

Manual of Petroleum Measurement Standards Chapter 17.4

Method for Quantification of Small Volumes on Marine Vessels (OBQ/ROB)

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Introduction

The purpose of this standard is to provide a method for determining the small volumes of on board quantity (OBQ) prior to loading a vessel or material remaining on board (ROB) a vessel upon completion of discharge.

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Method for Quantification of Small Volumes on Marine Vessels (OBQ/ROB)

1 Scope

This standard applies only to quantification by manual gauging of small volumes on marine vessels prior to loading or upon completion of discharge. It does not address clingage, hydrocarbon vapors, cargoes in transit, or cargo pumpability. Refer to *API Manual of Petroleum Measurement Standards (MPMS) Chapter 3*.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API MPMS Chapter 3 (all relevant sections), *Tank Gauging*

API MPMS Chapter 3.1A, *Standard Practice for the Manual Gauging of Petroleum and Petroleum Products*

API MPMS Chapter 7, *Temperature Determination*

API MPMS Chapter 8.1, *Manual Sampling of Petroleum and Petroleum Products*

API MPMS Chapter 12.1.1, *Calculation of Static Petroleum Quantities—Upright Cylindrical Tanks and Marine Vessels*

API MPMS Chapter 17.1, *Guidelines for Marine Inspection*

API MPMS Chapter 17.2, *Measurement of Cargoes On Board Tank Vessels*

API MPMS Chapter 17.11, *Measurement and Sampling of Cargoes On Board Tank Vessels Using Closed and Restricted Equipment*

3 Terms and Definitions

For the purposes of this standard, the following terms and definitions apply. Other terms used in this standard are defined in API MPMS Chapter 1 or other API petroleum-measurement standards.

3.1

clingage

Cargo that adheres to all surfaces of the emptied portion of the tank other than bottom surfaces.

3.2

liquid volume

The measurable amount of material that is free-flowing at the time of measurement.

3.3

multipoint gauging

The activity of measuring cargo in a vessel tank through two or more openings in the top of the tank.

3.4**nonliquid volume**

The measurable amount of material that is not free-flowing at the time of measurement. Nonliquid material may include any one or a combination of hydrocarbon waxes, water/oil emulsions, sediment, or solidified cargo.

3.5**on board quantity****OBQ**

The material in a vessel's cargo tanks and piping before the cargo is loaded.

3.6**remaining on board****ROB**

The material remaining in a vessel's cargo tanks and piping after the cargo is discharged.

3.7**sediment**

Solid materials including, but not limited to, sand, rust, and scale.

3.8**slops**

Oil, oil/water/sediment, and emulsions contained in slop tanks or designated cargo tanks. The mixture usually results from tank stripping, tank washing, or dirty ballast phase separation.

3.9**sludge**

That element of the material in a ship's cargo tank that is essentially not free-flowing. Sludge consists of hydrocarbon waxes and may contain water/oil emulsions and sediment. The use of this term is not recommended.

3.10**wedge formula**

A mathematical means to approximate small quantities of measurable liquid and/or nonliquid material on board that is in a wedge configuration and does not touch all bulkheads of the vessel's tank. The formula is based on cargo compartment characteristics, vessel trim, and the depth of the material.

3.11**wedge table**

A vessel's cargo tank volume table calculated on the wedge formula for use when cargo does not touch all bulkheads of the tanks. Wedge tables preclude the need for calculation by wedge formula at times of cargo transfer.

4 Safety and Health Considerations**4.1 General**

Personnel involved with the gauging and sampling of petroleum and petroleum-related substances should be familiar with their physical and chemical characteristics, including potential for fire, explosion, and reactivity, and with the appropriate emergency procedures as well as potential toxicity and health hazards. Personnel should comply with the individual company safe operating practices and with local, state, federal, and national regulations, including the use of proper protective clothing and equipment.

Personnel involved in inspection, measurement, and/or sampling on board a vessel shall at all times be accompanied by a designated ship's representative.

4.2 Static Electricity Hazards

If the tank is in a noninert condition, specific precautions will be required with regard to safe measurement and sampling procedures when handling static accumulator oils. These are generally as follows: during loading, and for 30 minutes after the completion of loading, metallic equipment for dipping (gauging), ullaging, or sampling shall not be introduced into or remain in the tank. Examples of equipment include manual steel ullage tapes, portable gauging devices mounted on deck stand pipes, metal sampling apparatus, and metal sounding rods.

Nonconducting equipment with no metal parts may, in general, be used at any time. However, ropes or tapes used to lower equipment into tanks shall not be made from synthetic materials. After the 30-minute waiting period, metallic equipment may also be used for dipping (gauging), ullaging, and sampling, but it is essential that it is effectively bonded and properly grounded before it is introduced into the tank and that it remains grounded until after it has been removed. Operations carried out through stand pipes are permissible at any time because it is not possible for any significant charge to accumulate on the surface of the liquid within a correctly designed and installed stand pipe. A stand pipe should extend the full depth of the tank and be effectively bonded and earthed to the tank structure.

4.3 Health Hazards

Petroleum vapor dilutes oxygen in the air and may also be toxic. Hydrogen sulfide (H_2S) vapors are particularly hazardous. Petroleum vapors with relatively low concentrations of hydrogen sulfide may cause unconsciousness or death. During and after the opening of any tank or vapor control valve, personnel should position themselves to avoid any gas that may be released. Harmful vapors or oxygen deficiency cannot always be detected by smell, visual inspection, or judgment. Appropriate precautions should be used for the protection against toxic vapors or oxygen deficiency. It is recommended that users always wear gas monitors that, as a minimum, measure gas concentrations of H_2S .

Procedures should be developed to provide for the following:

- a) exposure monitoring,
- b) need for personal protective equipment,
- c) emergency rescue precautions.

When necessary, suitable fresh air breathing equipment should be worn prior to entering the gauge site and during the gauging and sampling procedure.

This discussion on safety issues is not exhaustive and the appropriate API or Energy Institute publications, together with *ISGOTT*^[5], International Convention for the Safety of Life at Sea (SOLAS)^[7], and Oil Companies International Marine Forum (OCIMF) publications, should be consulted for applicable safety precautions.

5 Quantification Procedures

5.1 General

Annex A provides examples of small volume calculations and configurations. Annex B provides an example of an on board quantity (OBQ)/remaining on board (ROB) report form. Annex C provides an explanation and example of the wedge formula and also provides a wedge calculation worksheet.

5.2 Gauging

5.2.1 Before taking any OBQ/ROB measurements, record the trim and list of the vessel. If a list condition exists, a request shall be made to remove this condition prior to commencing measurement.

5.2.2 All compartments on board the vessel that could contain OBQ/ROB shall be gauged and quantified prior to loading and after discharge. Gauging shall be performed in accordance with procedures outlined in API MPMS Chapter 3, API MPMS Chapter 17.1, API MPMS Chapter 17.2, and API MPMS Chapter 17.11, as applicable. Pipeline volumes should be accounted for based on condition of pipeline since they cannot be directly gauged.

5.2.3 Gauging OBQ/ROB at several points in a vessel compartment is very useful to establish whether material is or is not distributed across a tank bottom. When multiple gauging points in a compartment are available, manual gauges from each gauge point should be taken and recorded.

5.3 Temperatures

Temperatures shall be obtained, recorded, and used for cargo volume correction whenever depth of material is sufficient and the nature of the material permits. Temperature measurements shall be obtained in accordance with API MPMS Chapter 7.

If temperature cannot be measured, the gross observed volume shall be reported as gross standard volume.

NOTE Volume correction factors are not applicable to nonliquid volumes (see API MPMS Chapter 3.1A).

5.4 Sampling

An attempt shall be made to sample liquid and nonliquid volumes of OBQ/ROB. Samples taken should be in sufficient quantity to permit any required analysis. Samples shall be taken in accordance with API MPMS Chapter 8.1 and/or API MPMS Chapter 17.11.

If sufficient OBQ/ROB quantity is available for sampling and a sample was not drawn, a note should be included in the inspection report.

5.5 Vessel Cargo Lines and Pumps

It is the vessel's responsibility to drain and strip all cargo lines and pumps prior to final OBQ/ROB measurement. If possible one vessel tank, preferably the smallest, should be designated to receive material drained from all lines and pumps. The designated tank(s) quantity shall be verified before and after line and pump draining.

