Measurement and Calibration of Tank Cars

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FOREWORD

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Suggested revisions are invited and should be submitted to the director of the Measurement Coordination Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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Standard Method for

MEASUREMENT AND CALIBRATION OF TANK CARS[1]

API Standard: 2554

ASTM Designation: D 1409 - 65

ADOPTED, 1965.[2, 3]

This standard of the American Petroleum Institute issued under the fixed designation API 2554 is also a standard of the American Society for Testing and Materials issued under the fixed designation D 1409; 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 tank cars. It is presented in two parts: Part I (Sections 2 to 21) outlines procedures for nonpressure-type tank cars; Part II (Sections 22 to 31) outlines procedures for pressure-type tank cars.

NOTE 1.—Other calibration standards are:
API Standard 2550—ASTM D 1220: Measurement and Calibration of Upright Cylindrical Tanks
API Standard 2551—ASTM D 1410: Measurement and Calibration of Horizontal Tanks
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 2555—ASTM D 1406: Liquid Calibration of Tanks

PART I. PROCEDURE FOR CALIBRATING NONPRESSURE TANK CARS

General

2. (*a*) The volume capacity of tank car tanks shall be determined in one of the three followings ways:

(*1*) By filling the tank with a quantity of water measured by discharge from calibrated tank or tanks (water gage plant procedure).

(*2*) By filling the tank with water and weighing the car before and after filling (water-weighing procedure).

(*3*) By computing the volume from external measurements of the tank and deducting for the thickness of walls, laps, etc. ("strapping" procedure).

(*b*) Since 1951 the volume of all new tank cars should have been determined by the water gage plant procedure.

(*c*) With reference to the use of the three different procedures for calibration, it has been realized that there should be some further clarification with regard to the relation of these three procedures. This has been expressed as follows:

(*1*) The water gage plant procedure is recommended as the most accurate.

(*2*) Where facilities are not available for the use of the water gage plant procedure, an acceptable alternative is the water-weighing procedure used for all types of tank cars, and the strapping procedure used for only nonpressure or noninsulated tank cars.

(*d*) The calibration procedures outlined herein require that the interior surface of the tank be clean and free from any foreign substance such as the residue of commodities adhering to the bottom and sides of the tank—dirt, rust, and the like. Examination and inspection of a tank car may indicate the need for thorough cleaning if the correct established capacity is to be assured.

(*e*) Tank cars modified or damaged to the extent that the capacity is changed should be recalibrated; and the new capacity should be reported in accordance with instructions in *Freight Tariff No. 300*, latest issue and supplements thereto, issued under ICC authority for United States, Canadian, and Mexican railroads.

WATER GAGE PLANT PROCEDURE

Design and Construction of Gage Plants

3. (*a*) The gage plant (see Fig. 1) shall consist of one or more elevated tanks

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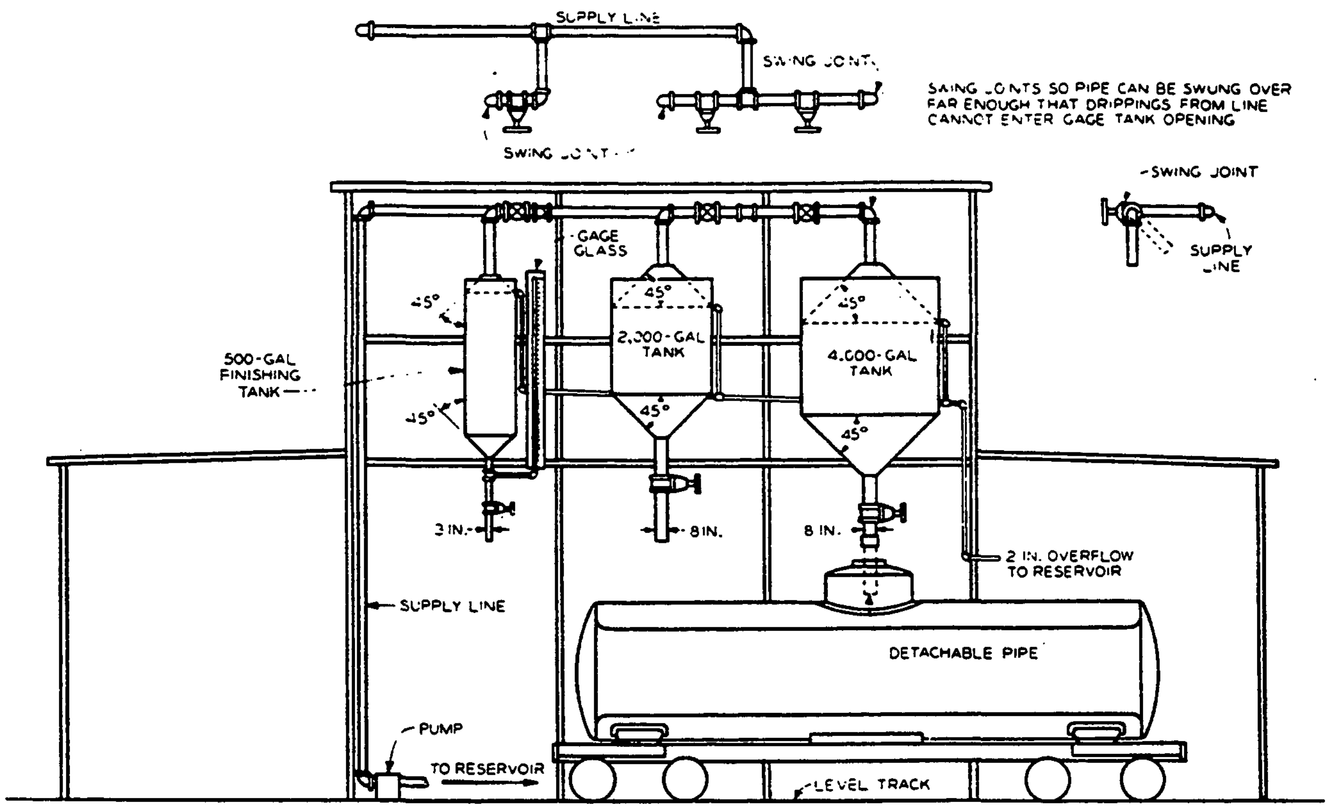
[1] Under the standardization procedures of the API and the ASTM, this standard is under the jurisdiction of the API Central Committee on Petroleum Measurement and the ASTM Committee D-2 on Petroleum Products and Lubricants.

[2] The API method was adopted as API Standard 2554 in October, 1965.

Prior to their present publication, the API methods of test were issued as API Code 1201 and API Code 1202. API Code 1201 was issued as tentative in July, 1948; it was revised and reissued in January, 1957 as API Standard 1201. API Code 1202 was issued as tentative in December, 1951; it was revised and reissued in February, 1960 as API Standard 1202.

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



NOTE.—Any and all delivery pipes to the car must have a slope of not less than 2 in. per foot to insure proper and rapid drainage. It is preferred to have a direct discharge pipe from the finishing tank to the car. However, the discharge pipes may be manifolded to avoid movement of car during casing.

FIG. 1.—TYPICAL LAYOUT OF WATER GAGE PLANT

of convenient size, and shall be used for water gaging tank car tanks. In addition to the main tank or tanks, there shall be a finishing tank equipped with an external gage glass throughout its length and so connected that the water level in the glass shall conform to the water level in the tank. This finishing tank shall be of small diameter so that accurate readings are obtained when small quantities of water are withdrawn.

(*b*) The gage tanks shall have conical bottoms and tops—preferably inclined at an angle of 45 deg or greater from the horizontal—and shall be provided with drawoff valves at the bottom and suitable connections at the top for filling with water. The connections for filling the tank shall be provided with swing joints so that they may be moved away from the opening at the top of the tank. The water in the tank will then be completely separated from its source of supply. All connections shall be so placed that the water on the tank side of the valve will drain completely.

(*c*) The openings at the top of the gage tanks (which shall be just large enough to permit entrance for inspection of the tanks) shall be circular or elliptical in shape, have true and absolutely level edges, or be equipped with V-notches, so that, when filled to overflowing, the tanks shall necessarily contain a definite volume.

(*d*) The water shall be conveyed by gravity from the gage tanks to the car tank. The piping between the valve of the gage tank and the dome opening of the car tank shall be as short and direct as possible, and shall be inclined at an angle that will promote rapid and complete drainage.

(*e*) During gaging operations the gage tanks and the tank car tanks shall be housed to protect them from the sun and rain.

(*f*) A section of level track—preferably laid on concrete—on which a car may remain undisturbed for any desired length of time shall pass directly under or at the side of the gage tanks. The gage tanks shall be at such a height that water from them will drain directly into the car tank to be gaged. Suitable apparatus shall be installed to raise the water into the gage tanks.

(*g*) When desired, gage tanks may be equipped with suitable connections for filling from the bottom, in which case the valves in the supply line leading to the gage tanks shall be doubled and the nipples between the valves shall be equipped with a drain cock or bleeder. To ascertain that no water is leaking into or out of the supply line, the drain cock or bleeder shall be opened after the tank has been filled. When the gage tank is filled from the bottom, a downspout shall also be used which reaches to within a few inches of the bottom of the car tank to be gaged, so that the outlet is under the surface of the water after the first few seconds of filling. The piping between the valve of the gage tank and the end of the downspout shall be as short and direct as possible, and shall be inclined at an angle which will promote rapid and complete drainage.

CALIBRATION OF WATER GAGE PLANTS

Primary Measures

4. (*a*) As it is of the utmost importance that great care be exercised to obtain accurate capacities, the calibration of gage plants shall be done by men thoroughly versed in the theory and practice of such work. A small error is greatly multiplied in the final result, for the result is based upon the number of times a measure of small capacity (the exact capacity of which is known) can be filled from the gage tanks. This is determined by the use of a measure of 5- or 10-gal nominal capacity (hereinafter referred to as the "principal primary measure") which is made of such material or protected in such manner that it cannot easily be dented by accident and its capacity thereby changed. The measure shall be constructed in such a manner that it will drain readily toward a mouth at the top drawn into a small diameter. The measure shall be fitted with a cover so that it will hold and deliver, within very narrow limits, the same amount of water time after time. This shall be accomplished by grinding or machining the top of the measure at the mouth and sliding a glass disk over the opening. The fit shall be such that, when the disk is held in place tightly and the measure is tipped, water will not leak from the measure unless the glass is slid off the opening. Also, the fit shall be such that a definite amount of water is always held under the glass when the measure stands in an upright position. The measure shall be provided with a pouring spout, so that its contents may be transferred to another vessel without the loss of a drop.

(*b*) Another procedure for calibration is to employ a measure constructed with a narrow mouth, using a needle gage to determine the height of the liquid in the measure. The top of the measure shall be machined or ground off, if necessary, to insure accuracy.

(*c*) In all cases the capacities of primary measures used shall be certified by the U.S. Bureau of Standards, Washington, D.C. The certificates shall show the capacity, based on the number of gallons or milliliters the measure *holds or delivers* at 60 F after draining for 30 sec.

(*d*) All measures larger than primary shall be calibrated either by filling from or by emptying into the primary measures. In the former case, the primary measures shall be calibrated *to deliver;* in the latter case, they shall be calibrated either *to hold* or *to deliver*. If calibrated *to hold*, they shall be wiped dry with a cloth *each time used;* if calibrated *to deliver*, the measures shall be cleaned out frequently to remove any dirt or oil.

Intermediate Measures

5. (*a*) For the calibration of gage tanks, a cylindrical measure shall be used. This measure shall be of intermediate capacity of approximately 50 to 500 gal (hereinafter referred to as the "intermediate measure"). It shall have cone-shaped ends, terminating in a small neck at each end (see Fig. 2), it shall be equipped with a drawoff valve at the bottom, and it shall be provided with an overflow at the top. If the tank is of such construction that it cannot be inspected for accumulation of foreign matter, it shall be recalibrated frequently.

(*b*) When calibrating the intermediate measure, level it accurately; fill it with water; and then drain it, allowing 2 min for this operation; and close the valve. Fill the principal primary measure, taking approximately 2 min for the operation and using a soft flexible connection which may be inserted into the measure in such a way that, while filling, the end will be below the surface of the water. After the primary measure has been filled, remove hose, make up outage, and strike the measure gently with the flat of the hand around the sides and the top to release any bubbles. Slide the glass disk, *ground side down*, over the opening, observing whether or not any bubbles are visible through the glass. If so, slide the glass back part way, and with a small sponge add more water until no bubble can be

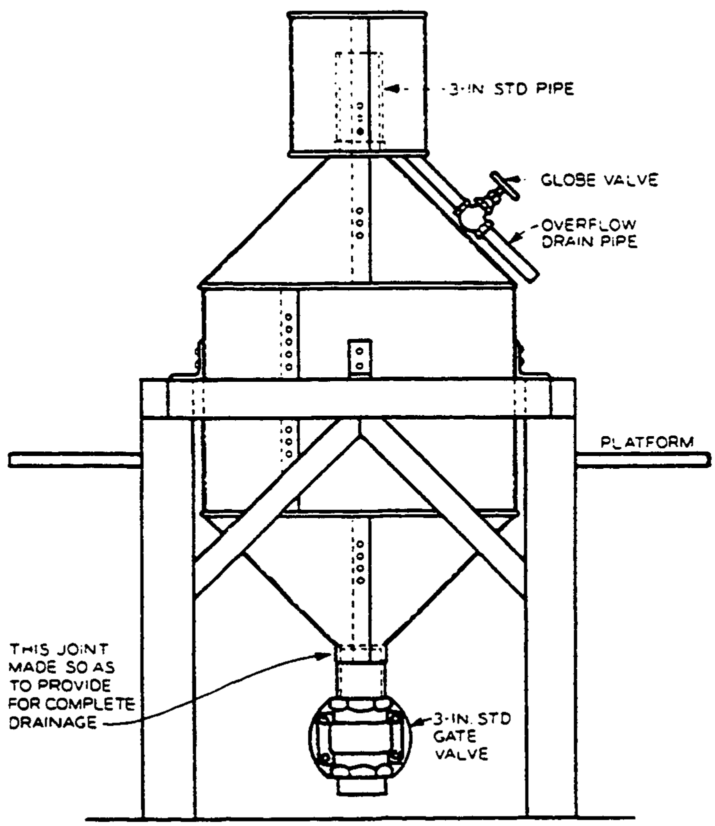


FIG. 2.—TYPICAL INTERMEDIATE MEASURE WITH SUPPORT.

seen. Hold the glass firmly in place, fully covering the opening, and with a small sponge take out all the water in the pouring lip. Thereupon, have an assistant carefully raise the measure to the proper position for pouring into the intermediate measure. The operator shall hold the glass firmly over the opening and, as the measure is being tilted to pour, he shall slide the disk off. While the contents of the principal primary measure are being poured into the intermediate measure, care shall be taken so that the primary measure is not allowed to rest against the intermediate measure—the primary measure shall be entirely supported in the hands of the assistant so as to avoid denting. It shall be emptied very slowly into the intermediate measure to avoid entrapping air, and shall be allowed to drain for 30 sec after each emptying.

(*c*) After the principal primary measure has been emptied into the intermediate measure a sufficient number of times so that the intermediate measure will not again hold the full contents of the primary measure, the shortage shall be made up by pouring an additional amount from one or more of the smaller containers, the capacity of which has been certified by the U.S. Bureau of Standards.

(*d*) After the intermediate measure has been filled with the aid of the smaller containers, total the number of milliliters in the small amounts which have been added; then divide by 3,785, the number of milliliters in the U.S. standard gallon. This quantity, added to the quantity poured in by means of the principal primary measure, gives the total capacity. The temperature of the water used must approximate 60 F; if a temperature change occurs during calibration, appropriate correction should be made.

(*e*) A delivery pipette is convenient for the removal of any excess liquid when a desired mark on a small container or graduate is overrun.

(*f*) If a primary measure with needle gage is used, the intermediate measure shall first be filled with water to the predetermined point; then the water shall be drained slowly into the principal primary measure to a point where the liquid just touches the needle gage. If this procedure is employed, the principal primary measure shall be calibrated preferably *to hold* rather than *to deliver*. If surplus water is drained into the principal primary measure, it shall be removed with a pipette—the accumulations of surplus liquid being measured after the intermediate measure has been drained. The quantity so measured shall be added to that measured in the principal primary measure.

(*g*) For the purpose of obtaining constant results, as well as for the purpose of ascertaining the average of calibrations used in determining the capacity of the gage tanks, the intermediate measure shall be calibrated at least three times—more, if necessary.

(*h*) When calibrating intermediate measures or gage tanks, the work shall be discontinued if the atmospheric conditions cause "sweating" or condensation on the outside or inside of the vessels being calibrated.

(*i*) After the exact capacity of the intermediate measure has been determined, the measure shall be placed under the measuring tank to be calibrated and carefully leveled. It is expedient to fasten to the sides of the measure lugs which can be made to rest on a stout wooden support or table of such height that the valves underneath the measure can be conveniently handled.

Procedure for Calibrating Gage Tanks

6. (*a*) A plug or reducer, of such design that no water can be entrapped in it, shall be connected to the outlet of the gage tank below its valve, the plug being tapped for approximately a 1-in. pipe. The operator shall then make certain that the inside of the tank to be gaged is clean and free from rust. Thereupon the discharge valve on the gage tank shall be closed, the supply valves opened, and the tank filled with water. It is important that water used for calibration be clean and clear. If the water is used repeatedly, it is well to treat it with a rust inhibitor. The valves of the gage tank shall then be examined to make certain that they are in good condition and that they do not leak. If a leak is found, the valves shall be repaired before proceeding.

(*b*) The 1-in. pipe shall then be screwed into the plug at the bottom of the tank; it shall be run down to a 1-in. valve which is placed in such a position that the operator can readily examine the inside of the intermediate measure and at the same time, by means of this valve, regulate the flow of the water into the top of the measure. To insure tightness and ease of operation, the 1-in. valve shall be tested before it is applied. The valve should close tightly without effort. To bring the operator to the proper height for conveniently inspecting the water in the intermediate measure, a platform shall be built around the measure.

(*c*) The piping having been installed and the gage tank having been filled with water, the intermediate measure shall be carefully examined to see that the interior is perfectly clean. It shall then be filled and emptied to wet the interior surfaces and allowed to drain for at least 2 min, whereupon the discharge valve at the bottom shall be closed. This "drainage period," once having been determined, shall be used at all times in connection with the operation of the gage plant.

