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Fixed Storage Tanks - General Requirements

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Réservoirs de stockage fixes - Prescriptions générales

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OIML International Recommendation R 71

Fixed Storage Tanks - General Requirements

Draft Revision

Committee draft CD2

19 October 2005

Contents

Explanatory note

[Will be deleted in the final text]

As part of an inquiry from 4th July 2000 the secretariat of OIML TC8/SC1 (Austria) investigated the need for revision of OIML Recommendation R71, Edition 1985.

From this inquiry it could be concluded that a majority of the voters was in favour for the confirmation of this Recommendation. A revision should not to be necessary. However, further action should be taken considering the inclusion of OIML R71 in the OIML Certificate System.

To submit a category of measuring instruments to the OIML Certificate System, the Recommendation concerned must contain the following elements: metrological requirements, test procedures and a format for the test report. The metrological requirements should already be fixed in the existing Recommendation R71. A working group should be established to develop the test procedures and the test report format.

To establish the working group a TC8/SC1 meeting was held on 30 and 31 October 2003 in Vienna. 6 P-Member countries and 1 O-Member country attended this meeting.

Contrary to the outcome of the inquiry in 2000 the delegates attending the meeting in Vienna advised the P-Members to re-consider there voting and to agree with the terms of reference of a new working group OIML TC8/SC1/WG2, convened by the Netherlands (Mr. Aart Kooiman), i.e.
Revision of OIML R71, in connection with R85;
Revision of OIML R85, and the implementation of automatic calculation of volume and/or converted volume and/or mass.
With respect to R71 the development of test procedures and a test report format would be not necessary. So, only the first verification shall be performed.

On 19 January 2004 the secretariat OIML TC8/SC1 sent out an enquiry to P-, O- and liaison Members of TC8/SC1, as well as BIML, for agreement of the decisions made in Vienna.

On 22 March 2004 the secretariat OIML TC8/SC1 informed the P-, O- and liaison Members of TC8/SC1, as well as BIML, about the outcome of this enquiry. It was agreed by 11 out of 12 votes to accept the terms of reference of OIML TC8/SC1/WG2 “Revision of OIML R71 and R85” and the working group could start work.

The first meeting took place from 14 – 17 June 2004 in Delft (The Netherlands). During this meeting the work program was presented. The first task would be to prepare revised documents for OIML R71 and R85, fully in accordance with the terms of reference of the working group.

Because there is a need for developing provisions for automatic calculation of volume and/or converted volume and/or mass based on an automatic level measurement and the tank table the working group proposes to develop a new OIML Recommendation “Measuring systems for the volume of liquids in fixed storage tanks”.

Moreover there is a need for an OIML Recommendation concerning Hybrid Tank Measuring Systems. The working group proposes the development of a new OIML Recommendation “Hybrid Tank Measuring Systems for determination of volume, density and mass of liquid and liquefied hydrocarbons and liquid chemicals in vertical cylindrical fixed storage tanks”.

During the OIML TC8/SC1 meeting in Vienna held on 21 and 22 April 2005 the working group asked for permission to develop these two new Recommendations.

End of September 2004 the second working draft for revision of OIML R71 was sent for comments by 1 November 2004 to the working group members. This working draft contains the decisions made on the first working draft during the WG meeting in Delft.

A first Committee Draft on OIML R71 has been distributed to P-, O- and liaison Members on 13 January 2005. These Members being requested to send their votes and comments and urgent matters for discussion during the TC8/SC1 meeting in Vienna not later than 15 April 2005. Due to a violation of time limits the voting had to be postponed.

The chairman of the working group, together with the secretariat TC8/SC1, made a selection of urgent matters. And these were discussed on 21 and 22 April 2005 in Vienna. The comments made at this meeting have been implemented here in a second committee draft. Superfluous definitions have been deleted. And the consistency between the definitions and the text has been improved. Furthermore, this draft has been brought in compliance with the Directives for the Technical Work, Part 2, in particular clause 3 and 4.
This rearrangement of the chapters made it not practical to distribute a marked version of the draft.

During that meeting in Vienna, it was also discussed to start the work on 2 other projects:

* R_{xxx}: Measuring Systems for the volume of liquids in fixed storage tanks
* R_{yyy}: Hybrid Tank Measuring Systems for determination of volume, density and mass of liquefied hydrocarbons in vertical cylindrical fixed storage tanks.

These projects could either been regarded as a logical extension of the revision of R 71 and R 85 (within the scope of these existing projects) or as 2 new projects of TC8/SC1.
Further communication with the BIML resulted in the decision that these are to be considered as 2 new projects. So, in accordance with the Directives for the Technical Work - Part 1, the Subcommittee first has to make a proposal to the CIML. After being accepted by CIML, the Subcommittee (or its Working Group) can formally start this work.

