भारतीय मानक
Indian Standard

IS 16648 (Part 3) : 2017

केन्द्रित सौर तापीय — विशिष्टि

भाग 3 पेराबॉलिक ट्रॉफ कॉन्सेन्ट्रेटर

Concentrated Solar Thermal — Specification

Part 3 Parabolic Trough Concentrator

ICS 27.160

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली-110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.org.in www.standardsbis.in

October 2017

Price Group 5

Renewable Energy Sources Sectional Committee, MED 4

FOREWORD

This Indian Standard (Part 3) was adopted by the Bureau of Indian Standards, after the draft finalized by the Renewable Energy Sources Sectional Committee had been approved by the Mechanical Engineering Division Council.

This standard has five parts under general title Concentrated solar thermal — Specification. Other parts in this series are:

Part 1 Paraboloid dish concentrator

Part 2 Scheffler concentrator

Part 4 Non imaging concentrator

Part 5 Test methods

The relevant SI units and corresponding conversion factors are given below for guidance:

Pressure 1Pa (Pascal) = 1 N/m^2

1 kgf/mm^2 = 9.806 65 MPa

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CONCENTRATED SOLAR THERMAL — SPECIFICATION

PART 3 PARABOLIC TROUGH CONCENTRATOR

1 SCOPE

1.1 This standard (Part 3) specifies requirements of solar parabolic trough collector (PTC) for process heating and steam generation for range 60°C to 250°C. The PTC shall be useful for steam generation, high pressure hot water and thermic fluid systems in the above mentioned temperature range.

1.2 This standard do not apply to PTC generating temperature > 250°, high pressure > 40 bar and superheated steam, normally used for power generation.

2 REFERENCES

The standards given in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMONOLGY

For purpose of this standard, following definitions shall apply:

3.1 Emittance — Ratio radiant existence of body to that of a black body at same temperature.

3.2 Reflectance — Ratio of the radiant flux reflected to that of incident radiation.

3.3 Absorptance — Ratio of the radiant flux absorbed to that of incident radiation.

3.4 Transmittance — Ratio of the radiant flux passing through a body to that of incident radiation.

3.5 Wind Speed — Air speed measured by anemometer at height of 10 m above ground level.

3.6 Parabolic Trough Collector (PTC) — Line focus collector that focuses solar radiation by means of a cylindrical reflector having a parabolic cross section.

3.7 Solar Tracker — Power driven operated movable support which shall be employed to keep PTC oriented with respect to sun.

3.8 Receiver — A part of concentrating collector to which solar radiation is finally directed comprising of absorber and any associated glass cover through which radiation is pass.

3.9 Aperture Area — Maximum projected area through which un-concentrated solar radiation enters the collector.

3.10 Time Constant —Time required for an exponential process to reach 63.22 percent of his final value.

3.11 Symbols

Q	—	rate of energy	W
A_P	—	aperture area	m^2
I_{bn}	—	beam normal solar irradiance	W/m^2
K_{qL}	—	longitudinal incidence angle modifier	Dimensionless
r	—	radial focal distance	metre
a_1	—	temperature dependence first degree heat loss coefficient	W/m^2K
a_2	—	temperature dependence first degree heat loss coefficient	W/m^2K^2
T_m	—	mean temperature at receiver	°C
T_a	—	ambient temperature	°C
η_o	—	optical efficiency	Dimensionless
h	—	thermal efficiency	Dimensionless
L_c	—	length per collector	metre
θ_L	—	longitudinal angle of incidence	Degree

4 COMPONENTS SPECIFICATIONS

The various components of PTC shall be as per specifications given below.

4.1 Reflector

4.1.1 *Aluminium Reflector*

Material should be solar grade anodized aluminium substrate with suitable coating for corrosion protection.

a) Specular reflectance shall be minimum 88 percent.

The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance

(or reflectance) are made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.

The solar transmittance, reflectance, or absorptance is obtained by calculating a weighted average over wavelength with a standard solar spectral irradiance as the weighting function by either the weighted or selected ordinate method.

b) Durability shall be minimum 10 years

The mirror specimen should be subjected to the neutral salt spray test as per IS 9844 or equivalent standards.

