Manual of Petroleum Measurement Standards Chapter 2—Tank Calibration

Section 8A—Calibration of Tanks on Ships and Oceangoing Barges

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American Petroleum Institute
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FOREWORD

This standard has been prepared as a guide for the calibration of tanks on ships and oceangoing barges by liquid calibration or by vessel drawings. This document and Chapter 2, Section 7, "Calibration of Barge Tanks," of the API *Manual of Petroleum Measurement Standards* (MPMS) supersede the previous API Standard 2553, "Standard Method for Measurement and Calibration of Barges" (ASTM D 1407).

Other sections of Chapter 2 contain an overview of tank calibration, detailed procedures for calibrating various types of tanks, and a detailed discussion of liquid calibration. Upon revision, Chapter 2 will be divided into eleven sections, as follows:

- 2.1 Introduction to Tank Calibration.
- 2.2A Calibration of Upright Cylindrical Tanks (API Standard 2550).
- 2.2B Calibration of Upright Cylindrical Tanks Using the Optical Reference Line Method.
- 2.3 Calibration of Underground Tanks.
- 2.4 Calibration of Horizontal Tanks.
- 2.5 Calibration of Tank Cars and Trucks.
- 2.6 Calibration of Spherical and Spheroidal Tanks.
- 2.7 Calibration of Barge Tanks.
- 2.8A Calibration of Tanks on Ships and Oceangoing Barges.
- 2.8B Recommended Practice for the Establishment of the Location of the Reference Gauge Point and the Reference Gauge Height of Tanks on Marine Tank Vessels.
- 2.9 Liquid Calibration.

Note: Users of this chapter and any of its sections should be aware of and comply with any federal, state, or municipal regulations that have a bearing on the procedures described, including, in particular, those regulations dealing with the safe handling of volatile materials, worker safety, and environmental protection.

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of the standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard rather than by rewriting or incorporating sections of this standard into another complete standard.

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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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SECTION 8A—CALIBRATION OF TANKS ON SHIPS AND OCEANGOING BARGES

2.8A.1 Scope

This standard describes three methods for determining the total and incremental volumes of liquids in tanks on ships, oceangoing barges, and integrated tug barge units that have integral hull tanks. The three methods are:

a. Liquid calibration.
b. Calibration by linear measurement.
c. Calibration from vessel drawings.

Paragraphs 2.8A.5 through 2.8A.7 describe procedures and equipment for obtaining the field measurement data and suggestions for the orderly and complete recording of field data. Paragraphs 2.8A.8 through 2.8A.10 include procedures for calculating the total and incremental tank capacities from field data and suggestions for the presentation of capacity tables. An example of a typical form for such calculations is presented in Appendix A. Terms specific to the maritime industry are defined in Appendix B.

For vessels having independent tanks, refer to other sections of Chapter 2 for a similar discussion of horizontal, spherical, upright, and other mobile tanks. For smaller coastal and inland waterway barges, refer to Chapter 2, Section 7.

This standard addresses liquid calibration procedures pertaining to ships. For details relating to metering systems, installation, meter proving requirements, and other guidelines relating to liquid calibration, refer to API Standard 2555.

The capacity tables should be computed so that volume is given at standard conditions, that is, at 60°F (15°C). Appropriate liquid and tape temperature corrections to 60°F (15°C) shall be applied. API Standard 2543 and Chapter 17 should be consulted for temperature determination in the marine environment.

2.8A.2 Field of Application

Although primarily intended for the calibration of cargo tanks on tankers, the procedures described here also apply to calibration of tanks for fuel oil, ballast, and fresh water on all types of seagoing vessels.

2.8A.3 Safety

Before entering any compartment, permission must be obtained from the vessel's master, senior deck officer, authorized shipyard official, or other responsible person in charge. This responsible person should supply information regarding particular materials and conditions or the applicable Material Safety Data Sheet (MSDS).

Due consideration should be given to applicable safety procedures. Safety considerations include, but are not limited to, potential electrostatic hazards, potential personnel exposure (and associated protective clothing and equipment requirements), and potential explosive and toxic hazards associated with a cargo tank's atmosphere, among others. The physical characteristics of the cargo and existing operational conditions should be evaluated, and applicable international, federal, state, and local regulations should be observed.

In addition, before entering a compartment, a valid marine chemist's certificate must be obtained and indicate that the compartment is "Safe for Workers" and/or "Safe for Hot Work," as prescribed in NFPA 306, U.S. Coast Guard, OSHA, or other international, federal, state, or local regulations that may apply. Testing must be made at least every 24 hours or more frequently when changing conditions warrant.

In addition, safety procedures designated by the employer, the vessel operator, and other concerned parties should also be observed. Internationally, the *International Safety Guide for Oil Tankers and Terminals* (ISGOTT), and publications of the Oil Companies International Marine Forum and API provide additional safety information and should be consulted. See Appendix C.

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

2.8A.4 Referenced Publications

The most recent editions of the following standards, codes, and specifications are cited in this chapter.

API

Manual of Petroleum Measurement Standards, Chapter 1, "Vocabulary"; Chapter 2, "Tank Calibration," Section 7, "Calibration of Barge Tanks"; Chapter 17, "Marine Measurement"

Publ 2026	*Safe Descent Onto Floating Roofs of Tanks in Petroleum Service*
Publ 2217	*Guidelines for Work in Confined Spaces in the Petroleum Industry.*
Std 2543	Method of Measuring the Temperature of Petroleum and Petroleum Products (ANSI/ASTM[1] D 1086).

[1]American Society for Testing Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Std 2550 Measurement and Calibration of Upright Cylindrical Tanks (ANSI/ASTM D 1220)
Std 2555 Liquid Calibration of Tanks (ANSI/ASTM D 1406)

IP[2]
202/69 *Petroleum Measurement Manual*; Part II "Tank Calibration"; Section 1, "Vertical Cylindrical Tanks—Measurement Methods"

NFPA[3]
306 *Control of Gas Hazards on Vessels*

OSHA[4]
Occupational Safety and Health Standards, (29 *Code of Federal Regulations* Sections 1910.100 and following)

2.8A.5 Significance and Use

An accurate calibration of vessel tanks is essential for accurate determination of volume of cargoes loaded or discharged from the vessel tanks, whether full or partial cargoes. This standard provides three methods for developing such calibrations of vessel tanks.

2.8A.6 Nomenclature

A = Half-width of horizontal section at centerline
B = Molded breadth of vessel
C = Camber
D = Molded depth of vessel
d = Depth of double bottom
G = Reference gauge height
H = Deadrise
I_M = Innage as measured at reference gauge point
I_T = Innage at desired transverse frames a, b, c . . . (I_a, I_b, I_c . . .)
K = Distance of reference gauge point from aft bulkhead
L = Length between draft marks
L_T = Tank length
R_b = Bilge radius
R_g = Gunwale radius
S = Half siding
T = Vessel trim
U_M = Measured ullage
U_T = Ullage corrected for trim or list
W_C = Center tank width
W_W = Wing tank width
Y = Distance from the reference gauge point to the transverse frame (Y_a, Y_b, Y_c ...)
Z = Distance of gauge point from tank centerline (wing or center)
θ = Angle of list

Note: All dimensions must be in consistent units.

[2]Institute of Petroleum, 61 New Cavendish Street, London, W1M 8AR, England.
[3]National Fire Protection Association, Battery March Park, Quincy, Massachusetts 02269.
[4]Occupational Safety and Health Administration, U.S. Department of Labor. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

2.8A.7 Tank Measuring Equipment

The equipment used in dimensional tank calibration is described in 2.8A.7.1 through 2.8A.7.8. All measuring tapes shall be in one piece and free of kinks.

2.8A.7.1 TAPES FOR HEIGHT MEASUREMENT

For height measurements, a steel tape of convenient length is recommended and should be 0.375 or 0.500 inch wide and 0.008 to 0.012 inch thick, graduated in feet and inches to eighths of an inch, or in feet, tenths and hundredths of a foot. Tapes graduated in metric units must meet similar specifications. (For metric tapes, refer to IP 202/69.) The working tape shall be calibrated against a master tape in accordance with procedures outlined in API Standard 2550. An example of a commonly used measuring tape is shown in Figure 1.

2.8A.7.2 TAPES FOR LENGTH AND WIDTH MEASUREMENTS

For length and width measurements, a steel tape of convenient length relative to the length or width of the tanks involved, usually 100 to 200 feet, is recommended, as shown in Figure 2.

