Petroleum and Liquid Petroleum Products—Calibration of Horizontal Cylindrical Tanks

Part 1: Manual Methods

ANSI/API MPMS CHAPTER 2.2E
FIRST EDITION, APRIL 2004

REAFFIRMED, AUGUST 2014

ERRATA, NOVEMBER 2009

ISO 12917-1: 2002 (Identical), Petroleum and liquid petroleum products—Calibration of horizontal cylindrical tanks—Part 1: Manual methods

AMERICAN PETROLEUM INSTITUTE

Date of Issue: November 11, 2009
Affected Publication: API *MPMS* Chapter 2.2E, *Petroleum and Liquid Petroleum Products—Calibration of Horizontal Cylindrical Tanks*, Part 1: *Manual Methods*, First Edition, April 2004

ERRATA

Page 8, Clause 15

At the end of the first sentence, replace “can be neglected” with “can be neglected if E/D is less than 0,012”. At the end of the paragraph, replace “normative annex A” with “Annex A”.

Page 14, Figure A.1:

Replace items 1 and 2 in the key with the following:

Key

Value of H/D: 0,5 to 0,999 — subtract volume correction when the tank is more than half full

Value of H/D: 0,001 to 0,5 — add volume correction when the tank is less than half full

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Standards department telephone (202) 682-8000. A catalog of API publications, programs and services is published annually and updated biannually by API, and available through Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the Director of the Standards department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should be addressed to the Director, Business Services.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

API Foreword

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to API, Standards department, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this part of ISO 12917 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12917-1 was prepared by Technical Committee ISO/TC 28, Petroleum products and lubricants, Subcommittee SC 3, Static petroleum measurement.

ISO 12917 consists of the following parts, under the general title Petroleum and liquid petroleum products — Calibration of horizontal cylindrical tanks:

— *Part 1: Manual methods*

— *Part 2: Internal electro-optical distance-ranging method*

Annex A forms a normative part of this part of ISO 12917. Annex B is for information only.

This corrected version of ISO 12917-1:2002 incorporates the following corrections.

On the cover page, “Première édition” has been replaced by “First edition”.

The missing Greek symbols have been added in the following equations:

— page 9, subclause 16.3, four equations;

— page 10, subclause 16.3, equation immediately above Figure 4;

— pages 15 and 16, clause B.2, six equations.

Introduction

This International Standard forms part of a series on tank calibration methods. In countries where some or all of the items covered by this part of ISO 12917 are subject to mandatory regulations, the regulations have to be observed. In cases where differences exist between this part of ISO 12917 and regulations, precedence is given to the latter.

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

Part 1: Manual methods

1 Scope

This part of ISO 12917 specifies manual methods for the calibration of nominally horizontal cylindrical tanks, installed at a fixed location. It is applicable to horizontal tanks up to 4 m in diameter and 30 m in length.

The methods are applicable to insulated and non-insulated tanks, either when they are above-ground or underground. The methods are applicable to pressurized tanks, and to both knuckle-dish-end and flat-end cylindrical tanks as well as elliptical and spherical head tanks.

This part of ISO 12917 is applicable to tanks inclined by up to 10 % from the horizontal provided a correction is applied for the measured tilt.

For tanks over and above these dimensions and angle of tilt, appropriate corrections for tilt and appropriate volume computations should be based on the "Coats" equation [1].

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 12917. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 12917 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1998 (all parts), *Petroleum industry — Terminology*

ISO 7507 (all parts), *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks*

3 Terms and definitions

For the purposes of this part of ISO 12917, the terms and definitions given in ISO 1998, ISO 7507-1 and the following apply.

3.1
telescopic rod
extendable tubular measuring device to measure a distance between two points

NOTE For example, to measure the internal diameter of a cylindrical tank.

4 Precautions

4.1 General

The general and safety precautions given in ISO 7507-1 shall apply to this part of ISO 12917.

4.2 Internal method

Before a tank which has been used is entered, a safe-entry certificate, issued in accordance with local or national regulations, shall be obtained. All lines entering the tank shall be disconnected and blanked. The national or local regulations regarding entry into tanks which have contained leaded fuels shall be meticulously observed.

4.3 External method

National or local regulations regarding entry to the tank area shall be observed.

5 Equipment

5.1 Equipment as used in the ISO 7507 series

The equipment required to carry out the calibration is dependent on the method to be employed. This part of ISO 12917 uses techniques and equipment described in ISO 7507-1. Equipment used in the calibration of horizontal tanks shall conform with the specifications laid down in the relevant parts of ISO 7507. All equipment shall be traceable to a reference standard.

5.2 Telescopic rod

5.2.1 In addition to the equipment mentioned in 5.1, a telescopic rod shall be used. This telescopic rod shall have a scale capable of being read to 1 mm, and shall be calibrated to within $\pm$ 0,5 mm.

5.2.2 The telescopic rod shall give a repeatability of maximum 1 mm.

6 General requirements

6.1 The tank shall be filled to its normal working capacity and working pressure at least once and allowed to stand while full for at least 24 h prior to emptying and preparing the tank for calibration.

NOTE The hydrostatic test applied to new or repaired tanks will satisfy this requirement when additional pressure tests are carried out.