The exposed specimen should not have any blisters, degradation of back coating after exposure of 250 h.

c) Thickness shall be 0.3 mm minimum in order to get parabolic shape.

4.1.2 *Glass Reflectors*

Material should be tempered and toughen solar grade glass with silver back reflective coating. The age sealing coat on all sides of mirror should be done for corrosion protection.

a) Specular reflectance shall be minimum 90 percent.

The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) are made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.

The solar transmittance, reflectance, or absorptance is obtained by calculating a weighted average over wavelength with a standard solar spectral irradiance as the weighting function by either the weighted or selected ordinate method.

b) Durability shall be minimum 10 years

The mirror specimen shall be subjected to the neutral salt spray test as per IS 9844 or equivalent standards.

The exposed specimen shall not have any blisters, degradation of back coating after exposure of 250 h.

c) Thickness shall be 3 mm to 4 mm with parabolic shape.

4.1.3 *Reflector Films*

Material shall be polyester, acrylic, epoxy acrylic coated with silver/ aluminium to get reflective coat. Silver reflective film should be backed by aluminium or any suitable substrate. Edged should to sealed using tape or any suitable material.

a) Specular Reflectance shall be minimum 94 percent.

The specimen of mirror shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) are made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.

The solar transmittance, reflectance, or absorptance is obtained by calculating a weighted average over wavelength with a standard solar spectral irradiance as the weighting function by either the weighted or selected ordinate method.

b) Durability shall be minimum 10 years

The mirror specimen should be subjected to the neutral salt spray test as per IS 9844 or equivalent standards.

The exposed specimen should not have any blisters, degradation of back coating after exposure of 250 h.

c) Thickness shall be 0.38 to 0.5 mm with substrate in order to get parabolic shape.

4.2 Receiver Assembly

Receiver assemble shall be of absorber tube generally made from suitable material as per IBR code, with glass cover either with evacuated or air jacket and optionally with secondary reflectors.

4.2.1 Absorber coating shall be black chrome, paint or selective coating [AS(C2-80)]. Absorptivity shall be minimum 0.9 and emissivity shall be less than 0.2. Transmittance of glass shall be minimum 95 percent.

The specimen of absorber tube and glass cover shall be tested as per ASTM E 903. Measurement of spectral near normal conical, hemispherical transmittance (or reflectance) are made over the spectral range from approximately 300 to 2 500 nm with an integrating sphere spectrophotometer having a small conical solid angle of incident flux on sample.

The solar transmittance, reflectance, or absorption is obtained by calculating a weighted average over wavelength with a standard solar spectral irradiance as the weighting function by either the weighted or selected ordinate method.

4.2.2 The absorber tube shall be made with thickness

suitable to stand the design pressure and temperature as per IBR code.

4.2.3 The absorber coating durability shall be minimum 10 years.

The absorber tube and glass cover specimen should be subjected to the neutral salt spray test as per IS 9844 or equivalent standards. The exposed should not have any blisters, degradation of back coating after exposure of 250 h of the specimen.

4.3 Glass Cover

The absorber tube shall be covered with glass having transmissivity 95 percent minimum with thickness of minimum 2 mm and diameter suitable for the absorber tube.

In case of vacuum tube the glass to metal sealing shall be capable of thermal expansion while in case of non-evacuated tube suitable fixing arrangement shall be provided for free moment of tube during thermal expansion.

4.4 Collector and Support Structure with Civil Foundation

The basic framework the trough support shall be steel or aluminium.

4.4.1 The structure should be design withstand wind speed of 47 m/s under stow condition and 10 m/s under operating condition. Design should be as per IS 800/ IS 875 (Part 3).

4.4.2 Material of collector structure and support should be as per IS 2062 and shall be protected from corrosion with suitable process such galvanization cathode electrode deposition(CED) or any suitable painting process as per Indian Standards for chosen coating. The design should be suitable for life span of 20 years.

4.4.3 Dimensional accuracy and tolerance shall be defined by manufacturer for his specific design in following manner.

Length	:	in mm with +/– tolerance
Width	:	in mm with +/– tolerance
Parabolic tolerance	:	tolerance from standard parabola
Axial accuracy	:	Tolerance from standard axis

The tolerance shall be defined by the manufacturer in order to get the required optical efficiency for the specific design.