(*d*) The gage tank shall then be inspected to see that it is filled to overflowing and that no more water can be added.

(*e*) The large valve of the gage tank shall next be opened *slowly*. If opened too quickly, an air bubble large enough to carry considerable water over the edge of the top of the tank may result. The supply pipe to the intermediate measure is thus filled from the gage tank. The supply valve shall then be opened and the intermediate measure filled. Care should be taken to see that no leakage occurs from the discharge valve at the bottom. The flow to the intermediate measure shall be regulated by the 1-in. valve—the water flowing very slowly as the level approaches the top. It is possible to regulate the valve in such a manner that but little more water will be released than the amount actually required to fill the intermediate measure. If too much water is released, the excess will, of course, be caught in the overflow and eventually measured.

(*f*) After the intermediate measure has been filled with water, it shall be allowed to settle 2 min to allow air to escape. Shortage due to settling shall be made up, the measure being filled to gage or overflowing. The intermediate measure shall then be emptied and drained for at least 2 min. This procedure shall be repeated, and a tally shall be kept of the number of times it is possible to fill the intermediate measure from the gage tank. When the gage tank is empty, the last intermediate measure may be partially filled—all water from the gage tank having been drained into the intermediate measure. The water in the overflow shall also be drained and poured into the intermediate measure. The intermediate measure shall then be filled with water (but not from the gage tank) by means of the principal primary measure and graduates. The gallonage added by means of the principal primary measure and graduates, not having come from the gage tank, shall be subtracted from the capacity of the intermediate measure; the difference, added to the gallonage obtained by the number of times the intermediate measure is filled, shall determine the capacity of the gage tank. The gage tank shall be calibrated at least three times, or as many additional times as shall be necessary to secure uniform results. The average of these results shall be the capacity used when gaging tank cars.

(*g*) All the gage tanks of the gage plant, including the small finishing tank, shall be calibrated by the foregoing procedure.

Procedure for Calibrating Finishing Tanks

7. (*a*) The finishing tank shall then be calibrated to show the number of gallons that it holds at any height. This tank shall be equipped with an external gage glass, behind which a suitable gage board shall be placed in a vertical position and securely fastened to prevent shifting. In order accurately to read the gage board, the use of a carpenter's small try-square is recommended; thus the line of vision will be in the same horizontal plane as the bottom of the meniscus. First to be marked on the gage board shall be the height of the water in the gage glass when the tank is full. The finishing tank shall be equipped with a plug with a 1-in. pipe and a 1-in. valve (the same as in the case of the calibration of the gage tank). A number of gallons of water shall be withdrawn into the principal primary measure, and the height again marked on the board. This procedure shall be repeated—the height of the water in the gage glass being marked on the board each time the same quantity of water is withdrawn—until the entire length of the tank has been calibrated. Before this calibration is started, the finishing tank shall be full; likewise, the pipe leading from the tank to the 1-in. valve (by which the operator regulates the flow of water) shall be full. Furthermore, if the principal primary measure does not hold the required gallonage, correction shall be made by means of a 25-ml measure, in order that the same gallonage will be withdrawn each time.

(*b*) Inasmuch as considerable time is consumed in calibrating the tank—due to the fact that definitely prescribed quantities are drawn off—the temperature of the water in the gage glass, especially in warm weather, may vary considerably with the temperature of the water in the main body of the finishing tank. These temperatures, therefore, shall be carefully checked. If the temperature of the water in the gage glass is higher or lower than that in the finishing tank, in order to equalize the temperature and to prevent errors in marking, water from the main body of the finishing tank shall be poured into the gage glass to displace the water in the glass. No new water shall be added to the finishing tank for this purpose; it is sufficient that a circulation of water in the gage glass shall be effected.

(*c*) When the operator is satisfied that the marks on the gage board are properly placed, the marks shall be deepened and the number of gallons of outage in the tank that each mark represents shall be stencilled on the board. Preferably, the scale on the gage board should be in gallons, rather than in inches. Closer readings can be made by interpolation and by the use of the try-square. With the gallonage of the principal primary measure definitely established on the board, the filling tank shall be refilled and the water shall be drained off in single gallons. The board shall be calibrated to show the height of the water in the finishing tank for each gallon. This can be done rather quickly, since the 5- or 10-gal marks are on the board; and the liquid level may be adjusted, if necessary, at each of these marks to avoid any cumulative error.

Check Gage Plant

8. After the gage plant has been calibrated, as outlined in Sections 4 to 7, it should be checked, if possible, by tank cars which have been gaged at other gaging plants whose accuracy has been established.

Procedure for Calibrating Single-Compartment [4] Tank Car Tanks

9. (*a*) In hot weather tank car tanks shall be cooled by spraying the outside with water before gaging.

(*b*) The capacity of the car to be gaged shall be determined as it stands on a level track. Before gaging commences, it is important that the gage track be checked to ascertain that it is level.

(*c*) The inside of the tank shall be examined for the purpose of removing any foreign substances, such as dirt, rust, etc. The outlet valve shall be thoroughly cleaned and put in good condition. All measuring tanks shall be examined to make certain that they are perfectly clean. A check shall be made to ascertain that the scale behind the gage glass on the finishing tank is tight and in its proper position. The gagers shall make certain that the water used is clean. When measuring tanks become nearly empty, they shall be watched for sediment. If any sediment is present, the water shall be stirred thoroughly to carry it away. The operator shall examine all valves on the measuring tanks to see that none are leaking. If any of the valves leak, they shall be repaired or renewed.

(*d*) Each gage tank shall be separately drained into the car tank, 5 min being allowed for draining after the tanks have become empty.

(*e*) When water is first emptied into the car tank, the outlet valve shall be examined; if it leaks more than 20 drops per minute, the water shall be drained from the car tank and the valve repaired before proceeding. A pail shall be placed under the valve in such a position that it will catch any leakage. Throughout the operation the outlet valve shall be watched carefully to see that leakage does not become excessive. If preferred, the valve cap may be screwed on (a tight gasket being used). However, if this is done, the outlet leg should be filled with water and the valve closed. Any surplus water left in the car from this operation should be removed by wiping.

(*f*) Repeat the filling and emptying of measuring tanks until the car tank is nearly full. In order to avoid error or duplication in tallying the number of measuring tanks emptied into the car tank, a record shall be made immediately after the valve from the measuring tank has been closed. When the car tank is nearly full, gaging shall be completed by the use

[4] This same procedure is applicable to multiple-compartment tank cars by considering each compartment individually as a single-compartment tank.

of the finishing tank. A straightedge shall be fastened across the manway opening in the shell of the car tank so that it is level with the inside of the shell at its highest point. When the water begins to trickle over the center of the straightedge, the tank is full.

(*g*) The finishing tank shall be completely filled each time, rather than filled to a point that is marked on the gage board.

(*h*) The last 100 gal shall not be permitted to run into the car tank faster than at the rate of 10 gpm.

(*i*) Just before the car tank becomes full, any leakage from the outlet valve shall be poured back into the tank, inasmuch as this water has already been measured.

(*j*) After the car tank has been filled, allow 15 min for settling to displace the air and fill to the top of straightedge if outage shows, care being taken to include any water that may have leaked from the outlet valve. The capacity of the tank shell shall be determined by taking the total number of gallons which have been emptied from the measuring tanks into the car tank, plus the final reading of the gage on the finishing tank.

(*k*) The capacity of the dome shall then be determined by the use of the finishing tank.

(*l*) Throughout tank car tank gaging operations, the gager shall make all important readings personally and check, as far as possible, all other readings. He shall take every possible precaution to insure accurate results, and shall impress upon his assistants the importance of avoiding haste which may result in inaccuracies.

ENTIRE OUTAGE TABLE

General

10. To provide an entire outage table, one car of each class shall be water gaged to show the volume held for each ½-in. increment from the bottom to the top of the tank. This work shall be done with extreme accuracy; and the table obtained, by the procedure discussed in Section 2, shall be used in determining the outage table for the class of cars represented by the tank gaged.

Procedure for Obtaining Outage Table

11. (*a*) Tank must be thoroughly cleaned inside.

(*b*) Tank to be gaged must be placed in the shelter of the gage plant after making sure that track is level, both for length and width of car. The location at which the car is placed within the gage plant shall be such that the water from the finishing tank shall drain directly into the tank to be gaged.

(*c*) The tank shall be leveled by means of wedges under the side bearings so that the bottom sheet on the inside of the tank is level longitudinally. The tank shall be leveled laterally by adjusting wedges at the side bearings so that the bob of a plumb line, when suspended from the center of the dome ring, rests on the longitudinal centerline of the bottom sheet.

(*d*) Unscrew the standard valve cap from the tank and replace with a cap having a ¾-in. union connection.

(*e*) Apply a bracket to the running board on which to support a gage glass and apply an adjustable connection to join the ¾-in. union on the valve cap to the bottom of the gage glass.

(*f*) Plumb the gage glass and clamp bracket solidly so that gage glass is supported in the plumb position.

(*g*) Fill the outlet nozzle and piping until the water reaches the top of the bottom sheet on the inside of the tank.

(*h*) Apply a steel scale to bracket adjacent to gage glass, locating the zero point on the scale at the level of the bottom of meniscus of the water in the glass at the top of the bottom sheet level.

(*i*) The steel scale shall be clamped securely in position to prevent any change in its position relative to the gage glass.

(*j*) Do not gage tanks on windy days nor in freezing weather.

(*k*) Use only clean water at a temperature as near 60 F as practicable.

(*l*) When gaging operations have started, they shall be continued until the entire tank has been gaged. If gaging continues longer than one day, the water shall be emptied from the tank each night and refilled the next day to the level where gaging was discontinued the night before.

(*m*) Fill the finishing tank in the gage plant with water and allow it to settle 5 min to free the water from air and make up the outage, if any. Allow enough water to pass from the finishing tank to the car tank to raise the water level in the gage glass to within a fraction of the first ½ in., and close the gage tank valve. Allow the water to settle and become calm, after which add additional small quantities until the first ½ in. is reached. Allow the water to settle and become calm.

(*n*) Check to see that the water in the gage glass is exactly on the ½-in. mark on the scale.

NOTE 2.—*Important:* Take each reading in gage glass with the eye on the level of the bottom of the water curve on meniscus.

(*o*) Read the glass on the finishing gage tank and record the gallonage conveyed to the car tank for the first ½ in.

(*p*) Repeat the operation for the second ½ in., third ½ in., etc.

(*q*) When nearing the top of the tank, apply a straightedge to the highest point on the inside of the tank shell.

(*r*) The last reading is to be taken when the water is at the top of the straightedge and is about to trickle over.

(*s*) Measure the inside of the tank with the scale and check with reading on the glass.

(*t*) Draw off the water in the outside gage glass occasionally, and pour it back into the tank. Keep the outside gage glass shaded from the sun to maintain the same temperature in the glass as in the tank. Also be sure that water in the gage glass of the finishing tank is circulated from time to time so that the temperature of the water in the glass is the same as the temperature of the water in the gage tank.

(*u*) After the water is emptied from the car tank, the car tank must again be leveled; if it is found that the level of the tank has changed during the gaging operation, the tank shall be leveled again and regaged.

WATER-WEIGHING PROCEDURE

General

12. Scales must be sensitive in order to respond quickly and accurately to small changes in weight. They should be checked at regular periods and, if necessary, they should be adjusted to meet check weights. The car weight must also be carefully checked and verified at three stages: (*1*) empty (dry); (*2*) tank shell filled with water; and (*3*) tank shell, including dome, filled with water.

Definitions

13. (*a*) *Tare Weight* is the weight of tank underframe and trucks (i.e., weight of car with empty, dry tank).

(*b*) *Gross Weight* is the combined weight of the underframe and trucks and the tank and dome filled with water.

(*c*) *Gross Weight, Tank Shell Full,* is the weight of the car with the tank shell —but not including the dome—filled with water.

(*d*) *Net Weights* are the difference between gross weights and tare weight. Please note that the term *"net weights"* is used because two different *"gross weights"* are possible [see Paragraphs (*b*) and (*c*)].

(*e*) *Corrected Net Weights* are net weights adjusted to density at 60 F, using the correction factor from Table VIII (Appendix).

Procedure

14. (*a*) Examine the inside of the tank shell for the purpose of removing any foreign substance, such as dirt, rust, etc., then weigh the car with the tank empty. This is the tare weight. (Wedges, if used to steady the car when filled, should also be used on empty weight to insure that net weight includes only the water in the tank.)

(*b*) After the tare weight is established, fill the tank shell with water. The last 100 gal shall be at a slow flow rate, not exceeding 10 gpm. Then allow the car to stand for 15 min to permit settling and escape of air in water. Following this, water should be added to bring the level to the inside of the top of the tank shell. The car shall then be weighed and the weight recorded. This is the gross weight, tank shell full.

(*c*) Following the weighing of the car with the tank shell full of water: (*1*) when the safety valve is on top of the dome, fill with water to the inside top of the dome; or (*2*) when the safety valve is on the side of the dome, fill to the top of the safety valve opening. This is the gross weight.

(*d*) Take the temperature of the water at approximately the vertical center of the tank.

NOTE 3.—For details relative to procedures, equipment and inspection, and testing of equipment, see *API Standard 2543—ASTM D 1086: Measuring the Temperature of Petroleum and Petroleum Products.*

(*e*) Obtain the net weights by subtracting the tare weight from the gross weights. Multiply net weight by correction factor to obtain corrected net weight for water at 60 F. The weight of one gallon of water in air at 60 F is equal to 8.328247 lb, established by the U. S. Bureau of Standards. Corrected net weight divided by 8.328247 equals gallons capacity for the tank shell or for the tank and dome. The dome capacity can be determined by deducting the calculated capacity of the tank shell from the calculated capacity of the tank and dome.

CALIBRATING SINGLE-COMPARTMENT TANK CAR TANKS BY EXTERNAL STRAPPING PROCEDURE

Equipment

15. (*a*) *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 1/64 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.

NOTE 4.—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 202.404—Steel Tapes.* The additional data indicated in Section 15(*a*), 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.

(*b*) *Steel Rulers:*

(*1*) The rulers used in making measurements, except for plate thicknesses, shall be of steel and of such thickness as to insure that they will not bend in ordinary use. The rulers shall be graduated in feet, and in tenths and hundredths of a foot.

(*2*) Plate thicknesses shall be measured with a suitable depth gage having graduations to 1/64 in. (0.0013 ft).

(*c*) *Straightedge:*

(*1*) The straightedge used in making measurements at the heads of tanks shall be of wood or other suitable material of sufficient width and thickness to maintain a substantially straight edge when held flat in a horizontal position and supported only at its ends. The length of the straightedge should be at least 12 in. greater than the diameter of the tank on which it is to be used. A small notch shall be cut in the middle of the straightedge so that the rivet in the head of the tank will not hold the straightedge away from the spherical plate.

(*2*) A straightedge provided with a pair of sliding blocks or wedges, which can be used in conjunction with graduated scales on the straightedge, may be used to estimate the radius of the outside surface of the spherical head. A procedure for graduating the straightedge is illustrated in Fig. 3. Data for graduating a straightedge equipped with blocks having a projection of 0.400 ft are presented in Table I.

Measuring Procedure

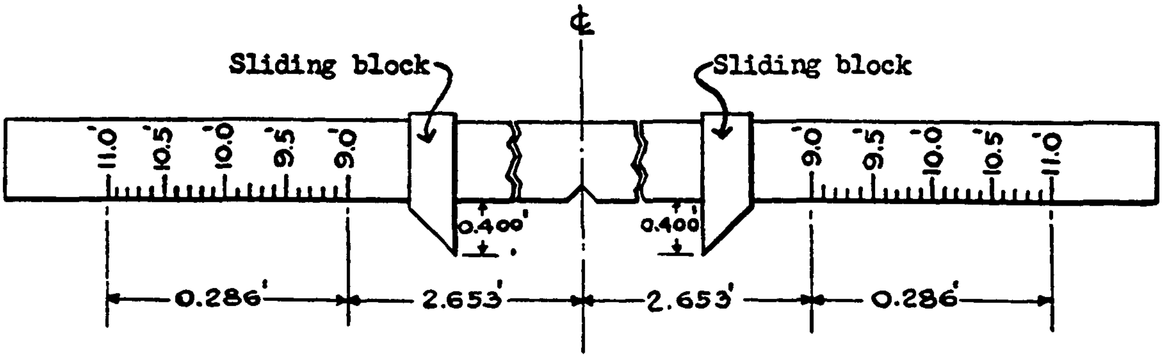
16. (*a*) All readings except thicknesses shall be made to the nearest 0.005 ft; thickness measurements shall be made to the nearest 1/64 in. (0.0013 ft).

(*b*) Determine the average overall circumference of the main cylinder (dimension C_m):

(*1*) If the tank is constructed of a bottom sheet and two longitudinal top sheets, at least four measurements of the circumference shall be made on each tank. When only four are made, they shall be taken as nearly as possible at 1/8, 3/8, 5/8, and 7/8 points of the length of the tank.

TABLE I.—GRADUATIONS FOR STRAIGHTEDGE.

Distance to Graduation, ft	Head Radius Graduation, ft	Distance to Graduation, ft	Head Radius Graduation, ft
2.653	9.0	2.80	10.0
2.668	9.1	2.814	10.1
2.683	9.2	2.828	10.2
2.698	9.3	2.843	10.3
2.713	9.4	2.857	10.4
2.728	9.5	2.871	10.5
2.742	9.6	2.884	10.6
2.757	9.7	2.898	10.7
2.771	9.8	2.812	10.8
2.786	9.9	2.926	10.9



NOTE.—Table I gives data for graduating a straightedge equipped with blocks having a projection of 0.400 ft.

FIG. 3.—STRAIGHTEDGE WITH SLIDES AND GRADUATIONS FOR ESTIMATING RADIUS OF TANK HEADS.

(*2*) If the tank is constructed of a bottom sheet and several top rings, or of a number of complete rings, at least one circumference shall be determined for each ring. If only one circumference is determined, it shall be measured as nearly as possible to the middle of each ring. If two are taken, they shall be made as nearly as possible at the ⅓ and ⅔ points of each ring.

(*3*) Since a circumference cannot be measured at the middle of the ring where the dome is located, at least one measurement on each side of the dome shall be made of that ring.

(*c*) Establish reference points X at ends of main cylinder:

(*1*) After determining the width of the circumferential lap between the main cylinder and the head cylinder (rivet row spacing plus twice the width of the calking edge), mark in clear and unmistakable manner four reference points, two at each end of the car on opposite sides as shown in Fig. 4.

