INTERNATIONAL STANDARD

ISO 7507-3

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Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks —

Part 3: Optical-triangulation method

Pétrole et produits pétroliers liquides — Étalonnage des réservoirs cylindriques verticaux

Partie 3: Méthode par triangulation optique

Reference number
ISO 7507-3:1993(E)

Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7507-3 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Sub-Committee SC 3, *Static petroleum measurement*.

ISO 7507 consists of the following parts, under the general title *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks*:

— *Part 1: Strapping method*

— *Part 2: Optical-reference-line method*

— *Part 3: Optical-triangulation method*

— *Part 4: Internal electro-optical distance-ranging methods*

— *Part 5: External electro-optical distance-ranging methods*

At the time of publication of this part of ISO 7507, parts 4 and 5 were in course of preparation.

Annexes A, B, C, D, E and F form an integral part of this part of ISO 7507.

Introduction

This method describes the calibration of vertical cylindrical tanks by means of optical triangulation using theodolites. The circumference of the tank is determined at different levels by reference to a base line which may be either a reference circumference measured by strapping or a base line between two stations of a theodolite measured by means of a tape or by an optical method. External circumferences are corrected to give true internal circumferences.

The method is an alternative to other methods such as strapping (ISO 7507-1) and the optical-reference-line method (ISO 7507-2).

Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks —

Part 3:
Optical-triangulation method

1 Scope

1.1 This part of ISO 7507 specifies a calibration procedure for application to tanks above 8 m in diameter with cylindrical courses that are substantially vertical. It provides a method for determining the volumetric quantity contained within a tank at gauged liquid levels. The measurement required to determine the radius may be made internally (clause 8) or externally (clause 9). The external method is applicable only to tanks that are free of insulation.

1.2 Abnormally deformed, e.g. dented or non-circular, tanks are excluded from this part of ISO 7507.

1.3 This method is suitable for tilted tanks up to 3 % deviation from the vertical provided that a correction is applied for the measured tilt as described in ISO 7507-1.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 7507. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7507 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7507-1:1993, *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 1: Strapping method.*

3 Definitions

For the purposes of this part of ISO 7507, the definitions given in ISO 7507-1 apply.

4 Precautions

The general precautions and safety precautions specified in ISO 7507-1 shall apply to this part of ISO 7507.

5 Equipment

5.1 Equipment for measurement of angles, as listed in 5.1.1 to 5.1.4 below.

5.1.1 Theodolites, with angular graduations and a resolution equal to or better than 0,000 2 grade[1]. Each theodolite shall be mounted on a tripod which is firm and stable. The legs of the tripod shall be steadied by means of magnetic bearers when being used for the internal method. Repeat readings shall agree to within 0,000 2 grade[1].

5.1.2 Low-power laser-beam emitter, equipped with a device such as a fibre-optic light-transfer system and a theodolite-telescope eye-piece connection, by which the laser beam can be transmitted through

1) 1 grade = $\pi/200$ radians = 0,9°.

a theodolite. The laser beam shall be coincident with the optical axis of the telescope.

5.1.3 Heavy weights, to set round the theodolite stations to prevent movement of the tank bottom plate.

5.1.4 Lighting, for use inside the tank to allow measurements to be read accurately.

5.2 Stadia, 2 m long, such that the graduated length, between two marks, remains constant to within ± 0,02 mm at the temperature at which it is used.

5.3 Equipment for bottom calibration:

Either

a) for a liquid method, equipment as specified in annex E;

or

b) for a survey method, theodolites, a dumpy level, a surveyor's level or water-filled tubes.

6 Equipment set-up and procedure

6.1 Preparation of tank

Fill the tank to its normal working capacity at least once and allow it to stand for at least 24 h prior to calibration.

If the tank is calibrated with liquid in it, record the depth, temperature and density of the liquid at the time of calibration. However, if the temperature of the wall surface could differ by more than 10 °C between the empty part and full part of the tank, the tank shall be completely full or empty. Do not make transfers of liquid during the calibration.

6.2 Theodolite set-up

6.2.1 Set up each theodolite with care according to the procedure and instructions given by the manufacturer. In addition, follow the procedures described in 6.2.2 and 6.2.3.

6.2.2 Set up the instrument so as to be stable.

For the internal method, steady the bottom of the tank near the theodolite station by installing weights or other heavy objects around the station. Mount the legs of the theodolite on magnetic bearers to prevent the legs from sliding on the tank bottom.

For the external method, drive the legs of the tripod fully home into the ground.

6.2.3 Set the bed plate of the instrument as near as possible to the horizontal.

NOTE 1 This will ensure verticality of the swivel axis of the theodolite.