4.5 Tracking system

Enables trough to remain focused towards sun so as to capture maximum possible direct radiation during the day. Tracking shall include motors, gearbox/rack and pinion and control system.

4.5.1 Accuracy requirement shall be decided for the specific manufacturer's design which shall be based on concentration ratio.

4.5.2 Tracking motor shall be Servo/Stepper/Induction as per IS 9815 (Part 1), IS 13079, IS 12615 respectively suitable for the load for taking in stow position at full speed.

4.5.3 Electrical system such as wiring, connections shall be as per IS 732.

Electronic and control system shall be mounted outdoor and shall get exposed all elements. In view of the same, the control panel and electronic components shall be protected as per IS/IEC 60529.

5 SHAPE AND DIMENSIONS

The shape and dimensions of the PTC may be decided by the manufacturer based on his design. The dimensions to be mentioned are given in Fig. 1. The typical arrangement of PTC system is given in Fig. 2.

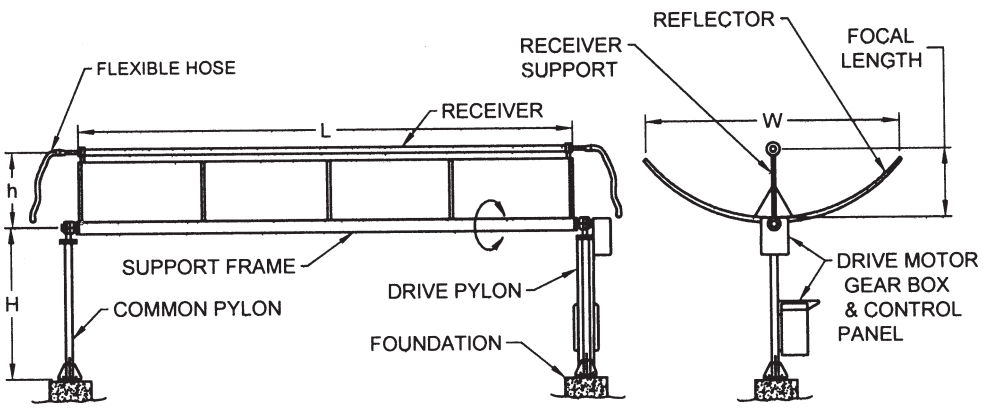

FIG. 1 SCHEMATIC OF PARABOLIC TROUGH

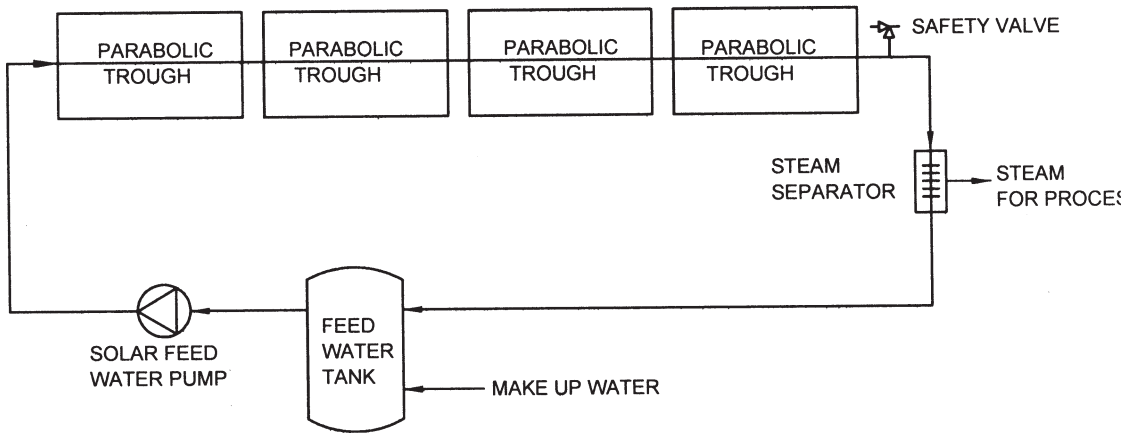

FIG. 2 TYPICAL ARRANGEMENT OF PTC SYSTEM

6 ASSEMBLY AND WORKMANSHIP

The entire assembly shall be free from surface defects. All sharp edges and corners shall be rounded off. The exposed surfaces shall be properly made corrosion resistant.

