Manual of Petroleum Measurement Standards Chapter 12—Calculation of Petroleum Quantities

Section 1—Calculation of Static Petroleum Quantities

Part 2—Calculation Procedures for Tank Cars

FIRST EDITION, MAY 2003

REAFFIRMED, MAY 2011

AMERICAN PETROLEUM INSTITUTE

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1 Introduction

This Chapter of the *Manual of Petroleum Measurement Standards* describes the standardized method for calculating target loading quantities and actual loading quantities of liquids in tank cars. Also addressed within this chapter is an explanation of the factors required for the calculations.

2 Scope

This Chapter is applicable to all crude oils, petroleum products, and petrochemicals (including LPGs and other liquefied gases) transported by rail tank car. It does not cover any products loaded or measured as solids. It defines the terms required to understand the calculations, and provides instructions for their use. The cars are assumed to be on level ground.

3 References

API

Manual of Petroleum Measurement Standards (API *MPMS*)

Chapter 1	"Vocabulary"
Chapter 3.2	"Tank Car Measurement"
Chapter 7	"Temperature Determination"
Chapter 11	"Physical Properties Data"
Chapter 11.1	"Volume X Background, Development, and Program Documentation"
Chapter 12.2	"Calculation of Petroleum Quantities Using Dynamic Measurement Methods and Volumetric Correction Factors"
API White Paper	"The Use of the Petroleum Measurement Tables — *Manual of Petroleum Measurement Standards*", Chapter 11.1 (API Std 2540, ASTM D1250, IP 200, ISO 91-1)
Std 2554	*Measurement and Calibration of Tank Cars*

DOT[1]

49 *CFR*, Parts 106–180
49 *CFR*, Ch. II 215.201

GPA[2]

8195-95	"Tentative Standard for Converting Net Vapor Space Volumes to Equivalent Liquid Volumes"

[1]U.S. Department of Transportation. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

[2]Gas Processors Association, 6526 East 60th Street, Tulsa, Oklahoma 74145.

ASTM[3]

ASTM-IP *Petroleum Measurement Tables,* 1952.

4 Definitions

Extended definition of vocabulary applicable to this Chapter is presented below. Terms of more general use (i.e., API Gravity, Density, etc.) may be found in API *MPMS* Chapter 1.

4.1 GENERAL

4.1.1 capacity table: See definition for tank car capacity table.

4.1.2 capacity table adjustment factor (CTAF): Since one capacity table may be used for hundreds of tank cars, yet tank cars cannot be constructed to exactly match the table, the table may be mathematically fitted to the tank car by applying an adjustment factor. This factor is calculated by dividing the stenciled volume (V_s) by the table max volume (V_{tblmax}).

4.1.3 closed loading/unloading: The manway remains closed or covered during loading/unloading. For a pressure car, sampling and measurement must be accomplished by external means or special local procedures.

4.1.4 compartment car: A car with two or more independent (no common walls) tanks, each with its own manway, reference point, and capacity table.

4.1.5 correction, temperature, liquid (CTL): See volume correction factor.

4.1.6 correction, temperature, shell (CTS): A correction for the expansion of the tank car's steel shell due to temperature.

4.1.7 custody transfer measurement: Provides quantity and quality information used for the physical and fiscal documentation of a change in ownership and/or responsibility for commodities.

4.1.8 dome tank cars: Non-pressure tank cars with an expansion trunk (dome) at the top center of the tank car to provide space for expansion of the liquid in the car. The manway nozzle is on the dome. These are generally 10,000 gallons or less and are no longer made. Since tank cars have a statutory 50-year lifetime, they will continue to be used for some time (49 *CFR* Ch. II, 215.201, as of this printing).

[3]American Society for Testing and Measurement, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, 19248.

4.1.9 domeless tank cars: Tank cars with the manway nozzle attached directly to the top of the tank car shell.

4.1.10 funnel flow cars: Tank cars that have a "V" shape to allow drainage. The manway nozzle is usually located about 6 inches off the center point, along the longitudinal axis of the car. The slope of each of the two halves is on the order of 0.25 inches/foot. Slope and manway position will vary with the manufacturer.

4.1.11 gauge: The measure of the liquid level in a tank, vertically from the tank car's reference gauge point.

4.1.12 gauging: A process of measuring the height of a liquid in a container.

4.1.13 general purpose tank car: A non-pressure tank car designed and constructed under DOT regulations to transport liquids of relatively low volatility, such as asphalts, crude oils, fuel oils, solvents, specialty chemicals, etc.

4.1.14 gross observed volume (GOV): The total volume of all petroleum liquids and sediment and water, excluding free water, at observed temperature and pressure.

4.1.15 heel: The amount of liquid and vapor present in a car before loading, or left in a car after unloading.

4.1.16 innage gauge: The depth of liquid measured at the tank car's reference gauge point from the bottom of the tank car shell upwards to the liquid surface.

4.1.17 interior lining: The surface coating applied to the interior of a tank car shell to prevent the contents from contacting the metal shell. Linings may be damaged if gauging equipment is not used carefully. The thickness of the lining is included in the calculation of the tank's capacity table. If a lining is removed, replaced, or added at a later date by the car's owner, the capacity table should be recalculated.

4.1.18 light weight (tare): The number painted on the sides of a tank car near its ends indicating the empty weight of the car.

4.1.19 liquefied gas: A generic term referring to gases (such as ammonia, butylene, propylene, ethylene oxide, propylene oxide, etc.) stored and transported under pressure as a liquid.

4.1.20 liquefied petroleum gas (LPG): Gas that is predominantly butane and propane, separated from natural gasoline or natural gas, and sold in liquid form as fuel-commonly known as bottled gas, tank gas, or LP gas.

4.1.21 liquid equivalent: The quantity of liquid product contained as a gas in the vapor space above the liquid surface in a pressure tank car.

4.1.22 load limit: The number painted on the sides of a tank car near its ends indicating the maximum legal weight of its contents.

4.1.23 magnetic float gauge: A gauging device fitted to a tank car to permit measuring the liquid level in the car without opening the car to the atmosphere. The device consists of a spherical toroidal float with an interior magnet that moves up and down a hollow tube (sealed to the outside) as the car's liquid level changes. Another magnet is attached to the bottom of a graduated gauge rod located in the hollow tube and accessible from the outside. When the gauge rod is manually pulled up until the two magnets link, the liquid level's outage may be read off the rod. An outage offset may have to be calculated if the gauge's reference relative density (specific gravity) is different from that of the product to be measured, or if the temperature of the liquid differs substantially from 60°F.

4.1.24 manway (manway nozzle): A cylindrical opening on the top of a tank car with a hatch for access to the interior of the car. The manway may extend into the car's shell a few inches or be ground flush with the shell at the weld. On general purpose cars, it may be used for open loading and gauging. On pressure cars, the hatch remains secured and usually contains thermowells, magnetic float gauges, and loading valves permanently installed.

4.1.25 manway height: The vertical distance downward from the top lip of the nozzle (hatch open) to the inside top of the car shell, measured at the point on the rim closest to the center of the car. This should not be confused with the length of the nozzle cylinder, which may extend several inches into the car's shell.

4.1.26 markers (2% marker): Metal liquid level indicators installed in domeless tank cars, usually at the level where the car is filled to 98% of capacity but occasionally at other levels. Markers are **not** accurate measurement devices, and are **not** recommended for custody transfer measurements.

4.1.27 net standard volume (NSV): The total volume of all petroleum liquids, excluding sediment and water and free water, corrected by the appropriate volume correction factor for the observed temperature and API gravity, relative density, or density to a standard temperature such as 60°F or 15°C, and also corrected by the applicable pressure correction factor.

4.1.28 NIST traceable: Instruments (gauge tapes and bobs, thermometers, hydrometers, yard sticks, etc.) whose accuracy has been verified to compare, within certain tolerances, to measurement reference standards at the NIST. A primary standard (1st generation standard) may be purchased from the NIST. Due to their expense, these are normally purchased by manufacturers who use them to verify the accuracy of the standards that they make (2nd generation). These less expensive standards are purchased by the industry for use as field standards, which are then used to verify the accuracy of the actual equipment used in the field (3rd generation). **This 3rd generation field equipment may not be used to verify other field equipment.** The verification of the field equipment must be performed (and documented) periodically.

4.1.29 open loading/unloading: For a general purpose car, the manway hatch remains open during loading/unloading. Sampling and measurements generally take place through the open manway.

4.1.30 outage gauge: The measured vertical distance from the tank car's reference gauge point downward to the liquid surface.

4.1.31 pressure tank car: A closed tank car (no direct access to the interior of the car for measurement) designed and constructed under DOT regulations to transport high volatility products and liquefied compressed gases under pressure (typically 200 psig for LPG). These cars are normally straight horizontal cylinders (no sloping bottoms) and have a permanently installed magnetic float gauge or slip tube.

4.1.32 reference conditions: The conditions of temperature and pressure to which measured volumes are to be corrected.

4.1.33 reference pressure: The pressure at which a product is traded, normally atmospheric pressure (14.696 psia, 0 psig, 1 atm), but equilibrium vapor pressure for liquefied gases.

4.1.34 reference temperature: The temperature at which a product is traded by volume, normally 60°F in the U.S., and either 15°C or 20°C elsewhere. In a VCF table, it is the temperature which has a VCF of 1.00000. For products that must be heated to load, or products that are sold by calculated weight, the reference temperature may be much higher (i.e., 120°F for phenol, 270°F for sulfur, etc.).

4.1.35 relative density: The ratio of the mass of given volume of liquid at 15°C (or other standard temperature, such as 60°F) to the mass of an equal volume of pure water at the same temperature. When reporting results, explicitly state the standard reference temperature (for example, relative density 15/15°C).

4.1.36 slip tube: A graduated hollow rod fitted into a gas-tight housing. The lower end of the rod is open to the cargo's contents and the upper end is fitted with a valve. The rod is withdrawn above the expected outage and then the valve is opened, expelling a vapor fog from the vapor space. The rod is then lowered towards the liquid surface. As it contacts the liquid, the expelled fog changes to liquid droplets. These devices are gradually being replaced with magnetic float gauges due to emissions concerns.

4.1.37 specific gravity: See relative density.

4.1.38 statutory outage: The percentage of the total liquid capacity of a tank car reserved for vapor space set by DOT 49 *CFR* 173.24b or 173.314 (as of this printing) for calculating loading target outage.

4.1.39 statutory temperature: The temperature set by DOT 49 *CFR* 173.24b or 173.314 (as of this printing) for calculating loading target outage.

4.1.40 stenciled capacity (stenciled volume, V_S): See tank car capacity.

4.1.41 table max volume (V_{tblmax}): The greatest volume in a capacity table.

4.1.42 tank car capacity (stenciled capacity, or volume): The number painted onto the ends or sides of a tank car indicating its shell-full capacity. This is the amount of water in gallons and liters that the car can contain at 60°F. This value is determined directly by metering water into the car or indirectly by strapping the car. See tank car shell-full.

4.1.43 tank car capacity table: Table often referred to as a tank capacity table or calibration table, showing the capacities or volumes in a tank for various liquid levels measured from the tank car's reference gauge point. The same capacity table may be assigned to many similar, but not identical, tank cars. The table may be based on either innage or outage gauges and may indicate either liquid or vapor space gallons. These are referred to as outage/liquid, outage/vapor, innage/liquid or innage/vapor tables. Tank car manufacturers have traditionally located the reference gauge point at the top inside of the car's shell at the shell-full point; the top of the manway closest to the center point of the car is now specified by API *MPMS* Chapter 3.2.

4.1.44 tank car reference gauge point: The point from which **all** liquid level measurements should be taken. When the tank car can be opened for liquid level measurement, the reference gauge point is now defined (API *MPMS* Chapter 3.2) as being at the top edge of the manway opening at the longitudinal centerline of the tank car at the point on the manway circumference closest to the midpoint of the tank car. Prior to the publication of API *MPMS* Chapter 3.2, the de facto industry standard was the shell-full point, and most capacity tables are referenced to this point. To convert the old reference point to the new one, add the manway height. Tank cars that cannot be opened for liquid level measurement are equipped with built-in measurement equipment; the reference gauge point in these tank cars should be established by the manufacturer of the measurement equipment.

4.1.45 tank car shell-full: The maximum amount of water the shell can contain at 60°F. For funnel flow cars, the shell-full point is at the center of the car (there will be air pockets on both sides where the liquid cannot reach). Pressure cars, which are horizontal cylinders, will include the manway volume.

4.1.46 thermometer well (thermowell): A metal tube, sealed at the bottom, which extends into tank cars requiring closed loading/unloading. The thermowell is filled with a heat-transferring liquid of low volatility and freeze point (usually ethylene glycol) which transmits the temperature of the tank car contents to a thermometer or thermoprobe lowered into the thermowell.

4.1.47 vapor space: The volume above the liquid surface.

4.1.48 volume correction factor (VCF): The ratio of the density of a liquid at a given temperature to its density at reference temperature (normally 60°F). Multiplying a liquid's volume by this value computes its volume at reference temperature (net standard volume). Also known as CTL (correction, temperature, liquid).

4.2 ABBREVIATIONS

4.2.1 CTL: Correction, Temperature, Liquid.

4.2.2 CTS: Correction, Temperature, Shell.

4.2.3 DOT: Department of Transportation.

4.2.4 GOV: Gross observed volume.

4.2.5 LPG: Liquefied petroleum gas.

4.2.6 NSV: Net standard volume.

4.2.7 NIST: National Institute of Standards and Technology, formerly the National Bureau of Standards (NBS).

4.2.8 VCF: Volume correction factor.

4.2.9 V_S: Stenciled volume.

5 Required Data Acquisition

As with any calculation, the results are only as reliable as the data entered. It is essential that the tank car information and measurements be NIST traceable and as accurate as possible. Temperature and level measurement equipment and procedures should also be reviewed for compliance with API custody transfer standards (see API *MPMS* Chapter 3.2).

5.1 TANK CAR DATA

Experience has shown that inaccurate tank car information is often used (sometimes for many years). Data obtained off the tank car should be verified to be identical to that in any industry or company data bases used.

5.1.1 Light Weight

Obtained from the side of the car or industry database.

5.1.2 Load Limit

Obtained from the side of the car or industry database.

5.1.3 Stenciled Volume

Obtained from either end of the car or industry database.

5.1.4 Tank Car Capacity Table

Obtained from the tank car owner, manufacturer, or industry database. Care must be taken to ensure that the correct capacity table is used (it is not uncommon for individual locations to have outdated or wrong tables). A car's useful statutory life is 50 years, so there may be several different versions in use for the same car. Furthermore, as of this writing there is no industry standard format, and a manufacturer may have changed their format several times over the years. Thus, it is generally impossible to determine by observation when the table was issued and thus if it is more current than another table. If in doubt, contact the owner of the tank car.

Care must also be taken to ensure that the capacity table is used properly. There may also be no indication as to what type of table it is, and thus the table may be used incorrectly. Generally, there are four possible types of tables: outage/liquid, outage/vapor, innage/liquid, and innage/vapor. The manufacturers have developed these tables using the inside top of the shell at the center of the car as a reference point. This is also known as the "shell-full point." Distance increments (normally $^1/_4$ inch) are then listed from the reference point down to the liquid surface (outage) or from the bottom of the car directly below the reference point to the liquid surface (innage), and the corresponding liquid or vapor volume is calculated and inserted in the table. Using an innage/vapor table as an outage/liquid table will introduce an error on the order of several hundred gallons as the tables are usually not symmetrical. Experience has shown that table misinterpretation is the most common cause of calculation error.

5.1.5 Manway Nozzle Height

Liquid levels are most commonly determined via outage measurements, especially if the product is hot and solidifies at ambient temperature. In practice, it is difficult if not impossible to take an outage measurement from the inside top of shell reference point unless a proper measuring device (commercially available) is at hand. Absent such a device, it is much easier to measure from the top of the open manway nozzle nearest the center point of the car. This requires measurement of the offset from the reference point, otherwise known as the manway nozzle height. This offset must be measured with the proper instrument (commercially available) for maximum accuracy. Absent this device, numerous "work arounds" (usually containing systematic errors) have been developed in the field to compensate. Most manways penetrate the tank car's shell by varying depths, as much as 3 inches This penetration is **not** part of the manway's height and should not be included. Some tank cars may already have their original tables changed to incorporate the manway height at the request of the car's owner.

