

Manual of Petroleum Measurement Standards Chapter 2.2A

Measurement and Calibration of Upright Cylindrical Tanks by the Manual Tank Strapping Method

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Measurement and Calibration of Upright Cylindrical Tanks by the Manual Tank Strapping Method

1 Scope

1.1 This standard describes the procedures for calibrating upright cylindrical tanks used primarily for the storage of petroleum liquids. It first addresses procedures for making necessary measurements to determine total and incremental tank volumes and then presents the recommended procedures for computing volumes.

1.2 Both SI (metric) and U.S. customary (USC) units are presented where appropriate in the document. SI and USC conversions may not necessarily be exact. The SI units often reflect what is available in commercial equipment.

1.3 The standard also provides guidelines for recalibration and for computerization of capacity tables.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Manual of Petroleum Measurement Standards (MPMS) Chapter 2.2B, Calibration of Upright Cylindrical Tanks Using the Optical Reference Line Method

API Standard 650, Welded Steel Tanks for Oil Storage

API Standard 653, Tank Inspection, Repair, Alteration, and Reconstruction

API Standard 2555, Method for Liquid Calibration of Tanks

ICS ¹/OCIMF ²/IAPH ³, International Safety Guide for Oil Tankers and Terminals (ISGOTT) ⁴

IP ⁵ Petroleum Measurement Manual, Part 2, "Tank Calibration," Section 1, "Vertical Cylindrical Tanks, Measurement Methods"

NFPA 306 ⁶, Standard for the Control of Gas Hazards on Vessels

3 Safety

3.1 Before entering any tank, permission shall be obtained from the terminal supervisor, authorized official, or other responsible person in charge. This responsible person should supply information regarding particular materials and conditions or the applicable Material Safety Data Sheet (MSDS).

3.2 Due consideration should be given to applicable safety procedures. Safety considerations include, but are not limited to, potential electrostatic hazards, potential personnel exposure (and associated protective

¹ International Chamber of Shipping, 38 St Mary Axe Street, London EC3A 8BH, United Kingdom, www.ics-shipping.org.

² Oil Companies International Marine Forum, 27 Queen Anne's Gate, London, SW1H 9BU, United Kingdom, www.ocimf.com.

³ International Association of Ports and Harbors, 7th Floor, South Tower New Pier Takeshiba 1-16-1 Kaigan, Minato-ku, Tokyo 105-0022, www.iaphworldports.org.

⁴ *ISGOTT* is available from Witherby Publishing Group Ltd. (Marine Publishing), 32/36 Aylesbury Street, London EC1R 0ET, United Kingdom.

⁵ Institute of Petroleum, 61 New Cavendish Street, London W1M 7AR, United Kingdom, www.energyinst.org.uk.

⁶ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

clothing and equipment requirements), and potential explosive and toxic hazards associated with a storage tank's atmosphere. The physical characteristics of the product and existing operational conditions should be evaluated, and applicable international, federal, state, and local regulations should be observed.

3.3 In addition, before entering a storage tank, safety procedures designated by the employer, the terminal operator, and all other concerned parties should also be observed. It shall be indicated that the tank is "Safe for Workers" and/or "Safe for Hot Work," as prescribed in NFPA 306, U.S. Coast Guard, OSHA, or other international, federal, state, or local regulations that may apply. Such testing shall be made at least every 24 hours or more frequently when conditions warrant.

3.4 Internationally, the *International Safety Guide for Oil Tankers and Terminals (ISGOTT)* should be consulted.

3.5 Furthermore, another person should stand watch at the tank entrance for the duration and sound an alarm if an emergency occurs. Appropriate protective clothing and equipment should be used. Normal safety precautions with respect to staging and ladders shall also be observed.

4 Terms and Definitions

For the purposes of this document, the following definitions apply.

4.1

capacity table

tank capacity table

Shows the capacities of or volumes in a tank for various liquid levels measured from the reference gauge point.

4.2

continuous wraparound procedure

The measurement of a tank circumference with a tape that is long enough to span the entire circumference of a tank.

4.3

deadwood

Refers to any object within the tank, including a floating roof, that displaces liquid and reduces the capacity of the tank; also any permanent appurtenances on the outside of the tank, such as cleanout boxes or manholes, that increase the capacity of the tank.

4.4

false bottom

Commonly referring to a new bottom installed on top of the previous tank bottom, which will reduce the bottom ring height and the effective inside tank height.

4.5

master tape

A tape that is used for calibrating working tapes for tank measurement and is identified with a Report of Calibration at 68 °F (20 °C) and at a specific tension designated by the National Institute of Standards and Technology (NIST) or an equivalent international standard organization.

4.6

reference gauge height

The vertical distance between the reference point on the gauge hatch and the striking point on the tank floor or on the gauge datum plate.

4.7

successive tangent method

The measurement of a circumference on a tank when the tape is not long enough to span the entire circumference of a tank.

4.8 tank strapping

The term commonly applied to the procedure for measuring tanks to provide the dimensions necessary for computing capacity tables that will reflect the quantity of product in a tank at any given depth/level.

5 Significance

5.1 Accurate tank circumference measurements are critical in determinations of liquid volume and the development of capacity table for custody transfer transactions and inventory control. This standard provides measurement and computational procedures for the development of such a capacity table.

5.2 All such measurements should be witnessed by all parties involved to ensure compliance with the procedure outlined in the standard and overall measurement integrity.

6 Equipment

6.1 General

The equipment used in dimensional tank calibration is described in 6.2 through 6.4. All equipment shall be in good working condition. All tapes shall be in one piece and free of kinks.

6.2 Tapes for Height Measurement

For height measurements, a steel tape (see Figure 1) of convenient length, $\frac{3}{8}$ in. or $\frac{1}{2}$ in. wide and 0.008 in. to 0.012 in. thick, graduated in feet and inches to eighths of an inch, or in feet, tenths, and hundredths of a foot is recommended. (For metric tapes, refer to IP's *Petroleum Measurement Manual*, Part 2, Section 1.) Graduations shall be accurate within $\frac{1}{6}$ in. or 0.005 ft (or to nearest millimeter) throughout that portion of the tape to be used.

