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Chapter 2 ————— Section 1

**METHOD FOR MEASUREMENT
AND
CALIBRATION OF UPRIGHT
CYLINDRICAL TANKS**



AMERICAN PETROLEUM INSTITUTE

API 2550



AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM D 1220



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NOTE: API Standard 2550-ASTM D 1220 was approved as an ANSI Standard Dec. 30, 1966.

FOREWORD

The standard in this publication is one of a series approved jointly by the American Petroleum Institute and the American Society for Testing and Materials. This standard is the result of a cooperative arrangement established by the two organizations to develop and jointly approve and publish standards dealing with quantitative and qualitative measurements of petroleum products and lubricants.

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Suggested revisions are invited and should be submitted to Industry Affairs, Non-Divisional, American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20006.

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Standard Method for MEASUREMENT AND CALIBRATION OF UPRIGHT CYLINDRICAL TANKS¹



API Standard: 2550

ASTM Designation: D 1220 - 65

ADOPTED, 1965.^{1,2}

This standard of the American Petroleum Institute issued under the fixed designation API 2550 is also a standard of the American Society for Testing and Materials issued under the fixed designation D 1220; the final number indicates the year of original adoption as standard, or, in the case of revision, the year of last revision.

This method was adopted as a joint API-ASTM Standard in 1965.

Scope

1. This standard describes the procedures for calibrating upright cylindrical tanks larger than a barrel or drum. It is presented in two parts; Part I (Sections to 41) outlines procedures for making necessary measurements to determine total and incremental tank volumes; Part II (Sections 42 to 58) presents the recommended procedure for computing volumes.

NOTE 1.—Other calibration standards are:
API Standard 2551—ASTM D 1410: Measurement and Calibration of Horizontal Tanks

¹ Under the standardization procedures of the API and the ASTM, this standard is under the jurisdiction of the API Central Committee on Petroleum Measurement and the ASTM Committee D-2 on Petroleum Products and Lubricants.

² The API method was adopted as API Standard 2550 in October, 1965.

Prior to their present publication, the API methods of test were issued in December, 1929 as API Code 25. API Code 25 was reissued in 1930, 1931, 1933, 1935, 1940, and 1948. The material was revised and reissued in September, 1955 as API Standard 2501, and the second edition was issued in July, 1961.

³ Revised and adopted as standard June, 1965 by action of the ASTM at the Annual Meeting and confirming letter ballot.

Prior to adoption as ASTM standard, this method was published as tentative from 1952 to 1959, being revised in 1955, 1956, 1957, 1958, and 1959.

API Standard 2552—ASTM D 1408: Measurement and Calibration of Spheres and Spheroids

API Standard 2553—ASTM D 1407: Measurement and Calibration of Barges

API Standard 2554—ASTM D 1409: Measurement and Calibration of Tank Cars

API Standard 2555—ASTM D 1406: Liquid Calibration of Tanks

Definitions

2. (a) "Tank strapping" is the term commonly applied to the procedure for the measurement of tanks to provide the dimensions necessary for the computation of gage tables. These tables will show the quantity of oil in a tank at any given depth.

(b) Tank strapping includes the following measurements:

(1) *Depth*.—Shell height, oil height, ring height, equalizer line height, and gaging height.

(2) *Thickness of Tank Walls*.—Stave thickness and metal thickness.

(3) *Circumferences of Tank at Specified Locations*.

(4) *Deadwood*.—Any object within the tank, including a floating roof, which 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, which increase the capacity of the tank.

Significance

3. Accurate tank measurements are a most important factor in liquid volume determinations, for the reason that an incorrect dimension results in an erroneous gage table, which might be in use over an extended period of time before the error is discovered. In most cases, the person who computes the gage tables is not the one making the actual field measurements and has no direct means of checking such measurements; therefore, this person must depend upon the tank strapper for accurate measurements. Errors in gage tables cause the accounting of tank contents to be inaccurate; therefore, payments are subject to question. Settlements involving such errors are very difficult, and sometimes impossible, to adjust without loss to one of the parties involved. As the procedure for taking measurements and the achievement of accuracy in tank strapping are so important, all such measurements should be witnessed by all parties interested in the subsequent measurement of quantities in the tanks being strapped. It is hoped that the foregoing will provide an adequate idea of the extreme importance of correctness in this particular detail.

Tank-Measuring Equipment and Its Calibration

4. The equipment to be used for tank measurements is covered in Sections 5 and 6. The measurement of any one tank will not require the use of all the equipment listed. Therefore, the type of tank and the proper calibration procedure must be considered carefully before selecting the equipment needed. All equipment shall be in good condition. All tapes shall be in one piece (unmended) and free of kinks.

Measuring Tapes

5. (a) *Tapes for Height Measurements.*—For height measurements, a steel tape, Fig. 1(a), of convenient length, $\frac{3}{8}$ or $\frac{1}{2}$ in. wide and 0.008 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. The working tape shall be calibrated against a “standard” tape in a vertical position, with equal tension (1 to 2 lb) applied to both. Graduations shall be accurate within $\frac{1}{32}$ in. or 0.05 ft throughout that portion of the tape length to be used.

(b) *Tapes for Circumference Measurements.*—For circumference measurements, a steel tape, Fig. 1(b), of convenient length relative to the tank circumference, usually 100, 200, 300, 500, or 600 ft in length, is recommended. The working tape 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 graduated in tenths and hundredths of a foot, or it may be graduated in feet, tenths, and hundredths of a foot throughout its length. The tape shall be calibrated (for required tension) by matching it against the standard tape in the following manner: Choose a convenient tape path on the lower ring and place the standard tape around the tank by the successive tangent method with constant application of tension as near as possible to that at which the standard tape was certified to be accurate, scoring the tank at each 100 ft or fraction thereof. Total the measurements thus obtained and place the working tape around the tank, using the same tape path, by the continuous “wraparound” procedure; slide the working tape to break frictional resistance; and apply tension sufficient to equal the measurement obtained with the standard tape. The amount of tension, in pounds, required to be placed on the work-

ing tape to obtain the same measurement as that recorded with the standard 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 standard tape. The amount of correction should not exceed 0.01 ft (approximately $\frac{3}{32}$ in.) for each 100 ft of tape in use. In making “critical measurements,” this procedure shall be carried out for each tank of different diameter where the circumference differs by more than 20 per cent from the calibrated tape section, and where tank surfaces are different. It should be noted that circumference measurements may be made with working tapes which have been calibrated by a standard tape of length based on 68 F.