5.2 PRODUCT DATA

5.2.1 Actual Liquid Temperature

Once the car is loaded, a temperature must be taken from the center of the product at the time of gauging (after motion ceases). For very hot products like asphalt, sulfur, etc., the temperature and gauge should be taken as soon as possible, as the product will quickly stratify, forming a nonlinear temperature gradient.

5.2.2 Liquid VCF Table

An accurate VCF table must be available to properly calculate liquid volumes at loading temperature. The table may be an industry accepted version developed by the API or ASTM (see the API White Paper, "The Use of the Petroleum Measurement Tables"), or a private version developed directly from density data. Occasionally, a product's composition may fluctuate (or have changed) enough to justify the preparation of a new table. It is critical that a product be properly sampled and stored to ensure that a sample representative of normal production be available for density measurement at different temperatures. These densities can then be converted to a VCF table via methods described elsewhere (API *MPMS* Chapter 11.1 Volume X, for example).

5.2.3 Liquid Density at Reference Temperature

The liquid's density may be directly measured at ambient temperature and corrected to reference temperature. It is commonly measured in g/cc (grams/cubic centimeter), kg/m^3 (kilograms/cubic meter), API gravity, or specific gravity and converted to pounds/gallon. Density units are commonly in vacuum, while weights are normally in air. To convert density to weight in air, ASTM Tables 8 or 26 should be used.

5.2.4 Liquid Gauge

5.2.4.1 General Purpose Cars

Once the car is loaded, a gauge must be taken at the reference point. This should be made at the same time an actual liquid temperature is recorded. The contents **must** be allowed to cease motion (some products may take as much as 15 minutes) before the gauge is taken, as any wave motion will result in an artificially low outage (or high innage) and thus the volume of liquid calculated will be overstated. The gauge may be taken from (a) as an outage gauge from the top of the manway nozzle, (b) as an outage gauge from the inside top of the shell, or (c) as an innage gauge.

5.2.4.2 Pressure Cars

Gauges are taken from installed equipment, usually a slip tube or magnetic float gauge. These are outage gauges normally referenced to the top inside of the shell, so manway heights are not required. Magnetic float gauge tubes should not contain so much antifreeze or similar type liquid (to prevent condensed water from freezing) as to wet the rod. If a tube is filled with such liquid, its buoyant force on the rod will make the gauge float higher and overstate the product level. The contents **must** be allowed to cease motion (some products may take as much as 15 minutes) before the gauge is taken, as any wave motion will result in an artificially low outage (or high innage) and thus the volume of liquid calculated will be overstated.

5.2.5 Tank Car Temperatures

A volume correction may be made for tank car shell expansion or contraction if its temperature is high or low enough to have a significant effect. When loading very hot material like asphalt (300 – 350°F) into an ambient tank car, it cannot be assumed that the shell temperature is the same as the liquid temperature. Measurements have shown that products with melting points higher than the ambient temperature will solidify and effectively insulate the shell from the bulk of the cargo. Furthermore, the product will form a nonlinear (because the car is round) temperature gradient fairly quickly. (Measurement of a 55°F ambient asphalt car [unpublished data] one-half hour after loading at 307°F and showing a temperature of 304°F near the middle of the car, 283°F one foot lower, 183°F just above the solidified asphalt on the shell, and 140°F an inch or two into the "rind.") Thus, a shell expansion correction should be made only when one can be sure of the shell temperature; normally this will only occur when there is no solidified material on the shell (Appendix B and Table B-1). Cars that have been steamed to melt the contents will also meet this criteria, and the temperature will be high enough to have a significant effect on the volume.

5.2.6 Tank Car Pressure

A volume correction may be made for tank car shell expansion if its pressure is high enough to have a significant effect (Appendix C and Table C-1).

6 Actual Loaded Quantity Calculations

Once a tank car is loaded and the actual loading temperature and gauge have been taken, calculation of the net standard volume and liquid weight is relatively straightforward.

6.1 GENERAL PURPOSE CARS

To calculate the net standard volume (NSV), look up the gauge in the tank car capacity table, interpolating if necessary, to find the corresponding gross observed volume (GOV). Multiply this volume first by the capacity table adjustment factor (CTAF = V_s / V_{tblmax}), then by the VCF at loading temperature. Multiply by the correction for the temperature of the steel shell (CTS), if desired (optional, Appendix B).

$$NSV = (GOV)(CTAF)(VCF)(CTS) \qquad (1)$$

To find the weight of the cargo, multiply the net standard volume by the density in pounds per gallon at the reference temperature (d_{ref}). Remember, although volume (and therefore density) changes with temperature, the weight of that volume does not.

$$W = NSV(d_{ref}) \qquad (2)$$

6.2 PRESSURE CARS

The net standard volume is calculated as above for general purpose cars, except that a correction for the tank car pressure (CPS) may also be applied, if desired (optional, Appendix C).

$$NSV = (GOV)(CTAF)(VCF)(CTS)(CPS) \qquad (3)$$

Pressure cars with magnetic float gauges may require additional special calculations to determine the offset to be applied to the observed gauge. The gauges are calibrated for a reference liquid at 60°F. A more dense liquid will cause the float to float higher and result in a smaller outage reading, thus indicating that there is more liquid in the car. A less dense liquid will have the opposite effect. Temperature has a similar effect. Temperatures higher than 60°F will make the liquid less dense, resulting in a larger outage as the float will float lower, so the gauge will understate the car's contents. Temperatures less than 60°F will have the opposite effect. The magnitude of the effect depends on the characteristics of the gauge and the magnitude of the change in relative density and temperature. Generally, calculations (see examples in Appendix D) show the gauge offset may vary from < $^1/_8$ inch to > 3 inches, depending on specific gravity and temperature changes. Successful calculation of this effect requires a knowledge of the gauge component specifications (volume of float, weight of float and rod assembly, reference relative density) which are available from the manufacturer. See Appendix D for the equations required and their derivations.

The weight of the cargo is calculated as for general purpose cars.

$$W = NSV(d_{ref}) \qquad (2)$$

6.3 VAPOR SPACE HEEL

Assuming no "noncompressible" or foreign gas has been introduced to offload product, liquefied gases and liquids of sufficiently high vapor pressure will also occupy the vapor phase above the liquid. While this may be insignificant when the vapor phase is a small percentage of the total volume of the car, it is a significant portion of the total product after the car has been emptied. It may be calculated (based on temperature, pressure, relative density, and composition) in liquid equivalent net gallons via GPA 8195 or any other acceptable procedure, or fixed by mutual agreement. For a loaded car, this can be added to the net liquid gallons; for an unloaded car, this may be subtracted from the net liquid gallons as a vapor heel.

6.4 OVERLOAD CHECK

The actual loaded weight should be calculated as shown above and compared to the Load Limit to assure the car is not overloaded by weight. The actual loaded volume should be calculated at the statutory temperature to make sure the outage (vapor space left for liquid expansion) is not less than the statutory outage. This is done by multiplying the table volume (GOV) at load temperature by the capacity table adjustment factor CTAF, the VCF at loading temperature, and (if applicable) the corrections for shell temperature expansion and/or shell pressure expansion factors at loading temperature to get the net volume. Then, divide by the VCF at statutory temperature to obtain the volume of liquid at statutory temperature (V_{astat}).

$$V_{astat} = \frac{(GOV)(CTAF)(VCF)(CTS)(CPS)}{(VCF_{stat})}$$

$$= \frac{(NSV)}{(VCF_{stat})}$$

The volume at statutory temperature is then divided by the stenciled volume (V_s), multiplied by 100, and subtracted from 100 to obtain the percent vapor space at statutory temperature. This number should be equal to or greater than the product's statutory outage (see Appendix A).

$$\text{Vapor Space \%} = 100 - \frac{(V_{astat}) \times 100}{V_s}$$

or

$$= 100 - \frac{(NSV) \times 100}{(VCF_{stat})(V_s)} \qquad (4)$$

The correction of V_s at statutory temperature for temperature and pressure expansions is not performed for reasons of: (a) calculation simplicity, and (b) safety (their omission results in slightly understating the vapor space percentage). The vapor space percentage at statutory temperature must be equal to or larger than that dictated by statute.

7 Rounding

7.1 DATA LEVEL

The number of decimal places used is influenced by the source of the data. If a tank car's capacity tables are in whole gallons, then all subsequent gallon values should be recorded accordingly. In those cases where there are no other limiting factors, the operator should be guided by Table 1.

7.2 ROUNDING OF NUMBERS

When a calculation result is to be rounded to a specific number of decimals, it shall always be rounded off in one step to the number of figures to be recorded, and not rounded in two or more successive steps. When the figure to the right of the last place to be retained is less than 5, the figure in the last

Table 1 — Significant Digits

Units	No. of Decimals
Gallons	xxxxx.xx
Pounds	xxx.0
Liters	xxx.0
Kilograms	xxx.0
API Gravity @ 60°F	xxx.x
VCF	x.xxxxx
Density pounds/gallon	xx.xxx
Relative density	x.xxxx
Temperature °F	xxx.x
Temperature °C	xxx.x5
CTS	x.xxxxx
CPS	x.xxxxx

APPENDIX A — LOADING TARGET QUANTITY CALCULATIONS

A.1 General

In order to maximize delivered quantities and minimize shipping costs, most tank cars are loaded to the maximum amount allowable. DOT regulations, railroad regulations, manufacturing standards, and company policies govern the maximum amount of material that a tank car may contain. DOT 49 *CFR* 179.13 (as of this printing) stipulates that no tank car used for transportation of hazardous materials and its contents may weigh more than 263,000 pounds or exceed 34,500 gallons capacity; however, individual tank car construction specifications may require a smaller total weight (for example, the total weight may be limited by the size of the truck assembly).

A.2 Required Data — Target Liquid Temperature

In addition to the requirements stated above, the following information is necessary to properly calculate target quantities:

A.2.1 COOL LOADING (BELOW STATUTORY LOADING TEMPERATURE)

DOT 49 *CFR* 173.24b stipulates (as of this printing) that for most hazardous materials a minimum expansion volume (vapor space) equivalent to 1% at the statutory temperature of 115°F (for uninsulated cars), 110°F (for thermally protected cars), or 105°F (for insulated cars) must be maintained. For materials deemed poisonous by inhalation (ethylene oxide, ammonia, chlorine, phosgene, allyl alcohol, bromine, hydrogen fluoride, etc.), the vapor space must be 5%. During the winter (November 1 through March 31), the statutory temperatures of 100°F, 90°F, and 85°F may be used for certain liquefied petroleum gases (LPGs, butanes, propylene, etc.) and ammonia (DOT 49 *CFR* 173.314). Tank cars loaded to these limits must be shipped directly and not be stored in transit. They must be unloaded as soon as possible after March. Liquids expand as their temperature increases and contract as it decreases. Since the liquids will rarely be loaded at either 115°F, 110°F, or 105°F, the volume actually loaded at loading temperature must expand to no more than 99% (or 95% for materials deemed poisonous by inhalation) of the tank car's capacity at the applicable statutory temperature. Thus, the lower the loading temperature the smaller the volume that can be legally loaded. Accurate liquid loading temperatures are therefore required both to optimize the amount loaded and avoid overloading. If the actual loading temperature is lower than that used for target calculations, the calculated target volume will be too high and the car will be overloaded. Conversely, if the actual loading temperature is higher than that used for target calculations, the calculated target volume will be too low and the car will be underloaded. Accurate loading temperatures are rarely obtained from the storage tank or loading line, especially when there is a large difference between liquid temperature and ambient temperature. The most accurate loading temperature can be obtained by measuring the liquid in the car during loading while the car is about two-thirds full. The final loading target outage can then be determined from this temperature.

A.2.2 HOT LOADING (ABOVE STATUTORY LOADING TEMPERATURE)

There are currently no DOT regulations regarding vapor space volumes for liquids loaded at temperatures above the statutory loading temperatures. Since these liquids will cool (and may solidify) during transport, they will normally be reheated via the tank car's steam coils. This may cause the liquid to be heated to a higher temperature than that at which it was loaded, thus expanding to a volume greater than that loaded and possibly overflowing the tank. In such cases a vapor space at loading temperature equivalent to or larger than the DOT outage limits (2% is common for most materials, 5% is normally adequate for materials poisonous by inhalation) is recommended and an accurate loading temperature is not required for target outage calculation.

A.3 General Purpose Cars

A.3.1 To avoid overloading a car by weight, the weight of the maximum amount of liquid allowed by volume must be determined. To calculate this amount, multiply the stenciled capacity by the DOT maximum fraction of liquid allowed (MFLA, 0.99 in most cases), correct the volume from the statutory temperature to 60°F, and multiply by the liquid's density at 60°F in pounds/gallon:

$$W_{ma} = V_s\,(MFLA)\,(VCF_{stat})\,(d_{ref}) \tag{A.1}$$

where

W_{ma} = weight maximum allowed by volume, pounds,

V_s = stenciled volume, gallons,

MFLA = DOT maximum fraction of liquid allowed (0.99 or 0.95, or 0.98 for hot loading),

VCF_{stat} = VCF at statutory temperature,

d_{ref} = density at reference temperature.

A.3.2 If W_{ma} exceeds the car's Load Limit, the Load Limit will determine the maximum volume of liquid the car can contain. To calculate this, divide the Load Limit by d_{ref} to find the reference volume. Next, divide the reference volume by the VCF at loading temperature to find the volume at loading temperature. This volume is then divided by the capacity table adjustment factor and that result is entered into the car's capacity table to find the corresponding gauge. If there is no volume match, the next smaller **liquid** volume in the table is chosen. One may wish to interpolate volumes and their gauges to the nearest $^1/_8$ inch

$$GOV = \frac{Wll}{(d_{ref})(VCF)(CTAF)} \qquad (A.2)$$

where

GOV = volume to be looked up in capacity table,

Wll = Load Limit weight,

VCF = VCF at load temperature,

CTAF = Capacity Table Adjustment Factor (stenciled volume divided by the car's maximum capacity table volume).

A.3.3 If W_{ma} does not exceed the car's Load Limit, the statutory outages apply (for cool loading). To calculate this, multiply the stenciled volume by the MFLA, correct the volume to 60°F by multiplying by the VCF for the statutory temperature, divide by the VCF at loading temperature, divide by the capacity table adjustment factor, and look up the corresponding (or next smaller) **liquid** volume in the capacity table.

$$GOV = \frac{V_s(MFLA)(VCF_{stat})}{(VCF)(CTAF)}$$

$$= \frac{V_s(MFLA)(VCF_{stat})}{(VCF)V_s/(V_{tblmax})}$$

$$= \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{VCF} \qquad (A.3)$$

Shell temperature and pressure correction factors are not estimated on a target calculation because omitting them gives an additional safety factor and overestimating them would cause the target GOV to be too high.

A.3.4 If the car is being loaded hot (above the statutory temperature) and W_{ma} does not exceed the car's Load Limit and loading hot (above the statutory temperature), multiply the stenciled volume by the MFLA of 0.98 (0.95 for materials deemed poisonous by inhalation), divide by the capacity table adjustment factor, and look up the gauge in the table as above.

$$GOV = \frac{V_s(0.98)}{CTAF} \qquad (A.4)$$

Weight overload checks and corresponding allowable outages are performed as above, except using VCF at loading temperature in place of VCF_{stat} to solve for W_{ma}.

A.4 Pressure Cars

To avoid overloading a pressure car, the same procedures outlined above should be followed. Pressure cars have a substantially greater light weight compared to general purpose cars (on the order of 110,000 pounds versus about 76,000 pounds). If a pressure car is used for normal liquids (resins that need a nitrogen cap, for example), the weight limitation will apply if the density at loading temperature is above approximately 5.0 pounds/gallon. For liquefied gases, the statutory outages will apply as above.

