

Manual of Petroleum Measurement Standards Chapter 2—Tank Calibration

Section 2D—Calibration of Upright Cylindrical Tanks Using the Internal Electro- optical Distance Ranging Method

FIRST EDITION, AUGUST 2003
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Measurement Coordination Department

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FOREWORD

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Manual of Petroleum Measurements Standards

Chapter 2—Tank Calibration

Section 2D—Calibration of Upright Cylindrical Tanks Using the Internal Electro-optical Distance Ranging Method

0 Introduction

The method described in this part of API *MPMS* Chapter 2 is an alternative to other tank calibration methods such as the strapping method (API *MPMS* Chapter 2, Section 2A), the optical-reference-line method (API *MPMS* Chapter 2, Section 2B) and the optical-triangulation method (API *MPMS* Chapter 2.2C).

The parts of Chapter 2 form part of a series on tank calibration which also includes: Standard 2551, *Measurement and Calibration of Horizontal Tanks*; Standard 2552, *Measurement and Calibration of Spheres and Spheroids*; Standard 2554, *Measurement and Calibration of Tank Cars*; Standard 2555, *Liquid Calibration of Tanks*; Recommended Practice 2556, *Correcting Gauge Tables for Incrustation*; *MPMS* Chapter 7, *Calibration of Barge Tanks*; *MPMS* Chapter 2.8A, *Calibration of Tanks on Ships and Oceangoing Barges*; *MPMS* Chapter 2.8B, *Establishment of the Location of the Reference Gauge Point and the Gauge Height of Tanks on Marine Tank Vessels*.

1 Scope

1.1 This part specifies a method for the calibration of upright cylindrical tanks having diameters greater than 5 m by means of internal measurements using an electro-optical distance-ranging instrument, and for the subsequent compilation of tank capacity tables. This method is known as the internal electro-optical distance-ranging (EODR) method.

1.2 This part of Chapter 2 is not applicable to the calibration of abnormally deformed (e.g. dented) tanks or of noncircular tanks.

1.3 This part of Chapter 2 is applicable to tanks tilted by $<$ or $= 3\%$ from the vertical, provided a correction is applied for the measured tilt as described in Chapter 2.2A.

1.4 This part of Chapter 2 is applicable to tanks with cone-up or cone-down bottoms, as well as to tanks with flat bottoms.

2 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this part of Chapter 2. 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 Chapter 2 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of API maintain registers of currently valid API Standards.

API

Manual of Petroleum Measurement Standards (MPMS)

Chapter 2.2A “Measurement and Calibration of Upright Cylindrical Tanks by the Manual Strapping Method”

Chapter 2.2B “Calibration of Upright Cylindrical Tanks Using the Optical Reference Line Method”

Chapter 2.2C Calibration of Upright Cylindrical Tanks Using the Optical Triangulation Method”

IEC¹

825-1:1993 *Safety of laser products—Part 1: Equipment Classification, Requirements and User’s Guide*

3 Definitions

For the purposes of this part of Chapter 2 the definitions given in API *MPMS* Chapter 2.2A and the following definitions apply.

3.1 reference target point: Fixed point clearly marked on the inside surface of the tank shell wall.

3.2 slope distance: Distance measured from the electro-optical distance-ranging instrument to a target point on any given course of the tank shell wall.

3.3 target point: One of a series of points on the inside surface of the tank shell wall to which slope distance, vertical and horizontal angles are measured by use of the electro-optical ranging instrument.

4 Precautions

The general and safety precautions contained in API *MPMS* Chapter 2.2A shall apply to this standard.

In addition, the laser beam emitted by the distance-ranging unit shall conform to IEC 825 for a class 1 laser.

¹International Electrochemical Commission, 3 Rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

5 Equipment

5.1 ELECTRO-OPTICAL DISTANCE-RANGING INSTRUMENT

5.1.1 The angular measuring part of the instrument shall have an angular graduation and resolution equal to or better than ± 0.0002 gon*, a repeatability equal to or better than ± 0.0005 gon, and an uncertainty equal to or better than ± 0.001 gon.

5.1.2 The distance-measuring part of the instrument, used for direct determination of the distances, shall have a graduation and resolution equal to or better than ± 1 mm, a repeatability equal to or better than ± 2 mm, and an uncertainty equal to or better than ± 2 mm.

5.2 INSTRUMENT MOUNTING consisting of a tripod which is firm and stable. The legs of the tripod shall be held firm, and steadied by suitable devices such as magnetic bearers.