5.6 Slops

Slops shall be measured, quantified, and reported on the OBQ/ROB form at loading and discharge ports in accordance with procedures for slop tanks outlined in API MPMS Chapter 17.2 and API MPMS Chapter 17.11.

6 OBQ/ROB Characteristics

6.1 General

Care should be taken to determine the liquid or nonliquid nature of OBQ/ROB. Both liquid and nonliquid material may coexist in the same vessel compartment.

OBQ/ROB quantity includes crude oil, refined products, lube oil, or chemicals in liquid and/or nonliquid stage. In some cargoes, it may also include any combination of slops, oil residue, oil/water emulsions, scale, rust, sludge, and sediment.

6.2 Liquid Material

6.2.1 Liquid material may include any one or a combination of liquid petroleum, suspended sediment and water, or free water. The free water interface can often be measured with water-finding paste or an electronic interface detector. See API *MPMS* Chapter 3.1A or API *MPMS* Chapter 17.11.

6.2.2 When a vessel is not on an even keel, liquid volumes shall be quantified by trim/list correction, wedge table, or wedge formula. When liquid contacts all bulkheads, a trim correction shall be applied to the vessel tank capacity tables, or a trim table shall be used. If liquid does not contact all bulkheads, a wedge table or the wedge formula shall be used. See Annex C.

NOTE Certified wedge table is preferable over wedge calculation.

Capacity and wedge tables used to determine cargo volumes should be certified by the shipbuilder, classification society, or an independent inspection company for accuracy of use on board the particular vessel for which they are issued.

6.2.3 Liquid may lie on top of nonliquid in the same compartment. When gauging indicates the presence of both liquid and nonliquid material, refer to A.4 and A.5 to obtain the total volume of OBQ/ROB in the compartment.

6.3 Nonliquid Material

6.3.1 To assist in determining the composition of nonliquid material, samples should be taken and examined or tested.

6.3.2 If it has been determined that nonliquid material exists, multipoint gauging shall be performed if multiple gauge points are available. The average of the multiple readings shall be used for volume determination. However, if only one gauge point is available, the material shall be assumed to be evenly distributed over the tank bottom.

6.3.3 If multipoint gauging indicates the material is in a wedge condition, see Annex A for wedge calculations.

7 Calculating Quantities

After carefully assessing the configuration of the material in the tank, calculate the material's volume according to the illustrative examples, formulas, and forms given in Annexes A through C.

Chain calculations shall be performed. Only the final result in the calculation is to be rounded. If it is necessary to report any intermediate values, the figure should be rounded as required in API *MPMS* Chapter 12.1.1 Section 6; however, the rounded figure is not to be inserted into the calculation sequence.

Annex A (normative)

Small Volume Calculations and Configuration Equations

A.1 Nonliquid Only

(See Figure A.1.)

No trim correction or wedge formula applicable. Volume to be obtained directly from vessel's capacity tables.

EXAMPLE (all units in meters)

S = observed sounding

$$S_1 = 0.15$$

$$S_2 = 0.12$$

$$S_3 = 0.15$$

If more than one sounding is taken, calculate the mathematical average (see below) and then go to the vessel's capacity tables. In this example, there are three soundings. If it is only possible to take one sounding, then the one is used to enter the tables.

$$\begin{aligned} S &= \frac{S_1 + S_2 + S_3}{3} \\ &= \frac{0.15 + 0.12 + 0.15}{3} \\ &= \frac{0.42}{3} \\ &= 0.14 \end{aligned}$$

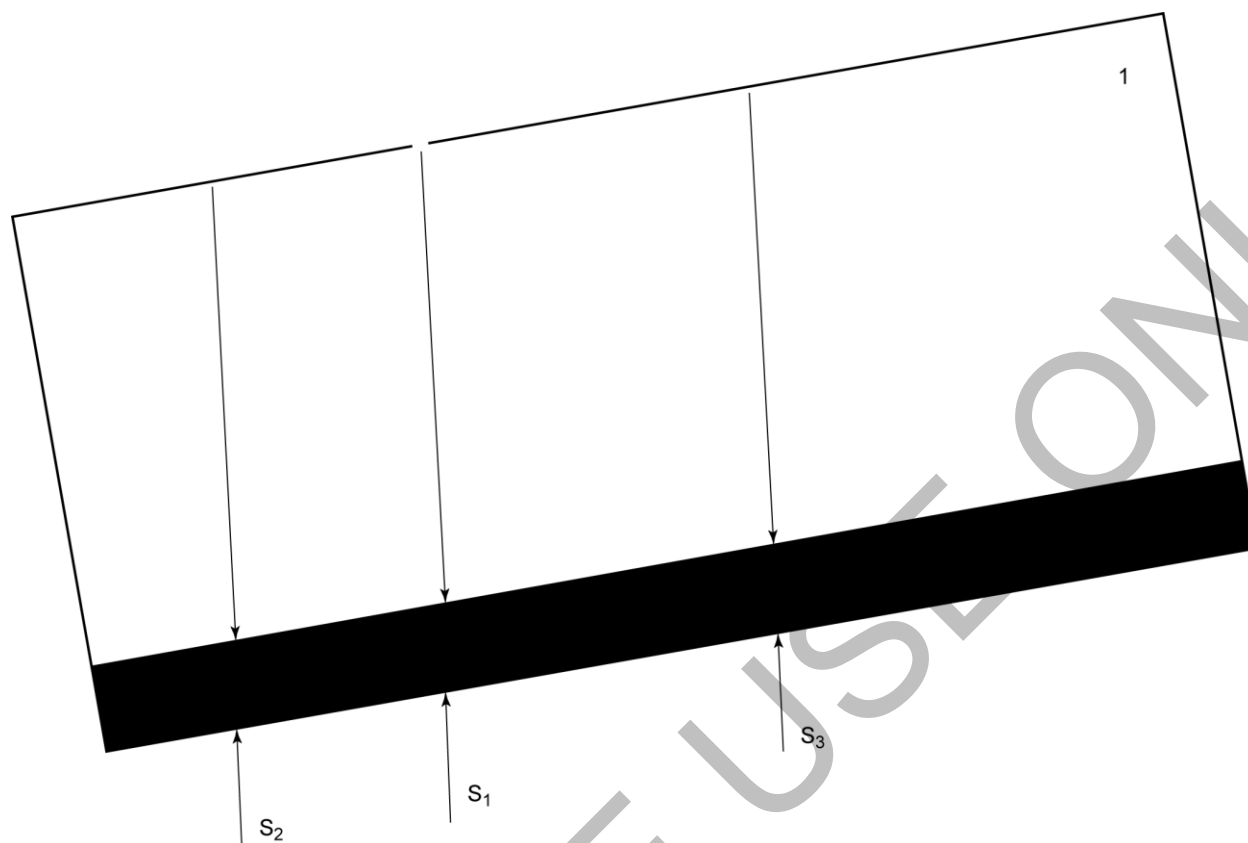


Figure A.1—Nonliquid Only

A.2 Single Liquid in Contact with All Four Bulkheads

(See Figure A.2.)

Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables.

S = observed sounding

The trim correction is typically applied to the observed sounding to arrive at a trim corrected sounding. The trim corrected sounding is used to enter the vessel's capacity tables to obtain the liquid volume.

Caution should be exercised when applying trim corrections to soundings. If the trim corrections are applicable to ullages, then the sign "+" or "-" shall be reversed when applying the corrections to soundings.

It is also acceptable in this situation to enter the vessel's capacity tables with a trim corrected ullage.

Alternative 1: On some vessels, the capacity tables are entered with the observed sounding and the trim. The trim adjusted volume is then read directly from the table.

Alternative 2: Some trim correction tables provide a volumetric adjustment that is applied to the volume obtained from the vessel's capacity tables using the observed sounding.