APPENDIX B — CALCULATION OF TANK CAR SHELL EXPANSION/CONTRACTION WITH TEMPERATURE

The equation for the expansion of a solid rod or hollow cylinder is derived in the following manner:

α = linear coefficient of expansion,

V = volume of cylinder,

V' = expanded volume after heating,

r = radius of cylinder,

Δr = change in radius upon heating,

l = length of cylinder,

Δl = change in length of cylinder upon heating,

ΔT = change in temperature.

α = $6.2 \times 10\text{-}6$ per °F for mild carbon steel,

= $9.6 \times 10\text{-}6$ per °F for 304 stainless steel,

= $8.83 \times 10\text{-}6$ per °F for 316 stainless steel.

$$\Delta r = \alpha * r * \Delta T$$

$$\Delta l = \alpha * l * \Delta T$$

$$V = \pi * r^2 * l$$

$$V' = \pi(r + \Delta r)^2 (l + \Delta l) = \pi(r^2 + 2r\Delta r + \Delta r^2) (l + \Delta l)$$

$$V' = \pi(lr^2 + 2lr\Delta r + l\Delta r^2 + r^2\Delta l + 2r\Delta r\Delta l + \Delta r^2\Delta l)$$

$$V' = \pi(lr^2 + 2lr\alpha r\Delta T + l\alpha^2r^2\Delta T^2 + r^2\alpha l\Delta T + 2r\alpha^2rl\Delta T^2 + \alpha^3r^2l\Delta T^3)$$

$$V' = V + 2V\alpha\Delta T + V\alpha^2\Delta T^2 + V\alpha\Delta T + 2V\alpha^2\Delta T^2 + V\alpha^3\Delta T^3$$

$$V' = V + 3V\alpha\Delta T + 3V\alpha^2\Delta T^2 + V\alpha^3\Delta T^3$$

$$\frac{V'}{V} = 1 + 3\alpha\Delta T + 3\alpha^2\Delta T^2 + \alpha^3\Delta T^3$$

$$CTS = \frac{V'}{V}$$

This is the same equation derived for a cube, rectangular block or sphere, and can also be found in API *MPMS* 12.2, truncated to the first two terms. The third term is small and the last term is insignificant (6.64×10^{-6} and 3.3×10^{-9}, respectively, at 300°F for carbon steel). The equation produces Table B-1 (using the first three terms).

Table B-1 — Tank Car Volume Correction Factors Due to Shell Temperature Expansion

Temp	CTS	Temp	CTS	Temp	CTS	Temp	CTS	Temp	CTS	Temp	CTS	Temp	CTS	Temp	CTS
0	0.99888	51	0.99983	102	1.00078	153	1.00173	204	1.00268	255	1.00363	306	1.00458	357	1.00553
1	0.99890	52	0.99985	103	1.00080	154	1.00175	205	1.00270	256	1.00365	307	1.00460	358	1.00555
2	0.99892	53	0.99987	104	1.00082	155	1.00177	206	1.00272	257	1.00367	308	1.00462	359	1.00557
3	0.99894	54	0.99989	105	1.00084	156	1.00179	207	1.00274	258	1.00369	309	1.00464	360	1.00559
4	0.99896	55	0.99991	106	1.00086	157	1.00181	208	1.00276	259	1.00371	310	1.00466	361	1.00561
5	0.99898	56	0.99993	107	1.00087	158	1.00182	209	1.00277	260	1.00372	311	1.00468	362	1.00563
6	0.99900	57	0.99994	108	1.00089	159	1.00184	210	1.00279	261	1.00374	312	1.00469	363	1.00565
7	0.99901	58	0.99996	109	1.00091	160	1.00186	211	1.00281	262	1.00376	313	1.00471	364	1.00567
8	0.99903	59	0.99998	110	1.00093	161	1.00188	212	1.00283	263	1.00378	314	1.00473	365	1.00568
9	0.99905	60	1.00000	111	1.00095	162	1.00190	213	1.00285	264	1.00380	315	1.00475	366	1.00570
10	0.99907	61	1.00002	112	1.00097	163	1.00192	214	1.00287	265	1.00382	316	1.00477	367	1.00572
11	0.99909	62	1.00004	113	1.00099	164	1.00194	215	1.00289	266	1.00384	317	1.00479	368	1.00574
12	0.99911	63	1.00006	114	1.00100	165	1.00195	216	1.00290	267	1.00386	318	1.00481	369	1.00576
13	0.99913	64	1.00007	115	1.00102	166	1.00197	217	1.00292	268	1.00387	319	1.00483	370	1.00578
14	0.99914	65	1.00009	116	1.00104	167	1.00199	218	1.00294	269	1.00389	320	1.00484	371	1.00580
15	0.99916	66	1.00011	117	1.00106	168	1.00201	219	1.00296	270	1.00391	321	1.00486	372	1.00581
16	0.99918	67	1.00013	118	1.00108	169	1.00203	220	1.00298	271	1.00393	322	1.00488	373	1.00583
17	0.99920	68	1.00015	119	1.00110	170	1.00205	221	1.00300	272	1.00395	323	1.00490	374	1.00585
18	0.99922	69	1.00017	120	1.00112	171	1.00207	222	1.00302	273	1.00397	324	1.00492	375	1.00587
19	0.99924	70	1.00019	121	1.00114	172	1.00208	223	1.00303	274	1.00399	325	1.00494	376	1.00589
20	0.99926	71	1.00020	122	1.00115	173	1.00210	224	1.00305	275	1.00400	326	1.00496	377	1.00591
21	0.99927	72	1.00022	123	1.00117	174	1.00212	225	1.00307	276	1.00402	327	1.00497	378	1.00593
22	0.99929	73	1.00024	124	1.00119	175	1.00214	226	1.00309	277	1.00404	328	1.00499	379	1.00595
23	0.99931	74	1.00026	125	1.00121	176	1.00216	227	1.00311	278	1.00406	329	1.00501	380	1.00596
24	0.99933	75	1.00028	126	1.00123	177	1.00218	228	1.00313	279	1.00408	330	1.00503	381	1.00598
25	0.99935	76	1.00030	127	1.00125	178	1.00220	229	1.00315	280	1.00410	331	1.00505	382	1.00600
26	0.99937	77	1.00032	128	1.00127	179	1.00222	230	1.00317	281	1.00412	332	1.00507	383	1.00602
27	0.99939	78	1.00033	129	1.00128	180	1.00223	231	1.00318	282	1.00413	333	1.00509	384	1.00604
28	0.99940	79	1.00035	130	1.00130	181	1.00225	232	1.00320	283	1.00415	334	1.00511	385	1.00606
29	0.99942	80	1.00037	131	1.00132	182	1.00227	233	1.00322	284	1.00417	335	1.00512	386	1.00608
30	0.99944	81	1.00039	132	1.00134	183	1.00229	234	1.00324	285	1.00419	336	1.00514	387	1.00609
31	0.99946	82	1.00041	133	1.00136	184	1.00231	235	1.00326	286	1.00421	337	1.00516	388	1.00611
32	0.99948	83	1.00043	134	1.00138	185	1.00233	236	1.00328	287	1.00423	338	1.00518	389	1.00613
33	0.99950	84	1.00045	135	1.00140	186	1.00235	237	1.00330	288	1.00425	339	1.00520	390	1.00615
34	0.99952	85	1.00047	136	1.00141	187	1.00236	238	1.00331	289	1.00427	340	1.00522	391	1.00617
35	0.99954	86	1.00048	137	1.00143	188	1.00238	239	1.00333	290	1.00428	341	1.00524	392	1.00619
36	0.99955	87	1.00050	138	1.00145	189	1.00240	240	1.00335	291	1.00430	342	1.00525	393	1.00621
37	0.99957	88	1.00052	139	1.00147	190	1.00242	241	1.00337	292	1.00432	343	1.00527	394	1.00623
38	0.99959	89	1.00054	140	1.00149	191	1.00244	242	1.00339	293	1.00434	344	1.00529	395	1.00624
39	0.99961	90	1.00056	141	1.00151	192	1.00246	243	1.00341	294	1.00436	345	1.00531	396	1.00626
40	0.99963	91	1.00058	142	1.00153	193	1.00248	244	1.00343	295	1.00438	346	1.00533	397	1.00628
41	0.99965	92	1.00060	143	1.00154	194	1.00249	245	1.00344	296	1.00440	347	1.00535	398	1.00630
42	0.99967	93	1.00061	144	1.00156	195	1.00251	246	1.00346	297	1.00441	348	1.00537	399	1.00632
43	0.99968	94	1.00063	145	1.00158	196	1.00253	247	1.00348	298	1.00443	349	1.00539	400	1.00634
44	0.99970	95	1.00065	146	1.00160	197	1.00255	248	1.00350	299	1.00445	350	1.00540		
45	0.99972	96	1.00067	147	1.00162	198	1.00257	249	1.00352	300	1.00447	351	1.00542		
46	0.99974	97	1.00069	148	1.00164	199	1.00259	250	1.00354	301	1.00449	352	1.00544		
47	0.99976	98	1.00071	149	1.00166	200	1.00261	251	1.00356	302	1.00451	353	1.00546		
48	0.99978	99	1.00073	150	1.00167	201	1.00262	252	1.00358	303	1.00453	354	1.00548		
49	0.99980	100	1.00074	151	1.00169	202	1.00264	253	1.00359	304	1.00455	355	1.00550		
50	0.99981	101	1.00076	152	1.00171	203	1.00266	254	1.00361	305	1.00456	356	1.00552		

APPENDIX C — CALCULATION OF TANK CAR SHELL EXPANSION WITH PRESSURE

The expansion due to pressure is calculated in the same manner as for meter provers (API *MPMS* Chapter 12.2).

$$CPS = 1 + (P \times D)/(E \times t)$$

where

CPS = Correction factor of pressure on steel,

P = tank car internal pressure, psig,

D = internal diameter of car = 120 inches,

t = thickness of tank car shell = $^{11}/_{16}$ inch,

E = modulus of elasticity = 30,000,000 psig (for mild steel),

= 28,000,000 psig (for 304 stainless steel),

= 29,000,000 psig (for 316 stainless steel).

For a typical pressure car with the values for D, t, and E given above, Table C-1 may be generated.

Table C-1 — Pressure Expansion Table for a Typical (D = 120 inches, t = $^{11}/16$ inch, mild steel) Pressure Car

P	CPS	P	CPS	P	CPS	P	CPS
0	1.00000	80	1.00047	155	1.00090	230	1.00134
5	1.00003	85	1.00049	160	1.00093	235	1.00137
10	1.00006	90	1.00052	165	1.00096	240	1.00140
15	1.00009	95	1.00055	170	1.00099	245	1.00143
20	1.00012	100	1.00058	175	1.00102	250	1.00145
25	1.00015	105	1.00061	180	1.00105	255	1.00148
30	1.00017	110	1.00064	185	1.00108	260	1.00151
35	1.00020	115	1.00067	190	1.00111	265	1.00154
40	1.00023	120	1.00070	195	1.00113	270	1.00157
45	1.00026	125	1.00073	200	1.00116	275	1.00160
50	1.00029	130	1.00076	205	1.00119	280	1.00163
55	1.00032	135	1.00079	210	1.00122	285	1.00166
60	1.00035	140	1.00081	215	1.00125	290	1.00169
65	1.00038	145	1.00084	220	1.00128	295	1.00172
70	1.00041	150	1.00087	225	1.00131	300	1.00175
75	1.00044						

APPENDIX D — CALCULATION OF MAGNETIC GAUGE OFFSETS

A correction for use with nonreference temperatures and/or with nonreference liquids can be made. The following procedure with examples is supplied for future use for incorporation into computer programs. Databases necessary for this procedure are not presently readily available.

D.1 Determination of Magnetic Gauge Data

Magnetic float gauges are designed for service with a specific car and a specific product (reference specific gravity). Normally the scale will be set to read zero at shell full (unless the customer requests a specific offset from shell full). The reference gravity cannot normally be ascertained visually; one must contact the manufacturer with the serial number off the gauge flange. As at some point the gauge rod may have been damaged and unofficially replaced, one should also supply rod data (diameter, length, distance from top of magnet to zero pt. of scale, and whether aluminum or fiberglass).

D.2 Derivation of Depth of Immersion Equation

The float consists of a sphere cut by a cylindrical hole (see Figure D.1). The volume of the immersed portion of the float is the volume of the spherical segment minus the volume of the cylindrical hole in the segment and the spherical end cap cut by the cylindrical hole (very small volume). The following data, which includes dimensions and weights for a standard installation, are required:

R = radius of spherical float (normally 3.75 inches),

a = radius of cylindrical hole (normally 0.8345 inch),

r = radius of floating segment,

h = half height of the cylindrical hole,

b = depth float is sitting in liquid,

b' = depth of spherical end cap segment (not shown in Figure D.1),

V_d = volume of float displaced,

Weight of float = 48.5 oz.,

Weight of magnet = 1.55 oz.,

Weight of $^3/_8$ inch × 74 inches aluminum rod = 5.45 oz.

The general equation for the volume of a normal spherical segment (bowl) is (see paragraph D.4 below for derivation):

$$V' = \frac{\pi}{6}b(b^2 + 3r^2) = \frac{\pi}{3}b^2(3R - b) \qquad \text{(D.1)}$$

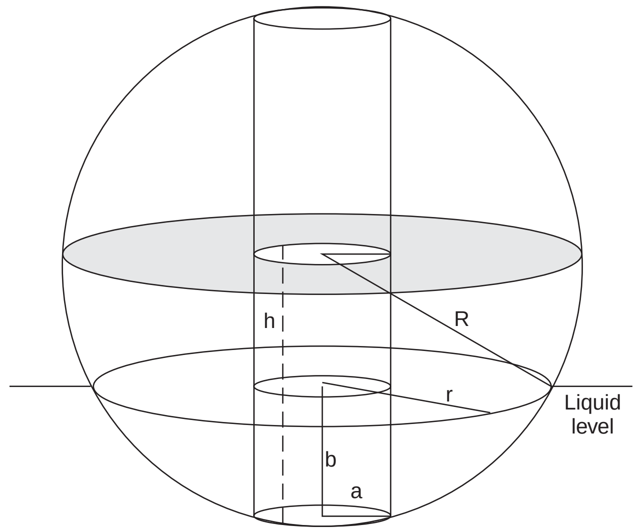

Figure D.1 — Magnetic Float Gauge

The volume of the cylindrical segment cut out of the spherical segment is:

$$V'' = \pi a^2 (b - b')$$

The height of the end cap bowl (b') is related to the sphere's radius (R) and the cylinder's radius (a) as follows:

$$b' = R - h$$

$$R^2 = h^2 + a^2$$

$$h = \sqrt{R^2 - a^2} = \sqrt{\left(\frac{7.5}{2}\right)^2 - \left(\frac{1.687}{2}\right)^2}$$

$$= \sqrt{14.0625 - 0.71149} = 3.6539 \text{ in.}$$

The height of the end cap is thus:

$$b' = R - h = \frac{7.5}{2} - 3.6539 = 0.096100 \text{ inch}$$

(not quite $^3/_{32}$ inch)

And from equation D.1, the volume of end cap cut by cylinder is (substituting b′ for b, and a for r):

$$V''' = \frac{\pi}{6}(0.096100)\left((0.096100)^2 + 3\left(\frac{1.687}{2}\right)^2\right)$$

$$= 0.10787 \text{ inch}^3$$

The volume of the displacing segment equals the whole segment minus the interior cylindrical hole minus the end cap cut by the cylinder, or

$$V_d = V' - V'' - V''$$

$$V_d = \frac{\pi b^2}{3}(3R - b) - \pi a^2(b - 0.0961) - (0.10787)$$

$$V_d = \pi R b^2 - \frac{\pi}{3}b^3 - \pi a^2 b + \pi a^2(0.0961) - (0.10787)$$

$$V_d = 11.7810\, b^2 - 1.04720\, b^3 - 2.23522\, b + 0.10618 \quad \text{(D.2)}$$

The volume of liquid displaced by the segment is also equal to the weight of the float, magnet, and rod assembly (in pounds) divided by the liquid's density (ρ in pounds/gallon):

$$V_d = \left(\frac{\text{weight}}{\text{density}}\right) = \left(\frac{48.5 + 1.55 + 5.45\text{oz}}{(16\text{ oz/lb})(\text{density})}\right)$$

$$= \left(\frac{3.46875\text{ lb}}{\rho(\text{lb/gal})}\right) = \left(\frac{3.46875\text{ lb}}{\rho(\text{lb/gal})}\left(\frac{231\text{ in.}^3}{\text{gal}}\right)\right)$$

$$V_d = \frac{801.28125\text{ lb}}{\rho(\text{lb/gal})}\left(\frac{\text{in.}^3}{\text{gal}}\right) = \frac{801.28125}{\text{density @ }60°\text{F}}\text{in.}^3 \quad \text{(D.3)}$$

Density (pounds/gallon) at 60°F is derived from relative density (RD) by:

density = RD *density of water at 60°F * 8.3454

It is then multiplied by 231 inch^3/gallon to obtain pounds/inch^3, and that result is divided into the weight of the gauge assembly to obtain V_d. Equation (D.3) may then be inserted into equation (D.2) and solved for b. Thus we can guess a value for b and see how close the right part of equation (D.2) is to the right part of equation (D.3). If they are not close, we can increment b up or down by a small amount and try again. By repeating this process over and over until equation (D.2) is just under or equal to equation (D.3), we can find the true value of b specific to the product. This process can be easily accomplished by a macro in a spreadsheet.