If the preceding calibration procedure is not practicable, a suitable flat, horizontal surface, such as a railroad rail, may be substituted for the tank shell surface. In either case, if two or more successive check readings are taken, the supporting surface frictional resistance to movement of the working tape should be broken between such successive readings.

(c) *Tape Calibration.*—The standard tape for calibrating tank-measuring (working) tapes shall be identified with a Report of Calibration at 68 F by the National Bureau of Standards attesting to the standard tape accuracy within 0.001 ft (approximately $\frac{1}{4}$ in.) per 100 ft of length. The Report of Calibration for a standard tape shall include these factors and/or formulas necessary to correct the tape length for use:

- (1) At 60 F.
- (2) Under tension differing from that used in calibration.
- (3) Under conditions of sag in an unsupported tape.
- (d) *Reels.*—Tapes shall be equipped with appropriate reels and handles.
- (e) *Tape Clamps.*—For assurance of positive grip on tape, clamps shall be used.

NOTE 2.—The National Bureau of Standards provides for standard tapes (NBS “reference” tapes) only a Report of Calibration at 68 F when the tape is completely supported in a horizontal position and subject to horizontal tension as prescribed in

National Bureau of Standards Test Fee Schedule 202404—Steel Tapes. The additional data indicated in Section 5(c), Items (1), (2), and (3), are included in the NBS Report of Calibration only when requested by the applicant and to the extent specifically requested.

Accessory Equipment

6. (a) Additional measuring equipment recommended is described in Paragraphs (b) to (m) and shown in Fig. 1(c) to (h) and Figs. 2, 3, and 4. Other similar equipment may be used, provided that it will give the same results.

(b) *Rope.* $\frac{3}{4}$ -in. Manila hemp, but not less than $\frac{1}{2}$ in., of a length approximately equal to four times the tank height. Block and tackle to be one single block with loose hook and becket and one double block with loose hook. Blocks to have hardwood shells about 8 in. long with sheaves for $\frac{1}{2}$ -in. or larger rope.

NOTE 3.—Blocks suitable for larger rope than required will provide an ample factor of safety and take care of swelling of Manila rope due to dampness.

(c) *Seat.* of oak or white pine board $1\frac{1}{4}$ to 2 in. thick, 30 in. long, and 10 in. wide; dressed; and with holes for rope drilled near each corner, top and bottom edges of holes slightly rounded; $\frac{1}{2}$ - or $\frac{3}{4}$ -in.-diameter rope passed through holes, ends spliced and wrapped together on each side above the board with short pieces of small rope.

(d) *Water Curtain Hook* for fastening block and tackle to the top of the tank, $\frac{5}{8}$ -in.-diameter steel, and bent to shape; each end welded into an eye suitable for receiving the hook of the double block; and fastened to spray or other fixed point on top of the tank with 1-in. Manila hemp rope.

(e) *Special Hook for Open-Top Tanks.* $\frac{5}{8}$ by 3 in., flat, bent to shape, and with hole in end suitable for receiving the hook of the double block.

(f) *Safety Belts.* two required, heavy canvas webbing with double buckles, leather shoulder straps for fastening, steel ring at crossing of straps in back to which ropes are fastened with a splice. Rope to be $\frac{1}{2}$ -in. Manila hemp.

(g) *Rope and Ring.*—Two lengths of rope line fitted with snap and ring to be used in raising and lowering circumference measurement tape. Alternatively, jointed-type pole guides may be used.

(h) *Depth Gage.*—Depth gage of case-

hardened steel, 6 in. in length, graduated $\frac{1}{4}$ in. This is for determination of thickness of steel plates, wooden tank staves, etc.

(i) *Calipers, Step-Overs, and Special Clamps.*—For spanning obstructions in making circumference measurements, the following are recommended:

(1) 6 in. maximum expansion calipers for spanning the smaller obstructions, such as vertical flanges, bolt heads, etc.

(2) 18 or 24 in. maximum expansion calipers for spanning the larger obstructions, such as butt straps, etc.

(3) Special clamps may be substituted for calipers in measuring projecting flanges.

(4) Fixed- or adjustable-span steel step-overs may be used instead of calipers or special clamps. See Fig. 1(f) for adjustable step-over.

(5) To measure the span of a step-over or caliper, apply the instrument in a horizontal position, as determined by use of a level, against the shell of the tank being strapped, near the center of a shell plate, and scribe marks on the shell with the two scribing points. Apply the circumferential working tape, under required tension, to the tank shell in such a position that the distance between the scribed lines, along the shell surface, may be estimated to the nearest 0.001 ft (approximately $\frac{1}{4}$ in.).

(j) *Straightedges:*

(1) Metal, 36 in. long.

(2) Engineer's straightedge, 10 ft long, for measuring tank heads.

(3) Profile board for measuring knuckles.

(k) *Miscellaneous:*

(1) A 6-ft ruler for general measurements.

(2) A 4-ft crowbar may be useful.

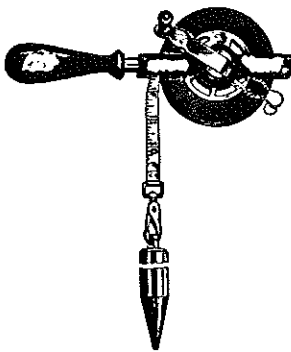
(3) Spirit level.

(4) Awl and scriber.

(5) Marking crayon.

(6) Record paper.