(*d*) Determine average length of main cylinder (dimension L_m):

(*1*) If the tank is constructed of a bottom sheet and two longitudinal top sheets, measure the distances between reference points X on both sides of the tank. The average of these measurements shall be taken as the length of the main cylinder.

(*2*) If the tank is constructed of a bottom sheet and several top rings or a number of complete rings, reference points shall be established along both sides of the tank on the outside of the overlapped rings opposite the calking edges of the underlapped rings (see Fig. 4). After these points are established, the net inside widths of the several rings shall be measured. The sum of these partial lengths of the main cylinder must be equal to the overall length as measured between the reference points X at the heads of the car.

(*e*) Determine the average overall projection of each head from the reference points X (dimensions P_a and P_b):

(*1*) With a suitable straightedge held against the center of the head, and two rulers held perpendicular to its edge and opposite the reference points, measure the overall projection of the head (length of head cylinder, plus depth of head, plus thickness of head); see Fig. 4.

NOTE 5.—The straightedge should be held so that it is tangent to the tank head at its center.

(*f*) Determine the outside radius of each tank head (dimensions R_a and R_b):

(*1*) The tank head radius may be ascertained by measuring—with the straightedge perpendicular to the axis of the tank—the distance to the tank head from the inside of the straightedge at two points on the straightedge equidistant from the tank center. Report the average of the depth measurements as outside depth of arc, and the distance between the two points on straightedge as chord at that depth. From these measurements, outside radius of head may be computed.

NOTE 6.—These measurements should be checked with the straightedge in an approximately horizontal position and in an approximately vertical position, plus a measurement at approximately 45 deg on either side of the vertical, taking care not to measure at points where tank head may be dented. The average of the depths so measured shall be reported. To avoid the knuckle curvature of the head, these measurements shall not be taken nearer than 1 ft from the edge of the head.

(*2*) The tank head radius may also be ascertained by use of a straightedge equipped with sliding blocks, as illustrated in Fig. 3.

NOTE 7.—The head at the end of the car, where the hand brake wheel is located, shall be designated as head *B—B* for "brake."

(*g*) Determine theoretical length of each head cylinder (dimensions L_a and L_b):

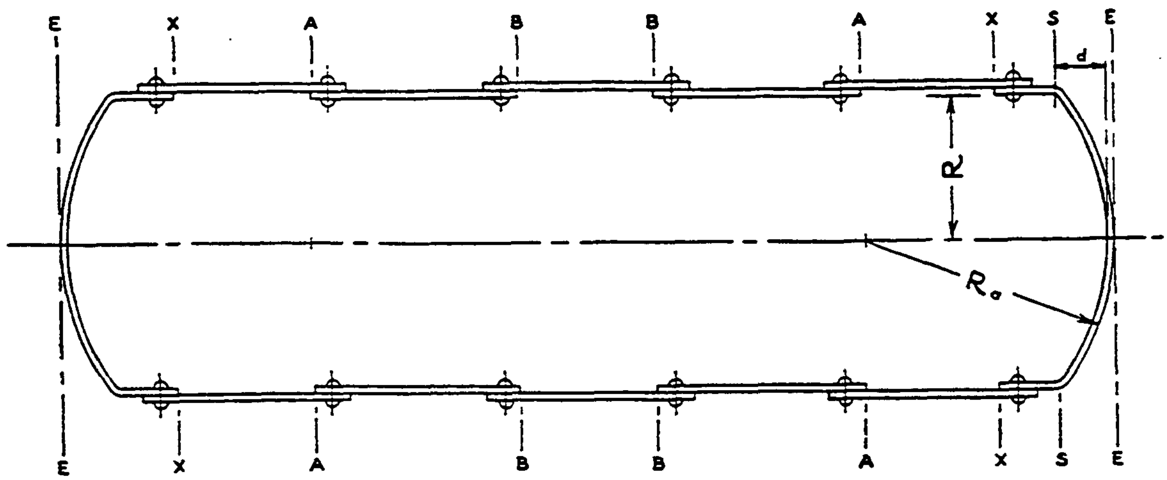
(*1*) With profile board (Fig. 5) held against the knuckle of the tank opposite reference point X, measure the distance between point T on the profile board and reference point X on the tank. This measurement shall be made on both sides of each head cylinder and the average reported as length of the head cylinder.

NOTE 8.—Procedure to be used in constructing a profile board is illustrated in Fig. 5.

(*h*) Determine the average external circumference of the dome (dimension C_d):

(*1*) Measure the external circumference of the dome at a point midway between the top of the main cylinder and the top of the dome.

(*i*) Determine height of dome above top of main cylinder (dimension H_d).



Explanation of reference points:

E = ends of car.
X = ends of head cylinder.
A and B = ends of ringed plates inside car.
S = theoretical intersection of spherical head with cylindrical head flange (determined by use of "profile board").

Description of lengths:

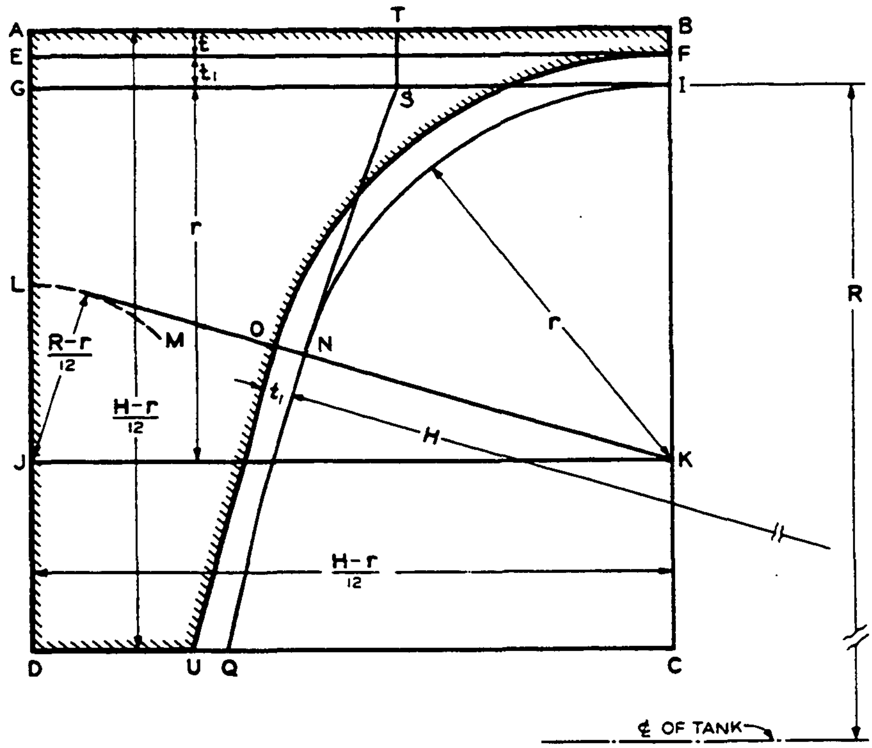
E to X = overall projection of head (dimensions P_a and P_b); head cylinder plus inside depth of head plus head thickness.
X to A and B to B = length of overlapped rings.
A to B = length of underlapped rings.
X to X = total length of main cylinder (dimension L_m).
S to X = length, or depth, of head cylinder (dimensions L_a and L_b).
d = internal depth of head.

Description of radii:

R_a or R_b = outside head radius.
H = internal head radius = overall head radius minus head thickness.
r = knuckle radius (K_a and K_b); see Fig. 5.
R = internal radius head cylinder.

NOTE.—Only reference points X are established on cars constructed entirely of longitudinal plates.

FIG. 4.—LOCATION OF REFERENCE POINTS FOR LENGTH MEASUREMENTS AT SIDES OF CAR.



Cutting Head Profile Boards

The following dimensions must be known before the boards can be cut accurately:

H = radius of inside surface of spherical head.
R = radius of inside surface of cylindrical head flange.
r = radius of inside surface of knuckle.
t = thickness of top plates of main tank cylinder.
t_1 = thickness of tank head plate.

Take a square block $ABCD$, each side of which is equal to $\frac{H-r}{12}$, and draw two lines EF and GI parallel to and at distances of t and $t + t_1$ from the edge AB. Then draw line JK parallel to and at a distance of r from line GI. With J as a center, swing a short arc LM with a radius equal to $\frac{R-r}{12}$. Draw a straight line through point K tangent to arc LM and then swing arc NI, using K as the center. This arc corresponds to the inside surface of the knuckle. Using the line NK as the perpendicular common to both the arc of the knuckle and the arc of the spherical head. and the point N as the point of common tangent. swing the arc QNS with a radius equal to H, the head radius. The point S where this arc cuts the line GI is a point on the theoretical intersection of the spherical head with the cylindrical head flange. This is the point needed in the making of measurements for the computation of head capacities.

Establish reference point T by drawing line ST parallel to AD. After this point is established swing arc FO with radius equal to $r + t_1$ and arc OU with radius equal to $H + t_1$ to establish profile line along which the board should be cut.

The finished board will be bounded by the points $A\ B\ F\ O\ U\ D$.

FIG 5.—A PROCEDURE FOR MAKING HEAD PROFILE BOARDS.

(j) Determine diameter of manhole opening (dimension D).

(k) Determine the following dimensions to be used in computing deductions (dimension W_1):

(1) Width of bottom plate (see Fig. 6).

(2) Width of top plate or plates plus width of two laps (dimensions W_2 and W_3); see Fig. 6.

(3) Thickness of bottom plate (dimension T_1).

(4) Thicknesses of top plates (dimensions T_2 and T_3).

(5) Thicknesses of tank heads (dimensions T_a and T_b).

a. If the thicknesses of tank and head plates are unknown and, due to corrosion or upsetting of calking edges, cannot be determined accurately by other means, it may be necessary to drill a sufficient number of holes to permit direct gaging of the plate thicknesses. The accurate determination of these plate thicknesses is important, inasmuch as on a large tank an error of 1/32 in. in thickness will result in an error of approximately 15 gal in capacity of the main cylinder.

(6) Thickness of dome plate (dimension T_d).

(7) Knuckle radii (dimensions K_a and K_b).

(8) Obtain data necessary to determine volume of deductions for deadwood such as inside heater coils and appurtenances and other fittings which may displace oil within the tank, excluding only rivet heads and valve and its mechanism. These data shall also include position of deadwood with reference to bottom of tank. Report whether a fixed ladder is present.

NOTE 9.—If the tank is found to be distorted, it shall be gaged by the water gage plant procedure as described in Sections 3 through 11.

Recording of Data

17. All measurements and derived dimensions shall be recorded on suitable record forms—the measurements to be recorded on the record forms immediately after readings are made. A suggested form is illustrated in Fig. 7.

Computation of Tank Volume

18. True mathematical principles shall be observed in computation of tank volume. The following equations are presented as ready aids in making the necessary calculations.

(a) *Main Cylinder:*

$$V_m = 0.59528 \times C^2 \times L_m \text{ ......(1)}$$

where:

V_m = volume of tank, in gallons.

C = average internal circumference of main cylinder, in feet.

L_m = average length of main cylinder, in feet.

Equation (1) may be simplified without materially sacrificing its accuracy to:

$$V_m = \frac{5C}{6} \times \frac{5C}{7} \times L_m \text{ ......(1A)}$$

NOTE 10.—If the tank is constructed of ringed plates instead of longitudinal plates, the computation of volume for the main cylinder will have to be divided into two operations: one for the sum of the overlapped rings, and one for the sum of the underlapped rings.

(b) *Tank Heads.*—If a profile board is not used to determine theoretical intersection of head and head cylinder, the following equation will be useful in tank head computations:

$$d = H - \sqrt{H^2 - R^2}$$
$$= H - \sqrt{H^2 - (0.159C_h)^2} \text{ .....(2)}$$

where:

d = internal depth of head measured from theoretical intersection of head and head cylinder, in feet.

H = radius of inside surface of head, in feet (dimension R_a or R_b minus thickness of head plate).

R = internal radius of head cylinder, in feet.

C_h = internal circumference of head cylinder, in feet.

Length of head cylinder is then determined by subtracting calculated internal head depth plus head thickness from overall depth measured from reference points X (dimensions P_a and P_b).

Volume of tank head may be computed as follows:

$$V_e = 7.83 \times d^2(3H - d) \text{ ....(3)}$$

or

$$V_e = 0.297 \times d \times C_h^2 + (3.92 \times d^3) \text{ ....(4)}$$

where:

V_e = volume of tank head, in gallons per head.

For tanks having circumferences of from 16 to 26 ft and having head radii approximating 10 ft, Equation (3) may be simplified, as follows:

$$V_e = 0.3dC_h^2 + 3d^3 \text{ (approximately)..(4A)}$$

(c) *Head Cylinder:*

$$V_c = \frac{5C_c}{6} \times \frac{5C_c}{7} \times L_c \text{........(5)}$$

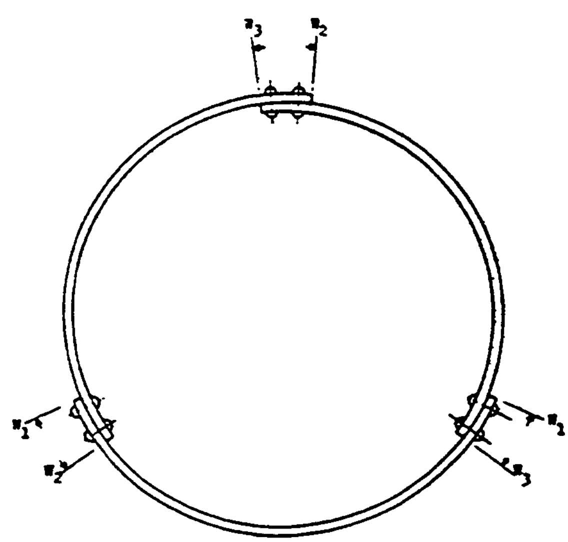


FIG. 6.—DIAGRAMMATIC ILLUSTRATION OF MAIN CYLINDER CONSTRUCTED OF THREE LONGITUDINAL SHEETS. SHOWING POINTS FROM WHICH WIDTHS OF SHEETS ARE TO BE MEASURED.

TANK HEADS

DIMENSIONS	ENDS OF CAR A	ENDS OF CAR B
Thickness of head plate	....................ft	....................ft
Depth of head	....................ft	....................ft
Length of head cylinder	....................ft	....................ft
Sum—overall length	....................ft	....................ft
Radius of head—outside of plate	....................ft	....................ft
Radius of head—inside surface	....................ft	....................ft
Circumference of cylindrical flange—external	....................ft	....................ft
Deduction for thickness of plate	....................ft	....................ft
Internal circumference of head	....................ft	....................ft
Capacity of spherical heads	..................gal	..................gal

HEAD CYLINDERS

	ENDS OF CAR A	ENDS OF CAR B
Capacity of head cylinders	..................gal	..................gal

DOME POCKETS

DOME		MAIN CYLINDER	
Circumference—external	......................ft	Circumference—external	......................ft
Circumference—internal	......................ft	Total capacity	..............................gal

MANHOLE OPENING

Diameter...............ft Volume to be added to capacity of tank.................................gal

VOLUMETRIC DEDUCTIONS

Rivet heads	................................gal	Valve and mechanism	........................gal
Ladder	................................gal	Knuckle	........................gal
Heater coils	................................gal	Other deductions	........................gal

RECAPITULATION

1. Capacity of tank
    - Main cylinder ....
    - Tank heads ....
    - Head cylinders ....
    - Dome pockets ....
    - Manhole opening ....
        - Gross volume ....
    - Less total volumetric deductions.................
        - Total capacity of tank..
2. Capacity of dome..

FIG. 7.—RECORD AND COMPUTATION SHEET FOR GAGING TANK CARS.

MAIN CYLINDER

Alternate A—Longitudinal Plate Tank

EXTERNAL CIRCUMFERENCES	DATA FOR DEDUCTIONS FROM CIRCUMFERENTIAL MEASUREMENTS	
1/8 point ....ft	Bottom plate—Width ....ft	Thickness..........ft
3/8 point ....ft	First top plate—Width * ....ft	Thickness..........ft
5/8 point ....ft	Second top plate—Width * ....ft	Thickness..........ft
7/8 point ....ft	(* Width is to include widths of both longitudinal laps.)	
Sum ....ft	Deduction for tape raises over calking edges..........ft	
Average ....ft	Deduction for circumferential plates..........ft	

Average inside circumference..........ft Net unit volume..........gal
Average length of main cylinder—..........+..........+2 = ...ft
Total volume—net unit volume × average length = ...gal

Alternate B—Ringed Plate Tank

EXTERNAL CIRCUMFERENCES

Overlapped Rings	Underlapped Rings
..........+..........+2 = ...ft	..........+..........+2 = ...ft
..........+..........+2 = ...ft	..........+..........+2 = ...ft
..........+..........+2 = ...ft	..........+..........+2 = ...ft
..........+..........+2 = ...ft	..........+..........+2 = ...ft
Sum ....ft	Sum ....ft
Average ....ft	Average ....ft

DATA FOR DEDUCTIONS FROM CIRCUMFERENTIAL MEASUREMENTS

Bottom plate—Width ....ft Thickness..........ft
Ringed plates—Overlapped—Circumferential length..........ft Thickness..........ft
Ringed plates—Underlapped—Circumferential length..........ft Thickness..........ft

Deductions for tape rises over calking edges..........ft
Deductions for circumferential plates—Overlapped..........ft Underlapped..........ft

Average inside circumference
Overlapped ....ft Unit volume ....gal
Underlapped ....ft Unit volume ....gal

Total length of cylinders

Overlapped	Underlapped
..........+..........+2 = ...ft	..........+..........+2 = ...ft
..........+..........+2 = ...ft	..........+..........+2 = ...ft
..........+..........+2 = ...ft	..........+..........+2 = ...ft
..........+..........+2 = ...ft	..........+..........+2 = ...ft
Sum ....ft	Sum ....ft

Average total length..........ft

Total volume of cylinders
Overlapped—(unit volume × sum of overlapped lengths) = ...gal
Underlapped—(unit volume × sum of underlapped lengths) = ...gal
Total volume of main cylinder—(sum) = ...gal

FIG. 7.—RECORD AND COMPUTATION SHEET FOR GAGING TANK CARS.

where:

V_c = volume of one head cylinder, in gallons.

C_c = internal circumference of cylinder, in feet.

