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METHOD FOR CALIBRATION OF VERTICAL OIL STORAGE TANKS

(*First Revision*)

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Indian Standard

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(First Revision)

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Indian Standard

METHOD FOR CALIBRATION OF VERTICAL OIL STORAGE TANKS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 8 November 1974, after the draft finalized by the Petroleum Measurements Sectional Committee had been approved by the Chemical Division Council.

0.2 This standard was first published in 1961. It is being revised in the light of experience gained and data collected. In this revised standard various characteristics namely, conditions for re-calibration, frequency of calibration and re-calibration, circumferential measurements with different width of plates, datum plate and tank shell temperature have been dealt precisely and the drawings modified suitably.

0.3 The problem of accurate measurement of bulk quantities of liquid petroleum products is not a simple one. Its solution involves accurate engineering and mathematical work, the skill of the experienced oil gauger, and the use of carefully standardized and calibrated equipment. Accuracy in measurement is essential in the sale, purchase and handling of oil. It not only obviates possible disputes between the buyer and the seller, but also provides the only reliable means of maintaining adequate control over storage and distribution losses.

0.4 The measurement of bulk quantities of liquid petroleum products involves various processes, such as temperature measurement of oils, calibration and computation of capacity tables of tanks, and gauging of tanks and calculation of bulk quantities of oils in tanks. The need for accurate calibration of tanks cannot, therefore, be overemphasized. The object of this standard is to lay down methods to be adopted uniformly in the country, to enable accurate calibration of vertical tanks.

0.5 In the formulation of this standard due weightage has been given to international coordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by basing the standard on Petroleum Measurement Manual published in 1969 by the Institute of Petroleum (IP), London.

0.6 For computation of capacity tables for vertical tanks IS : 2008-1961* shall be followed.

0.7 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960†.

1. SCOPE

1.1 This standard prescribes methods for calibration and re-calibration of vertical tanks by strapping and internal measurements. These tanks are meant for bulk storage of petroleum and liquid petroleum products.

2. CONDITIONS FOR MEASUREMENTS

2.1 All data and methods, whereby measurements are obtained, necessary for the preparation of calibration tables, should be in accordance with sound engineering principles.

2.2 When drawings for the tanks are available, all measurements shall be compared with those obtainable from the drawings and measurements showing discrepancies greater than the tolerance specified in **11.3** shall be verified. A similar process of check shall be employed in all cases where reliable information beyond the measurements taken is available.

2.3 Measurements shall be taken only after the tank has been filled at least once at its present location with the product to be stored, to i working capacity or with water to its equivalent height, and such product or water has been held in the tank for at least 24 hours to allow for settling (*see* **8.1**).

2.4 Liquid calibration shall be preferred for any tank or portion of tank not susceptible to adequate or accurate measurement.

3. CONDITIONS FOR RE-CALIBRATION

3.1 Re-calibration of the tank shall be done in the case of the following situations:

a) When restored to service after being disconnected or abandoned;
b) Whenever disassembled and re-erected or moved bodily; and
c) In case of any change in the deadwood, for example, when concrete or other material is placed on the bottom or on the shell of the tank or when the tank is changed in any manner which would affect the incremental or total volume.

*Method for computation of capacity tables for vertical oil storage tanks.
†Rules for rounding off numerical values (*revised*).

4. FREQUENCY OF CALIBRATION AND RE-CALIBRATION

4.1 Tanks with Water Bottom — shall be re-calibrated once in every ten years.

4.2 Tanks with Oil Bottoms

4.2.1 Strapping and tilt checks shall be given not later than 5 years for the new tanks. In case the variation is more than ± 0·25 percent by volume, the tanks shall be completely re-calibrated. However, for lagged tanks re-calibration shall be done at least once in every 10 years.

4.2.2 The third calibration shall be carried out ten years after the second, if the variation observed at full product height is less than ± 0·25 percent by volume during the second calibration as compared with the first calibration. Thereafter, the subsequent calibrations shall be done at ten-year intervals.

4.2.3 The third calibration shall be carried out after five years from the second if the variation mentioned in **4.2.2** is greater than ± 0·25 percent. Such re-calibrations shall be carried out at five-year intervals if the variation each time is in excess of ± 0·25 percent as compared with the previous calibration. However, if at any one calibration, the variation is less than ± 0·25 percent as compared with the last calibration, subsequent calibrations shall be at ten-year intervals.

5. INTERRUPTED MEASUREMENTS

5.1 If the calibration of a tank is required to be interrupted, it may be resumed with minimum delay without repetition of work previously completed provided that:

a) there is no major change in equipment and, as far as possible, no change in personnel;

b) all records of work done are complete and legible; and

c) same hydrostatic head as before is maintained in the tank.

6. DESCRIPTIVE DATA

6.1 Complete descriptive data shall be entered on the Tank Measurements Record Form being used. A recommended record form is shown in Table 1.

6.2 Supplemental pencil sketches or notations, each completed, identified, dated and signed, shall form an important part of field data. These shall be made to indicate typical horizontal and vertical joints, number of plates per course (ring), locations of courses (rings) at which thickness of plates changes, arrangement and size of angles at top and bottom of shell, location and sizes of pipes and manholes, dents and bulges in shell plates, direction of lean from vertical, method used in by-passing a large

TABLE 1 RECOMMENDED RECORD FORM FOR MEASUREMENTS OF VERTICAL TANKS

(*Clause* 6.1)

Report No. ....

Date.............................

Tank No. ....

(Old Tank No.) ....

Owner's Name...

Plant or Property Name..

Location ....

Manufactured by...

Erected by........... ....

Description...

Prepare.............................Copies..............Increments in...........Fractions to ... . Table Form or Size Desired...........................

Height : Shell ....Gauging ....

Type of Roof ....Weight of Floating Roof....................................

Tank Contents............Name...............Average Liquid Temperature, °C..............

Gauge................cm or mm Innage to: Shelf [ ] Floor [ ] or Outage [ ]

Hydrometer Reading ....at ....°C.............Sample Temperature

Gauging Reference Point to Top of Top Angle...........cm or mm..............Normal

Service ....

