INTERNATIONAL STANDARD

ISO 9091-2

First edition
1992-12-15

Refrigerated light hydrocarbon fluids — Calibration of spherical tanks in ships —

Part 2:
Triangulation measurement

Hydrocarbures légers réfrigérés — Jaugeage des réservoirs sphériques à bord des navires —

Partie 2: Méthode par triangulation

INTERNATIONAL ISO

Reference number
ISO 9091-2:1992(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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 9091-2 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Sub-Committee SC 5, *Measurement of light hydrocarbon fluids*.

ISO 9091 consists of the following parts, under the general title *Refrigerated light hydrocarbon fluids — Calibration of spherical tanks in ships*:

- *Part 1: Stereo-photogrammetry*
- *Part 2: Triangulation measurement*

Annexes A, B, C, D, E and F of this part of ISO 9091 are for information only.

Introduction

Large quantities of light hydrocarbons consisting of compounds having one to four carbon atoms are stored and transported by sea as refrigerated liquids at pressures close to atmospheric. These liquids can be divided into two main groups: liquefied natural gas (LNG) and liquefied petroleum gas (LPG). Bulk transportation of these liquids by sea requires special technology in ship design and construction to enable such transportation to be safe and economical.

Measurement of cargo quantities in ships' tanks for custody transfer purposes has to be of a high order of accuracy. The two parts of this International Standard, together with other standards in the series, specify methods of internal measurement of ships' tanks from which tank calibration tables can be derived.

For internal measurement, methods of liquid calibration, physical measurement, optical measurement and stereo-photogrammetry, etc. are in general use. Liquid calibration cannot be used for large spherical tanks designed to operate at near atmospheric pressure with refrigerated light hydrocarbons because the hydrostatic pressure exerted by the calibrating liquid may exceed the design pressure when filled higher than a certain level. This part of ISO 9091 covers a calibration technique applicable to spherical tanks equipped with a central pipe/instrumentation column.

Refrigerated light hydrocarbon fluids — Calibration of spherical tanks in ships —

Part 2:
Triangulation measurement

1 Scope

1.1 This part of ISO 9091 specifies a triangulation method for the internal measurement of spherical tanks in liquefied gas carriers.

1.2 This part of ISO 9091 also sets out the calculation procedures for compiling the calibration tables to be used for the measurement of cargo quantities.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9091. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9091 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 8311:1989, *Refrigerated light hydrocarbon fluids — Calibration of membrane tanks and independent prismatic tanks in ships — Physical measurement.*

3 Definitions

For the purposes of this part of ISO 9091, the following definitions apply.

3.1 base point: Centre point of the theodolite set above the traverse point.

3.2 basic pentagon: Pentagon connecting base points.

3.3 basic target: Portable target mounted on a tripod with a tribrach.

3.4 benchmark: Point on which a staff is erected to determine the height of the theodolite above the south pole.

3.5 calibration: Process of determining the total capacity or partial capacities of a tank corresponding to different levels.

3.6 calibration table; main gauge table: Table, often referred to as a tank table or a tank capacity table, showing the capacities of or volumes in a tank corresponding to various liquid levels measured from the gauge reference point, with the ship on an even keel and upright.

3.7 datum point: Position used as the datum in the preparation of a calibration table.

NOTE 1 This position may differ from the gauge reference point.

3.8 deadwood: Any tank fitting which affects the capacity of a tank.

3.8.1 positive deadwood: Fitting whose capacity adds to the effective capacity of the tank.

1) To be published.

3.8.2 negative deadwood: Fitting whose volume displaces liquid and reduces the effective capacity.

3.9 equator: Largest horizontal circumference of a spherical tank.

3.10 gauge reference point: Point from which the liquid depth is measured.

3.11 latitude: Horizontal circumferences on the surface of the sphere parallel to the equator.

3.12 longitude: Vertical circumferences on the surface of the sphere passing through the north and south poles.

3.13 list: Transverse inclination of a ship.

3.14 north pole: Zenith, or highest point, of a spherical tank shell, an imaginary point in most spherical tanks due to the pipe tower or other appurtenances.

3.15 pipe tower: Large-diameter pipe coaxial with the tank's north-south axis, containing pipes for loading and discharging, measuring instrumentation, ladder, wiring and other in-tank facilities.

3.16 port: Left-hand side of a ship facing forward.

3.17 south pole: Nadir, or lowest point, of a spherical tank.

3.18 starboard: Right-hand side of a ship facing forward.