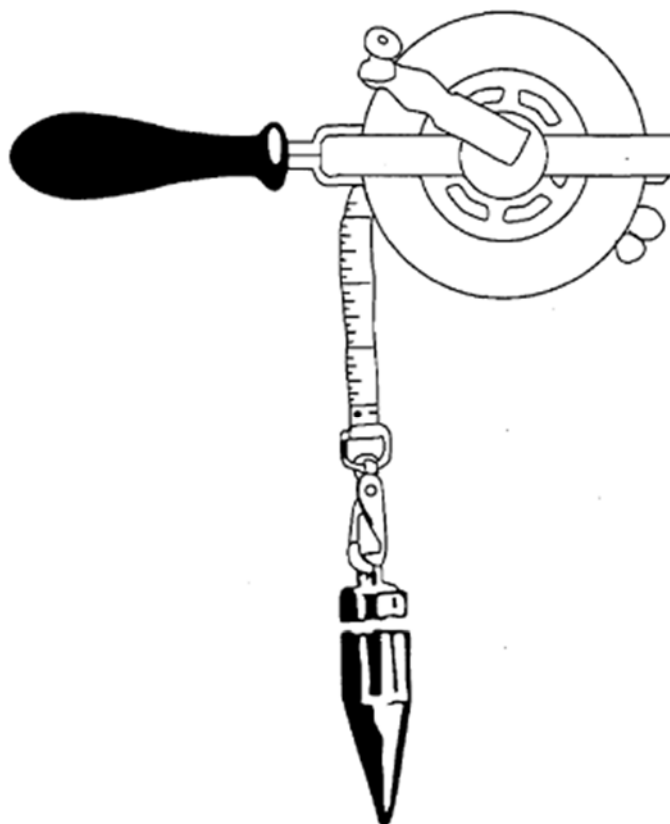


Figure 1—Height Measuring Tape and Bob

6.3 Tapes for Circumference Measurement

For circumference measurements, a mild steel tape, (see Figure 2) of convenient length relative to the tank circumference is recommended. The working tape is usually 100, 200, 300, or 500 ft long and should not be more than $\frac{1}{4}$ in. wide, and approximately 0.01 in. thick. The tape may be graduated in feet, with an extra 1 ft length at the zero end of the tape and graduated in tenths and hundredths of a foot, or it may be graduated in feet, tenths, and hundredths of a foot throughout its length (for metric tapes, refer to IP's *Petroleum Measurement Manual*, Part 2, Section 1). All working tapes should be calibrated with a master tape (refer to Section 7).

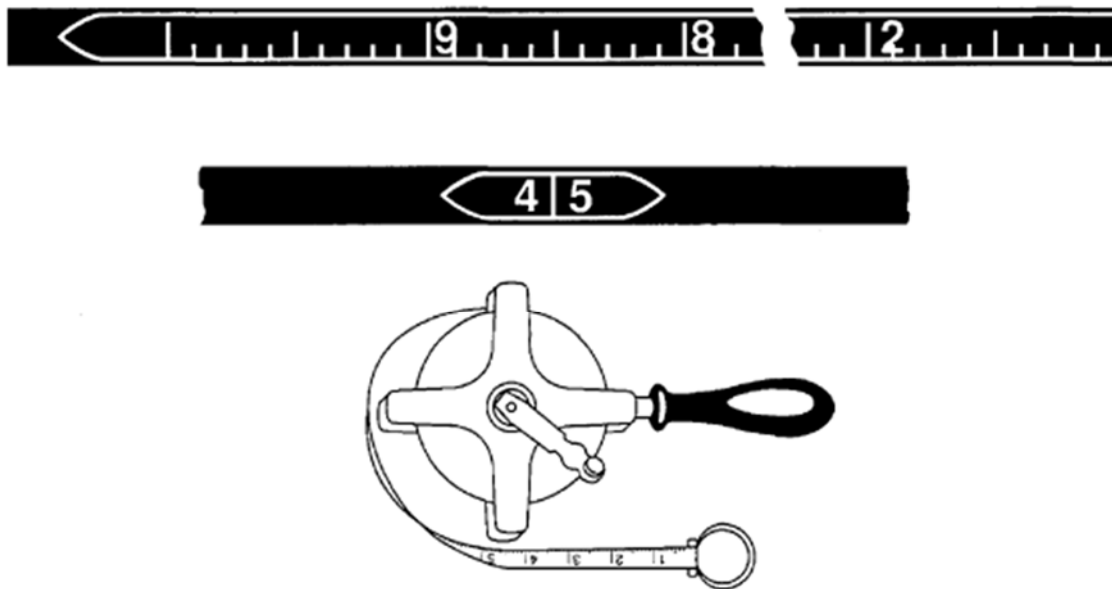


Figure 2—Strapping Tapes for Circumference Measurements

6.4 Accessory Equipment

Additional measuring equipment recommended is listed below. Other similar equipment may be used, provided it will give the same results.

- Reels and tapes shall be equipped with appropriate reels and handles.
- Tape clamps—For assurance of positive grip on tape, clamps shall be used.
- A spring tension scale is needed.
- Rope and ring—Two lengths of rope line fitted with snap and ring are to be used in raising and lowering circumference measurement tape. Alternatively, jointed-type pole guides may be used (see Figure 3).
- Transit or level or both are used when required.
- Ladders to facilitate handling of tapes and removal of scale, rust, dirt, etc. from the path of measurement are needed.
- An ultrasonic thickness measurement device is used.
- A plumb line is needed.

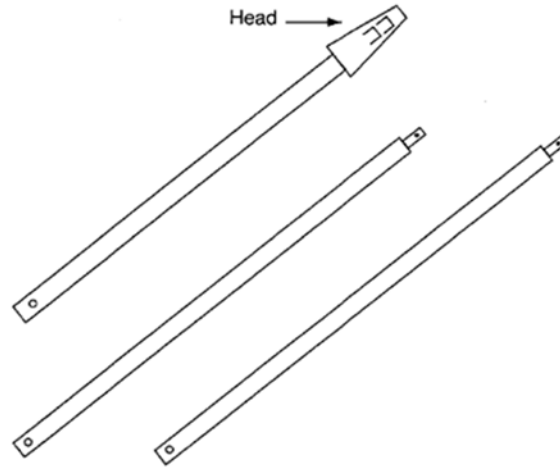


Figure 3—Jointed-type Tape Guides

- i) Depth gauge—A depth gage of case-hardened steel, 6 in. in length, graduated to $\frac{1}{64}$ in. (1 mm resolution and read to nearest 0.5 mm) is for determination of thickness of steel plates is needed.
- j) Straightedge—A straightedge of appropriate length and a profile board for measuring knuckles are used.
- k) Calipers and special clamps for spanning obstructions in making circumference measurements; the following are recommended:
 - 1) maximum expansion calipers of 6 in. (or 15 cm) for spanning the smaller obstructions, such as vertical flanges, bolt heads, etc.;
 - 2) maximum expansion calipers of 18 in. (45 cm) or 24 in. (61 cm) for spanning the larger obstructions, such as butt straps, etc.;
 - 3) special clamps may be substituted for calipers in measuring projecting flanges.

The following may be useful equipment: a 6-ft ruler for general measurements, shovel, spirit level, awl and scribe, marking crayon, record paper, and cleaning instruments, such as a putty knife and a hard bristle brush for eliminating dirt, grease, paint scale, rust particles, etc. from the path of circumference measurements.

7 Calibration of Working Tape with the Master Tape

7.1 The tape used for circumference measurements shall be calibrated (for required tension) by matching it against the master tape in the following manner.

- a) Choose a convenient tape path (i.e. 20 % of ring height) on the lower ring, and place the master tape around the tank.
- b) Using the successive tangent method, make a scribe mark on the shell, determining the origin of the circumference. Apply the tape, with constant application of tension at which the master tape was certified to be accurate, to the tank shell at the proper tape path with the tape's zero mark located exactly on the scribe mark designating the origin point. The tape is placed in position with required tension, and the last reading on the tape is scribed on the tank shell at each 100 ft (or 30 m) or fraction thereof. This measurement is written on the tank shell and recorded. This procedure is repeated until the entire circumference is measured.
- c) Total the measurements obtained.