Foreword

The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States.

The two main categories of OIML publications are:

- **International Recommendations (OIML R**),which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity; the OIML Member States shall implement these Recommendations to the greatest possible extent;

- **International Documents (OIML D**), which are informative in nature and intended to improve the work of the metrological services.

OIML Draft Recommendations and Documents are developed by Technical Committees or Subcommittees which are formed by the Member States. Certain international and regional institutions also participate on a consultation basis.

Cooperative agreements are established between OIML and certain institutions, such as ISO and IEC, with the objective of avoiding contradictory requirements; consequently, manufacturers and users of measuring instruments, test laboratories, etc. may apply simultaneously OIML publications and those of other institutions.

International Recommendations and International Documents are published in French (F) and English (E)and are subject to periodic revision.

This publication – reference OIML R 71, edition XXXX (E) – was developed by the OIML Technical Subcommittee TC 8/SC 1 *Static volume measurement*. It was approved for final publication by the International Committee of Legal Metrology in XXXX.

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Fixed Storage Tanks - General Requirements

1 Introduction

[In the final text, this will be an excerpt of the present Explanatory Note.]

2 Scope

2.1 Fixed storage tanks at atmospheric pressure or under pressure (hereinafter called « tanks ») are built for bulk liquid storage and may be used for measurement of quantities (volume or mass) of liquid contained. When used for that measurement they shall comply with the requirements of this Recommendation.

2.2 Tanks represent a category of simple measuring equipment, but the measurement of quantities (volume or mass) of liquid contained in a tank is a complex operation which, in addition to the tank, involves the use of other devices and measuring instruments (see OIML R125, OIML Rxxx and OIML Ryyy).

2.3 This recommendation specifies the general requirements all stationary storage tanks onshore with fixed or floating roofs including pressured, non pressured, refrigerated and non refrigerated.

3 Terminology

3.1 Calibration

The set of operations carried out to establish under specified conditions, the relationship between the liquid level in the tank and the volume of that liquid.

3.2 Nominal capacity

The rounded value of the maximum volume of liquid a tank may contain under normal conditions of use.

3.3 Gauge hatch (Dip-hatch)

The opening in the top of a tank through which dipping and sampling operations are carried out.

3.4 Vertical measurement axis

The vertical line which passes through the middle of the still well (guide pipe), if provided, belonging to the gauge hatch concerned, and corresponding to the position intended for automatic or manual level gauges.

3.5 Dipping datum plate (see Annex A)

A horizontal plate located along the vertical axis descending from the upper reference point, providing a fixed contact surface from which manual liquid depth measurements are made.

A dipping datum plate is not required when the tank bottom is sufficiently stable and no risk of sediment forming is present.

Note: The term “datum plate” is synonymous.

3.6 Dipping datum point

The intersection of the vertical measurement axis with the upper surface of the dipping datum plate, or with the bottom surface of the tank if a dipping datum plate is not provided. It constitutes the origin for the measurement of liquid levels (zero reference or dipping reference point)

3.7 Upper reference point

The point located on the vertical measurement axis, with reference to which the ullage is measured.

3.8 Ullage

The distance between the free surface of the liquid and the upper reference point, measured along the vertical measurement axis.

3.9 Reference conditions

Reference conditions applicable for the Calibration certificate.

3.10 Deadwood

Any tank fitting which affects the capacity of a tank.
Deadwood is referred to as « positive deadwood » when the capacity of the fitting adds to the effective capacity of the tank, or « negative deadwood » when the volume of the fitting displaces liquid and reduces the effective capacity.

3.11 Calibration table

The expression in the form of a table, of the mathematical function V (h) which represents the relation between the height h (independent variable) and the volume V (dependent variable).

3.12 Lower limit of accurate capacity

The capacity below which the maximum permissible error is exceeded, taking account of the shape of the tank and the calibration method.

3.13 Dipping tape

A material measure of length for measuring the liquid level. See for general requirements OIML Recommendation R35.

4 Classification and description

4.1 Regarding their calibration and the establishing of calibration tables, the tanks may be classified according to the following criteria :

- shape (4.1.1);
- position with reference to the ground (4.1.2);
- means used for measuring levels or volumes (quantities) of liquid contained (4.1.3);

- kind of liquid(s) to be contained (hydrostatic pressure, (4.1.4);
- conditions of use (supplementary influence quantities) (4.1.4).

4.1.1 The most common shapes of the tanks are the following :
- cylindrical with vertical or horizontal axis, and with flat, conical, truncated, hemispherical, elliptical or dome-shaped bottom or ends;
- spherical or spheroidal;
- parallelepipedic.