3.19 target: Position distinctively marked on the inside surface of the tank for the triangulation method (see 6.1).

3.20 traverse point: Position on the inside surface of the tank above which a theodolite is set for determining the coordinates of a target.

3.21 trim: Longitudinal inclination of a ship.

4 Precautions during measurement

4.1 Utmost care and attention shall be exercised in taking measurements and anything unusual occurring during the measurement which might affect the results shall be recorded. The calibration method described in this part of ISO 9091 may be applied to ships whether afloat or in dry-dock. However, its use in dry-dock may be preferable, because trim or list, if any, will remain the same throughout the measurement.

4.2 If any unusual distortions are found in the tank shell, additional measurements shall be taken by the calibrator to obtain sufficient data for correct calculation in the calibration table, and the calibrator's notes should be provided in connection with such extra measurements.

4.3 Duplicate measurements of angles shall be taken to check whether they agree within 16 s, and if they do not agree, measurement shall be continued until two consecutive readings agree. The average of the two shall be recorded.

If consecutive measurements do not agree, the reason for the disagreement shall be clarified and, if necessary, the entire calibration procedure shall be repeated.

If the measurement has been interrupted, the last angle measurement taken should be repeated. If the new angle values do not agree, within the required tolerance of 16 s, with the earlier measurements, then the earlier set should be rejected.

4.4 Measurement shall be carried out when the temperature fluctuation of the wall is limited to the minimum.

NOTE 2 Temperature fluctuations should be checked during measurement procedures.

4.5 Measurements shall not be carried out when there is any motion of the ship, or vibration of the tank.

If calibration is carried out before installation of the tank in the hull of the ship, the distance between predetermined points on the interior of the tank shall be measured after installation to ensure that no distortion of the tank has occurred. If distortion has occurred, the calibration shall be repeated.

4.6 The paint used to mark the targets shall be manufactured from materials which are resistant to liquids at cryogenic temperatures.

5 Equipment

5.1 Basic target

A target mounted on a tribrach indicating a base point.

5.2 End-to-end rule

A rule graduated in centimetres and millimetres, to be used to measure deadwood, etc. The rule should bear the identification of a recognized standardizing authority or certificate of identification.

5.3 Measuring tape

A tape bearing the identification of a recognized standardizing authority or a certificate of identification.

5.4 Optical level

An optical level having an erect image, a magnification of × 20 or greater, capable of being focussed to 1,5 m or less and with a spirit-level sensitivity of 40 s per 2 mm or less.

5.5 Staff

A scale graduated in millimetres to be erected on a benchmark.

5.6 Steel rule

A rule, to be used to measure clearances, etc., graduated in millimetres. The rule should bear the identification of a recognized standardizing authority or certificate of identification.

5.7 Subtense bar

A subtense bar having a length greater than 5 % of the distance between the base points with a length uncertainty of less than 0,01 % of its length.

5.8 Surface thermometer

A thermometer used to measure the temperature of the surface of the tank with an accuracy of ± 0,5 °C in order to convert the coordinates of the targets at the temperature at the time of measurement to those at the certified reference temperature.

5.9 Theodolite

A theodolite, recommended to have an erect image with a minimum circular reading of 1 s and a spirit plate level sensitivity of 20 s per 2 mm or less.

5.10 Tribrach

A levelling platform, mounted on the tripod, with three levelling screws and a clamping device to fasten the theodolite.

6 Preparation

6.1 Marking of targets

During construction of the tank and prior to the installation of the pipe tower, targets (see figure 1) shall be stencilled on the inside surface of the tank shell at each intersection of latitude and longitude at 20° intervals. The marking error shall be less than 10 mm in both vertical and horizontal directions.

Dimensions in millimetres

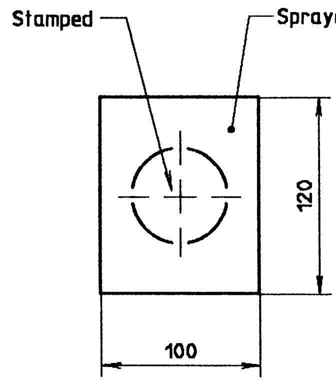


Figure 1 — Example of marking

6.2 Basic pentagon

6.2.1 Determination of traverse points

Mark five traverse points so that each target can be measured from at least four traverse points without being obstructed by the pipe tower.

6.3 Marking of benchmark

Mark the benchmark at an arbitrary position near the south pole of the tank (see figure 2).