5.3 LASER BEAM EMITTER having a low-power laser beam complying with IEC 825, which is either an integral part of the EODR instrument or a separate device. If the laser beam emitter is a separate device, it may be fitted with a fiber optic light transmitter system and a theodolite telescope eyepiece connection, by which the laser beam may be transmitted through a theodolite, or such that it may be fitted to a theodolite with its axis parallel to the axis of the theodolite. The laser beam may be coincident with the optical axis of the telescope

Note 1: The laser beam emitter is used to position target points on the tank shell.

5.4 STADIA a rigid bar, usually 2 m long, such that the graduated length between the two stadia marks remains constant to within ± 0.02 mm.

5.5 EQUIPMENT FOR BOTTOM CALIBRATION (see 11.1)

5.6 AUXILIARY EQUIPMENT including:

- a. heavy weights to be set around the instrument to steady the unit;
- b. lighting within the tank, if required.

6 General Considerations

6.1 The EODR instrument shall be maintained so that the values of its measurement uncertainty do not exceed the values given in this part of Chapter 2.

6.2 Tanks shall only be calibrated after they have been filled at least once with a liquid of density equal to or greater than that of the liquid which they will hold when in use.

* $2 \text{ pi radians} = 400 \text{ gons} = 400 \text{ grades}$

Note 2: The hydrostatic test applied to new tanks will satisfy this requirement in most cases.

6.3 Calibration shall be carried out without interruption.

6.4 The EODR instrument shall be verified prior to calibration.

The accuracy of the distance-measuring unit as well as the angular measuring unit shall be verified using the procedures recommended by the manufacturer.

The appropriate procedures given in Appendix A shall be used for the verification of equipment in the field.

6.5 The tank shall be free from vibration and airborne dust particles.

Note 3: The floor of the tanks should be as free as possible from debris, dust and loose scale.

6.6 Lighting, when required, shall be placed within the tank so as not to interfere with the operation of the EODR instrument.

7 EODR Instrument Setup Within the Tank

7.1 INSTRUMENT SETUP

7.1.1 The instrument shall be set up with care, according to the procedure and instructions given by the manufacturers.

7.1.2 The instrument shall be set up so as to be stable.

If necessary, the tank bottom in the vicinity of the instrument shall be made firm and steady by placing heavy weights in the area.

The legs of the tripod on which the instrument is mounted shall be steadied by use of suitable devices, such as magnetic bearers, to prevent slippage on the tank bottom.

7.1.3 The instrument shall be located at, or near, the center of the tank.

Note 4: This will ensure that the measured slope distances, at any one horizontal level, do not vary significantly and minimizes the overall uncertainty of slope distance determination.

7.1.4 The instrument shall be set horizontal, thus ensuring that the vertical axis (standing axis) is vertical.

7.1.5 The instrument shall be free from external vibration.

7.1.6 The sighting lines from the instrument to the tank shell wall shall not be obstructed.

7.2 PRELIMINARY PROCEDURES

7.2.1 Switch on the instrument and bring to operating temperature, allowing at least the minimum warm-up time recommended by the manufacturer.

7.2.2 After the instrument has reached its correct operating temperature, carry out the appropriate procedure given in

Appendix A. Then select and clearly mark on the tank shell wall two reference target points.

Note 5: The two reference target points should be approximately 100 gon apart and preferably on the same horizontal plane as the instrument.

7.2.3 The slope distances to each of the two reference target points shall be measured. Two successive readings to each reference target point shall be taken. The two readings, at each point, shall agree within ± 2 mm. The average distance to each point shall be calculated. The slope distances shall be recorded.

7.2.4 Wait 15 min and repeat 7.2.3. The repeated slope distances shall agree within ± 2 mm with the slope distances originally measured. The slope distances shall be recorded.

7.2.5 If the original and repeated average slope distances do not agree within ± 2 mm, determine the reason for the difference.

- If the reason for differences is due to the instrument and or its stability, repeat the procedure from 7.1.
- If the instrument was switched off during the determination of the differences, repeat the procedure from 7.2.1.
- If neither a) nor b) is appropriate, repeat the procedure from 7.2.3
- Repeat the appropriate procedures until two successive readings agree within ± 2 mm.

8 Selection of Target Points

8.1 Select two sets of target points per course, 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.

The number of target points per set, on each course of the tank shell wall, is dependent on tank circumference. The minimum number of target points per set, as a function of tank circumference, is given in Table 1 and illustrated in Figure 1.

