Dennis Campbell
Hazmat Trainer – FRA
Office: (281) 259-4923
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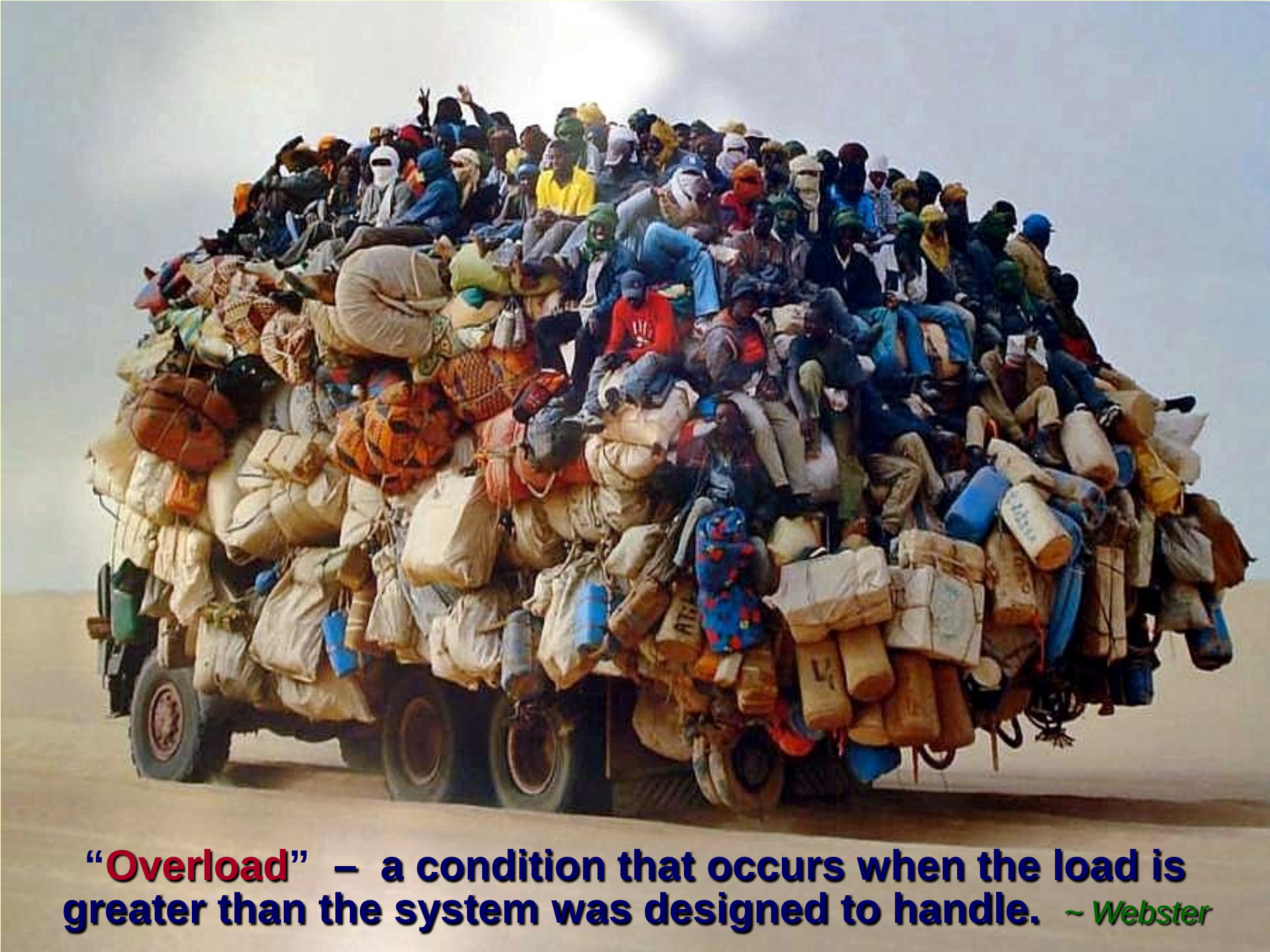
Tank Car Filling Limit & Filling Density Standards



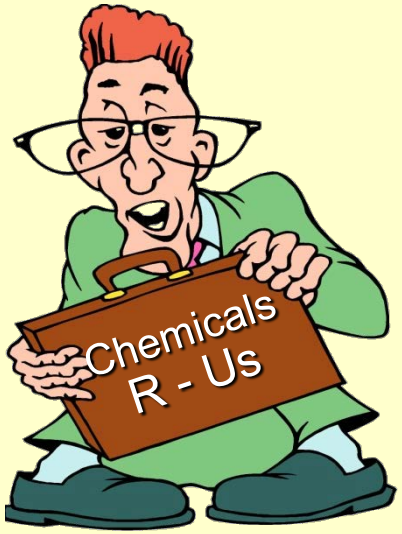
"Overload" – a condition that occurs when the load is greater than the system was designed to handle. *~ Webster*