Shell Circumferences or Diameters:

A.............................D.............................G.............................
B.............................E.............................H.............................
C.............................F.............................J.............................

Description of Shell Plates and Joints*:

Course (ring) No.	Thickness	Type of vertical joint	Set, in or out	Width of lap of strap	Thickness of strap	No. of joints	Exposed course (ring) height	Inside course (ring) height
5.	....	....	....	....	....	....	....	....
4.	....	....	....	....	....	....	....	....
3.	....	....	....	....	....	....	....	....
2.	....	....	....	....	....	....	....	....
1.	....	....	....	....	....	....	....	....

(*Continued*)

TABLE 1 RECOMMENDED RECORD FORM FOR MEASUREMENTS OF VERTICAL TANKS — *Contd*

Bottom Course (Ring) Shell Connections†

No.	Description	Elevation, top of floor to bottom of connection
1.	....	....
2.	....	....
3.	....	....
4.	....	....

Type of Bottom..................................Height of Crown..................................

Deadwood and Remarks (Use reverse side, if necessary):

Description	No.	Size	Elevation	
			From	To
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

Thickness..Measurements by...............

Amount of Tank Lean from Vertical‡

Circumference Tape Used............................Date Checked...........at.................

Tank Measured by......................................For..

Deadwood and Tank Bottom — Use separate sheets. For each piece or item of deadwood record description, size, number of occurrences, and location related to other height measured data recorded.

Explanatory Notes (such as type of bottom, height or depth of crown, etc)

*Show sketches of vertical and horizontal joints at the back of this table.

†Show circumferential location on plan view sketched on back of this table.

‡Show direction of lean on plan view sketched on back of this table.

obstruction, such as clean-out box or insulation box located in the path of a circumferential measurement, location of tape path, location and elevation of possible datum plate and all other items of interest and value which will be encountered.

6.3 All measurements made by the tank calibrator shall be recorded on site and shall not be subjected to subsequent correction.

7. DEGREE OF ACCURACY

7.1 In order to obtain maximum obtainable accuracy in calibration tables, adjustments for effects of the following variables shall be incorporated in the tables:

a) Expansion and contraction of steel tank shell due to liquid heads and temperature,

b) Tilt from upright position, and

c) Tank bottoms that are irregular in shape.

NOTE — The degree of accuracy desired or required in the completed calibration table for a specific tank shall be the governing factor in determining the procedure to be followed.

8. EXPANSION AND CONTRACTION OF STEEL TANK SHELLS DUE TO LIQUID HEAD AND TEMPERATURE

8.1 These effects shall be eliminated by strapping the tank when it is at least two-thirds full with water or approximately full with the product (*see* also **2.3**). The strapping record shall include water or product level from a known reference point, temperature of the tank contents and that of adjacent air.

8.1.1 In the case of non-insulated metal tanks the temperature of the shell shall be taken, in general, as the mean of the adjacent liquid and ambient temperatures on opposite sides at the same location. In such a case:

$$t_S = \frac{t_L + t_A}{2}$$

where

t_S = temperature of the shell,

t_L = liquid temperature, and

t_A = ambient temperature.

8.1.2 For insulated metal tanks the temperature of the shell may be taken as closely approximating the adjacent liquid temperature. In which case, $t_S = t_L$.

SECTION I CALIBRATION BY STRAPPING

9. GENERAL

9.1 This method is based on the measurement of external circumferences which are subsequently corrected to yield the true internal circumferences.

9.2 Circumferences shall be measured under conditions of liquid head as given under **2.3** and **8.1**.

9.3 The stipulated number of external circumference measurements, together with the subsidiary measurements, where necessary, to correct for deviation of the tape from the true circular path, shall be obtained as described under **11.1**.

9.4 An internal diameter may be measured at approximately the same height as that at which a circumference has been measured, if verification of that circumferential measurement is desired.

9.5 It may be necessary in practice to refer all tank dips to a datum point other than the datum point used for the purposes of tank calibration. If so, the difference in level between these datum points shall be determined either by normal surveying methods or by other suitable means.

9.6 The overall height shall be measured, using dip-tape and dip-weight, from the dipping datum point to the reference point (the dipping reference point) on the dip hatch. This overall height shall be recorded and marked on the tank at the dip hatch.

10. EQUIPMENT

10.1 Steel Strapping Tapes — shall comply with the specifications under **A-1.1**. The tape shall be greased well before use.

10.2 Spring Balance — reading up to 10 kg with 0·1 kg graduations, for measuring the tension applied to the tape. It is preferable to have two balances. Spring balance shall comply with specifications given under **A-1.2**.

10.3 Step-Overs — as described under **A-1.3**. This is used to correct deviations of the tape from its normal circular path, namely, passing over fittings or joints between plates.

10.4 Dip-Tape and Dip-Weight — complying with the specifications of IS : 3515-1966*.

*Specification for tapes for use in measurements of oil quantities.

10.5 Loops and Cords — One or more metal loops which can slide freely on the tape and to which are attached two cords, each of sufficient length to reach from the top of the tanks to the ground. The tape is positioned and its tension evenly distributed by passing these loops around the tank.

10.6 Accessory Equipment

a) Rope
b) Hooks
c) Safety Belts
d) Ladders

10.7 Miscellaneous Equipment

a) Steel Rule
b) Spirit Level
c) Awl and Scriber
d) Marking Crayon
e) Record Paper
f) Plumb Line
g) Dumpy Level
h) Positive Displacement Meter