(7) Cleaning instruments such as a putty knife and a hard-bristle brush for eliminating dirt, grease, paint scale, rust



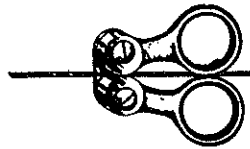
(a) Height-measuring tape and bob, usually 50 ft long (including bob) and $\frac{3}{8}$ or $\frac{1}{2}$ in. wide.



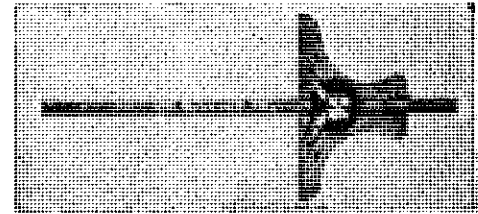
(b) Strapping tape for circumference measurement, usually 100, 200, 300, 500, or 600 ft long and not more than $\frac{1}{4}$ in. wide, graduated in feet with extra foot at zero end and graduated in tenths and hundredths of a foot.



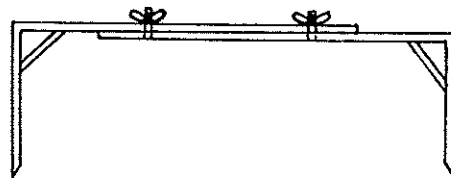
(c) Spring tension gage.



(d) Tape clamp.



(e) Depth gage.



(f) Step-over.



(g) Special hook for bosun's chair, cone-roof tank.

(h) Special hook for bosun's chair, open-top tank.

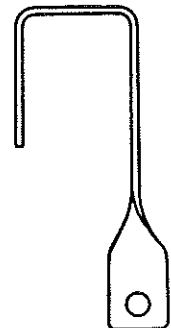


FIG. 1.—TYPICAL TANK-MEASURING EQUIPMENT.

particles, etc., from the path of circumference measurements.

(8) In certain instances, a combined transit and level is required, such as for measurements over floating roofs, tanks that are out of round, inclined tanks, etc.

(9) Ladders to facilitate handling of tapes, and removal of paint scale, rust, dirt, etc., from the path of measurement.

(10) Plumb line.

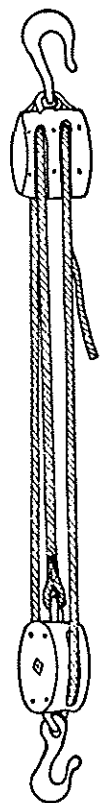
(11) Spring tension scale.

(12) Dynamometer.

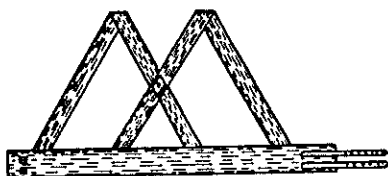
(l) *Equipment for Determining Temperature and Gravity:*

(1) *Sample Can.*—A clean container of suitable size.

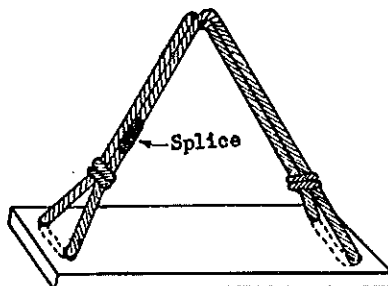
(2) *Hydrometer Cylinder.*—Preferably of nonbreakable material, diameter 1 in.



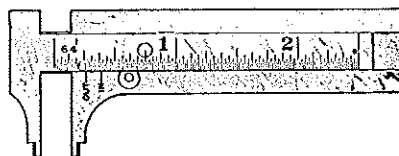
(a) Block and tackle.



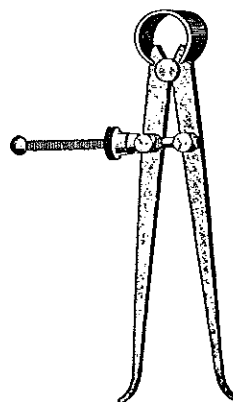
(b) Safety belt.



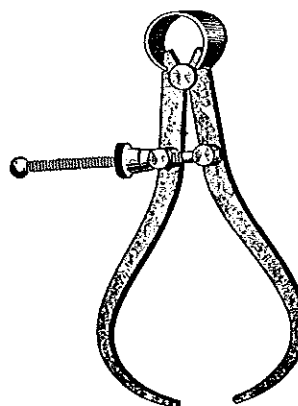
(c) Seat.



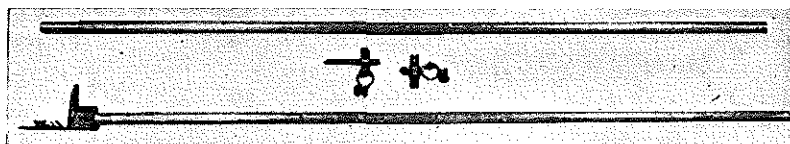
(d) Calipers.



(e) Calipers.



(f) Calipers.



(g) Tape positioner—type with attachments marking tape path.

FIG. 2.—TYPICAL TANK-MEASURING EQUIPMENT.

greater than the outside diameter of the hydrometer to be used, height 1 in. greater than the portion of the hydrometer which is immersed beneath the surface of the liquid.

(3) *Hydrometer*.—Plain form or combined thermometer and hydrometer known as a thermohydrometer, calibrated in terms of API gravity, the range to be a suitable portion of the interval between 0 and 100° API and graduated in 0.1° API and conforming to Specifications E 100, for ASTM Hydrometers.⁴

(4) *Thermometer*.—ASTM Gravity Thermometer, total immersion, having a range of –5 to 215 F and conforming to the requirements for Thermometer 12 F as prescribed in Specifications E 1, for ASTM Thermometers.⁴

NOTE 4.—For making gravity measurements, reference should be made to *API Standard 2544—ASTM D 287: Method of Test for API Gravity of Crude Petroleum and Petroleum Products*.