The whole system shall be so assembled, that replaceable components are accessible for repair or replacement at site in accordance with the manufacturer instructions.

7 COMPONENT SAMPLES AND TESTS

7.1 Component Samples

The assembled PTC alongwith components below shall be submitted for testing.

a) Reflector piece 150 mm × 150 mm,
b) One piece of receiver tube assembly,
c) Manufacturers certificates for all components for specifications and properties, and
d) Information regarding maximum operating temperature and pressure.

7.2 Routine Test

7.2.1 *Outdoor no Flow Exposure Test*

This test shall be done to check response of PTC when there is no flow. In case of PTCs where manufacturer have mentioned that the PTC is capable of stagnation temperature, the test at **7.2.1.1** shall be performed. In case manufacture recommends defocus in case of no flow condition, test at **7.2.1.2** shall be performed.

7.2.2 *Type Stagnation Temperature Test*

Test shall be conducted only when manufacturer confirm that the design is suitable for stagnation. In case design has auto safety defocus facility the procedure is given at **7.2.1.2** shall be used.

Place the system in tracking mode, with no flow inside the receiver. Temperature is measured in stagnant air inside the receiver tube. The temperature shall be measured at the both ends of receiver tubes and the sensors shall not contact the wall. A 50 mm thick thermal insulation shall be used at the open ends of the receiver.

7.2.3 *Test Procedure*

When the solar radiance is $G > 600 W/m^2$, record the solar irradiance, temperature inside the receiver tube and ambient temperature every 5 min. Record the temperature inside the receiver by taking average of readings from both sensors. Stop the test when temperature inside the receiver tube reached a quasi steady state. The steady state conditions shall be defined as 10 min period when;

a) variation in receiver tube temperature is ± 1°C.
b) variation in solar radiation is ± $20 W/m^2$.
c) variation in ambient temperature is ± 0.2°C .
d) Solar radiation is greater than $600 W/m^2$.

7.2.4 *Auto Defocus Safety Feature Test*

This is safety test to check auto defocus of PTC when temperature exceeds design temperature process given by the manufacturer in instruction manual.

7.3 Thermal Efficiency Test

7.3.1 Testing as per IS 16648 (Part 5) test method for steam and fluid.

7.3.2 *Acceptance Criteria*

Parabolic Trough is a moving line focus, single axis tracking system. It tracks the sun from morning to evening. Due to single axis tracking, the value of equals to unity. Also, since the system doesn't track the sun's declination, some fraction of a receiver tube will not receive solar radiation due to longitudinal angle of

incidence. This loss is known as end loss. The performance of the system can be expressed by following equation:

$$\frac{Q}{A_p} = I_{bn} \times \eta_o \times (1 - \text{End loss}) \times K_{\theta_L} - a_1 \times (T_m - T_a) - a_2 \times (T_m - T_a)^2$$

where

$$\text{End loss} = \frac{r}{L_C} \times \tan \theta_L$$

For determination of incidence angle modifier, rotating platform is required so as to have dual axis tracking. Otherwise for tropical region, year around testing would be required to compute the incidence angle modifier. Regions outside tropical region will always have incidence angle modifier.

Minimum performance requirement.

PTC shall have η_0= 0.6 (minimum), a_1= 1.5 (maximum) and a_2= 0.07(maximum)

The manufacturer shall give the performance graph of the PTC as per format given in Fig. 3.

7.4 Time Constant

The solar collector shall be subjected to thermal test for determination effective thermal capacity and time constant in accordance with **6.5** of IS 12933 (Part 5). The value of time constant shall be reported along with test condition for guidance.

The heat transfer fluid is circulated through the PT and the inlet temperature is adjusted as close to ambient temperature as possible, preferably within ± 1°C. The steady state and test conditions are maintain as specified in IS 16648 (Part 2). The incident solar energy shall be then abruptly reduced to zero by defocusing the system. The following parameters should be measured during the test:

a) Collector fluid inlet temperature,
b) Collector fluid outlet temperature, and
c) Surrounding air temperature.