The vertical cylindrical tanks may have a fixed or floating roof (or a floating cover).

4.1.2 The position of the tanks with reference to the ground may be:
- on the ground;
- partially underground;
- underground;
- above ground.

4.1.3 The means used for measuring the levels or volumes (quantities) of liquid contained may be:
- a single graduation mark;
- a measuring device with a graduated scale (with a viewing window or an external gauge tube);
- a graduated rule (dipstick), divided in units of volume or of length, or a graduated tape (dipping tape), divided in units of length, with dip-weight or sinker (manual measurement);
- an automatic level gauge (automatic measurement).Tanks, where the quantity of liquid is determined by use of a graduated dipstick or dipping tape, divided in units of length or by use of an automatic level gauge shall be accompanied by a calibration table.

4.1.4 The main influence quantities which affect calibration are pressure and temperature. Pressure, including hydrostatic pressure, may alter the apparent volume by distorting the shell; differences from the reference temperature will alter the volumes by expansion or contraction of the shell.

a) With reference to pressure, the tanks may be:
- at ambient atmospheric pressure;
- closed, at low pressure;
- closed, at high pressure.

Note:
Low pressure: Reid vapour pressure less than 100 kPa
High pressure: Reid vapour pressure more than 100 kPa

b) With reference to temperature, the tanks may be :
- without heating;
- with heating, but without thermal insulation;
- with heating and thermal insulation;
- with refrigeration and thermal insulation.

5 Units of measurement

The authorized units of measurement are those of the International System of Units (SI).

If, in any country, units of measurement outside the SI are authorized, the legal units of measurement of that country may be used. In international trade, the officially agreed equivalents between these units of measurement and those of the SI shall be applied.

6 Technical characteristics of tanks

6.1 The tanks shall be built in accordance with sound engineering practice.

With reference to their construction, position and conditions of use, the tanks shall comply with the legal requirements for storage of contained liquids, in relation to the characteristics of these liquids (potable, petroleum, chemical, etc.).

6.2 The tanks may be provided with devices necessary to prevent, as far as possible, the loss of liquid by evaporation.

6.3 The tanks, to be accepted for-fiscal / custody transfer applications, shall comply with the following general requirements, aiming to ensure the accuracy of measurement of the volume of liquid contained.

a) The shape, material, reinforcement, construction and assembly shall be such that the tank is sufficiently resistant to the atmosphere and the effects of the contained liquid and that, under the normal conditions of use, it suffers no permanent deformation which may alter its capacity.

b) The dipping datum point and the upper reference point shall be constructed so that their positions remain practically unchanged whatever the state of filling of the tank, the temperature, etc.

   Examples for the position of gauge hatches and the construction of reference points are shown in Annex A.

c) The shape of the tanks shall be such that the formation of air pockets during filling, or of pockets of liquid after draining is prevented

d) The tanks shall be stable on their foundations ; this may be ensured by anchoring or by an adequate period of stabilization, the tank remaining full, so that its base will not vary greatly with time.

6.4 If a calibration table is obligatory the tanks shall be provided with a data plate bearing an identification of the tank

The data plate shall be made of a metal, which remains practically unchanged under normal conditions of use. The plate shall be fixed on an integral part of the tank, so located that it is readily visible and easily legible, not subject to deterioration, and in such a manner that it cannot be removed without breaking the seals which carry the verification marks

Other forms of identification and records of data may be authorized by national regulations.

7 Metrological characteristics of tanks

7.1 The maximum permissible calibration uncertainty applies to the values between the lower limit of accurate capacity and the nominal capacity, shown in the calibration table.

The maximum permissible uncertainty, calculated according to GUM for k = 2, positive or negative, shall be equal to:

0.2 % of the indicated volume for vertical cylindrical tanks.,

0.3 % of the indicated volume for horizontal or tilted cylindrical tanks.

0.5 % of the indicated volume for spherical or spheroidal tanks.

The maximum permissible uncertainties indicated above do not include the uncertainty of the quantity below the datum plate, which is stated in the tank calibration table.

7.2 ***Preliminary text (the secretary will draft a more detailed proposal and will submit this as soon as possible as a separate file):***
The correlation between the level (height) of the liquid and its volume can be demonstrated by:
a) either the known basic geometry of the tank (an "ideal" sphere or cylinder), or
b) a calibration table

7.2.1 The direct application of the geometry according to 7.2, a) is only acceptable under the following conditions:
a) the shape of the tank shall be a basic geometrical form as a sphere or a cylinder
....
....