(m) *Liquid Calibration*.—Liquid calibration of the entire or partial volume of tanks is sometimes recommended in lieu of physical measurement of dimensions and calculations of tank volumes. Liquid calibration is especially useful for the following conditions: The critical zone of a floating roof; irregularly shaped portions of tanks, particularly bottoms; unstable bottoms where the deflection of the bottom varies with the liquid-head height in the tank or water-table level of its foundation; tanks that are unevenly tilted, irregular in shape, or inaccessible for measurement. Instructions for liquid calibration for these or any other reasons may be found in API Standard 2555—ASTM D 1406.

General Practices

7. (a) Prevailing safety practices should be observed at all times.

(b) The number of men required in a

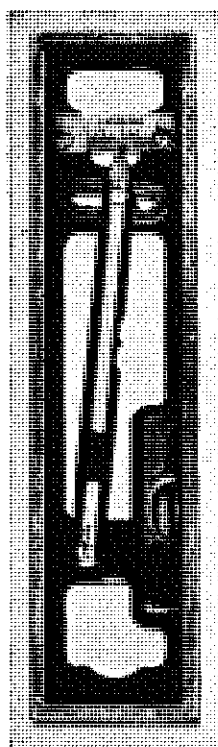


FIG. 3.—COMBINATION PITCH INDICATOR AND LEVEL.

strapping crew will depend upon conditions to be encountered, such as the experience of the men, the weather, strapping schedule, rigging available, and the height of tanks. As a general rule, a crew of three may be considered practical, including at least one man who has had previous tank-measuring experience. It would also be decidedly advantageous if the previous experience included some amount of office work in the calculation of gage tables.

(c) Do not use ropes, ladders, or other rigging of questionable strength or condition. This is particularly important in regard to rope that has been stored while wet, saturated with oil or gasoline, or used on an acid tank.

PART I. MEASUREMENT PROCEDURES

Conditions for Measurements

8. (a) All data, and procedures whereby they are obtained, necessary for the preparation of gage tables should be supported by sound engineering principles.

(b) Measurements should be taken only after the tank has been filled at least once at its present location with liquid at least as dense as it is expected to contain.

⁴ 1960 Book of ASTM Standards, Part 18.

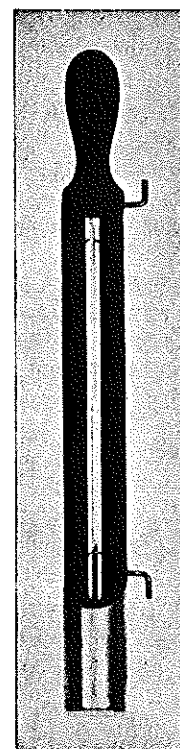


FIG. 4.—CUP-CASE THERMOMETER.

(d) If ladders are used, all rungs should be inspected and tested at ground level. Ladders should not be “stretched,” for convenience, beyond their normal safe working range. It should be understood that the inherent danger in ladders may be increased considerably by conditions on a tank job, such as possibly soggy footing, relatively smooth upper bearing surface, strong gusts of wind, sudden slack or pull in circumference tape, etc.

(e) All measurements and descriptive data taken at the tank site should be checked and legibly recorded immediately, with the recording assigned, preferably, to one man.

(f) Take time to do a good job.

The usual water test, if made, will meet this requirement.

(c) The calibration procedures which are outlined herein are based upon internal cleanliness of the tank. The interior upright cylindrical surface and roof-supporting members, such as columns and braces in the tank, should be clean and free from any foreign substance including, but not limited to, residue of commodities adhering to the sides, rust, dirt, emulsion,

and paraffin. Examination and inspection of a tank may indicate the need for thorough cleaning if accuracy in the calibration is to be achieved. Internal incrustation or adhesion has the same effect on the tank capacity as deadwood and should be accounted for in the same manner. For additional information for various solutions to this problem, see *API Bulletin on Incrustation* (Supplement No. 1 to API Standard 2500).

(d) *Tanks with a Nominal Capacity of 500 Bbl or Less.*—These tanks may be strapped at any condition of fill, provided they have been filled at least once at their present location. Small movements of oil into or out of such tanks are allowed during strapping.

(e) *Tanks with a Nominal Capacity of More Than 500 Bbl:*

(1) *Bolted Tanks* must have been filled at least once at their present location and must be at least two-thirds full when strapped. Small movements of oil into or out of such tanks are allowed during strapping.

(2) *Riveted Tanks and/or Welded Tanks* must 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 Section 53. No movement of oil into or out of such tanks is allowed during the strapping operation.

Disputes

9. In case of controversy, when agreement cannot be reached between the buyer and the seller, a joint strapping should be taken. This joint strapping should be considered final.

Tank Numbers

10. (a) *Identification.*—Each tank should be identified clearly and legibly by number or by some other suitable marking, but this identification should not be painted on hoops or tank attachments.

(b) *Restrapped Tanks.*—A tank which has been restrapped should be identified completely, either by renumbering or by some other adequate method.

Interrupted Measurements

11. 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 gage and average temperatures of both liquid and outside atmosphere are included as parts of the subsequent strapping operations.

Descriptive Data

12. (a) Complete descriptive data should be entered on the Tank Measurements Record Form being used. Suggested record forms are shown in Figs. 6 to 9 and Tables III and IV (see Section 21).

(b) Usually the commonly used name

for a tank's contents may be a sufficient description. In those cases in which a more accurate description is desired, as for example in critical measurements, the API gravity and the temperature of the tank's contents should be obtained and recorded.

(c) Supplemental pencil sketches or notations, each completely identified, dated, and signed, should accompany the strapping. These should be made to indicate typical horizontal and vertical joints; number of plates per ring; location of rings at which thickness of plates change; arrangement and size of angles at top and bottom of shell; location and size of pipes and manways; dents and bulges in shell plates; direction of lean from vertical; procedure used in bypassing a large obstruction, such as a cleanout box or insulation box located in the path of a circumferential measurement; location of tape path different from that shown in Figs. 11 to 19; location and elevation of a possible datum plate; and all other items of interest and value which will be encountered.

(d) 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 pencil line and the new data recorded adjacent to it.