D.3 Gauge Offset Calculations

A gauge floating in a liquid with a lower relative density than the reference will sink deeper into the liquid, thus giving a larger outage gauge (there will appear to be less liquid in the car). A gauge floating in a liquid with a higher relative density than the reference will float higher, thus giving a smaller outage gauge (there will appear to be more liquid in the car). Temperature change produces the same effect. A temperature higher than the reference temperature (normally 60°F) will lower the fluid's relative density; conversely, a lower temperature will raise the fluid's relative density.

D.3.1 Example 1: Relative Density Offset

Calculate the gauge offset at 60°F due to the difference in relative density between the gauge's reference relative density (0.500) and a product of relative density 1.000 (water). The depth of the submerged part of the float (b) must be calculated for both liquids; the difference is the offset.

Step 1. Calculate the immersion depth in the reference liquid. The reference liquid's relative density of 0.500 is equivalent to a density of 4.1686 pounds/gallon. The volume displaced is thus:

$$V_d = \left(\frac{55.5/16}{4.1686/231}\right) = 192.21831\text{ in.}^3$$

$$= 11.7810\, b^2 - 1.04720\, b^3 - 2.23522\, b + 0.01618 \quad \text{(D.4)}$$

One can set up the spreadsheet so that rough guesses can be made for b. When the right half of equation (D.4) is close to 192.21831, start the iteration in increments of 0.001 inch (one thousandth of an inch) or less. For instance:

increment b = 0.001	increment b = 0.0001
V_d = 192.21152 inches^3	V_d = 192.21788 inches^3
b = 6.3210 inches	b = 6.3213 inches

This 0.0003 inch difference is insignificant when one considers the required $^1/_8$ inch accuracy ($^1/_8$ inch = 0.125 inch, $^1/_{16}$ inch = 0.0625 inch, $^1/_{32}$ inch = 0.0313 inch, $^1/_{64}$ inch = 0.0156 inch, $^1/_{128}$ inch = 0.00781 inch, etc.). This means that the float is immersed 6.321 inches in the reference liquid at 60°F. The gauge's scale has been adjusted to read zero inches when the liquid level at 60°F is at the shell-full point and the float is immersed 6.321 inches.

Step 2. Calculate the immersion depth in the non-reference liquid. Its relative density of 1.000 is equivalent to a density of 8.3372 pounds/gallon. The volume displaced is thus:

$$V_d = \left(\frac{55.5/16}{8.3372/231}\right) = 96.10916\text{ in.}^3$$

$$= 11.7810\, b^2 - 1.04720\, b^3 - 2.23522\, b + 0.01618$$

Solving for b as in the previous example:

increment b = 0.001	increment b = 0.0001
V_d = 96.09288 inches^3	V_d = 96.10544 inches^3
b = 3.6050 inches	b = 3.6053 inches

Again, the 0.0003-inch difference is insignificant. This means that the float is immersed 3.605 inches in the non-reference liquid at 60°F.

Step 3. For these two extreme examples (specific gravity 0.500 and 1.000), the float sets 6.321 – 3.605 = 2.716 inches (or roughly $^1/_{32}$ inch less than $2^3/_4$ inches) **higher** in the water. Thus, the gauge indicates 2.716 inches more product in the car than is actually there.

D.3.2 Example 2: Temperature Offset For A Reference Relative Density Of 0.500

Calculate the gauge offset arising from using a float for service at non-reference temperatures. The depth of the submerged part of the float (b) must be calculated at reference temperature and operating temperature; the difference is the offset.

Calculate the immersion depth of the reference liquid (relative density 0.500, 4.1686 pounds/gallon) at various non-reference temperatures. The density of the liquid in equation (D.3) at a non-reference temperature is the density at reference temperature multiplied by the liquid's VCF. VCFs are obtained from the appropriate API/ASTM table. The volume displaced at various temperatures is thus:

$$V_d = \left(\frac{55.5/16}{(\mathrm{VCF})(4.1686)/231}\right) = \frac{192.21831\ \mathrm{in.}^3}{\mathrm{VCF}}$$

$$= 11.7810\ b^2 - 1.04720\ b^3 - 2.23522\ b + 0.01618$$

For each temperature, obtain the VCF and calculate the volume displaced at that temperature, then solve for *b* as above.

Temp (°F)	VCF	b (in.)	V_d for b (in.^{3})	b@60°F – b	Offset
20	1.064	5.853	180.63879	0.457	$^4/_8$ in.
30	1.049	5.947	183.21619	0.363	$^3/_8$ in.
40	1.033	6.057	186.07703	0.253	$^2/_8$ in.
50	1.017	6.177	188.99762	0.133	$^1/_8$ in.
60	1.000	6.310	192.21152	0.000	0 in.
70	0.983	6.489	195.53639	– 0.179	– $^1/_8$ in.
80	0.965	6.711	199.18006	– 0.401	– $^3/_8$ in.
90	0.946	7.082	203.18841	– 0.772	– $^6/_8$ in.

This float assembly sinks at 92°F. Note that the float is about 87% immersed at 60°F. The offset is added or subtracted, as indicated by its sign, from the observed gauge to obtain the true liquid level.

D.3.3 Example 3: Temperature Offset for a Reference Relative Density of 1.000

Calculate the immersion depth for a petroleum product reference liquid (relative density 1.0000, 8.3372 pounds/gallon) at a various non-reference temperatures. The density of the liquid in equation (D.3) at a non-reference temperature is the density at reference temperature multiplied by the liquid's VCF. VCFs are obtained from API Table 6B. The volume displaced at various temperatures is thus:

$$V_d = \left(\frac{55.5/16}{(\mathrm{VCF})(8.3372)/231}\right) = \frac{96.1092\ \mathrm{in.}^3}{\mathrm{VCF}}$$

$$= 11.7810\ b^2 - 1.04720\ b^3 - 2.23522\ b + 0.01618$$

For each temperature, obtain the VCF and calculate the volume displaced at that temperature, then solve for *b* as above.

Temp (°F)	VCF	b (in.)	V_d for b (in.^{3})	b@60° F – b	Offset
20	1.0149	3.571	94.66961	0.034	$^1/_{32}$ in.
60	1.0000	3.605	96.09288	0.000	0 in.
200	0.9469	3.733	101.45845	– 0.128	– $^1/_8$ in.

Note that the float is roughly half immersed at 200°F and has sunk only $^1/_8$ inch from its position at 60°F. These two extremes (Examples 2 and 3) show that the lower the relative density, the more effect temperature has.

D.4 Derivation of Volume Segment or Bowl (Equation D.1)

Strategy: Offset a sphere from the origin by its radius R and add up the volume of the small circular segments of thickness, dx within it from x = 0 to x = b:

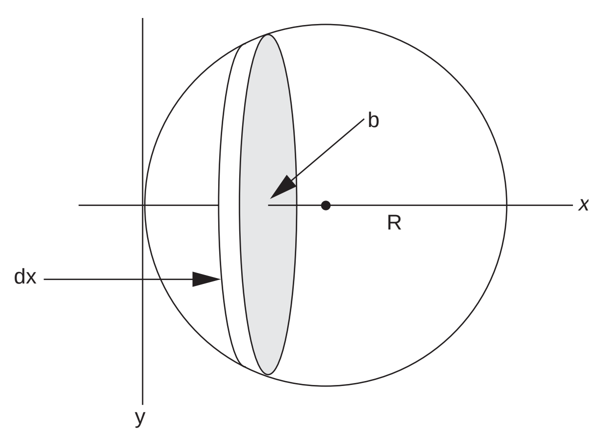

Figure D.2 — Derivation of a Spherical Volume Segment or Bowl

$$V = \int_a^b dV = \int_o^b \pi y^2 dx = \pi \int_o^b R^2 - (R-x)^2 dx$$

$$V = \pi \int_o^b R^2 dx - \pi \int_o^b (R-x)^2 dx$$

$$V = \pi x \Big]_o^b - \pi\left(R^2 x - Rx^2 + \frac{x^3}{3}\right)\Big]_o^b$$

$$V = \pi\left[(bR^2) - R^2 b + Rb^2 - \frac{b^3}{3}\right] = \pi\left(Rb^2 - \frac{b^3}{3}\right)$$

$$= \frac{\pi}{3} b^2 (3R - b)$$

If the radius of the segment is r,

$$R^2 = (R-b)^2 + r^2$$

$$R^2 = R^2 - 2bR + b^2 + r^2$$

$$R = \frac{b^2 + r^2}{2b}$$

Substituting into the volume equation above,

$$V = \frac{\pi}{3} b^2\left(3\frac{(b^2 + r^2)}{2b} - b\right)$$

$$V = \frac{\pi b}{6}(b^2 + 3r^2)$$

APPENDIX E — CALCULATION EXAMPLES

Example 1: Outage Liquid Capacity Table — Loading Target Calculation — Volume Limitation

A general purpose car is to be loaded with Isopropyl Alcohol.

Tank Car Data	
Tare:	67,900 pounds
Load Limit:	195,100 pounds
Stenciled Volume:	30,168 gallons
Capacity Table:	Table E-1
Insulated?	No

Product Data	
Estimated LoadingTemperature:	85°F
Manway Nozzle Height:	12.5 in.
VCF Table (alpha value):	API 6C (0.000578)
Density at Reference Temp:	6.574 pounds/gallon
Statutory Temp:	115°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From API Table 6C, the liquid's VCF at 115°F (uninsulated car) is 0.9679.

$$
\begin{aligned}
W_{ma} &= V_s\ (MFLA)\ (VCF_{stat})\ (d_{ref}), \\
&= (30{,}168)\ (0.99)\ (0.9679)\ (6.574), \\
&= 190{,}039 \text{ pounds}
\end{aligned}
$$

Since this is less than the Load Limit, the car can be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (67,900 + 190,039 = 257,939) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From API Table 6C, the liquid's VCF at 85°F is 0.9855.

VCF_{stat}: From API Table 6C, the liquid's VCF at 115°F (uninsulated car) is 0.9679.

V_{tblmax}: From the capacity table, the car's maximum volume is 30,154 gallons.

$$
\begin{aligned}
GOV &= \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)} \\
&= \frac{(30{,}154)(0.99)(0.9679)}{(0.9855)} \\
&= 29{,}319 \text{ gallons}
\end{aligned}
$$

Looking up this volume in the capacity table, it falls between volumes representing 7.75 inches and 8 inches Interpolating to the nearest $^1/_8$ inch, 7.875 inches is equal to:

(29,334 – 29,292)/2 + 29,292 = 29,313 gallons

Since *GOV* is greater than the volume corresponding to 7.875 inches, we round to the outage corresponding to a **smaller** liquid volume, 7.875 inches We do **not** round up to the outage corresponding to a larger volume (7.75 inches). If we wish to measure only to the nearest $^1/_4$ inch, we would choose 8 inches.

If measuring from the top of the manway, we must add the manway nozzle height to this value.

7.875 in. + 12.5 in. = 20.375 in.

or, if to the nearest $^1/_4$ inch:

8 in. + 12.5 in. = 20.5 in.

Example 2: Outage Liquid Capacity Table — Actual Loaded Calculation

A general purpose car is loaded with isopropyl alcohol close to the target outage determined in Example 1.

Tank Car Data	
Tare:	67,900 pounds
Load Limit:	195,100 pounds
Stenciled Volume:	30,168 gallons
Capacity Table:	Table E-1
Insulated?	No

Product Data	
Loaded Temperature:	87°F
Manway Nozzle Height:	12.5 in.
VCF Table (alpha value):	API 6C (0.000578)
Density at Reference Temp:	6.574 pounds/gallon
Outage Gauge (from top of manway):	20.625 in.
Statutory Temp:	115°F
MFLA	0.99

Net Standard Volume is determined with equation (1).

GOV: The capacity table (Table E-1) volumes do not include a nozzle height, so one must first subtract the manway nozzle height from the outage gauge:

20.625 in. – 12.5 in. = 8.125 in.

Since the capacity table is an Outage Liquid table in quarter-inch increments, one must interpolate between the entries for 8.00 inches and 8.25 inches:

(29,292 – 29,250)/2 + 29,250 = 29,271 gallons

CTAF: From the stenciled volume and the capacity table, the capacity table adjustment factor is (30,168 / 30,154).
VCF: From API Table 6C, the liquid's VCF at 87°F is 0.9843.
CTS: Since the liquid is not solid at ambient temperature, we obtain from Table B-1 a factor of 1.00050.

NSV = GOV (CTAF) (VCF) (CTS)
= (29,271) (30,168/30,154) (0.9843) (1.00050)
= 28,839 gallons

The cargo's weight is:

W = NSV (d_{ref}) = 28,839 (6.574) = 189,588 pounds

Overload check by volume, using equation (4):

VCF_{stat}: From API Table 6C, the liquid's VCF at 115°F (uninsulated car) is 0.9679.

$$\text{Vapor Space \%} = 100 - \frac{(GOV)(VCF)(CTS) \times 100}{(VCF_{stat})(V_{tblmax})}$$

$$= 100 - \frac{(29{,}271)(0.9843)(1.00050) \times 100}{(0.9679)(30{,}154)}$$

$$= 1.28\%$$

Since the vapor space at 115°F would be greater that 1%, the car is **not** overloaded by volume.

Overload check by weight:

1. Compare cargo weight calculated above to Load Limit weight. 189,589 pounds is less than 195,100 pounds, **or**
2. Add Tare weight to cargo weight calculated above and compare to statutory limit:

67,900 + 189,589 = 257,489 pounds, which is less than 263,000 pounds

Thus, the car is **not** overloaded by weight.

Example 3: Outage Liquid Capacity Table — Loading Target Calculation — Weight Limitation

The same general purpose car used in Examples 1 and 2 is to be loaded with Hexylene Glycol.

Tank Car Data	
Tare:	67,900 pounds
Load Limit:	195,100 pounds
Stenciled Volume:	30,168 gallons
Capacity Table:	Table E-1
Insulated?	No

Product Data	
Estimated Loading Temperature:	70°F
Manway Nozzle Height:	12.5 in.
VCF Table:	Private Table
Density at Reference Temp:	7.710 pounds/gallon
Statutory Temp:	115°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From the company's privately determined table, the liquid's VCF at 115°F (uninsulated car) is 0.97679.

$$W_{ma} = V_s\ (MFLA)\ (VCF_{stat})\ (d_{ref})$$
$$= (30{,}168)\ (0.99)\ (0.97679)\ (7.710)$$
$$= 224{,}925 \text{ pounds}$$

Since this is greater than the Load Limit, the car **cannot** be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (67,900 + 224,925 = 292,825) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory weight using equation (A.2).