The measurements are continue until,

$$(T_{o,t} - T_i)/(T_{o,\,initial} - T_i) < 0.3$$

where

$T_{o,t}$ = temperature of the heat transfer fluid leaving receiver at specified time t, °C,

T_i = temperature of the heat transfer fluid entering the receiver, and

$T_{o,\,initial}$ = temperature of the heat transfer fluid leaving receiver at the beginning of time constant test period, °C.

The value of time constant shall be noted.

The actual time constant is the time required for the quantity on left hand side of equation to change from 1.0 to 0.368.

7.5 Incident Angle Modifier Test

The solar collector shall be subjected to thermal tests for determining incident angle modifier using either of the two methods given in **6.6** of IS 12933 (Part 5). The value of incident angle modifier shall be reported along with graphical presentation.

8 INSTRUCTION MANUAL

The manufacturer shall provide with collector an instruction manual containing schematic diagram of collector, recommended diagram of the system; installation procedure, startup and shut down procedure. The safety instructions during installation and operation shall be included in the manual. The process of repair,

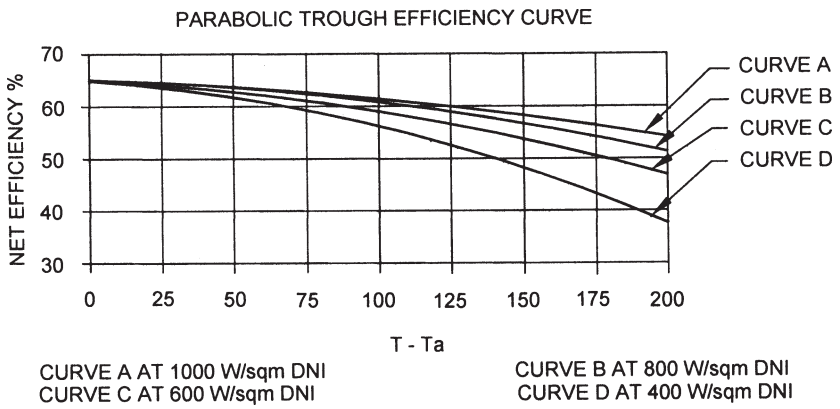

FIG. 3 PERFORMANCE GRAPH FORMAT FOR PTC

replacement of parts such as broken glass tube, peeling of paint and the prevention method shall be mentioned in the instruction manual. The service outlet with contact details shall be given in the manual.

9 MARKING

9.1 The PTC lot shall be supplied with document containing,

a) manufacturer name, address and contact details;
b) batch or lot number with date of manufacture;
c) maximum working pressure and temperature;
d) the performance graph and values of a_1 and a_2 with performance equation as per **7.3.2**; and
e) mirror and receiver information as per **4.1** and **4.2**.

9.2 BIS Certification Marking

Each parabolic trough concentrator may also be marked with the Standard Mark.

9.2.1 The use of the Standard Mark is governed by the provision of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

10 PACKING

The packing shall be as agreed to between the manufacturer and the purchaser.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS/International Standard No.	*Title*
732 : 1989	Code of practice for electrical wiring installations (*third revision*)
800 : 2007	General construction in steel — Code of practice (*third revision*)
875 (Part 3) : 2015	Design loads (other than earthquake) for buildings and structures— Code of practice : Part 3 Wind loads (*third revision*)
2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
9815 (Part 1) : 1994	Servo-motor operated automatic line voltage correctors : Part 1 Correctors for single-phase appli-cations — Specification (*second revision*)
9844 : 1961	Methods of testing corrosion resistance of electroplated and anodized aluminium coatings by neutral salt spray test
12615 : 2011	Energy efficient induction motors — Three phase squirrel cage (*second revision*)
12933 (Part 5) : 2003	Solar flat plate collector— Specification : Part 5 Test methods (*second revision*)
13079 : 1991	Stepping motors — Specification
16648	Concentrated solar thermal — Specification:
(Part 2) : 2017	Scheffler concentrator
(Part 5) : 2017	Test methods
IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP Code)
ASTM E903-12	Standard test method for solar absorptance, reflectance and transmittance of materials using integrating spheres