UPRIGHT CYLINDRICAL TANK SHELLS—ABOVEGROUND

Classification of Tank Services

13. (a) The degree of accuracy desired in the completed gage table for a specific tank will be the governing factor in determining the procedure to be followed. Tanks may be considered to fall within one of two broad classifications:

(1) *Operating Control.*—Tanks used in intraplant or intradepartmental service.

(2) *Critical Measurements.*—Tanks used in intercompany or interdepartmental service.

NOTE 5.—It should be remembered that the maximum obtainable accuracy in gage tables for all tanks, regardless of service, is of value for inventory.

(b) A critical measurements gage table is more precise (Note 6) than an "operating control" gage table (Note 7) because adjustments are included for the effects of the following variables:

(1) Differences in requirements for circumferential measurements (see Figs. 10 to 25).

(2) Expansion and contraction of steel tank shell due to liquid heads.

(3) Expansion and contraction of steel tank shell with temperature.

(4) Tilt from a vertical position.

(5) Tank bottoms that are irregular in shape, or unstable under varying liquid loads, or both.

NOTE 6.—Tolerances for measurements and calculations included in this procedure apply to the development of both critical measurements and operating control gage tables.

NOTE 7.—Adjustment for effect of such variables may be incorporated in gage tables for operating control tanks. The gage table should indicate the adjustments which have been incorporated.

Expansion and Contraction of Steel Tank Shells Due to Liquid Head and Temperature

14. These effects may be determined in accordance with procedures given in Part II, Sections 53 and 54. In the case of the calculation procedure for expansion and contraction due to liquid head, as mentioned in Section 53(c), Item (1), a tank may be measured empty or at any condition of fill. When no liquid-head correction is to be made, a tank should be measured only when at least two-thirds full. In either case, the strapping record should include liquid gage, API or specific gravity of liquid, and the average temperature of the liquid and the temperature of the air adjacent to shell at time of circumferential measurements.

Effect of Tilt on Cylindrical Tank Shell

15. 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 [see Section 19(a)].

Recalibration of Welded, Riveted, or Bolted Tanks

16. (a) In order to obtain a check on the accuracy of existing circumference measurement records, the tank circumferences in question should be remeasured at the same circumference measurement elevations as taken originally. The check measurements should be made in accordance with rules for circumferential measurements as covered in this standard.

(b) If the final check measurements taken at a later date—and after further service sufficient to induce maximum stress variations in the shell; permanent "set, if any; etc.—do not check the questioned

circumference measurements within the appropriate allowance shown in Table I, a complete recalibration and new gage tables based thereon should be required.

(c) Vertical or upright tanks should be remeasured and recalibrated:

(1) When restored to service after being disconnected or abandoned.

(2) When disassembled and re-erected, or when "moved bodily."

(3) When deadwood is changed, when concrete or other material is placed on the bottom or on the shell of the tank, or when the tank is changed in any manner which would affect the incremental or total volume.

NOTE 8.—Experience in checking the circumference measurements of bolted steel tanks indicates that such tanks, in sizes up to a nominal capacity of 1000 bbl, show no significant volumetric change over a period of 10 yr. Tanks having a nominal capacity in excess of 1000 bbl show volumetric changes of a small order of magnitude over a 10-yr period which may be sufficient to warrant recalibration of the tank when considering the type of service and the value of the product involved.

Tolerances

17. (a) Single circumferential measurements should be read and recorded to the nearest 0.005 ft, which is equal to one-half of the distance between two adjacent hundredth-foot division marks on the tape. A segmental circumferential measurement, such as is made in conjunction with the use of a step-over, should be estimated and recorded to the nearest 0.001 ft, which is equal to one-tenth of the distance between two adjacent hundredth-foot division marks on the tape. These interpolations should be made by eye. Therefore, all circumferential measurements should be recorded through the third decimal place.

(b) Vertical tank measurements should be read and recorded to the nearest $\frac{1}{8}$ in.

(c) Thermometers should be read to the nearest scale division.

(d) Tank plate thicknesses should be determined to the nearest $\frac{1}{64}$ in.

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

Shell Plate Thickness

18. (a) Where type of construction leaves the plate edges exposed, a minimum of four thickness measurements should be

TABLE I.—TOLERANCES FOR RECALIBRATION OF WELDED, RIVETED, OR BOLTED STEEL TANKS.

Circumference, ft	Welded		Riveted		Bolted		Other Types
	Tolerance, ft	Avg. per cent by Volume	Tolerance, ft	Avg. per cent by Volume	Tolerance, ft	Avg. per cent by Volume	
Up to 100, incl.....	0.010	0.040	0.020	0.080	0.030	0.120	Consider on individual merits, by types of construction and in terms of closest applicable similar tolerance, expressible as a percentage by volume.
101 to 200, incl.....	0.015	0.020	0.025	0.033	0.040	0.053	
201 to 300, incl.....	0.020	0.016	0.030	0.022	..	..	
301 to 400, incl.....	0.025	0.014	0.035	0.020	..	..	
401 to 500, incl.....	0.030	0.013	0.040	0.018	..	..	

made on each ring at points approximately equally spaced about the circumference. 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 which should form a part of the measurements record. Care should be taken to avoid plate thickness measurements at locations where edges have been distorted by caulking.

(b) Where plate edges are concealed by the type of construction, the strapping record should be marked "not obtainable at tank." Alternatively, plate thickness measurements may be obtained as described in Paragraph (c).

(c) 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 thicknesses obtained and recorded before or during construction, those shown on the fabricator's drawings may be accepted and so identified in the calculation records. Paint thickness on the various rings should be noted and included with the strapping records.

Vertical Tank Measurements

19. (a) 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 gage hatch. Additional height 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 in plan view.

(b) Gaging height is the vertical distance between the reference point on the gage hatch and the striking point on tank floor or on gage datum plate, and should be measured at the commonly used point on the hatch rim. If a gaging reference point other than the top of the gage hatch rim is known to be commonly used, a description of the reference point should be included in the record.