6.3 Stadia set-up and procedure

6.3.1 Mount the stadia on the tripod with care according to the procedure and instructions given by the manufacturer. In addition, follow the procedures described in 6.3.2 and 6.3.3.

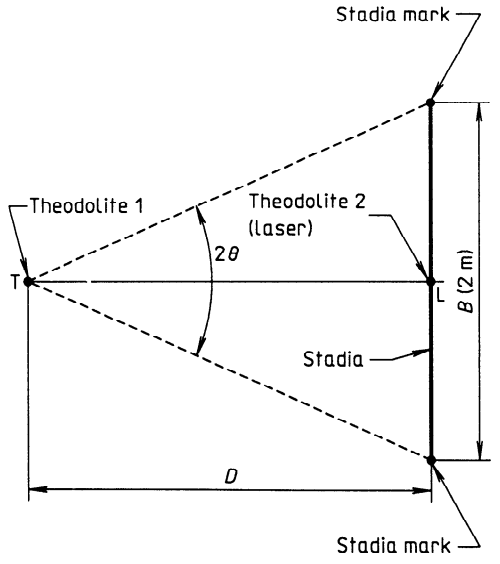
6.3.2 Mount the stadia horizontally and perpendicular to the aiming axis by adjusting the device on the stadia.

6.3.3 Once setting-up is complete, lock the stadia in position and verify the horizontality and the perpendicularity.

7 Measurement of distance between two theodolite stations

7.1 Take the measurement prior to the commencement of the optical readings. Set up the stadia as described in 6.3.

Measure the horizontal angle 2θ subtended at the theodolite (see figure 1) by the two marks on the stadia, using the theodolite.



NOTE — Points T and L are interchangeable.

Figure 1 — Measurement of distance between two theodolites

7.2 Compute the horizontal distance D between the two theodolite stations from the formula

$$D = \frac{B}{2} \text{ cotan } \theta$$

where

B is the distance, in metres, between the two reference marks on the stadia (i.e. 2 m);

θ is half the angle, in degrees, subtended at theodolite 1 by the two reference marks.

7.3 Carry out the measurement of the angle 2θ and the computation of the distance D a minimum of five times and calculate and record the average value. The computed distance D shall be within the tolerances given in table 3 or the entire procedure shall be repeated.

7.4 Redetermine the distance D after completion of all the optical measurements described in 8.13.

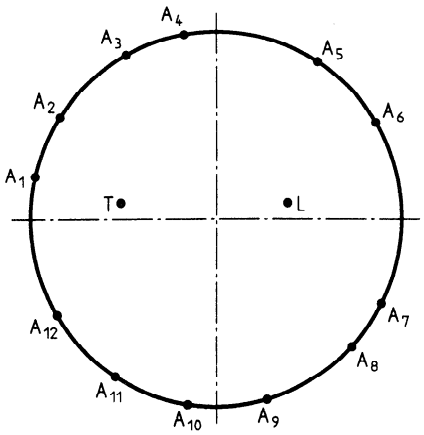
The distances computed before and after the optical measurements shall agree within the tolerances given in table 3. If they do not, repeat the calibration procedure until a set of measurements is obtained with the values for D at the beginning and end in agreement.

8 Procedure for internal optical tank wall measurements

8.1 Set up two theodolite stations inside the tank as illustrated in figure 2 and as described in 6.2.

8.2 Locate the two stations approximately on a diametrical plane and at least one quarter diameter apart. Adjust the theodolites and measure the distance TL (TL = D) as described in clause 7.

8.3 Set the reference axis TL optically on the horizontal planes (circles) of both instruments by sighting from each instrument the vertical graticule wires of the other instrument as described in 8.4 to 8.7.



NOTES

1 The example shows 12 wall points per circumference (see 8.10).

2 T and L are interchangeable theodolite and laser theodolite stations.

3 Do not locate wall points where the line through T and L meets the tank wall.

Figure 2 — Example of locations of theodolite stations and wall points for internal procedure

8.4 Shut off the laser beam of the laser theodolite and remove the two filters of the laser theodolite.

8.5 Adjust theodolite T to set the telescope to infinity and illuminate the eyepiece of this telescope with a light source.

8.6 Sight the object lens of theodolite from the telescope of the laser theodolite (L) and continue focussing until the graticules become visible. Make the vertical graticule wires coincide by using the adjusting device on the laser theodolite (L).

8.7 Repeat the operation from theodolite. Repeat the operation as many times as is necessary until the vertical graticule wires coincide perfectly.

8.8 The TL axis is now set. Record the relative locations of the two theodolites by taking readings on both horizontal scales as the horizontal reference angles.