The working tape should not be more than 0.25 inch wide and approximately 0.01 inch thick. Graduations should be in feet and inches to eighths of an inch or in feet, to tenths and hundredths of a foot. (For metric tapes, refer to IP 202/69.) The tapes shall be checked and conform with specified limits of accuracy when compared with the master tape as described in 2.8A.7.3.

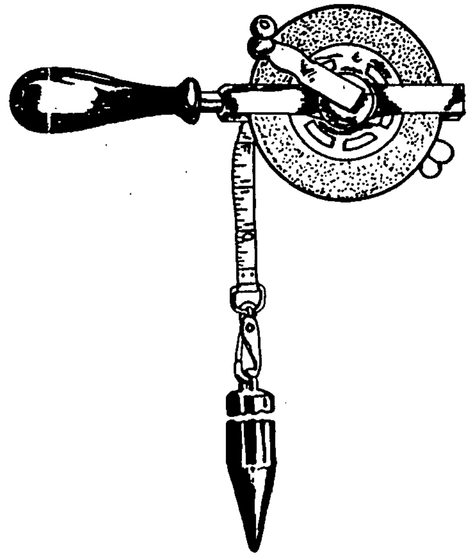

Figure 1—Height-Measuring Tape and Bob

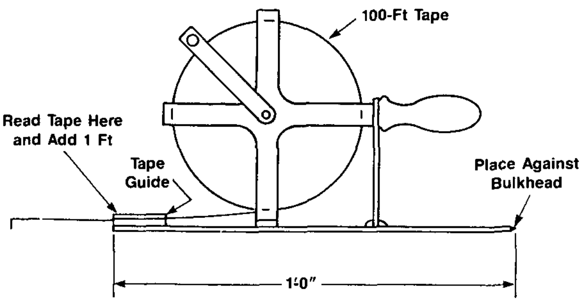

Figure 2—Length- and Width-Measuring Tape

2.8A.7.3 MASTER TAPES

The master tape that is used for calibrating working tapes for tank measurement shall be identified with a Report of Calibration at 68°F by the National Institute of Standards and Technology. The Report of Calibration attests to the tape accuracy within 0.001 foot (approximately 1/64 inch) per 100 feet of length. The Report of Calibration also includes the factors and formulas necessary to correct tape length for use at either 60°F (or 15°C) under tension differing from that used during calibration and under conditions of sag in an unsupported tape.

2.8A.7.4 REELS AND BRACKETS

Tapes shall be equipped with either adequate reels and handles or 1-foot tape brackets with guides, whichever is appropriate for the tape to be used.

2.8A.7.5 TAPE CLAMPS

To ensure a positive grip on the tape, clamps shall be used, as shown in Figure 3.

2.8A.7.6 MEASURING DEVICES (TELESCOPING BARGE AND STRAPPING POLE)

The measuring devices shall be constructed of straight-grained hardwood, fiberglass, aluminum, or other suitable material. The scales along the faces of the measuring device shall be graduated in eighths of an inch or in tenths or hundredths of a foot. The measuring device shall be fabricated in two or more sections so that it may be readily adjusted to the required height. Two measuring devices are illustrated in Figure 4.

2.8A.7.7 OTHER REQUIRED EQUIPMENT

A flexible steel ruler of suitable length, a line level or leveling device, and a depth gauge for determining strike plate thickness are also required.

2.8A.7.8 ACCESSORY EQUIPMENT

The following supplementary equipment may also be needed:

a. Straightedge.
b. Crayon, awl, and scriber.
c. Cleaning instruments (for example, a putty knife).
d. Ladders.
e. Coil of wire or fishing line.

2.8A.8 Measurement Conditions and Tolerances

2.8A.8.1 MEASUREMENT CONDITIONS

Measurements should be taken only after all construction work has been completed. New tanks may be measured with staging in place. All tanks must be clean, gas-free, and safe for persons to enter the tank.

2.8A.8.2 MEASUREMENT TOLERANCES

The procedures outlined below should be followed to ensure that measurements are within the proper tolerances:

a. All tape measurements should be read and recorded to the nearest 0.005 foot (or to the nearest 1 millimeter).
b. Temperature readings should be recorded to at least the nearest 1°F (or to the nearest 0.5°C).
c. Tank plate thickness should be determined to the nearest 0.02 inch (or to the nearest 0.5 millimeter).
d. Deadwood should be measured and located to the nearest even-numbered 0.125 inch (or to the nearest 3 millimeters).

2.8A.9 Measurement Procedures

Tank calibration may be accomplished by three methods: liquid calibration, calibration by linear measurement, and calibration from vessel drawings. All three methods have certain advantages and disadvantages in specific applications, and a combination of the three methods is recommended. For example, liquid calibration is desirable for end

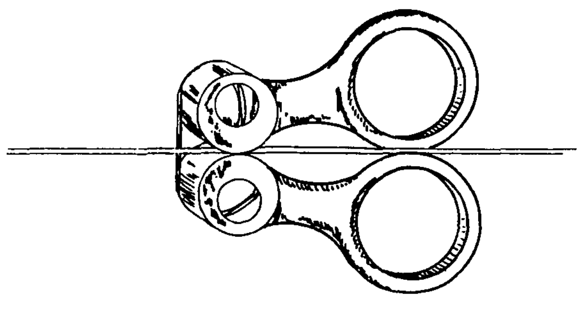

Figure 3—Tape Clamp

wing tanks with a great deal of variation in shape, but liquid calibration may not be practical for the remainder of the vessel. Calibration from vessel drawings must be supplemented by as many linear measurements as possible and should be used only if tanks are inaccessible for linear or liquid measurement.

Vessels should be recalibrated and new capacity tables prepared if any physical changes to the vessel affected capacities. Such changes include, but are not limited to, structural alterations, deadwood alterations, or relocation of the reference gauge point.

2.8A.9.1 LIQUID CALIBRATION BY METER METHOD

If the vessel is to be calibrated by the use of meters, then calibration should be conducted in accordance with API Standard 2555.

Each predetermined level on the vessel will require a preliminary as well as final gauge, including vessel drafts or suitable freeboard measurements.

The preliminary gauges on the vessel should be taken when the liquid has been transferred into each vessel tank to the approximate location desired. The final gauge shall be taken after all vessel tanks are filled to the same approximate level and the vessel tank has returned to even keel.

Temperatures of the liquid in the vessel tanks should also be recorded during each level measurement. The exact location of the vessel tank gauging points with reference to the centerline and transverse bulkheads of the vessel shall also be recorded.

2.8A.9.2 CALIBRATION BY LINEAR MEASUREMENT

2.8A.9.2.1 Preliminary Measurements

Before entering the vessel's tanks, measurements should be taken on deck. A line shall be stretched transversely across the deck, or a transit may be used, to determine the amount of camber. The distances from the line to the deck at the centerline and at each side of the vessel (or at a measured distance from the centerline) shall be measured. This camber should be established in at least two separate places on the vessel's deck.

The forward and aft tanks on some ships may have longitudinal sheer, and it should be measured with a straight line or transit, fore and aft.