6.2 The following variables shall be considered for the development of the capacity tables:

— slope/tilt;

— deadwood;

— temperature;

— pressure;

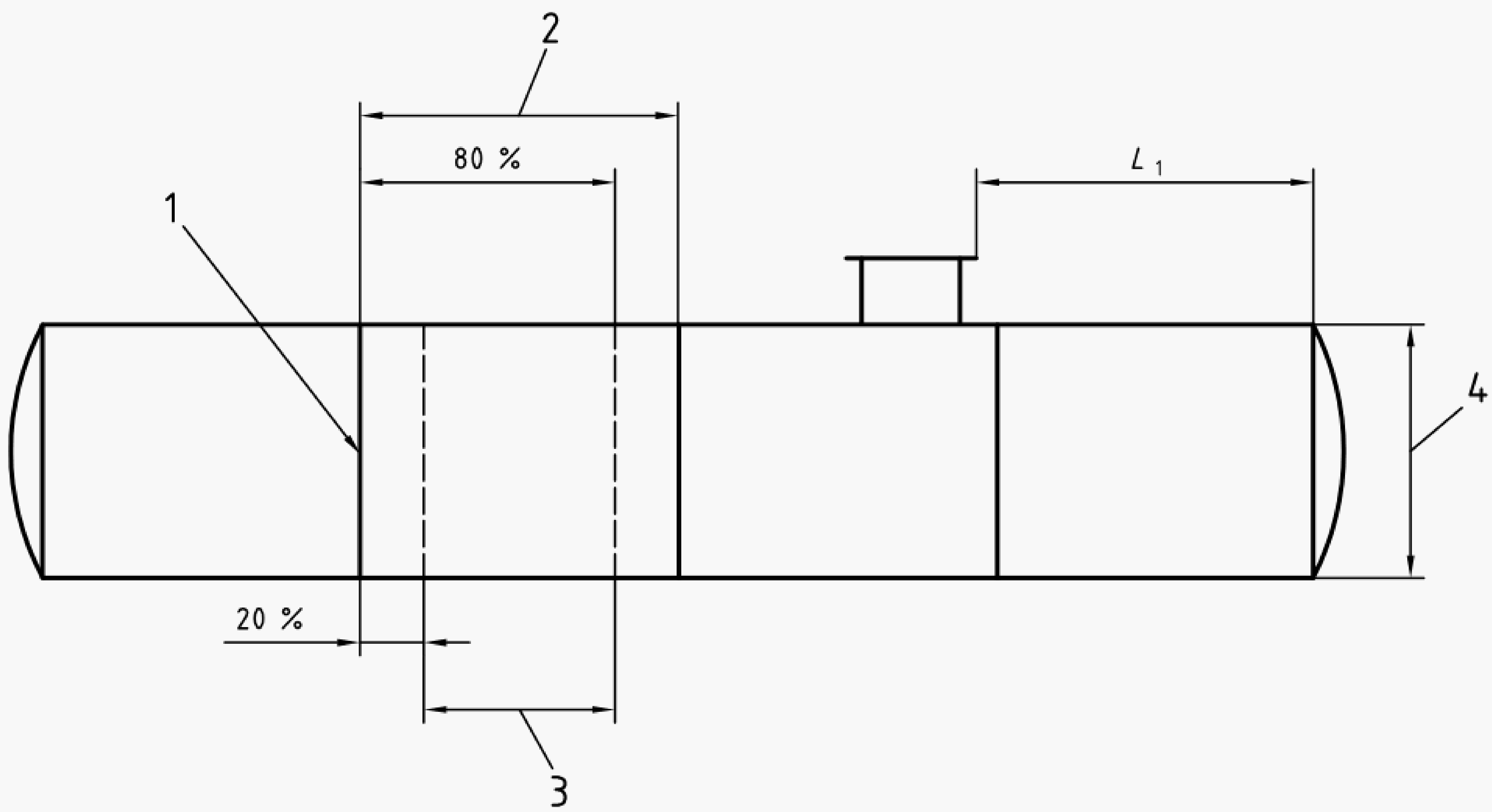
— liquid head;

— position of gauge point.

7 Calibration procedures

The calibration procedures for calibration of horizontal cylindrical tanks are described in clause 8 (external measurements) and clause 9 (internal measurements).

For both methods, measurements will be taken at around 20 % and 80 % of the width of each ring (see Figure 1).



Key

1 Weld line

2 Course length

3 Circumference measurement

4 Reference height

Figure 1 — Measurements of the diameters/circumferences

8 External measurements

8.1 Introduction

External measurements may be executed with any depth of liquid and liquid pressure in the tank. The depth, temperature, density and pressure of the liquid at the time of calibration shall be recorded. However, if the temperature of the tank wall could differ by more than 10 °C between the empty part and full part of the tank whilst the measurements are being taken, the tank shall be either completely full or empty during the procedure.

8.2 General

For the measurement procedures, a circumferential tape of sufficient length to completely encircle the tank should be used and measurements of the total circumference shall be taken.

a) In all cases, the tape to be used should be applied to the tank surface at the prescribed locations by the wraparound procedure; i.e. the required length of tape should be applied in a slack condition, positioned, and tightened by the application of the proper tension.

As indicated in Figure 1, strapping should be undertaken around 20 % and 80 % of the course length

b) In the case in which the circumferential measuring tape is in contact with the tank surface at all points along its path, circumferential measurements should be made and checked in accordance with the relevant procedure given in ISO 7507-1. The checked measurements should be recorded as final measurements.

8.3 Repetition of measurements

After the circumference has been measured, the tension shall be released and the tape brought again to the required level and tension. The readings shall then be repeated and recorded.

8.4 Tolerances

Measurements shall be read to the nearest 1 mm and shall be considered satisfactory if two consecutive readings are within ± 0,03 % of the circumference or 3 mm, whichever is greater.

If agreement is not obtained, further measurements shall be taken and recorded until two consecutive readings agree. The average of these two readings shall be taken as the circumference. If consecutive measurements do not agree, the reason for the disagreement shall be determined and the calibration procedure shall be repeated.