L_c = length of head cylinder, in feet.

(*d*) *Dome Pockets:*

$$V_p = \frac{0.01184 C_d^4}{C_m}\left(1 + \frac{C_d^2}{5C_m^2}\right) \ldots\ldots (6)$$

where:

V_p = volume of two dome pockets, in gallons.

C_d = internal circumference of dome, in feet.

C_m = external circumference of tank, in feet.

Equation (6) may be simplified without materially affecting its accuracy to:

$$V_p = \frac{C_d^4}{80C_m} \ldots\ldots\ldots\ldots (6A)$$

(*e*) *Manhole Opening:*

$$V_o = 4.4 \times D^2 \times T_2 \ldots\ldots\ldots (7)$$

where:

V_o = volume, in gallons, to be added to capacity of tank.

D = diameter of opening, in feet.

T_2 = thickness of plate, in decimals of a foot.

(*f*) *Deductions from Circumferential Measurements:*

(*1*) *For Tape Rises.*—In making circumferential measurements the measuring tape is held away from the inner tank plate at each joint by the calking edge. A deduction from the tape reading must be made to compensate for this fact. Such a deduction for each calking joint may be approximated by the following equation:

$$D_1 = \frac{T}{C_m} \text{(for } C_m \text{ between 16 and 26 ft)} \ldots (8)$$

where:

D_1 = deduction per joint, in feet.

T = thickness of calking edge, in feet.

C_m = circumference of tank, in feet.

EXAMPLE:

For a tank 26 ft in circumference with three ½-in. joints, the total deduction would be:

$$3D_1 = \frac{3T}{C_m} = \frac{0.126}{26}$$

$$= 0.005 \text{ ft (approximately)}$$

(*2*) *For Plates and Plate Laps in Main Cylinder.*—In order to determine the internal circumference from the corrected external circumference it is necessary to apply a deduction to compensate for the thickness of metal in the cylindrical shell. This may be computed by the use of the following equation:

$$D_2 = \frac{6.28[(W_1 \times T_1) + (W_2 \times T_2) + (W_3 \times T_3)]}{C_m - 3.14\left(\frac{T_1 + T_2 + T_3}{3}\right)} \ldots\ldots (9)$$

where:

D_2 = deduction to be applied to corrected external circumference to obtain the internal circumference.

W_1 = overall width of bottom plate, in feet.

T_1 = thickness of bottom plate, in decimals of a foot.

W_2 = overall width of first top plate (including widths of two laps), in feet.

T_2 = thickness of first top plate, in decimals of a foot.

W_3 = overall width of second top plate (including widths of two laps), in feet.

T_3 = thickness of second top plate, in decimals of a foot.

Equation (9) may be simplified without materially affecting its accuracy to:

$$D_2 = \frac{6.28[(W_1 \times T_1) + (W_2 \times T_2) + (W_3 \times T_3)]}{C_m - (T_1 + T_2 + T_3)} \ldots\ldots (9A)$$

(*3*) *For Plate and Lap in Dome.*—The deduction for thickness of plate in dome may be computed from the following equation:

$$D_3 = 6.28\, T_4 \ldots\ldots\ldots\ldots (10)$$

where:

D_3 = deduction to be made from external circumference to obtain internal circumference.

T_4 = thickness of dome plate, in decimals of a foot.

(*4*) *For Plate in Head Cylinder.*—Equation (10) may be used to compute the difference between the external and internal circumferences of the head cylinder.

(*g*) *Deductions from Measurements of Length.*—The only deduction to be applied will be that equivalent to the thickness of the head which must be subtracted from the overall depth of head to obtain the internal depth of head.

(*h*) *Volumetric Deductions.*—In addition to the deductions which are applied to the linear measurements, there are several volumetric deductions which must be applied to the gross volume of the tank as computed.

(*1*) *Deduction for Rivet Heads on Inside of Tank.*—This deduction may be taken from Table II.

(*2*) *Deduction for Heater Coils.*—This deduction shall be computed from the length and cross-sectional area of the pipe, adding thereto the volume of fittings, cradles, manifolds, etc., determined from their number and unit volumes as computed from dimensions, weight, or displacement.

(*3*) *Deduction for Valve and Mechanism.*—This deduction may be taken from Table II.

(*4*) *Deduction for Ladder.*—If the tank contains a ladder, the volume to be deducted on its account may be taken from Table II.

(*5*) *Deduction for Knuckle on Tank Head.*—The deduction to be made for the knuckle on each tank head may be ascertained approximately from the following equation:

$$V_k = 10\, K^3 \ldots\ldots\ldots\ldots (11)$$

where:

V_k = volume, in gallons, to be deducted from each head.

K = knuckle radius, in decimals of a foot.

Dome Capacity

19. The capacity of the dome is computed separately from that of the tank. The dome capacity may be computed by the following equation:

$$V_d = 0.5953 \times C_d^2 \times H_d \ldots\ldots (12)$$

TABLE II.—VOLUMETRIC DEDUCTIONS FOR RIVET HEADS, VALVE AND MECHANISM, AND INSIDE LADDER IN STANDARD, SINGLE-COMPARTMENT TANK CAR TANKS

Nominal Capacity, gal	Rivet Heads	Valve and Mechanism	Inside Ladder	Total, gal
6,500	2.8	1.2	0.8	4.8
8,000	3.2	1.3	0.9	5.4
10,000	3.6	1.4	0.9	5.9
12,000	4.5	1.3	1.0	6.8

where:

V_d = capacity of dome, in gallons.
C_d = internal circumference of dome, in feet.
H_d = height of dome above top of tank, in feet.

Equation (12) may be simplified to:

$$V_d = \frac{5 \times C_d}{6} \times \frac{5 \times C_d}{7} \times H_d \ldots (12A)$$

EXAMPLE:

The following example may clarify the steps taken in computing the capacity of a tank car tank:

A tank car tank—constructed with a ½-in. bottom plate (8 ft wide), two 13/32-in. longitudinal top plates (each 8.33 ft wide), and ½-in. tank heads—has an average external circumference of 23.147 ft and an average length, between reference points, of 30.490 ft. Each head has an overall radius of 9.83 ft and an average overall depth, from reference points, of 1.23 ft, which includes head cylinder with average length of 0.50 ft. The dome, constructed of 5/16-in. plate, has an external circumference of 16.015 ft. The knuckle radius, to inside surface, is 0.25 ft. The diameter of the manhole opening is 2.50 ft. A fixed steel ladder is installed in the tank.

Tank Capacity

20. (*a*) The capacity of the tank is computed as follows:

(*1*) *Main Cylinder:*

Deduction from average external circumference for tape rises over calking edges

$$= \frac{(2 \times 0.0417) + 0.0339}{23.147}$$

$$= \frac{0.1173}{23.147} = 0.005 \text{ ft} \ldots\ldots\ldots\ldots (8)$$

Deduction from corrected external circumference for thickness of plates and laps

$$= \frac{6.28[(8.00 \times 0.0417) + 2(8.33 \times 0.0339)]}{23.142 - 0.110}$$

$$= \frac{6.28(0.3336 + 0.5648)}{23.032} = \frac{6.28 \times 0.8984}{23.032}$$

$$= 0.245 \text{ ft} \ldots\ldots\ldots\ldots (9A)$$

Average net internal circumference

$$= 23.147 - (0.005 + 0.245) = 22.897 \text{ ft}$$

Volume of main cylinder

$$= \left(\frac{5 \times 22.897}{6}\right)\left(\frac{5 \times 22.897}{7}\right) 30.49$$

$$= 19.0808 \times 16.3550 \times 30.49$$

$$= 9514.91 \text{ gal} \ldots\ldots\ldots\ldots (1A)$$

(*2*) *Tank Heads* (*Each*):

Deduction from overall head radius for thickness of plate = 0.0417 ft

Internal head radius

$$= 9.83 - 0.0417 = 9.7883 \text{ ft}$$

Internal depth of head

$$= 1.23 - (0.50 + 0.0417) = 0.688 \text{ ft}$$

Capacity of one head

$$= 7.83 \times 0.688 \times 0.688[(3 \times 9.7883) - 0.688]$$

$$= 7.83 \times 0.4733 \times 28.6769$$

$$= 106.27 \text{ gal} \ldots\ldots\ldots\ldots (3)$$

(*3*) *Head Cylinder* (*Each*):

Deduction from external circumference of head cylinder for thickness of head plate

$$= 6.28 \times 0.0417 = 0.262 \text{ ft} \ldots (10)$$

Internal circumference of head cylinder

$$= 22.897 - 0.262 = 22.635 \text{ ft}$$

$$\text{Capacity} = \left(\frac{5 \times 22.635}{6}\right)\left(\frac{5 \times 22.635}{7}\right) 0.50$$

$$= 18.8625 \times 16.1679 \times 0.50$$

$$= 152.48 \text{ gal} \ldots\ldots\ldots\ldots (5)$$

(*4*) *Dome Pockets* (*Both*):

Internal circumference of dome

$$= 16.015 - (6.28 \times 0.0260) = 15.852 \text{ ft}$$

$$\text{Capacity} = \frac{15.852 \times 15.852 \times 15.852 \times 15.852}{80 \times 23.147}$$

$$= 34.10 \text{ gal} \ldots\ldots\ldots\ldots (6A)$$

(*5*) *Manhole Opening:*

$$\text{Capacity} = 4.4 \times 2.5 \times 2.5 \times 0.0339$$

$$= 0.93 \text{ gal} \ldots\ldots\ldots\ldots (7)$$

(*6*) *Volumetric Deductions:*

Deduction for rivet heads	= 3.56 gal
Deduction for valve	= 1.42 gal
Deduction for ladder	= 0.93 gal
Deduction for knuckle radius (0.625 × 2)	= 1.25 gal
Total	7.16 gal

(*7*) *Total Capacity of Tank:*

Main cylinder	=	9,514.91 gal
Tank heads	= 2×106.27 =	212.54 gal
Head cylinders	= 2×152.48 =	304.96 gal
Dome pockets	=	34.10 gal
Manhole opening	=	0.93 gal
Gross volume		10,067.44 gal
Volumetric deductions		7.16 gal
Net capacity		10,060.28 gal

Preparation of Volume Table

21. (*a*) The volume of each horizontal segment in the heads shall be computed by use of Table V (Appendix).

(*b*) The volume of each horizontal segment in the head cylinders and in the main cylinder shall be computed by use of Table VI (Appendix).

(*c*) The volume of each segment in the dome pockets shall be computed from Table VII (Appendix).

(*d*) The gage table shall be prepared with a depth equal to the inside diameter of the main cylinder at the dome. If the car is constructed entirely of longitudinal sheets, this diameter is assumed to be the average inside diameter of the main cylinder. If the tank is constructed of a series of overlapped and underlapped rings, the table shall be prepared with depth equal to the average inside diameter of the ring series in one of whose rings the dome is located. For example, if the dome is located in an overlapped ring, the depth of the table shall be the average inside diameter of all the overlapped rings.

(*e*) The volume of each horizontal segment shall be calculated separately for the combined capacity of the two heads, for the combined capacity of the two head cylinders, for the capacity of the main cylinder, and for the combined capacity of the two dome pockets, except that, if the main cylinder is constructed of overlapped and underlapped rings, the segmental volumes shall be computed separately for each series.

(*f*) To use Table V (Appendix), first find ratio m/r of the depth of segment to the average inside radius of the head cylinders, with six significant figures to the right of the decimal point; then find the value of coefficient K for the value of m/r desired, interpolating as necessary. The total volume of the two heads multiplied by coefficient K equals volume of the segment in both heads.

(*g*) To use Table VI (Appendix) for head cylinders, first find ratio m/R of the depth of segment to the average inside radius of the head cylinders; these will be the m/R values established for the heads. Then find the value of coefficient G for the value of m/R desired, interpolating as necessary. The total volume of the two head cylinders multiplied by coefficient G equals the volume of the segment in both head cylinders.

(*h*) To use Table VI (Appendix) for main cylinder, first find ratio m/R of depth of segment to the inside radius of main cylinder (or that portion of main cylinder being computed if of ringed construction), with six significant figures to the right of the decimal point; then find the value of coefficient G for the value of m/R desired, interpolating as necessary.

The full volume of the main cylinder (or part being computed) multiplied by coefficient G equals the volume of the segment.

(*i*) To use Table VII (Appendix), first determine depth of dome pockets, using the formula:

$$D = R - \sqrt{R^2 - r^2}$$

where:

D = depth of each dome pocket.
R = external radius of main cylinder at dome.
r = internal radius of dome.

Next, find the percentage d of depth of segment to total depth of pocket, making this calculation to the nearest one per cent; then find the value of coefficient C for the value of d desired. The full volume of the two dome pockets multiplied by coefficient C equals volume of the segment in both pockets.

(*j*) An innage table shall have its zero point at the lowest point on the inside bottom of the main cylinder underneath the dome, and the separate volumes of the segments in the heads, the head cylinders, and the main cylinder shall be totaled in their proper relation to that point. The incremental volumes shall then be determined by subtracting the volume of each segment from that of the succeeding segment. Only the lower one-half of the tank shall be so computed and the figures for the differences shall be added, in reverse order, to the volume of half the tank.

(*k*) The incremental volumes of the dome pockets shall be determined by subtracting the volume of each segment from that of the succeeding segment, and these differences shall be added to the tank shell volume in their proper relation to the upper part of the tank.

(*l*) Deadwood allowance for rivet heads, valve and mechanism, and inside ladder may be deducted in a lump sum from main cylinder capacity; allowance for head knuckle may be similarly deducted from capacity of the heads, the resultant net figures being used as total volumes when computing segmental volumes. Deadwood, such as heater coils, which is confined to a relatively small depth zone of the tank, shall be deducted in its proper relation to the bottom of the tank.

(*m*) The table shall be prepared with capacity given at each ¼-in. interval of depth. Incremental volumes shall be computed with not less than four significant figures to the right of the decimal point, and these values shall be used in the progressive accumulation of the tank's capacity. However, the completed table shall be prepared with the capacity at each ¼-in. interval of depth given in whole gallons.

(*n*) Computations shall be made by ¼-in. segments for the first 6 in. of the tank, then by whole inches to center of tank, the 1-in. values to be divided by 4 for ¼-in. values. Because of the relatively small capacity of the dome pockets, segments throughout their depth may be computed at 1-in. intervals and the segmental differences divided by 4 for ¼-in. values.

(*o*) The capacity of the dome per inch of height shall be computed and this capacity, in gallons and hundredths of a gallon, shall be noted on the table.

EXAMPLE:

Using as an example in preparation of the table the tank car which was used as an example in computation of volume, the following procedure would be observed:

(*1*) *Main Cylinder:*

Gross capacity	= 9515.84 gal
Deduction for deadwood	= 5.91 gal
Net capacity	= 9509.93 gal

Internal radius, in inches

$$= \frac{22.897 \times 12}{6.28}$$
$= 43.7522$, or 43¾, to nearest ¼ in.

Internal diameter, in inches
= 87½ (7 ft 3½ in., depth of table)
Ratio m/R for ¼-in. segment = 0.0057142857
Ratio m/R for 1-in. segment = 0.0228571428

(*2*) *Tank Heads:*

Gross capacity	= 212.54 gal
Deduction for knuckle	= 1.25 gal
Net capacity	= 211.29 gal

Internal radius (internal radius of head cylinders), in inches

$$= \frac{22.635 \times 12}{6.28}$$
$= 43.2516$, or 43¼, to nearest ¼ in.

Ratio m/r for ¼-in. segment = 0.0057803468
Ratio m/r for 1-in. segment = 0.0231213872

(*3*) *Head Cylinders:*

Gross capacity	= 304.96 gal
Deductions	= none
Internal radius, in inches	= 43¼ (same as heads)

Ratio m/R for ¼-in. segment = 0.0057803468
Ratio m/R for 1-in. segment = 0.0231213872

NOTE 11.—m/R values throughout depth of head cylinders are the same as m/r values for heads.

(*4*) *Dome Pockets:*

Gross capacity	= 34.10 gal
Deductions	= none
Depth	$= R - \sqrt{R^2 - r^2}$

where:

R = external radius of main cylinder, in inches

$$= \frac{23.142 \times 12}{6.28} = 44.2204$$

r = internal radius of dome, in inches

$$= \frac{15.852 \times 12}{6.28} = 30.2904$$

$$\text{Depth} = 44.2204 - \sqrt{44.2204^2 - 30.2904^2}$$
= 12.0034, or 12, to nearest ¼ in.

NOTE 12.—Addition of incremental volumes of dome pockets will begin at depth of table minus depth of dome pockets, which in this example will be 87½ − 12 = 75½. Therefore, additions will begin in the increment between 6 ft 3½ in. and 6 ft 4½ in. of the table. The increments should be calculated from gross capacity (34.10 gal) and factors from Table VII (Appendix). Factors in Table VII may be found by first solving for d, per cent of total depth for 1-in. segment:

$$d = 1/12 = 8.33 \text{ per cent}$$

Enter Table VII at the per cent of total depth (in this case, 8 per cent) to find factor C (in this case, 0.27 per cent). The volumetric increase is found by multiplying C (0.27 per cent) by the gross capacity of dome pockets (34.10 gal).

(*5*) *Dome (Above Pockets):*

Internal circumference, in feet = 15.852
Capacity, in gallons per inch

$$= \left(\frac{5 \times 15.852}{6}\right)\left(\frac{5 \times 15.852}{7}\right)\frac{1}{12} = 12.46$$

NOTE 13.—Table III illustrates the steps which will be made in computing the ¼-in. values for the table.

NOTE 14.—Table IV illustrates the steps which will be made in computing the ¼-in. values of the dome pocket increments.

(*p*) If an outage table is desired, the incremental values as established by the foregoing procedure shall be deducted successively from the total tank capacity, starting from the top, with the zero depth point of the table at the inside top of the tank.

TABLE III.—EXAMPLE: COMPUTATION OF ¼-IN. VALUES FOR THE TABLE.