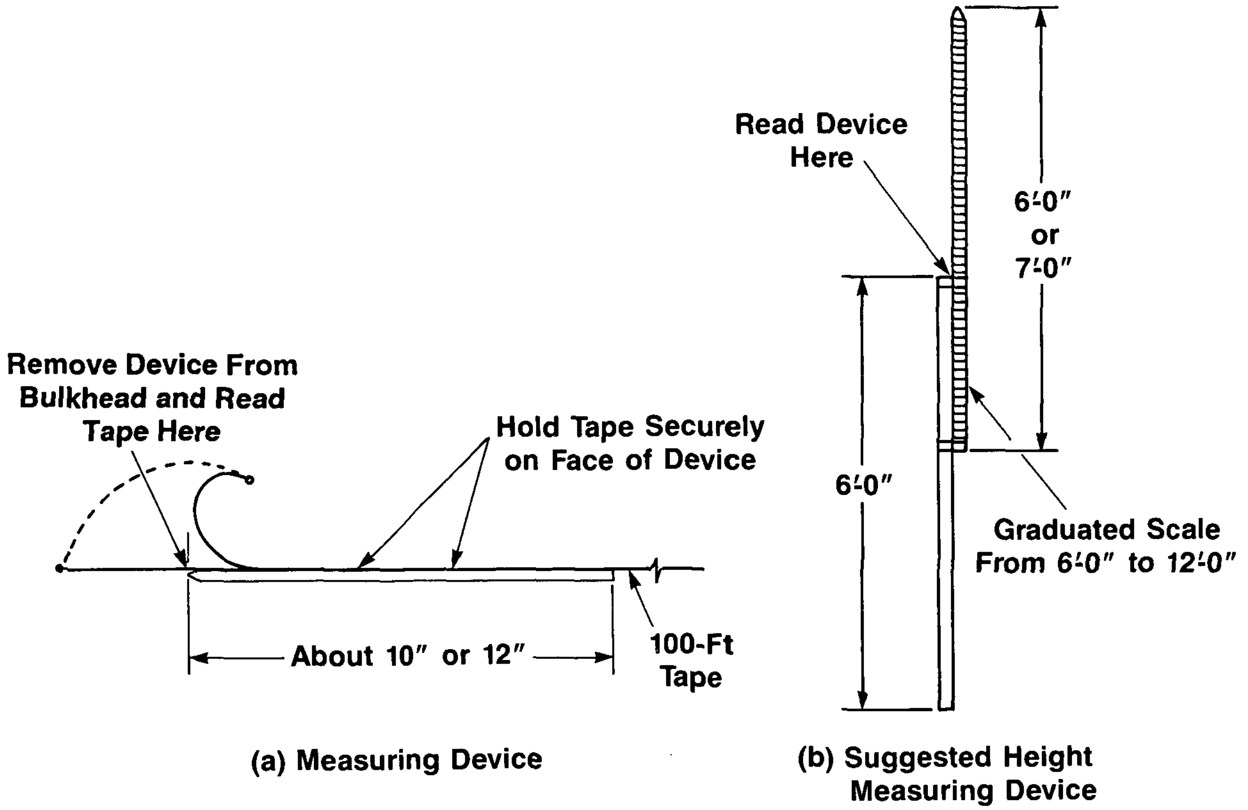

Figure 4—Measuring Devices

The size and height of the gauge hatches shall be measured, and their position shall be defined with respect to the centerline or longitudinal bulkhead and the nearest transverse bulkhead, as shown in Figure 5. The reference gauge heights of each tank shall also be measured and recorded at this time, as illustrated in Figure 5.

Note: When the gauge hatch is located on an expansion trunk, the overall reference gauge height of the tank may change with the opening and closing of the expansion trunk cover because of compression of the cover gasket.

2.8A.9.2.2 Internal Tank Measurements

When entering a vessel tank, tape paths should be chosen that permit unobstructed measurements in the following locations, wherever possible:

a. Tank lengths at the bottom. These measurements can generally be made through the slots for the longitudinals in the bottom transverse web frames and should be made through the middle of the tank and along each side of the tank; that is, near each longitudinal bulkhead in the case of a center tank and near the longitudinal bulkhead and the side shell in a wing tank.

b. Tank middle lengths at the level of the tops of the bottom transverse web frames or along the top of the inner bottom, if fitted. In a center tank, the middle length may be taken along the top of the center vertical keel.

c. Tank widths clear of longitudinal obstructions above the tank bottom and just above the bilge radius or inner bottom if in a wing tank.

d. Other length and width measurements at the levels of horizontal girders or stringers to which access is available.

e. Tank heights at each deck opening for portable tank washing machines. These heights are measured to the underside of the deck plating.

Note: When widths, lengths, and heights are recorded, measuring locations should be referenced.

2.8A.9.2.3 Other Measurements

The bilge radius amidships may be determined by establishing a plumb line at the point of bilge tangency to the bottom shell plating and by measuring from the side shell to the plumb line.

If the vessel is in drydock at the time of measurement, the deadrise amidships may be determined by establishing a transverse level line under the ship's bottom and by measuring heights at the centerline and at the tangent point of the bilge radius to the bottom shell plating. The slope thus obtained must be projected to the molded half-breadth of the hull to obtain the deadrise. If such measurements are not possible, the deadrise and bilge radius may be taken from the ship's drawings.

All internal deadwood shall be measured, described, and located with respect to height as measured from the bottom shell

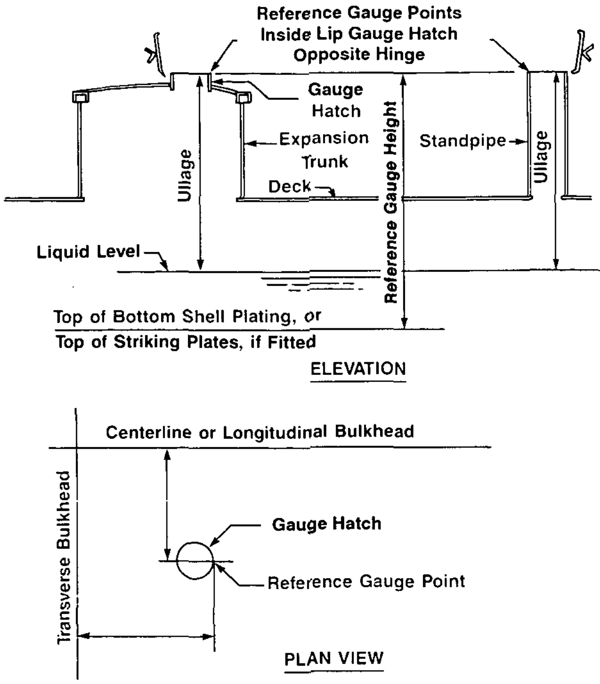

Figure 5—Reference Gauge Height and Location of Reference Gauge Point

or deck. The items comprising deadwood and the allocation of deadwood to zones is accomplished as described in 2.8A.10.3.

For end wing tanks with a great deal of variation in shape, width measurements should be taken at least at each transverse frame if possible, or at closer intervals if necessary, and at the height of each longitudinal frame from the bottom to the deck. These measurements describe the shape of the hull at each frame from which the transverse area to any given depth of liquid may be determined. The volume to a given depth of liquid is then determined by integration or by any other numerical methods.

2.8A.9.3 CALIBRATION FROM VESSEL DRAWINGS

2.8A.9.3.1 Required Drawings

Adequate detailed drawings depicting the ship's construction, including tank dimensions and deadwood, must be available. These drawings must be final, finished drawings incorporating all alterations made during construction. The following drawings are required:

a. General arrangement and capacity plan.
b. Midship section.
c. Transverse sections at ends.
d. Transverse oil-tight bulkheads.
e. Swash bulkheads.

f. Construction profile and deck plan.
g. Lines and/or offsets.
h. Cargo piping diagram.
i. Arrangement of cargo piping in tanks.
j. Arrangement of heater coils.
k. Arrangement of hydraulic valve control piping.
l. Arrangement of reach rods.
m. Arrangement and details of ladders and gratings.
n. Details of anode installation.

2.8A.9.3.2 Check Measurements

The ship as finally constructed will generally have some dimensional differences from the builder's finished drawings; therefore, it is necessary to conduct as many check measurements as possible on board to confirm the actual tank dimensions. The following check measurements to be taken on deck are considered appropriate (Figure 5):

a. Reference gauge height.
b. Inside height of tank at gauge point.
c. Height of gauge point above deck.
d. Longitudinal and transverse location of gauge point.
e. Verification of camber.
f. Verification of molded breadth of ship.
g. Length between draft marks.

When tanks are gas-free, safe to enter, and free from ballast, they should be entered and check measurements should be taken at convenient internal locations as follows:

a. Length of tank between transverse bulkheads.
b. Width of tank between longitudinal bulkheads or between longitudinal bulkheads and shell.
c. Verification of the existence of heater coils.
d. Size and extent of cargo piping.
e. Size and dimension of miscellaneous structures or fittings.

2.8A.10 Calculations

2.8A.10.1 CALCULATIONS FOR LIQUID CALIBRATION PROCEDURES

Refer to API Standard 2555 for an explanation of calculations for liquid calibration procedures.

2.8A.10.2 CALCULATIONS FOR CALIBRATION BY LINEAR MEASUREMENT AND BY VESSEL DRAWINGS

The dimensions of all transverse sections of the ship may be obtained from the field report or from the vessel's drawings as described in 2.8A.9.3. A series of transverse tank sections are developed for each tank; each is determined from an average of the applicable measurements. Figure 6 shows a typical transverse section. All measurements should be read and recorded in consistent units.