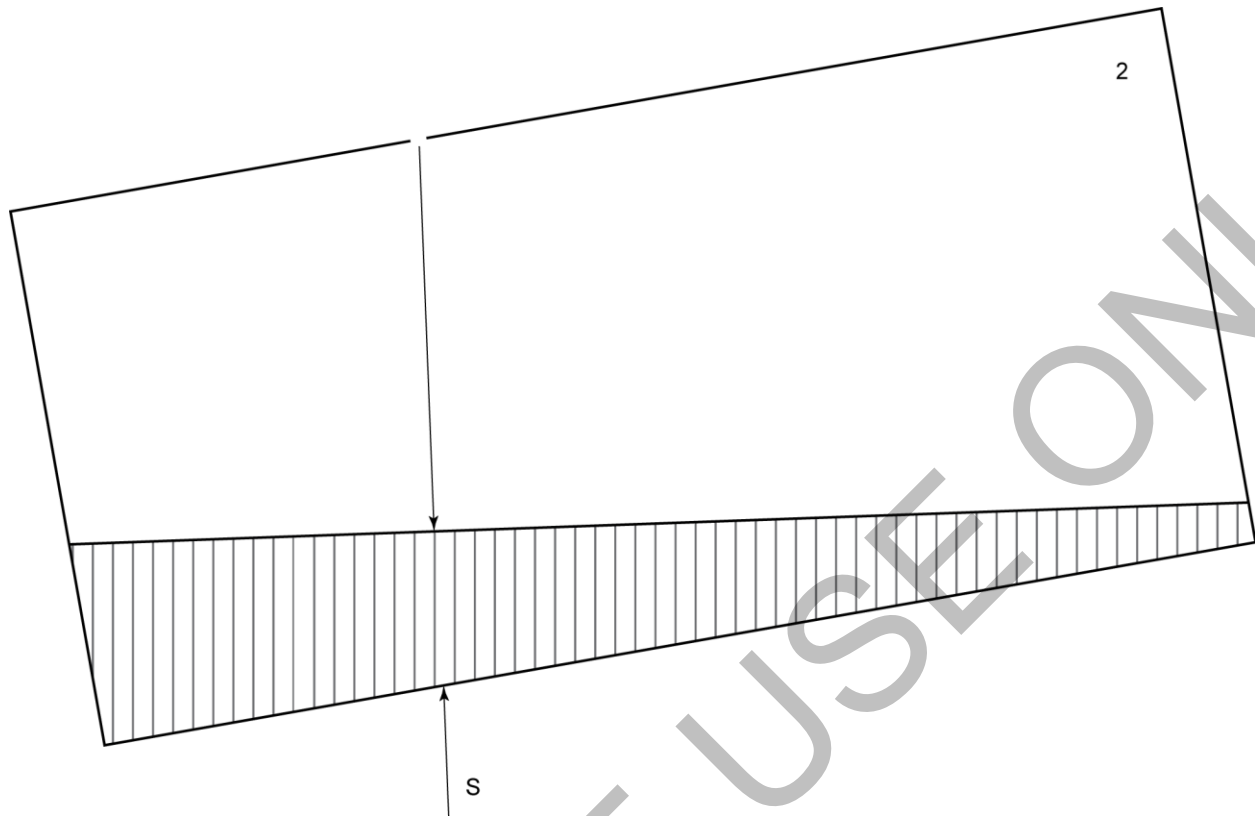


Figure A.2—Single Liquid in Contact with All Four Bulkheads

A.3 Single Liquid in Contact with Three Bulkheads Only

(See Figure A.3.)

A.3.1 General

Wedge table or formula to be used for volume calculation.

If wedge tables are available, they should be used. Wedge tables are usually entered with the observed sounding and the trim. Wedge volume is read directly from the table.

In the wedge formula, there are four basic steps to follow:

Step 1: Calculate the adjusted sounding "A."

Step 2: Verify the existence of the wedge condition.

Step 3: Divide A by two and extract the table volume (for this sounding) from the vessel's capacity tables.

Step 4: Calculate the wedge volume, which is a function of the table volume obtained in Step 3.

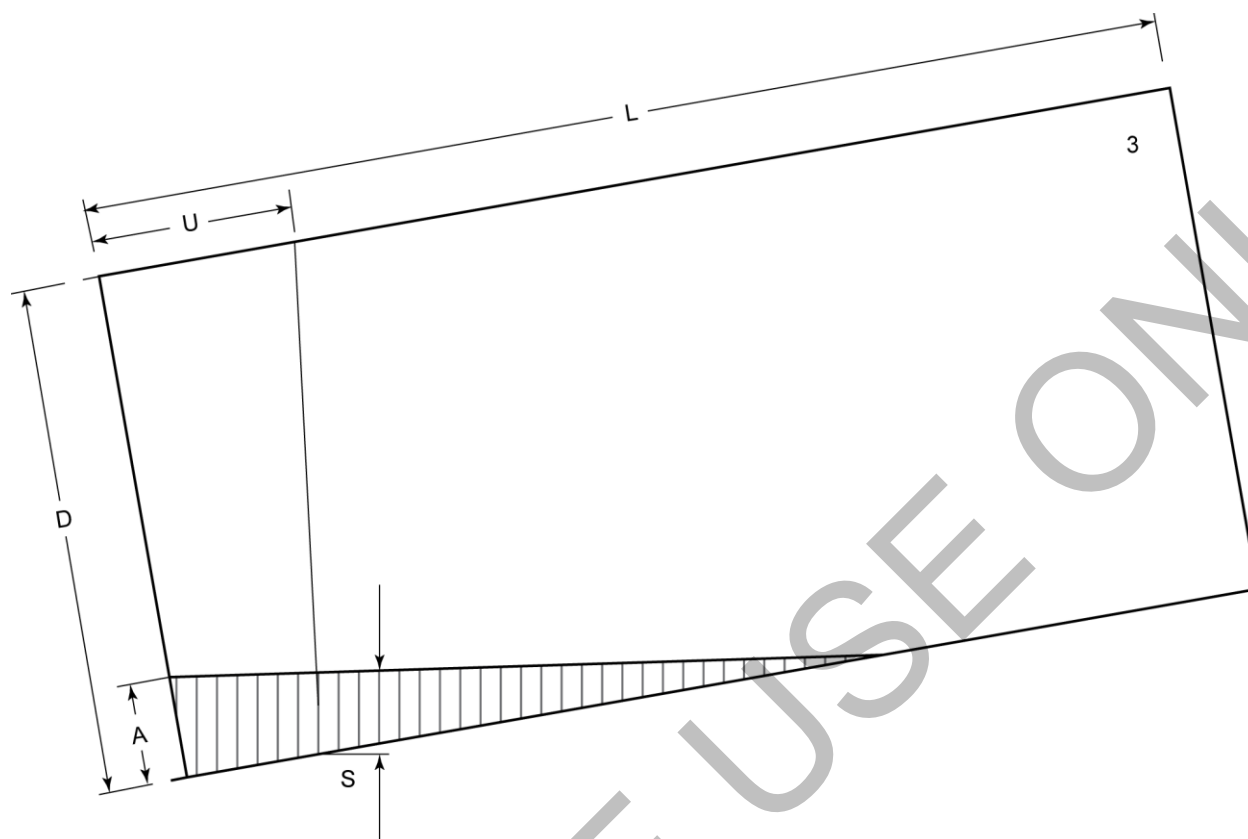


Figure A.3—Single Liquid in Contact with Three Bulkheads Only

EXAMPLE (all units in meters)

Required Field Information	Legend	Field Data
Forward Draft	N/A	3.20
After Draft	N/A	8.50
Trim	N/A	5.30
Length Between Perpendiculars (LBP)	N/A	220.00
Length of Tank	<i>L</i>	35.35
Width of Tank	<i>W</i>	12.82
Reference Gauge Height	<i>D</i>	20.18
Distance from Aft Bulkhead to Gauge Point	<i>U</i>	4.90
Observed Sounding	<i>S</i>	0.19
Trim Factor (trim divided by LBP)	<i>F</i>	0.02409

Step 1: Calculate the adjusted sounding *A* as follows:

$$\begin{aligned}
 A &= \{[U - (D \times F)] \times F\} + S \\
 &= \{[4.90 - (20.18 \times 0.02409)] \times 0.02409\} + 0.19
 \end{aligned}$$

$$= [(4.90 - 0.486) \times 0.02409] + 0.19$$

$$= (4.414 \times 0.02409) + 0.19$$

$$= 0.106 + 0.19 = 0.296$$

$$A = 0.296$$

Step 2: Verify the existence of the wedge condition. Determine the validity of the wedge condition as follows:

$$\text{length of wedge} = \frac{A}{F} (0.296/0.02409) = 12.287 \text{ (length of wedge)}$$

If the calculated length is greater than the actual compartment length, a wedge condition DOES NOT EXIST. Vessel's trim correction is applicable in this situation; refer to A.2.