- d) Place the working tape around the tank, using the same tape path, by the continuous “wraparound” procedure.
- e) Slide the working tape to break frictional resistance, and apply tension sufficient to equal the measurement obtained with the master tape.
- f) The amount of tension, in pounds, required to be pulled on the working tape to obtain the same measurement as that recorded with the master tape shall be applied to the working tape when taking circumferential measurements. If the tension determined to be proper for the working tape is insufficient to hold the tape in the proper position, additional tension should be applied and a correction made to bring the reading into agreement with that obtained with the master tape.

7.2 The preceding procedure shall be carried out when calibrating other tanks whose circumference differs by more than 20 % from the calibrated tape section and where tank surfaces are different.

7.3 Two working tape corrections are illustrated in the following examples ⁷. Note that conditions 1 and 2 for application of working tape corrections apply for either case, that is, where the master tape and working tape are of equal or different lengths. The same procedure applies for metric measurements.

- a) Condition No.1—If additional tension is required to be applied to the working tape to equal the measurement obtained by the master tape, then no mathematical correction is needed. The additional tension required to equal the master tape measurement shall be applied to all subsequent circumferences obtained with the working tape.
- b) Condition No. 2—If the same or additional tension is applied to both the master tape and the working tape and the measurements do not agree, then a mathematical correction shall be applied as indicated in the examples below. The determined differences shall be applied to all working tape circumferences before the processing of the capacity table.
- c) Examples

EXAMPLE 1

314.515 ft	Master tape at 10 lb tension per 100 ft or part thereof
314.475 ft	Working tape at 20 lb tension
0.040 ft	Correction for working tape to be <i>added</i> to each circumference measured

EXAMPLE 2

314.515 ft	Master tape at 10 lb tension per 100 ft or part thereof
314.590 ft	Working tape at 20 lb tension
0.075 ft	Correction for working tape to be <i>subtracted</i> from each circumference measured

⁷ The following examples are merely examples for illustration purposes only. They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

8 General Practices

All measurements and descriptive data taken at the tank site should be checked and immediately, legibly recorded with the recording preferably assigned to a single individual, as follows.

- a) All measurements should be taken without disruption and preferably on the same day of calibration with the liquid level remaining static. If measurements have to be disrupted, interrupted tank measurement work may be continued at a later date, without repeating the work previously completed, provided all records of the work are complete and legible. Movement of liquid into or out of the tank may be tolerated, provided a clearly marked liquid gauge and average temperatures of both liquid and outside atmosphere are included as parts of these subsequent strapping operations.
- b) All data and procedures necessary for the preparation of capacity tables should be supported by sound engineering principles.
- c) Each tank shall be identified clearly and legibly by number or by some other suitable marking, but this identification should not be painted on tank attachments.

9 Tank Status Before Calibration

9.1 Before calibration, the tank shall have been filled at least once at its present location with liquid at least as dense as is expected to contain. The hydrostatic test (for a period of approximately 24 hours) will usually satisfy this requirement. Any hydrostatic test should be performed in accordance with applicable construction and operating standards (API 650 and API 653). When possible, the liquid in the tank should be allowed to stand still for approximately 24 hours before calibration is performed.

9.2 Tanks with a nominal capacity of 500 bbl or less may be strapped at any condition of fill, provided the tanks have been filled at least once at their present location. Small movements of oil into or out of such tanks are allowed during strapping.

9.3 Tanks with a nominal capacity of more than 500 bbl should be handled as follows.

- a) Bolted tanks (usually in production service) shall have been filled at least once at their present location and shall be at least two-thirds full when strapped. Small movements of oil into or out of such tanks are allowed during strapping.
- b) Riveted tanks and/or welded tanks shall have been filled at least once at their present location. They may be strapped at any condition of fill and the full capacity computed as shown in 19.6. No movement of oil into or out of such tanks is allowed during the strapping operation.

10 Descriptive Data

10.1 Complete descriptive data should be entered on the Tank Measurements Record Form being used. Suggested record forms are shown in Figure 4 and Tables 1 and 2.

10.2 The API Gravity and the temperature of the tank's contents at the time of strapping shall be obtained and recorded. The average API Gravity, average overall ambient temperature at which the tank shall operate and maximum safe fill height (refer to 13.5) shall be obtained from the tank owner and recorded.

TANK NO.

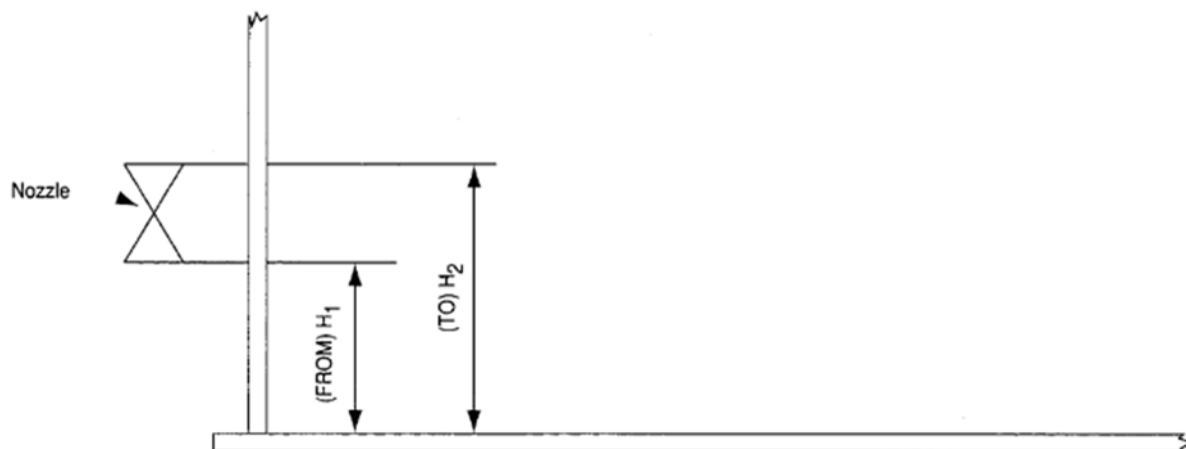
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Figure 4—Record Form for Deadwood

Table 1—Suggested Record Form “A” for Measurements of Upright Cylindrical Tanks

	Report No.:
	Date:
Tank No.:	
(Old Tank No.):	
Owner's Name:	
Plant or Property Name:	
Location:	
Manufactured by:	
Erected by:	
Prepare:	Copies: Increments in: Fractions to:
Table Form or Size Desired:	
Height: Shell:	Gauging:
Type of Roof:	Weight of Floating Roof:
Tank Contents—Name:	Avg. Liquid Temp., °F:
Gauge: ft. in.;	Innage to: Shell Floor or Outage
Hydrometer Reading: at °F Sample Temperature	
Gauging Reference Point to Top of Top Angle: ft. in.; Normal Service:	
Shell Circumferences:	
A.	D. G.
B.	E. H.
C.	F. J.

