IS : 2978 - 1964
(Reaffirmed 1996)

Indian Standard

SPECIFICATION FOR OPTICAL THEODOLITE

(Second Reprint DECEMBER 1982)

UDC 528·52

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4

March 1965

Indian Standard

SPECIFICATION FOR OPTICAL THEODOLITE

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Indian Standard

SPECIFICATION FOR OPTICAL THEODOLITE

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 6 December 1964, after the draft finalized by the Optical and Mathematical Instruments Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 Theodolite is an instrument for precise measurements of horizontal and vertical angles. An optical theodolite is a precision instrument, easy in manipulation, much lighter in weight, and giving greater accuracy as compared to other types of theodolites. The optical theodolite may be used for all types of surveys required for small and large scale mapping and for geodetic surveys.

0.3 This standard is one of a series of Indian Standards dealing with optical instruments. A separate Indian Standard has also been prepared to cover the requirements of vernier theodolites (IS : 2988-1965).

0.4 For the purpose of deciding whether a particular requirement of this standand is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the functional and general requirements of optical theodolites. The theodolite shall be referred to not by the size of its horizontal circle but by the least count of its micrometer, such as optical theodolite of one second. A typical optical theodolite is shown in Fig. 1.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Alidade — The term alidade is applied to the whole of that part of the theodolite that rotates with the telescope.

*Rules for rounding off numerical values (*revised*).

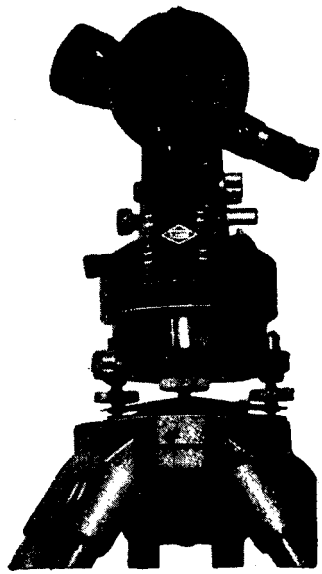

FIG. 1 OPTICAL THEODOLITE

2.2 Dark Glasses — Coloured glasses used over the eyepiece to protect the eye during observation of the sun.

2.3 Diagonal Eyepiece — An eyepiece fitted with a reflecting prism to reflect the rays of light at right angles to the ordinary line of sight and is used for astronomical and high angle observations.

2.4 Limb — The limb consists of the vertical axis, the horizontal circle and the illumination system.

2.5 Standard — Two vertical arms of the theodolite which bear the transit axis, telescope, vertical circle and the optical reading device.

2.6 Striding Level — A sensitive level mounted at right angle to the telescope axis and used mainly in astronomical observations for levelling the horizontal axis or measuring any error in the level of the axis.

2.7 Transit, Horizontal or Trunnion Axis — The axis about which the telescope and vertical circle rotate.

2.8 Tribrach — The part of the theodolite carrying the levelling screws.

2.9 Trivet — An underpart of the theodolite which may be secured to the tripod top with which the toes of the levelling screws make contact.

2.10 Vertical Axis — The axis about which the alidade rotates.

3. ENERAL REQUIREMENTS

3.1 Each part of the theodolite shall be made from material of suitable strength and shall be suitably finished.

3.1.1 Different parts of the theodolite as far as possible shall be made of metals with similar thermal expansion, so that its accuracy is unaffected by large variations in temperature.

3.1.2 Coating and plating on each part shall be durable to resist discolouration, wear and rust.

3.2 The theodolite shall be carefully adjusted so that it rotates uniformly on its axes. It shall be thoroughly tested by the manufacturers, particularly against vibration and variation in temperature.

3.3 The optical parts shall be clear of fog and moulds. The optical parts shall conform to IS : 988-1959*. The telescope shall be hermetically sealed to avoid fungus growth. The optical system shall be reasonably free from aberrations.