11. CIRCUMFERENCE MEASUREMENTS

11.1 Strapping Levels

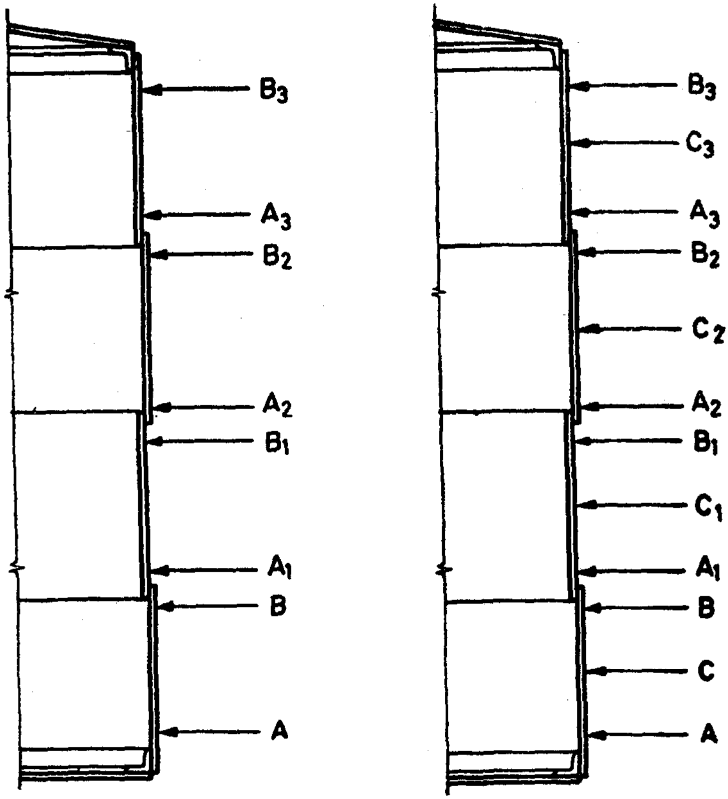
11.1.1 Circumference shall be measured by a minimum of two strappings per course (ring) at the following levels:

a) *For riveted tanks with width of plates up to 2 metres*

1) at 7 percent to 10 percent of the height of exposed portion of each course (ring) above the level of the top of the bottom angle iron of the tank and above the upper edge of each horizontal overlap between courses (rings) (*see A* of Fig. 1A), and

2) at 7 percent to 10 percent of the height of exposed portion of each course (ring) below the lower edge of each horizontal overlap between courses (rings) and below the level of the lowest part of the top angle iron of the tank (*see B* of Fig. 1A).

b) *For riveted tanks with width of plates over 2 metres* — In addition to the circumferential measurements as in (a) third measurement at point *C* which is the midpoint of *A* and *B* shall be done (*see* Fig. 1B).



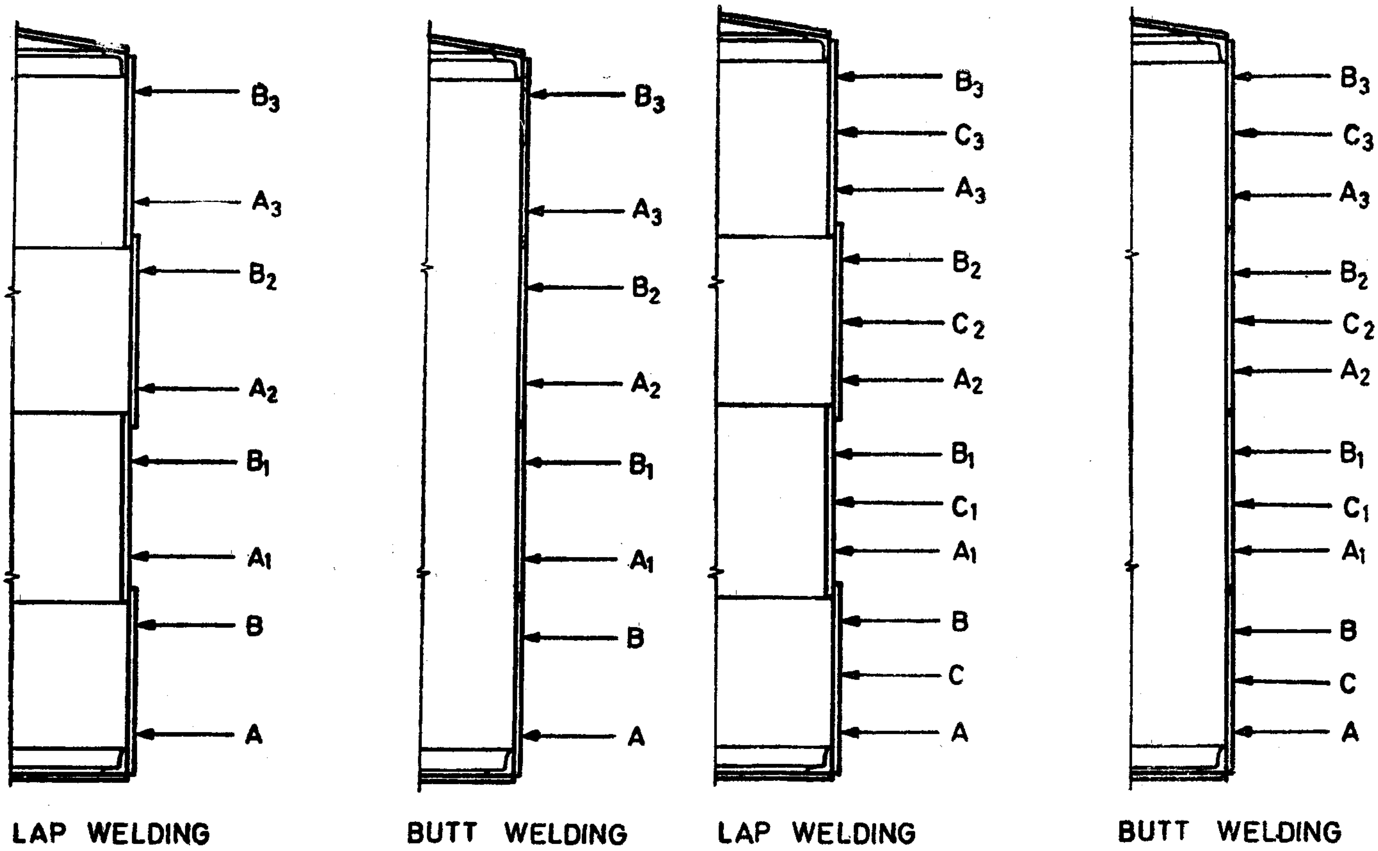
1A Width of Plates Up to 2 m 1B Width of Plates Over 2 m

NOTE — Point '*C*' to be the midpoint of '*A*' and '*B*'.