Step 3: Divide "A" by 2.

$$\frac{0.296}{2} = 0.148$$

Extract from the tank table the volume corresponding to a sounding of 0.148 meter, with the vessel on an even keel and upright. (For the purposes of this example, this volume is quoted as 379.68 bbl.)

Step 4: Calculate the wedge volume as follows:

$$\begin{aligned} \text{wedge volume} &= \frac{\text{table volume} \times A}{L \times F} \\ &= \frac{379.68 \times 0.296}{35.35 \times 0.02409} \\ &= \frac{112.39}{0.85158} \\ &= 131.98 \text{ bbl} \end{aligned}$$

NOTE If the table volume is in barrels, the answer will be in barrels. (All units of measurement shall be of the same denomination—that is, decimal feet or meters.)

The use of the table volume provides a volumetric factor that, when applied to the total expression of the formula, partially accounts for the internal tank framing (if included in the vessel's capacity tables), volume below tank datum, and width of the tank at the lower extremities of the tank.

A.3.2 Vessels Trimmed by the Head

For vessels that are trimmed by the head, the value for U is the distance from the gauge point to the forward bulkhead as opposed to the after bulkhead as shown in Figure A.3. The calculation for vessels trimmed by the head is termed "reverse wedge." See NOTE in C.2.2.

A.3.3 Compartments with Extreme Shape due to Hull Curvature

Refer to Annex C.

A.4 Single Liquid above Nonliquid

(See Figure A.4.)

Liquid in contact with all four bulkheads.

For Total Volume: Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. (Refer to A.2; the sounding represented by "XZ" is the applicable observed sounding.)

For Nonliquid Volume: No trim correction or wedge formula applicable. Volume to be obtained directly from vessel's capacity tables. (Refer to A.1; the sounding represented by "YZ" is the applicable observed sounding.)

For Liquid Volume: Deduct the nonliquid volume from the total volume.

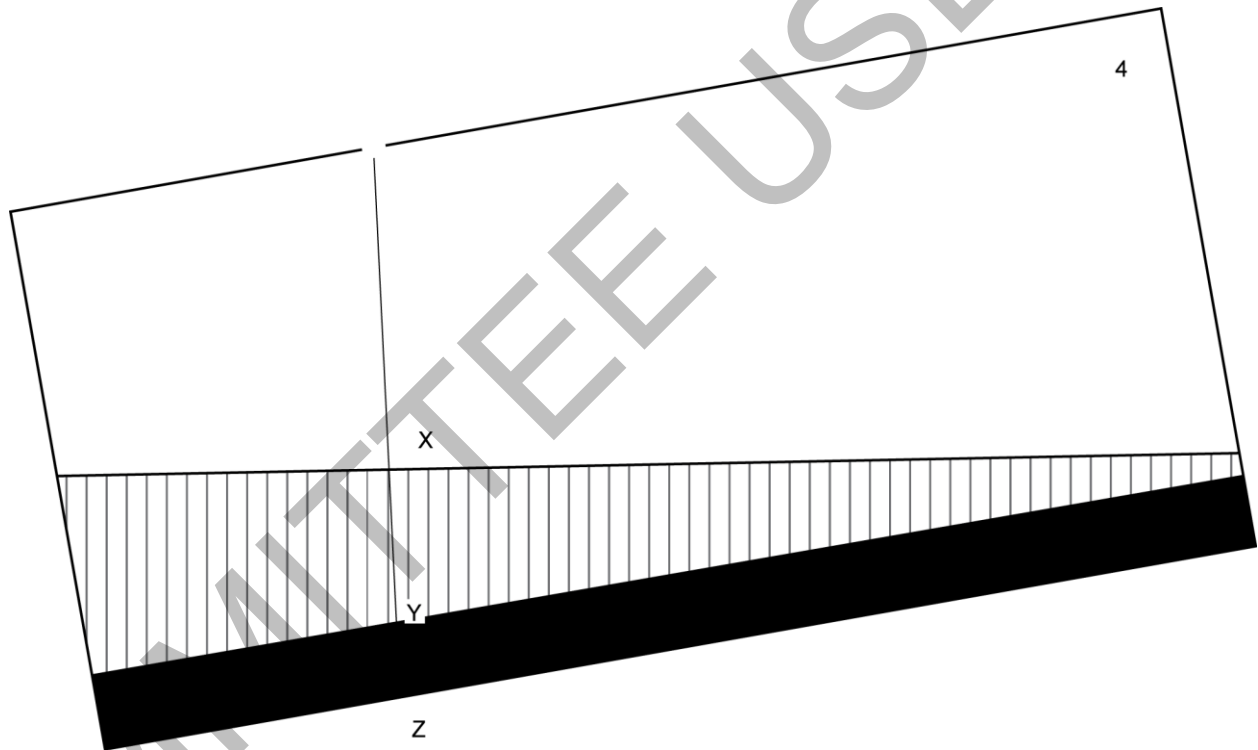


Figure A.4—Single Liquid above Nonliquid (Liquid in Contact with All Four Bulkheads)

A.5 Single Liquid above Nonliquid

(See Figure A.5.)

Liquid in contact with three bulkheads only.

For Total Volume: Sum of nonliquid volume and wedge volume. Nonliquid volume to be obtained directly from vessel's capacity tables. [Refer to A.1; the sounding represented by "YZ" is the applicable observed sounding ($S = YZ$).]

For Wedge Volume: Wedge formula to be used to calculate liquid volume. [Refer to A.3; the sounding represented by "XY" is the applicable observed sounding ($S = XY$). The reference gauge height should be reduced by the amount of the nonliquid sounding.]

A.6 Two Liquids (Oil and Water)

(See Figure A.6.)

Both liquids in contact with all four bulkheads.

For Total Liquid: Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. (Refer to A.2; the sounding represented by "XZ" is the applicable observed sounding.)

For Lower Liquid: Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. (Refer to A.2; the sounding represented by "YZ" is the applicable observed sounding.)

For Upper Liquid: Subtract the lower liquid volume from the total liquid volume.

It is also acceptable in this situation to enter the vessel's capacity tables with trim corrected ullages for the total liquid and the lower liquid, respectively.

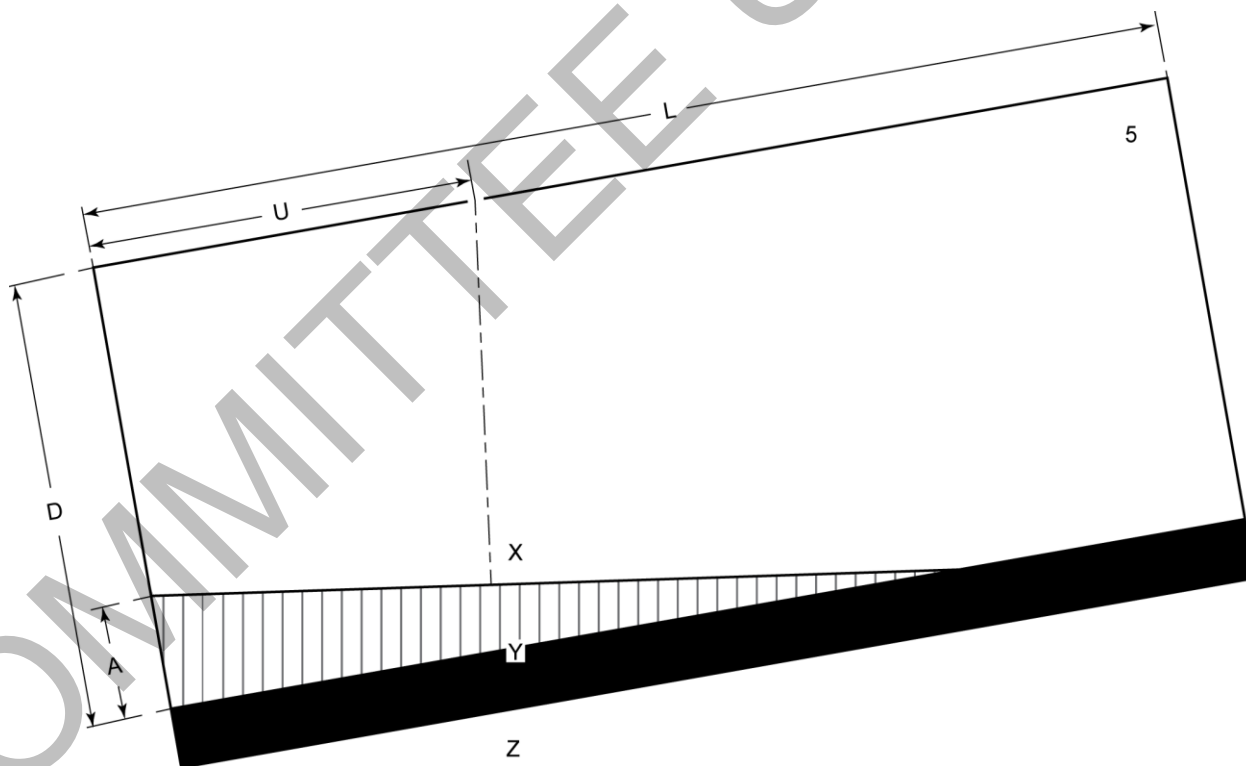


Figure A.5—Single Liquid above Nonliquid (Liquid in Contact with Three Bulkheads Only)