VCF: From the company's privately determined table, the liquid's VCF at 70°F is 0.99570.

CTAF: From the stenciled volume and the capacity table, the capacity table adjustment factor is (30,168/30,154).

$$GOV = \frac{Wll}{(d_{ref})(VCF)(CTAF)}$$

$$= \frac{(263,000 - 67,900)}{(7.710)(0.99570)(30,168/30,154)}$$

$$= 25,402 \text{ gallons}$$

Looking up this volume in the capacity table, it falls between volumes representing 25.75 inches and 26 inches Interpolating to the nearest 1/8 inch, 25.875 inches is equal to:

(25,416 – 25,350)/2 + 25,350 = 25,383 gallons

Since GOV is greater than the volume corresponding to 25.875 inches, we round to the outage corresponding to a **smaller** liquid volume, 25.875 inches. We do **not** round up to the outage corresponding to a larger volume (25.75 inches). If we wish to measure only to the nearest 1/4 inch, we would choose 26 inches.

If measuring from the top of the manway, we must add the manway nozzle height to this value:

25.875 in. + 12.5 in. = 38.375 in.

or, if to the nearest 1/4 inch:

26 in. + 12.5 in. = 38.5 in.

Example 4: Outage Liquid Capacity Table with Nozzle Height Included — Loading Target Calculation — Volume Limitation

A two compartment general purpose car is to be loaded with Odorless Mineral Spirits in the first compartment.

Tank Car Data	
Tare:	67,200 pounds
Load Limit:	195,800 pounds
Stenciled Volume:	11,348 gallons
Capacity Table:	Table E-3
Insulated?	No

Product Data	
Estimated Loading Temperature:	35°F
Manway Nozzle Height:	12.5 in.
VCF Table (API gravity):	API 6B (55.1)
Density at Reference Temp:	6.313 pounds/gallon
Statutory Temp:	115°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From API Table 6B, the liquid's VCF at 115°F (uninsulated car) is 0.9635.

$$W_{ma} = V_s (MFLA) (VCF_{stat}) (d_{ref})$$
$$= (11{,}348) (0.99) (0.9635) (6.313)$$
$$= 68{,}335 \text{ pounds}$$

Since this is less than the Load Limit, the car can be loaded to statutory volume limits **if the second compartment is still empty**. If the Load Limit is not available, add W_{ma} to the Tare (67,200 + 68,335 = 135,535) and compare with the weight limitation for that particular car (263,000 pounds for this car). If the second compartment has been loaded, the cargo weight will have to be subtracted from the Load Limit (or added to the Tare weight and subtracted from the weight limitation) to get the maximum amount allowed.

If the second compartment is empty, one can now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From API Table 6B, the liquid's VCF at 35°F is 1.0163.
VCF_{stat}: From API Table 6B, the liquid's VCF at 115°F (uninsulated car) is 0.9635.
V_{tblmax}: From the capacity table, the car's maximum volume is 11,348 gallons.

$$GOV = \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)}$$
$$= \frac{(11,348)(0.99)(0.9635)}{(1.0163)}$$
$$= 10,651 \text{ gallons}$$

Looking up this volume in the capacity table, it falls between volumes representing 24.25 inches and 24.5 inches
Interpolating to the nearest $^1/_8$ inch, 24.375 inches is equal to:

(10,666 – 10,645)/2 + 10,645 = 10,656 gallons

Since GOV is less than the volume corresponding to 24.375 inches, we round to the outage corresponding to a **smaller** liquid volume, 24.5 inches We do **not** round up to the outage corresponding to a larger volume (24.25 inches). If we wish to measure only to the nearest $^1/_4$ inch, we would also choose 24.5 inches.

Since this table includes a 12.5-inches manway nozzle, we must subtract that value if using an instrument that measures from the top inside of the shell to the liquid surface.

24.5 in. – 12.5 in. = 12.0 in.

If the second compartment is already loaded, one must calculate the weight corresponding to the statutory volume limitation using a different Load Limit. Assume the cargo in the second compartment weighs 66,140 pounds. As shown above:

VCF_{stat}: From API Table 6B, the liquid's VCF at 115°F (uninsulated car) is 0.9635.

$$W_{ma} = V_s\,(MFLA)\,(VCF_{stat})\,(d_{ref})$$
$$= (11{,}348)\,(0.99)\,(0.9635)\,(6.313)$$
$$= 68{,}335 \text{ pounds}$$

This must be compared to the new Load Limit of 263,000 – 67,200 + 66,140 = 129,660 pounds (or 195,800 – 66,140 = 129,660 pounds). Since W_{ma} is easily within this limit, we can use the statutory volume limit as above. If it were not, we would proceed as shown in Example 3.

Example 5: Outage Liquid Capacity Table with Nozzle Height Included — Actual Loaded Calculation

A two-compartment general purpose car is loaded with Odorless Mineral Spirits in the first compartment, close to the outage determined in Example 4.

Tank Car Data	
Tare:	67,200 pounds
Load Limit:	195,800 pounds
Stenciled Volume:	1,348 gallons
Capacity Table:	Table E-3
Insulated?	No

Product Data	
Loaded Temperature:	39°F
Manway Nozzle Height:	12.5 in.
VCF Table (API gravity):	API 6B (55.1)
Density at Reference Temp:	6.313 pounds/gallon
Outage Gauge (from top of manway):	24.375 in.
Outage Gauge (from inside shell top):	11.875 in.
Statutory Temp:	115°F
MFLA	0.99

Net Standard Volume is determined with equation (1).

GOV: The capacity table (Table E-3) volumes include a nozzle height, so if one is using a gauging instrument that does not include the manway, one must first add the manway nozzle height to the outage gauge:

11.875 in. + 12.5 in. = 24.375 in.

Since the capacity table is an outage vapor table in quarter-inch increments, one must interpolate between the entries for 24.25 inches and 24.5 inches:

(10,666 – 10,645)/2 + 10,645 = 10,656 gallons

CTAF: From the stenciled volume and the capacity table, the capacity table adjustment factor is (11,348/11,348).
VCF: From API Table 6B, the liquid's VCF at 39°F is 1.0137.
CTS: Since the liquid is not solid at loading temperature, we obtain from Table B-1 a factor of 0.99961.
NSV = GOV (CTAF) (VCF) (CTS)
= (10,656) (11,348/11,348) (1.0137) (0.99961)
= 10,798 gallons

The cargo's weight is determined with equation (2):

W = NSV (d_{ref}) = 10,798 (6.313) = 68,168 pounds

Overload check by volume, using equation (4):

VCF_{stat}: From API Table 6B, the liquid's VCF at 115°F (uninsulated car) is 0.9635.

$$\text{Vapor Space \%} = 100 - \frac{(GOV)(VCF)(CTS) \times 100}{(VCF_{stat})(V_{tblmax})}$$

$$= 100 - \frac{(10{,}656)(1.0137)(0.99961) \times 100}{(0.9635)(11{,}348)}$$

$$= 1.24\%$$

Since the vapor space at 115°F would be greater that 1%, the car is **not** overloaded by volume.

We know from the Target calculations in Example 4 that we cannot overload this product in this car by weight. However, if we did not know that, we would have to again consider the loading status of the second compartment.

If the second compartment is empty:

1. Compare cargo weight calculated above to Load Limit weight. 68,168 pounds is less than 195,800 pounds, **or**
2. Add Tare weight to cargo weight calculated above and compare to statutory limit:

   67,200 + 68,168 = 135,368 pounds, which is less than 263,000 pounds.

If the second compartment is filled with 66,140 pounds of product:

1. Compare the sum of the calculated weights to the Load Limit weight. 68,168 + 66,140 = 134,308 pounds, **or**
2. Add the Tare weight to both cargo weights and compare to the statutory limit:

   67,200 + 68,168 + 66,140 = 201,508 pounds, which is less than 263,000 pounds

Thus, the car is **not** overloaded by weight.

Example 6: Outage Vapor Capacity Table — Loading Target Calculation — Volume Limitation

A general purpose car is to be loaded with Light Cat Cracked Gasoline.

Tank Car Data	
Tare:	72,700 pounds
Load Limit:190,300 pounds	
Stenciled Volume:	23,639 gallons
Capacity Table:	Table E-2
Insulated?	Yes

Product Data	
Estimated Loading Temperature:	95°F
Manway Nozzle Height:	9.25 in.
VCF Table (API gravity):	API 6B (65.0)
Density at Reference Temp:	5.994 pounds/gallon
Statutory Temp:	105°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From API Table 6B, the liquid's VCF at 105°F (insulated car) is 0.9677

W_{ma} = V_s (MFLA) (VCFstat) (d_{ref})
= (23,639) (0.99) (0.9677) (5.994)
= 135,744 pounds

Since this is less than the Load Limit, the car can be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (72,700 + 135,744 = 208,444) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From API Table 6B, the liquid's VCF at 95°F is 0.9749.

VCF_{stat}: From API Table 6B, the liquid's VCF at 105°F (insulated car) is 0.9677.

V_{tblmax} : From the capacity table, the car's maximum volume is 23,679 gallons.

$$GOV = \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)}$$

$$= \frac{(23,679)(0.99)(0.9677)}{(0.9749)}$$

$$= 23,269 \text{ gallons}$$

Since the capacity table is an outage/vapor, the volumes listed are vapor volumes. To convert GOV to its corresponding vapor volume, subtract GOV from the maximum vapor volume in the table:

23,679 – 23,269 = 410 gallons vapor

Looking up this volume in the capacity table, it falls between volumes representing 3.75 inches and 4 inches. Interpolating to the nearest $^1/8$ inch, 3.875 inches is equal to:

(381 – 412)/2 + 412 = 397 gallons

Since GOV is greater than the volume corresponding to 3.875 inches, we round to the outage corresponding to a **larger** vapor volume, 4.0 inches. We do **not** round up to the outage corresponding to a smaller vapor volume (3.875 inches). If we wish to measure only to the nearest $^1/4$ inch, we would choose 4 inches.

If measuring from the top of the manway, we must add the manway nozzle height to this value:

4.0 in. + 9.25 in. = 13.25 in.

Example 7: Outage Vapor Capacity Table — Loading Target Calculation — Understated Loading Temperature

A general purpose car is to be loaded with Light Cat Cracked Gasoline. However, here the assumed loading temperature is 60°F instead of the real 95°F as shown in Example 6.

Tank Car Data	
Tare:	72,700 pounds
Load Limit:	190,300 pounds
Stenciled Volume:	23,639 gallons
Capacity Table:	Table E-2
Insulated?	Yes

Product Data	
Estimated Loading Temperature:	60°F
Manway Nozzle Height:	9.25 in.
VCF Table (API gravity):	API 6B (65.0)
Density at Reference Temp:	5.994 pounds/gallon
Statutory Temp:	105°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From API Table 6B, the liquid's VCF at 105°F (insulated car) is 0.9677.

$$W_{ma} = V_s\ (MFLA)\ (VCFstat)\ (d_{ref})$$
$$= (23{,}639)\ (0.99)\ (0.9677)\ (5.994)$$
$$= 135{,}744 \text{ pounds}$$

Since this is less than the Load Limit, the car can be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (72,700 + 135,744 = 208,444) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From API Table 6B, the liquid's VCF at 60°F is 1.0000.

VCF_{stat}: From API Table 6B, the liquid's VCF at 105°F (insulated car) is 0.9677.

V_{tblmax} : From the capacity table, the car's maximum volume is 23,679 gallons.

$$GOV = \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)}$$
$$= \frac{(23,679)(0.99)(0.9677)}{(1.000)}$$
$$= 22,685 \text{ gallons}$$

Since the capacity table is an outage/vapor, the volumes listed are vapor volumes. To convert GOV to its corresponding vapor volume, subtract GOV from the maximum vapor volume in the table:

23,679 – 22,685 = 994 gallons vapor

Looking up this volume in the capacity table, it falls between volumes representing 8.0 inches and 8.25 inches. Interpolating to the nearest 1/8 inch, 8.125 inches is equal to:

(984 – 1,024)/2 + 1024 = 1,004 gallons

Since GOV is less than the volume corresponding to 8.0 inches, we round to the outage corresponding to a **larger** vapor volume, 8.125 inches. We do **not** round up to the outage corresponding to a smaller vapor volume (8.0 inches). If we wish to measure only to the nearest 1/4 inch, we would choose 8.25 inches.

If measuring from the top of the manway, we must add the manway nozzle height to this value.

8.125 in. + 9.25 in. = 17.375 in.

or, if to the nearest 1/4 inch:

8.25 in. + 9.25 in. = 17.5 in.

Notice, comparing Example 6 to Example 7, that by ignoring the actual loaded temperature of 95°F and using 60°F, one **underloads** the car by 4.125 inches – 4.25 inches, or 576 – 596 net gallons. Thus, it is always best to determine the loading temperature as accurately as possible. This example also illustrates that one must not overestimate the actual loading temperature or the target calculation will result in **overloading** the car.

Example 8: Outage Vapor Capacity Table — Actual Loaded Calculation

A general purpose car is loaded with Light Cat Cracked Gasoline close to the target outage determined in Example 6.

Tank Car Data	
Tare:	72,700 pounds
Load Limit:	190,300 pounds
Stenciled Volume:	23,639 gallons
Capacity Table:	Table E-2
Insulated?	Yes

Product Data	
Loaded Temperature:	97°F
Manway Nozzle Height:	9.25 in.
VCF Table (API gravity):	API 6B (65.0)
Density at Reference Temp:	5.994 pounds/gallon
Outage Gauge (from top of manway):	13.5 in.
Statutory Temp:	115°F
MFLA	0.99

Net Standard Volume is determined with equation (1).

GOV: The capacity table (Table E-2) does not include a nozzle height, so one must first subtract the manway nozzle height from the outage gauge:

13.5 in. – 9.25 in. = 4.25 in.

Since the capacity table is an outage vapor table in quarter-inch increments, one need not interpolate for 4.25 inches, but must subtract the corresponding vapor volume from the table maximum volume. The resulting liquid volume is:

(23,679 – 444) = 23,235 gallons

CTAF: From the stenciled volume and the capacity table, the capacity table adjustment factor is (23,639/23,679).
VCF: From API Table 6B, the liquid's VCF at 97°F is 0.9735.
CTS: Since the liquid is not solid at ambient temperature, we obtain from Table B-1 a factor of 1.00069.

$$\begin{aligned} NSV &= GOV\,(CTAF)\,(VCF)\,(CTS) \\ &= (23{,}235)\,(23{,}639/23{,}679)\,(0.9735)\,(1.00069) \\ &= 22{,}597 \text{ gallons} \end{aligned}$$

The cargo's weight is determined with equation (2):

$$W = NSV\,(d_{ref}) = 22{,}597\,(5.994) = 135{,}446 \text{ pounds}$$

Overload check by volume, using equation (4):

VCF_{stat}: From API Table 6B, the liquid's VCF at 105°F (insulated car) is: 0.9677.

$$\begin{aligned} \text{Vapor Space \%} &= 100 - \frac{(GOV)(VCF)(CTS) \times 100}{(VCF_{stat})(V_{tblmax})} \\ &= 100 - \frac{(23{,}235)(0.9735)(1.00069) \times 100}{(0.9677)(23{,}679)} \\ &= 1.22\% \end{aligned}$$

Since the vapor space at 105°F would be greater that 1%, the car is **not** overloaded by volume.
Overload check by weight:

1. Compare cargo weight calculated above to Load Limit weight. 135,446 pounds is less than 190,300 pounds, **or**
2. Add Tare weight to cargo weight calculated above and compare to statutory limit:

72,700 + 135,446 = 208,146 pounds, which is less than 263,000 pounds.

Thus, the car is **not** overloaded by weight.

Example 9: Outage Vapor Capacity Table — Actual Loaded Calculation — Overstated Target Loading Temperature Results in Overloading by Volume

A general purpose car is loaded with Light Cat Cracked Gasoline close to the target outage determined in Example 6, but at a colder temperature (90°F) than that used in the target calculation (95°F).