FIG. 1 LOCATIONS OF MEASUREMENTS OF RIVETED TANKS

c) *For welded tanks with width of plates up to 2 metres* — Two levels (*see* *A* and *B* of Fig. 2A) the upper and the lower levels, at the top and bottom of courses (rings), shall be 20 percent of the height of the exposed portion of the respective course (ring) away from the angle irons or seams.

d) *For welded tanks with width of plates over 2 metres* — In addition to the circumferential measurements as in (c), third measurement at point *C* which is the midpoint of *A* and *B* shall be done (*see* Fig. 2B).



2A Width of Plates Up to 2 m

2B Width of Plates Over 2 m

NOTE — Point '*C*' to be the midpoint of '*A*' and '*B*'.

FIG. 2 LOCATIONS OF MEASUREMENTS OF WELDED TANKS

11.1.2 Circumferential tape paths, having been located at elevations as under **11.1.1**, shall be examined for obstructions and type of vertical joints. Projections of dirt and scale shall be removed along each path.

11.1.3 Occasionally, some feature of construction, such as a manhole or insulation box, may make it impracticable to use a circumference elevation at the prescribed location. If the obstruction can be spanned by a step-over, then the circumference shall be measured at the prescribed elevation, using a suitable method given under **11.4.** If the obstruction cannot be conveniently spanned by a step-over, then a substitute path located nearer to the centre of the course (ring) may be chosen. The strapping record shall include the location of the substitute path and the reason for the departure.

11.1.4 The type and characteristics of vertical joints shall be determined by close examination in order to establish the method of measurement and equipment required. If the tape is not in close contact with the surface of the tank throughout its whole path owing to the vertical joints, a step-over shall be applied so that a correction may be calculated to adjust the gross difference for this effect.

11.2 Strapping Procedure

11.2.1 The tanks shall be strapped by either of the methods described under **11.2.2** and **11.2.3.** In either case a tension of 4·5±0·5 kg shall be applied to the tape and, if necessary, transmitted throughout its length by suitable means namely, by means of metal loops sliding freely on the tape, the loops being passed around the tank by operators with the aid of light chain or cords. The tape path shall be parallel with the circumferential seams of the tank.

11.2.2 If the tape to be used is not long enough to encircle the tank completely then, after the level of the tape path has been chosen, fine lines shall be scribed perpendicular to this path to allow the circumference to be measured in sections. The scribed lines shall be drawn in the middle circumferential third of any plate at such distances as will ensure that the whole of the length of the tape used is under the observations of one or other of the calibrators. Subject to the conditions under **11.1.3** and **11.1.4**, the external circumference of the tank is then the sum of the lengths between the scribed lines.

11.2.3 If the tape to be used can encircle the tank completely then, after the level of the tape path has been chosen, the tape is passed around the circumference and held so that the first graduated centimetre lies within the middle circumferential third of any plate. The other end of the tape shall be brought alongside. The tension is then applied through the spring balance and transmitted throughout the length of the tape.

11.2.4 After a circumference has been measured (*see* **11.2.3**), the tape shall be shifted a little around the tank, brought to level and tension as in **11.2.3**, and the reading repeated. The final reading shall be arithmetic mean of the two readings if the width of the plates is up to 2 metres (*see* Fig. 1A and 2A). In case the width is more than 2 metres, weighted average of the three readings shall be taken (*see* Fig. 1B and 2B).

11.3 Tolerances — Measurements shall be read to the nearest 1 mm and within the following tolerances when readings are taken at the same point:

Circumference	*Tolerance*
m	mm
Up to 30	± 2
Over 30 and up to 50	± 4
,, 50 ,, ,, ,, 70	± 6
,, 70 ,, ,, ,, 90	± 8
,, 90	± 10

11.4 Step-Overs

11.4.1 If the tape shall cross obstructions, such as projections, deformities, fittings or lapped joints, it will deviate from a true circular path and an erroneous circumferential measurement will result. In order to avoid such errors, a step-over is used to measure the correction to be applied for such obstructions.

11.4.2 *Construction* — A step-over is a frame rigidly holding two scribing points, and of such dimensions that the points may be applied to the tape well clear of the obstruction and of its effects on the tape path, while the frame itself does not touch either the obstruction or the tank shell. Rigidity of construction is essential; suitable designs are illustrated in Fig. 3.

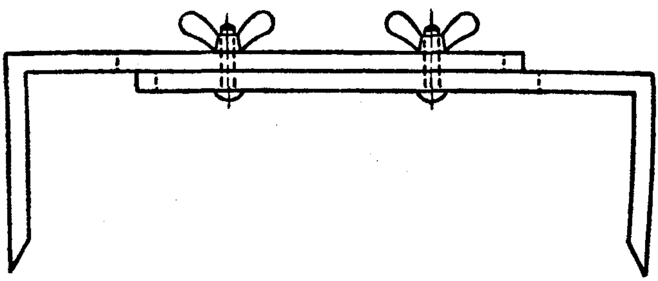


FIG. 3 STEP-OVER

11.4.3 *Use of Step-Overs*

11.4.3.1 For obstructions, the strapping tape shall be stretched as if in measurement of a circumference on the tank which is being calibrated, but not within 30 cm of any horizontal seam. The scribing points shall then be applied to the tape near the middle of a plate where the tape is fully in contact with the tank surface. The length between the points, as measured on the curved tape, is then read off as closely as possible, fractions of tape divisions being estimated. The readings shall be repeated on a minimum of two and maximum of four plates equally spaced around the circumference, and the average of the results taken, as the step-over will vary with the tank diameter and the course concerned, since they are made on surfaces differently curved.

11.4.3.2 With the tape still in position and under the tension used in strapping, the step-over shall be applied to the tape on either side of each obstruction lying on the tape path, and readings shall be taken of the lengths of tape included between the scribing points. All step-over readings shall be recorded for subsequent use in calculation.

11.4.3.3 Care shall be taken in placing the instrument in a truly level position at each obstruction to avoid distortions in the circumferential path. In the case of a step-over of relatively long space, the use of a spirit level is recommended as an aid in determining its correct position before scribed marks are struck off on the places.