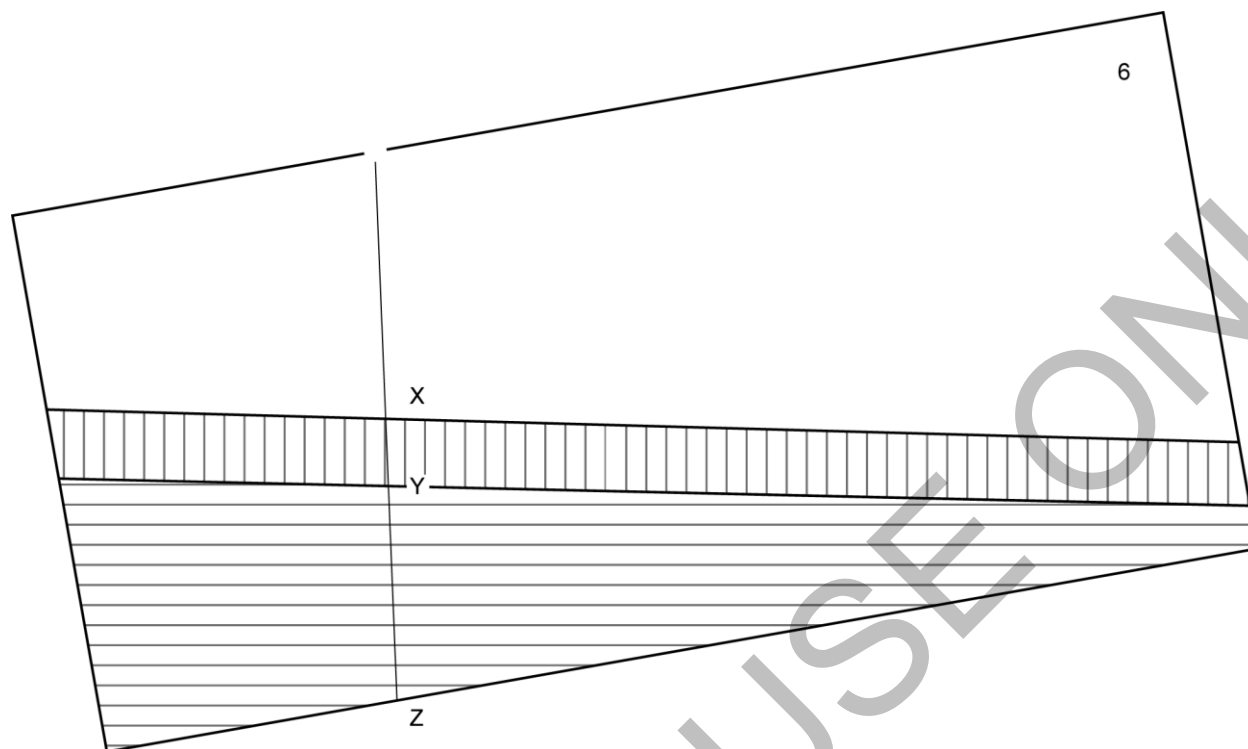


Figure A.6—Two Liquids (Both Liquids in Contact with All Four Bulkheads)

A.7 Two Liquids (Oil and Water)

(See Figure A.7.)

Lower liquid in contact with three bulkheads only.

For Total Liquid: Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. [Refer to A.2; the sounding represented by "XZ" is the applicable observed sounding ($S = XZ$).]

For Lower Liquid: Wedge table or formula to be used for volume calculation. [Refer to A.3; the sounding represented by "YZ" is the applicable observed sounding ($S = YZ$).]

For Upper Liquid: Subtract the lower liquid wedge volume from the total liquid volume.

A.8 Two Liquids (Oil and Water)

(See Figure A.8.)

Both liquids in contact with three bulkheads only.

For Total Liquid: Wedge table or formula to be used for volume calculation. [Refer to A.3; the sounding represented by "XZ" is the applicable observed sounding ($S = XZ$).]

For Lower Liquid: Wedge table or formula to be used for volume calculation. [Refer to A.3; the sounding represented by "YZ" is the applicable observed sounding ($S = YZ$). The adjusted sounding at the after bulkhead is represented by the lowercase "a."]

For Upper Liquid: Subtract the lower wedge volume from the total wedge volume.

A.9 Two Liquids (Oil and Water) with a Nonliquid Lower Layer

(See Figure A.9.)

Lower layer liquid in contact with three bulkheads only.

For Total Volume: Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. (Refer to A.2; the sounding represented by "VZ" is the applicable observed sounding.)

For Lower (Nonliquid) Volume: No trim correction or wedge formula applicable. Volume to be obtained directly from vessel's capacity tables. (Refer to A.1; the sounding represented by "YZ" is the applicable observed sounding.)

For Central Wedge Volume: Wedge formula to be used for volume calculation. [Refer to A.3; the sounding represented by "XY" is the applicable observed sounding ($S = XY$). The reference gauge height should be reduced by the amount of the nonliquid sounding.]

For Upper Volume: Deduct the lower and central volumes from the total volume.

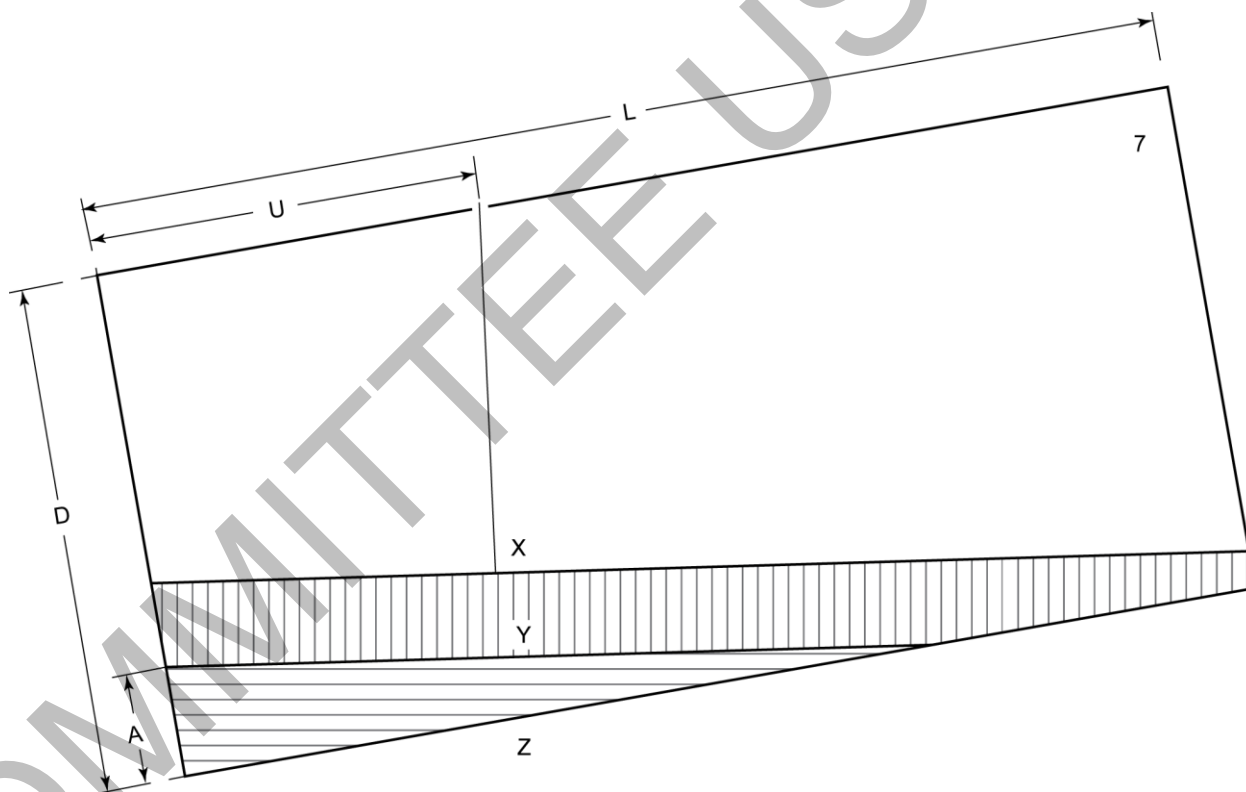


Figure A.7—Two Liquids (Lower Liquid in Contact with Three Bulkheads Only)