(c) A comparison should be made immediately of the gaging height with the sum of shell height plus the height (approximate) from the top of the top angle to the level of the gaging point on the hatch rim, in order to investigate the possible existence of a gaging datum plate or false bottom. The result of this field investigation should be recorded by identifying the gaging height as a distance to the floor (Note 9) or to the datum plate. The measurements and calculations involved should be attached to, and become a part of, the measurements record.

NOTE 9.—If a false bottom is known or suspected to be present, the record should be so marked.

(d) Effective inside tank height is a vertical distance along the gaging path. This is of primary concern to the gage table calculator in that it establishes the upper and lower limits of variable gages to be provided for in the gage table. If the effective tank height can be obtained directly on the tank, it should be measured and reported as such. If it cannot be measured directly, the strapper should assure himself that other vertical meas-

urements taken and recorded will permit the calculator to develop therefrom the effective inside tank height.

(e) 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. The measurement record should include a complete description of such a connection, including size and location, and whether or not a valve, which can be closed and sealed, is included in the line. If such a valve is present, its location should be included in the record. 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 gaging 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 gage table. If the connection can be closed and sealed against overflow, then the effective inside tank height, and the gage table, should extend upward to the top of the top angle. In this latter case, in which the gage table is extended upward beyond the connection, the gage table should include a note, at the elevation of the connection, citing its presence and stipulating the condition under which that portion of the gage table may be used.

(f) Liquid in tank at time of strapping should be gaged and its mean temperature and API gravity determined. Checked results should be recorded, including a description of gaging procedure used; i.e., whether innage or outage.

(g) Shell plate height of each ring should be measured and recorded.

NOTE 10.—Where rings are lapped horizontally, the lap should be reported so that the inside height of the ring can be developed by the calculator.

Preparations for Circumferential Measurements

20. (a) The strapper should first determine where circumferential measurements are to be taken. A summary of elevations for circumference measurements on various types of upright cylindrical tanks is shown in Table II. Circumferential tape paths located at elevations shown in the appropriate illustration in Figs. 10 to 25 should be examined for obstructions and type of upright joints. Projections of dirt and scale should be removed along each path. Occasionally, some

feature of construction, such as a manway or insulation box, may make it impracticable to use a circumference elevation prescribed on the appropriate illustration. If the obstruction can be spanned by a step-over, then the circumference should be measured at the prescribed elevation, using a suitable procedure in Section 21. If the obstruction cannot be conveniently spanned by a step-over, then a substitute path, located nearer to the center of the ring, may be chosen. The strapping record should include the location of the substitute path and the reason for the departure.

(b) The type and characteristics of upright joints should be determined by close examination in order to establish the procedure of measurement and equipment required. In the case of butt-welded joints, or butt-strap or lap joints at which voids between tape and shell at the joints will be caused only by butt-strap or plate thickness, uniform at each joint, then

circumferences may be measured in accordance with the procedure described in Section 21(a) and (b), without the use of a step-over. In the case of butt-strap or lap joints in which voids at joints are not uniform because of interference by rivet heads or other features, then circumferences should be measured in accordance with the procedure described in Section 21(a) and (c), which incorporates the use of a step-over at each joint. In the case of flanged upright joints, circumference measurements should be made in accordance with the procedure described in Section 21(a) and (f), which incorporates the use of a step-over or special clamps.

(c) The amount of tension, in pounds, to be applied to the measuring tape in all cases should have been determined previously in accordance with the procedure described in Section 5(a) or (b).

TABLE II.—ELEVATIONS FOR CIRCUMFERENCE MEASUREMENTS ON VARIOUS TYPES OF UPRIGHT CYLINDRICAL TANKS.

Type of Tank Construction	Circumference Measurement Elevations	
	Operating Control	Critical Measurements
Welded Steel, One or More Rings	20 per cent down from top of exposed height of each of 3 lower rings, below circumferential weld on outer surface, and 20 per cent down from top of top ring, whether butt or lap joints.	20 per cent of exposed portion of each ring, whether butt or lap joints. ^a
Riveted Steel, Shingled Arrangement	0 per cent (exposed portion) on each of lower 4 rings, and 12 in. below top of top ring. ^a	0 per cent (exposed portion) on each ring and 12 in. below top of top ring. ^a
Riveted Steel, In-and-Out Arrangement	Lowest exposed portion above horizontal rivet rows on each of lower 4 rings and 12 in. below top of top ring. ^a	Lowest exposed portion above horizontal rivet rows on each ring, and 12 in. below top of top ring. ^a
Riveted Steel, Combination Shingled and In-and-Out Arrangement	Lowest exposed portion above horizontal rivet rows on each ring to and including first two shingled, and 12 in. below top of top ring. ^a	Lowest exposed portion above horizontal rivet rows on each ring, and 12 in. below top of top ring. ^a
Steel Tank One Ring High, Riveted Lap Joints	25 and 75 per cent above bottom of shell.	
Bolted Steel, Lapped Vertical Joints	25 and 75 per cent above bottom of each ring.	
Bolted Steel, Flanged Vertical Joints	75 per cent above bottom of each ring.	
Corrugated Steel	50 per cent of each ring, in valley.	
Wooden Stave, Plain Tapered	0 ft 6 in. above inside bottom surface and at 2 ft 0 in. intervals thereafter.	
Wooden Stave, Barrel Shape	0 ft 6 in. above inside bottom surface and at 1 ft 0 in. intervals thereafter.	

^a When bottom angle is welded, take lowermost circumference 12 in. above bottom of bottom ring. Where tank shells are of composite construction, take measurements in accordance with instructions above for each type of construction.

^b For one-ring tanks, two circumferential measurements shall be taken at 20 per cent and 80 per cent down from the top of the ring. For tanks of more than one ring, if obstructions block the tape path at the 20 per cent down plane, the measurement may be taken at a point 80 per cent down. If circumference measurements taken on successive rings indicate unusual variations or distortions, sufficient additional measurements should be taken to satisfy the requirements of all concerned.