11.4.3.4 When the butt-strap or lap joints, or tank shell, include rivets or other features which exert uneven effects on the resultant void between tape and tank from joint to joint, then a step-over will be required. The span of the instrument should be measured prior to use in accordance with **11.4.3.1**. The two legs shall be separated by a distance sufficient to span each void between tape and shell encountered. The legs shall be of sufficient length to prevent contact between the interconnecting member and the tank plate or obstruction. Stretch the tape over the joints and place the step-over in position at each location of void between tape and shell, completely spanning the void, so that the scribing points contact the shell at an edge of the tape. The length of tape encompassed by the scribing points, with the tape maintained in proper position and tension, should be estimated to the nearest 0·5 mm. At each step-over location, therefore, the difference between the length of tape encompassed by the scribing points and the known span of the instruments is the effect of the void, at that point, on the circumference as measured. The sum of such differences in any given path, subtracted from the measured circumference, will give the corrected circumference.

12. SHELL PLATE THICKNESS

12.1 Where the type of construction leaves the plate edges exposed, a minimum of four thickness measurements shall be made on each course (ring) at points approximately equally spaced about the circumference.

The arithmetical average of the measurements for each course (ring) shall be recorded; all thickness measurements, properly identified, shall be noted on a supplemental data sheet which shall form a part of the measurements record. Care shall be taken to avoid plate thickness measurements at locations where edges have been distorted by caulking.

12.2 Where plate edges are concealed by the type of construction, the strapping record shall be marked 'not obtainable at tank'. Alternately, plate thickness measurement may be obtained as described under **12.3**.

12.3 Plate thickness measurements obtained before or during construction, and recorded on a properly identified strapping record, may be acceptable. In the absence of any direct measurements of plate thickness obtained and recorded before or during construction either those shown on the fabricator's drawings may be accepted and so identified in the calculation records or any other practicable method may be used for measurements of plate thickness.

12.4 For the calibration of old tanks, fresh shell thickness measurements should be obtained preferably by non-destructive methods.

12.5 Whenever the shell thickness is taken from drawings or by non-destructive techniques, then the paint film thickness should be added to the shell thickness. Further, the number of coats of paint applied should also be recorded in the data sheet. For this, a suitable paint measuring equipment shall be used for the purpose.

13. VERTICAL MEASUREMENTS

13.1 A tape shall be suspended internally along the wall of the shell from the top curb angle to the bottom course (ring) and the height of the course (ring) measured to the nearest millimetre. The difference in height between the datum plate at which dip is taken and the bottom course (ring) shall be measured and the readings of the course (ring) height shall be transferred to the datum plate by applying the correction (*see* Fig. 4).

Example:

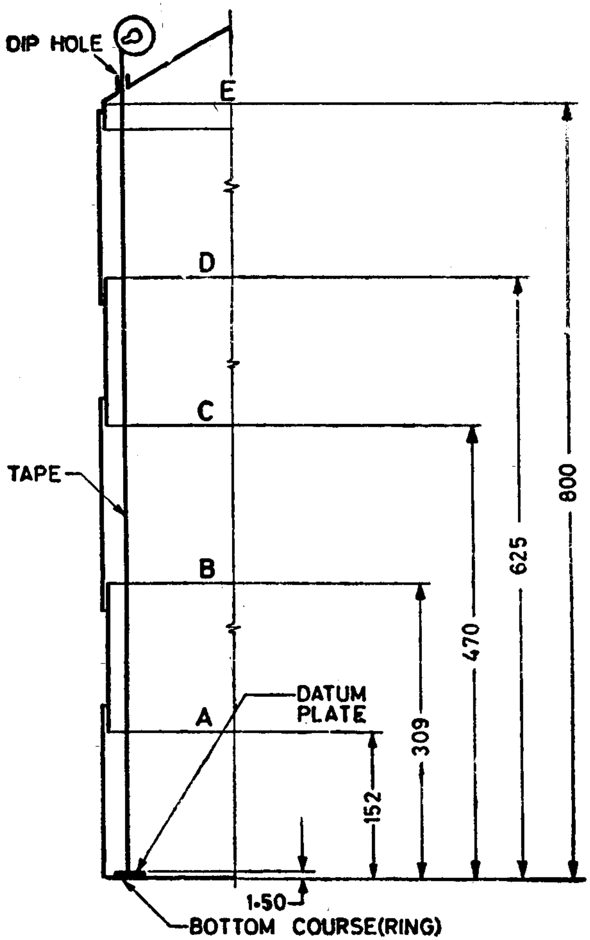
In Fig. 4, the difference between bottom course (ring) and datum plate is 152 − 150·5 cm = 1·5 cm. Applying this correction the corrected height of the course (ring) at

B = 307·5 cm

C = 468·5 cm

D = 623·5 cm

E = 798·5 cm



All dimensions in centimetres.

FIG. 4 MEASUREMENT OF COURSE (RING) HEIGHT INTERNALLY

13.2 When it is inconvenient to measure the course (ring) heights internally, then they shall be computed from external measurements, due allowance being made for the effect of horizontal seam overlaps. The h eights obtained shall be the vertical distances, measured to the nearest 5 mm, between successive edges of the courses (rings) as exposed internally in the tank. For this purpose, in the case of lap joints, it will be necessary to determine the width of lap in each course (ring).

13.3 If necessary, heights at more than one vertical point around the tank may be taken and, for each course (ring), an average of the results obtained.

14. DEADWOOD

14.1 Any fitting which adds to or subtracts from the capacity of the tank is called deadwood. Deadwood shall be accurately accounted for, as to size and location to the nearest millimetre in order to permit:

a) adequate allowance for volumes of liquid displaced or admitted by the various parts like isolation valves, and

b) adequate allocation of the effects at various elevations within the tank.

14.2 Deadwood should be measured, if possible, within the tank. Dimensions shown on the builder's drawings may be accepted if actual measurement is impracticable.

14.3 Measurements of deadwood should show the lowest and the highest levels, measured from the tank bottom adjacent to the shell, at which deadwood affects the capacity of the tank. Measurements should be in increments which permit allowance for its varying effect on tank capacity at various elevations.