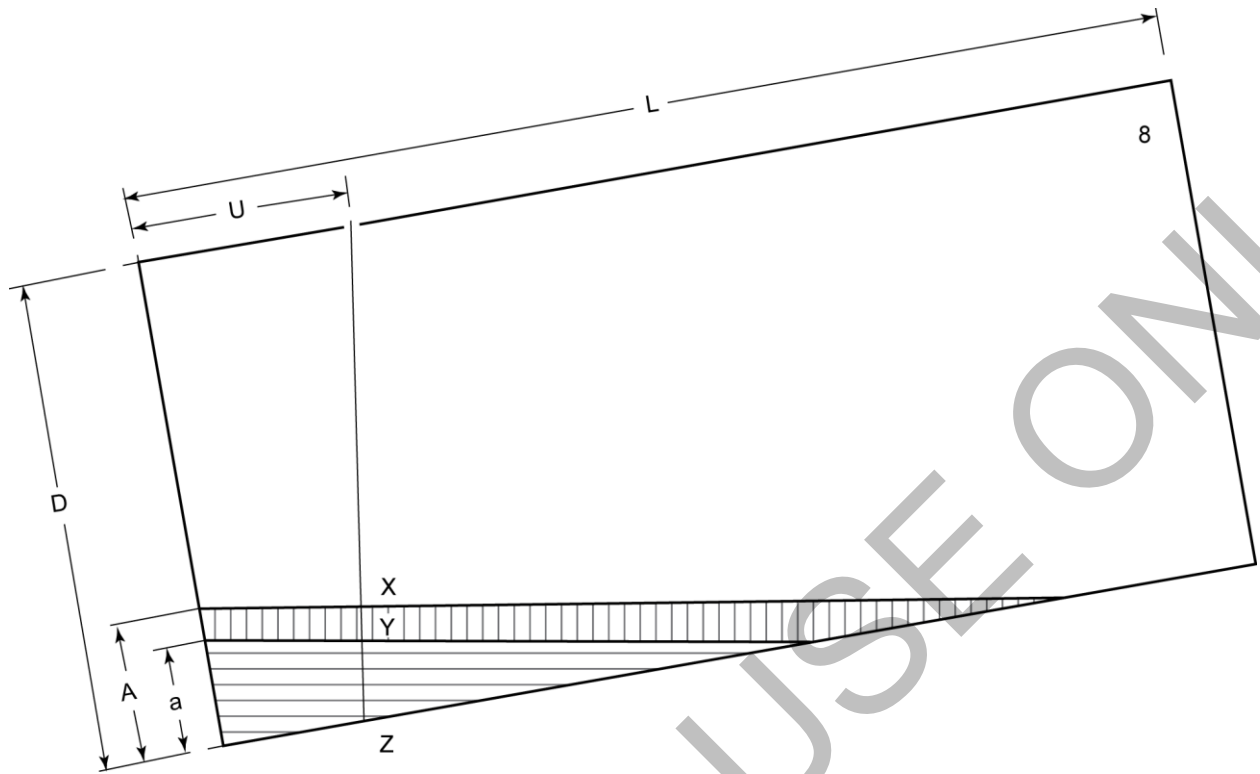


Figure A.8—Two Liquids (Both Liquids in Contact with Three Bulkheads Only)

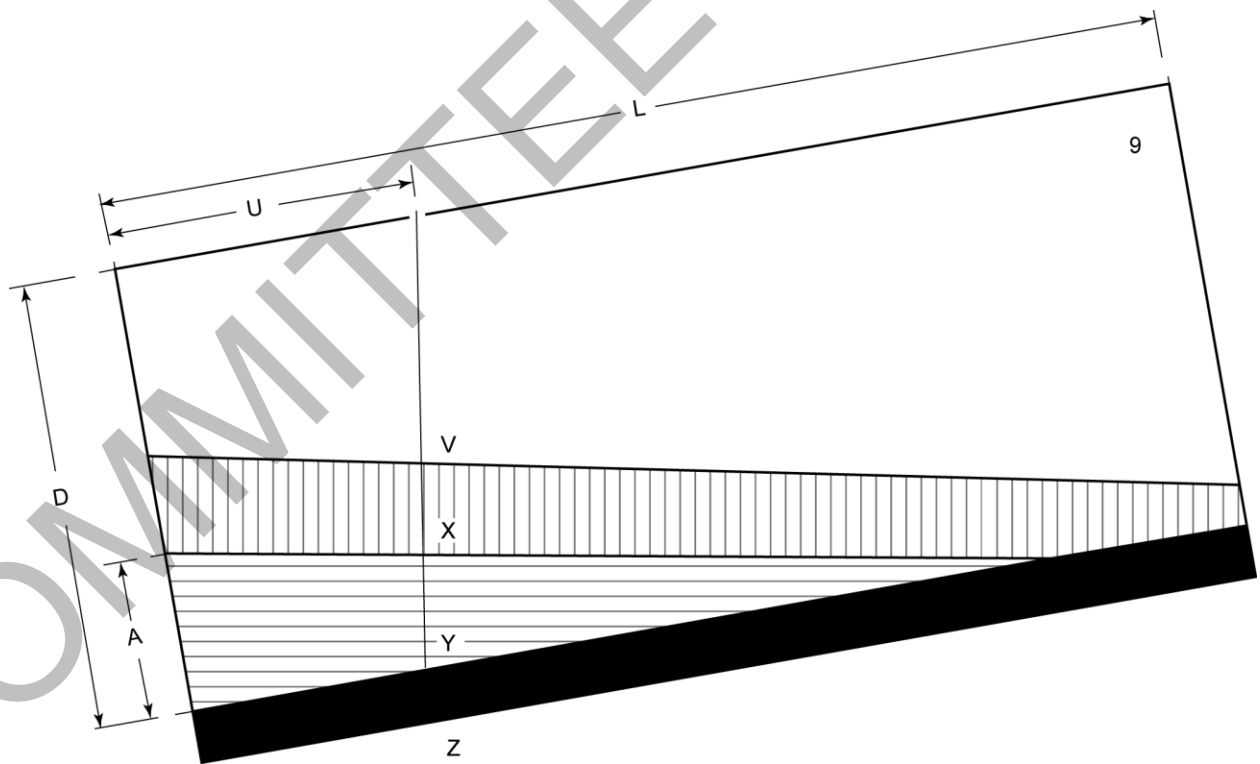


Figure A.9—Two Liquids with a Nonliquid Lower Layer (Lower Layer Liquid in Contact with Three Bulkheads Only)

A.10 Two Liquids (Oil and Water) with a Nonliquid Lower Layer

(See Figure A.10.)

Lower layer liquid in contact with all four bulkheads.

For Total Volume: Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. (Refer to A.2; the sounding represented by "VZ" is the applicable observed sounding.)

For Two Lower Volumes (Combined): Trim correction to be applied. Corrected volume to be obtained directly from vessel's capacity tables. (Refer to A.2; the sounding represented by "XZ" is the applicable observed sounding.)

For Lower (Nonliquid) Volume: No trim correction or wedge formula applicable. Volume to be obtained directly from vessel's capacity tables. (Refer to A.1; the sounding represented by "YZ" is the applicable observed sounding.)

For Upper Liquid Volume: Deduct the two lower volumes from the total volume.

For Central Liquid Volume: Deduct the lower nonliquid volume from the lower volumes.