8.9 Replace the two filters in the laser theodolite and switch on the laser beam. This beam is then used to provide a series of points on the tank shell wall. Sight these points in turn using the other theodolite, and take and record the horizontal-scale readings on both instruments.

8.10 The minimum number of points on the tank shell wall per circumference shall be as given in table 1. These points shall not be closer than 300 mm from the vertical weld seam.

For each course, there shall be two horizontal sets of points — one set on a circumference at 1/5 to 1/4 of the course height above the lower horizontal seam, and the other at 1/5 to 1/4 of the course height below the upper horizontal seam as shown in figure 3.

8.11 Sight all the points along a horizontal set, as indicated in figure 3, by the theodolite and the laser beam. Then move to the next level.

NOTE 2 This will ensure that each set of points on the tank wall is at the same level for a given circumference.

8.12 Calculate by difference the angles α and β indicated in figure 4 for each of these points.

Table 1 — Minimum number of points per circumference for internal procedure

Circumference m	Minimum number of points
up to 50	8
above 50, up to 100	12
above 100, up to 150	16
above 150, up to 200	20
above 200, up to 250	24
above 250, up to 300	30
above 300	36

Dimensions in millimetres

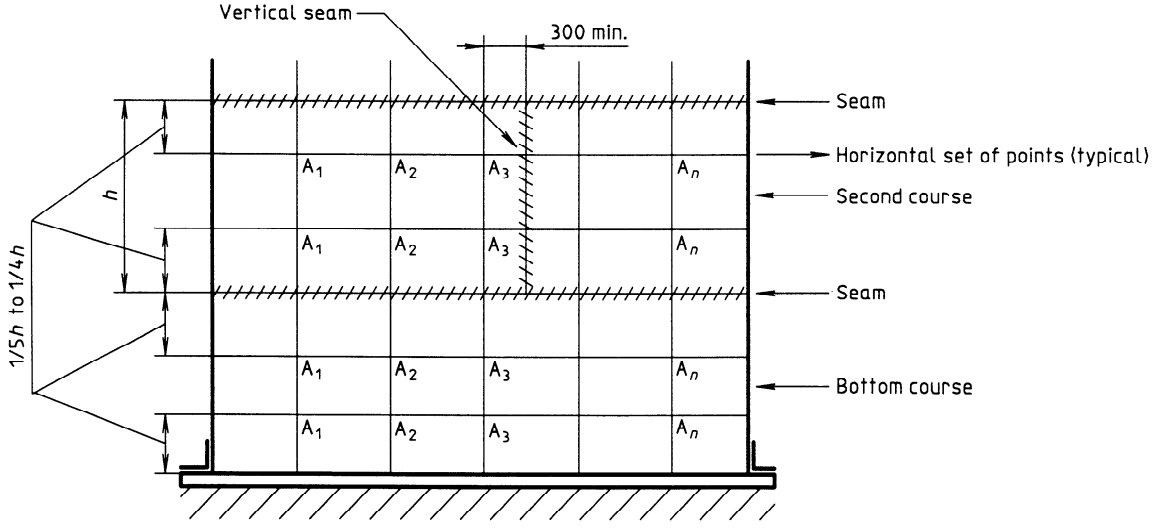
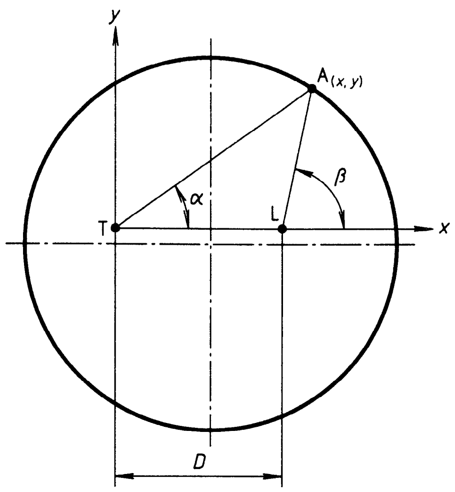


Figure 3 — Location of horizontal sets of points on tank wall



T = Theodolite station

L = Laser theodolite station

A = An observed point on the tank

Figure 4 — Horizontal angles between sightings on points on tank wall and the reference axis TL

8.13 After completion of optical measurement of all points, redetermine the horizontal distance TL (TL = *D*) (see 7.4). If the original and final values of TL do not agree as specified in 7.4, repeat the calibration procedures until such agreement is obtained.