14.4 Large deadwood of irregular shape may have to be measured in separate sections suitably chosen.

14.5 Work sheets on which details of deadwood are sketched, dimensioned and located, should be clearly identified and should become part of the strapping record.

14.6 For variable deadwood, such as nozzles and manholes, encountered in the bottom one or two courses (rings) of the tanks, an average deadwood correction shall be made.

15. GAUGE HATCH

15.1 The gauge hatch or gauging column for taking tank dips should be located within 60 cm from the tank shell.

16. DATUM PLATE

16.1 The datum plate is a level metal plate, preferably attached to the tank shell located directly under the reference point to provide a fixed contact surface for the innage bob (*see* Fig. 4).

17. TANK BOTTOMS

17.1 Flat Type

17.1.1 Tank bottoms which are flat and stable under varying liquid loads will have no effect on tank capacity determined on the basis of geometric principles.

17.1.2 Where tank bottom conditions of irregularity, slope and instability exist, and where correct capacities cannot be determined conveniently from linear measurements alone, it shall be necessary to resort either to liquid calibration or to floor survey.

17.1.3 *Liquid Calibration* — The procedure in carrying out the liquid calibration is to fill into the tank quantities of known volume of water or other non-volatile liquid until the datum point is just covered and the total quantity recorded. Additional quantities shall then be added until the highest point of the bottom is just covered. This may be done in one or more stages as desired and the dip reading and quantity at each stage recorded. It is convenient for dip readings to be taken at intervals of approximately 3 cm, the successive intervals not necessarily being identical.

17.1.3.1 This liquid may conveniently be measured into the tank by a positive displacement meter which should be previously calibrated for the liquid and rate of flow to be used. Alternatively, an accurately calibrated tank may be used.

17.1.4 Volumes for the tank calibration table above the elevation shall be computed from linear measurements.

17.1.5 *Floor Survey* — The floor survey consists in recording levels of floor by means of dumpy level with the help of spirit levels. The floor should be marked in circular segments or in 1·5-metre square or squares corresponding to the width of the bottom plates. The levels taken at the centre of the squares will define the profile and the geometric pattern of the bottom ˜the tank. Thus, the capacity of the tank may be calculated.

17.1.6 During the tank bottom calibration the difference in height between the datum plate and the bottom of the bottom course (ring) should be recorded, wherever possible.

17.2 Conical, Hemispherical, Semi-ellipsoidal and Spherical Segment — Tank bottoms conforming to geometrical shapes have volumes which may either be computed from linear measurements or measurements by liquid calibration by incremental filling or by floor survey, as desired. Any appreciable differences in shape affecting the volume, such as knuckle, radii, etc, shall be measured and recorded in sufficient detail to permit computation of the true volume.

18. MEASUREMENT OF TILT

18.1 Measurements shall be taken to determine the amount, if any, by which the tank is tilted. This can conveniently be done by suspending a plumb line from the top angle and measuring the offset at the bottom angle (*see* Fig. 5). Alternatively, if the tank bottom is being calibrated by floor survey with a dumpy level as in **17.1.5**, the tilt can be estimated by taking readings along the periphery of the tank bottom. Also, if a liquid calibration of the bottoms is being made as outlined in **17.1.3**, the tilt can be determined by taking measurements from the surface of the liquid to the bottom of the tank. In any of these methods, measurements shall be taken at each vertical weld of the first shell course.

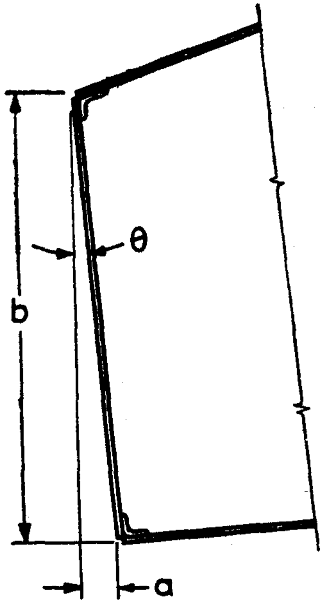


FIG. 5 ANGLE OF TILT OF THE TANK

19. FLOATING-ROOF TANKS

19.1 All calibration measurements shall be made exactly as for tanks with fixed roofs.

19.2 Liquid Calibration for Floating-Roof Displacement

19.2.1 Corrections for floating-roof displacement arising from the weight of the roof and the deadwood associated with it shall be allowed for in the calibration measurement.

19.2.2 If weight of the floating-roof is accurately known, correction for the displaced liquid may be applied knowing density and temperature of the tank contents, at the time of determining the actual inventory.

19.3 Alternately, displacement due to the floating-roof and deadwood may be determined by admitting oil to the tank until the dip reading is just below the lowest point of the roof. Known quantities accurately determined (for example, by flow meter or delivery from a portable tank which has been accurately calibrated) are then admitted to the tank and the corresponding dip readings recorded at a number of suitable intervals until the point is reached when the roof just becomes oil borne. Record the density and temperature of oil used.

19.3.1 It is advisable to use a liquid of nearly the same density as that for which tank is intended. If this is not practical, water may be used and suitable corrections applied.

19.3.2 During liquid calibration any space under the roof that will trap gas should be vented to the atmosphere.

19.3.3 Before liquid calibration the height of the lowest joint of the roof with reference to datum point should be recorded, wherever possible.

19.3.4 To assess the point at which roof becomes oil borne the following procedure may be followed:

> With the roof resting fully on its supports, paint four short horizontal white lines about 3 cm wide on the tank sides in such a position that, viewed from some definite point, their lower edges are just above four similar lines marked on the roof edges or shoes. Then slowly pump oil into the tank; when all roof markings are seen to have moved upwards, regard the roof as oil borne, and take the dip reading of the oil at this level. Alternatively, from some chosen viewpoint on the dipping platform, note the position of the roof against rivet heads on vertical seam or other markings on the tank walls instead of paint marks. In both cases extend the points of reference round the greater part of the tank interior, and see movement relative to all points.

19.4 Floating Weight — The floating weight of the entire roof shall include weight of roof plus half the weight of the rolling ladder and other hinged and flexibly supported accessories that are carried up and down in the tank with the roof. These are calculated by the tank fabricator and given on the drawing and on the roof name-plate.