3.3.1 The optical parts shall preferably be coated with antireflection coating.

3.4 The clamps shall be positive and shall not strain the axes of the theodolite. To avoid inadvertent wrong handling, the heads of different screws, which are placed together, shall have different designs.

4. FUNCTIONAL REQUIREMENTS

4.0 The essential parts of the instrument shall meet the following requirements.

4.1 Tribrach — This shall be so designed as to accommodate the theodolite or a target or a subtense bar, without affecting the centring and levelling of the tribrach.

4.1.1 A clamp which should be firm and non-slipping shall be provided for locking the tribrach with the theodolite or the target or the subtense bar.

4.1.2 A foot screw tension plate shall be provided to keep the foot screws firm in the sleeves of the base plate.

4.1.3 The foot screws shall operate smoothly and be adjustable in run and enclosed so as to be dust-tight.

4.1.4 A suitable fixing arrangement shall be provided for clamping the trivet to the head of the tripod (*see also* **4.4**).

4.1.5 A circular bubble shall be provided on the tripod stand or tribrach to allow for quick pre-levelling of the instrument.

4.2 Limb — The limb shall turn smoothly about the vertical axis.

*General requirements for optical components.

4.2.1 The horizontal glass circle shall be so enclosed in the limb as to make it dust-tight. A setting knob, where provided for orientation of the horizontal glass circle, shall be protected by a suitable cap to prevent accidental turning.

4.2.2 The glass circle shall be graduated clockwise to 360° at convenient intervals. Each degree division shall be numbered and be longer than the sub-divisions.

4.2.3 An illuminating window shall be provided for illuminating horizontal and vertical circles. The window shall be so constructed as to allow the use of mirror or an electric lamp.

4.2.4 It will be preferable to have only one window for illuminating both the circles. However, if separate windows are provided, the one illuminating the horizontal circle should be on the limb so that the illumination does not change as the theodolite is moved in azimuth.

4.3 Alidade — It shall be secured to the limb or to the base. A spring-loaded slow motion screw, without backlash, shall be fitted for fine setting of the theodolite in azimuth.

4.3.1 An azimuth bubble shall be mounted, preferably at the middle of the vertical supports. Capstan screw working against spring shall be provided at one end of the bubble for adjustment, the other end being hinged. A bubble guard shall be provided.

4.3.2 The movement of the telescope about the horizontal axis shall be smooth. Two concentric rings shall be provided on the horizontal axis on either side of the telescope on to which a striding level may be fitted.

4.3.3 Telescope, free to transit from both ends, shall be mounted on the horizontal axis. A spring-loaded slow motion screw, without backlash, shall be fitted to the telescope for its fine setting in altitude.

4.3.3.1 The telescope shall have internal focussing mechanism capable of smooth movement. It shall be provided with a graticule, with cross lines and stadia lines, as shown in Fig. 2. The telescope shall be of astronomical type.

4.3.3.2 To control illumination of the graticule at night, the telescope shall be provided with an adjustable internal reflector which could be operated by a knob from outside.

4.3.3.3 Sighting vanes or optical sights shall be provided on the telescope.

4.3.4 The vertical circle shall be mounted concentrically with horizontal axis enclosed, so as to make it dust-tight. It shall be coupled to the telescope.

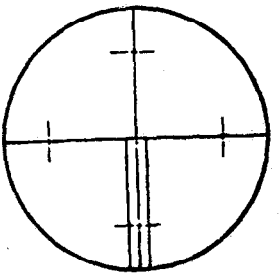

FIG. 2 GRATICULE

4.3.5 The altitude bubble shall be capable of adjustment by a tilting screw and a rotatable prism shall be provided so that the altitude bubble may be viewed by the observer from either side, without changing his position.

4.3.6 To read the horizontal and vertical circles, a microscope shall be mounted adjacent to the telescope to facilitate sighting and reading from the same position of the observer.

4.3.6.1 The horizontal and vertical readings shall be read through the same microscope, preferably by an arrangement of simultaneous viewing of both circles or separately, through the operation of a selector prism which may be actuated from either side of the vertical supports.