Table Depth		Heads and Head Cylinders	Heads		Head Cylinders		Main Cylinder			Total Shell			Minus Deadwood	Plus Dome Pockets	Table Gallons per ¼ In.
Ft	In.	$m/r.m/R$	K	$K\times$Volume	G	$G\times$Volume	m/R	G	$G\times$Volume	Total Gallons	Difference in Gallons	Gallons per ¼ In.			
0	0														
0	0¼						0.005714	0.0002590	2.4688	2.4688	2.4688	2.4688			2.4688
0	0½						0.011429	0.0007326	6.9670	6.9670	4.4982	4.4982			4.4982
0	0¾	0.005780	0.00000	0.0000	0.0002040	0.0805	0.017143	0.0013440	12.7813	12.8618	5.8948	5.8948			5.8948
0	1	0.011561	0.00002	0.0042	0.0007453	0.2278	0.022857	0.0020672	19.0589	19.8904	7.0286	7.0286			7.0286
BY ¼ IN. TO 6 IN.															
0	6	0.127168	0.00538	1.1367	0.0266937	8.1405	0.137143	0.0298486	283.8581	293.1359					
0	7	0.150289	0.00805	1.7009	0.0341708	10.4207	0.160000	0.0374780	256.4132	368.5348	75.3906	18.8499			18.8499
BY INCHES TO CENTER OF TANK															
3	6	0.959538	0.46604	98.4698	0.4742481	144.6267	0.960000	0.4745420	4,512.8612	4,756.9575					
3	7	0.982059	0.48545	102.5707	0.4889609	149.1135	0.982857	0.4890869	4,651.1822	4,902.8604	146.9089	36.7272			36.7272
3	7¾	1.000000	0.50000	105.6450	0.5000000	152.4800	1.000000	0.5000000	4,754.9650	5,013.0900	110.2236	36.7412			36.7412
3	8¼											36.7412			36.7412
3	9¼											36.7272			36.7272
BY INCHES TO 6 IN. BELOW TOP OF TANK (NOTE: ADDITION OF DOME POCKET VOLUMES STARTS AT 0 FT 3½ IN.)															
6	8½														
6	9½											18.8499		0.3802	19.2301
BY ¼ IN. TO TOP OF TANK															
7	2½														
7	2¾											7.0286		2.1312	9.1598
7	3											5.8948		2.1312	8.0260
7	3¼											4.4982		2.1312	6.6294
7	3½											2.4688		2.1312	4.6000

TABLE IV.—EXAMPLE: COMPUTATION OF ¼-IN. INCREMENTAL VOLUMES OF DOME POCKETS.

Table Depth		Pocket Depth		Dome Pocket Depth,* per cent	Total Capacity,* per cent	$C \times$ Gross Capacity of Dome Pockets,** 34.10 gal	Difference in Gallons	Gallons per ¼ In.
Ft	In.	Ft	In.	d	C			
6	3½	0	0	...	.....	......	.....	.....
				...	.....	......	0.0921	0.0230
6	4½	0	1	8	0.27	0.0921	.....	.....
				...	.....	......	0.1432	0.0358
6	5½	0	2	17	0.69	0.2353	.....	.....
BY INCHES TO TOP OF POCKET								
6	8½	0	5	42	7.69	2.6223	.....	.....
				...	.....	......	1.5209	0.3802
6	9½	0	6	50	12.15	4.1432	.....	.....
7	1½	0	10	83	55.00	18.7550	.....	.....
				...	.....	......	6.8200	1.7050
7	2½	0	11	92	75.00	25.5750	.....	.....
				...	.....	......	8.5250	2.1312
7	3½	1	0	100	100.00	34.1000	.....	.....

* See Table VII (Appendix).

** See Note 12 (p. 22).

PART II. PROCEDURE FOR CALIBRATING PRESSURE TANK CARS

General

22. (*a*) Determine the volume capacity of liquified petroleum gases (LPG) pressure-type tank car tanks in one of the two following ways:

(*1*) By filling the tank with a quantity of water measured by discharge from calibrated tank or tanks (water gage plant procedure).

(*2*) By filling the tank with water and weighing car before and after filling (water-weighing procedure).

The volume of all new LPG pressure-type tank cars should be determined by the water gage plant procedure.

(*b*) With reference to the use of the two different methods of calibration, it has been realized that there should be some further clarification with regard to the relation of these two procedures. This has been expressed as follows:

(*1*) The first method is recommended as the basic accurate procedure (see "Water Gage Plant Procedure," Part I, Sections 3 through 11).

(*2*) Where facilities are not available for the use of the first procedure, the alternative procedure is acceptable for use on cars now in operation (see "Water-Weighing Procedure," Part I, Sections 12 through 14).

Tank cars modified or damaged to the extent that the capacity is changed should be recalibrated; and the new capacity should be reported in accordance with instructions in *Freight Tariff No. 300*, latest issue and supplements thereto, issued under ICC authority for United States, Canadian, and Mexican railroads.

Installation of Gage Tube (Slip Tube)

23. With gage tube set with zero graduation mark in line with gage pointer, the bottom of excess-flow valve or liquid inlet must be at a point representing inside top of tank (see Fig. 8).

WATER GAGE PLANT PROCEDURE

NOTE 15.—See Part I, Sections 3 through 8, for "Design and Construction of Gage Plant."

Procedure for Calibrating Pressure-Type Tank Car Tanks

24. (*a*) The capacity of the car to be gaged shall be determined as it stands on a level track. Before gaging commences, it is important that the gage track be checked to ascertain that it is level.

(*b*) The inside of the tank shall be examined for the purpose of removing any foreign substances, such as dirt, rust, etc. All measuring tanks shall be examined to make certain that they are perfectly clean. A check shall be made to ascertain that the scale behind the gage glass on the finishing tank is tight and in its proper position. The gagers shall make certain that the water used is clean. When measuring tanks become nearly empty, they shall be watched for sediment. If any sediment is present, the water shall be stirred thoroughly to carry it away. The operator shall examine all valves on the measuring tanks to see that none are leaking. If any of the valves leak, they shall be repaired or renewed.

(*c*) Each gage tank shall be separately drained into the car tank, 5 min being allowed for draining after the tanks have become empty.

(*d*) Repeat the filling and emptying of measuring tanks until the car tank is nearly full. In order to avoid error or duplication in tallying the number of measuring tanks emptied into the car tank, record shall be made immediately after the valve from the measuring tank has been closed. When the car tank is nearly full, gaging shall be completed by the use of the finishing tank. A straightedge shall be fastened across the manway opening in the shell of the car tank so that it is level with the inside of the shell at its highest point. When the water begins to trickle over the center of the straightedge, the tank is full.

(*e*) The finishing tank shall be completely filled each time rather than filled to a point which is marked on the gage board.

(*f*) The last 100 gal shall not be permitted to run into the car tank faster than at the rate of 10 gpm.

(*g*) After the car tank has been filled, allow 15 min for settling to displace the air and fill to the top of the straightedge if outage shows. The capacity of the tank shell shall be determined by taking the total number of gallons which have been emptied from the measuring tanks into the car tank, plus the final reading of the gage on the finishing tank.

(*h*) The capacity of the manway nozzle shall then be determined by the use of the finishing tank.

(*i*) Throughout gaging operations on tank car tanks, the gager shall make all important readings personally and check as far as possible all other readings. He shall take every possible precaution to insure accurate results.

Calibrating Pressure-Type Tank Cars for Incremental Capacity Tables

25. To provide an entire incremental capacity table, fill one car of each class with exactly one-half its gallonage capacity. Then water-gage the top half to show the capacity of each 1-in. increment from the center up to 18 in. from inside top of tank and of each ½-in. increment from the 18-in. level to inside top of shell. Then use the incremental capacities thus determined in reverse order for the determination of incremental capacities for bottom half of tank. Determine capacities for fractional increments by interpolation.

Preparation for Calibrating

26. (*a*) Tank must be cleaned thoroughly inside.

(*b*) Tank to be gaged must be placed in the shelter of the gage plant after making sure that track is level, both for length and width of car. The location at which the car is placed within the gage plant shall be such that the water from the finishing tank shall drain directly into the tank to be gaged.

(*c*) The tank shall be leveled by means of wedges under the side bearings so that the bottom sheet on the inside of the tank is level longitudinally. The tank shall be leveled laterally by adjusting wedges at the side bearings so that the bob of a plumb line, when suspended from the center of the manway nozzle, rests on the longitudinal center of the bottom sheet.

(*d*) Apply a bracket to the running board on which to support gage glass and piping. Plumb the gage glass and clamp the bracket solidly so that gage glass is supported in the plumb position (see Fig. 9).

(*e*) Fill the sump (if tank is so equipped) and piping until the water reaches the top of the bottom sheet on the inside of the tank.

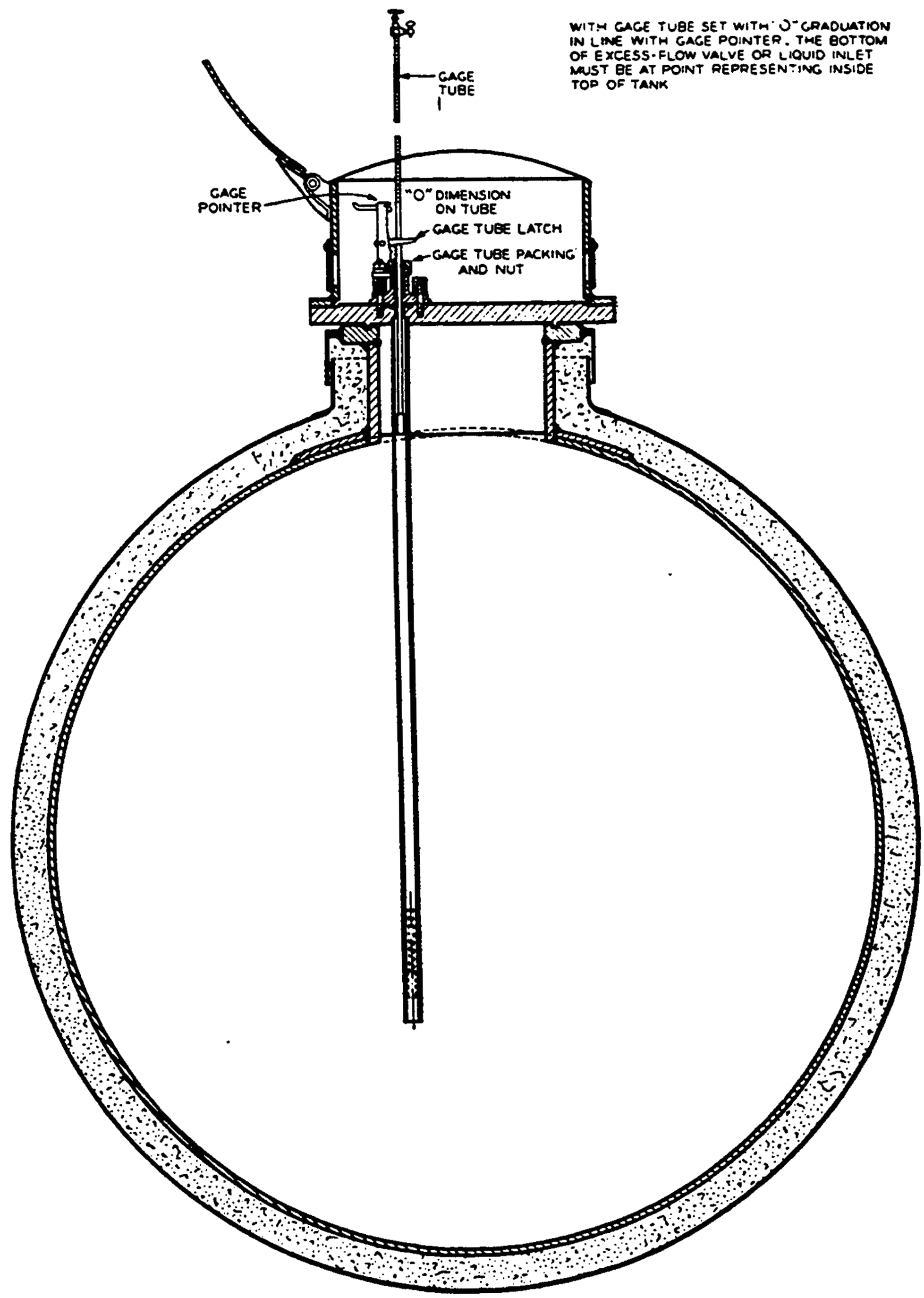


FIG. 8.—SYSTEM OF INSTALLING OUTAGE GAGING DEVICE.

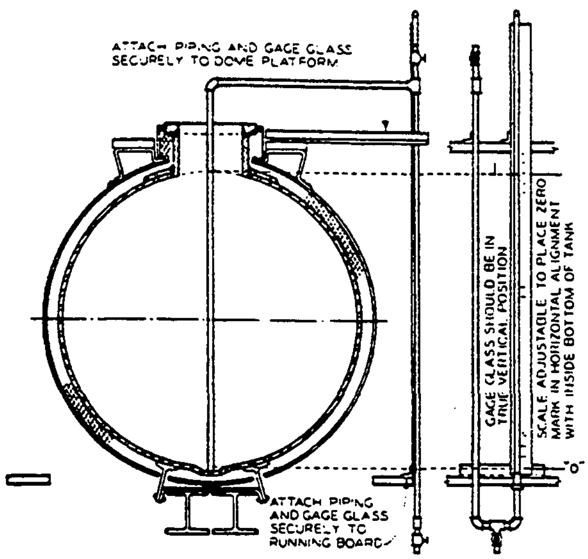


Fig. 9.—Piping and Gage Glass Arrangement to Be Used for Incremental Gaging of Pressure Cars

(*f*) Apply a steel scale to bracket adjacent to gage glass, locating zero point on scale at the level of the bottom of meniscus of water in the glass at the top of bottom sheet level.

(*g*) Clamp the steel scale securely in position to prevent any change in its position relative to the gage glass.

Calibrating Car Tanks for Incremental Capacity Tables

27. (*a*) Do not gage tanks on windy days or in freezing weather.

(*b*) Use only clean water at a temperature as near 60 F as practicable.

(*c*) When gaging operations have started, they shall be continued until entire tank has been gaged. If gaging continues longer than one day, empty the water from tank each night and refill the next day to the level at which gaging was discontinued the night before.

(*d*) Gage tank to inside top of shell, record capacity, and note reading of inside diameter on gage glass scale.

(*e*) Again fill the sump (if tank is so equipped) and piping until the water reaches the top of bottom sheet on inside of tank and check zero setting on scale.

(*f*) Fill tank to exactly one-half its capacity as gaged to inside top of shell and check reading on scale as being at center of inside diameter of tank.

(*g*) Fill the finishing tank in the gage plant with water and allow it to settle 5 min to free the water from air and make up the outage, if any. Allow water to flow from the finishing tank into the car tank until the level is nearly 1 in. higher than the midpoint of the car tank and close the gage tank valve. Allow the water to settle and become calm, and resume flow from the finishing tank into the car tank at a reduced rate of flow until the car tank level is exactly 1 in. above the midpoint level in the gage glass.

(*h*) Allow the water level to come to rest, and check to determine if the bottom of the meniscus in the gage glass is exactly in the same horizontal plane as the scale mark 1 in. above the center of the car tank and above the previous level.

(*i*) Read the glass on the finishing gage tank and record the gallonage conveyed to the car tank for the first inch in top half of tank.

(*j*) Repeat operations for the second inch, third inch, etc., until an 18-in. outage level is reached, after which readings for each half inch shall be taken.

(*k*) When nearing the top of tank, apply a straightedge to the highest point on inside of tank shell.

(*l*) The last reading is to be taken when the water begins to trickle over the center of the straightedge.

(*m*) Draw off water in outside gage glass occasionally and pour it back into the tank. Keep outside gage glass shaded from the sun to maintain the same temperature in the glass as in the tank. Also, be sure that the water in the gage glass of the finishing tank is circulating from time to time so that the temperature of the water in the glass is the same as the temperature of the water in the gage tank.

(*n*) After the water is emptied from the car tank, the car tank must again be leveled; and if it is found that the level of the tank has changed during the gaging operation, the tank shall be leveled again and regaged.

Preparation of Gage Tables by Calculations

28. (*a*) The table shall be prepared with capacity given at each ¼-in. interval of depth. Incremental volumes shall be computed with not less than four significant figures to the right of the decimal point, and these values shall be used in the progressive accumulation of the capacity of the tank; however, the completed table shall be prepared with the capacity at each ¼-in. interval of depth given in whole gallons.

(*b*) Computations shall be made by ¼-in. segments for the first 6 in. of the tank, then by whole inches to the center of the tank. Capacities for fractional increments shall be determined by interpolation.

(*c*) An innage table shall have its zero point at the lowest point on the inside bottom of the main cylinder underneath the nozzle; and the separate volumes of the segments in the heads, the head cylinders, and the main cylinder shall be totaled in their proper relation to that point. The incremental volumes shall then be determined by subtracting the volume of each segment from that of the succeeding segment. Only the lower half of the tank shall be so computed, and the figures for the differences shall be added, in reverse order, to the volume of half the tank.

(*d*) Deadwood allowance shall be made for any fittings or reinforcement plates inside the tank. Such volume shall be deducted in its proper relation to the bottom of the tank.

(*e*) The capacity of the nozzle per inch of height shall be computed; and this capacity, in gallons and hundredths of a gallon, shall be noted on the table.

(*f*) The volume of each horizontal segment in the main cylinder and in the head cylinders shall be computed from Table VI (Appendix).

(*g*) The volume of each horizontal segment in the heads shall be computed from the equation in Fig. 10.

(*h*) The volume of each horizontal segment shall be calculated separately for the combined capacity of the two heads and for the capacity of the main cylinder.

(*i*) To use the equation in Fig. 10, calculations for each increment are made. The results are volumes for the sum of the two heads.

(*j*) To use Table VI (Appendix) for main cylinder, first find ratio m/R of depth of segment to the inside radius of main cylinder with six significant figures to the right of the decimal point; then find the value of coefficient G for the value of m/R desired, interpolating as necessary. The full volume of the main cylinder multiplied by coefficient G equals the volume of the segment.

To use Table VI (Appendix) for head cylinder, first find ratio m/R of depth of segment to the average inside radius of the head cylinders; these will be the m/R values established for the heads. Then find the value of coefficient G for the value of m/R desired, interpolating as necessary. The total volume of the two head cylinders multiplied by coefficient G equals the volume of the segment in both head cylinders.

(*k*) This step may be omitted when head cylinders are of the same inside diameter as the main cylinder, provided they are added to length of main cylinder.

(*l*) The following example may clarify the steps taken in the preparation of gage tables for pressure-type tank car tanks.

(*m*) A tank car tank constructed with an 85¼-in. inside diameter and a cylinder length, including head cylinders, of 30 ft 0 in. has a nozzle with an 18-in. inside diameter and ellipsoidal heads of 2:1 ratio. The problem is to determine its volume at a depth of 35¼ in. from the bottom of the tank.