19.5 Deadwood

19.5.1 Fixed deadwood shall be measured as described in **14**. The drain lines and other accessories attached to the underside of the roof shall be treated as fixed deadwood in the position they occupy when the roof is at rest on its supports.

19.5.2 When all or part of the weight of the roof is resting on its supports, the roof itself is deadwood and as the liquid level rises around the roof, its geometric shape will determine how it should be deducted. The geometric shape should be taken from the fabricator's drawings or measured in the field with the aid of an engineer's level while the roof is resting on its supports.

20. VARIABLE VOLUME ROOFS

20.1 Roofs such as lifter, flexible membrane, breather, or balloon, may require special deadwood measurements for roof parts that are sometimes submerged. When these parts, such as columns, are fixed relative to the tank shell, they should be measured as deadwood in the usual way. When these parts move with the roof and hang down into the liquid, they should be deducted as fixed deadwood with the roof in the lowest position. Details may be secured from the fabricator or measured in the field.

20.2 Some variable volume roofs have flexible members which may float on the surface when the membrane is deflated and the liquid level is high. The floating weight of the membrane displaces a small volume of liquid. Data on the floating weight should be secured from the fabricator and supplemented, if necessary, by field observation and measurement.

20.3 Some variable volume roofs have liquid seal troughs or other appurtenances which make the upper outside part of the shell inaccessible for outside circumference measurements. Liquid calibration of this portion of the shell may be made, or (a) theoretical dimensions may be taken from the fabricator's drawings, or (b) the highest measurable circumferential measurement may be used as a basis for the portion of the tank that cannot be measured. When the method (a) or (b) is used, it shall be so indicated on the calibration table.

SECTION II CALIBRATION BY INTERNAL MEASUREMENT

21. GENERAL

21.1 This method is based on the measurement of internal diameters.

21.2 Diameters shall be measured only after the tank has been filled at least once at its present location with the product to its working capacity or with water to its equivalent height, and such product or water has been held in the tank for at least 24 hours to allow for setting.

21.3 The stipulated number of internal diameters shall be obtained as described under **23.1.4**.

21.4 Where practicable, an external circumference shall be measured at approximately the same height as that at which a set of diameters of which a verification is desired, has been taken. The resulting internal diameters shall be compared and, if a discrepancy is found, the measurements shall be verified.

21.5 It may be necessary in practice to refer to all tank dips to a datum point other than the datum point used for the purpose of tank calibration. If so, the difference in levels between these datum points shall be determined either by normal surveying methods or by other suitable means.

21.6 The overall height shall be measured using dip-tape, and dip-weight, from the dipping datum point mentioned in **21.5**, to the reference point (the dipping reference point) on the dip hatch. This overall height shall be recorded and marked on the tank at the dip hatch.

22. EQUIPMENT

22.1 Steel Tape — complying with the specification given under **A-2.1**. The tape shall be greased well before use.

22.2 Dynamometer — complying with the specification given under **A-2.2**. This is used for applying tension to the steel tape.

22.3 Other equipment shall be as given under **10**.

23. DIAMETER MEASUREMENTS

23.1 Procedure

23.1.1 All diameter measurements shall be made with a tension of $4·5 \pm 0·5$ kg applied to the tape as indicated by the dynamometer.

23.1.2 All tape measurements shall be recorded as read, that is, without including the length of the dynamometer.

23.1.3 The dynamometer length at 4·5 kg shall be taken accurately before it is put into commission, and subsequently checked before and after calibration of each tank, the final check being made before leaving the site.

23.1.4 The measurements shall be taken between diametrically opposite points at the following levels on eachcourse (ring), the minimum number allowable at each level being two on each course (ring), at right angles to each other:

a) *For riveted tanks with width of plates up to 2 metres* (*see Fig.* 1A):

1) at 10 percent of the height of exposed portion of each course (ring) above the level of the top of the bottom angle iron of the tank and above the upper edge of each horizontal over-lap between courses (rings), and

2) at 10 percent of the height of exposed portion of each course (ring) below the level of the lower edge of each horizontal overlap between courses (rings) and below the level of the lowest part of the top angle iron of the tank.

b) *For riveted tanks with width of plates over* 2 *metres* (*see Fig.* 1B) — In addition to the diametric measurements as in (a) above third measurement at point *C* which is the midpoint of *A* and *B* shall be done.

c) *For welded tanks with width of plates up to* 2 *metres* (*see Fig.* 2A) — Two levels, the upper and the lower levels, at the top and the bottom of courses (rings), shall be 20 percent of the height of the exposed portion of the respective course (ring) away from the angle irons or seams.

d) *For welded tanks with width of plates over* 2 *metres* (*see Fig.* 2B) — In addition to the diametric measurements as in (c) above third measurement at point *C* which is the midpoint of *A* and *B* shall be done.

e) *All tanks* — No measurement shall be taken nearer than 30 cm to any vertical seam.

23.1.5 If for any reason it is impracticable to take measurements at the positions described in **23.1.4**, then the diameters shall be taken as close to the proper position as practicable, but not nearer the horizontal seams than is specified under **23.1.4**.

23.1.6 The levels at which measurements have been taken shall be recorded together with reasons for abandoning the prescribed levels.

23.1.7 Measurements shall be taken with the zero end of the steel tape attached to the dynamometer, one operator placing the dynamometer on the predetermined point and the second operator placing the rule end-on to a point diametrically opposite. The tape with the graduated side wholly upwards is then pulled along the rule until the requisite tension is registered by the sounding of the buzzer in the dynamometer. The relative position of tape and rule is maintained by a firm grip until the rule is removed from the side of the tank and the measurement read on the tape at the end of the rule which was previously in contact with the tank side. The operation shall be repeated at the various positions at which measurements are required throughout the tank. The measurements shall be recorded clearly in white chalk on the steel plates in such a manner as to indicate the positions at which they were taken.