Circumferential Measurements

21. (a) For the measurements described in Paragraphs (b), (c), (d), or (e), a circumference tape of sufficient length to encircle the tank completely should be used, in which case measurement of total circumference with one reading should be taken. In the event that the tank circumference is too great to be completely encircled by the tape, increments of circumference measurement should be read and recorded to the nearest 0.005 ft. For the measurements described in Paragraph (f), where the length of circumferential path to be measured at any one time is limited to the distance between extremities of the spanning instrument in adjacent locations, any approved tape, with either of the two types of graduations described in Section 5(b), may be used. In all cases, the tape to be used should be applied to the tank surface, at the prescribed elevations, by the continuous wraparound procedure, as described in Section 5(b). All points at which circumferential readings (Note 11) are taken should be located at least 2 ft from an upright joint. After a circumferential measurement reading has been taken, the tension should be reduced sufficiently to permit the tape to be shifted. It should then be returned to position and required tension and another reading taken. This procedure should be repeated until two equal readings have been obtained. The equal readings should be recorded as the circumferential measurement at that location.

NOTE 11.—The word “reading” is used in this paragraph for convenience and is not intended to indicate a difference in meaning from the word “estimate” used in the procedures described in Paragraphs (d) and (e).

(b) Butt-welded joints at which there is no void between tape and tank shell, or butt-strap or lap joints at which void between tape and tank shell is uniform at all joints: When the circumference measuring tape is in contact with the tank surface at all points along its path, circumference measurements should be made and checked in accordance with Paragraph (a). The checked measurements should be recorded as final measurements. When butt-strap or lap joints cause uniform voids between tape and tank shell at each joint, circumference measurements should be made in accordance with Paragraph (a). Measure and record the width and thickness of butt straps, and record the number of butt straps in each ring. In

the case of lapped joints, measure and record the thickness of exposed lapped plate, Fig. 5, at at least three joints in each ring about the circumference, and record the number of such joints in each ring. The measured circumferences, properly checked and recorded, should be corrected later for tape rise as described in Part II, Section 52(c) or (d).

(c) When butt-strap or lap joints, or tank shell, include rivets or other features which exert uneven effects on the resultant void between the tape and tank, from joint to joint, then a step-over will be required. The span of the instrument should be measured prior to use in accordance with Section 6(i), Item (5). The

step-over must be of sturdy construction, either adjustable or fixed in spread, but an adjustable step-over is preferable. The two legs must be separated by a distance sufficient to span each void encountered between tape and shell. The legs must be of sufficient length to prevent contact between the interconnecting member and the tank plate or obstruction. The manner in which the step-over may be used is related to the type of measuring tape used; i.e., whether the tape is graduated in hundredths of a foot throughout its length [see Paragraph (d)] or in feet only, with an extra 1-ft length at the zero end graduated in tenths and hundredths of a foot [see Paragraph (e)].

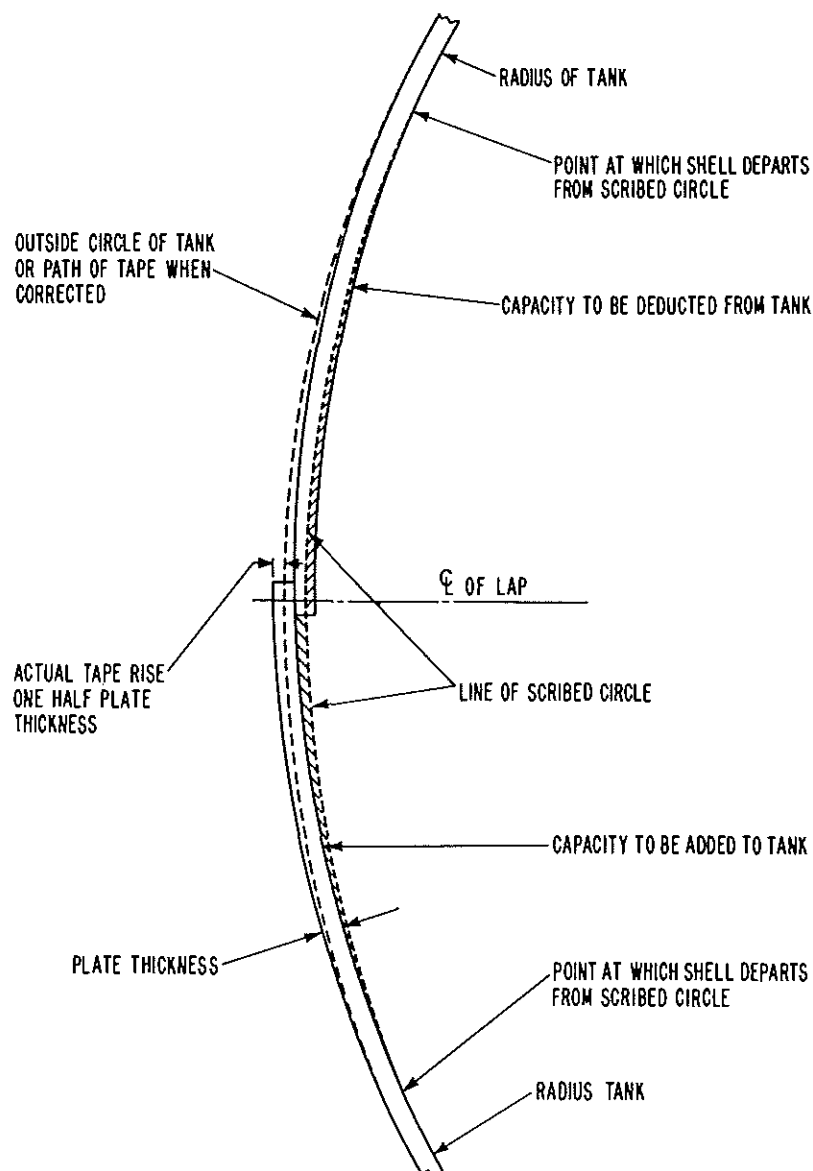


FIG. 5.—TRUE CIRCUMFERENCE versus TAPE PATH AT AXIAL LAP JOINT AWAY FROM CIRCUMFERENTIAL JOINT.