7.2.2 The application of a calibration table according to 7.2.2 shall fulfil the following requirements:
....
....

8 Metrological controls

7.1 The granting of the « legal » status to a tank and the retention of that status shall include all or part of the following operations :

- initial verification;
- periodic verification or recalibration in service.

These operations are carried out by or under the control of the national metrological authorities.

7.2 In countries where type approval is mandatory the approval of design drawings partially replaces type approval, which is normally required for ordinary measuring instruments. This approval must be obtained by the manufacturer before he starts construction; for this purpose, he shall submit to the competent authority the design drawings of the tank, showing:

- the general layout;

- the method of fixing the tank on the ground (or underground);
- the position of the valves and of the inlet and outlet pipes, so that the way in which the tank can be completely emptied for the purpose of cleaning and periodic calibration can be deduced;
- the position and dimensions of deadwoods (positive and negative);
- the details concerning the floating roof or floating cover (if provided) including its mass;
- the details of fitting the liquid level measuring device in the tank;
- the details of fitting the temperature and pressure sensors in the tank;
- the position of the data plate.

If no type approval is required similar procedure shall be applied at the level of initial verification.

7.3 Initial verification is carried out in two stages:

7.3.1 Examination of the tank in situ
During the in situ examination, the finished construction is checked with reference to the “as built” drawings, establishing its conformity with the requirements. One shall take into consideration: the uniformity of construction, any possible permanent deformations, the rigidity of the structure, stability, manholes, access to the gauge hatch, the possibility of carrying out calibration (if appropriate, additional work which would facilitate calibration, may be required), internal fittings (deadwood), floating roof or floating cover, attachments for the fitting of the calibration information plate.

The tanks shall be pressure tested, leak proof and cleaned, the results being recorded in a document which shall be presented before calibration starts.

7.3.2 Calibration
Carry out tank calibration in accordance with the applicable ISO standards, or national standards as required.

7.4 Subsequent or periodic verification is up to the national metrological authorities.

At least in-service recalibration shall be carried out after any accident or deformation of the tank, which could cause a change in its metrological qualities (including changing its position and modifications).

Periodic verification and in-service recalibration consist of :
— examination of the construction and of its external appearance;
— calibration.

7.4.1 During the examination of the construction and of its external appearance, it shall be ascertained that no modifications were carried out with reference to the “as build” drawings. If this is not the case, the problem may be solved in situ if it is of minor importance, or the drawings shall be amended and their approval renewed.

7.4.2 Recalibration may be carried out after it has been confirmed that :

- the result of the examination of construction and external appearance is satisfactory;
- the requirements in point 4.5 are complied with.

Concerning the calibration itself, the requirements in point 5.5 shall also be taken into account.

7.5 Calibration of tanks

The calibration of a tank may be carried out by one of the following methods :

- geometric;
- volumetric;
- a combination of the two.

The choice of the method or of the procedure is imposed by the nominal capacity of the tank, the shape, the position, the conditions of use, etc.

For calibration one of the ISO calibration methods should be used.

A list of ISO Standards and Draft Standards for different calibration methods is given in Appendix 2.

7.5.1 The geometric methods consist of direct or indirect measurement of external or internal dimensions of the tank, of the positive and negative deadwoods and of the floating roof or floating cover, if provided.

Note : the procedure of internal measurement by means of a tape with a tensioning device is generally not admitted for calibration of tanks containing liquids involved in international trade, except when no better method is applicable (for example, in the case of a thermally insulated tank).

The geometric methods may be used on tanks with a nominal capacity of about 50 m^3 and greater, which have a regular geometric shape and show no deformation.

7.5.2 The volumetric method consists in establishing directly the internal capacity, by measuring, by means of a measurement standard, the partial volumes of a non-volatile liquid which are successively delivered into, or withdrawn from the tank. Water is a very suitable non-volatile liquid with the additional advantage of having a small coefficient of expansion.

The volumetric method is generally used for the calibration of the following categories of tanks:

- underground tanks, of any type;
- tanks on the ground or above ground, with a nominal capacity up to 100 m^3;
- tanks of a shape not suitable for a geometric method.

7.5.3 The combination method consists in establishing, by means of the geometric method, the volumes corresponding to the shell of the tank and by means of the volumetric method the volumes corresponding to the bottom of the tank.

This method applies, under the same conditions as the geometric method, to tanks of which the lower part consists of a shape for which the volume cannot be determined with sufficient accuracy, by means of the geometric method.

7.6 Granting of the calibration certificate and application of the verification mark (according to national regulations).