8.2 The target points shall be at least 300 mm from any vertical welded seam.

9 Calibration Procedure

9.1 Sight all of the target points along the horizontal plane at each course location, and measure the slope distance, horizontal angle and vertical angle to each, as illustrated in Figure 2.

9.2 Measure and record the slope distance, horizontal angle and vertical angle to each of the reference target points.

9.3 Complete the measurements to the target points on each course prior to moving to the next course.

Note 6: Measurements should begin at the bottom course and extend, course by course, to the top.

9.4 After all measurements on a course are completed, repeat the measurements to the reference target points.

Table 1—Minimum Number of Target Points Per Set

Tank Circumference, C m	Minimum Number of Target Points
$C < \text{or} = 50$	8
$50 < C < \text{or} = 100$	12
$100 < C < \text{or} = 150$	16
$150 < C < \text{or} = 200$	20
$200 < C < \text{or} = 250$	24
$250 < C < \text{or} = 300$	30
$300 < \text{or} = C$	36

Note: A number of points greater than the minimum number of points in Table 1 may be chosen depending on specific circumstances and tank conditions.

9.5 If the repeated slope distances to the reference target points do not agree with the measurements taken during the setting up of the instrument, within the tolerance given in 10.1, then repeat 9.1 to 9.5.

9.6 If the horizontal and the vertical angles to the reference target points do not agree within the tolerance given in 10.2, repeat 9.1 to 9.5.

9.7 If statistical agreement is not obtained between the original and repeated measurements of slope distances, horizontal angles or vertical angles, then the reasons for such disagreement shall be determined, the cause eliminated and the tank calibration procedure repeated.

9.8 Carry out all measurements without interruption.

10 Tolerances

10.1 REFERENCE TARGET POINT: DISTANCE VERIFICATION

The slope distance to each of the reference target points before and after the tank calibration has been carried out shall be within ± 2 mm.