4.3.6.2 The optical micrometer shall be graduated to one second of an arc. The reading of circles shall preferably be by the method of coincidence of graduations, 180° apart.

4.4 Tripod — The tripod may be 1 600 mm in length and shall be made of well-seasoned wood or light and strong alloy. Tripod shall be either of telescopic or of rigid design. The tripod shall be fitted with a metal stirrup to mount the battery case and with a provision for mounting illuminating unit.

4.4.1 An arrangement for centring the theodolite to an extent of 30 to 50 mm shall be provided either on the stand or in the instrument.

5. TECHNICAL SPECIFICATIONS

5.1 The magnification of the telescope shall be between 25 × and 30 × and the resolving power of the telescope shall be 1·3 mm and 1 mm for 35 mm and 45 mm free aperture of the objective respectively, at 100 m. The field of view shall be 2° ± 5 percent for 25 × and 1° 40′ ± 5 percent for 30 ×.

5.1.1 The minimum focussing distance shall be 1·5 m and the telescope shall have the stadia multiplication constant 100 and addition constant zero.

5.2 The sensitivity of azimuth bubble and altitude bubble shall not be less than 20 seconds per 2 mm. The sensitivity of the circular bubble fixed to the tribrach shall be 10 minutes per 2 mm.

5.2.1 The optical plummet shall be of the following specifications:

Magnification	2·5 ×
Shortest sighting distance	0·5 m
Field of view	6°
Error in centring	Not to exceed 1 mm at a height of 10 m

5.3 The error due to vertical axis strain shall not exceed one second.

5.3.1 The horizontal axis shall be accurate when an elevated point 1·5 m away at an altitude of 45° is transferred on the ground, the error in transference shall not exceed 0·02 mm.

5.3.2 Horizontal and vertical circle graduation errors shall not exceed ±1 second of arc. In micrometer, error due to its graduations and run error shall not exceed ±1 second of arc.

5.4 The graticule line thickness shall be such that it subtends an angle of one second of arc ±25 percent at the objective of the telescope.

6. ACCESSORIES

6.1 The following accessories shall be provided with each theodolite:

a) Diagonal eyepiece	Two (one for telescope and the other for micrometer)
b) Dark glasses (to be so designed as to fit on eyepiece without change of eyepiece adjustment)	Three (dark green, light green and light blue)
c) Waterproof cover (made of durable waterproof material)	One
d) Plumb-bob with adapter plug	One
e) Tripod spanner	One
f) Adjusting pins	Two
g) Screw driver	One
h) Cleaning brush	One

j) Oil bottle	One
k) Electrical illuminating unit	One
m) Desiccating material which may be reactivated (silicagel)	One packet

6.2 The following complementary instruments may be provided (if desired by the indentors):

a) Beacon lamps	Six
b) Centring rod	One
c) Compass (desirable)	One
d) Spare graticule	One
e) Striding level	One
f) Subtense bar	One
g) Suitable base plate with a centring pin to enable observations from a pillar instead of a tripod	One
h) Levelling tape	One
j) Targets, fitted with longitudinal levels, with tripods and plumb-bobs	Two

7. TESTS

7.1 The theodolite shall initially be examined for the following possible external fault:

a) Loose, missing or damaged screws, nuts and other small parts;

b) Scratched, broken or dirty object glass, eye lenses, bubble and dark glasses, deterioration of balsam in the optical components;

c) Damage to telescope body, standards, tribrach and trivet stage, eye cups, focussing heads, open sights and ray shades;

d) Bent or otherwise damaged clamps, slow motion screws and levelling screws; and

e) Damage to general external finish.

7.2 The azimuth movement and associated controls shall be tested as follows:

a) Tighten the azimuth clamp and see if the respective assemblies are properly secured. Release the clamp and rotate the alidade; the movement should be smooth.

b) Tighten the clamp and turn the slow motion screw in each direction. The screw should turn smoothly and be free from any

play and backlash. The spring-loaded plunger should maintain the lug in firm contact with the screw whichever direction the screw is rotated.