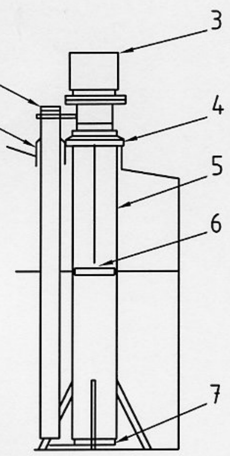
7.6.1 The tanks which comply with all the requirements of this Recommendation shall be accepted for fiscal and custody transfer applications ; after calibration, the calibration certificate is issued and the markings on the data plate are completed.

7.6.2 The calibration certificate shall be issued in accordance with the standard used for the calibration :

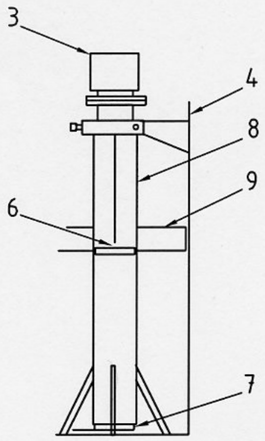
7.6.3 The legality of the verification is confirmed by applying a verification mark on:
— the calibration certificate;
— the data plate.

Annex A Examples of location of gauge hatches and of realization of the reference points
(Informative)

Some pictures are taken from ISO documents.
Before publication, permission by ISO has to be granted.



a) Installation of top-mounted ALGs on fixed-roof tanks with still-well



b) Installation of top-mounted ALGs on external floating-roof tanks or on internal floating-roof tanks with still-well

Key

1 Flexible weather seal
2 See note 1
3 Automatic level gauge (ALG) attached to top of still-well
4 Perforated still-well sliding guide
5 Perforated still-well (see notes 1 and 5)
6 Level-detecting element (see note 2)
7 Datum plate (see note 4)
8 Perforated still-well (see notes 1 and 3)
9 Pontoon

NOTE 1 Separate still-well(s) for manual gauging and temperature measurement may be installed adjacent to the ALG still-well.

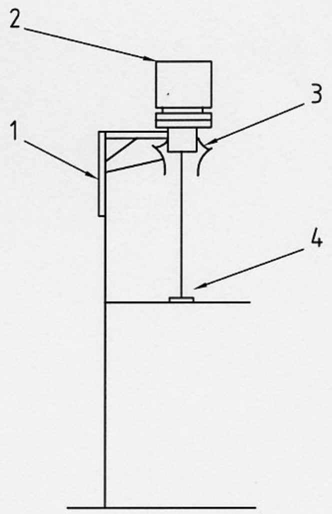
NOTE 2 Typical for some intrusive ALGs. Non-intrusive top-mounted ALGs can be installed in a similar way.

NOTE 3 Local environmental restrictions may require the use of non-perforated still-well(s) on external floating-roof (EFR) tanks, but this can result in serious gauging errors and have safety implications (risk of tank overflow) in certain circumstances (see 6.5.7).

NOTE 4 The datum plate should be mounted on the tank bottom located below the still-well, or attached to the still-well (as shown).

NOTE 5 An ALG may also be mounted on the stable section of the roof of a fixed-roof tank (not shown in this figure).

Example of an ALG (intrusive or non-intrusive) mounted on a still-well supported by the tank bottom