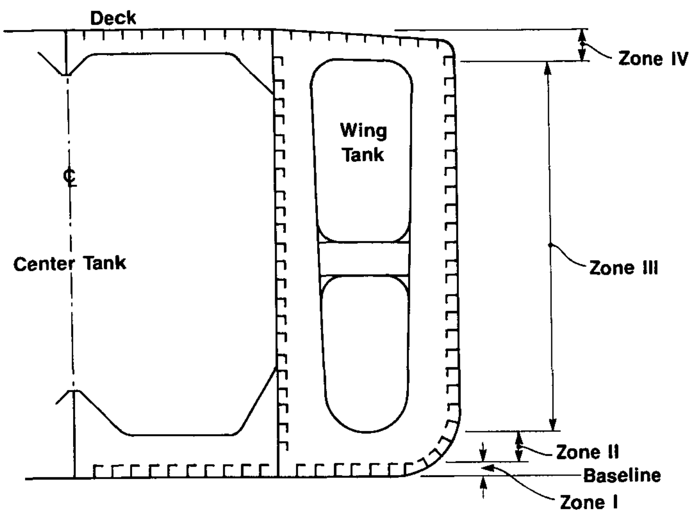

Figure 6—Typical Transverse Section

2.8A.10.2.1 Calculations for a Center Tank

Figure 7 shows a typical transverse cross section with appropriate tank dimensions. The basic volume of a center tank is expressed in cubic feet or cubic meters as follows:

$$\text{Basic Volume} = L_T \times W_c \times D \qquad (1)$$

The volume lost due to deadrise, if any, must be deducted from the basic volume. The volume gained due to the camber of the deck must be added to the basic volume. The deduction for deadrise for the center tank may be expressed in cubic feet or cubic meters as follows:

$$\text{Deduction} = L_T \times H \times \frac{\left\{\frac{W_C}{2} - S\right\}^2}{\left\{\frac{B}{2} - S\right\}} \qquad (2A)$$

The deduction for deadrise is spread incrementally and linearly from the bottom up through the extent of deadrise.

The addition for camber volume may be expressed in cubic feet or cubic meters as follows if a flat horizontal deck section at the centerline with straight line camber from that point to the gunwale is assumed:

$$\text{Addition} = (L_T \times 2A \times C) + \left(L_T \times C \times \frac{\left\{\frac{W_C}{2} - A\right\}^2}{\left\{\frac{B}{2} - A\right\}}\right) \qquad (2B)$$

This addition is spread incrementally and linearly from the bottom to the top through the extent of the camber.

Where parabolic camber is involved, the camber curve may be depicted graphically, and the transverse area under the camber curve may be obtained by planimeter or by numerical integration. The average area multiplied by the tank length provides the addition for camber volume.

2.8A.10.2.2 Calculations for Wing Tank Volume Amidships

The basic volume of a wing tank amidships (Figure 7) is expressed in cubic feet or cubic meters as follows:

$$\text{Basic Volume} = L_T \times W_W \times D \qquad (3)$$

From this basic volume, the volume corresponding to deadrise, the volume lost due to bilge radius, and the volume lost due to gunwale radius must be deducted. The volume due to the camber of the deck must be added to this volume.

The deduction for deadrise may be expressed in cubic feet or cubic meters as follows:

$$\text{Deduction} = \tfrac{1}{2} \times L_T \times W_W \times [H \times \frac{\left\{\frac{W_C}{2} - S\right\}^2}{\left\{\frac{B}{2} - S\right\}} + H] \qquad (4A)$$

The deduction for bilge radius and gunwale radius may be expressed as follows in cubic feet or cubic meters as indicated in Figure 7.

$$\text{Deduction} = L_T \times (R_b^2 - \pi \frac{R_b^2}{4}) \text{ (for Bilge)} \qquad (4B)$$

$$\text{Deduction} = L_T \times (R_g^2 - \frac{\pi R_g^2}{4}) \text{ (for Gunwale)} \qquad (4C)$$

The deductions for deadrise, bilge radius, and gunwale radius are spread incrementally and linearly from the bottom to the top of the deduction.

The addition for camber may be expressed in cubic feet or cubic meters as follows:

$$\text{Addition} = \tfrac{1}{2} \times \frac{(L_T \times W_W^2 \times C)}{(\frac{B}{2} - A)} \qquad (5)$$

This addition is spread incrementally and linearly from bottom to top. Where parabolic camber is involved, the procedure noted in 2.8A.10.2.1 is to be followed.

2.8A.10.2.3 Calculations for Wing Tank Volume at the Ends of Ship

For end wing tanks with a nonrectangular shape, width measurements should be taken at each transverse frame and, if possible, at the height of each longitudinal frame from the bottom to the deck. These measurements determine the shape of the hull at each frame from which the transverse area to any given depth of liquid may be determined. The volume of a given depth of liquid is then determined by integration.

If the shipbuilder has the lines of the vessel in offset form on a computer program, that program may be used to obtain tank volumes.

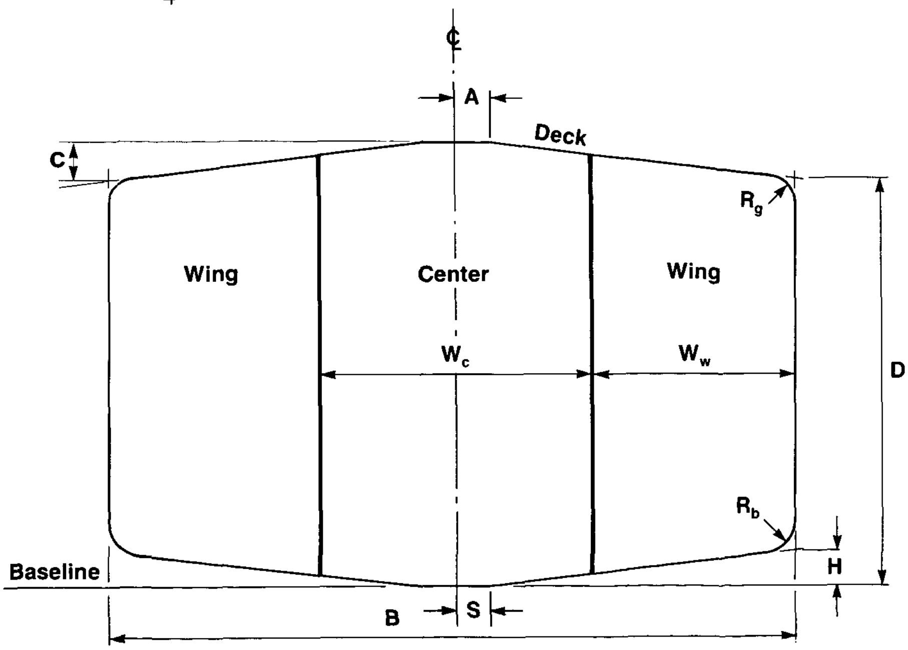

Figure 7—Typical Transverse Section of Vessel Showing Nomenclature for Calculations

Furthermore, whenever feasible, the use of liquid calibration procedures should be considered for end wing tanks for at least the lower portion of the tank when the shape is extreme.

2.8A.10.2.4 Calculations for Tanks Where an Inner Bottom Is Fitted

The basic volume for a center cargo tank when an inner bottom is fitted may be obtained by substituting the expression (D – d) for D in Equation 1 and as shown in Figure 8, where d is the depth of the double bottom (distance from top of the bottom shell plating at centerline to underside of inner bottom plating). Volume gained because of the camber of the deck must be added to the basic volume in accordance with Equation 2B. The basic volume for a wing cargo tank amidships may be obtained by substituting the expression (D – d) for D in Equation 3. Volume gained because of the camber of the deck must be added in accordance with Equation 5 and deduction for gunwale radius made in accordance with Equation 4C.

No deductions for volumes lost because of deadrise or bilge radius are made for the foregoing tanks. Such deductions apply to the double bottom ballast tank below the inner bottom.

If the inner bottom is recessed to form a well in the way of cargo suctions, the volume of such a well must be added to the tank above the inner bottom and deducted from the tank below.

2.8A.10.2.5 Calculation of Incremental Tank Volumes

Calculation of incremental tank volumes should be made at the following intervals, as defined in Figure 6. For center tanks, the calculation should be made at intervals of 3 inches (75 millimeters) from the bottom to the top of Zone I; intervals of 6 inches (152 millimeters) from the top of Zone I to the top of Zone II; intervals of 1 foot (0.3 meter) from the top of Zone II to the top of Zone III; and intervals of 3 inches (75 millimeters) in Zone IV.