8.14 Check the axis TL by switching off the laser, removing the filters from the laser theodolite and repeating the operations described in 8.3 to 8.8. The original and final horizontal reference angles shall be within the tolerance specified in 10.2. If not, repeat the calibration procedures until a set of readings ending in such agreement is obtained. Record the average values of the horizontal reference angles.

9 Procedures for external measurements

9.1 General

The measurements shall be related either to a reference circumference using the procedure described in 9.2 or to reference distances measured between pairs of theodolite stations as described in 9.3.

9.2 Reference circumference measured by strapping

9.2.1 Reference circumference

9.2.1.1 Determine the reference circumference using the reference method described in ISO 7507-1 and in 9.2.1.2 to 9.2.1.6.

9.2.1.2 Take the measurement of the reference circumference prior to the commencement of the optical readings.

9.2.1.3 Take the measurement of the reference circumference at a position where work conditions allow reliable measurements. Strap the tank at one of the following levels:

a) at 1/5 to 1/4 of the course height above the lower horizontal seam;

b) at 1/5 to 1/4 of the course height below the upper horizontal seam

and repeat the measurement to achieve measurements agreeing within the tolerances specified in 10.3.

9.2.1.4 After completion of the optical readings, repeat the reference circumference measurement.

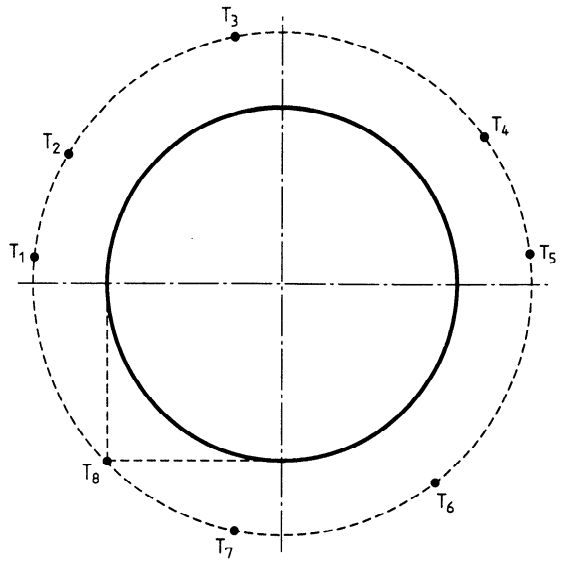
9.2.1.5 The measurements referred to in 9.2.1.2 and 9.2.1.4 shall agree within the tolerances specified in 10.3.

9.2.1.6 If agreement is not obtained, further measurements of the reference circumference shall be taken until two consecutive readings do so agree. Record the arithmetic mean of the two measurements as the reference circumference. If consecutive measurements do not agree, determine the reasons for the disagreement and repeat the calibration procedure.

9.2.2 Theodolite readings

9.2.2.1 Set up the optical theodolite outside the tank, as illustrated in figure 5 for eight theodolite stations, and as described in 6.2.

The minimum number of stations (T_1, T_2, etc.) per circumference shall be as given in table 2.



T_1 ... T_8 = Theodolite stations

Figure 5 — Example of theodolite station locations for external procedure based on a reference circumference (see 9.2)

Table 2 — Minimum number of theodolite stations for external procedures

Tank circumference m	Minimum number of stations
up to 50	4
above 50, up to 100	6
above 100, up to 150	8
above 150, up to 200	10
above 200, up to 250	13
above 250, up to 300	15
above 300	18

9.2.2.2 From each station and for each level (see 9.2.2.3 and 9.2.2.4), make two sightings tangentially to the tank on either side of the theodolite as shown in figure 5. Maintain the same vertical angle of the theodolite in both sightings.

NOTE 3 This will ensure that the intended targets on the tank are at the same level for a given circumference.

Record the horizontal angles subtended by the tangents at the theodolite.

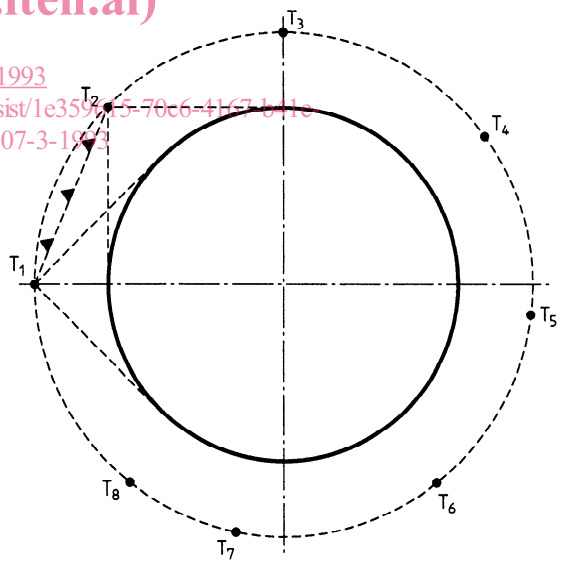
9.2.2.3 For the reference level, make the sightings at the level at which the reference circumference was measured (see 9.2.1).