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Renewable Energy Sources Sectional Committee, MED 04

Organization	*Representative(s)*
Ministry of New and Renewable Energy, New Delhi	Shri Sohail Akthar (***Chairman***)
Biogas Forum India, New Delhi	Dr A. R. Shukla
Bipin Engineers Pvt Ltd, Pune	Shri H. S. Revankar Shri A. K. Baikerikar (*Alternate*)
Central Arid Zone Research Institute, Jodhpur	Dr Anil Kumar Singh Dr Priyabrata Santara (*Alternate*)
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Verma Shri D. K. Tulani (*Alternate*)
Centre for Wind Energy Technology, Chennai	Dr S. Gomathinayagam Shri A. Senthil Kumar (*Alternate*)
Central Mechanical Engineering Research Institute, Durgapur	Shri Bhoplab Choudhary Shri Siva Prakashris (*Alternate*)
Consumer Coordination Council, Noida	Shri Arun Kumar Mishra Shri R. K. Kaplesh (*Alternate*)
Directorate General of Meteorology, New Delhi	Dr Devendra Pradhan
EMMVEE, Bangalore	Shri Vijay Kumar C. R.
Gujarat Energy Development Agency, Vadodara	Shri K.V. Doshi Shri S. B. Patil (*Alternate*)
Indian Institute of Technology, Mumbai	Shri J. K. Nayak Shri Shireesh Kedare (*Alternate*)
Indian Institute of Technology, New Delhi	Prof S. C. Mullick Dr T. C. Kandpal (*Alternate*)
Indian Council of Agricultural Research Institute, New Delhi	Dr Kanchan K Singh Dr Anil Kumar Dubey (*Alternate*)
Indian Renewable Energy Development Agency Ltd, New Delhi	Shri B. M. Chauhan Shri Sompal (*Alternate*)
International Copper Association India, Mumbai	Shri V. K. Gupta Shri Sanjeev Ranjan (*Alternate*)
Karnataka Solar Manufacturers Association, Bangalore	Shri A. Palani
Mechanical Engineering IIT BHU, Varanasi	Shri S. K. Shukla
Maharashtra Solar Manufacturers Association, Pune	Shri Suhas Ghotikar Shri Mangal Akole (*Alternate*)
National Bank for Agriculture and Rural Development, Mumbai	Dr A. R. Khan Shri R. Anand (*Alternate*)
Regional Test Centre, Pune	Prof (Dr) Sandesh R. Jadkar Dr Anagha M. Pathak (*Alternate* 1) Dr Adinath Funde (*Alternate* 2)
Regional Test Centre, Indore	Dr S. P. Singh Prof R. N. Singh (*Alternate*)
Rajgiri School of Engineering Technology, Kochi	Dr V. Panthalookan Shri Joel George (*Alternate*)
RITES Ltd, Gurgaon	Shri G. S. Swaroop Shri Rajiv Milind (*Alternate*)
Sardar Patel Renewable Energy Research Instiuite, Vallabh Vidyanagar	Dr Mukul Kumar Dubey Dr Jay Pandey (*Alternate*)
Solar Energy Centre, New Delhi	Dr B. Bandyopadhyay Dr S. K. Singh (*Alternate*)

Organization	*Representative(s)*
Solar Energy Society of India, New Delhi	Shri A. P. Shrivastava Shri Rajinder Kumar (*Alternate*)
Solchrome Systems India Limited, Parwanoo	Shri K. K. Singla
The Energy and Resources Institute, New Delhi	Shri Girishri garud Dr Ishan Purohit (*Alternate*)
The Maharashtra Energy Development Agency (MEDA), Pune	Shri Manoj A. Pise Shri H. Manik Kulkarni (*Alternate*)
In personal capacity (*C-103 A, JVTS Garden Chaterpur Extention, New Delhi 110074*)	Shri Atam Kumar
BIS Directorate General	Shri A. Renga Rajan Scientist 'E' and Head (MED) [Representing Director General (*Ex-officio*)]