Tank Car Data	
Tare:	72,700 pounds
Load Limit:	190,300 pounds
Stenciled Volume:	23,639 gallons
Capacity Table:	Table E-2
Insulated?	Yes

Product Data	
Loaded Temperature:	90°F
Manway Nozzle Height:	9.25 in.
VCF Table (API gravity):	API 6B (65.0)
Density at Reference Temp:	5.994 pounds/gallon
Outage Gauge (from top of manway):	13.5 in.
Statutory Temp:	105°F
MFLA	0.99

Net Standard Volume is determined with equation (1).

GOV: The capacity table (Table E-2) does not include a nozzle height, so one must first subtract the manway nozzle height from the outage gauge:

13.5 in. – 9.25 in. = 4.25 in.

Since the capacity table is an Outage Vapor table in quarter-inch increments, one need not interpolate for 4.25 inches, but must subtract the corresponding vapor volume from the table maximum volume. The resulting liquid volume is:

(23,679 – 444) = 23,235 gallons

CTAF: From the stenciled volume and the capacity table, the capacity table adjustment factor is (23,639/23,679).
VCF: From API Table 6B, the liquid's VCF at 90°F is 0.9785.
CTS: Since the liquid is not solid at ambient temperature, we obtain from Table B-1 a factor of 1.00058.

NSV = GOV (CTAF) (VCF) (CTS)
= (23,235) (23,639/23,679) (0.9785) (1.00058)
= 22,710 gallons

The cargo's weight is determined with equation (2):

W = NSV (d_{ref}) = 22,710 (5.994) = 136,124 pounds

Overload check by volume, using equation (4):

VCF_{stat}: From API Table 6B, the liquid's VCF at 105°F (insulated car) is: 0.9677.

$$\text{Vapor Space \%} = 100 - \frac{(GOV)(VCF)(CTS) \times 100}{(VCF_{stat})(V_{tblmax})}$$

$$= 100 - \frac{(23{,}235)(0.9785)(1.00058) \times 100}{(0.9677)(23{,}679)}$$

$$= 72\%$$

Since the vapor space at 105°F would be less that 1%, the car is **overloaded** by volume (23,639 × 0.0028 = 66 gallons).
Overload check by weight:

1. Compare cargo weight calculated above to Load Limit weight. 136,124 pounds is less than 190,300 pounds, **or**
2. Add Tare weight to cargo weight calculated above and compare to statutory limit:

72,700 + 136,124 = 208,824 pounds, which is less than 263,000 pounds.

Thus, the car is **not** overloaded by weight.

Example 10: Outage Vapor Capacity Table — Pressure Car Target Loading Calculation — Summer Loading

A pressure car is to be loaded with Propane in the summer.

Tank Car Data	
Tare:	100,800 pounds
Load Limit:	162,200 pounds
Stenciled Volume:	33,648 gallons
Capacity Table:	Table E-5
Insulated?	No

Product Data	
Estimated Loading Temperature:	92°F
Manway Nozzle Height:	0.00 in.
VCF Table (relative density):	ASTM 24 (0.507)
Density at Reference Temp:	4.2174 pounds/gallon
Statutory Temp:	115°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From ASTM Table 24, the liquid's VCF at 115°F (uninsulated car) is 0.9016.

$$\begin{aligned} W_{ma} &= V_s\,(MFLA)\,(VCF_{stat})\,(d_{ref}) \\ &= (33{,}648)\,(0.99)\,(0.9016)\,(4.2174) \\ &= 126{,}664 \text{ pounds} \end{aligned}$$

Since this is less than the Load Limit, the car can be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (100,800 + 126,664 = 227,464) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From ASTM 24, the liquid's VCF at 92°F is 0.9448.

VCF_{stat}: From ASTM 24, the liquid's VCF at 115°F (uninsulated car) is 0.9016.

V_{tblmax}: From the capacity table, the car's maximum volume is 33,653 gallons.

$$\begin{aligned} GOV &= \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)} \\ &= \frac{(33,653)(0.99)(0.9016)}{(0.9448)} \\ &= 31,793 \text{ gallons} \end{aligned}$$

Since the capacity table is an outage/vapor, the volumes listed are vapor volumes. To convert GOV to its corresponding vapor volume, subtract GOV from the maximum vapor volume in the table:

33,653 – 31,793 = 1,860 gallons vapor

Looking up this volume in the capacity table, it falls between volumes representing 12.5 inches and 12.75 inches Interpolating to the nearest $^1/_8$ inch, 12.625 inches is equal to:

(1,837 – 1,892)/2 + 1,892 = 1,865.5 gallons

Since *GOV* is less than the volume corresponding to 12.625 inches, we round to the outage corresponding to a **larger** vapor volume, 12.625 inches do **not** round up to the outage corresponding to a smaller vapor volume (12.5 inches). If we wish to measure only to the nearest $^1/_4$ inch, we would choose 12.75 inches.

Since this is a pressure car, the product level is measured by an internal gauge, and the manway height is not needed.

Example 11: Outage Vapor Capacity Table — Pressure Car Target Loading Calculation — Winter Loading

The pressure car in Example 10 is to be loaded with propane under winter regulations.

Tank Car Data	
Tare:	100,800 pounds
Load Limit:	162,200 pounds
Stenciled Volume:	33,648 gallons
Capacity Table:	Table E-5
Insulated?	No

Product Data	
Estimated Loading Temperature:	92°F
Manway Nozzle Height:	0.00 in.
VCF Table (relative density):	ASTM 24 (0.507)
Density at Reference Temp:	4.2174 pounds/gallon
Statutory Temp:	100°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From ASTM Table 24, the liquid's VCF at 100°F (uninsulated car) is 0.9302.

$$W_{ma} = V_s\,(MFLA)\,(VCF_{stat})\,(d_{ref})$$
$$= (33{,}648)\,(0.99)\,(0.9302)\,(4.2174)$$
$$= 130{,}682 \text{ pounds}$$

Since this is less than the Load Limit, the car can be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (100,800 + 130,682 = 231,482) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From ASTM 24, the liquid's VCF at 92°F is 0.9448.

VCF_{stat}: From ASTM 24, the liquid's VCF at 100°F (uninsulated car) is 0.9302.

V_{tblmax}: From the capacity table, the car's maximum volume is 33,653 gallons.

$$GOV = \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)}$$
$$= \frac{(33,653)(0.99)(0.9302)}{(0.9448)}$$
$$= 32,802 \text{ gallons}$$

Since the capacity table is an outage/vapor, the volumes listed are vapor volumes. To convert GOV to its corresponding vapor volume, subtract GOV from the maximum vapor volume in the table:

33,653 – 32,802 = 851 gallons vapor

Looking up this volume in the capacity table, it falls between volumes representing 7.250 inches and 7.500 inches. Interpolating to the nearest $^1/_8$ inch, 7.375 inches is equal to:

(819 – 861)/2 + 861 = 840 gallons

Since GOV is less than the volume corresponding to 7.375 inches, we round to the outage corresponding to a **larger** vapor volume, 7.500 inches, and load to 861 gallons of vapor. We do **not** round up to the outage corresponding to a smaller vapor volume (7.375 inches). If we wish to measure only to the nearest $^1/4$ inch, we would choose 7.500 inches.

Comparing this result to Example 10, we can load 1,004.5 gallons (1865.5 – 861) more product at 92°F (or 949 gallons net) under winter regulations than under summer regulations.

Since this is a pressure car, the product level is measured by an internal gauge, and the manway height is not needed.

Example 12: Outage Vapor Capacity Table — Pressure Car Actual Loaded Calculation

A pressure car is loaded with Propane in the summer close to the Target outage determined in Example 10.

Tank Car Data	
Tare:	100,800 pounds
Load Limit:	162,200 pounds
Stenciled Volume:	33,648 gallons
Capacity Table:	Table E-5
Insulated?	No

Product Data	
Estimated Loading Temperature:	95°F
Manway Nozzle Height:	0.00 in.
VCF Table (relative density):	ASTM 24 (0.507)
Density at Reference Temp:	4.2174 pounds/gallon
Outage Gauge (internal):	12.750 in.
Product Pressure:	200 psig
Statutory Temp:	115°F
MFLA	0.99

Net Standard Volume is determined with equation (1).

GOV: The capacity table (Table E-5) does not include a nozzle height, but since the internal gauge measures from the top inside of the car's shell, no correction is needed and the outage can be looked up directly in the car's capacity table.

Since the capacity table is an Outage Vapor table in quarter inch increments, one need not interpolate for 12.750 inches but must subtract the corresponding vapor volume from the table maximum volume. The resulting liquid volume is:

(33,653 – 1,892) = 31,761 gallons

CTAF: From the stenciled volume and the capacity table, the capacity table adjustment factor is (33,648/33,653).
VCF: From ASTM Table 24, the liquid's VCF at 95°F is 0.9388.
CTS: Since the liquid is not solid at ambient temperature, we obtain from Table B-1 a factor of 1.00065.
CPS: The expansion of the shell for pressure obtained from Appendix C is 1.00116.
NSV = GOV (CTAF) (VCF) (CTS) (CPS)
= (31,761) (33,648/33,653) (0.9388) (1.00065) 1.00116)
= 29,867 gallons

The cargo's weight is determined with equation (2):

$$W = NSV(d_{ref}) = 29{,}867\,(4.2174) = 125{,}961 \text{ pounds}$$

Overload check by volume, using equation (4):

VCF_{stat}: From ASTM Table 24, the liquid's VCF at 115°F (uninsulated car) is 0.9016.

$$\text{Vapor Space \%} = 100 - \frac{(GOV)(VCF)(CTS)\times 100}{(VCF_{stat})(V_{tblmax})}$$

$$= 100 - \frac{(31{,}761)(0.9388)(1.00065)(1.00116)\times 100}{(0.9016)(33{,}653)}$$

$$= 1.55\%$$

Since the vapor space at 115°F is more than 1%, the car is **not** overloaded by volume.
Overload check by weight:

1. Compare cargo weight calculated above to Load Limit weight. 125,960 pounds is less than 162,200 pounds, **or**
2. Add Tare weight to cargo weight calculated above, and compare to statutory limit:

100,800 + 125,961 = 226,761 pounds, which is less than 263,000 pounds.

Thus, the car is **not** overloaded by weight.

Example 13: Innage Liquid Capacity Table — Loading Target Calculation — Volume Limitation

A general purpose car is to be loaded with Xylene.

Tank Car Data	
Tare:	65,900 pounds
Load Limit:	197,100 pounds
Stenciled Volume:	26,859 gallons
Capacity Table:	Table E-4
Insulated?	No

Product Data	
Estimated Loading Temperature:	75°F
Manway Nozzle Height:	13.375 in.
VCF Table:	ASTM D1555
Density at Reference Temp:	7.251 pounds/gallon
Statutory Temp:	115°F
MFLA	0.99

The weight corresponding to the statutory volume limitation must be calculated using equation (A.1).

VCF_{stat}: From ASTM Table D1555, the liquid's VCF at 115°F (uninsulated car) is 0.9698.

$$\begin{aligned} W_{ma} &= V_s\,(MFLA)\,(VCF_{stat})\,(d_{ref}) \\ &= (26{,}859)\,(0.99)\,(0.9698)\,(7.251) \\ &= 186{,}984 \text{ pounds} \end{aligned}$$

Since this is less than the Load Limit, the car can be loaded to statutory volume limits. If the Load Limit is not available, add W_{ma} to the Tare (65,900 + 186,984 = 252,884) and compare with the weight limitation for that particular car (263,000 pounds for this car).

One must now determine the target outage (liquid level) derived from the statutory volume using equation (A.3).

VCF: From ASTM Table D1555, the liquid's VCF at 75°F is 0.9919.

VCF_{stat}: From ASTM Table D1555, the liquid's VCF at 115°F (uninsulated car) is 0.9698.

V_{tblmax}: From the capacity table, the car's maximum volume is 26,838 gallons.

$$\begin{aligned} GOV &= \frac{(V_{tblmax})(MFLA)(VCF_{stat})}{(VCF)} \\ &= \frac{(26,838)(0.99)(0.9698)}{(0.9919)} \\ &= 25,978 \text{ gallons} \end{aligned}$$

Since the capacity table is an innage/vapor, the volumes listed are liquid volumes.

Looking up this volume in the capacity table, it falls between volumes representing 101.250 inches and 101.500 inches. Interpolating to the nearest $^1/_8$ inch, 101.375 inches is equal to:

(25,975 – 26,018)/2 + 25,975 = 25,996.5 gallons

Since *GOV* is greater than the volume corresponding to 101.250 inches, but less than that corresponding to 101.375 inches, we round to the innage corresponding to a **smaller** liquid volume, 101.250 inches. We do **not** round up to the innage corresponding to a larger liquid volume (101.375 inches). If we wish to measure only to the nearest $^1/4$ inch, we would choose 101.250 inches.

Since this is an innage table, we do not need the manway nozzle height if we are going to perform an innage measurement. If measuring from the top of the manway, we must add the manway nozzle height to the shell diameter (maximum value in the table), and subtract the above calculated innage to get the target outage:

108.75 in. + 13.375 in. – 101.25 in. = 20.875 in.

Table E-1 — Tank Car Capacity Table

Tank Car: ACFX 75538 | Nozzle Volume: 0 | Stencil Volume: 30168 | Tare: 67900
Capacity Table: ACF 1785 | Nozzle Height: 12.5 | Nozzle Height Included? No | Type: Outage Liquid