6.4 Set-up of measuring instruments (see figure 2)

6.4.1 Set staffs upright on the benchmark and on the south pole of the tank.

6.4.2 Set up a level (for the basic target) using a tripod and tribrach, on an arbitrary point at which the staff on the south pole can be observed through the opening of the pipe tower (see figure 3).

6.4.3 Set up a levelled tribrach (for the base point) on a tripod at each of five traverse points (see figure 4).

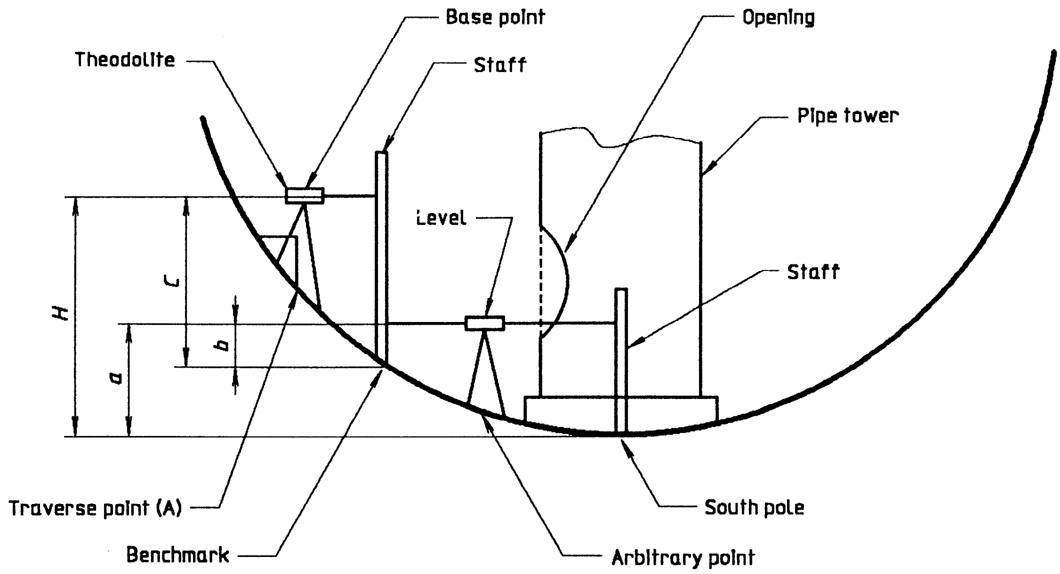


Figure 2 — Set-up of instruments for determining the height of the base point

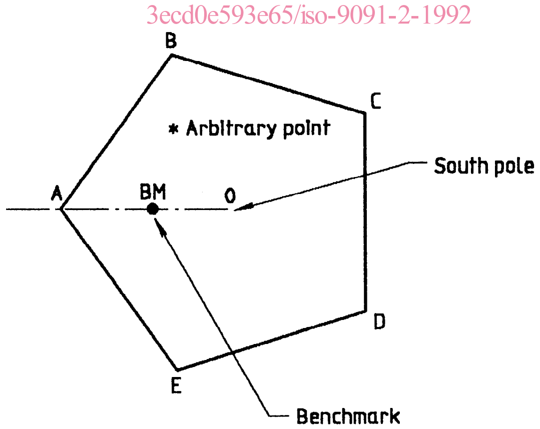


Figure 3 — Location of benchmarks and target

Dimensions in millimetres

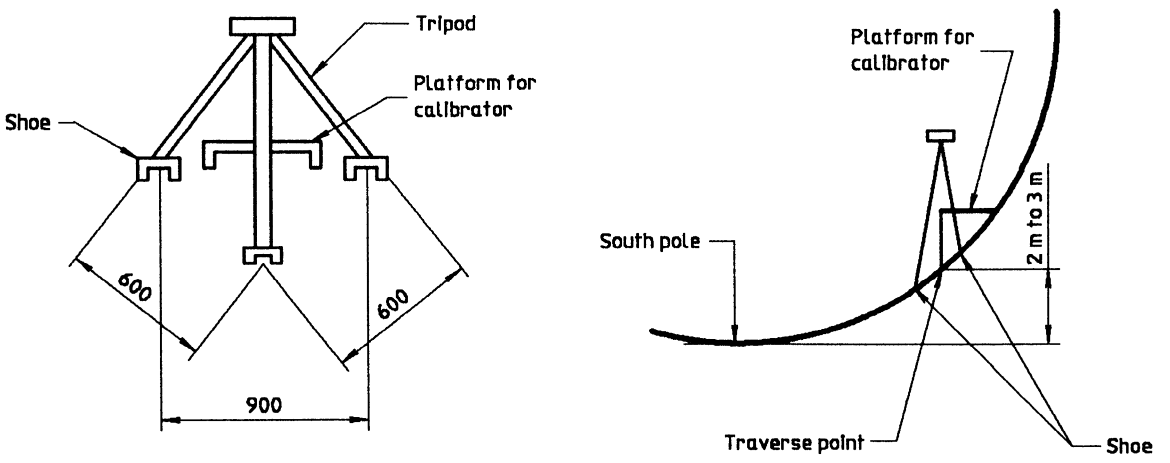


Figure 4 — Example of shoe arrangement for platform

7 Measurement

7.1 Elevation of base point from south pole

7.1.1 With the level, read the scale of the staffs set up on the south pole and on the benchmark respectively, as shown in figure 2.

7.1.2 With the theodolite mounted on the tripod of the traverse point (A) as shown in figure 2, read the scale of the staff set up on the benchmark.

7.1.3 Elevation H of the base point is determined as follows:

$$H = C + (a - b)$$

where

H is the elevation of the theodolite from the south pole;

C is the reading of the theodolite on the benchmark staff;

$(a - b)$ is the elevation of the benchmark from the south pole,

where

a is the level reading on the south pole staff;