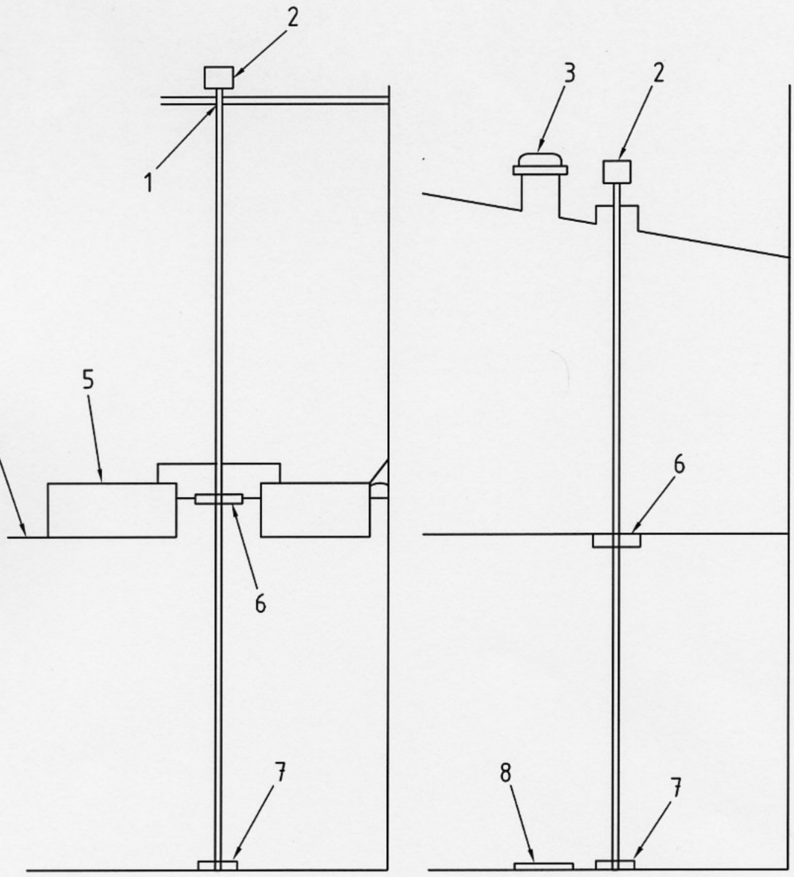
Key

1	Bracket welded to upper ring-segment of tank
2	Automatic level gauge (ALG) mounted on a bracket
3	Flexible seal to prevent emission of vapour from tank (see note 2)
4	Level-detecting element (see note 1)

NOTE 1 Typical for some intrusive ALGs. Non-intrusive, top-mounted ALGs can be installed in a similar way.

NOTE 2 Use of a flexible seal may be subject to environmental regulations.

- Example of an ALG supported by a "gallows"



Key

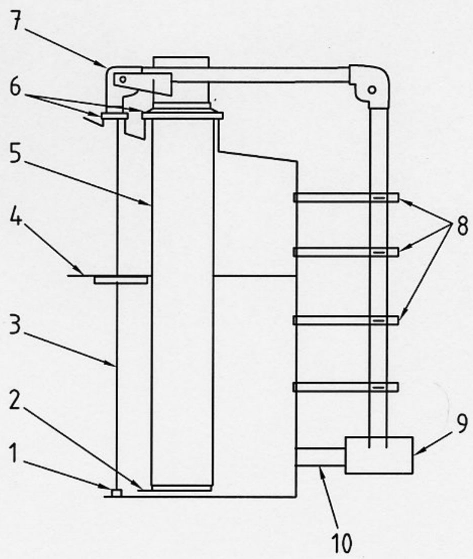
1	ALG guided through gauger's platform
2	ALG (see notes 1 et 3)
3	Manual gauge hatch
4	Floating roof
5	Pontoon
6	Level sensor
7	ALG support
8	Dipping datum plate

NOTE 1 A still-well is often not required for innage ALGs, especially in small tanks. Where a still-well is provided for protection, for stability of mounting, and to minimize turbulence, it should be perforated (see 6.5.7).

NOTE 2 A means to secure and support the innage ALG should be provided at the tank bottom.

NOTE 3 An innage ALG should not be rigidly mounted on, nor supported from, the tank roof (fixed-roof tanks) or the gauger's platform (external floating-roof tanks). Instead, it should be guided through the roof and platform so that it remains vertical and is not affected by movement of the roof/platform due to tank-shell bulging with increasing hydrostatic head of the tank contents, and/or thermal expansion/contraction effects.

Example of an innage ALG supported on the tank bottom



Key

1	Anchor bar or weight
2	Datum plate (see note 3)
3	Guide wire
4	Level-sensing element
5	Perforated still-well (see notes 1 and 2)
6	Sliding guides
7	Pulley housing attached to top of still-well
8	Sliding guides
9	Automatic level gauge (ALG) attached to tank shell
10	Bracket