TABLE III.—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, Gaging									
Type of Roof:, Weight of Floating Roof:									
Tank Contents—Name:, Avg. Liquid Temp., °F:									
Gage: ... ft. ... in.; Innage to: Shelf ☐ Floor ☐ or Outage ☐									
Hydrometer Reading: at °F Sample Temperature									
Gaging Reference Point to Top of Top Angle: ft. in.; Normal Service:									
Shell Circumferences: ^a									
A	D	G							
B	E	H							
C	F	J							
Descriptions of Shell Plates and Joints: ^b									
	Ring No.	Thick- ness	Type of Vertical Joint	Set, in or out	Width of Lap or Strap	Thick- ness of Lap or Strap	No. of Joints	Ex- posed Ring Height	Inside Ring Height
	7								
	6								
	5								
	4								
	3								
	2								
(Btm. Ring)	1								
Shell Connections: ^c									
No.	Description	Elevation—Top of Floor to Bottom of Connection							
1	.....	.....							
2	.....	.....							
3	.....	.....							
4	.....	.....							
5	.....	.....							
6	.....	.....							
Amount of Tank Lean from Vertical: ^d 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.):									
.....									
.....									

^a Length measurements are recorded as values taken with a tape of length based on 68 F calibration. Each value thus recorded shall be mathematically corrected to the equivalent 60 F value for use in computing gage tables.

^b Show sketches of vertical and horizontal joints on back of this Table.

^c Show circumferential location on plan view sketched on back of this Table.

^d Show direction of lean on plan view sketched on back of this Table.

TABLE IV.—SUGGESTED RECORD FORM "B" FOR MEASUREMENTS OF UPRIGHT CYLINDRICAL TANKS.

[illegible]

^a Length measurements are recorded as values taken with a tape of length based on 68 F calibration. Each value thus recorded shall be mathematically corrected to the equivalent 60 F value for use in computing gage tables.

OWNER _____
 LEASE _____
 LOCATION _____
 MEASURED BY _____
 DATE _____ EFFECTIVE DATE _____
 TANK NUMBER _____

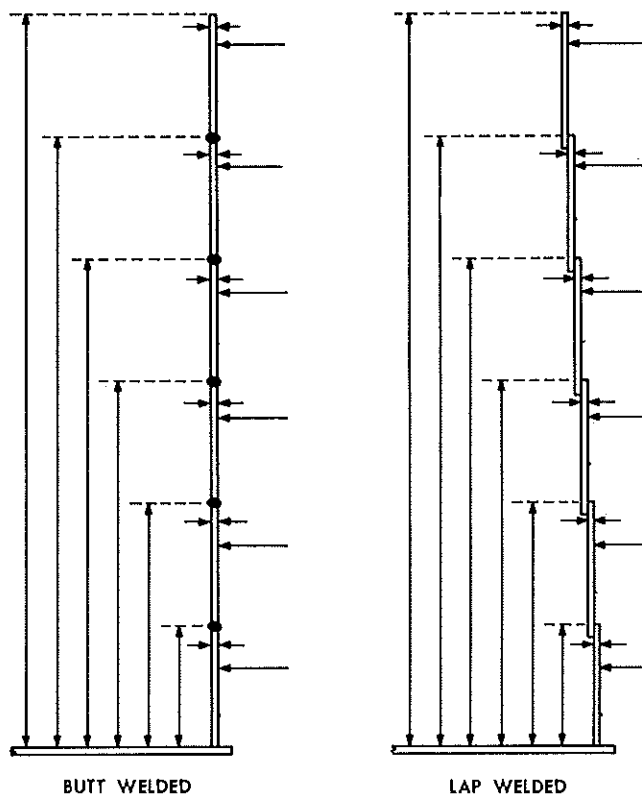
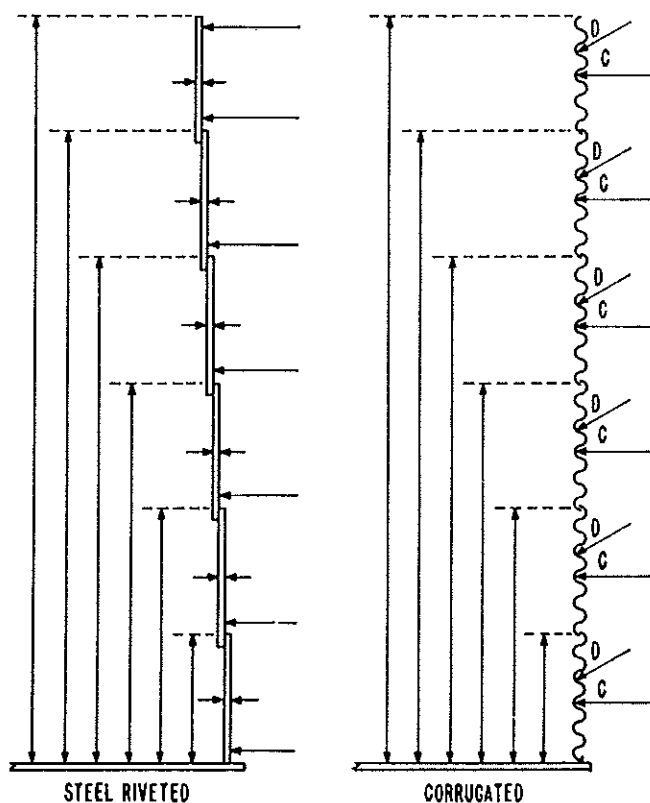


FIG. 6.—EXAMPLE OF RECORD FORM FOR MEASUREMENT OF UPRIGHT TANK SHELL, BUTT- AND LAP-WELDED.

OWNER _____
 LEASE _____
 LOCATION _____
 MEASURED BY _____
 DATE _____ EFFECTIVE DATE _____
 TANK NUMBER _____



D = measured depth of valley.
 C = circumference measurement.

FIG. 8.—EXAMPLE OF RECORD FORM FOR MEASUREMENT OF UPRIGHT TANK SHELL, RIVETED AND CORRUGATED.