b is the level reading on the benchmark staff.

7.2 Horizontal distance of base points

Horizontal distances can be obtained using the subtense bar method. This part of ISO 9091 describes the subtense bar method, but an alternative method is acceptable if it gives an accuracy equivalent to the subtense bar method.

7.2.1 Set a subtense bar on the tribrach of point B, as shown in figure 5.

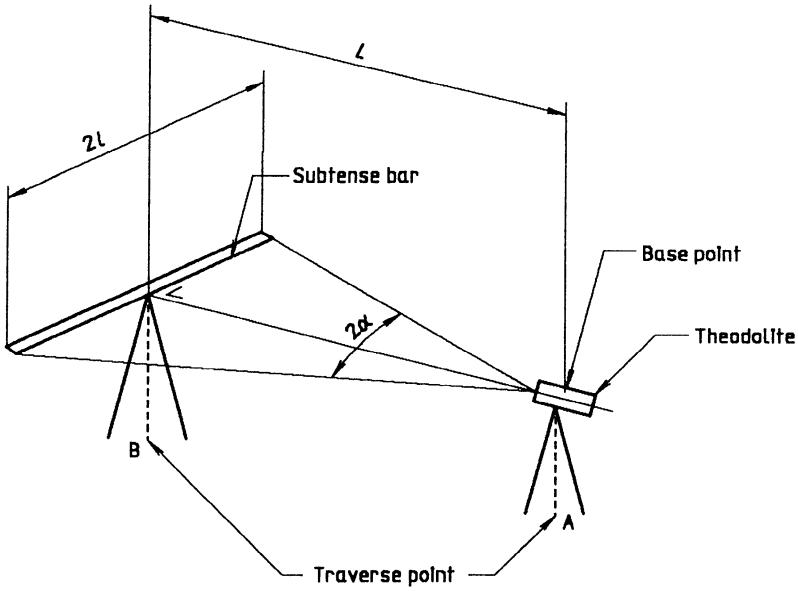


Figure 5 — Setting of subtense bar

7.2.2 Measure the horizontal angle 2α subtended at point A between the end-marks of the subtense bar. This measurement shall be taken at least twice (see 4.3).

7.2.3 Calculate the mean horizontal angle at each traverse point from the average of two consecutive readings.

7.2.4 The horizontal distance L can be calculated from equation (1):

$$L = l \frac{1}{\tan \alpha} \qquad \ldots (1)$$

where l is one-half the length of the subtense bar.

7.3 Vertical height and horizontal angle of base point

7.3.1 Repeat the same procedure as described in 7.1.

7.3.2 Set up a basic target on each of the tripods at points B, C, D and E.

7.3.3 With the theodolite at point A, collimate the basic target at point B and adjust the scale of the horizontal angle to 0°00′00″.

7.3.4 Measure the horizontal angles of ∠BAC, ∠BAD and ∠BAE as shown in figure 6.

7.3.5 Remove the theodolite from point A and reset it on the tripod at point B. Set up a basic target on point A.

Repeat the measurement procedures given in 7.3.3 and 7.3.4.