9.2.2.4 For each theodolite station (e.g. T_1), sight each of the courses at two levels, one at 1/5 to 1/4 of course height above the lower horizontal seam, the other at 1/5 to 1/4 of course height below the upper horizontal seam.

9.2.2.5 Move the theodolite from station T_1 to T_2 to T_3, etc., until the whole circumference is covered. Repeat all the above steps at each station (i.e. T_1, T_2, etc.), for each level. The repeat readings of the horizontal angles recorded in 9.2.2.2 shall agree within the tolerances specified in 10.2. If they do not, repeat the measurements until two consecutive sets agree within this tolerance. Record the average horizontal angle for each of the points sighted.

9.3 Reference distances measured between pairs of theodolite stations

9.3.1 Set up the two theodolite stations outside the tank, as illustrated in figure 6 for eight stations, and as described in 6.2, using an optical theodolite (5.1.1) and a second tripod. The minimum number of stations (T_1, T_2, etc.) per circumference shall be as given in table 2.



T_1 ... T_8 = Theodolite stations

Figure 6 — Example of theodolite station locations for external procedure based on reference distances between pairs of theodolites (see 9.3)

9.3.2 Determine the horizontal distance T_1T_2 between the two theodolite stations by using the stadia as described in clause 7 ($T_1T_2 = D$) with the stadia mounted on T_2 as described in 6.3.

9.3.3 From station T_1, sight the tank wall tangentially on either side, maintaining the same vertical angle of the theodolite for the two observations, and record the horizontal angle subtended at the theodolite.

9.3.4 Leaving the tripod supports in the same position, interchange the stadia and the optical device, so that the stadia is at location T_1 and the theodolite is at location T_2.

Repeat the determinations described in 9.3.2 and 9.3.3.

9.3.5 The value for D obtained in 9.3.2 shall agree with that obtained in 9.3.4 within the tolerances given in 10.1. If agreement is not obtained, repeat the measurements, starting at station T_1, until two consecutive values do so agree. Record the arithmetic mean of the two values as the horizontal distance T_1T_2.

9.3.6 Transfer the tripod set up at T_1 to T_3, leaving the tripod set up at T_2 in place. Apply the procedure in 9.3.2 to 9.3.4 for locations T_1 and T_2 to locations T_2 and T_3.

9.3.7 Continue the above procedures for all subsequent stations around the circumference until station T_1 is reached again.

9.3.8 For each course, repeat the procedure described in 9.3.2 to 9.3.7 at two levels, one at 1/5 to 1/4 of the course height above the lower horizontal seam and the other at 1/5 to 1/4 of the course height below the upper horizontal seam.

10 Tolerances

10.1 Distance between theodolites

The measurements of the distance D between the two theodolite stations taken before and after other optical readings shall not differ by more than the tolerances given in table 3.

Table 3 — Tolerance on distance between theodolites

Distance m	Tolerance mm
up to 25	2
above 25, up to 50	4
above 50, up to 100	6

2) 1 grade = π/200 radians = 0,9°.

10.2 Horizontal angles

The repeated values for the measurement of horizontal angles using the theodolites shall not differ by more than 0,01 grade[2].

10.3 Reference circumference

The reference circumference measurements taken before and after the optical readings (see 9.2.1) shall not differ by more than the tolerances given in table 4.

Table 4 — Tolerance on reference circumference

Circumferential measurement m	Tolerance mm
up to 50	2
above 25, up to 50	3
above 50, up to 100	5
above 100, up to 200	6
above 200	8

11 Other measurements for tank calibrations

11.1 Tank bottom calibration

Calibrate the tank bottom preferably by filling with measured quantities of a non-volatile liquid (preferably clean water) as specified in annex E to a minimum level that covers the bottom completely, immersing the dip-plate and eliminating the effect of bottom deformations or, alternatively, by a physical survey using a reference plane to determine the shape of the bottom.

11.2 Reference height determination

Measure the overall height of the reference point on each dip-hatch (upper reference point) above the dip-point using the dip-tape and dip-weight as specified in annex F. Record this overall height, to the nearest and smallest graduation mark of the dip-tape, and permanently mark it on the tank adjacent to that dip-hatch.

If possible, compare measurements of the reference height with the corresponding dimensions shown on the drawings and investigate any discrepancies.