For wing tanks, the calculation should be made at intervals of 1 inch (25 millimeters) from the bottom to the top of Zone II; intervals of 3 inches (75 millimeters) from the top of Zone II to the top of Zone III; and intervals of 1 inch (25 millimeters) in Zone IV. Curves of capacity versus depth may then be plotted and the capacities obtained for each 0.25 inch (5 millimeters) of ullage. The vertical extents of the zones are defined in 2.8A.10.3.

2.8A.10.3 CALCULATIONS FOR DEADWOOD

When calibration is by liquid measurement, no further calculation for deadwood is required.

When calibration is by linear measurement or from the vessel's drawings, deadwood must be deducted from the molded volumes described in 2.8A.10.2.1 through 2.8A.10.2.5 and in accordance with the following procedure.

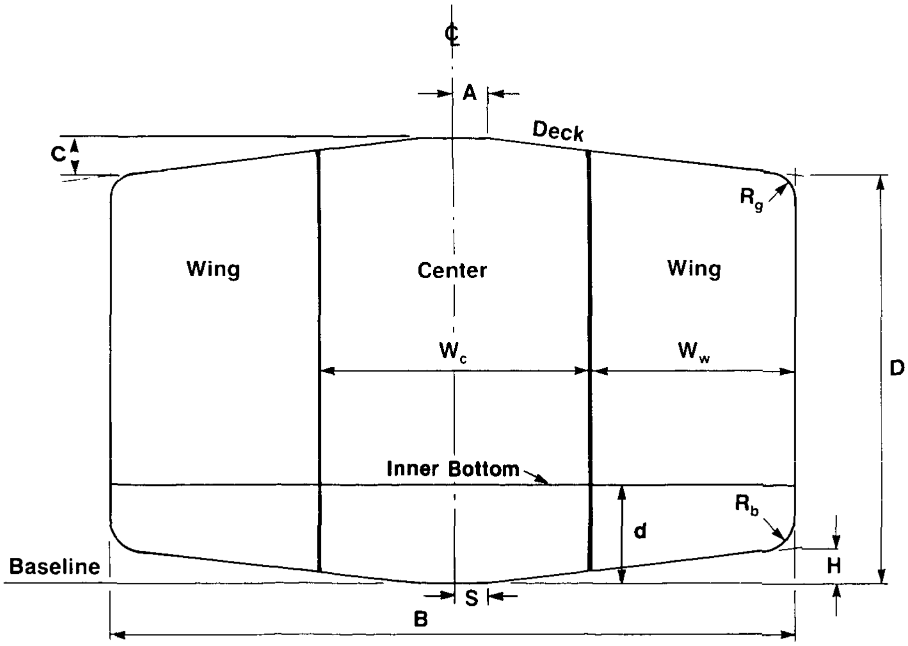

Figure 8—Typical Transverse Section of Vessel With Inner Bottom Showing Nomenclature for Calculations

To calculate and allocate the volume of deadwood in a tank properly, the depth of each tank is divided into four zones (Figure 6):

a. Zone I—From the top of the bottom shell plating up to and including the top flange or face plate of the bottom shell longitudinals. If an inner bottom is fitted, Zone I extends from the top of the bottom shell plating to the underside of the inner bottom.
b. Zone II—From the top of Zone I up to and including the top face plate of the bottom transverse web frames. If an inner bottom is fitted, Zone II extends from the top of the inner bottom plating to the top of the first horizontal shell or bulkhead stiffener above the inner bottom. (Refer to Figure 8.)
c. Zone III—From the top of Zone II up to the underside of the face plate of the deck transverse web frames.
d. Zone IV—From the top of Zone III up to the underside of the deck plating.

The volume of deadwood in each of these zones is calculated and distributed over the depth of the zone by 0.25-inch (6-millimeter) increments. These incremental volumes are deducted from the corresponding incremental molded volumes within the zone to obtain the actual internal volume available for liquid at a given innage or ullage height. See Appendix D for a sample of deadwood calculations.

The following items are included in deadwood volumes allocated to the proper zone:

a. All internal steel structure. When the calculations are made from drawings, the deadwood in each zone in each tank includes the volume of the plating of one transverse bulkhead. On vessels with twin bulkheads, the volume of the plating of oil-tight longitudinal bulkheads is allocated to the appropriate zone in the wing tank. On a centerline oil-tight bulkhead, the volume of the plating is allocated to the appropriate zone in the tank in which the stiffeners are fitted.
b. Volume of the outside diameter of heater coils, if fitted, including risers.
c. Volume of the outside diameter of the closed cargo piping and volume of the wall thickness of the open-ended piping.
d. Volume of miscellaneous deadwood, including ladders, platforms, reach rods, hydraulic piping to valves, support structure for anodes and full volume of consumable anodes, and the volume of internally mounted tank cleaning machines including their supports and piping.
e. Volume of immersed deepwell pumps to the outer diameter of outer barrel.

2.8A.10.4 CALCULATIONS FOR TRIM AND LIST CORRECTIONS

The capacity tables must contain correction tables for the observed gauges obtained when the vessel is other than on an even keel longitudinally and transversely and the liquid is in contact with all four bulkheads, but not with the underside of the deck. For a vessel out of trim, the measured ullage U_M should be corrected for trim as illustrated in Figure 9. The correction to observed ullage height for trim may be expressed in feet or meters as follows:

$$U_T = \left\{U_M \frac{\sqrt{(L^2+T^2)}}{L}\right\} + \frac{T}{L}\left\{\frac{L_T}{2} - K\right\} \quad (6)$$

$$U_T = \left\{U_M \frac{\sqrt{(L^2+T^2)}}{L}\right\} - \frac{T}{L}\left\{\frac{L_T}{2} - K\right\} \quad (6A)$$

The second portion of the expression in Equation 6 is positive for trim when the gauge point is aft of the mid-length of the tank. Opposite conditions will reverse the sign, as indicated in equation 6A.

The observed ullage U_M should be corrected for list, as illustrated in Figure 10. The correction for list may be expressed as follows:

$$U_T = \frac{U_M}{\cos\theta} \pm Z\tan\theta \quad (6B)$$

The sign for the second portion of the expression is positive when the list is toward the side on which the ullage point is located and negative when the list is toward the side opposite from the ullage point. (Refer to Figure 10.)

A formula for combined trim and list corrections may be used as follows:

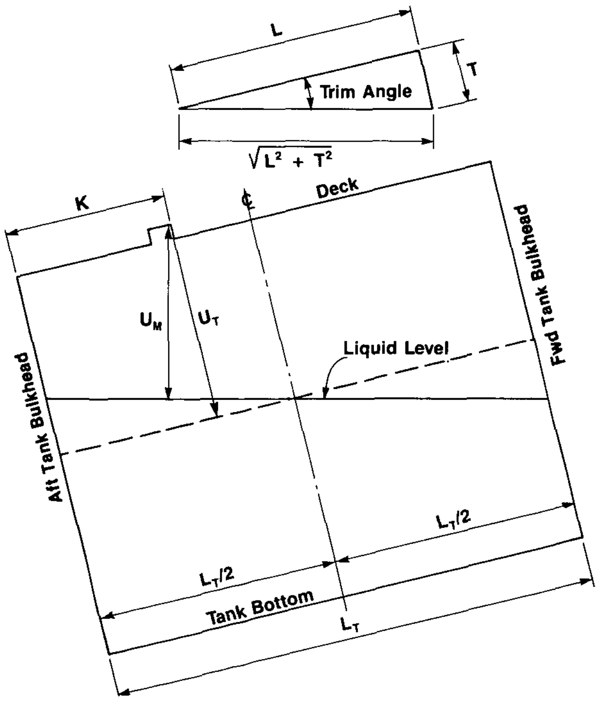

Figure 9—Trim Correction

$$U_T = U_M \frac{\sqrt{(L^2 + T^2)}}{L\cos\theta} + Z\tan\theta \frac{\sqrt{(L^2 + T^2)}}{L} \pm \frac{T}{L}\left(\frac{L_T}{2} - K\right) \quad (6C)$$

2.8A.11 Calibration of Tanks for Wedge Volumes

The capacity tables shall contain "wedge" tables to show the tank capacities for varied trim of the ship when the entire bottom of the tank is not covered by liquid. These tables shall be prepared from the line drawings of the ship, and should consider the shape of the hull with respect to deadrise, bilge radius, and the curvature of the sections at the forward and aft ends of the ship. These tables shall be prepared for various trims aft, up to about 3 percent of the length of the ship by increments of not more than 5 feet (1.5 meters), and for innages, by 0.02-foot (6-millimeter) increments from zero up to an innage that results when the entire bottom of the tank is covered by liquid. The tables are prepared on the assumption that this small volume is entirely a free-flowing liquid.