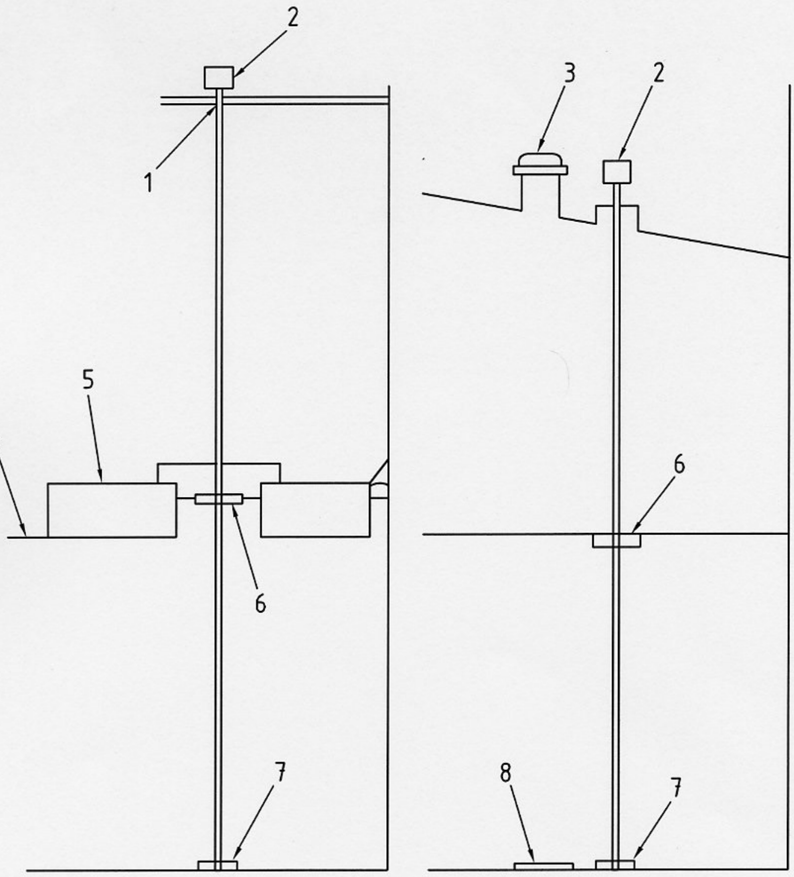
NOTE 1 A separate still-well for an automatic tank thermometer may be installed adjacent to the manual still-well.

NOTE 2 Local environmental restrictions may require the use of non perforated still-well(s) on external floating-roof (EFR) tanks, but this can result in serious gauging errors and have safety implications (risk of tank overflow) in certain circumstances (see 6.5.7).

NOTE 3 The dipping datum plate should be mounted on the tank bottom, located below the still-well or attached to the still-well (as shown).

NOTE 4 The manual gauging still-well may alternatively be supported by a hinged trunnion arrangement, as shown in Figure 2.

Example of an intrusive ALG (displacement type) attached to the tank shell near the tank bottom



Key

1 ALG guided through gauger's platform
2 ALG (see notes 1 et 3)
3 Manual gauge hatch
4 Floating roof
5 Pontoon
6 Level sensor
7 ALG support
8 Dipping datum plate

NOTE 1 A still-well is often not required for innage ALGs, especially in small tanks. Where a still-well is provided for protection, for stability of mounting, and to minimize turbulence, it should be perforated (see 6.5.7).

NOTE 2 A means to secure and support the innage ALG should be provided at the tank bottom.

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Example of an innage ALG supported on the tank bottom

Annex B Deformation of tanks
(Informative)

(See article 7.1.4 and ISO 7507-1)

B.1 Vertical cylindrical tanks

For a vertical cylindrical tank the relative reduction in height of the tank (lowering of the upper part of the tank shell) due to complete filling with a liquid whose density is ρ (kg/m^3) can be calculated(*) using the formula below, where:
$\Delta H/H$ = relative reduction in height (%)
H = height of the tank (m)
D = diameter of the tank (m)
g = gravitational acceleration (m/s^2)
E = modulus of elasticity (N/m^2)
μ = Poisson ratio (non-dimensional)
h_n = height of the n th course from the bottom (m)
w_n = thickness of the n th course from the bottom (mm)
(See also Figure 2).

Note: The Poisson ratio μ is the lateral contraction divided by the elongation (e.g. μ_{steel} = 3.3).

$$\frac{\Delta H}{H} = \frac{D\rho g}{4\mu E}\left[\frac{H}{w_1} + \frac{(H-h_1)^2}{H}\left(\frac{1}{w_2} - \frac{1}{w_1}\right) + \frac{(H-h_1-h_2)^2}{H}\left(\frac{1}{w_3} - \frac{1}{w_2}\right) + \right.$$

$$\left. \dots \dots + \frac{(H-(h_1+h_2+\dots+h_{n-1}))^2}{H}\left(\frac{1}{w_n} - \frac{1}{w_{n-1}}\right)\right]$$

B.2 Horizontal cylindrical tanks
As long as no formulas are available possibly this Recommendation should not cover these tanks. To be discussed.

For a horizontal cylindrical tank the effect of complete filling with a liquid can be calculated using formulae which will be developed by ISO/TC 28/SC 3/WG 1.

B.3 Spherical and prismoidal tanks

For spherical and prismoidal tanks the effect of complete filling with a liquid can be calculated using formulae which will be developed by ISO/TC 28/ SC 5/WG 1.

(*)Sometimes the real behavior of tanks differs from the formula. In field tests some tanks have shown no measurable reduction while others have shown significant variations.