Descriptions of Shell Plates and Joints ^a

Ring No.	Thickness	Type of Vertical Joint	Set, in or out	Width of Lap or Strap	Thickness of Lap or Strap	No. of Joints	Inside Ring Height
7							
6							
5							
4							
3							
2							
(Btm. Ring) 1							

Shell Connections: ^b

No.	Description	Elevation—Top of Floor to Bottom of Connection
1		
2		
3		
4		
5		
6		

Amount of Tank Lean from Vertical: ^c in. in. ft. in.

Circumference Tape Used: Date Chk'd at

Tank Measured by: for

Deadwood and Tank Bottom—Use separate sheets. For each piece or item of deadwood record description, size, number of occurrences, and location related to other height measurement data recorded.

Explanatory Notes (such as type of bottom, height or depth of crown, etc.)

Note: No. = Number; Avg. Liquid Temp. = Average Liquid Temperature; ft. = foot/feet; in. = inch(es)

^aShow sketches of vertical and horizontal joints on back of this Table.^bShow circumferential location on plan view sketched on back of this Table.^cShow direction of lean on plan view sketched on back of this Table.

Table 2—Suggested Record Form “B” for Measurements of Upright Cylindrical Tanks

Report No.:

Date:

Tank No:

(Old Tank No.):

Owner's Name:

Plant or Property Name:

Location:

Manufactured by:

Erected by:

Prepare: Copies: Increments in : Fractions to:

Table Form or Size Desired:

Height: Shell : Gauging:

Type of Roof: Weight of Floating Roof:

Tank Contents—Name: Avg. Liquid Temp., °F:

Gauge: ft. in.; Tank Service: API Gravity:

Hydrometer Reading: at °F Sample Temperature

Shell Circumferences:

A.	D.	G.
B.	E.	H.
C.	F.	J.

Descriptions of Shell Plates and Joints:

Ring No.	Thickness	Type of Vertical Joint	Set, in or out	Width of Lap or Strap	Thickness of Lap or Strap	No. of Joints	Inside Ring Height
7							
6							
5							
4							
3							
2							
(Btm. Ring) 1							

Deadwood and Remarks (use reverse side if necessary):

<u>Deadwood</u> <u>Description</u>	<u>No.</u>	<u>Size</u>	<u>Elevation</u> <u>From</u>	<u>To</u>
.....				
.....				
.....				
.....				

Type of Bottom: Height of Crown:

Witness: Measurements by:

Note: Avg. Liquid Temp.=Average Liquid Temperature; °F=degrees Fahrenheit.; in.=inches; ft=foot; Btm = Bottom

10.3 Supplemental sketches or notations, each completely identified, dated, and signed, should accompany the strapping report. These should indicate the following.

- a) Typical horizontal and vertical joints.
- b) Number of plates per ring.
- c) Location of rings at which thickness of plates change arrangement.
- d) Size of angles at top and bottom of shell.
- e) Location and size of pipes and manways.
- f) Dents and bulges in shell plates.
- g) Amount of lean from vertical in relation to the reference gauge point.
- h) Procedure used in bypassing a large obstruction, such as a cleanout box or insulation box located in the path of a circumferential measurement.
- i) Location of tape path different from that shown in Figures 5 through 7.
- j) Location and elevation of a possible datum plate.
- k) All other items of interest and value that will be encountered.

10.4 Entries of data on a tank measurements record form or supplemental data sheets should not be erased. If alteration is necessary, the entry to be changed should be marked out with a single line and the new data recorded adjacent to the old entry.

11 Tolerances

11.1 Single circumferential measurements should be read and recorded to the nearest 0.005 ft (or nearest millimeter), which is equal to one-half of the distance between two adjacent hundredth-foot division marks on the tape. Therefore, all circumferential measurements should be recorded through the third decimal place.

11.2 Vertical tank measurements should be read and recorded to the nearest $\frac{1}{6}$ in. (or nearest 1 mm).

11.3 Thermometers should be read to the nearest 1 °F (or 0.5 °C).

11.4 Tank plate thicknesses should be determined to the nearest $\frac{1}{64}$ in. (1-mm resolution and read to nearest 0.5 mm).

11.5 Deadwood should be determined and located by measurement readings to the nearest $\frac{1}{8}$ in. (or 3 mm).

12 Shell Plate Thickness

12.1 Plate thickness should be measured by ultrasonic measurement device as the preferred method. A minimum of two measurements per ring should be obtained.

12.2 Plate thickness measurements obtained before or during construction and recorded on a properly identified strapping record may be accepted. In the absence of any direct measurements of plate thickness obtained and recorded before or during construction, the least preferred method is to use the plate thickness shown on the fabricator's drawings and so identified in the calculation records or information provided by tank owner.

12.3 The alternate method of measuring plate thickness is by depth gauge. Where the type of construction leaves the plate edges exposed, a minimum of two thickness measurements should be made on each ring. The arithmetical average of the measurements for each ring should be recorded; all thickness measurements, properly identified, should be noted on a supplemental data sheet that should form a part of the measurement record. Care should be taken to avoid plate thickness measurements at locations where edges have been distorted by caulking.