Such tables are prepared by dividing the length of the tank into an equally spaced station; these stations are most conveniently located at the transverse frames in the tank. Figure 11 shows the longitudinal section through the tank through a reference gauge point.

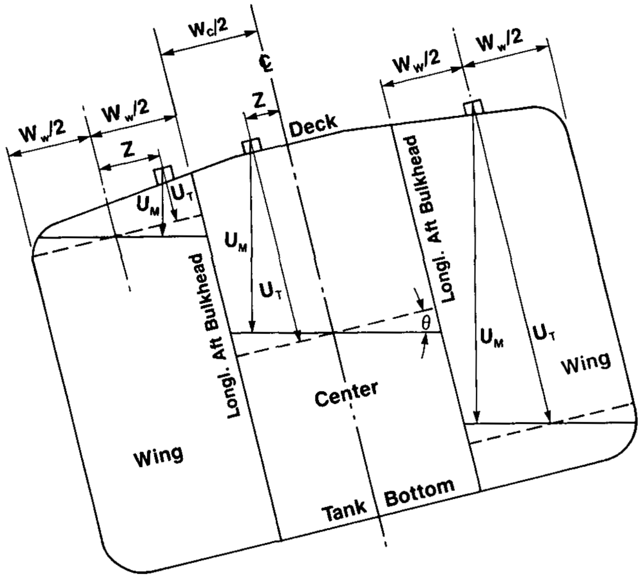

Figure 10—List Correction

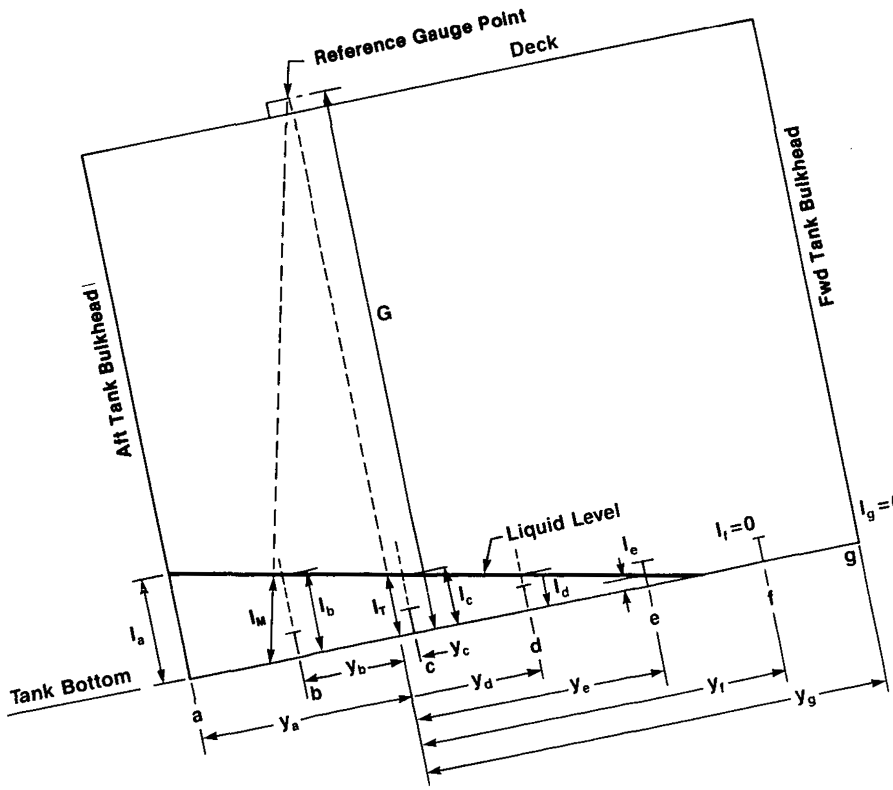

Figure 11—Longitudinal Section of Tank

An observed innage is converted into a true innage at each one of these transverse frames using the following formula:

$$I_T = I_M + \left\{ Y - \frac{GT}{L} \right\} \frac{T}{L} \qquad (7)$$

The lines of the hull must be obtained either from the builder's line drawing or from internal measurements in the tank. If the calculated innage is taken at each frame, the transverse areas of the tank at each frame from the bottom up to such innage are determined from the hull lines. These areas are then integrated by Simpson's Rule or by equivalent numerical integration methods to obtain a volume from which a deduction for deadwood must be made to obtain the true volume of the wedge.

The application of the wedge volume determination procedure is illustrated in Figure 12 for a typical wing tank on a 70,000 deadweight ton black oil tanker. This tank is assumed to extend between oil-tight transverse bulkheads at frame 99 and at frame 104 of the vessel, and frames are spaced 4.720 meters apart giving a wing tank length of 23.6 meters.

Other pertinent data for the vessel are as follows:

a. Length between perpendiculars: 240.000 meters.
b. Length between draft marks: 232.971 meters.
c. Molded beam: 32.200 meters.
d. Trim: 4.000 meters.
e. Location of reference gauge point from aft bulkhead: 7.2000 meters.
f. Reference gauge height: 18.464 meters.
g. Innage at the reference gauge point: 0.199 meters.
h. Frames: 99 (aft), 100, 101, 102, 103, and 104 (forward).

The lines of the hull as previously selected at each frame are illustrated in Figure 13.

Innages calculated at each frame using Figure 11 and Equation 7 are tabulated in Table 1.

These innages are plotted on each transverse frame as shown in Figures 14 through 17. The transverse area of the liquid at each frame is determined by planimeter or other means. These areas are then integrated by Simpson's Rule to obtain the molded volume, as shown in Table 2.

Table 1—Computed Innages for Frames

Frame No.	Innage (meters)
99	0.317
100	0.236
101	0.155
102	0.074
103	0.000
104	0.000

Table 2—Calculations of Wedge Volume

Frame No.	Area (square meters)	Simpson's Multiplier	f(V)
99	2.209	1	2.209
100	1.522	4	6.088
101	0.869	2	1.738
102	0.340	4	1.360
103	0.000	1	0.000

Σ f(V) = 11.395

Molded volume = ⅓ × 4.72 × 11.395 = 17.928 cubic meters

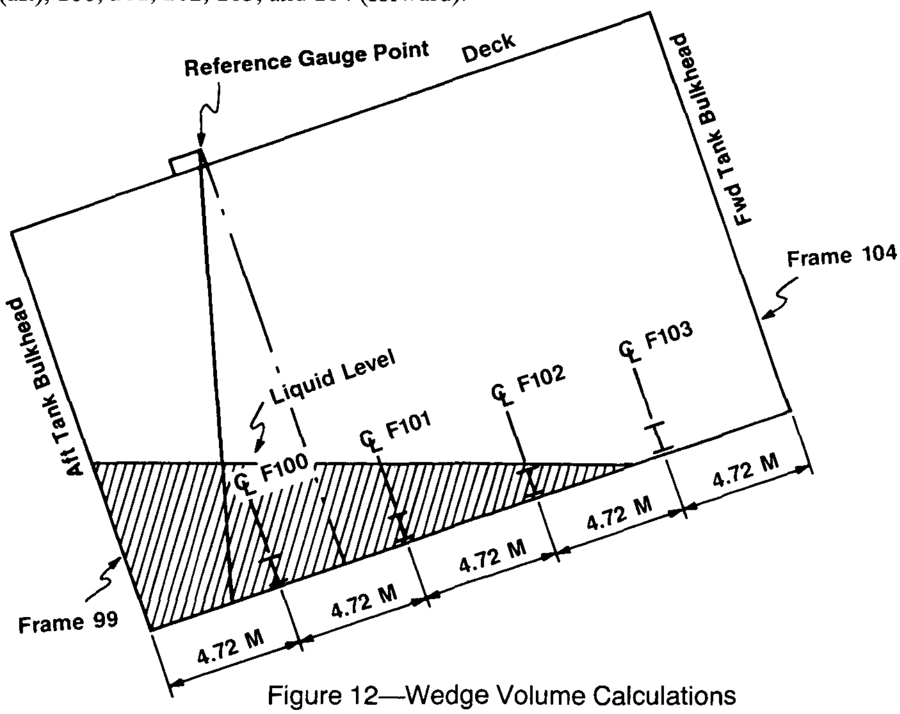

Figure 12—Wedge Volume Calculations

The deadwood in Zone I for this vessel is 2.68 percent of the molded volume. This number results in a net volume of liquid in the wedge of 17.448 cubic meters or 109.82 barrels.