7.3 The elevation movements and associated controls shall be tested as follows:

a) Tighten the telescope clamp and see that the telescope is properly secured. Release the clamp; the telescope should elevate or depress smoothly. Friction of the trunnion bearings should be just sufficient to maintain the telescope in any position.

b) Tighten the clamp and turn the telescope slow motion screw in each direction. The screw should turn smoothly and be free from any play or backlash. The spring-loaded plunger should maintain the lug in firm contact with the screw whichever direction the screw is rotated.

7.4 The levelling screw assemblies shall be tested as follows:

a) Turn all the levelling screws through their full range of movement, turning each one about half a turn at a time. Each screw should turn smoothly and be free from play or backlash in any position.

b) The toes of the levelling screws should be held in firm contact with the trivet stage by spring plate or locking plate.

7.5 The centring movement shall be tested as follows:

Tighten the clamp without using force; this should secure the theodolite firmly againt lateral movement. Release the clamp and it should be possible to slide the theodolite laterally to any position within the limits of the movement. The movement should be smooth in all positions.

7.6 The focussing movements shall be tested as follows:

a) Turn the telescope focussing head or collar through its full range. The movement should be smooth and free from play or backlash.

b) The telescope focussing eyepiece should move smoothly and be free from play or backlash.

c) Focussing-eyepiece for the circle reading microscope should move smoothly and be free from play or backlash.

7.7 The tripod shall be examined for stability, damage to legs and other parts.

7.8 The carrying case shall be examined for the general condition of the box, hinges, catches, locks, and carrying strap, internal fittings and accessories.

7.9 The mechanical examination of the theodolite shall be completed as follows:

Mount the theodolite firmly on its tripod; direct and focus the telescope on to a distant object. Ensure that all clamps are tightened. Observe while gently twisting the tribrach in each direction. The cross wires shall move off the object but should spring back when the hands are removed.

7.10 To test that the tangent to the plate vial curve is normal to the vertical axis, proceed as under:

Make a rough levelling of the instrument with the tripod legs with the help of the circular bubble. This will save time and also wear on the footscrew threads. Next proceed as follows:

a) Turn the plate so that the bubble is parallel to a line joining two of the footscrews;

b) Turn these two screws in opposite directions until the bubble is in the exact centre of its run;

c) Turn the plate through 90° to bring the bubble at right angles to its previous position and operate the third screw until the bubble is once more centred. If the bubble is displaced considerably, repeat (a), (b) and (c); and

d) Now return to the first position and make whatever correction is necessary as at (a) above. Turn the plate through 180° and if the bubble moves away from the centre tangent to the curve of the bubble vial, it is not correctly set to the vertical axis of rotation.

This may easily be adjusted by taking half the indicated error by means of the footscrews and half by means of the adjusting screws or nuts of the bubble case.

The above adjustment should be carried with the horizontal circular plate clamped.

7.11 To test that the tangent to the altitude vial curve is normal to the vertical axis, proceed as follows:

Having obtained verticality of the main axis of rotation, bring the altitude bubble to the centre of its run by means of the index setting screw, and relevel the instrument by this more sensitive bubble.

7.12 To eliminate parallax, proceed as follows:

Focus the eyepiece on the cross wires by first screwing outwards and then inwards, until the cross wires are clearly focussed. This eyepiece setting will now be correct for objects at all distances. Pick up a distant object by means of the open sight and see that the inverted image of the same object is seen in the field of view of the telescope. Focus the image of the distant object until a movement of the eye

sideways ca... no appreciable relative movement between the image and the cross w... es. This adjustment shall, of course, be made for every object distance. It shall be ensured that there is no parallax.