EXAMPLE:

Determination of tank volume at depth of 35¼ in.:

(*1*) *Main Cylinder:*

$$\frac{m}{R} = \frac{35.25}{42.625} = 0.826979$$

From Table VI (Appendix):

$$\text{At } \frac{m}{R} = 0.826$$

$$G = 0.3897897$$

$$\text{At } \frac{m}{R} = 0.827$$

$$G = 0.3904166$$

$$\text{Difference} = 0.0006269$$

$$(0.0006269)(0.979) = 0.0006137$$

$$G \text{ at } \frac{m}{R} \text{ of } 0.826979 = 0.3897897 + 0.0006137 = 0.3904034$$

(*2*) ***Full Volume of Cylinder:***

$$(0.0034D^2)(\text{length, in inches}) = \text{gallons}$$

$$(24.710)(360) = 8895.60 \text{ gal}$$

where:

D = diameter, in inches

(*3*) *Volume of Cylinder at 35¼ In.:*

$$(8895.60)(0.3904034) = 3472.872 \text{ gal}$$

(*4*) *Ellipsoidal Heads:*

With the use of equation from Fig. 10,

$$V = 35.25^2\left(\frac{0.01360}{2}\right)\left(42.625 - \frac{35.25}{3}\right) = 260.876 \text{ gal}$$

(*5*) *Total Tank Capacity at 35¼ In.:*

$$3472.872 + 260.876 = 3733.748 \text{ gal}$$

Water-Weighing Procedure

29. Scales must be sensitive, checked at regular periods, and adjusted to meet check weights. The car weight should be taken when the car is empty (dry) and with shell and manway filled with water; it should be carefully checked and verified.

Definitions

30. (*a*) *Tare Weight* designates the weight of the empty tank, including manway; underframe; and trucks.

(*b*) *Gross Weight* designates the combined weight of underframe; trucks; and tank, including manway, filled with water.

(*c*) *Net Weight* designates the difference between gross and tare weight.

(*d*) *Corrected Net Weight* designates the net weight adjusted density at 60 F, using correction factor from Table VIII (Appendix).

Procedure

31. (*a*) Examine the inside of the tank shell for the purpose of removing any foreign substance, such as dirt, rust, etc. Then weigh the car with tank empty. This is the tare weight. (Wedges, if used to steady the car when filled, should also be used on empty weight to insure that net weight includes only the water in the tank.)

(*b*) After the tare weight is established, fill the tank with water up to the top of the nozzle. The last 100 gal shall be at a slow flow rate, not exceeding 10 gpm. Then allow the car to stand for 15 min to permit settling and escape of air in water. Following this, water should be added to bring the level to top of nozzle. The car shall then be weighed and the weight recorded. This is the gross weight.

(*c*) Take the temperature of water at approximately the vertical center of tank. The thermometer used for determining

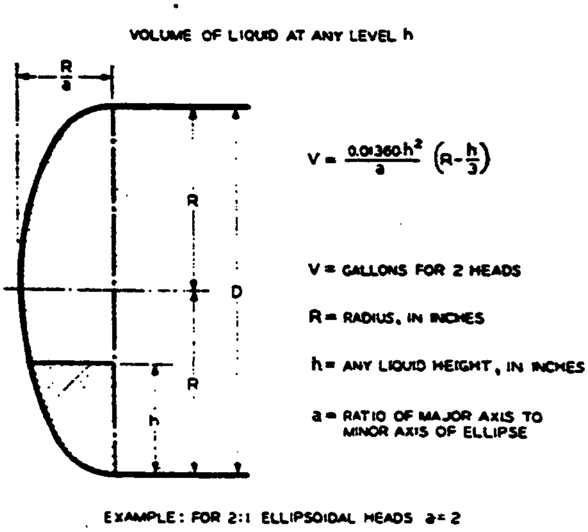


FIG. 10.—VOLUME EQUATIONS FOR VARIOUS LIQUID LEVELS—ELLIPSOIDAL HEADS.

temperature shall be a type which is accurately calibrated. Inspect the mercury column for separations before each occasion of use. The thermometer shall be checked periodically against a "standard" thermometer. Replace any thermometers with readings deviating from the standard thermometer by more than plus or minus ½ F.

(*d*) Obtain the net weight by subtracting the tare from the gross weight. Multiply this weight by the correction factor to obtain corrected net weight for water at 60 F. The weight of one gallon of water in air at 60 F is equal to 8.328247 lb established by the U. S. Bureau of Standards. Corrected net weight divided by 8.328247 equals gallons capacity for the tank. The shell capacity can be determined by deducting the calculated capacity of the manway nozzle.

APPENDIX

TABLES FOR DETERMINATION OF INCREMENTAL VOLUMES AND WATER DENSITY COEFFICIENTS

TABLE V.—COEFFICIENTS FOR THE VOLUMES OF SEGMENTS OF DISHED HEADS.

Taken with Permission of California Natural Gasoline Association from Their Bulletin TS-341 (1934)

USE OF TABLE

In the table find the value of coefficient *K* for the desired value of *m/r* (ratio of depth of segment to radius of head cylinder). The full volume of the head multiplied by the coefficient equals the volume of the segment.

m/r	*K*	Diff.	*m/r*	*K*	Diff.	*m/r*	*K*	Diff.	*m/r*	*K*	Diff.
.001	.00000	0	.050	.00055	3	.100	.00300	8	.150	.00801	13
2	.00000	0	1	.00058	3	1	.00308	7	1	.00814	13
3	.00000	0	2	.00061	3	2	.00315	7	2	.00827	13
4	.00000	0	3	.00064	3	3	.00322	8	3	.00840	13
5	.00000	0	4	.00067	3	4	.00330	8	4	.00853	13
6	.00000	0	5	.00070	2	5	.00338	8	5	.00866	14
7	.00000	1	6	.00072	4	6	.00346	8	6	.00880	14
8	.00001	0	7	.00076	3	7	.00354	8	7	.00894	13
9	.00001	0	8	.00079	3	8	.00362	8	8	.00907	14
			9	.00082	4	9	.00370	9	9	.00921	14
.010	.00001	1	.060	.00086	4	.110	.00379	9	.160	.00935	14
1	.00002	0	1	.00090	3	1	.00388	8	1	.00949	14
2	.00002	0	2	.00093	4	2	.00396	8	2	.00963	15
3	.00002	0	3	.00097	4	3	.00404	9	3	.00978	14
4	.00002	0	4	.00101	4	4	.00413	9	4	.00992	14
5	.00002	1	5	.00105	4	5	.00422	9	5	.01006	15
6	.00003	1	6	.00109	4	6	.00431	9	6	.01021	15
7	.00004	0	7	.00113	4	7	.00440	9	7	.01036	15
8	.00004	1	8	.00117	5	8	.00449	9	8	.01051	15
9	.00005	1	9	.00122	4	9	.00458	10	9	.01066	15
.020	.00006	0	.070	.00126	4	.120	.00468	10	.170	.01081	15
1	.00006	1	1	.00130	5	1	.00478	9	1	.01096	16
2	.00007	1	2	.00135	5	2	.00487	9	2	.01112	16
3	.00008	1	3	.00140	4	3	.00496	10	3	.01128	15
4	.00009	1	4	.00144	5	4	.00506	10	4	.01143	15
5	.00010	1	5	.00149	5	5	.00516	10	5	.01158	16
6	.00011	1	6	.00154	5	6	.00526	10	6	.01174	16
7	.00012	1	7	.00159	5	7	.00536	11	7	.01190	16
8	.00013	1	8	.00164	5	8	.00547	10	8	.01206	16
9	.00014	2	9	.00169	5	9	.00557	10	9	.01222	17
.030	.00016	1	.080	.00174	6	.130	.00567	11	.180	.01239	17
1	.00017	1	1	.00180	5	1	.00578	11	1	.01256	16
2	.00018	2	2	.00185	5	2	.00589	11	2	.01272	17
3	.00020	1	3	.00190	6	3	.00600	10	3	.01289	17
4	.00021	1	4	.00196	6	4	.00610	12	4	.01306	17
5	.00022	2	5	.00202	6	5	.00622	11	5	.01323	17
6	.00024	2	6	.00208	6	6	.00633	11	6	.01340	17
7	.00026	2	7	.00214	6	7	.00644	11	7	.01357	17
8	.00028	2	8	.00220	6	8	.00655	11	8	.01374	18
9	.00030	2	9	.00226	6	9	.00666	12	9	.01392	17
.040	.00032	2	.090	.00232	6	.140	.00678	12	.190	.01409	18
1	.00034	2	1	.00238	7	1	.00690	12	1	.01427	18
2	.00036	2	2	.00245	7	2	.00702	12	2	.01445	17
3	.00038	2	3	.00252	6	3	.00714	12	3	.01462	18
4	.00040	2	4	.00258	7	4	.00726	12	4	.01480	18
5	.00042	3	5	.00265	7	5	.00738	13	5	.01498	19
6	.00045	3	6	.00272	7	6	.00751	13	6	.01517	19
7	.00048	2	7	.00279	7	7	.00764	12	7	.01536	18
8	.00050	2	8	.00286	7	8	.00776	12	8	.01554	18
9	.00052	3	9	.00293	7	9	.00788	13	9	.01572	19

TABLE V.—(*Continued*)

m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.
.200	.01591	19	.260	.02948	26	.320	.04762	34	.380	.07029	41
1	.01610	19	1	.02974	27	1	.04796	34	1	.07070	42
2	.01629	19	2	.03001	27	2	.04830	34	2	.07112	42
3	.01648	20	3	.03028	27	3	.04864	35	3	.07154	42
4	.01668	20	4	.03055	27	4	.04899	35	4	.07196	42
5	.01688	19	5	.03082	27	5	.04934	34	5	.07238	42
6	.01707	19	6	.03109	27	6	.04968	35	6	.07280	42
7	.01726	20	7	.03136	27	7	.05003	35	7	.07322	43
8	.01746	20	8	.03163	27	8	.05038	35	8	.07365	43
9	.01766	20	9	.03190	28	9	.05073	35	9	.07408	42
.210	.01786	20	.270	.03218	28	.330	.05108	36	.390	.07450	43
1	.01806	20	1	.03246	28	1	.05144	35	1	.07493	43
2	.01826	20	2	.03274	28	2	.05179	35	2	.07536	43
3	.01846	21	3	.03302	28	3	.05214	36	3	.07579	43
4	.01867	21	4	.03330	28	4	.05250	36	4	.07622	44
5	.01888	21	5	.03358	29	5	.05286	36	5	.07666	43
6	.01909	21	6	.03387	29	6	.05322	36	6	.07709	43
7	.01930	21	7	.03416	28	7	.05358	37	7	.07752	44
8	.01951	21	8	.03444	29	8	.05395	36	8	.07796	44
9	.01972	21	9	.03473	29	9	.05431	36	9	.07840	44
.220	.01993	21	.280	.03502	29	.340	.05467	37	.400	.07884	44
1	.02014	22	1	.03531	29	1	.05504	37	1	.07928	44
2	.02036	22	2	.03560	30	2	.05541	37	2	.07972	44
3	.02058	22	3	.03590	29	3	.05578	37	3	.08016	44
4	.02080	22	4	.03619	29	4	.05615	37	4	.08060	45
5	.02102	22	5	.03648	30	5	.05652	37	5	.08105	45
6	.02124	22	6	.03678	30	6	.05689	37	6	.08150	44
7	.02146	22	7	.03708	29	7	.05726	38	7	.08194	45
8	.02168	22	8	.03737	31	8	.05764	38	8	.08239	45
9	.02190	23	9	.03768	30	9	.05802	37	9	.08284	45
.230	.02213	23	.290	.03798	30	.350	.05839	38	.410	.08329	45
1	.02236	22	1	.03828	30	1	.05877	38	1	.08374	46
2	.02258	23	2	.03858	30	2	.05915	38	2	.08420	45
3	.02281	23	3	.03888	31	3	.05953	38	3	.08465	45
4	.02304	24	4	.03919	31	4	.05991	39	4	.08510	46
5	.02328	23	5	.03950	31	5	.06030	38	5	.08556	46
6	.02351	23	6	.03981	31	6	.06068	39	6	.08602	46
7	.02374	24	7	.04012	32	7	.06107	39	7	.08648	46
8	.02398	24	8	.04044	31	8	.06146	38	8	.08694	46
9	.02422	23	9	.04075	31	9	.06184	39	9	.08740	46
.240	.02445	24	.300	.04106	32	.360	.06223	39	.420	.08786	46
1	.02469	24	1	.04138	32	1	.06262	40	1	.08832	47
2	.02493	25	2	.04170	32	2	.06302	39	2	.08879	47
3	.02518	24	3	.04202	31	3	.06341	39	3	.08926	47
4	.02542	24	4	.04233	33	4	.06380	40	4	.08973	47
5	.02566	25	5	.04266	32	5	.06420	40	5	.09020	47
6	.02591	25	6	.04298	32	6	.06460	40	6	.09067	47
7	.02616	24	7	.04330	32	7	.06500	40	7	.09114	47
8	.02640	25	8	.04362	33	8	.06540	40	8	.09161	47
9	.02665	25	9	.04395	33	9	.06580	40	9	.09208	48
.250	.02690	26	.310	.04428	33	.370	.06620	40	.430	.09256	48
1	.02716	25	1	.04461	33	1	.06660	41	1	.09304	47
2	.02741	25	2	.04494	33	2	.06701	41	2	.09351	48
3	.02766	26	3	.04527	33	3	.06742	40	3	.09399	48
4	.02792	26	4	.04560	34	4	.06782	41	4	.09447	48
5	.02818	25	5	.04594	33	5	.06823	41	5	.09495	48
6	.02843	27	6	.04627	33	6	.06864	41	6	.09543	48
7	.02870	26	7	.04660	34	7	.06905	41	7	.09591	48
8	.02896	26	8	.04694	34	8	.06946	42	8	.09639	49
9	.02922	26	9	.04728	34	9	.06988	41	9	.09688	48

TABLE V.—(*Continued*)

m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.
.440	.09736	49	.500	.12861	55	.560	.16372	62	.620	.20234	67
1	.09785	49	1	.12916	56	1	.16434	61	1	.20301	67
2	.09834	49	2	.12972	56	2	.16495	62	2	.20368	68
3	.09883	49	3	.13028	55	3	.16557	62	3	.20436	67
4	.09932	49	4	.13083	56	4	.16619	62	4	.20503	67
5	.09981	49	5	.13139	56	5	.16681	62	5	.20570	68
6	.10030	50	6	.13195	56	6	.16743	62	6	.20638	68
7	.10080	49	7	.13251	56	7	.16805	62	7	.20706	67
8	.10129	50	8	.13307	57	8	.16867	63	8	.20773	68
9	.10179	50	9	.13364	56	9	.16930	62	9	.20841	68
.450	.10229	50	.510	.13420	56	.570	.16992	62	.630	.20909	68
1	.10279	50	1	.13476	57	1	.17054	63	1	.20977	68
2	.10329	50	2	.13533	57	2	.17117	63	2	.21045	68
3	.10379	50	3	.13590	56	3	.17180	63	3	.21113	68
4	.10429	51	4	.13646	57	4	.17243	63	4	.21181	69
5	.10480	50	5	.13703	57	5	.17306	63	5	.21250	68
6	.10530	50	6	.13760	58	6	.17369	63	6	.21318	68
7	.10580	51	7	.13818	57	7	.17432	63	7	.21386	69
8	.10631	51	8	.13875	57	8	.17495	63	8	.21455	69
9	.10682	51	9	.13932	58	9	.17558	64	9	.21524	69
.460	.10733	51	.520	.13990	58	.580	.17622	64	.640	.21593	69
1	.10784	51	1	.14048	57	1	.17686	63	1	.21662	68
2	.10835	51	2	.14105	57	2	.17749	64	2	.21730	69
3	.10886	52	3	.14162	58	3	.17813	64	3	.21799	69
4	.10938	52	4	.14220	58	4	.17877	63	4	.21868	70
5	.10990	51	5	.14278	58	5	.17940	64	5	.21938	69
6	.11041	51	6	.14336	58	6	.18004	64	6	.22007	69
7	.11092	52	7	.14394	59	7	.18068	65	7	.22076	69
8	.11144	52	8	.14453	59	8	.18133	64	8	.22145	69
9	.11196	52	9	.14512	58	9	.18197	64	9	.22214	70
.470	.11248	52	.530	.14570	58	.590	.18261	65	.650	.22284	70
1	.11300	53	1	.14628	59	1	.18326	64	1	.22354	70
2	.11353	52	2	.14687	59	2	.18390	65	2	.22424	70
3	.11405	52	3	.14746	59	3	.18455	65	3	.22494	69
4	.11457	53	4	.14805	59	4	.18520	64	4	.22563	70
5	.11510	53	5	.14864	59	5	.18584	65	5	.22633	70
6	.11563	53	6	.14923	59	6	.18649	65	6	.22703	71
7	.11616	52	7	.14982	60	7	.18714	65	7	.22774	70
8	.11668	53	8	.15042	59	8	.18779	65	8	.22844	70
9	.11721	53	9	.15101	59	9	.18844	66	9	.22914	70
.480	.11774	54	.540	.15160	60	.600	.18910	66	.660	.22984	70
1	.11828	53	1	.15220	60	1	.18976	65	1	.23054	71
2	.11881	53	2	.15280	60	2	.19041	65	2	.23125	71
3	.11934	54	3	.15340	59	3	.19106	66	3	.23196	70
4	.11988	54	4	.15399	61	4	.19172	66	4	.23266	71
5	.12042	54	5	.15460	60	5	.19238	65	5	.23337	71
6	.12096	54	6	.15520	60	6	.19303	66	6	.23408	71
7	.12150	54	7	.15580	60	7	.19369	66	7	.23479	71
8	.12204	54	8	.15640	60	8	.19435	66	8	.23550	71
9	.12258	54	9	.15700	61	9	.19501	66	9	.23621	71
.490	.12312	54	.550	.15761	61	.610	.19567	67	.670	.23692	71
1	.12366	55	1	.15822	60	1	.19634	66	1	.23763	71
2	.12421	55	2	.15882	61	2	.19700	66	2	.23834	72
3	.12476	54	3	.15943	61	3	.19766	67	3	.23906	71
4	.12530	55	4	.16004	61	4	.19833	67	4	.23977	71
5	.12585	55	5	.16065	61	5	.19900	66	5	.24048	72
6	.12640	55	6	.16126	62	6	.19966	67	6	.24120	72
7	.12695	55	7	.16188	61	7	.20033	67	7	.24192	72
8	.12750	56	8	.16249	61	8	.20100	67	8	.24264	72
9	.12806	55	9	.16310	62	9	.20167	67	9	.24336	71