A.11 Two Liquids (Oil and Water) with a Nonliquid Lower Layer

(See Figure A.11.)

Both liquids in contact with three bulkheads only.

For Lower (Nonliquid) Volume: No trim correction or wedge formula applicable. Volume to be obtained directly from vessel's capacity tables. (Refer to A.1; the sounding represented by "YZ" is the applicable observed sounding.)

For Total Wedge Volume (Upper and Central Volumes): Wedge formula to be used for volume calculation. [Refer to A.3; the sounding represented by "VY" is the applicable observed sounding ($S = VY$). The reference gauge height should be reduced by the amount of the nonliquid sounding.]

For Central Wedge Volume: Wedge formula to be used for volume calculation. [Refer to A.3; the sounding represented by "XY" is the applicable observed sounding ($S = XY$). The reference gauge height should be reduced by the amount of the nonliquid sounding. The adjusted sounding at the after bulkhead is represented by the lowercase "a."]

For Upper Liquid Volume: Deduct the central wedge volume from the total volume.

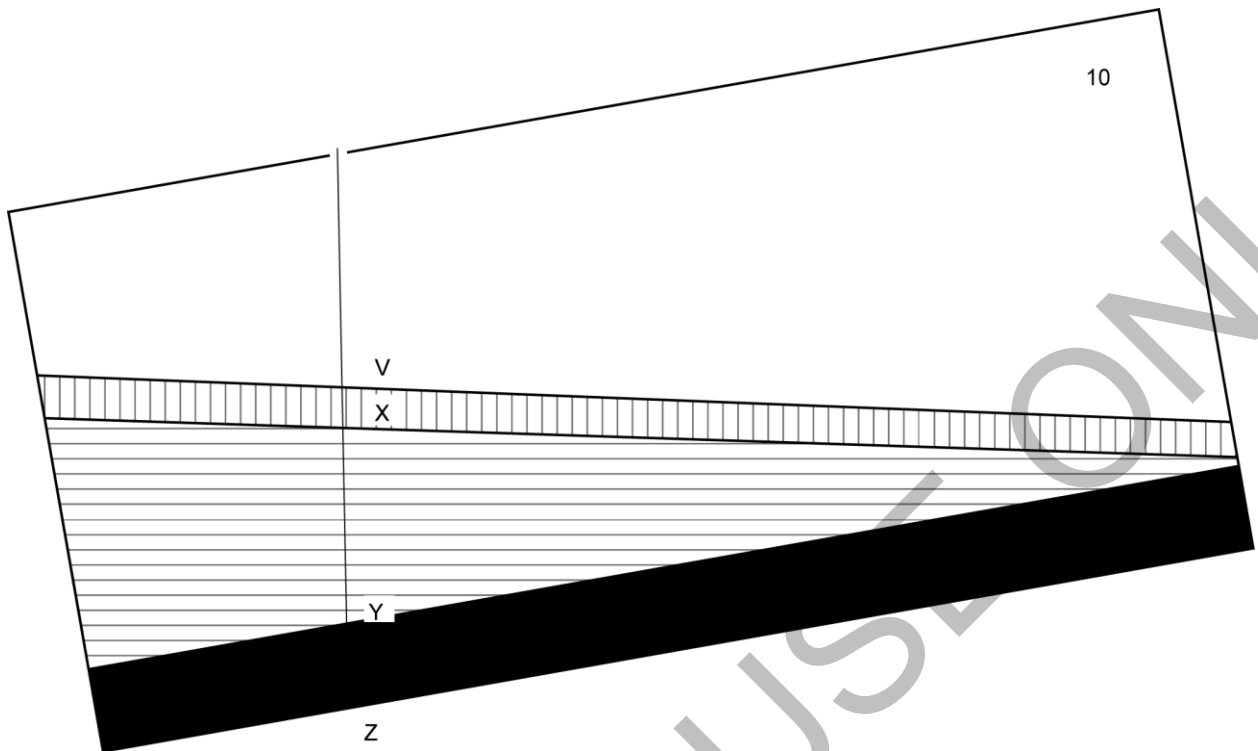


Figure A.10—Two Liquids with a Nonliquid Lower Layer (Lower Layer Liquid in Contact with All Four Bulkheads)

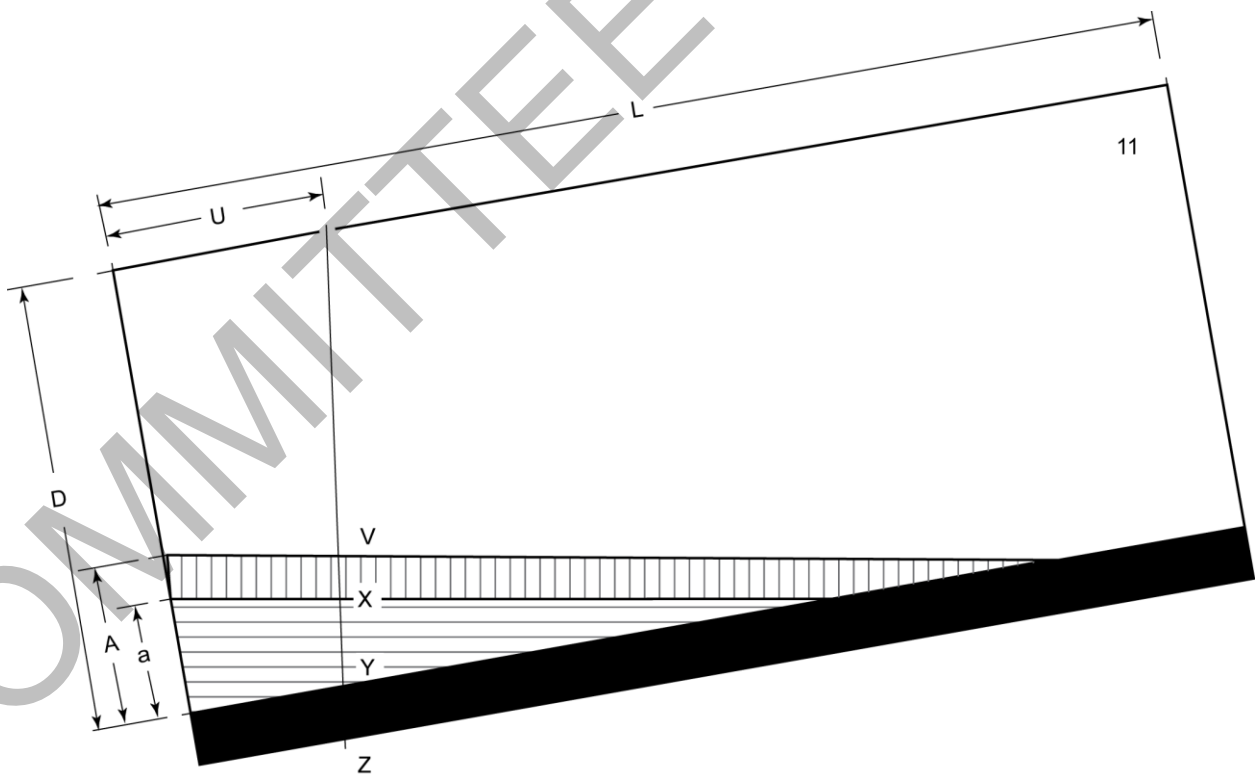


Figure A.11—Two Liquids with a Nonliquid Lower Layer (Both Liquids in Contact with Three Bulkheads Only)

Annex B
(informative)

On Board Quantity/Remaining On Board Report

COMMITTEE USE ONLY

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[illegible]

ADDITIONAL SPACE PROVIDED ON REVERSE SIDE OF FORM

() IDENTIFY UNIT OF VOLUME AND/OR MEASUREMENT

NOTES

1. F = Forward
C = Center
A = Aft
O = Other
2. If wedged, attach wedge calculation
3. Liquid indicated is free-flowing (in the opinion of the measurement representative)

GSV ()							FORWARD DRAFT ()			
FREE WATER ()							AFT DRAFT ()			
TCV ()							LIST (DEGREES) P/S			
LIQUID () (NOTE 3)							BALLAST TANKS USED THIS VOYAGE			
NONLIQUID () (NOTES 2 and 3)										
		STRIPPED		DROPPED		TANK NO.	OTHER (EXPLAIN)			
		YES	NO	YES	NO					
TOP LINES							SAMPLES TAKEN YES NO			
BOTTOM LINES							SEA VALVE SEAL NUMBERS			
HOSES/ARM							PORT _____			
							STARBOARD _____			
							OVERBOARD _____			

SIGNATURES
VESSEL REPRESENTATIVE
TERMINAL REPRESENTATIVE
MEASUREMENT REPRESENTATIVE

Page 2 of 2

() IDENTIFY UNIT OF VOLUME AND/OR MEASUREMENT

1. F = Forward
C = Center
A = Aft
O = Other

- 20

Annex C (normative)

Wedge Calculation

C.1 The Method of Calculating Wedge Volumes on Marine Vessels

The method described below details the formula and calculations necessary to determine the volume remaining in a marine vessel's cargo compartment when the marine vessel is trimmed by the stern and the vessel's trim correction is not applicable—that is, the material in the compartment does not extend the full length of the tank/compartment (i.e. not touching the forward bulkhead).