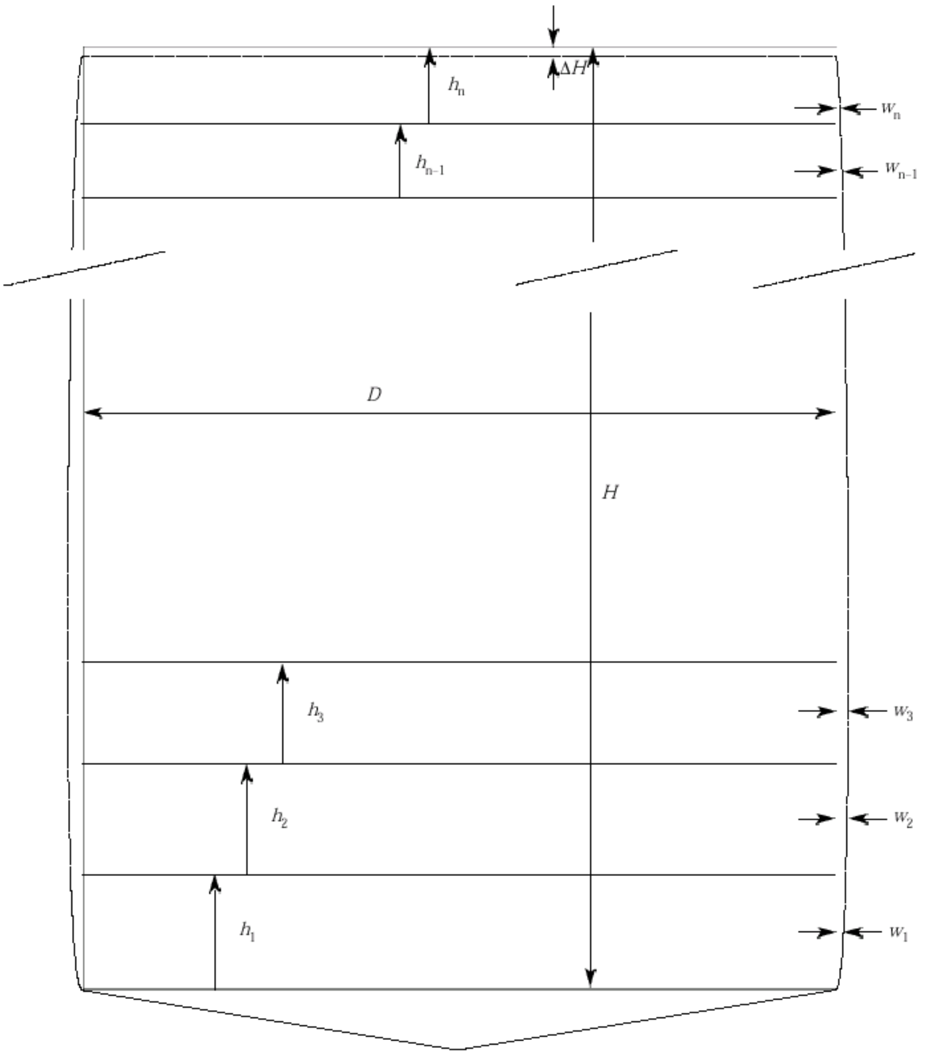

Figure 2 Deformation of tanks

Annex C Bibliography

[To be completed later]

ISO/TC 28/SC 3

[1] ISO 4512 Petroleum and liquid petroleum products — Equipment — Tank gauging and calibration — Manual methods.

[2] ISO 4269 Petroleum and liquid petroleum products — Tank calibration — Liquid methods.

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

[4] ISO 7507-2 Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 2 : Optical reference line method.

[5] ISO 7507-3 Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 3 : Optical triangulation method.

[6] ISO7507-4 Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 4 : Electro-optical distance ranging method.

[7] ISO 7507-5 Calibration of vertical cylindrical tanks -- Part 5: External electro-optical distance-ranging method

[8] ISO 7507-6: Calibration of vertical cylindrical tanks - Part 6: Recommendations for monitoring, checking and verification of tank calibration and capacity table

[9] ISO 12917-1 and 12917-2 (2002): Calibration of horizontal cylindrical tanks — Geometric method.

[10] ISO 9770 liquid (1989) and 8973 LPG (1997): Compressibility correction.

[11] DP 4267/1 Petroleum and liquid petroleum products — Calculation of oil quantities — Part 1 : Static measurement.

ISO/TC 28/SC 1 and 5

[12] ISO 4273 Vocabulary of petroleum measurement terms.

[13] ISO 5024-1976 Petroleum liquid and gases — Measurement — Standard reference conditions.

[14] ISO 7394 Natural gas liquids and vapours — Conversion to equivalent liquid volumes.

[15] ISO 6578 Refrigerated hydrocarbon liquids — Static measurement — Calculations procedure.