This example has been presented in a longhand and graphic manner to demonstrate the procedure and only covers an input of one trim and one innage. For practical application, when a series of innages and a range of trims are required, the above calculations should be established in a computer program. The program input would cover the appropriate vessel characteristics, including the length of the vessel between draft marks and the location of the reference gauge point.

The program would also include the width of the tank at closely spaced increments of tank depth at each frame. The area of each increment would be the tank width at that depth multiplied by the depth of the increment. If these incremental areas are added and if the variables of innage at the reference gauge point and the trim are entered, the areas of liquid at each frame are produced. The areas are then integrated to give the molded volume. If the volume of the deadwood in this region of the tank is deducted, the true volume of the liquid in the wedge is produced.

2.8A.12 Presentation of Capacity Tables

Information locating the reference gauge point both longitudinally and transversely may be a sketch similar to the plan view of Figure 5. The location of the reference gauge point should be dimensioned in feet or meters from suitable reference points, such as oil-tight bulkheads or the ship's centerline. The notation or sketch must also indicate the reference gauge height for each tank, expressed in feet or meters, from the reference gauge point (top inside lip of the

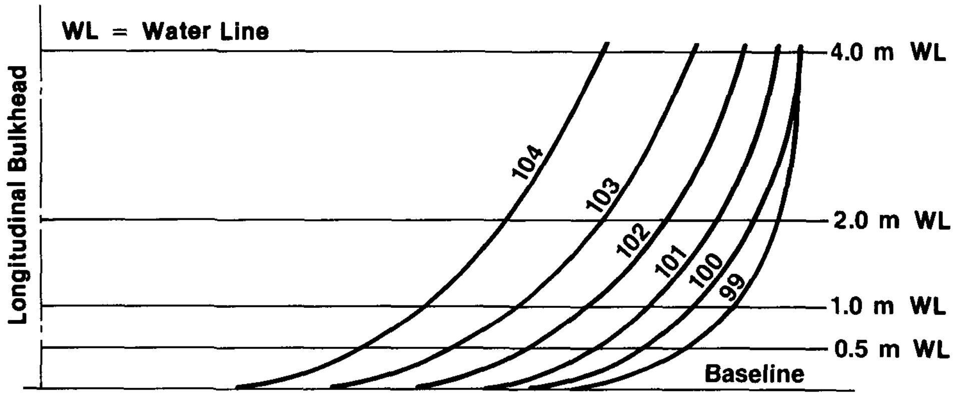

Figure 13—Lines of Hull

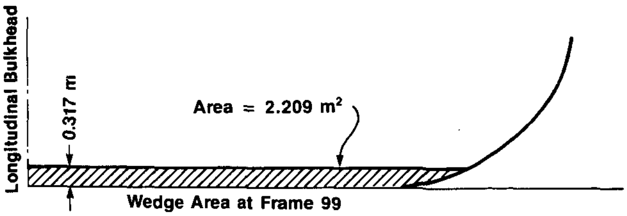

Figure 14—Area of Liquid at Frame 99

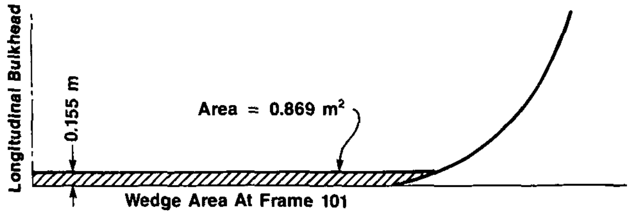

Figure 16—Area of Liquid at Frame 101

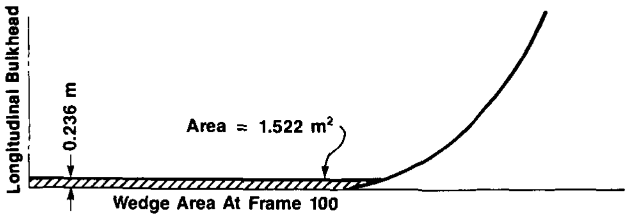

Figure 15—Area of Liquid at Frame 100

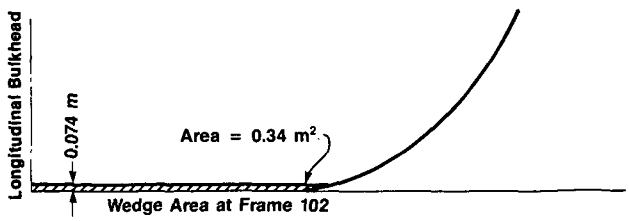

Figure 17—Area of Liquid at Frame 102

gauge hatch at a point opposite the hinge of the gauge hatch cover) to the top of the bottom shell plating or to the top of the striking plate, if fitted. Such a notation or sketch indicates gauging location for the ullage opening for hand gauging and for the gauging location of the closed gauging system, if fitted. The flame screen retainer ring should have a notch located below reference gauge point to permit tape passage.

When the reference gauge height is measured on an existing vessel that has the gauge hatch in the expansion trunk cover, the cover should be dogged down as in normal operation. With the cover in this position, a check measurement should be made from the lip of the cover to the deck. Because this dimension varies around the circumference of the expansion trunk due to the deck camber, the measurement should be taken in line with the reference gauge point as shown in Figure 5. The measured gauge heights and ullages are then corrected for this particular gasket compression.

The capacity tables for each tank shall indicate a volume corresponding to each 0.25 inch (6 millimeters) of ullage for the full height of the tank. The volume of liquid below the zero gauge point shall be indicated for each tank. When the ullage opening is located in the cover of the expansion trunk, the capacity tables shall be carried up to show capacities up to zero ullage at the reference gauge point. If the ullage opening is on a standpipe, the capacity tables shall be carried up to the deck, and this finding should be noted in the tables. Volumes are to be expressed in barrels of 42 U.S. gallons; however, at the owner's option, additional columns may be included giving the volumes in cubic feet, cubic meters, U.S. gallons, Imperial gallons, and/or long tons or metric tons of salt water or fresh water.

The internal volume of closed pipelines on the tanks shall be indicated on the capacity tables as a footnote. It should be clearly stated whether the pipelines are considered empty or full in the development of the capacity tables.

The capacity tables shall note the length of the ship between draft marks.

Trim correction tables shall be prepared for various trims up to a trim of 3 percent of the length of the ship by increments not to exceed 5 feet (1.5 meters). If desired, tank capacities may also be presented as innages using similar procedures.

2.8A.13 Calibration Information Plates

In addition to the information described here, each tank on each vessel should be provided with a calibration information plate bearing the following information:

a. Identification of the tank.

b. Reference gauge height (total gauge height) of the tank in feet, inches, or equivalent metric units.

c. Number of the calibration certificate, followed by the last two figures of the year in which the calibration was made and preceded by the name or acronym of the institution that carried out the calibration.

d. A statement indicating that the tank is calibrated based on ullage or innage.

The calibration information plate must be made of metal that is impervious to corrosion by atmospheric conditions or by the cargo and that is resistant to mechanical damage. The plate shall be permanently attached to an integral part of the tank and readily visible. If the ullage opening is located on the cover of the expansion trunk, the plate should be attached to the cover; if the ullage opening is a standpipe, the plate should be located on the standpipe. The plate should be installed on the side of the ullage opening designated as the reference gauge point.