The method should only be applied after certain factors have been established:

- a) The material is lying in a wedge configuration on the compartment bottom (see C.2.2).
- b) The material is not touching the forward bulkhead of the compartment.
- c) The observed innage (gauge) represents part of the wedge surface area that extends from the aftermost compartment bulkhead to the foremost leading edge of the material surface—that is, the gauge is not a puddle of liquid or part of a small wedge lying directly forward of a transverse frame. It is recommended that additional innages be obtained forward and/or aft of the primary innage to verify the validity and use of the wedge calculation.

C.2 Formula/Method of Application

C.2.1 Calculation of Adjusted Innage/Gauge (A)

Step 1: Calculate the adjusted innage/gauge (A) at the aftmost compartment bulkhead, using the observed innage as follows:

$$\left[(U - DF) \times F \right] + S = A$$

where

A is adjusted innage at aft bulkhead;

U is distance from aft bulkhead to ullage position;

DF is reference gauge height (D) \times trim factor (F);

F is trim factor (trim divided by LBP);

S is observed innage (gauge).

The formula assumes that the cargo tank is “box shaped” with no internal structural/piping systems, heating coils, etc. that would impact the accuracy of the volume calculated from sounding.

C.2.2 Test for Wedge

Step 2: Determine that the material is lying in a wedge configuration.

$$\frac{A}{F} = \text{length of wedge}$$

If the result is greater than the compartment length, a wedge condition does not exist. Do not proceed with the calculation; apply the vessel's trim correction.

If A is less than the compartment length, continue with the second part of the formula expression (shown below).

Step 3: If a wedge condition does exist, the third step is to extract the mean table volume for use in the formula. The adjusted innage (A) is divided by two, and the table volume for this depth is extracted from the vessel's capacity tables.

Step 4: This mean table volume is used in the second expression of the formula to calculate the wedge volume:

$$\frac{T_v \times A}{L \times F} = \text{wedge volume (in table units)}$$

where

T_v is table volume (vessel ullage tables);

A is adjusted innage at aft bulkhead;

L is length of compartment (tank);

F is trim factor (trim divided by LBP).

NOTE All units of measurement shall be of the same denomination—that is, decimal feet or meters.

The use of the table volume provides a volumetric ratio that, when applied to the total expression of the formula, partially compensates for the internal tank framing (if included in the vessel's capacity tables), volume below tank datum, and width of the tank at the lower extremities of the compartment.

The total formula expression, therefore, is as follows:

$$\frac{\{[(U - DF) \times F] + S\} \times T_v}{L \times F} = \text{wedge volume (in table units)}$$

NOTE For vessels that are trimmed down by the head, the distance from the ullage hatch to the forward bulkhead shall be used in the calculation ($L - U$), as opposed to using the distance from the aft bulkhead. The calculation for vessels trimmed by the head is termed "reverse wedge."

C.3 Compartments with Extreme Shape Due to Hull Curvature

Care should be exercised on compartments where the vessel's hull curvature is extreme, such as on the forward- and aftermost wing tanks where significant variation in longitudinal width and/or depth is evident. For such tanks, the mean width at the liquid surface should be ascertained.

An example of this is, where the width at the aft end of a tank, 1 Starboard is 10 meters, whereas the width at the forward end is 5 meters. A small liquid volume at the aft end of the tank would have a width close to that of 10 meters. In this case, it would be more appropriate to use the actual width at the bottom of the tank

in the simplified formula thus:

$$\frac{A^2 \times W}{2 \times F} = \text{wedge volume (in measured units)}$$

where

A is adjusted innage at the aft bulkhead (squared).

W is width at the tank bottom (usually aft end).

F is trim factor (trim divided by LBP).

EXAMPLE (1 Starboard)

Trim = 4.00 meters

LBP = 230.00 meters

Trim Factor = 0.01739 (to five places)

A = 0.05 (adjusted innage)

Width = 8.00 meters (at bottom aft section of tank, as taken from the vessel's drawings)

$$\begin{aligned} \text{wedge volume} &= \frac{A^2 \times W}{2 \times F} \\ &= \frac{0.05^2 \times 8.00}{2 \times 0.01739} \\ &= \frac{0.02}{0.03478} \\ &= 0.575 \text{ cubic meters} \\ &= 3.62 \text{ barrels (cubic meters} \times 6.289812) \end{aligned}$$

In aftmost wing compartments, the effect of hull curvature is reversed: the width is much smaller at the aft end. Additionally, in such tanks, it is quite common for the gauge tape not to reach the very bottom of the tank because the tape comes into contact with the shell (curving in toward the tank bottom). As the vessel's capacity tables give the volume below the datum, using the table volume in the formula will most often result in a more accurate ratio than using the simplified formula. Hull curvature and tank configuration vary significantly from vessel to vessel. Where possible, a vessel's drawings should be consulted to help qualify the choice of appropriate wedge formula application.

Wedge Calculation Worksheet

[illegible]

Key (all values to be in same units)	
A	Adjusted innage at aft bulkhead
D	Reference height (depth)
S	Sounding (observed innage)
U	Ullage distance (from aft bulkhead) (See Note 3)
L	Length of tank
F	Trim factor (trim ÷ LBP)

FIELD INFORMATION		
Draft Aft		
Draft Forward	–	
Trim	=	
LBP	+	
Trim Factor (F)	=	
Mean Height (D)	×	

NOTES

1. Wedge length = A/F . If the length of the wedge is greater than the tank length, do not proceed with the calculation; use applicable trim correction.
2. Extract the table volume for a vessel on an even keel and upright.
3. Reverse wedge: If the vessel (barge) is trimmed down by the head (bow), then use the distance from the ullage hatch to the forward bulkhead.
4. On tanks with extreme shape (e.g. 1 wings), calculate the adjusted innage (A) and use the compartments' bottom width (W) in substitute formula $A2 \times W/F$ and multiply by 0.089055 (customary).

INSPECTOR: _____

FOR VESSEL: _____

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- [1] API Publication 2026, *Safe Access/Egress Involving Floating Roofs of Storage Tanks in Petroleum Service*
- [2] API Publication 2217A, *Guidelines for Work in Inert Confined Spaces in the Petroleum Industry*
- [3] API *Manual of Petroleum Measurement Standards (MPMS)* Chapter 1, *Vocabulary*
- [4] ACGIH ¹, *Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment*
- [5] ICS ²/OCIMF ³/IAPH ⁴, *International Safety Guide for Oil Tankers and Terminals (ISGOTT)* ⁵
- [6] OSHA ⁶, *Occupational Safety and Health Standards, 29 Code of Federal Regulations* Section 1910.1000 and following
- [7] SOLAS ⁷, *International Convention for the Safety of Life at Sea*

¹ American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240.
² International Chamber of Shipping, 38 St Mary Axe, London EC3A 8BH, United Kingdom.
³ Oil Companies International Marine Forum, 29 Queen Anne's Gate, London SW1H 9BU, United Kingdom.
⁴ International Association of Ports and Harbors, 7th Floor, South Tower New Pier Takeshiba, 1-16-1 Kaigan, Minato-ku, Tokyo 105-0022, Japan.
⁵ *ISGOTT* is available from Witherby Seamanship International (Division of Witherby Publishing Group Ltd). 4 Dunlop Square, Deans Estate, Livingston EH54 8SB, United Kingdom.
⁶ 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, DC 20402.
⁷ International Maritime Organization, 4 Albert Embankment, London SE1 7SR, United Kingdom.



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