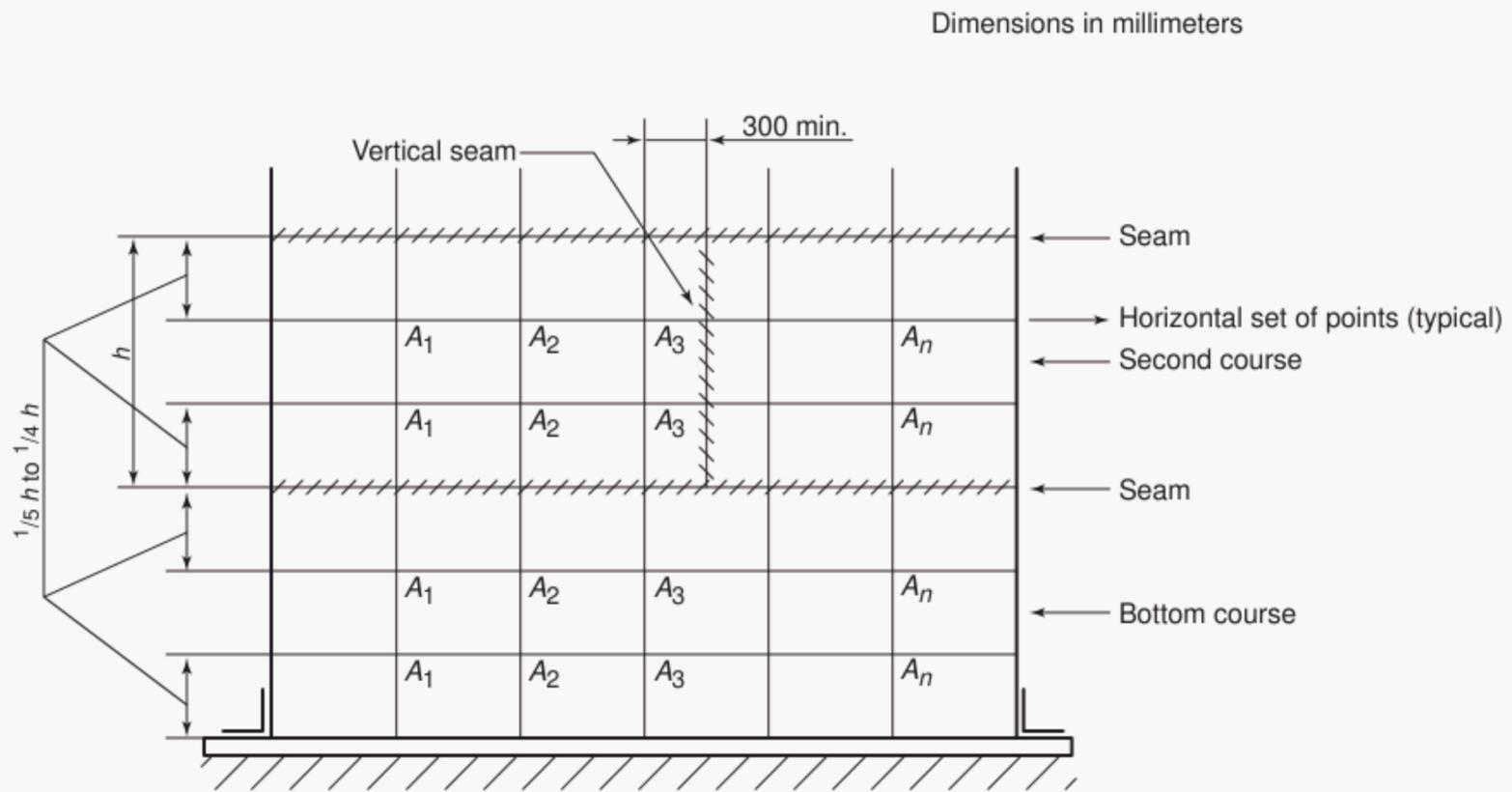
10.2 REFERENCE TARGET POINT: HORIZONTAL AND VERTICAL ANGLE VERIFICATION

The horizontal and vertical angle to each of the reference target points before and after the tank calibration has been carried out shall be within ± 0.001 gon.

11 Other Measurements

11.1 The tank bottom shall be calibrated by the liquid method in accordance with API Standard 2555, or by use of the electro-optical ranging instrument as a surveyor's level or by use of a surveyor's level in accordance with API *MPMS* Chapter 2.2A, or by use of water-filled tubes in accordance with API *MPMS* Chapter 2.2A.