TABLE V.—(*Continued*)

m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.
.680	.24407	72	.740	.28848	76	.800	.33510	79	.860	.38343	81
1	.24479	72	1	.28924	76	1	.33589	79	1	.38424	82
2	.24551	72	2	.29000	76	2	.33668	80	2	.38506	82
3	.24623	72	3	.29076	77	3	.33748	79	3	.38588	82
4	.24695	73	4	.29153	76	4	.33827	79	4	.38670	82
5	.24768	72	5	.29229	76	5	.33906	80	5	.38752	82
6	.24840	72	6	.29305	77	6	.33986	80	6	.38834	82
7	.24912	73	7	.29382	76	7	.34066	79	7	.38916	82
8	.24985	73	8	.29458	76	8	.34145	80	8	.38998	82
9	.25058	72	9	.29534	77	9	.34225	80	9	.39080	82
.690	.25130	72	.750	.29611	77	.810	.34305	79	.870	.39162	82
1	.25202	73	1	.29688	76	1	.34384	80	1	.39244	82
2	.25275	73	2	.29764	77	2	.34464	80	2	.39326	82
3	.25348	73	3	.29841	77	3	.34544	80	3	.39408	82
4	.25421	73	4	.29918	77	4	.34624	80	4	.39490	82
5	.25494	73	5	.29995	77	5	.34704	80	5	.39572	82
6	.25567	73	6	.30072	77	6	.34784	80	6	.39654	82
7	.25640	73	7	.30149	77	7	.34864	80	7	.39736	83
8	.25713	73	8	.30226	77	8	.34944	80	8	.39819	83
9	.25786	74	9	.30303	77	9	.35024	80	9	.39902	82
.700	.25860	74	.760	.30380	77	.820	.35104	80	.880	.39984	82
1	.25934	73	1	.30457	77	1	.35184	80	1	.40066	82
2	.26007	73	2	.30534	78	2	.35264	80	2	.40148	82
3	.26080	74	3	.30612	77	3	.35344	81	3	.40230	83
4	.26154	74	4	.30689	77	4	.35425	81	4	.40313	83
5	.26228	73	5	.30766	78	5	.35506	80	5	.40396	82
6	.26301	74	6	.30844	78	6	.35586	80	6	.40478	82
7	.26375	74	7	.30922	77	7	.35666	81	7	.40560	83
8	.26449	74	8	.30999	77	8	.35747	81	8	.40643	83
9	.26523	74	9	.31076	78	9	.35828	80	9	.40726	82
.710	.26597	74	.770	.31150	78	.830	.35908	80	.890	.40808	83
1	.26671	74	1	.31232	78	1	.35988	81	1	.40891	83
2	.26745	75	2	.31310	78	2	.36069	81	2	.40974	82
3	.26820	74	3	.31388	78	3	.36150	81	3	.41056	83
4	.26894	74	4	.31466	78	4	.36231	81	4	.41139	83
5	.26968	75	5	.31544	78	5	.36312	80	5	.41222	82
6	.27043	75	6	.31622	78	6	.36392	81	6	.41304	83
7	.27118	74	7	.31700	78	7	.36473	81	7	.41387	83
8	.27192	74	8	.31778	78	8	.36554	81	8	.41470	83
9	.27266	75	9	.31856	78	9	.36635	81	9	.41553	83
.720	.27341	75	.780	.31934	78	.840	.36716	81	.900	.41636	83
1	.27416	74	1	.32012	79	1	.36797	81	1	.41719	83
2	.27490	75	2	.32091	79	2	.36878	81	2	.41802	82
3	.27565	75	3	.32170	78	3	.36959	81	3	.41884	83
4	.27640	75	4	.32248	78	4	.37040	81	4	.41967	83
5	.27715	75	5	.32326	79	5	.37121	81	5	.42050	83
6	.27790	76	6	.32405	79	6	.37202	82	6	.42133	83
7	.27866	75	7	.32484	78	7	.37284	81	7	.42216	84
8	.27941	75	8	.32562	78	8	.37365	81	8	.42300	83
9	.28016	75	9	.32640	79	9	.37446	82	9	.42383	83
.730	.28091	75	.790	.32719	79	.850	.37528	81	.910	.42466	83
1	.28166	76	1	.32798	79	1	.37609	81	1	.42549	83
2	.28242	76	2	.32877	79	2	.37690	82	2	.42632	83
3	.28318	75	3	.32956	79	3	.37772	81	3	.42715	83
4	.28393	76	4	.33035	79	4	.37853	81	4	.42798	84
5	.28469	76	5	.33114	79	5	.37934	82	5	.42882	83
6	.28545	75	6	.33193	79	6	.38016	82	6	.42965	83
7	.28620	76	7	.33272	79	7	.38098	82	7	.43048	83
8	.28696	76	8	.33351	79	8	.38180	82	8	.43131	83
9	.28772	76	9	.33430	80	9	.38262	81	9	.43214	84

TABLE V.—(*Concluded*)

m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.	m/r	K	Diff.
.920	.43298	83	.940	.44967	84	.960	.46643	84	.980	.48322	84
1	.43381	83	1	.45051	84	1	.46727	84	1	.48406	84
2	.43464	84	2	.45135	83	2	.46811	83	2	.48490	84
3	.43548	83	3	.45218	84	3	.46894	84	3	.48574	84
4	.43631	83	4	.45302	84	4	.46978	84	4	.48658	84
5	.43714	84	5	.45386	84	5	.47062	84	5	.48742	85
6	.43798	84	6	.45470	84	6	.47146	84	6	.48827	84
7	.43882	83	7	.45554	83	7	.47230	84	7	.48911	84
8	.43965	83	8	.45637	83	8	.47314	84	8	.48995	84
9	.44048	84	9	.45720	84	9	.47398	84	9	.49079	84
.930	.44132	84	.950	.45804	84	.970	.47482	84	.990	.49163	84
1	.44216	83	1	.45888	84	1	.47566	84	1	.49247	84
2	.44299	83	2	.45972	84	2	.47650	84	2	.49331	84
3	.44382	84	3	.46056	84	3	.47734	84	3	.49415	84
4	.44466	84	4	.46140	84	4	.47818	84	4	.49499	84
5	.44550	83	5	.46224	83	5	.47902	84	5	.49583	84
6	.44633	83	6	.46307	84	6	.47986	84	6	.49667	84
7	.44716	84	7	.46391	84	7	.48070	84	7	.49751	84
8	.44800	84	8	.46475	84	8	.48154	84	8	.49835	83
9	.44884	83	9	.46559	84	9	.48238	84	9	.49918	82
									1.000	.50000	

TABLE VI.—COEFFICIENTS FOR THE AREAS OF SEGMENTS OF CIRCLES.

Taken with Permission of California Natural Gasoline Association from Their Bulletin TS-341 (1934)

USE OF TABLE

In the table find the value of coefficient G for the desired value of m/R (ratio of depth of segment to radius of cylinder). The full volume of the cylinder multiplied by the coefficient equals the volume of the segment.

m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.
.000	.0000000	190	.050	.0066600	1998	.100	.0186930	2782	.150	.0340737	3359
1	.0000190	347	1	.0068598	2016	1	.0189712	2794	1	.0344096	3369
2	.0000537	449	2	.0070614	2036	2	.0192506	2808	2	.0347465	3379
3	.0000986	531	3	.0072650	2054	3	.0195314	2821	3	.0350844	3389
4	.0001517	603	4	.0074704	2073	4	.0198135	2833	4	.0354233	3400
5	.0002120	667	5	.0076777	2092	5	.0200968	2846	5	.0357633	3409
6	.0002787	725	6	.0078869	2109	6	.0203814	2859	6	.0361042	3420
7	.0003512	778	7	.0080978	2128	7	.0206673	2871	7	.0364462	3429
8	.0004290	828	8	.0083106	2145	8	.0209544	2884	8	.0367891	3440
9	.0005118	875	9	.0085251	2163	9	.0212428	2897	9	.0371331	3449
.010	.0005993	920	.060	.0087414	2181	.110	.0215325	2909	.160	.0374780	3459
1	.0006913	963	1	.0089595	2198	1	.0218234	2921	1	.0378239	3469
2	.0007876	1003	2	.0091793	2216	2	.0221155	2934	2	.0381708	3479
3	.0008879	1043	3	.0094009	2232	3	.0224089	2945	3	.0385187	3488
4	.0009922	1080	4	.0096241	2249	4	.0227034	2958	4	.0388675	3498
5	.0011002	1116	5	.0098490	2266	5	.0229992	2970	5	.0392173	3508
6	.0012118	1152	6	.0100756	2283	6	.0232962	2983	6	.0395681	3518
7	.0013270	1186	7	.0103039	2299	7	.0235945	2994	7	.0399199	3527
8	.0014456	1218	8	.0105338	2316	8	.0238939	3006	8	.0402726	3536
9	.0015674	1251	9	.0107654	2332	9	.0241945	3018	9	.0406262	3546
.020	.0016925	1283	.070	.0109986	2348	.120	.0244963	3029	.170	.0409808	3556
1	.0018208	1313	1	.0112334	2364	1	.0247992	3042	1	.0413364	3565
2	.0019521	1343	2	.0114698	2380	2	.0251034	3053	2	.0416929	3574
3	.0020864	1372	3	.0117078	2395	3	.0254087	3064	3	.0420503	3584
4	.0022236	1400	4	.0119473	2412	4	.0257151	3077	4	.0424087	3593
5	.0023636	1429	5	.0121885	2426	5	.0260228	3088	5	.0427680	3602
6	.0025065	1456	6	.0124311	2442	6	.0263316	3099	6	.0431282	3612
7	.0026521	1482	7	.0126753	2458	7	.0266415	3110	7	.0434894	3621
8	.0028003	1509	8	.0129211	2472	8	.0269525	3122	8	.0438515	3630
9	.0029512	1535	9	.0131683	2488	9	.0272647	3134	9	.0442145	3639
.030	.0031047	1560	.080	.0134171	2502	.130	.0275781	3144	.180	.0445784	3649
1	.0032607	1586	1	.0136673	2518	1	.0278925	3156	1	.0449433	3657
2	.0034193	1610	2	.0139191	2532	2	.0282081	3167	2	.0453090	3666
3	.0035803	1633	3	.0141723	2546	3	.0285248	3177	3	.0456756	3676
4	.0037436	1658	4	.0144269	2561	4	.0288425	3189	4	.0460432	3684
5	.0039094	1681	5	.0146830	2576	5	.0291614	3200	5	.0464116	3694
6	.0040775	1705	6	.0149406	2590	6	.0294814	3211	6	.0467810	3702
7	.0042480	1727	7	.0151996	2604	7	.0298025	3221	7	.0471512	3711
8	.0044207	1749	8	.0154600	2619	8	.0301246	3233	8	.0475223	3720
9	.0045956	1772	9	.0157219	2632	9	.0304479	3243	9	.0478943	3729
.040	.0047728	1793	.090	.0159851	2647	.140	.0307722	3254	.190	.0482672	3738
1	.0049521	1815	1	.0162498	2660	1	.0310976	3265	1	.0486410	3747
2	.0051336	1836	2	.0165158	2674	2	.0314241	3275	2	.0490157	3755
3	.0053172	1858	3	.0167832	2688	3	.0317516	3286	3	.0493912	3764
4	.0055030	1877	4	.0170520	2701	4	.0320802	3297	4	.0497676	3772
5	.0056907	1899	5	.0173221	2715	5	.0324099	3306	5	.0501448	3782
6	.0058806	1919	6	.0175936	2729	6	.0327405	3318	6	.0505230	3789
7	.0060725	1938	7	.0178665	2742	7	.0330723	3328	7	.0509019	3799
8	.0062663	1959	8	.0181407	2755	8	.0334051	3338	8	.0512818	3807
9	.0064622	1978	9	.0184162	2768	9	.0337389	3348	9	.0516625	3815

TABLE IV.—(*Continued*)

m/R	*G*	Diff.	*m/R*	*G*	Diff.	*m/R*	*G*	Diff.	*m/R*	*G*	Diff.
.200	.0520440	3824	.260	.0763934	4285	.320	.1032755	4670	.380	.1322897	4998
1	.0524264	3833	1	.0768219	4292	1	.1037425	4677	1	.1327895	5003
2	.0528097	3840	2	.0772511	4300	2	.1042102	4682	2	.1332898	5007
3	.0531937	3850	3	.0776811	4307	3	.1046784	4689	3	.1337905	5013
4	.0535787	3857	4	.0781118	4313	4	.1051473	4694	4	.1342918	5017
5	.0539644	3866	5	.0785431	4320	5	.1056167	4700	5	.1347935	5022
6	.0543510	3875	6	.0789751	4327	6	.1060867	4706	6	.1352957	5027
7	.0547385	3882	7	.0794078	4334	7	.1065573	4712	7	.1357984	5033
8	.0551267	3891	8	.0798412	4340	8	.1070285	4716	8	.1363017	5037
9	.0555158	3899	9	.0802752	4348	9	.1075001	4724	9	.1368054	5042
.210	.0559057	3907	.270	.0807100	4354	.330	.1079725	4728	.390	.1373096	5047
1	.0562964	3916	1	.0811454	4361	1	.1084453	4736	1	.1378143	5052
2	.0566880	3923	2	.0815815	4369	2	.1089189	4740	2	.1383195	5057
3	.0570803	3932	3	.0820184	4374	3	.1093929	4746	3	.1388252	5062
4	.0574735	3940	4	.0824558	4381	4	.1098675	4752	4	.1393314	5066
5	.0578675	3948	5	.0828939	4389	5	.1103427	4757	5	.1398380	5071
6	.0582623	3955	6	.0833328	4394	6	.1108184	4763	6	.1403451	5077
7	.0586578	3964	7	.0837722	4401	7	.1112947	4769	7	.1408528	5080
8	.0590542	3972	8	.0842123	4408	8	.1117716	4774	8	.1413608	5086
9	.0594514	3980	9	.0846531	4415	9	.1122490	4780	9	.1418694	5091
.220	.0598494	3988	.280	.0850946	4422	.340	.1127270	4786	.400	.1423785	5095
1	.0602482	3995	1	.0855368	4427	1	.1132056	4790	1	.1428880	5100
2	.0606477	4004	2	.0859795	4435	2	.1136846	4797	2	.1433980	5105
3	.0610481	4012	3	.0864230	4441	3	.1141643	4802	3	.1439085	5110
4	.0614493	4019	4	.0868671	4447	4	.1146445	4808	4	.1444195	5114
5	.0618512	4027	5	.0873118	4454	5	.1151253	4813	5	.1449309	5119
6	.0622539	4035	6	.0877572	4461	6	.1156066	4819	6	.1454428	5124
7	.0626574	4042	7	.0882033	4467	7	.1160885	4824	7	.1459552	5129
8	.0630616	4051	8	.0886500	4473	8	.1165709	4830	8	.1464681	5133
9	.0634667	4058	9	.0890973	4480	9	.1170539	4835	9	.1469814	5137
.230	.0638725	4066	.290	.0895453	4487	.350	.1175374	4841	.410	.1474951	5142
1	.0642791	4073	1	.0899940	4492	1	.1180215	4846	1	.1480093	5147
2	.0646864	4081	2	.0904432	4499	2	.1185061	4851	2	.1485240	5152
3	.0650945	4089	3	.0908931	4506	3	.1189912	4857	3	.1490392	5157
4	.0655034	4096	4	.0913437	4512	4	.1194769	4862	4	.1495549	5161
5	.0659130	4104	5	.0917949	4518	5	.1199631	4868	5	.1500710	5165
6	.0663234	4111	6	.0922467	4524	6	.1204499	4873	6	.1505875	5170
7	.0667345	4119	7	.0926991	4531	7	.1209372	4878	7	.1511045	5175
8	.0671464	4126	8	.0931522	4536	8	.1214250	4884	8	.1516220	5179
9	.0675590	4134	9	.0936058	4544	9	.1219134	4889	9	.1521399	5184
.240	.0679724	4142	.300	.0940602	4549	.360	.1224023	4894	.420	.1526583	5187
1	.0683866	4148	1	.0945151	4556	1	.1228917	4899	1	.1531770	5194
2	.0688014	4156	2	.0949707	4562	2	.1233816	4906	2	.1536964	5197
3	.0692170	4164	3	.0954269	4569	3	.1238722	4910	3	.1542161	5202
4	.0696334	4171	4	.0958838	4574	4	.1243632	4915	4	.1547363	5206
5	.0700505	4178	5	.0963412	4580	5	.1248547	4920	5	.1552569	5211
6	.0704683	4185	6	.0967992	4587	6	.1253467	4926	6	.1557780	5215
7	.0708868	4193	7	.0972579	4592	7	.1258393	4931	7	.1562995	5220
8	.0713061	4200	8	.0977171	4599	8	.1263324	4936	8	.1568215	5223
9	.0717261	4207	9	.0981770	4605	9	.1268260	4942	9	.1573438	5229
.250	.0721468	4214	.310	.0986375	4611	.370	.1273202	4946	.430	.1578667	5233
1	.0725682	4222	1	.0990986	4617	1	.1278148	4952	1	.1583900	5237
2	.0729904	4229	2	.0995603	4623	2	.1283100	4957	2	.1589137	5243
3	.0734133	4236	3	.1000226	4629	3	.1288057	4962	3	.1594380	5246
4	.0738369	4243	4	.1004855	4635	4	.1293019	4967	4	.1599626	5250
5	.0742612	4250	5	.1009490	4641	5	.1297986	4972	5	.1604876	5255
6	.0746862	4257	6	.1014131	4647	6	.1302958	4977	6	.1610131	5259
7	.0751119	4265	7	.1018778	4653	7	.1307935	4983	7	.1615390	5264
8	.0755384	4271	8	.1023431	4659	8	.1312918	4987	8	.1620654	5268
9	.0759655	4279	9	.1028090	4665	9	.1317905	4992	9	.1625922	5272