8.5 Other measurements on tank-shell plates

8.5.1 Plate and paint thickness

Plate, paint and any coating thickness shall either be measured for each course, whenever possible, by an ultrasonic device/primary method, or will be taken from the drawings. The plate and paint thickness for each course shall be recorded to the nearest 0,5 mm. Physical measurements are preferred to readings from drawings.

8.5.2 Length of the horizontal cylinder

The length of the horizontal tank (cylindrical part) shall be measured at the welding of the first knuckle at four measuring points representative of the length of the tank (see Figure 2).

For each measuring point, a reference point shall be marked on the tank. The measurement of the length should be repeated at least twice. Measurements shall be read to the nearest 1 mm and shall be considered satisfactory if two consecutive readings are within 0,03 % of the length or ± 3 mm, whichever is greater. Determine the overall length by taking the average of the two consecutive readings.

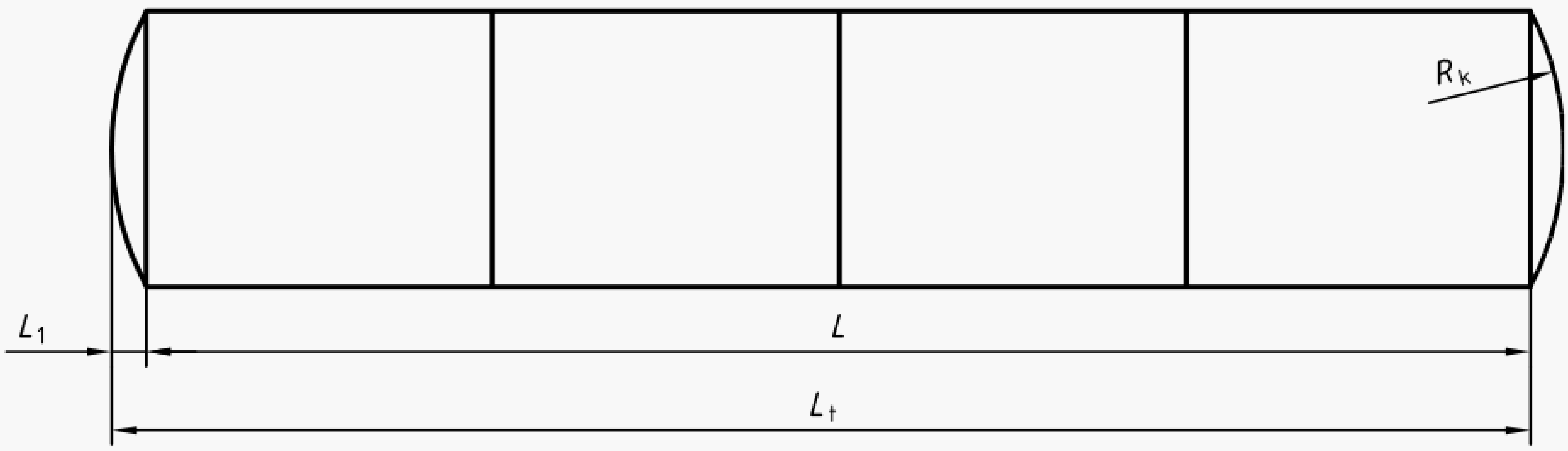
8.5.3 Head radii measurements

The radius of the knuckle shall be measured using templates or depth gauges whenever possible (see Figure 2), taking up to eight measurements around the circumference, if practical, or taken from the drawings. An average of eight measurements shall then be computed.

NOTE Physical measurements are preferred to readings from drawings.

8.5.4 Head length measurements

The length of the head shall be measured between the weldings mentioned in 8.5.2 at least two points (see Figure 2).



L Length of cylindrical part of tank (see 8.5.2 and 9.4.2);

L_t Total length of tank (see 9.4.5);

L_1 Length of head (see 8.5.4 and 9.4.4);

R_k Radius of knuckle (see 8.5.3 and 9.4.3).

Figure 2 — Measurements of lengths and radii

9 Internal measurements

9.1 General

For the measurement procedures, a telescopic rod (5.2) of sufficient length to completely measure the internal diameter of the tank shall be used. The internal method is applicable to tanks less than 4 m in diameter.

In all cases, the telescopic rod shall be applied to the tank at the prescribed locations, at four positions, equally divided around the circumference. The average of these four measurements shall be recorded.

9.2 Repetition of measurements

After an internal diameter has been measured, the telescopic rod shall be released and brought back again to the tank shell. The readings shall be repeated and recorded.

9.3 Tolerances

Measurements shall be read to the nearest 1 mm and shall be considered satisfactory if they are within ± 0,05 % of the diameter or ± 1 mm, whichever is greater.

If agreement is not obtained, further measurements shall be taken and recorded until two consecutive averages agree. The overall average of these two averages shall be taken as the diameter. If consecutive measurements do not agree, the reason for the disagreement shall be determined and the calibration procedure shall be repeated.

9.4 Other measurements on tank-shell plates

9.4.1 Plate thickness

The plate thickness shall either be measured for each course, whenever possible, or will be taken from the drawings. The plate thickness for each course shall be recorded to the nearest 0,5 mm. Physical measurements are preferred to readings from drawings.

NOTE The thickness is required for pressure correction.

9.4.2 Length of the horizontal cylinder

The length of the horizontal tank (cylindrical part) is measured at the welding of the first knuckle at four measuring points representative of the length of the tank (see Figure 2).

For each measuring point, a reference point shall be marked on the tank. The measurement of the length should be repeated at least twice. Measurements shall be read to the nearest 1 mm and shall be considered satisfactory if two consecutive readings are within 0,03 % of the length or ± 3 mm, whichever is greater. Determine the overall length by taking the average of the two consecutive readings.