0.00	30,154	12.00	28,608	24.00	25,873	36.00	22,519	48.00	18,783	60.00	14,857	72.00	10,975	84.00	7,254	96.00	3,942	108.00	1,272
0.25	30,151	12.25	28,561	24.25	25,808	36.25	22,444	48.25	18,702	60.25	14,774	72.25	10,895	84.25	7,179	96.25	3,879	108.25	1,226
0.50	30,145	12.50	28,514	24.50	25,744	36.50	22,368	48.50	18,622	60.50	14,691	72.50	10,816	84.50	7,105	96.50	3,817	108.50	1,180
0.75	30,137	12.75	28,465	24.75	25,679	36.75	22,291	48.75	18,542	60.75	14,608	72.75	10,737	84.75	7,030	96.75	3,754	108.75	1,136
1.00	30,125	13.00	28,416	25.00	25,613	37.00	22,214	49.00	18,461	61.00	14,526	73.00	10,658	85.00	6,956	97.00	3,692	109.00	1,093
1.25	30,111	13.25	28,366	25.25	25,548	37.25	22,137	49.25	18,380	61.25	14,443	73.25	10,579	85.25	6,882	97.25	3,630	109.25	1,051
1.50	30,095	13.50	28,316	25.50	25,482	37.50	22,060	49.50	18,300	61.50	14,360	73.50	10,500	85.50	6,809	97.50	3,568	109.50	1,008
1.75	30,076	13.75	28,265	25.75	25,416	37.75	21,983	49.75	18,219	61.75	14,278	73.75	10,421	85.75	6,736	97.75	3,507	109.75	966
2.00	30,055	14.00	28,213	26.00	25,350	38.00	21,906	50.00	18,138	62.00	14,195	74.00	10,343	86.00	6,664	98.00	3,445	110.00	925
2.25	30,032	14.25	28,162	26.25	25,283	38.25	21,829	50.25	18,057	62.25	14,113	74.25	10,264	86.25	6,593	98.25	3,384	110.25	884
2.50	30,008	14.50	28,110	26.50	25,216	38.50	21,753	50.50	17,976	62.50	14,031	74.50	10,185	86.50	6,521	98.50	3,323	110.50	844
2.75	29,982	14.75	28,058	26.75	25,149	38.75	21,676	50.75	17,895	62.75	13,949	74.75	10,107	86.75	6,450	98.75	3,262	110.75	805
3.00	29,955	15.00	28,006	27.00	25,082	39.00	21,599	51.00	17,814	63.00	13,867	75.00	10,028	87.00	6,379	99.00	3,202	111.00	766
3.25	29,927	15.25	27,953	27.25	25,014	39.25	21,522	51.25	17,733	63.25	13,785	75.25	9,950	87.25	6,308	99.25	3,143	111.25	728
3.50	29,898	15.50	27,900	27.50	24,946	39.50	21,445	51.50	17,652	63.50	13,704	75.50	9,871	87.50	6,226	99.50	3,084	111.50	696
3.75	29,868	15.75	27,846	27.75	24,878	39.75	21,368	51.75	17,570	63.75	13,622	75.75	9,793	87.75	6,164	99.75	3,025	111.75	656
4.00	29,838	16.00	27,792	28.00	24,809	40.00	21,291	52.00	17,489	64.00	13,541	76.00	9,715	88.00	6,092	100.00	2,967	112.00	621
4.25	29,807	16.25	27,738	28.25	24,739	40.25	21,213	52.25	17,408	64.25	13,460	76.25	9,636	88.25	6,020	100.25	2,909	112.25	587
4.50	29,777	16.50	27,683	28.50	24,670	40.50	21,136	52.50	17,326	64.50	13,379	76.50	9,558	88.50	5,948	100.50	2,852	112.50	555
4.75	29,746	16.75	27,628	28.75	24,600	40.75	21,059	52.75	17,245	64.75	13,298	76.75	9,430	88.75	5,877	100.75	2,794	112.75	524
5.00	29,715	17.00	27,572	29.00	24,531	41.00	20,982	53.00	17,163	65.00	13,217	77.00	9,402	89.00	5,806	101.00	2,738	113.00	493
5.25	29,685	17.25	27,516	29.25	24,461	41.25	20,905	53.25	17,082	65.25	13,136	77.25	9,324	89.25	5,735	101.25	2,681	113.25	462
5.50	29,656	17.50	27,460	29.50	24,392	41.50	20,827	53.50	17,000	65.50	13,055	77.50	9,246	89.50	5,665	101.50	2,625	113.50	433
5.75	29,627	17.75	27,403	29.75	24,323	41.75	20,750	53.75	16,919	65.75	12,974	77.75	9,168	89.75	5,595	101.75	2,565	113.75	404
6.00	29,597	18.00	27,346	30.00	24,255	42.00	20,672	54.00	16,837	66.00	12,893	78.00	9,090	90.00	5,526	102.00	2,513	114.00	375
6.25	29,564	18.25	27,288	30.25	24,186	42.25	20,595	54.25	16,755	66.25	12,813	78.25	9,012	90.25	5,456	102.25	2,458	114.25	347
6.50	29,529	18.50	27,230	30.50	24,117	42.50	20,517	54.50	16,674	66.50	12,732	78.50	8,934	90.50	5,388	102.50	2,403	114.5	319
6.75	29,493	18.75	27,172	30.75	24,047	42.75	20,440	54.75	16,592	66.75	12,652	78.75	8,857	90.75	5,319	102.75	2,349	114.75	292
7.00	29,455	19.00	27,113	31.00	23,978	43.00	20,362	55.00	16,510	67.00	12,571	79.00	8,779	91.00	5,251	103.00	2,294	115.00	265
7.25	29,416	19.25	27,054	31.25	23,907	43.25	20,284	55.25	16,429	67.25	12,491	79.25	8,701	91.25	5,183	103.25	2,240	115.25	239
7.50	29,375	19.50	26,995	31.50	23,837	43.50	20,206	55.50	16,347	67.50	12,411	79.50	8,624	91.50	5,115	103.50	2,187	115.50	212
7.75	29,334	19.75	26,934	31.75	23,766	43.75	20,128	55.75	16,265	67.75	12,330	79.75	8,546	91.75	5,048	103.75	2,133	115.75	187
8.00	29,292	20.00	26,874	32.00	23,695	44.00	20,050	56.00	16,182	68.00	12,250	80.00	8,468	92.00	4,981	104.00	2,080	116.00	161
8.25	29,250	20.25	26,813	32.25	23,623	44.25	19,971	56.25	16,100	68.25	12,170	80.25	8,391	92.25	4,914	104.25	2,027	116.25	136
8.50	29,208	20.50	26,752	32.50	23,551	44.50	19,893	56.50	16,018	68.50	12,090	80.50	8,313	92.50	4,847	104.50	1,974	116.50	111
8.75	29,167	20.75	26,690	32.75	23,479	44.75	19,815	56.75	15,935	68.75	12,010	80.75	8,235	92.75	4,781	104.75	1,921	116.75	87
9.00	29,125	21.00	26,628	33.00	23,406	45.00	19,736	57.00	15,852	69.00	11,930	81.00	8,158	93.00	4,715	105.00	1,869	117.00	62
9.25	29,085	21.25	26,567	33.25	23,333	45.25	19,657	57.25	15,770	69.25	11,850	81.25	8,080	93.25	4,649	105.25	1,817	117.25	38
9.50	29,043	21.50	26,505	33.50	23,259	45.50	19,578	57.50	15,687	69.50	11,770	81.50	8,003	93.50	4,584	105.50	1,765	117.50	20
9.75	29,002	21.75	26,442	33.75	23,185	45.75	19,499	57.75	15,604	69.75	11,690	81.75	7,925	93.75	4,518	105.75	1,714	117.75	9
10.00	28,960	22.00	26,380	34.00	23,111	46.00	19,420	58.00	15,521	70.00	11,611	82.00	7,848	94.00	4,453	106.00	1,663	118.00	3
10.25	28,918	22.25	26,318	34.25	23,036	46.25	19,341	58.25	15,438	70.25	11,531	82.25	7,770	94.25	4,385	106.25	1,613	118.25	1
10.50	28,875	22.50	26,255	34.50	22,962	46.50	19,261	58.50	15,355	70.50	11,451	82.50	7,696	94.50	4,324	106.50	1,564	118.50	0
10.75	28,832	22.75	26,192	34.75	22,887	46.75	19,182	58.75	15,272	70.75	11,372	82.75	7,621	94.75	4,260	106.75	1,514		
11.00	28,788	23.00	26,128	35.00	22,813	47.00	19,102	59.00	15,189	71.00	11,292	83.00	7,548	95.00	4,196	107.00	1,465		
11.25	28,744	23.25	26,065	35.25	22,740	47.25	19,023	59.25	15,106	71.25	11,213	83.25	7,475	95.25	4,132	107.25	1,416		
11.50	28,699	23.50	26,001	35.50	22,667	47.50	18,943	59.50	15,023	71.50	11,133	83.50	7,402	95.50	4,069	107.50	1,368		
11.75	28,654	23.75	25,937	35.75	22,593	47.75	18,863	59.75	14,940	71.75	11,054	83.75	7,328	95.75	4,005	107.75	1,320		

Table E-2 — Tank Car Capacity Table

Tank Car: GATX 3741 | Nozzle Volume: 0 | Stencil Volume: 23639 | Tare: 72700
Capacity Table: GAT 8582 | Nozzle Height: 9.5 | Nozzle Height Included? No | Type: Outage Vapor

0.25	19	20	3,301	79.0	18,805	107.50	23,645
0.50	40	21	3,524	80.0	19,045	107.75	23,652
0.75	61	22	3,751	81.0	19,282	108.00	23,658
1.00	83	23	3,981	82.0	19,516	108.25	23,664
1.25	107	24	4,215	83.0	19,747	108.50	23,668
1.50	131	25	4,452	84.0	19,974	108.75	23,671
1.75	156	26	4,692	85.0	20,197	109.00	23,674
2.00	182	27	4,935	86.0	20,416	109.25	23,676
2.25	208	28	5,181	87.0	20,632	109.50	23,677
2.50	235	29	5,430	88.0	20,843	109.75	23,678
2.75	263	30	5,681	89.0	21,050	110.25	23,679
3.00	291	31	5,934	90.0	21,252		
3.25	321	32	6,190	91.0	21,449		
3.50	350	33	6,448	91.5	21,546		
3.75	381	34	6,707	92.0	21,642		
4.00	412	35	6,969	92.5	21,736		
4.25	444	36	7,233	93.0	21,829		
4.50	476	37	7,498	93.5	21,920		
4.75	509	38	7,765	94.0	22,010		
5.00	542	39	8,033	94.5	22,098		
5.25	576	40	8,303	95.0	22,185		
5.50	611	41	8,574	95.5	22,271		
5.75	646	42	8,846	96.0	22,354		
6.00	682	43	9,119	96.5	22,436		
6.25	718	44	9,394	97.0	22,517		
6.50	755	45	9,669	97.5	22,595		
6.75	792	46	9,944	98.0	22,672		
7.00	829	47	10,221	98.5	22,747		
7.25	867	48	10,498	99.0	22,820		
7.50	906	49	10,775	99.5	22,891		
7.75	945	50	11,053	100.0	22,960		
8.00	984	51	11,331	100.5	23,027		
8.25	1,024	52	11,609	100.8	23,059		
8.50	1,064	53	11,887	101.0	23,091		
8.75	1,105	54	12,165	101.3	23,123		
9.00	1,146	55	12,443	101.5	23,154		
9.25	1,188	56	12,721	101.8	23,184		
9.50	1,230	57	12,998	102.0	23,213		
9.75	1,272	58	13,275	102.3	23,242		
10.00	1,315	59	13,552	102.5	23,270		
10.50	1,402	60	13,827	102.8	23,298		
11.00	1,490	61	14,102	103.0	23,325		
11.50	1,580	62	14,376	103.3	23,351		
12.00	1,671	63	14,650	103.5	23,376		
12.50	1,764	64	14,922	103.8	23,401		
13.00	1,857	65	15,193	104.0	23,425		
13.50	1,953	66	15,463	104.3	23,448		
14.00	2,050	67	15,731	104.5	23,470		
14.50	2,147	68	15,998	104.8	23,491		
15.00	2,247	69	16,263	105.0	23,511		
15.50	2,347	70	16,527	105.3	23,530		
16.00	2,448	71	16,789	105.5	23,548		
16.50	2,551	72	17,049	105.8	23,564		
17.00	2,655	73	17,307	106.0	23,579		
17.50	2,760	74	17,563	106.3	23,593		
18.00	2,866	75	17,816	106.5	23,606		
18.50	2,973	76	18,067	106.8	23,618		
19.00	3,081	77	18,316	107.0	23,628		
19.50	3,191	78	18,562	107.3	23,637		

Table E-3 — Tank Car Capacity Table

Tank Car:	SCMX 2197 1	Nozzle Volume:	0	Stencil Volume:	11348	Tare:	67200
Capacity Table:	SCM 922197	Nozzle Height:	12.5	Nozzle Height Included?	Yes	Type:	Outage Liquid

12.50	11,348	28.50	10,285	44.50	8,448	60.50	6,285	76.50	4,048	92.50	2,025	108.500	467
12.75	11,345	28.75	10,262	44.75	8,416	60.75	6,251	76.75	4,014	92.75	1,996	108.750	448
13.00	11,342	29.00	10,238	45.00	8,384	61.00	6,216	77.00	3,981	93.00	1,966	109.000	429
13.25	11,336	29.25	10,215	45.20	8,351	61.25	6,182	77.25	3,947	93.25	1,936	109.250	410
13.50	11,329	29.50	10,189	45.50	8,319	61.50	6,147	77.50	3,913	93.50	1,907	109.500	393
13.75	11,323	29.75	10,162	45.75	8,287	61.75	6,113	77.75	3,879	93.75	1,877	109.750	377
14.00	11,317	30.00	10,135	46.00	8,254	62.00	6,078	78.00	3,845	94.00	1,847	110.000	362
14.25	11,307	30.25	10,108	46.25	8,222	62.25	6,044	78.25	3,811	94.25	1,818	110.250	347
14.50	11,297	30.50	10,082	46.50	8,190	62.50	6,009	78.50	3,777	94.50	1,789	110.500	331
14.75	11,287	30.75	10,055	46.75	8,157	62.75	5,973	78.75	3,743	94.75	1,761	110.750	316
15.00	11,277	31.00	10,028	47.00	8,125	63.00	5,937	79.00	3,709	95.00	1,734	111.000	300
15.25	11,267	31.25	10,002	47.25	8,093	63.25	5,902	79.25	3,675	95.25	1,706	111.250	285
15.50	11,256	31.50	9,975	47.50	8,060	63.50	5,866	79.50	3,641	95.50	1,678	111.500	270
15.75	11,245	31.75	9,948	47.75	8,028	63.75	5,830	79.75	3,607	95.75	1,651	111.750	254
16.00	11,234	32.00	9,922	48.00	7,995	64.00	5,794	80.00	3,573	96.00	1,623	112.000	239
16.25	11,222	32.25	9,895	48.25	7,962	64.25	5,759	80.25	3,539	96.25	1,595	112.250	223
16.50	11,210	32.50	9,868	48.50	7,929	64.50	5,723	80.50	3,505	96.50	1,568	112.500	208
16.75	11,197	32.75	9,841	48.75	7,895	64.75	5,687	80.75	3,474	96.75	1,540	112.750	194
17.00	11,183	33.00	9,815	49.00	7,862	65.00	5,651	81.00	3,443	97.00	1,513	113.000	182
17.25	11,170	33.25	9,787	49.25	7,828	65.25	5,616	81.25	3,411	97.25	1,485	113.250	169
17.50	11,157	33.50	9,759	49.50	7,795	65.50	5,580	81.50	3,380	97.50	1,457	113.500	156
17.75	11,143	33.75	9,732	49.75	7,762	65.75	5,544	81.75	3,349	97.75	1,430	113.750	144
18.00	11,130	34.00	9,704	50.00	7,728	66.00	5,508	82.00	3,317	98.00	1,402	114.000	131
18.25	11,117	34.25	9,677	50.25	7,695	66.25	5,472	82.25	3,286	98.25	1,378	114.250	119
18.50	11,100	34.50	9,649	50.50	7,661	66.50	5,437	82.50	3,255	98.50	1,354	114.500	106
18.75	11,083	34.75	9,621	50.75	7,628	66.75	5,401	82.75	3,224	98.75	1,329	114.750	96
19.00	11,067	35.00	9,594	51.00	7,595	67.00	5,365	83.00	3,192	99.00	1,305	115.000	88
19.25	11,050	35.25	9,566	51.25	7,561	67.25	5,329	83.25	3,161	99.25	1,281	115.250	79
19.50	11,033	35.50	9,538	51.50	7,528	67.50	5,294	83.50	3,130	99.50	1,256	115.500	71
19.75	11,017	35.75	9,511	51.75	7,494	67.75	5,258	83.75	3,098	99.75	1,232	115.750	63
20.00	10,998	36.00	9,483	52.00	7,459	68.00	5,222	84.00	3,067	100.00	1,208	116.000	54
20.25	10,980	36.25	9,456	52.25	7,425	68.25	5,186	84.25	3,036	100.25	1,184	116.250	48
20.50	10,962	36.50	9,428	52.50	7,390	68.50	5,151	84.50	3,005	100.50	1,159	116.500	43
20.75	10,944	36.75	9,399	52.75	7,356	68.75	5,115	84.75	2,974	100.75	1,135	116.750	39
21.00	10,925	37.00	9,370	53.00	7,321	69.00	5,079	85.00	2,943	101.00	1,111	117.000	34
21.25	10,907	37.25	9,340	53.25	7,287	69.25	5,043	85.25	2,912	101.25	1,086	117.250	30
21.50	10,889	37.50	9,310	53.50	7,252	69.50	5,008	85.50	2,881	101.50	1,062	117.500	26
21.75	10,871	37.75	9,281	53.75	7,218	69.75	4,973	85.75	2,850	101.75	1,038	117.750	21
22.00	10,853	38.00	9,251	54.00	7,183	70.00	4,938	86.00	2,820	102.00	1,014	118.000	17
22.25	10,834	38.25	9,221	54.25	7,149	70.25	4,904	86.25	2,789	102.25	990	118.250	12
22.50	10,816	38.50	9,192	54.50	7,114	70.50	4,869	86.50	2,758	102.50	966	118.500	9
22.75	10,795	38.75	9,162	54.75	7,080	70.75	4,835	86.75	2,727	102.75	943	118.750	8
23.00	10,773	39.00	9,132	55.00	7,045	71.00	4,800	87.00	2,696	103.00	919	119.000	6
23.25	10,752	39.25	9,103	55.25	7,011	71.25	4,766	87.25	26,66	103.25	895	119.250	5
23.50	10,730	39.50	9,073	55.50	6,976	71.50	4,731	87.50	2,635	103.50	872	119.500	4
23.75	10,709	39.75	9,043	55.75	6,941	71.75	4,697	87.75	2,604	103.75	848	119.750	2
24.00	10,687	40.00	9,014	56.00	6,907	72.00	4,662	88.00	2,573	104.00	825	120.000	1
24.25	10,666	40.25	8,982	56.25	6,872	72.25	4,628	88.25	2,542	104.25	801	120.625	0
24.50	10,645	40.50	8,951	56.50	6,838	72.50	4,593	88.50	2,511	104.50	781		
24.75	10,623	40.75	8,920	56.75	6,803	72.75	4,559	88.75	2,481	104.75	761		
25.00	10,602	41.00	8,888	57.00	6,769	73.00	4,524	89.00	2,450	105.00	741		
25.25	10,580	41.25	8,857	57.25	6,734	73.25	4,490	89.25	2,419	105.25	721		
25.50	10,559	41.50	8,826	57.50	6,700	73.50	4,456	89.50	2,388	105.50	701		
25.75	10,537	41.75	8,794	57.75	6,665	73.75	4,422	89.75	2,357	105.75	681		
26.00	10,516	42.00	8,763	58.00	6,631	74.00	4,388	90.00	2,327	106.00	661		
26.25	10,493	42.25	8,732	58.25	6,596	74.25	4,354	90.25	2,296	106.25	641		
26.50	10,470	42.50	8,701	58.50	6,562	74.50	4,320	90.50	2,265	106.50	621		
26.75	10,446	42.75	8,669	58.75	6,527	74.75	4,286	90.75	2,234	106.75	601		
27.00	10,423	43.00	8,638	59.00	6,492	75.00	4,252	91.00	2,203	107.00	582		
27.25	10,400	43.25	8,607	59.25	6,458	75.25	4,218	91.25	2,174	107.25	563		
27.50	10,377	43.50	8,575	59.50	6,423	75.50	4,184	91.50	2,144	107.50	544		
27.75	10,354	43.75	8,544	59.75	6,389	75.75	4,150	91.75	2,114	107.75	525		
28.00	10,331	44.00	8,513	60.00	6,354	76.00	4,116	92.00	2,085	108.00	506		
28.25	10,308	44.25	8,480	60.25	6,320	76.25	4,082	92.25	2,055	108.25	486		