11.2 The overall height of the reference point at each dip-hatch (upper reference point), if fitted, above the dip-point



h : Course height
 A_1 to A_n : Target point at any given height

Figure 1—Illustration of Target Positioning on Tank Shell Wall

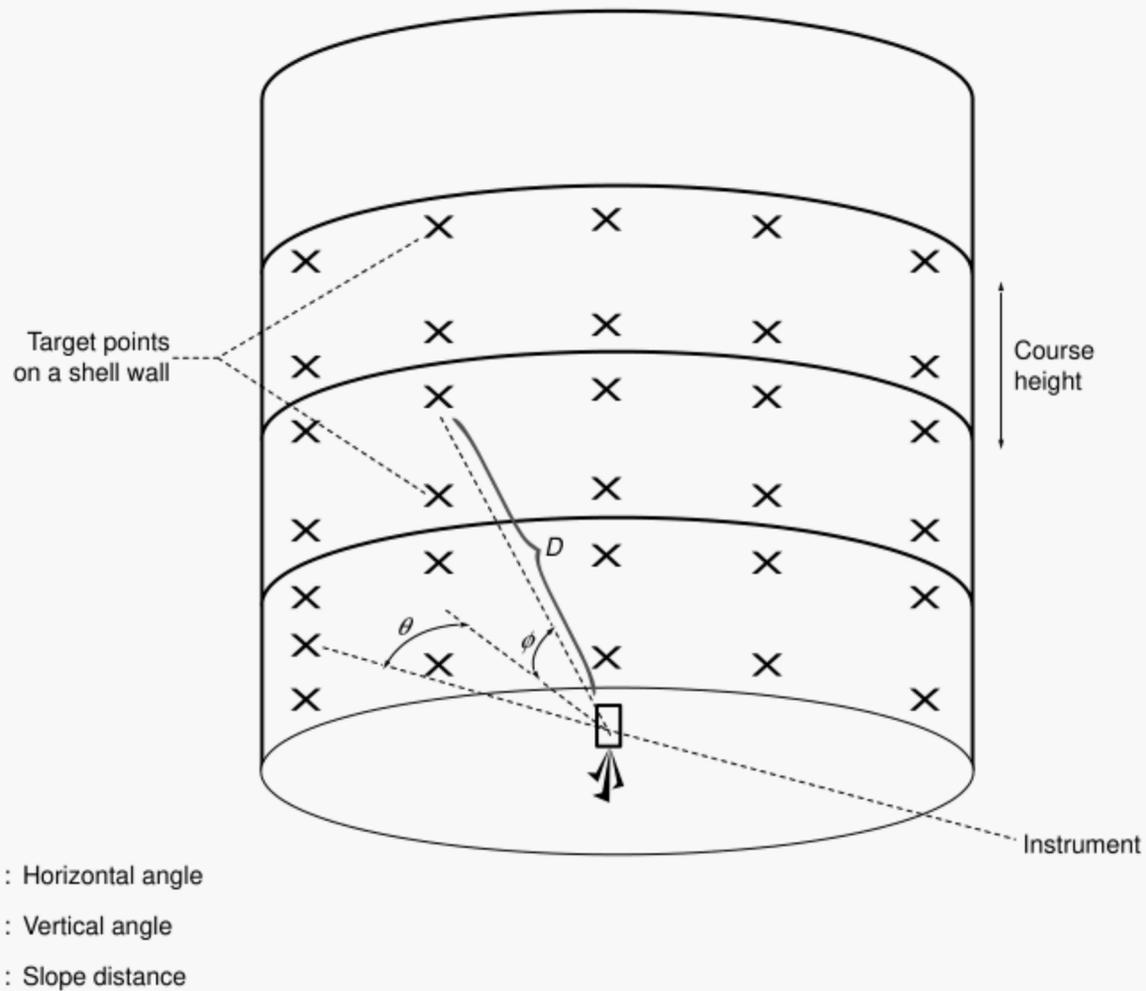


Figure 2—Illustration of Calibration Procedure

shall be measured using a dip tape and weight, in accordance with API *MPMS* Chapter 2.2A. This overall height, to the nearest millimeter, shall be marked on the tank adjacent to that dip hatch.

11.3 The following data shall be determined and processed in accordance with API *MPMS* Chapter 2.2A.

- a. the density and the working temperature of the liquid to be stored in the tank;
- b. the height of each course;
- c. the thickness of each course of plating;
- d. the safe filling height and maximum filling height;
- e. deadwood;
- f. the tilt of the tank as shown by the deviation from a vertical line.

11.4 The vertical height difference between the datum-point and the dip-point, if any, shall be measured by normal surveying methods and recorded.

Note 7: In use, each measured tank dip is referred to a dip-point; the position of the dip-point may differ from the datum-point used for the purpose of tank calibration (e.g. on the intersection of the tank shell and the tank bottom plate).

11.5 If tank construction drawings are available, calibration measurements shall be compared with the corresponding dimensions shown in the tank construction drawings. Any measurements which show significant discrepancies shall be checked.

If the calibration and drawing measurements do not agree, the reasons for the discrepancy shall be determined and the calibration procedure repeated if necessary.

12 Calculation and Development of Capacity Tables

12.1 Calculate the internal radii of the tank by the procedures described in Appendix B.

12.2 Once the internal radii are calculated, the development of the capacity table shall be carried out in accordance with API *MPMS* Chapter 2.2A. The following corrections, described in Chapter 2.2A, shall be applied in the development of the capacity tables:

- a. correction for hydrostatic head effect;
- b. correction to the certified tank shell temperature;
- c. correction for deadwood;
- d. correction for tilt.

.....

APPENDIX A—FIELD EQUIPMENT VERIFICATION

The following procedures provide a method of on-site verification of the equipment prior to, and on completion of, a calibration procedure.

The procedures shall be followed each time the instrument is switched on and brought to operating temperature, and on completion of any set of measurements at a measurement station.

A.1 Angular Measurement Verification

A.1.1 The following procedure assumes that the instrument has been verified prior to calibration using the procedures recommended by the manufacturer; it relies on the angular measurement accuracy of the EODR instrument.

Note 8: The angular measurement uncertainty of the instrument is normally adjusted to a minimum by the manufacturer.

A.1.2 Set up the instrument, following the procedures described in Clause 7.

A.1.3 Each particular EODR instrument will have manufacturer's instructions concerning collimation of both the vertical and horizontal angular measurement components of the instrument. These instructions shall be followed exactly, and the uncertainty of both the vertical and horizontal angular measurement components of the instrument calculated and recorded.

A.1.4 The collimation uncertainty of both the horizontal and vertical components of the instrument shall not exceed ± 0.001 gon.

A.2 Distance Measurement Verification

A.2.1 Complete the procedures in A-1 before verifying the distance-measurement component of the instrument.

A.2.2 Set up the stadia using the procedures given in API *MPMS* Chapter 2.2C.