The DANGER of shell-full containers

If a product does not have sufficient room to expand within its container, pressure will rise in measurable proportions. *For example*, Fuel Oil has a coefficient of expansion factor = .00045 per unit volume, per ºF rise in temperature. This translates to a trapped volume of fuel oil will increase its pressure by 75 psi with a 1º F rise in temperature.

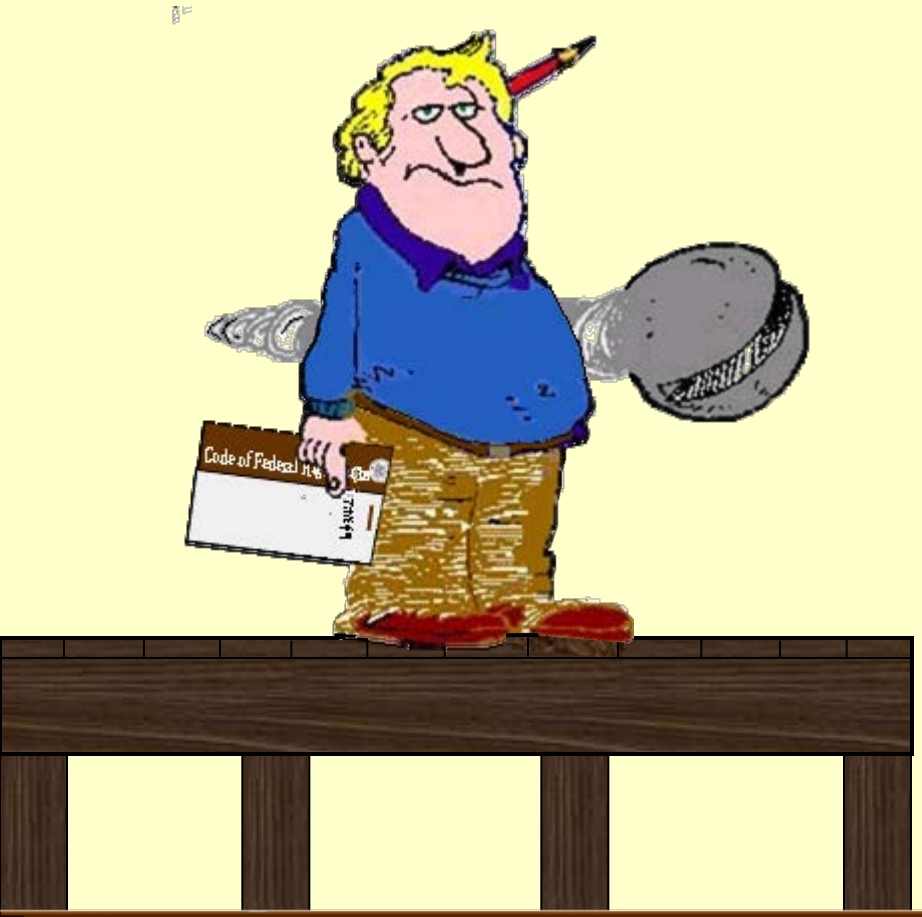
Source: ***American Petroleum Institute***

Shipper's Responsibilities



- ✓ *Unless excluded*, **register with DOT**
- ✓ **Class & describe the hazardous material**
- ✓ **Choose an authorized packaging**
- ✓ **Properly communicate the hazard of the material**
- ✓ **Comply with all applicable special permits** *(exemptions)*
- ✓ **Instruct each of their officers, employees & agents / contractors as to applicable regulations**
- ✓ **Develop a security plan & provide emergency response information during transport**
- ✓ **Limit the quantity of the product loaded per DOT standards**
- ✓ **Comply with applicable loading & unloading requirements**
- ✓ **Examine the shipment before offering into transportation**

Carrier's Responsibility



No person may accept for transportation or transport by rail any shipment of hazardous material that is NOT in conformance with the requirements of this subchapter.

§174.3


When is a hazmat package considered "overloaded"?