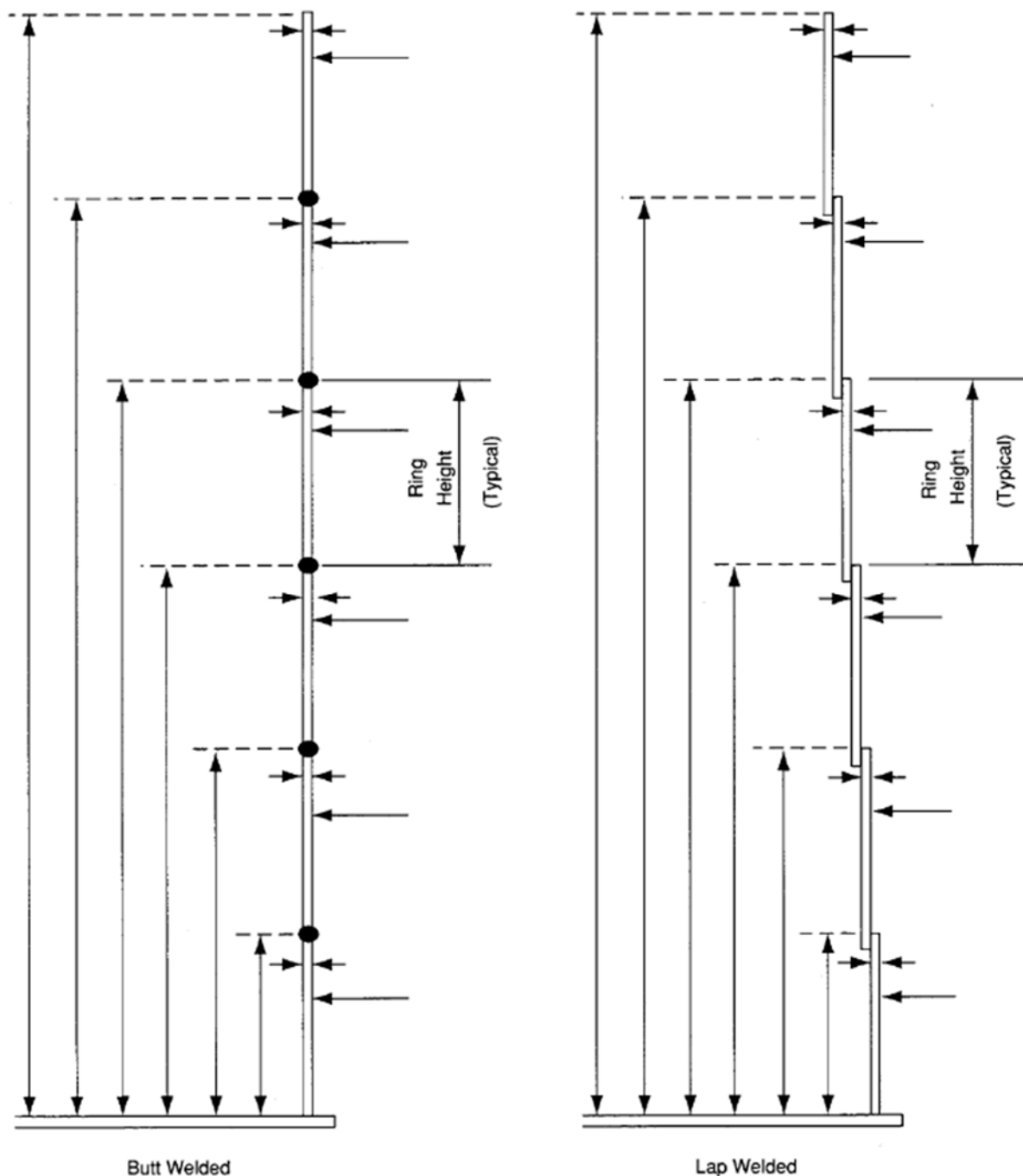


Figure 5—Measurement Locations for Welded Upright Tanks

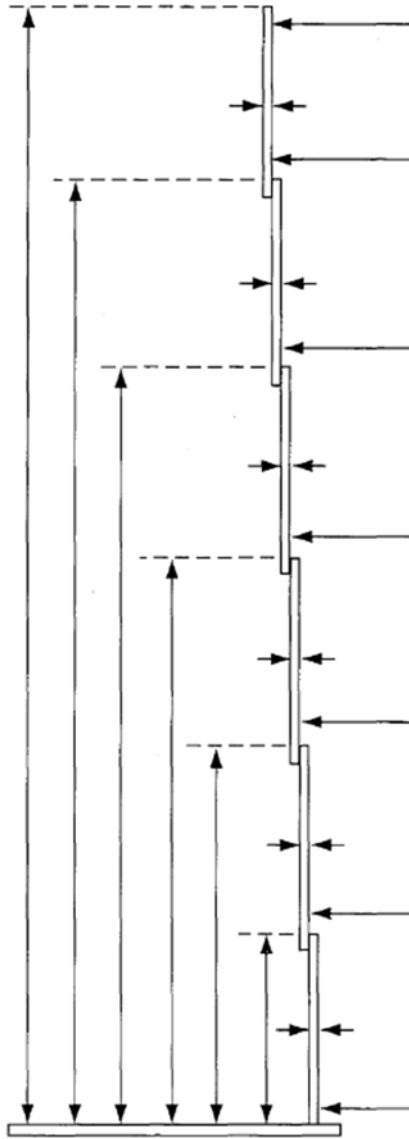


Figure 6—Measurement Locations for Riveted Shingled Arrangement

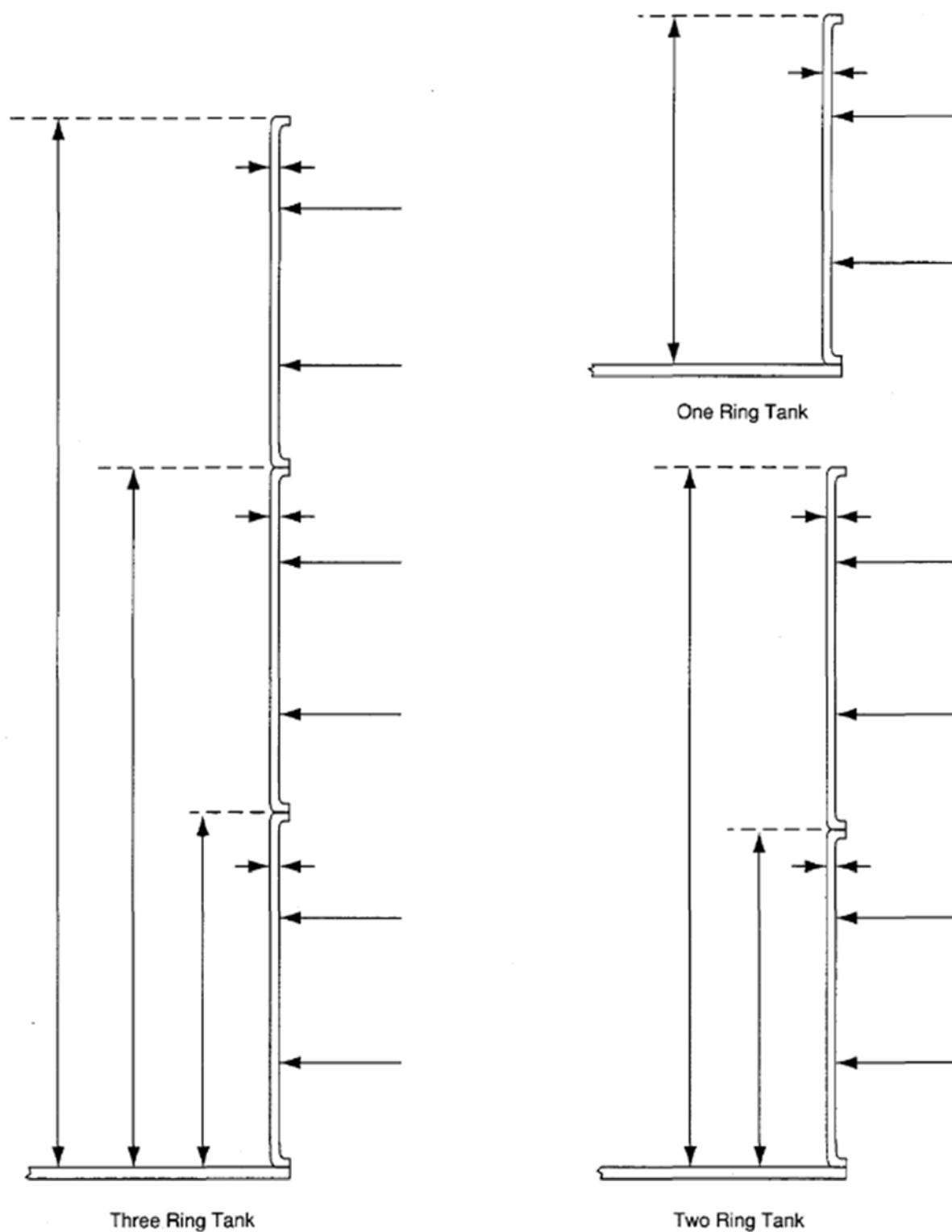


Figure 7—Measurement Locations for Bolted Tanks

13 Vertical Tank Measurements

13.1 Shell height is the vertical distance between bottom of bottom angle (or top of floor plate) and top of top angle and should be measured at a point near the reference gauge hatch (see Figures 8, 9, and 10).