Table E-4 — Tank Car Capacity Table

Tank Car: ACFX 79298 Nozzle Volume: 0 Stencil Volume: 26859 Tare: 65900
Capacity Table: ACF 1769 Nozzle Height: 13.375 Nozzle Height Included? No Type: Innage Liquid

0.00	0	13.00	1,371	26.00	4,341	39.00	8,052	52.00	12,127	65.00	16,290	78.00	20,288	91.00	23,827	104.00	26,403
0.25	3	13.25	1,418	26.25	4,406	39.25	8,128	52.25	12,206	65.25	16,370	78.25	20,362	91.25	23,888	104.25	26,434
0.50	7	13.50	1,465	26.50	4,472	39.50	8,204	52.50	12,286	65.50	16,450	78.50	20,436	91.50	23,949	104.50	26,463
0.75	11	13.75	1,513	26.75	4,538	39.75	8,280	52.75	12,366	65.75	16,529	78.75	20,510	91.75	24,010	104.75	26,493
1.00	17	14.00	1,561	27.00	4,605	40.00	8,356	53.00	12,446	66.00	16,609	79.00	20,584	92.00	24,070	105.00	26,524
1.25	23	14.25	1,609	27.25	4,672	40.25	8,433	53.25	12,526	66.25	16,688	79.25	20,658	92.25	24,131	105.25	26,555
1.50	30	14.50	1,658	27.50	4,739	40.50	8,509	53.50	12,606	66.50	16,768	79.50	20,732	92.50	24,191	105.50	26,586
1.75	37	14.75	1,707	27.75	4,807	40.75	8,585	53.75	12,686	66.75	16,847	79.75	20,805	92.75	24,251	105.75	26,616
2.00	46	15.00	1,757	28.00	4,874	41.00	8,662	54.00	12,766	67.00	16,926	80.00	20,878	93.00	24,310	106.00	26,645
2.25	55	15.25	1,807	28.25	4,941	41.25	8,738	54.25	12,846	67.25	17,005	80.25	20,951	93.25	24,368	106.25	26,674
2.50	65	15.50	1,858	28.50	5,009	41.50	8,815	54.50	12,927	67.50	17,084	80.50	21,024	93.50	24,425	106.50	26,701
2.75	75	15.75	1,910	28.75	5,076	41.75	8,892	54.75	13,007	67.75	17,163	80.75	21,096	93.75	24,482	106.75	26,727
3.00	87	16.00	1,961	29.00	5,144	42.00	8,969	55.00	13,087	68.00	17,242	81.00	21,168	94.00	24,539	107.00	26,750
3.25	99	16.25	2,014	29.25	5,212	42.25	9,046	55.25	13,167	68.25	17,320	81.25	21,239	94.25	24,595	107.25	26,772
3.50	111	16.50	2,066	29.50	5,280	42.50	9,123	55.50	13,248	68.50	17,398	81.50	21,311	94.50	24,650	107.50	26,791
3.75	124	16.75	2,119	29.75	5,348	42.75	9,200	55.75	13,328	68.75	17,477	81.75	21,382	94.75	24,705	107.75	26,807
4.00	138	17.00	2,173	30.00	5,417	43.00	9,277	56.00	13,408	69.00	17,555	82.00	21,453	95.00	24,759	108.00	26,820
4.25	153	17.25	2,228	30.25	5,485	43.25	9,355	56.25	13,489	69.25	17,633	82.25	21,523	95.25	24,813	108.25	26,830
4.50	168	17.50	2,283	30.50	5,554	43.50	9,432	56.50	13,569	69.50	17,710	82.50	21,594	95.50	24,866	108.50	26,836
4.75	184	17.75	2,338	30.75	5,623	43.75	9,510	56.75	13,650	69.75	17,788	82.75	21,664	95.75	24,919	108.75	26,838
5.00	200	18.00	2,394	31.00	5,693	44.00	9,588	57.00	13,730	70.00	17,865	83.00	21,734	96.00	24,971		
5.25	218	18.25	2,450	31.25	5,763	44.25	9,666	57.25	13,810	70.25	17,943	83.25	21,803	96.25	25,023		
5.50	239	18.50	2,506	31.50	5,833	44.50	9,745	57.50	13,891	70.50	18,020	83.50	21,873	96.50	25,075		
5.75	263	18.75	2,563	31.75	5,904	44.75	9,823	57.75	13,971	70.75	18,097	83.75	21,942	96.75	25,126		
6.00	288	19.00	2,619	32.00	5,975	45.00	9,902	58.00	14,051	71.00	18,174	84.00	22,011	97.00	25,176		
6.25	316	19.25	2,676	32.25	6,046	45.25	9,980	58.25	14,132	71.25	18,250	84.25	22,080	97.25	25,226		
6.50	346	19.50	2,732	32.50	6,118	45.50	10,059	58.50	14,212	71.50	18,327	84.50	22,149	97.50	25,276		
6.75	377	19.75	2,789	32.75	6,191	45.75	10,138	58.75	14,292	71.75	18,404	84.75	22,218	97.75	25,325		
7.00	409	20.00	2,846	33.00	6,264	46.00	10,217	59.00	14,372	72.00	18,480	85.00	22,287	98.00	25,374		
7.25	442	20.25	2,904	33.25	6,337	46.25	10,296	59.25	14,452	72.25	18,557	85.25	22,355	98.25	25,423		
7.50	476	20.50	2,962	33.50	6,410	46.50	10,375	59.50	14,532	72.50	18,633	85.50	22,423	98.50	25,471		
7.75	510	20.75	3,020	33.75	6,484	46.75	10,454	59.75	14,612	72.75	18,709	85.75	22,491	98.75	25,520		
8.00	544	21.00	3,079	34.00	6,557	47.00	10,534	60.00	14,692	73.00	18,785	86.00	22,558	99.00	25,568		
8.25	579	21.25	3,139	34.25	6,631	47.25	10,613	60.25	14,772	73.25	18,861	86.25	22,624	99.25	25,616		
8.50	616	21.50	3,199	34.50	6,704	47.50	10,693	60.50	14,852	73.50	18,937	86.50	22,691	99.50	25,664		
8.75	653	21.75	3,260	34.75	6,778	47.75	10,772	60.75	14,932	73.75	19,013	86.75	22,757	99.75	25,711		
9.00	691	22.00	3,321	35.00	6,852	48.00	10,852	61.00	15,011	74.00	19,089	87.00	22,822	100.00	25,757		
9.25	730	22.25	3,383	35.25	6,926	48.25	10,931	61.25	15,091	74.25	19,164	87.25	22,888	100.25	25,803		
9.50	769	22.50	3,446	35.50	7,001	48.50	11,011	61.50	15,171	74.50	19,240	87.50	22,953	100.50	25,847		
9.75	809	22.75	3,508	35.75	7,075	48.75	11,091	61.75	15,251	74.75	19,315	87.75	23,018	100.75	25,891		
10.00	850	23.00	3,571	36.00	7,150	49.00	11,170	62.00	15,331	75.00	19,391	88.00	23,082	101.00	25,933		
10.25	890	23.25	3,635	36.25	7,224	49.25	11,250	62.25	15,411	75.25	19,466	88.25	23,147	101.25	25,975		
10.50	932	23.50	3,699	36.50	7,299	49.50	11,330	62.50	15,491	75.50	19,541	88.50	23,211	101.50	26,018		
10.75	973	23.75	3,763	36.75	7,374	49.75	11,409	62.75	15,571	75.75	19,616	88.75	23,275	101.75	26,060		
11.00	1,015	24.00	3,826	37.00	7,449	50.00	11,489	63.00	15,651	76.00	19,691	89.00	23,340	102.00	26,102		
11.25	1,058	24.25	3,890	37.25	7,524	50.25	11,569	63.25	15,731	76.25	19,766	89.25	23,403	102.25	26,143		
11.50	1,100	24.50	3,954	37.50	7,599	50.50	11,649	63.50	15,811	76.50	19,841	89.50	23,465	102.50	26,183		
11.75	1,144	24.75	4,018	37.75	7,674	50.75	11,728	63.75	15,891	76.75	19,916	89.75	23,526	102.75	26,223		
12.00	1,188	25.00	4,082	38.00	7,750	51.00	11,808	64.00	15,971	77.00	19,990	90.00	23,587	103.00	26,262		
12.25	1,233	25.25	4,146	38.25	7,825	51.25	11,888	64.25	16,051	77.25	20,065	90.25	23,647	103.25	26,299		
12.50	1,279	25.50	4,211	38.50	7,901	51.50	11,967	64.50	16,131	77.50	20,139	90.50	23,707	103.50	26,335		
12.75	1,325	25.75	4,276	38.75	7,976	51.75	12,047	64.75	16,210	77.75	20,214	90.75	23,767	103.75	26,370		

Table E-5 — Tank Car Capacity Table

Tank Car:	GATX 40671	Nozzle Volume: 0	Stencil Volume:	33648	Tare:	100800
Capacity Table:	GAT 6895	Nozzle Height: 0	Nozzle Height Included?	No	Type:	Outage Vapor

0.00	3	12.50	1,837	25.00	5,068	37.50	9,025	50.00	13,388
0.25	8	12.75	1,892	25.25	5,142	37.75	9,109	50.25	13,478
0.50	18	13.00	1,947	25.50	5,215	38.00	9,193	50.50	13,568
0.75	30	13.25	2,002	25.75	5,289	38.25	9,278	50.75	13,658
1.00	45	13.50	2,058	26.00	5,363	38.50	9,362	51.00	13,748
1.25	61	13.75	2,115	26.25	5,438	38.75	9,447	51.25	13,838
1.50	80	14.00	2,172	26.50	5,512	39.00	9,532	51.50	13,928
1.75	100	14.25	2,229	26.75	5,587	39.25	9,617	51.75	14,018
2.00	121	14.50	2,287	27.00	5,663	39.50	9,703	52.00	14,108
2.25	144	14.75	2,346	27.25	5,738	39.75	9,788	52.25	14,198
2.50	169	15.00	2,404	27.50	5,814	40.00	9,873	52.50	14,288
2.75	194	15.25	2,464	27.75	5,890	40.25	9,959	52.75	14,378
3.00	221	15.50	2,523	28.00	5,966	40.50	10,045	53.00	14,469
3.25	248	15.75	2,583	28.25	6,043	40.75	10,131	53.25	14,559
3.50	277	16.00	2,644	28.50	6,119	41.00	10,217	53.50	14,650
3.75	307	16.25	2,705	28.75	6,196	41.25	10,303	53.75	14,740
4.00	338	16.50	2,766	29.00	6,273	41.50	10,389	54.00	14,830
4.25	370	16.75	2,828	29.25	6,351	41.75	10,476	54.50	15,012
4.50	403	17.00	2,890	29.50	6,429	42.00	10,562	55.00	15,193
4.75	436	17.25	2,953	29.75	6,506	42.25	10,649	55.50	15,374
5.00	471	17.50	3,016	30.00	6,585	42.50	10,736	56.00	15,556
5.25	506	17.75	3,079	30.25	6,663	42.75	10,823	56.50	15,737
5.50	543	18.00	3,143	30.50	6,742	43.00	10,910	57.00	15,919
5.75	580	18.25	3,207	30.75	6,820	43.25	10,997	57.50	16,100
6.00	618	18.50	3,271	31.00	6,900	43.50	11,084	58.00	16,282
6.25	656	18.75	3,336	31.25	6,979	43.75	11,172	58.50	16,464
6.50	696	19.00	3,401	31.50	7,058	44.00	11,259	59.00	16,646
6.75	736	19.25	3,467	31.75	7,138	44.25	11,347	59.50	16,828
7.00	777	19.50	3,533	32.00	7,218	44.50	11,435	60.00	17,010
7.25	819	19.75	3,599	32.25	7,298	44.75	11,523	60.50	17,191
7.50	861	20.00	3,666	32.50	7,378	45.00	11,610	61.00	17,373
7.75	904	20.25	3,733	32.75	7,459	45.25	11,699	61.50	17,555
8.00	948	20.50	3,800	33.00	7,540	45.50	11,787	62.00	17,737
8.25	992	20.75	3,868	33.25	7,621	45.75	11,875	62.50	17,918
8.50	1,037	21.00	3,936	33.50	7,702	46.00	11,963	63.00	18,100
8.75	1,083	21.25	4,005	33.75	7,783	46.25	12,052	63.50	18,281
9.00	1,129	21.50	4,073	34.00	7,865	46.50	12,140	64.00	18,463
9.25	1,176	21.75	4,142	34.25	7,946	46.75	12,229	119.00	33,653
9.50	1,223	22.00	4,212	34.50	8,028	47.00	12,318		
9.75	1,272	22.25	4,281	34.75	8,110	47.25	12,406		
10.00	1,320	22.50	4,352	35.00	8,193	47.50	12,495		
10.25	1,369	22.75	4,422	35.25	8,275	47.75	12,584		
10.50	1,419	23.00	4,492	35.50	8,358	48.00	12,673		
10.75	1,470	23.25	4,563	35.75	8,440	48.25	12,762		
11.00	1,521	23.50	4,635	36.00	8,523	48.50	12,852		
11.25	1,572	23.75	4,706	36.25	8,607	48.75	12,941		
11.50	1,624	24.00	4,778	36.50	8,690	49.00	13,030		
11.75	1,677	24.25	4,850	36.75	8,773	49.25	13,120		
12.00	1,730	24.50	4,923	37.00	8,857	49.50	13,209		
12.25	1,783	24.75	4,995	37.25	8,941	49.75	13,299		

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