9.4.3 Head radii measurements

The radius of the knuckle shall be measured using templates or depth gauges whenever possible (see Figure 2) taking up to eight measurements around the circumference, if practical, or taken from the drawings. An average of eight measurements is then computed.

NOTE Physical measurements are preferred to readings from drawings.

9.4.4 Head length measurements

The length of the head shall be measured between the weldings mentioned in 9.4.2 at at least two points (see Figure 2).

9.4.5 Measurement of length between centre head

The total length of the tank shall be measured between each end (between centre heads). Repeat the measurements until two consecutive readings agree within a tolerance of ± 0,03 % of the length or 3 mm, whichever is greater.

10 Additional measurements

10.1 Deadwood

The dimensions of the deadwood shall be measured, whenever possible, or taken from the drawings and the heights of the lowest and highest point of such deadwood measured in relation to the datum point of the tank. The measurements shall be recorded to the nearest 5 mm.

10.2 Measurement of tilt

10.2.1 Above-ground tanks

When the tank is installed above the ground, a theodolite instrument with a measuring stroke can be used to determine the tilt of the tank by measuring the difference in horizontal height at the weldings, i.e. at the knuckle-weldings.

The theodolite is therefore installed at the middle of the horizontal length of the tank, a little distance from the tank. The angle to the target points on the knuckle-weldings is then measured, and used for the calculation of the tilt angle (standard survey technique).

10.2.2 Underground tanks

When the tank is installed underground, a theodolite instrument with a measuring stick can be used to determine the tilt of the tank.

The theodolite is therefore installed at the middle of the horizontal length of the tank and the height and distance of the measuring stroke (standard survey technique) is then measured.

10.2.3 Measurement of overall dip height

Measure the overall dip height at the reference gauge hatch.

11 Other parameters

For the computation of the capacity table, the following additional parameters should be taken into account:

- liquid head;
- working pressure;
- working temperature.

12 Recalibration

Tanks shall be recalibrated whenever the calibration becomes suspect or the tank becomes physically deformed, for example, due to movement off the tank foundations or as required by national regulations. Similarly, if new equipment affecting deadwood volume is fitted or deadwood is removed, the tank calibration table shall be recalculated.

13 Descriptive data

13.1 Descriptive data should be entered on the tank measurement form. The commonly used name for the contents of the tank is a sufficient description. If a more accurate description is desired, a hydrometer reading shall be obtained and recorded with the temperature of the sample.

13.2 Supplemental pencil sketches, each completely identified, dated and signed, will form an important part of the field data. The sketches should show

a) typical vertical and circumferential seams,

b) number and size of plates per ring,

c) location of rings at which the thickness of the plate changes,

d) arrangements and size of nozzles and manways,

e) dents and bulges in shell plates,

f) amount of off-level from the horizontal position,

g) method used in bypassing an obstruction in the path of a circumferential measurement,

h) location of the tape path different from that shown on guide sheets, and

i) location and estimated size of a gauging shelf.

NOTE Further details can be found in annex C of ISO 7507-1:1993.

14 Computation of tank capacity tables — General rules

14.1 All calculations shall be made in accordance with accepted mathematical principles. Errors in calculation are minimized and checking facilitated by the adoption of a standard form of calculation and data sheet.

14.2 The calculation methods given below lay down minimum requirements for precision, but it is permissible to use alternative procedures which produce a final tank capacity table of similar or greater precision. Unless otherwise specified, volume shall be expressed with an accuracy of five significant figures.

14.3 Tank capacity tables prepared in accordance with the recommendations set out below shall bear the words:

"Calibrated by the External/Internal Manual Method in accordance with ISO 12917-1."

14.4 The standard temperature and standard pressure flow, for which the tank capacity table has been calculated, shall also be recorded at the head of the table.

14.5 All deadwood shall be accurately accounted for concerning volume and location, in order to provide adequate allowance for the volume of liquid displayed by the various parts and to provide allocation of the effects of various elevations within the tank.

14.6 All measurements shall be corrected for thermal expansion and according to the devices calibration if necessary.

NOTE If the linear thermal expansion of the tank and the measuring device (tape or rod) are similar, no further correction is necessary.

15 Effects of tilt

When the gauging point of the tank is in the centre (longitudinally), the correction for tilt can be neglected. In all other situations, an additional correction for the tilt, related to the position of the gauging point shall be applied (see normative annex A).

16 Systematic calculations (summary)

16.1 General

The systematic calculations are built up in three sequential parts:

a) calculation of the volume of the cylindrical part of the tank (see 16.2);

b) calculation of the volume of the tank heads (see 16.3);

c) calculation of the volume of the deadwood (see 16.4).

After completion of 16.2 to 16.4, additional corrections are made to the volume for working pressure, tank wall temperature, liquid head and tilt. These corrections are calculated according to the formulae in annex A.

16.2 Cylindrical volume

The volume of the cylindrical part of the tank (see Figure 3) is calculated from:

$V = A \times L$ with $0 \leqslant h \leqslant 2R$

in which $A = 0{,}5\, R^2\, (\alpha - \sin\alpha^N)$

in which $\alpha^N = 2 \times \arccos \frac{(R-h)}{R}$

in which $R = \frac{D}{2}$

where

D is the average internal diameter of the tank;

h is the height of liquid in the tank;

V is the volume as a function of liquid level;

L is the length of the cylindrical part of the tank.