13.1.1 Additional measurements should be made, as required, at other identified points sufficient to investigate and describe known or suspected conditions in the tank, such as tilt or false bottom. Locations of measurements should be marked on a supplemental sketch.

13.1.2 The amount of tilt in shell height should be measured and recorded. The measurements for possible tilt may be made in conjunction with measurements of shell heights using a theodolite, an optical plummet, or a plumb bob.

13.2 A description of the reference gauge point should be included in the record, for example: to top lip of 8-in. (or 20-cm) diameter hatch, opposite hinge.

13.3 A comparison should be made immediately of the reference gauge height with the sum of the shell height plus the height from the top of the top angle of the tank shell to the level of the reference gauge point on the hatch rim, in order to investigate the possible existence of a datum plate or false bottom.

13.3.1 The result of this field investigation should be recorded by identifying the reference gauge height as a distance to the floor or to the datum plate. The measurements and calculations involved should be attached to, and become a part of, the measurement record.

13.3.2 If a false bottom is known or suspected to be present, the record should be so marked.

13.4 Effective inside tank height is a vertical distance along the gauging path (see Figures 11 and 12). This is of primary concern to the capacity table calculations, establishing the upper and lower limits of variable gauges to be provided for in the capacity table.

13.4.1 The maximum upper limit of the capacity table can be one of the following two items:

- a) effective inside tank height,
- b) maximum fill height requested by the tank owner, such as at the underside of an overflow.

13.4.2 If the effective inside tank height should be obtained directly on the tank, this height should be measured and reported as such. If effective inside tank height cannot be measured directly, the person responsible for obtaining the measurements should obtain as-built blueprints to enable calculation of the effective inside tank height.

13.5 In some installations, an overflow line or other appurtenance is connected to the tank shell just below the top angle and provides a potential liquid overflow level at some point below the top of the shell (see Figure 12).

13.5.1 The measurement record should include a complete description of such a connection, including size and location and whether or not a valve that can be closed and sealed is included in the line. If such a valve is present, its location should be included in the record.

13.5.2 If the connection cannot be closed and sealed against overflow, then the effective inside tank height is the vertical distance from the striking point on the tank floor, or datum plate, upward to the level at which the tank's contents will begin to overflow; the tank capacity between the point of overflow and the tank roof should be disregarded in the capacity table.

13.5.3 If the connection can be closed and sealed against overflow, then the effective inside tank height and the capacity table should extend upward to the top of the top angle.

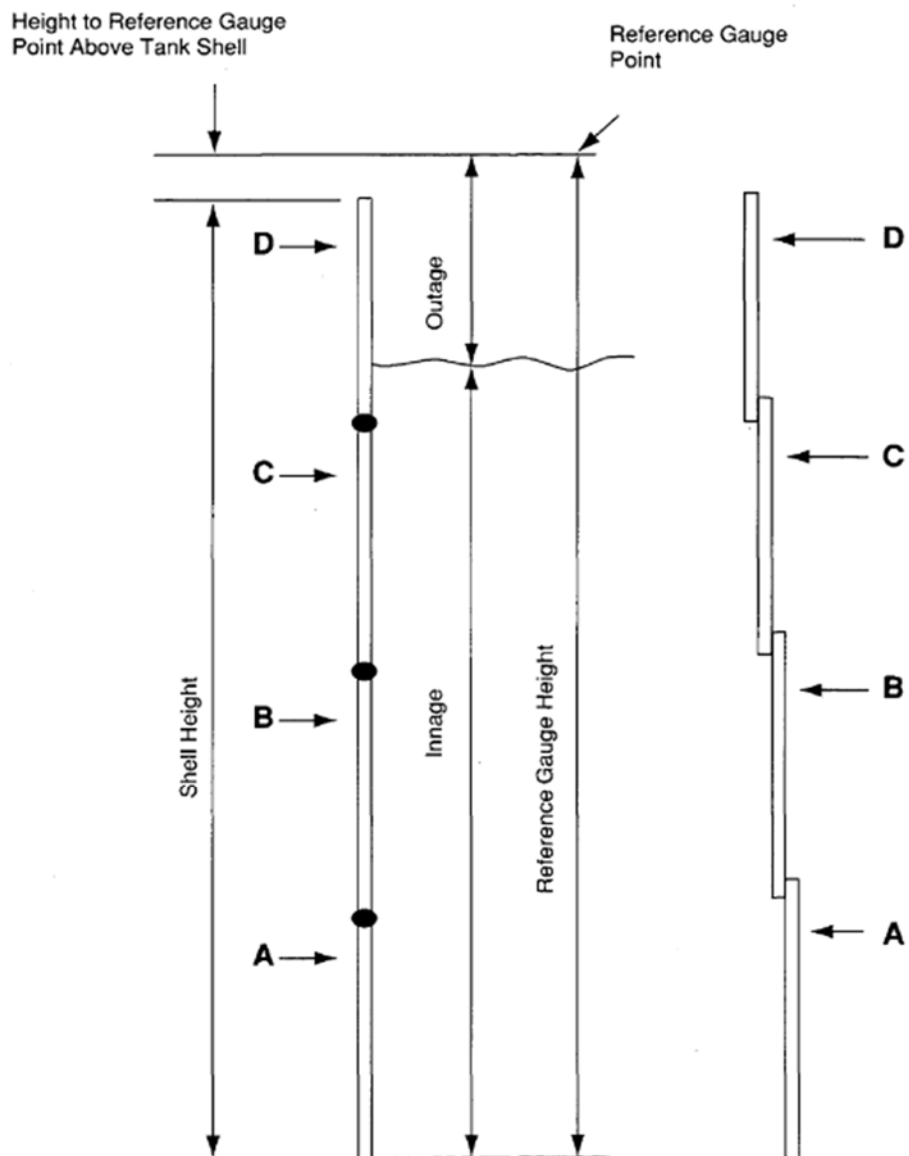


Figure 8—Vertical Tank Measurements (Welded)