APPENDIX A—SHIP CALIBRATION FORM

NAME OF VESSEL ______________________

OWNER ______________________ CONTRACT NO. ______________

LOCATION ______________________ HULL NO. ______________

BUILT BY ______________________ CALIBRATED BY ______________

LENGTH BETWEEN DRAFT MARKS ______________ DATE CALIBRATED ______________

TYPE CAPACITY TABLE: (Circle Those Required)

Barrels: Gallons: Cubic Meters
1/8", 1/4", 0.005 ft.
Innage, Ullage

TANK NO.: ___

REFERENCE GAUGE HEIGHT: ______________

INSIDE TANK HEIGHT AT REFERENCE GAUGE POINT: ______________________

HEIGHT OF REFERENCE GAUGE HATCH ABOVE DECK: ______________________

LOCATION OF REFERENCE GAUGE POINT: From Aft Bulkhead ___
From Centerline of Ship ___

SIZE OF EXPANSION TRUNK DOME: Height ______________ Diameter: ______________

LENGTH MEASUREMENTS AT EACH LONGITUDINAL FRAME		WIDTH MEASUREMENTS AT EACH TRANSVERSE FRAME	
1st Frame Fwd	______________	1st Frame Fwd	______________
2nd Frame Fwd	______________	2nd Frame Fwd	______________
3rd Frame Fwd	______________	3rd Frame Fwd	______________
4th Frame Fwd	______________	4th Frame Fwd	______________
5th Frame Fwd	______________	5th Frame Fwd	______________
6th Frame Fwd	______________	6th Frame Fwd	______________
7th Frame Fwd	______________	7th Frame Fwd	______________
8th Frame Fwd	______________	8th Frame Fwd	______________
At Aft Bulkhead	______________	At Fwd Bulkhead	______________

OVERALL LENGTHS @ PORT SIDE BHD ______________
CENTER OF TANK ______________
STBD. SIDE BHD ______________

APPENDIX B—VOCABULARY

Chapter 2, Section 8A necessarily includes some terminology specific to the maritime industry. The definitions of the terms used in the text are given below. For other definitions, refer to Chapter 1.

B.1 Terms

The *baseline* is the fore and aft reference line at the upper surface of the flat plate keel at the centerline for flush shell plate vessels, or the thickness of the garboard strake above that level for vessels having lap seam shell plating.

The *bilge radius* is the radius of the rounded portion of the vessel's shell that connects the bottom to the sides.

The *breadth, extreme,* is the maximum breadth of the hull measured to the outside surfaces of the side shell plating or to the outside of the guards, if fitted.

The *breadth, molded,* is the maximum breadth of the hull measured between the inside surfaces of the side shell plating of flush plated vessels or between the inside surfaces of the inside strakes of lap seam plated vessels.

Bulkhead applies to the vertical partition walls that subdivide the interior of a vessel into compartments or rooms.

Camber is the arching or rounding up transversely of the vessel's deck.

Deadrise is the transverse rise of the vessel's bottom from the keel to the bilge.

Deadwood is any internal tank structural member, fitting, or appurtenance, expressed as a volume, that affects the total or incremental liquid capacity of the tank.

The *depth, molded,* is the vertical distance from the baseline to the underside of the deck plating at the vessel's side, measured at the mid-length of the vessel.

The *draft, extreme,* is the depth of the vessel below the waterline measured vertically from the waterline to the lowest projecting portion of the vessel.

The *draft, molded,* is the depth of the vessel below the waterline measured vertically from the baseline to the waterline.

The *draft marks* are the vertical column of numbers on each side of the vessel at each end and amidships to indicate the distance from the lower edge of each number to the bottom of the keel.

An *expansion trunk (dome)* is a trunk extending above a space used for the stowage of liquid cargo that provides space for the thermal expansion of the liquid without overflowing.

Garboard is the strake of shell plating adjacent to the keel plate.

Gunwale is the intersection of the deck plating with the side shell plating and may be a tee connection or a radius connection.

Half-siding is the flat, horizontal section of the bottom shell plating measured from the centerline of the vessel to the edge of the flat keel plate.

A *hatch* is an opening in the top of a tank providing access for gauging, cleaning, or other purposes.

Hog is the distortion of a ship's form due to stresses in which the bow and stern drop below their normal positions relative to the midship portion of the vessel.

An *independent tank* is a tank whose boundaries are not part of the hull structure of the vessel.

An *integral hull tank* is a tank whose boundaries are the bottom, side, deck, or bulkhead of the vessel's hull.

The *keel, flat plate,* is the horizontal centerline bottom shell strake or plating.

The *length between perpendiculars* is the distance on the summer load waterline from the fore side of the stern to the aft side of the rudder post or stern post. On vessels without a rudder or stern post, the length is measured to the centerline of the rudder stock.

List is the transverse deviation of a vessel from the upright position, expressed in degrees.

Molded dimensions are the dimensions of a vessel to the molded lines.

The *molded lines* are the lines defining the geometry of a hull as a surface without thickness.

The *molded volume* is the volume of a compartment without deduction for internal structure or fittings.

Rake applies to the fore and aft inclination from the vertical of the mast, smokestack, stem, and so on. On barges, it is the end portion of the hull that rises from the bottom at an inclination from the vertical to meet the deck at the headlog.

Sag is the distortion of a vessel's form because of stresses in which the midship portion of the vessel drops below its normal position relative to the bow and stern.

Sheer is the longitudinal curve of a vessel's deck in a vertical plane. As a result of sheer, a vessel's deck height above the baseline is higher (or lower) at the ends than amidships.

The *shell* is the plating forming the outer side and bottom skin of the hull.

Stern notch is the recess in the stern of a barge in which the bow of the tug is inserted and secured so that the two vessels may be maneuvered as a single integrated unit.

A *strake* is a course or row of shell, deck, bulkhead, or other plating.

Trim is the difference between the draft forward and the draft aft.

B.2 References

The preceding vocabulary definitions were obtained from the following sources:

Shipbuilding Cyclopedia, Simmons-Boardman Publishing Company, April 1920.

Ship Design and Construction, Society of Naval Architects and Marine Engineers, 1980.

American Bureau of Shipping, *Rules for Building and Classing Steel Vessels,* 1983.

APPENDIX C—PHYSICAL CHARACTERISTICS AND FIRE CONSIDERATIONS

Personnel involved with the handling of petroleum-related substances (and other chemical materials) should be familiar with their physical and chemical characteristics, including potential for fire, explosion and reactivity, and appropriate emergency procedures. They should comply with individual company safe operating practices and local, state, and federal regulations, including use of proper protective clothing and equipment. Personnel should be alert to avoid potential sources of ignition and should keep containers of materials closed when not in use.

API Publications 2217 and 2026 and any applicable regulations should be consulted when sampling requires entry into confined spaces.

INFORMATION REGARDING PARTICULAR MATERIALS AND CONDITIONS SHOULD BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

APPENDIX D—DEADWOOD CALCULATIONS

Vessel: S/S Product Carrier
Tank: Center Tank No. 6, Zone One

Overall Dimensions	
Length of tank, feet	40.00
Width of tank, feet	44.00
Ullage height, feet	50.24
Ullage point from aft bulkhead, feet	6.00
Ullage point off centerline, port, feet	6.85
Deadrise, feet	0.66
Height of Zone I, feet	1.50

Deadwood Tabulation	
Bottom longitudinals	
Section, inches × inches × angle	18" × 4" × 38.2 lbs/ft
Cross section area, square inches	11.23
Area × length, cubic inches	5390.40
Area of 1 drain hole, square inches	20.56
Area of 12 drain holes, cubic inches	246.72
Volume of 12 drain holes, cubic inches	123.36
Net volume per longitudinal, cubic inches (feet)	5267.04 (3.048)
Total volume of 14 longitudinals, cubic feet	42.67
Bottom transverses	
Thickness, inches (feet)	0.50 (0.04)
Width, feet	44.00
Height, feet	1.50
Gross volume, cubic feet	2.75
Volume radius holes at center vertical keel and bulkheads, cubic feet	0.0245
Volume at 14 slots for longitudinals (18 × 4 inches), cubic feet	0.28
Net volume per transverse, cubic feet	2.44
Total volume 3 transverses, cubic feet	7.34
Center vertical keel	
Thickness, inches (feet)	0.50 (0.04)
Length, feet	40.00
Height, feet	1.50
Gross volume, cubic feet	2.40
Volume 12 drain holes with 3 inch radius, cubic feet	0.047
Volume of holes at bulkhead, cubic feet	0.014
Net volume center vertical keel, cubic feet	2.34
Transverse bulkhead	
Thickness, inches (feet)	0.52 (0.043)
Width, feet	44.00
Height, feet	1.50
Volume, cubic feet	3.43
Docking Brackets	
Area of each bracket, square feet (12 brackets per tank)	5.84
Thickness, feet	0.035
Total volume, cubic feet	2.40

Deadwood Summary	
Longitudinals, cubic feet	42.67
Transverse, cubic feet	7.34
Center vertical keel, cubic feet	2.34
Transverse bulkhead, cubic feet	3.43
Docking brackets, cubic feet	2.40
Total deadwood, cubic feet	58.18
Total deadwood, barrels	10.36
Deadwood per 0.25 inches of height of zone, barrels	0.1439
Molded volume of Zone I, cubic feet	2400.62
Molded volume of Zone I, barrels	427.91
Net volume Zone I, barrels	417.55

Order No. 852-30049

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