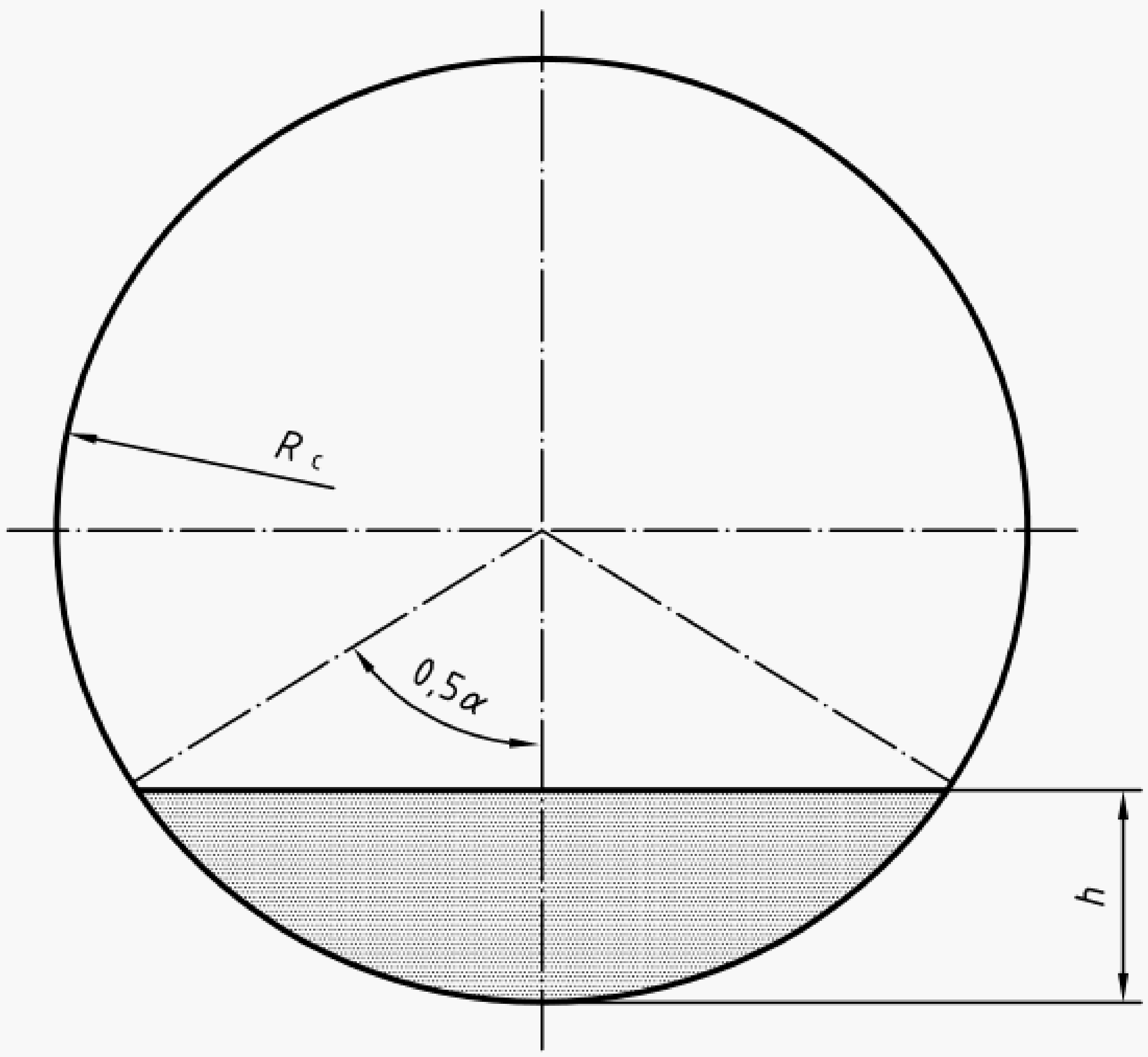


Figure 3 — Calculation of cylindrical volume

16.3 Volume of the knuckle-dish ends

Calculation of the volume of the knuckle-dish ends is based on the following data:

a) radius of the knuckle, R_k;

b) radius of the dish, R_d;

c) radius of the cylinder, R.

The measured length of the head is only for checking the calculations.

From Figure 4, the following equations can be derived:

$$\sin\beta = \frac{(R - R_k)}{(R_d - R_k)}$$

$$R_2 = R_d \times \sin\beta$$

$$x_2 = R_k \times \cos\beta$$

$$x_1 = R_d - (R_d - R_k) \times \cos\beta \text{ (calculated depth)}$$

Using this information, the radii of the dish as a function of the distance, R_x, will be calculated:

$$0 \leqslant x \leqslant x_2$$

$$R_x = (R - R_k) + \sqrt{R_k^2 - x^2}$$

and

$$x_2 \leqslant x \leqslant x_1$$

$$R_x = \sqrt{R_d^2 - (M + x)^2}$$

in which $M = (R_d - R_k) \times \cos \beta$

The volume as a function of liquid level (h) of the knuckle dish will then be calculated by the numerical integration according to Simpson:

$$V_h = \int_0^h A_h(x) dx$$

in which $A_h(x) = R_x^2 \times (0,5\alpha_x - 0,5 \sin \alpha_x)$

in which $\alpha_x = 2 \times \arccos\left(\frac{R - h}{R_x}\right)$

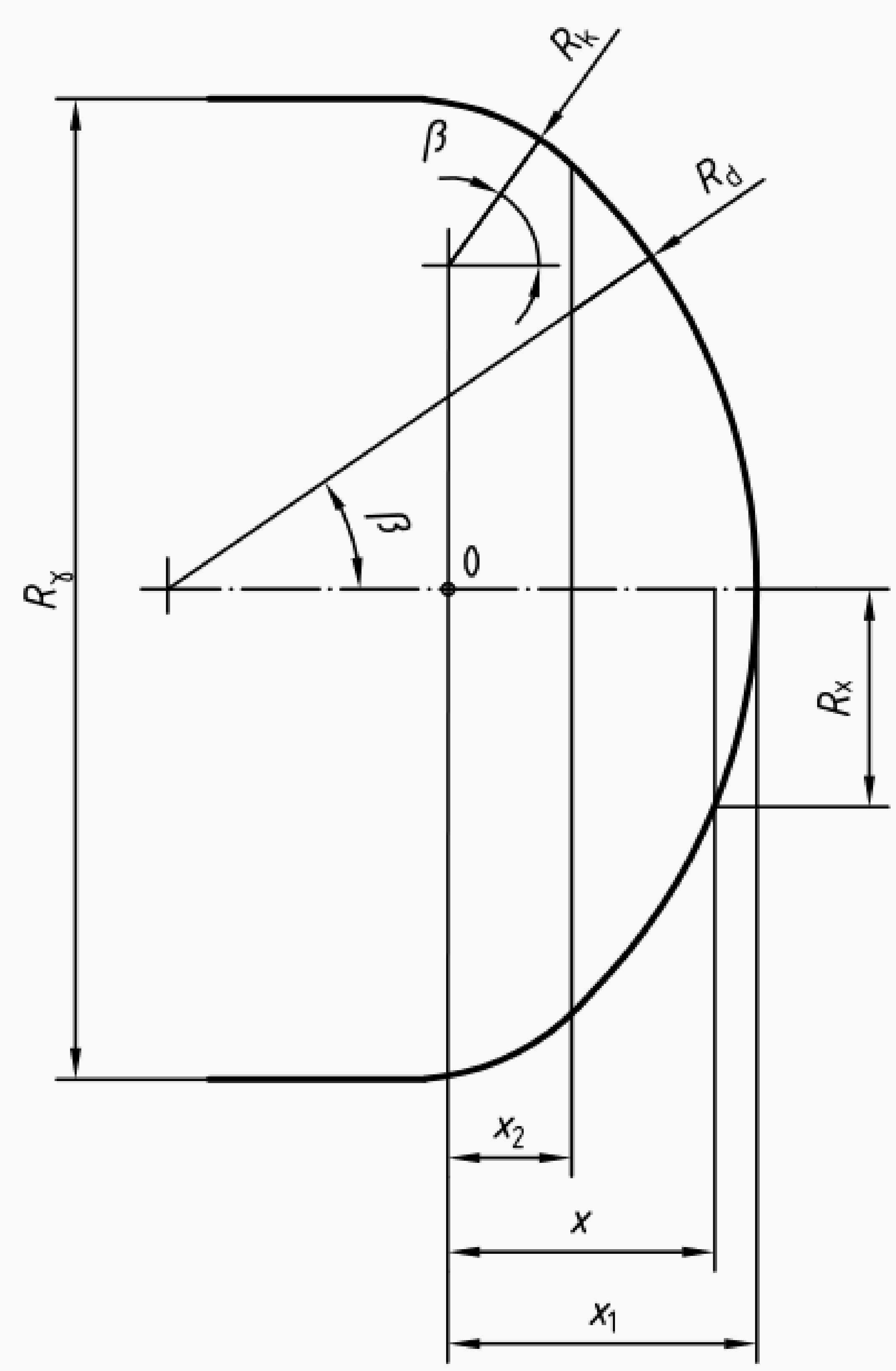


Figure 4 — Calculation of volume of the knuckle-dish end

16.4 Elliptical ends

16.4.1 Total volume

The total volume, V_t, is calculated from:

$$V_t = \frac{2}{3} \times \pi \times R^2 \times L_1$$

where

R is the radius of the head (see Figure 5);

L_1 is the length of the head.

16.4.2 Partial volume

The partial volume, V_h, is calculated from:

$$V_h = \frac{\pi \times L_1 \times h^2}{2} \times \left(1 - \frac{h}{3R}\right)$$

where h is the product height (see Figure 5).