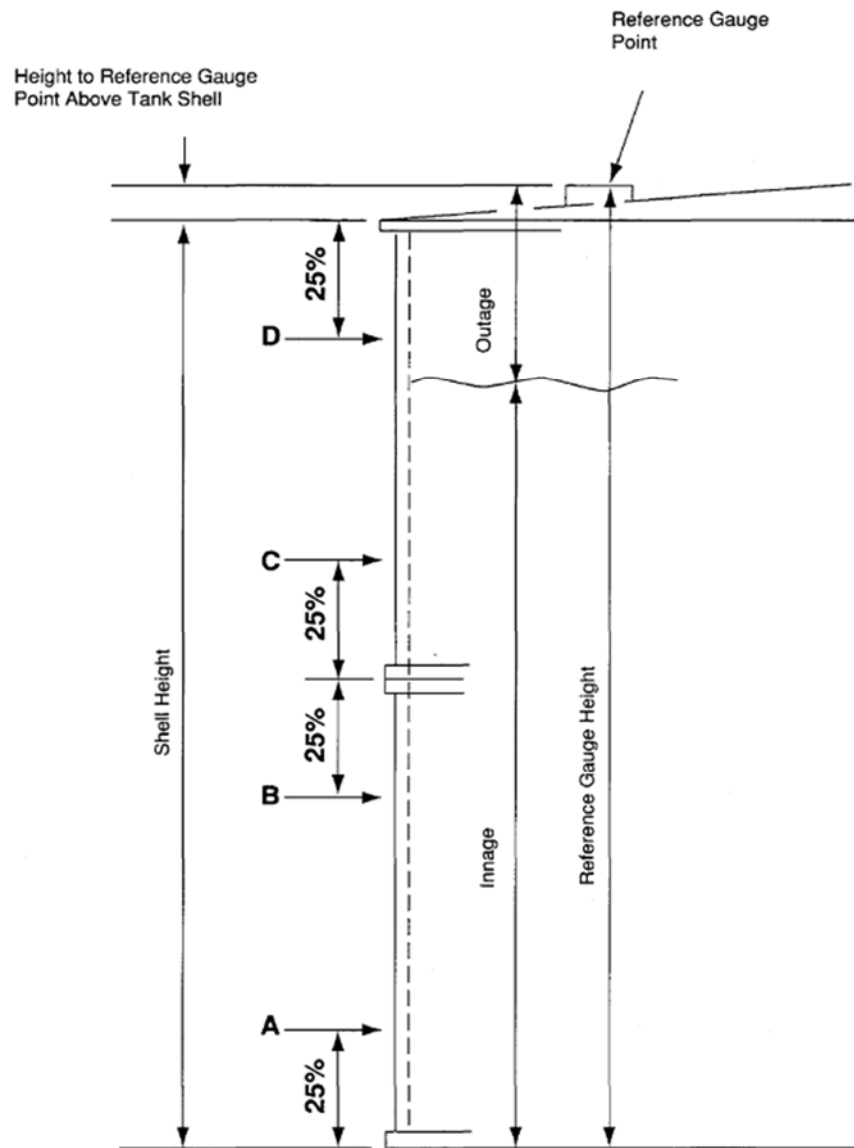


Figure 9—Vertical Tank Measurements (Bolted)

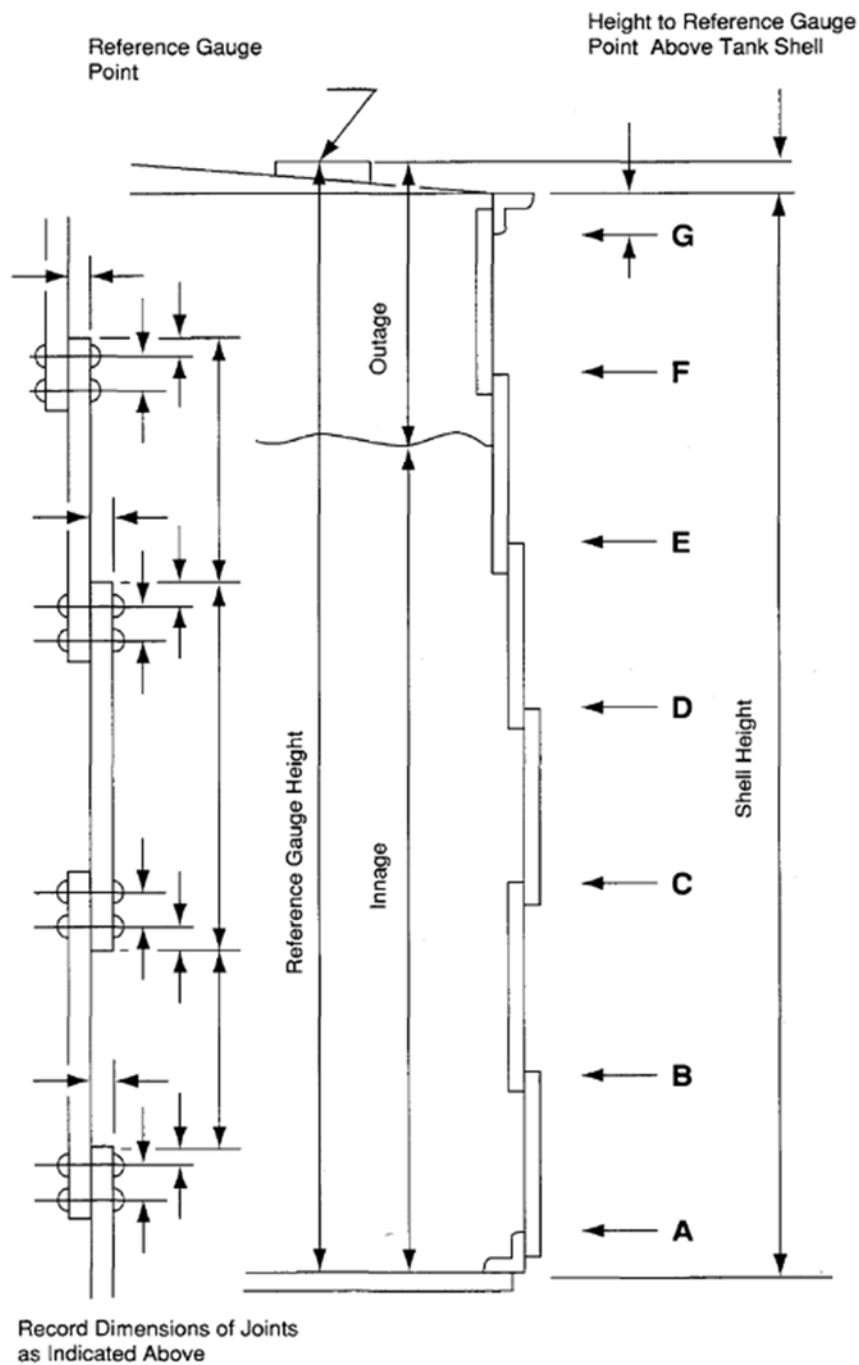


Figure 10—Vertical Tank Measurements (Riveted)