23.1.8 Each measurement of diameter shall be recorded to the nearest 1 mm.

23.2 All other measurements shall be followed in accordance with Section I.

APPENDIX A

(*Clauses* 10 *and* 22)

RECOMMENDED SPECIFICATIONS FOR EQUIPMENT

A-1. EQUIPMENT FOR STRAPPING METHOD

A-1.1 Steel Tapes

A-1.1.1 *Material* — carbon steel of quality as currently used for measuring tapes and suitably treated to resist corrosion.

A-1.1.2 *Construction* — Each tape shall be fitted at its end with a swive allowing easy attachment of the spring balance 10 to 15 cm from the first graduation on the tape. Tape reels, cases and other incidental fittings not specifically mentioned in this specification may be provided as desired.

A-1.1.3 *Dimensions* — Width shall be 6 or 8 mm, depending upon the overall length; thickness shall be uniform and approximately 0·4 mm. A 6-mm tape is preferable for overall lengths over 100 metres and for riveted tanks.

A-1.1.4 *Graduation* — The graduation shall be only on one side of the tape. The tape shall be graduated from the beginning of its markings at every whole metre of its length. At least the first metre of its graduated length shall be further subdivided into decimetres, centimetres and millimetres.

A-1.1.5 *Figuring* — The length from the zero graduation shall be clearly shown at every metre with figuring at every centimetre, and at each multiple of 10 cm in larger figures on those parts of the tape so subdivided. The figures and graduations shall be bright, and the tape shall be deeply etched, leaving the markings well raised against a dead black or white background as required.

A-1.1.6 *Overall Length* — as required.

A-1.1.7 *Calibration and Allowable Error* — When the whole length of the tape is held horizontally, supported throughout, at 20°C and under 4·5 kg tension, its reading at any graduation shall not be in error by more than 1·5 mm.

A-1.1.7.1 The tape shall be proved to meet these conditions either by a certificate of National Physical Laboratory or by a certificate of any other institution authorized or recognized by the Government of India to issue such a certificate.

A-1.1.8 *Marking* — Each tape shall bear the manufacturer's or vendor's trade-mark and serial number.

A-1.2 Spring Balance

A-1.2.1 *Material* — Nickel-plated brass body and handle with steel spring and hook.

A-1.2.2 *Construction* — The balance shall be of the usual design and shall have a loop handle at one end, through which to apply tension, and at the other a hook for attaching it to the tape swivel; this hook shall be fitted with a self-closing device so that the tape does not become detached if tension is slackened.

A-1.2.3 *Graduation* — The balance shall be graduated to show every 0·1 kg from 0 to 10 kg. The smaller scale divisions shall not be less than 1 mm apart.

A-1.2.4 *Calibration and Permissible Error* — When a weight of 4·5 kg is hung on the hook of the balance, the reading of the pointer on the scale shall not be in error by more than 0·1 kg.

A-1.3 Step-Over

A-1.3.1 *Construction* — The step-over is a frame holding two scribing points rigidly and at such a distance apart as meets the conditions of use laid down under **11.4**. The frame may be constructed of wood; it should be painted if required.

A-2. EQUIPMENT FOR INTERNAL MEASUREMENT METHOD

A-2.1 Steel Tapes

A-2.1.1 *Material* — carbon steel of quality as currently used for measuring tapes and suitably treated to resist corrosion.

A-2.1.2 *Construction* — Each tape shall be fitted with a D-loop at its end, allowing easy attachment of the dynamometer. Tape reels, cases and other incidental fittings not specifically mentioned in this standard may be provided as desired.

A-2.1.3 *Dimensions* — width 6 or 8 mm; thickness uniform and approximately 0·25 mm.

A-2.1.4 *Graduation* — The graduation shall be only on one side of the tape. The zero graduation shall be at the outside of the end of the D-loop (D-loop included). The tape shall be graduated at every metre of its length starting from its zero, and preferably the whole length of the tape shall be further divided into decimetres, centimetres and millimetres.

A-2.1.5 *Figuring* — The length from the zero graduation shall be clearly shown at every metre, with figuring at every centimetre and at each multiple of 10 cm in large figures on those parts of the tape so divided.

The figures and graduations shall be bright, and the tape shall be deeply etched, leaving the markings well raised against a dead black background.

A-2.1.6 *Overall Length* — as required.

A-2.1.7 *Calibration and Permissible Error* — When the whole length of the tape is held horizontally, supported throughout, at 20°C and under 4·5 kg tension, its reading at any graduation shall not be in error by more than 1·5 mm.

A-2.1.7.1 The tape shall be proved to meet these conditions either by a certificate of National Physical Laboratory or by a certificate of any other institution authorized or recognized by the Government of India to issue such a certificate. The weight of the tape in kilograms per metre shall be certified by the manufacturer, or determined satisfactorily otherwise.

A-2.1.8 *Marking* — Each tape shall bear the manufacturer's or vendor's trade-mark and serial number.

A-2.2 The Harling-Redwood Dynamometer or Equivalent

A-2.2.1 *Material* — aluminium body and handle, steel spring and hook.

A-2.2.2 *Construction* — The instrument consists essentially of a box containing a spring. electric buzzer and accumulator, so arranged that pull of 4·5 kg applied to the hook causes the buzzer to operate.

A-2.2.3 *Graduation* — The inset scale shall be graduated in 0·5 kg from 2 to 7 kg. The scale divisions shall be not less than 2 mm apart. The instrument shall be adjusted by hanging a 4·5 kg weight on the hook, the scale being provided for a preliminary and approximate setting.

A-2.2.4 *Calibration and Permissible Error* — When a weight of 4·5 kg is hung on the hook, the electric contact shall operate the buzzer, the allowable tolerance being ± 0·1 kg.

A-2.2.5 *Marking* — Each dynamometer shall bear the manufacturer's name and serial number.

A-2.3 Scale or Rule

A-2.3.1 *Materials* — boxwood or lancewood, and brass.

A-2.3.2 *Construction* — The rule shall have brass-tipped ends.

A-2.3.3 *Dimensions* — The rule shall be 1 m long, 2·5 cm wide, and 5 mm thick.

A-2.3.4 *Graduation* — The rule shall be graduated in centimetres and millimetres throughout.

A-2.3.5 *Calibration* — The rule shall bear the acceptance stamp of a recognized standardizing authority.

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