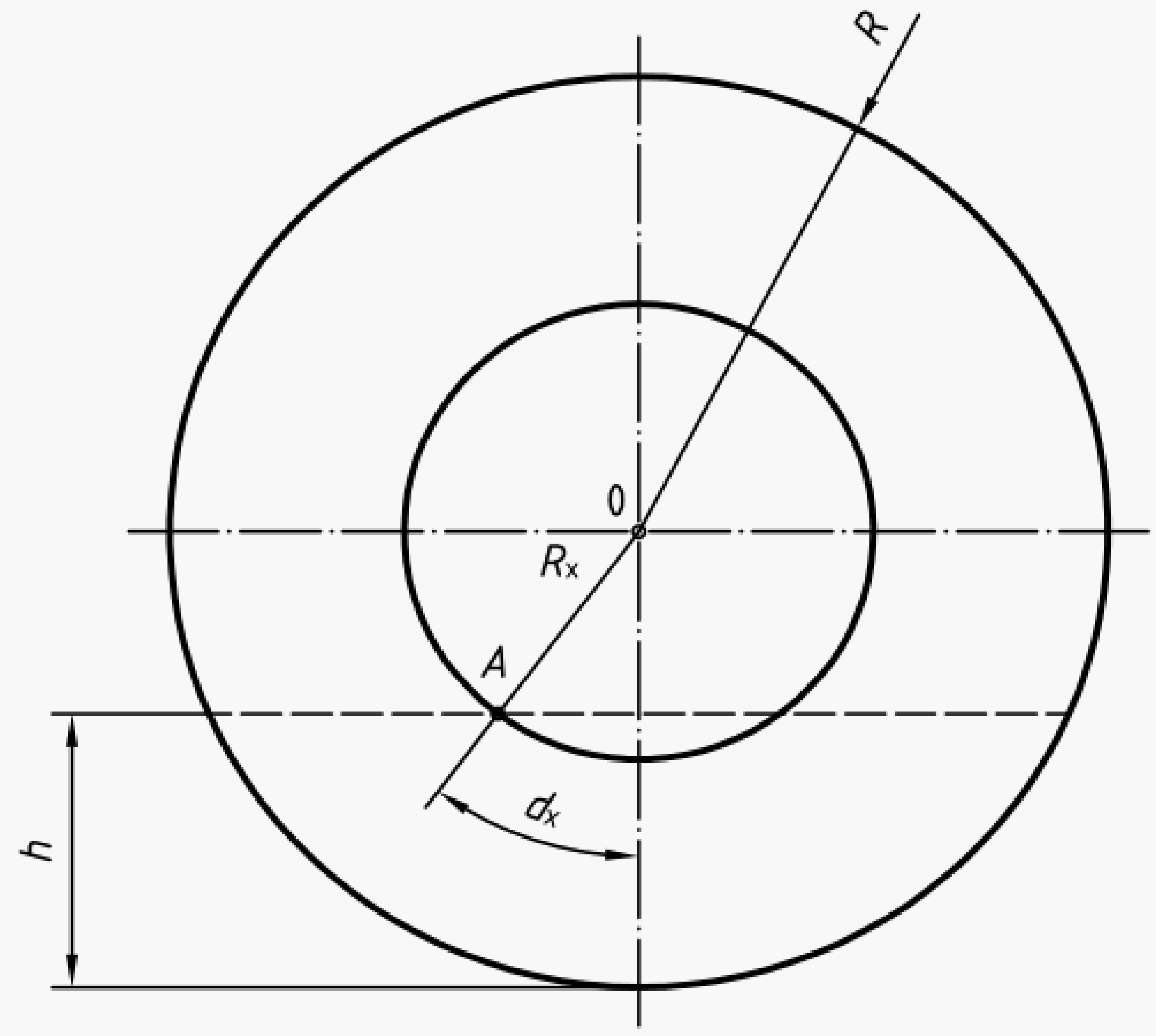


Figure 5 — Ends

16.5 Spherical head

16.5.1 Total volume

The total volume, V_t, is calculated from:

$$V_t = \frac{\pi \times L_1}{6}\left(3R^2 + L_1^2\right)$$

16.5.2 Partial volume

Calculate as knuckle head with knuckle radius = 0.

16.6 Deadwood

The calculation of the volume of the deadwood shall be carried out as described in ISO 7507-1.

Annex A
(normative)

Tilt

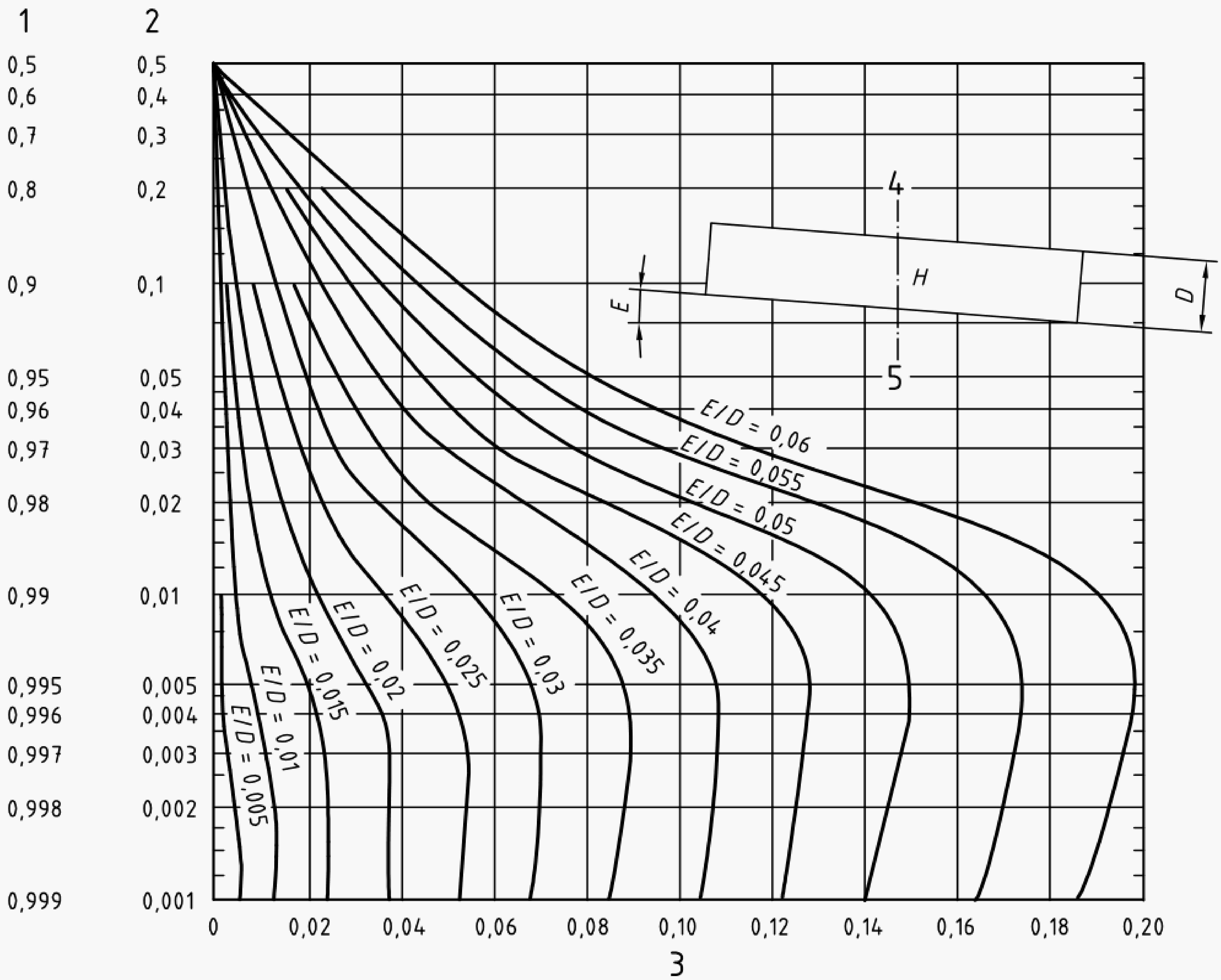
Disregard the effect of tilt if the value of E/D, as shown in Figure A.1, is less than 0,012.