7.13 Collimation of the telescope shall be done as follows:

The line of collimation is the line of sight of telescope, passing through the optical centre of the objective system and the point of intersection of the vertical and horizontal cross wires situated in the focal plane. The direction of this line will, therefore, depend on the position of the cross wires, and the latter should be adjusted until the line of sight is normal to the transit axis. It is also required that the transit axis and the line of sight shall meet in a point and that point shall lie on the prolongation of the vertical axis. The line of collimation, as the telescope is turning, sweeps out a plane normal to the transit axis, and if the latter is horizontal, it is coincident with the vertical axis of rotation.

7.14 After the instrument has been tested and adjusted in the manner prescribed in **7.1** to **7.13**, it should be subjected to the following tests to ascertain the accuracy of the adjustments:

a) To test for collimation in azimuth: (that is the plane of vision through the vertical line is perpendicular to the transit axis).

1) Direct the telescope to some small clearly defined object situated 60 to 90 metres away, and by means of the slow motion screws, cause the vertical cross wire to bisect it. Let this point be X;
2) Transit the telescope, and observe the exact position of the same wire upon an object (for example, a staff held horizontally) situated at about the same distance and level, but in opposite direction. Let this reading be Y;
3) Turn the upper part of the instrument through approximately 180° to sight X again; and
4) Transit the telescope, and note where the vertical cross wire now appears with reference to Y. Let this point be Y'.

If Y and Y' coincide, the collimation is correct.

b) To test collimation in azimuth by reference to the horizontal circle:

1) Set the circle to read zero on the horizontal circle, and sight a distant target X; and
2) Turn the alidade exactly through 180°, as indicated by the circle; transit the telescope to bring the target on the horizontal wire. The vertical wire will now be at Y.

If there is no error, X and Y shall coincide.

NOTE — This method assumes the absence of errors in dividing and mounting the circle.

7.14.1 A repetition of either of the tests given in **7.14** on a near object should give results which correspond with those obtained on a distant object. Any discrepancy would be due to the lack of parallelism of the sides along which the focussing lens is translated with the line of collimation. Only the vertical cross wire shall be used for these tests.

a) Test for collimation in altitude (for all focussing distances):
   1) Direct the telescope to some small clearly defined object situated 60 to 90 metres away and make the horizontal cross wire coincide with the target;
   2) Set up a vertical scale at the nearest focussing distance, and without unclamping in altitude, read against the point of intersection of the horizontal wire;
   3) Transit the telescope and rotate it through 180° and bring the horizontal cross wire on to the distant point and close the altitude clamp; and
   4) Refocus the scale, and again read the point of intersection. The absence of coincidence in the two readings indicates error.

b) To check centring of the vertical circle and alignment of the altitude bubble:
   1) Check the verticality of the axis before proceeding further;
   2) Adjust the altitude bubble and set the zero of the vertical circle exactly against the zero of the micrometer using the slow motion screw;
   3) Sight on a staff held vertically at such a distance that it can be accurately read, and take the reading (A) of the horizontal cross wire;
   4) Release the clamp screw, transit the telescope and again set the zero or 180° of the circle exactly to the zero of the micrometer; and
   5) Turn the hand of the instrument through 180° in azimuth and again read the staff (B).

   If the readings are the same, the index setting is correct.

c) *Optical Plummet* — Direct the optical plummet against a cross marked on the ground. When the alidade is rotated in azimuth through 360°, the cross should always be seen in the centre of the plummet.

7.15 Climatic and Durability Tests — These tests are type approval tests and shall be carried out only when agreed to between the manufacturers and the purchasers. These are not to be used in routine testing for performance of instrument during bulk production, although these may be used for control testing of batch samples by arrangement between the manufacturer and the purchaser. The tests shall be carried out in accordance with

IS : 2352-1963*. The outline of tests and degree of severity shall be as given below or as agreed to between the manufacturer and the purchaser.

7.15.1 *Rain Test* — The theodolite shall be put in the rain chamber with taps on, and allowed to remain there for at least 10 minutes. The water spray shall be adjusted to represent a heavy shower of rain.