TABLE VI.—(*Continued*)

m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.
.440	.1631194	5276	.500	.1955011	5515	.560	.2292081	5719	.620	.2640397	5890
1	.1636470	5282	1	.1960526	5519	1	.2297800	5721	1	.2646287	5892
2	.1641752	5284	2	.1966045	5522	2	.2303521	5724	2	.2652179	5896
3	.1647036	5290	3	.1971567	5526	3	.2309245	5729	3	.2658075	5897
4	.1652326	5293	4	.1977093	5530	4	.2314974	5730	4	.2663972	5901
5	.1657619	5298	5	.1982623	5534	5	.2320704	5735	5	.2669873	5902
6	.1662917	5302	6	.1988157	5537	6	.2326439	5736	6	.2675775	5906
7	.1668219	5306	7	.1993694	5541	7	.2332175	5740	7	.2681681	5908
8	.1673525	5311	8	.1999235	5543	8	.2337915	5744	8	.2687589	5911
9	.1678836	5315	9	.2004778	5548	9	.2343659	5745	9	.2693500	5913
.450	.1684151	5318	.510	.2010326	5551	.570	.2349404	5750	.630	.2699413	5915
1	.1689469	5323	1	.2015877	5555	1	.2355154	5752	1	.2705328	5918
2	.1694792	5328	2	.2021432	5559	2	.2360906	5754	2	.2711246	5921
3	.1700120	5331	3	.2026991	5562	3	.2366660	5759	3	.2717167	5924
4	.1705451	5336	4	.2032553	5565	4	.2372419	5761	4	.2723091	5925
5	.1710787	5339	5	.2038118	5570	5	.2378180	5764	5	.2729016	5929
6	.1716126	5345	6	.2043688	5572	6	.2383944	5767	6	.2734945	5930
7	.1721471	5348	7	.2049260	5576	7	.2389711	5770	7	.2740875	5933
8	.1726819	5351	8	.2054836	5580	8	.2395481	5773	8	.2746808	5937
9	.1732170	5357	9	.2060416	5583	9	.2401254	5776	9	.2752745	5937
.460	.1737527	5360	.520	.2065999	5587	.580	.2407030	5779	.640	.2758682	5940
1	.1742887	5365	1	.2071586	5590	1	.2412809	5782	1	.2764622	5944
2	.1748252	5368	2	.2077176	5594	2	.2418591	5785	2	.2770566	5945
3	.1753620	5372	3	.2082770	5597	3	.2424376	5788	3	.2776511	5948
4	.1758992	5377	4	.2088367	5600	4	.2430164	5790	4	.2782459	5951
5	.1764369	5380	5	.2093967	5604	5	.2435954	5794	5	.2788410	5953
6	.1769749	5384	6	.2099571	5606	6	.2441748	5797	6	.2794363	5955
7	.1775133	5389	7	.2105177	5612	7	.2447545	5799	7	.2800318	5957
8	.1780522	5392	8	.2110789	5614	8	.2453344	5802	8	.2806275	5960
9	.1785914	5397	9	.2116403	5617	9	.2459146	5805	9	.2812235	5962
.470	.1791311	5401	.530	.2122020	5622	.590	.2464951	5808	.650	.2818197	5965
1	.1796712	5404	1	.2127642	5623	1	.2470759	5811	1	.2824162	5968
2	.1802116	5409	2	.2133265	5629	2	.2476570	5813	2	.2830130	5969
3	.1807525	5412	3	.2138894	5631	3	.2482383	5817	3	.2836099	5971
4	.1812937	5416	4	.2144525	5634	4	.2488200	5819	4	.2842070	5975
5	.1818353	5421	5	.2150159	5637	5	.2494019	5823	5	.2848045	5975
6	.1823774	5424	6	.2155796	5641	6	.2499842	5824	6	.2854020	5980
7	.1829198	5428	7	.2161437	5644	7	.2505666	5828	7	.2860000	5981
8	.1834626	5431	8	.2167081	5648	8	.2511494	5831	8	.2865981	5984
9	.1840057	5437	9	.2172729	5652	9	.2517325	5833	9	.2871965	5985
.480	.1845494	5439	.540	.2178381	5653	.600	.2523158	5837	.660	.2877950	5988
1	.1850933	5444	1	.2184034	5658	1	.2528995	5838	1	.2883938	5990
2	.1856377	5448	2	.2189692	5661	2	.2534833	5841	2	.2889928	5994
3	.1861825	5450	3	.2195353	5664	3	.2540674	5845	3	.2895922	5994
4	.1867275	5456	4	.2201017	5668	4	.2546519	5847	4	.2901916	5998
5	.1872731	5459	5	.2206685	5671	5	.2552366	5850	5	.2907914	5999
6	.1878190	5463	6	.2212356	5673	6	.2558216	5852	6	.2913913	6002
7	.1883653	5466	7	.2218029	5677	7	.2564068	5856	7	.2919915	6003
8	.1889119	5470	8	.2223706	5681	8	.2569924	5857	8	.2925918	6008
9	.1894589	5475	9	.2229387	5684	9	.2575781	5862	9	.2931926	6008
.490	.1900064	5477	.550	.2235071	5686	.610	.2581643	5864	.670	.2937934	6011
1	.1905541	5483	1	.2240757	5690	1	.2587507	5865	1	.2943945	6013
2	.1911024	5485	2	.2246447	5694	2	.2593372	5868	2	.2949958	6015
3	.1916509	5489	3	.2252141	5696	3	.2599240	5873	3	.2955973	6017
4	.1921998	5493	4	.2257837	5700	4	.2605113	5874	4	.2961990	6019
5	.1927491	5496	5	.2263537	5703	5	.2610987	5877	5	.2968009	6022
6	.1932987	5501	6	.2269240	5705	6	.2616864	5879	6	.2974031	6024
7	.1938488	5503	7	.2274945	5709	7	.2622743	5882	7	.2980055	6026
8	.1943991	5508	8	.2280654	5713	8	.2628625	5885	8	.2986081	6028
9	.1949499	5512	9	.2286367	5714	9	.2634510	5887	9	.2992109	6030

TABLE VI.—(*Continued*)

m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.
.680	.2998139	6032	.740	.3363631	6149	.800	.3735300	6238	.860	.4111652	6305
1	.3004171	6035	1	.3369780	6149	1	.3741538	6240	1	.4117957	6304
2	.3010206	6038	2	.3375929	6151	2	.3747778	6241	2	.4124261	6306
3	.3016244	6038	3	.3382080	6153	3	.3754019	6242	3	.4130567	6307
4	.3022282	6041	4	.3388233	6156	4	.3760261	6243	4	.4136874	6307
5	.3028323	6044	5	.3394389	6157	5	.3766504	6245	5	.4143181	6308
6	.3034367	6045	6	.3400546	6157	6	.3772749	6246	6	.4149489	6310
7	.3040412	6047	7	.3406703	6161	7	.3778995	6247	7	.4155799	6310
8	.3046459	6050	8	.3412864	6161	8	.3785242	6249	8	.4162109	6310
9	.3052509	6051	9	.3419025	6163	9	.3791491	6249	9	.4168419	6312
.690	.3058560	6054	.750	.3425188	6166	.810	.3797740	6250	.870	.4174731	6313
1	.3064614	6055	1	.3431354	6166	1	.3803990	6253	1	.4181044	6314
2	.3070669	6058	2	.3437520	6168	2	.3810243	6254	2	.4187358	6313
3	.3076727	6060	3	.3443688	6169	3	.3816497	6253	3	.4193671	6316
4	.3082787	6062	4	.3449857	6172	4	.3822750	6256	4	.4199987	6315
5	.3088849	6064	5	.3456029	6173	5	.3829006	6257	5	.4206302	6318
6	.3094913	6065	6	.3462202	6175	6	.3835263	6258	6	.4212620	6316
7	.3100978	6068	7	.3468377	6176	7	.3841521	6260	7	.4218936	6318
8	.3107046	6071	8	.3474553	6178	8	.3847781	6261	8	.4225254	6321
9	.3113117	6071	9	.3480731	6179	9	.3854042	6261	9	.4231575	6319
.700	.3119188	6074	.760	.3486910	6181	.820	.3860303	6262	.880	.4237894	6321
1	.3125262	6076	1	.3493091	6182	1	.3866565	6265	1	.4244215	6320
2	.3131338	6078	2	.3499273	6184	2	.3872830	6265	2	.4250535	6322
3	.3137416	6081	3	.3505457	6185	3	.3879095	6266	3	.4256857	6324
4	.3143497	6081	4	.3511642	6188	4	.3885361	6267	4	.4263181	6323
5	.3149578	6084	5	.3517830	6188	5	.3891628	6269	5	.4269504	6325
6	.3155662	6086	6	.3524018	6191	6	.3897897	6269	6	.4275829	6325
7	.3161748	6088	7	.3530209	6191	7	.3904166	6271	7	.4282154	6326
8	.3167836	6089	8	.3536400	6194	8	.3910438	6272	8	.4288480	6325
9	.3173925	6092	9	.3542594	6195	9	.3916709	6273	9	.4294805	6328
.710	.3180017	6094	.770	.3548789	6196	.830	.3922982	6273	.890	.4301133	6328
1	.3186111	6095	1	.3554985	6197	1	.3929255	6276	1	.4307461	6329
2	.3192206	6097	2	.3561182	6199	2	.3935531	6276	2	.4313790	6328
3	.3198303	6099	3	.3567381	6201	3	.3941807	6278	3	.4320118	6331
4	.3204402	6102	4	.3573582	6203	4	.3948085	6278	4	.4326449	6331
5	.3210504	6103	5	.3579785	6203	5	.3954363	6280	5	.4332780	6331
6	.3216607	6105	6	.3585988	6205	6	.3960643	6280	6	.4339111	6332
7	.3222712	6107	7	.3592193	6207	7	.3966923	6282	7	.4345443	6332
8	.3228819	6109	8	.3598400	6208	8	.3973205	6283	8	.4351775	6334
9	.3234928	6110	9	.3604608	6210	9	.3979488	6283	9	.4358109	6334
.720	.3241038	6113	.780	.3610818	6211	.840	.3985771	6285	.900	.4364443	6335
1	.3247151	6115	1	.3617029	6213	1	.3992056	6285	1	.4370778	6335
2	.3253266	6115	2	.3623242	6213	2	.3998341	6287	2	.4377113	6335
3	.3259381	6119	3	.3629455	6216	3	.4004628	6288	3	.4383448	6336
4	.3265500	6119	4	.3635671	6216	4	.4010916	6289	4	.4389784	6338
5	.3271619	6122	5	.3641887	6218	5	.4017205	6290	5	.4396122	6337
6	.3277741	6123	6	.3648105	6219	6	.4023495	6290	6	.4402459	6339
7	.3283864	6126	7	.3654324	6221	7	.4029785	6291	7	.4408798	6340
8	.3289990	6127	8	.3660545	6222	8	.4036076	6293	8	.4415138	6339
9	.3296117	6128	9	.3666767	6224	9	.4042369	6295	9	.4421477	6340
.730	.3302245	6131	.790	.3672991	6225	.850	.4048664	6295	.910	.4427817	6340
1	.3308376	6133	1	.3679216	6226	1	.4054959	6296	1	.4434157	6342
2	.3314509	6133	2	.3685442	6227	2	.4061255	6295	2	.4440499	6341
3	.3320642	6136	3	.3691669	6229	3	.4067550	6298	3	.4446840	6343
4	.3326778	6138	4	.3697898	6231	4	.4073848	6298	4	.4453183	6343
5	.3332916	6141	5	.3704129	6231	5	.4080146	6299	5	.4459526	6343
6	.3339057	6140	6	.3710360	6234	6	.4086445	6301	6	.4465869	6344
7	.3345197	6143	7	.3716594	6234	7	.4092746	6302	7	.4472213	6345
8	.3351340	6144	8	.3722828	6235	8	.4099048	6301	8	.4478558	6344
9	.3357484	6147	9	.3729063	6237	9	.4105349	6303	9	.4484902	6346

TABLE VI.—(*Concluded*)

m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.	m/R	G	Diff.
.920	.4491248	6346	.940	.4618257	6355	.960	.4745420	6361	.980	.4872685	6364
1	.4497594	6347	1	.4624612	6355	1	.4751781	6361	1	.4879049	6365
2	.4503941	6347	2	.4630967	6356	2	.4758142	6363	2	.4885414	6365
3	.4510288	6346	3	.4637323	6356	3	.4764505	6362	3	.4891779	6366
4	.4516634	6349	4	.4643679	6357	4	.4770867	6362	4	.4898145	6366
5	.4522983	6348	5	.4650036	6357	5	.4777229	6361	5	.4904511	6365
6	.4529331	6350	6	.4656393	6356	6	.4783590	6363	6	.4910876	6366
7	.4535681	6350	7	.4662749	6358	7	.4789953	6363	7	.4917242	6366
8	.4542031	6350	8	.4669107	6357	8	.4796316	6364	8	.4923608	6365
9	.4548381	6349	9	.4675464	6359	9	.4802680	6363	9	.4929973	6366
.930	.4554730	6351	.950	.4681823	6359	.970	.4809043	6363	.990	.4936339	6366
1	.4561081	6352	1	.4688182	6358	1	.4815406	6363	1	.4942705	6367
2	.4567433	6351	2	.4694540	6359	2	.4821769	6365	2	.4949072	6364
3	.4573784	6352	3	.4700899	6360	3	.4828134	6363	3	.4955436	6367
4	.4580136	6353	4	.4707259	6359	4	.4834497	6365	4	.4961803	6366
5	.4586489	6352	5	.4713618	6359	5	.4840862	6364	5	.4968169	6366
6	.4592841	6354	6	.4719977	6361	6	.4847226	6364	6	.4974535	6366
7	.4599195	6354	7	.4726338	6360	7	.4853590	6365	7	.4980901	6367
8	.4605549	6353	8	.4732698	6361	8	.4859955	6364	8	.4987268	6365
9	.4611902	6355	9	.4739059	6361	9	.4866319	6366	9	.4993633	6367
									1.000	.5000000	

TABLE VII.—INCREMENTAL FILLS FOR TWO DOME POCKETS COMBINED.

d Dome Pocket Depth, per cent	*C* Total Capacity, per cent	*d* Dome Pocket Depth, per cent	*C* Total Capacity, per cent
1	0.03	51	12.75
2	0.07	52	13.50
3	0.10	53	14.25
4	0.13	54	15.00
5	0.17	55	15.78
6	0.20	56	16.71
7	0.23	57	17.59
8	0.27	58	18.50
9	0.30	59	19.50
10	0.33	60	20.50
11	0.37	61	21.59
12	0.40	62	22.59
13	0.43	63	23.64
14	0.47	64	24.73
15	0.50	65	25.82
16	0.63	66	27.00
17	0.69	67	28.25
18	0.75	68	29.55
19	0.88	69	30.82
20	1.00	70	32.33
21	1.06	71	33.63
22	1.23	72	35.11
23	1.47	73	36.50
24	1.61	74	38.18
25	1.75	75	39.63
26	1.85	76	41.35
27	2.16	77	43.25
28	2.40	78	45.00
29	2.64	79	46.90
30	2.88	80	48.68
31	3.25	81	50.71
32	3.50	82	52.88
33	3.87	83	55.00
34	4.21	84	57.13
35	4.58	85	59.29
36	5.00	86	61.25
37	5.34	87	63.40
38	5.80	88	65.55
39	6.21	89	67.68
40	6.71	90	70.00
41	7.21	91	72.38
42	7.69	92	75.00
43	8.18	93	77.55
44	8.71	94	80.25
45	9.25	95	83.10
46	9.78	96	86.00
47	10.29	97	89.13
48	10.77	98	92.35
49	11.48	99	96.10
50	12.15	100	100.00

TABLE VIII.—RELATIVE DENSITY OF WATER.

Water Density, lb per gal	Correction Factor	Temperature, °F	Water Density, lb per gal	Correction Factor
		70	8.3195248	1.0010484
		71	.3185015	1.0011715
8.3351290	.9991743	72	.3174520	1.0012978
.3354207	.9991394	73	.3163767	1.0014273
.3356664	.9991099	74	.3152758	1.0015599
8.3358669	.9990859	75	8.3141495	1.0016956
.3360231	.9990672	76	.3129982	1.0018343
.3361357	.9990536	77	.3118221	1.0019761
.3362057	.9990453	78	.3106215	1.0021208
.3362336	.9990419	79	.3093967	1.0022685
8.3362204	.9990435	80	8.3081478	1.0024192
.3361665	.9990500	81	.3068752	1.0025728
.3360729	.9990612	82	.3055790	1.0027292
.3359400	.9990771	83	.3042595	1.0028886
.3357686	.9990976	84	.3029170	1.0030507
8.3355593	.9991227	85	8.3015516	1.0032157
.3353127	.9991523	86	.3001635	1.0033835
.3350294	.9991863	87	.2987531	1.0035540
.3347100	.9992245	88	.2973204	1.0037273
.3343550	.9992671	89	.2958657	1.0039033
8.3339650	.9993139	90	8.2943891	1.0040820
.3335404	.9993648	91	.2928910	1.0042634
.3330819	.9994198	92	.2913714	1.0044474
.3325899	.9994788	93	.2898305	1.0046341
.3320649	.9995418	94	.2882686	1.0048235
8.3315074	.9996087	95	8.2866858	1.0050154
.3309177	.9996794	96	.2850823	1.0052099
.3302965	.9997540	97	.2834582	1.0054070
.3296440	.9998323	98	.2818137	1.0056066
.3289608	.9999143	99	.2801490	1.0058088
8.3282473	1.0000000	100	8.2784642	1.0060135
.3275037	1.0000892	101	.2767595	1.0062207
.3267306	1.0001821	102	.2750351	1.0064304
.3259283	1.0002785	103	.2732911	1.0066426
.3250972	1.0003783	104	.2715275	1.0068572
8.3242376	1.0004816	105	8.2697447	1.0070742
.3233499	1.0005883	106	.2679427	1.0072937
.3224345	1.0006984	107	.2661217	1.0075156
.3214916	1.0008118	108	.2642817	1.0077400
.3205216	1.0009285	109	.2624230	1.0079667

1-1700—10/65—4M
1-1700—1/82—5C
1-1700—9/83—5C
1-1700—11/84—5C
1-1700—9/86—2.5C
1-1700—12/87—2.5C
1-1700—8/89—2C (2A)
1-1700—5/90—2C (5D) C
1-1700—3/92—1C (1E) C
1-01102—10/93—1C (1E) U
PD-01200—11/96—0.75C (3E) U
11/98—XXV
6/00—0.3C

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