For tanks with tilt exceeding the limit of 0,012, correction of the volume will be carried out according to Figure A.1.

When the gauging is done from the longitudinal centre of the tank, a procedure based on measurements and computations may be used. Compute the total volume of the cylindrical section of the tank. Incremental volumes for the inclined position are determined by taking percentages of total volume. Figure A.1 gives satisfactory correction factors for the volume at any point of tilted tanks. This procedure applies only to the cylindrical sections of off-level tanks.

The effect of tilt upon the volume of the heads is negligible.

NOTE For tanks larger than 4 m in diameter and 30 m in length, the “Coats” equations [1] should be used for tilt corrections and volume computation.



Key

1 Value of H/D – subtract volume correction when tank is less than half full

2 Value of H/D – add volume correction when tank is less than half full

3 Volume correction, percentage of total tank capacity

4 Centre of tank

5 D, E and H may be measured vertically, if desired

D Diameter of the tank, in metres

E Elevation (height) of the higher end of the tank above the lower end of the tank, in metres

H Height of liquid in the tank, in metres

Figure A.1 — Volume correction for cylindrical tanks with axis inclined

Annex B
(informative)

Corrections of volume of tank table

B.1 General

Corrections on volume of the tank table to be made because of

- working pressure,
- tank shell temperature,
- liquid head, and
- tilt.

B.2 Working pressure

Corrections on the volume of the tank, for the working pressure of the tank when calibrated, will be carried out according to the following principle (Young's modulus).

The stress in one direction causes an extension of the wall in that direction. It also causes a contraction in the perpendicular direction, the size of which depends upon Poisson's ratio for the material.

The combination of these two effects causes a uniform strain in the material of the hemispherical ends of a cylinder given by

$$\frac{pr}{2tE}(1-\sigma)$$

where

p is the working pressure, in pascals;

r is the radius of the tank, in metres;

t is the wall thickness, in metres;

E is Young's modulus, in pascals;

σ is Poisson's ratio.

This strain corresponds to an increase in the radius of the ends, r_e, given by

$$\frac{\delta r_e}{r} = \frac{pr}{2tE}(1-\sigma)$$

(The subscript is used to distinguish the increase in the radius of the hemispherical ends of a cylindrical tank from the increase in the radius of the cylindrical part, which will be denoted by δr_c.)

In the cylindrical part of a tank the hoop stress is pr/t and, due to the pull exerted by the hemispherical ends, the longitudinal stress is $pr/2t$.

Hence it follows that:

$$\text{strain in longitudinal direction} = \frac{\delta l}{l} = \frac{pr}{2tE}(1-2\sigma)$$

$$\text{strain in circumferential direction} = \frac{\delta r_{\text{c}}}{r} = \frac{pr}{2tE}(2-\sigma)$$

where

- l is the length, in metres, of the cylindrical part;
- δl is the increase, in metres, in this length;
- δr_{c} is the increase in the radius, in metres, of the cylindrical part;
- p is the working pressure, in pascals;
- r is the radius of the tank, in metres;
- t is the wall thickness, in metres;
- σ is Poisson's ratio;
- E is Young's modulus, in pascals.

Combining these formulas will give the following correction factor to the volume of the tank (Poisson's ratio typically equals 0,3):

$$V_{\text{full}} = V_{\text{c}} \times C_{\text{pvc}} + V_{\text{e}} \times C_{\text{pve}}$$

with

$$C_{\text{pvc}} = 1 + \frac{pr}{2tE}(5-4\sigma)$$

$$C_{\text{pve}} = 1 + \frac{3pr}{2tE}(1-\sigma)$$

where

- V_{c} is the total cylindrical volume of the tank;
- V_{e} is the total volume of the ends.

B.3 Tank-shell temperature

Corrections on the volume of the tank, because of the fact that the tank-shell temperature is different from the temperature when calibrated, will be carried out according to the following formula.

NOTE This is valid if a gauge tape correction is made.

$$C_{tv} = 1 + 2C_1 (T_s - T_r)$$

where

C_1 is the linear expansion coefficient of the tank material;

T_r is the reference tank-shell temperature;

T_s is the actual tank-shell temperature.

$$T_s = \frac{7T_l + T_a}{8}$$

where

T_l is the liquid temperature;

T_a is the ambient temperature.

NOTE For insulated tanks or buried tanks, the shell temperature is assumed to be equal to the liquid temperature.

B.4 Liquid head

Corrections to the volume of horizontal cylindrical tanks due to liquid head may be ignored as the effect is minimal due to the limited dimensions, and hence capacities, of tanks of this type.

Bibliography

[1] COATS, W. L., *Calibration of the ends of cylindrical and elliptical barrels with axis horizontal and combined,* Institute of Petroleum Quarterly Journal of Technical Papers, July-September 1989

Additional copies are available through Global Engineering Documents at (800) 854-7179 or (303) 397-7956

Information about API Publications, Programs and Services is available on the World Wide Web at http://www.api.org

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

Product No: HX202E01