7.3.6 Repeat the same procedure of measurement at points C, D and E.

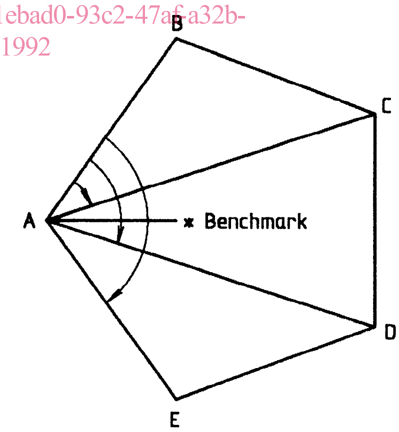


Figure 6 — Measurements with the theodolite on point A

7.4 Horizontal and vertical angles of target

7.4.1 Set up the theodolite on the tripod at base point A and the basic target on the tripod at base point B.

7.4.2 Collimating the basic target with the theodolite, adjust the horizontal scale to an angle of 0°00′00″.

7.4.3 Measure and record the horizontal and vertical angles to each target (see figure 7). If the line of sight to a target is obstructed by the pipe tower, then record this fact in the calibrator's notes.

7.4.4 Shift the theodolite and the basic target onto the other base points and measure the angles in the manner described in 7.4.2 and 7.4.3.

7.5 Temperature

Take the average temperature of the inside surface of the tank with a surface thermometer.

7.6 Height of gauge reference point

If the gauge reference point and the datum point differ, measure the height of the gauge reference point from the datum point (south pole) of the tank by means of an optical level or any other levelling device.

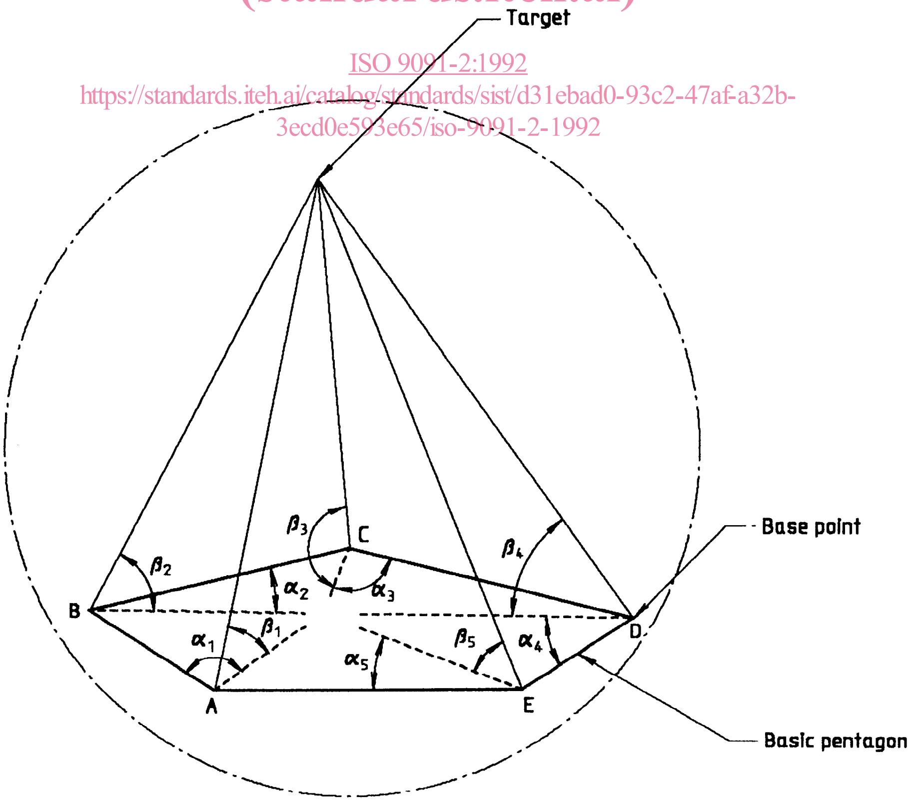
7.7 Location of level gauge

For trim and list corrections, measure the horizontal distance of the level gauge on the tank bottom from the vertical axis connecting the south and north poles.

7.8 Vertical diameter

If the tank has a dome with a built-in north pole, measure the distance between the north and south poles with a steel tape.

In the case of a dome that lacks the north pole and has only the grating top floor of the pipe tower, set an optical level by standing a theodolite in the middle of the above-mentioned floor, above the imaginary north pole, and measure with a steel tape the distance H between the above-mentioned optical level and the south pole.



Measured horizontal angles: α_1, α_2, α_3, α_4, α_5

Measured vertical angles: β_1, β_2, β_3, β_4, β_5

Figure 7 — Measurement of the target