mesh if required.

4. **Close back pipe Insulation**

   After pipe has been satisfactorily repaired, fold wire mesh around the pipe to be insulated, fill back insulation material in wire mesh and twist metallic ends of wire mesh so as to hold insulation material at its position.

   \[\text{CAUTION!}\]

   If wire mesh is not in condition to be reused, get a new mesh.

   Put back Aluminum/ SS sheets and tighten them with screws.

**CAUTION!**

Risk for hand! Wear hand gloves.
# Standard Task Procedure 06

## Replacing Broken/ Sun-Damaged Mirrors

**Responsible Person:** Technician  

**Effective Date:** 2013-09-05  
**Revision:** 002  

**This Standard Task Procedures is used:**

1. As a learning aid  
2. To assess competence  
3. As a job aid while performing the function  
4. To conduct a Planned Task Observation

### Equipment/Tools

- Hex Screwdriver, Spanner, Measurement Tape

### Material

- Cotton Cloth

### Safety Equipment:

- Other prerequisites:

### Steps

**Replacing Broken/ Damaged Mirrors**

1. Identify mirror to be replaced

Identify damaged mirror to be replaced.

Go to SCADA/HMI system to turn PT such that damaged mirror lies flat to ground, so that operator can easily fix it. Each mirror on a PT is being held by Mirror Holders (with a nut in middle) at edges which holds the Trough. These mirror holders are made of Silicon for weather protection (Extreme temperature, rains).
<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
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<tbody>
<tr>
<td>2. Removing Damaged Mirror</td>
<td>Open the nuts on Mirror Holders using female hex Screwdriver (as shown). Remove clamps from top &amp; bottom of Mirror.</td>
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<tr>
<td>3. Fixing New mirror</td>
<td>Lift the broken mirror from the truss, and in its place gently place a new mirror on the same surface so that position of Mirror Holders match the same old position. Close nuts for Mirror Holders tightly. Fix bottom clamps first and then top adjustable clamps.</td>
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</table>

**CAUTION!**

Risk for hand! Wear hand gloves.

Risk for eye! Always wear dark sunglasses.
# Standard Task Procedure 07
## Descaling of Pipelines

**Responsible Person:** Engineer/Technician  
**Effective Date:** 2013-10-14  
**Revision:** 001

This Standard Task Procedures is used:

1. As a learning aid
2. To assess competence
3. As a job aid while performing the function
4. To conduct a Planned Task Observation

### Preparation

<table>
<thead>
<tr>
<th>Equipment/tools: Wrench, Descaler Pump, Hose Pipes, Bucket</th>
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<tbody>
<tr>
<td>Material: Descaling Chemical, Cloth</td>
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### Safety Equipment:

- [ ] Other prerequisites:

### Documentation to be completed

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<th>Submitted to</th>
<th>By when</th>
</tr>
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<tbody>
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<td></td>
<td>Supervisor</td>
<td>Monthly, before following Tuesday</td>
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### Pre-operational checks

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<th>Criteria</th>
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</thead>
<tbody>
<tr>
<td>Check state of system: Should not be in working condition</td>
</tr>
<tr>
<td>Check circulating fluid temperature: Should be at workable temperature</td>
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</table>

*Note: This Task is done once a while, depending on site water quality, and RO System Usage, and is generally outsourced.*

### Step

<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
</tr>
</thead>
</table>
| Preparation | 1. When several modules are to be descaled, the units are to be disconnected and descaled individually  
2. Close isolating gate valve to isolate system module to be descaled.  
3. Get the following items:  
  - Descaler Pump  
  - Bucket  
  - Hoses  
  - Vinegar and Water*  |

*There are chemicals available for better removal of scales from inner lining of module. Contact experienced descaling technicians for professional Descaling of your system.*
**Setup**

Prepare the setup as shown in figure above:
1. Place Descaler Pump at the bottom of the bucket.
2. Connect Descaler Pump’s outlet to a module (Receiver Tube), with a hose pipe.
3. Fix outlet of another hose pipe in the bucket to collect back chemical solution from the module.

<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
<th>✓/✗</th>
</tr>
</thead>
</table>
| **Starting Descaling Process** | 1. Pour Vinegar or Descaling Chemical solution with water in ratio of 1:3 in the bucket  
2. Start Descaler Pump  
3. Allow the solution to circulate for about 1 hour  
4. Now stop the Pump. Dispense discard descaling chemical in the bucket into sink |       |
| **Fresh Water Rinse**         | 1. Fill the bucket with cold water  
2. Start the Pump to circulate fresh water in the module for about 15 minutes  
3. You may need to replace fresh water and repeat this procedure of Rinsing if you notice any residual taste in the module. |       |

**CAUTION!**

Acid Spill, wear Hand Gloves.
## Standard Task Procedure 08
### Calibration of Temperature Transmitter

**Responsible Person:** Technician  
**Effective Date:** 2013-09-05  
**Revision:** 001

This Standard Task Procedures is used:

1. As a learning aid  
2. To assess competence  
3. As a job aid while performing the function  
4. To conduct a Planned Task Observation

### Preparation

<table>
<thead>
<tr>
<th>Equipment/tools: Spanner, oil bath, stirrer, thermometer, resistance wires of different values</th>
<th>Material: Silicone Oil</th>
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</thead>
</table>

### Safety Equipment:

<table>
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<th>Other prerequisites:</th>
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### Documentation to be completed

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<th>By when</th>
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<tbody>
<tr>
<td>Supervisor</td>
<td>Monthly, before following Tuesday</td>
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### Pre-operational checks

<table>
<thead>
<tr>
<th>a. Check state of system</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>Should not be in working condition</td>
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<table>
<thead>
<tr>
<th>b. Check circulating fluid temperature</th>
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<tr>
<td>Should be at workable temperature</td>
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### Step

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<tr>
<th>Preparation for Calibration</th>
<th>Criteria: Operating/Safety/Quality</th>
</tr>
</thead>
</table>
| 5. Take a vessel.  
6. Put oil, which can sustain temperature of about 300 °C  
7. Heat the oil using heater.  
8. Use a calibrated thermometer to observe temperature of Silicon oil bath (in range 200-230 °C) | ✓/✗ |
Calibrating Temperature Transmitters

2. Continuously stir the oil bath.
3. Keep the temperature bath at steady state for 15 min by using ON/OFF switch.
4. Note the readings of thermometer and TT simultaneously (adjust your watch time with the data logging system time)

<table>
<thead>
<tr>
<th>Step</th>
<th>Criteria: Operating/Safety/Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjust Shunt (pot) resistance/Amplifier of all thermocouples to give temperature of oil bath on SCADA screen.</td>
</tr>
<tr>
<td></td>
<td>Now connect back Temperature Transmitters back to their original location.</td>
</tr>
</tbody>
</table>

Note: there are Temperature Transmitter calibrating devices available, operator can refer to these devices for accurate calibration.

CAUTION!

Risk for hand! Wear hand gloves.

For thermocouples used at high temperatures, replacement rather than recalibration is recommended.