Member Secretary
Shri Chandan Gupta
Scientist 'C' (MED), BIS

Solar Thermal Energy Sub-Committee, MED 04:1

Regional Test Centre, Indore	Dr S. P. Singh (***Convener***) Prof R. N. Singh (*Alternate*)
Bharat Heavy Electricals, Hyderabad	Shri M. R. Pawar
Bipin Engineers Pvt Ltd, Pune	Shri H. S. Revankar Shri A. K. Baikerikar (*Alternate*)
Borosil Glass Works Ltd, Mumbai	Shri Das Gupta S. Shri Shreevar Kheruka (*Alternate*)
Bosch Limited, Bangalore	Shri Gangadhar N. H. Shri Ramakrishnappa K. T. (*Alternate*)
EMMVEE, Bangalore	Shri Vijay Kumar C. R.
Indian Institute of Technology, Mumbai	Shri J. K. Nayak
Indian Institute of Technology, New Delhi	Prof S. C. Mullick
Jain Irrigation System Ltd, Jalgaon	Shri Sanjeev Hanumant Shri Y. Shrikanth (*Alternate*)
Karnataka Solar Manufacturers Association, Bangalore	Shri A. Palani
Karnataka Renewable Energy Development Ltd, Bangalore	Director
Lloyd Insulations (I) Ltd, New Delhi	Shri K. K. Mitra Shri A. K. Rastogi (*Alternate*)
Maharashtra Solar Manufacturers Association, Pune	Shri Suhas Ghotikar Shri Mangal Akole (*Alternate*)
Non-Conventional Energy Development Agency (U.P.), Lucknow	Director Shrimati Namrata Kalra (*Alternate*)
Planters Energy Network-Pen, Tamil Nadu	Dr C. Palaniappan
Punjab Agricultural University, Ludhiana	Dr V. P. Sethi Shri V. S. Hans (*Alternate*)
Punjab Energy Development Agency, Chandigarh	Director
Racold Thermo Ltd, Pune	Shri Mahesh Bhangale Ms Trishala Changule (*Alternate*)
Regional Test Centre, Pune	Prof (Dr) Sandesh R. Jadkar Dr Anagha M. Pathak (*Alternate* 1) Dr Adinath Funde (*Alternate* 2)
Rohitas Electronics, Kanpur	Shri C. K. Rohatagi Shrimati Niharika Rohtagi (*Alternate*)

Organization	*Representative(s)*
Society for Energy, Environment and Development (SEED), Hyderabad	Shri M. Ramakrishna Rao Prof D. P. Rao (*Alternate*)
Solar Energy Society of India, Delhi	Shri A. P. Shrivastava Shri Rajinder Kumar (*Alternate*)
Solar Thermal Federation of India, Pune	Shri Ravindra R. Kulkarni
Solchrome Systems India Limited, Parwanoo	Shri K. K. Singla
SSVPS BSD College of Engineering, Dhule	Dr Ajay Chandak
Thermax Limited, Pune	Shri Kiran Deshpande Shri Yashavant Joshi (*Alternate*)
In personal capacity (*C-103 A, JVTS Garden Chaterpur Extention, New Delhi 110074*)	Shri Atam Kumar

Parabolic Trough Concentrator Panel, MED 04:1/P-3

Thermax Limited, Pune	Shri Kiran Deshpande (***Convener***)
Savitribai Phule Pune University, Pune	Shrimati Anagha Pathak
Thermosol Glass Pvt Ltd, Delhi	Shri Mahesh Biyani

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed from Doc No.: MED 04 (11239).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices: *Telephones*

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002 — 2323 7617, 2323 3841

Eastern : 1/14 C.I.T. Scheme VII M, V. I. P. Road, Kankurgachi, KOLKATA 700054 — 2337 8499, 2337 8561, 2337 8626, 2337 9120

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg, CHANDIGARH 160019 — 26 50206, 265 0290

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113 — 2254 1216, 2254 1442, 2254 2519, 2254 2315

Western : Manakalaya, E9 MIDC, Marol, Andheri (East), MUMBAI 400093 — 2832 9295, 2832 7858, 2832 7891, 2832 7892

Branches: AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. COIMBATORE. DEHRADUN. DURGAPUR. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. JAMMU. JAMSHEDPUR. KOCHI. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAIPUR. RAJKOT. VISAKHAPATNAM.

Published by BIS, New Delhi