No damage should be done to any part of the instrument including its telescope, the interior of which should not show any sign of moisture.

7.15.2 *Vibration Test* — The theodolite in its case shall be clamped on vibrating table giving approximately 450 vibrations per minute with an amplitude of 3 mm, for a period of 5 minutes. The direction of the vibrations should be parallel to the line of sight of the telescope. The telescope should be in correct adjustment after this test.

7.15.3 *Jolting Test* — The theodolite housed in its case shall be held in a vertical position and dropped over from a height of 300 mm on to a 225-mm layer of sand contained in a box and covered with a cloth. The telescope shall be in correct adjustment after this test.

8. ACCURACY REQUIREMENTS

8.1 The following accuracies are expected in an ordinary theodolite:

Sl No.	*Test*	*Expected Accuracy*
1	Diopter scale	$\pm 0{\cdot}5\ D$
2	Definition	Should be very good at least for the 2/3 of the field of view in the centre and fair elsewhere
3	Azimuth bubble sensitivity† (20″)	According to IS : 1632-1960†
4	Altitude bubble sensitivity† (20″)	,,
5	Bubble spacing† (2 mm div)	,,
6	Dividing of circles	1 second
7	Dividing of verniers	1 second
8	Circles for concentricity and misplacement of vernier	Combined error 1 second
9	Perpendicularity of cross lines	Line thickness of graticule

*Procedure for basic climatic and durability tests for optical instruments.

†*See* IS : 1632-1960 Specification for bubbles.

Sl No.	*Test*	*Expected Accuracy*
10	Collimations	
	i) Ref to distant object (in azimuth)	±10 seconds
	ii) Ref to horizontal circle	
	iii) All focussing (in azimuth)	0·75 mm between nearest point of focus and distant object
	iv) All focussing (in altitude)	
11	Adjustment of the vertical circle index and altitude bubble	±10 seconds
12	Concentricity of the trunnion axis and fitting carrying altitude bubble	½ division of bubble spacing
13	Sighting vane	10 minutes

9. WEIGHT

9.1 The weight of the theodolite shall not be more than 8 kg.

9.2 The weight of the metal container of the theodolite shall not exceed 3 kg and the weight of the tripod shall not exceed 6 kg.

10. MARKING

10.1 Theodolite, tripod and other attachments, which are packed separately, shall be suitably numbered. The maker's name or trade-mark and the year of manufacture, if desired by the purchaser, shall be legibly and indelibly marked on each instrument and their container.

10.2 The theodolite and its attachments may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act, and the Rules and Regulations made thereunder. Presence of this mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard, under a well-defined system of inspection, testing and quality control during production. This system, which is devised and supervised by ISI and operated by the producer, has the further safeguard that the products as actually marketed are continuously checked by ISI for conformity to the standard. Details of conditions, under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

11. PACKING

11.1 A light metal container shall be provided for protecting the theodolite.

11.2 A convenient carrying device, which may be preferably slung on the back, for the theodolite with the container shall be provided.

11.3 A padded wooden box with locking arrangement shall be provided for transporting the theodolite over long distances.

11.4 The metal container and the padded wooden box shall be so designed that the theodolite may be fitted only in one position.

11.5 Attachments and any accessories, which cannot be accommodated with the theodolite or the tripod, shall be suitably packed separately.

11.6 An instruction booklet containing the broad features of the instrument, the reading devices, the system of adjustments, and the like shall be provided with each theodolite.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N=1kg.m/s^2
Energy	joule	J	1 J=1 N.m
Power	watt	W	1 W=1 J/s
Flux	weber	Wb	1 Wb=1 V.s
Flux density	tesla	T	1 T=1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1c/s (s^{-1})
Electric conductance	siemens	S	1 S=1 A/V
Electromotive force	volt	V	1 V=1 W/A
Pressure, stress	Pascal	Pa	1 Pa=1 N/m^2

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Printed at Today & Tomorrow's Printers & Publishers, New Delhi, India