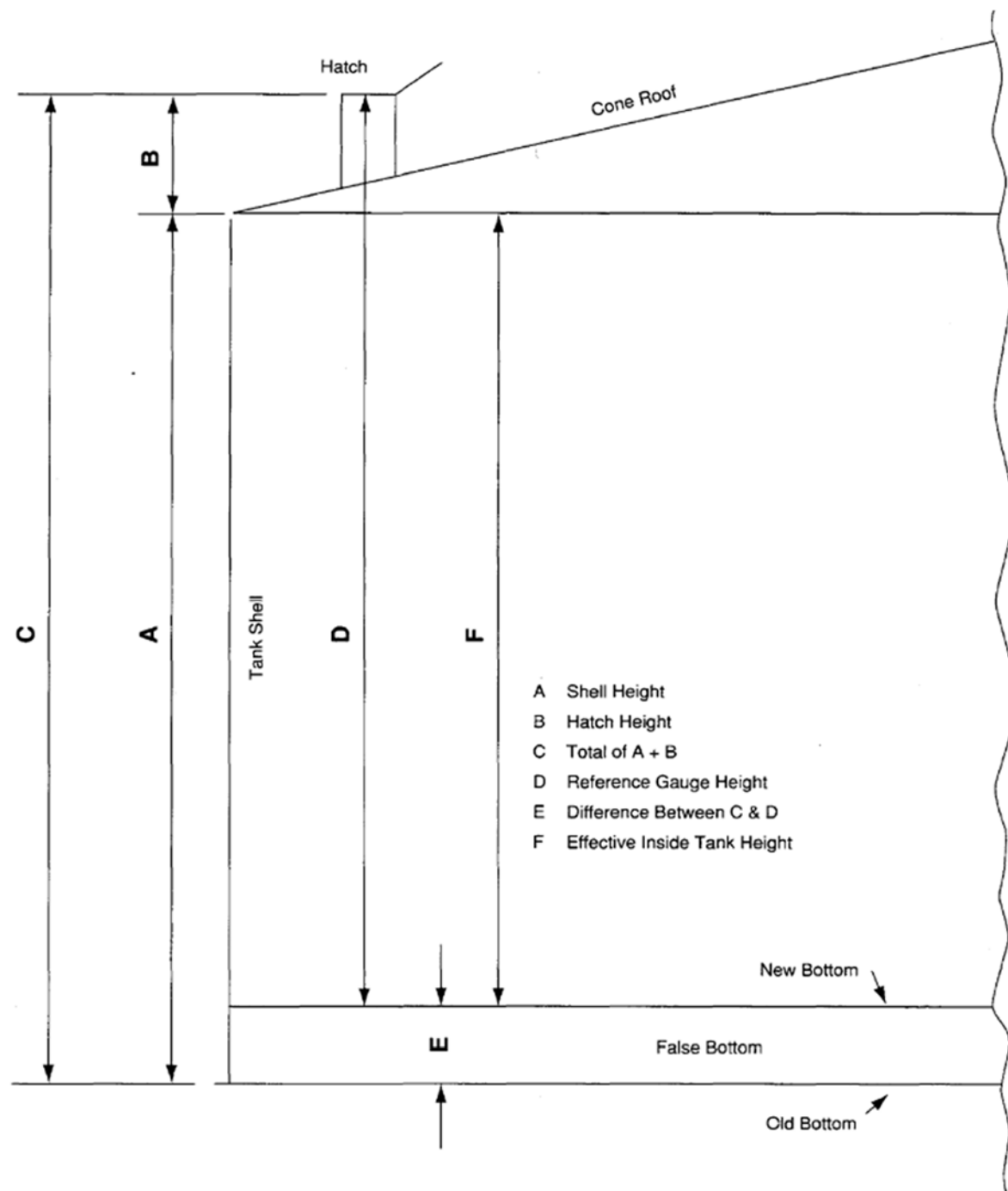


Figure 11—Effective Inside Tank Height (Cone Roof)

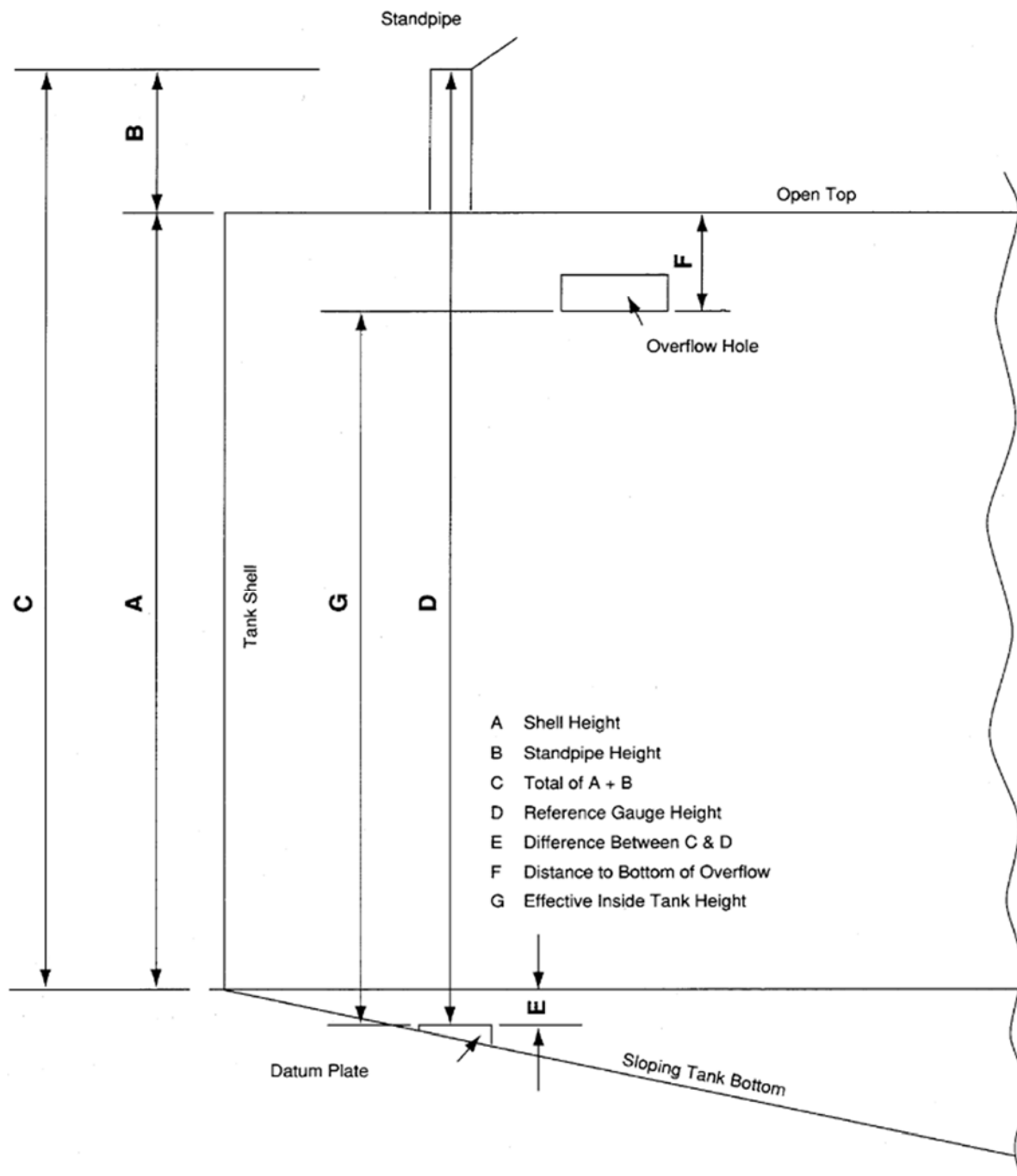


Figure 12—Effective Inside Tank Height (Floating Roof)