A.2.3 Place the stadia at a distance between 5 m and 15 m from the instrument and normal to an imaginary line between the instrument and the center mark of the stadia, as illustrated in Figure A-1.

A.2.4 Using the EODR instrument, measure the horizontal angle 2θ subtended at the instrument by the two marks on the stadia.

A.2.5 Calculate the horizontal Distance D (figure A-1) from the equation:

$$D = (B / 2) \times \cot \theta \quad \text{Equation A-1}$$

where B is the length, in meters, between the two reference marks on the stadia.

A.2.6 Carry out the measurement of the angle and the calculation of the distance D a minimum of five times. The variations in the calculated distance D shall be within the tolerances given in Table 3 of API *MPMS* Chapter 2.2C or the entire procedure shall be repeated. Calculate and record the average values.

A.2.7 The slope distance D measured by the EODR instrument and the average calculated distance D shall agree to within ± 2 mm.

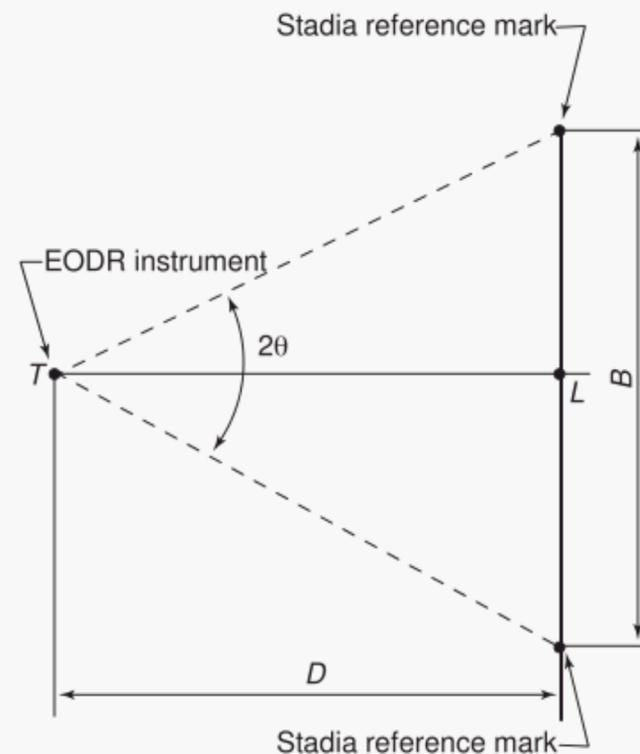


Figure A-1—Illustration of the Distance Measurement Setup

APPENDIX B—CALCULATION OF INTERNAL RADII FROM MEASURED PARAMETERS

B.1 The dimensional coordinates of each target point (see Figure 2) shall be converted to cartesian coordinates using the following equation:

$$X = [D][\cos \theta] [\cos \phi] \quad \text{Equation B-1}$$

$$Y = [D][\sin \theta] [\sin \phi] \quad \text{Equation B-2}$$

$$Z = [D] [\sin \phi] \quad \text{Equation B-3}$$

where:

D = is the measured slope distance;

θ = is the measured horizontal angle;

ϕ = is the measured vertical angle.

B.2 The calculation of the positions of the various target points at any one, horizontal, level is simplified if the vertical

height coordinates, Z values, are all reduced to a common level. Care shall be exercised in this reduction to ensure that the values of the Z coordinates are reduced to a common value which ensures that the adjusted positions of the target points are on a plane which is normal to the vertical axis of symmetry of the tank. It should not be assumed that the tank is truly vertical.

Alterations of the value of a Z coordinate will require a compensating alteration in the values of the X and Y coordinates of that point.

Such adjustments shall be carried out by established mathematical techniques.

B.3 Reduction of the values of the X and Y coordinates to the internal radius at each level at which measurements have been taken shall be carried out by established mathematical techniques.

APPENDIX C—BIBLIOGRAPHY

The following list of ISO standards contains information which may prove of use to the reader of this part of API MPMS Chapter 2.

- a. ISO 7507-2: 1993, *Petroleum and Liquid Petroleum Products—Calibration of Vertical Cylindrical Tanks—Part 2: Optical-reference-Line Method.*
- b. ISO 7078: 1985, *Building Construction—Procedures for Setting Out, Measurement and Surveying—Vocabulary and Guidance Notes.*
- c. ISO 8322-8: 1992, *Building Construction Measuring Instruments—Procedures for Determining Accuracy in Use—Part 8: Electronic Distance-measuring Instruments Up to 150 m.*

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