A tank car can be OVERLOADED by:

- ✓ **Exceeding the maximum gross weight for the journal size, which is the Load Limit (LD LMT) + Light Weight (Tare Wt)** ***or,***

  Gross Weight on Rail (GWR)

- ✓ **Exceeding the maximum filling limit *or* filling density standards in the regulations** ***or,***

  Min. Outage Requirement

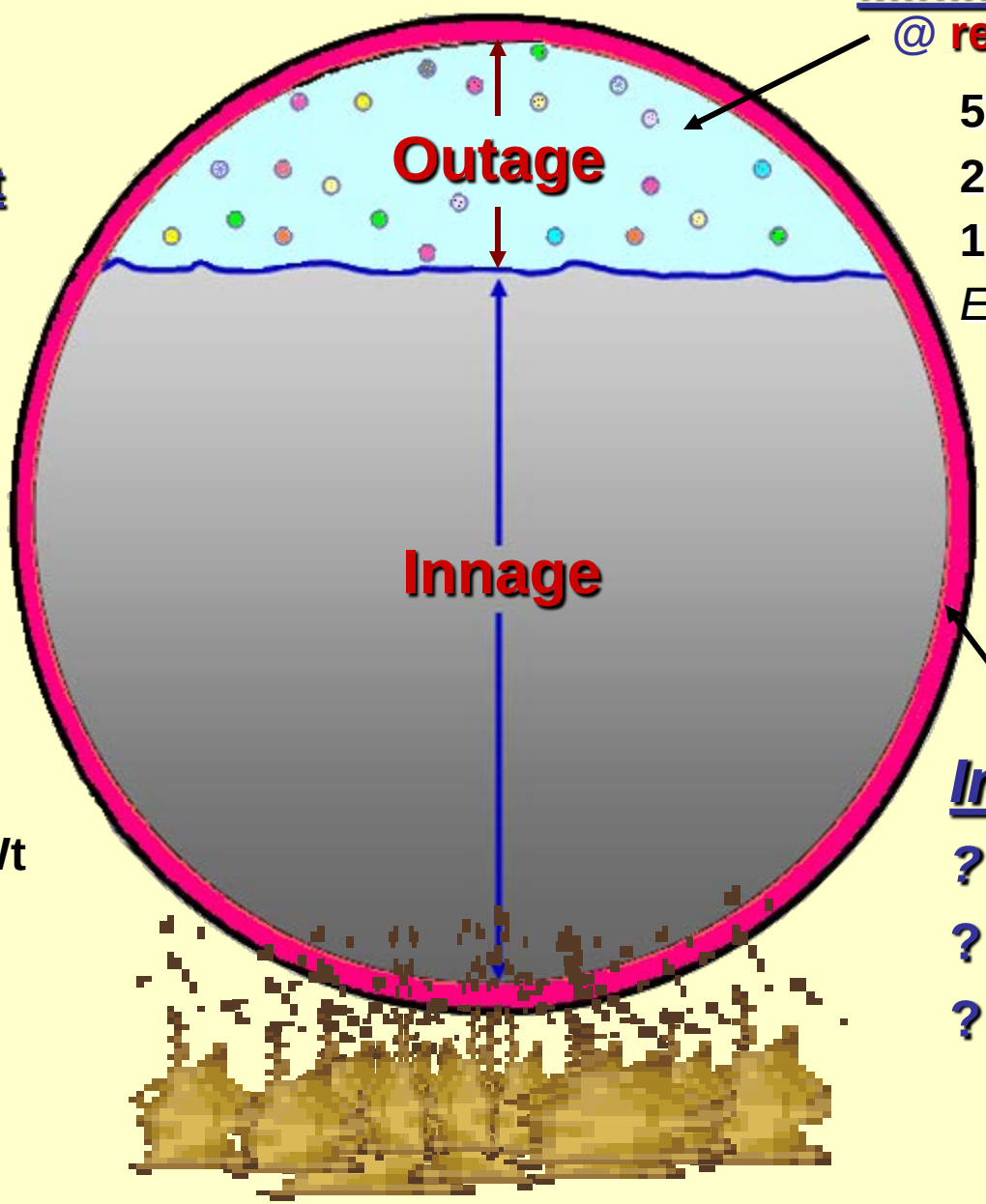
- ✓ **Both methods *!***

Filling Limit Basics

Minimum Outage
@ **reference temp.**

- **5% PIH**
- **2% AA**
- **1% all others**
- *Exceptions ??*

Weight of the product does not change, but its volume will vary due its temperature !



Scale Wt - LT WT = Product Wt

Product Wt - Max. Allowable Wt = Overage

Insulation

- **? Fully-insulated**
- **? Quasi-insulated**
- **? Non-insulated**

Applicable 49 CFR References – Filling Limits

§173.26 Quantity limitations

When quantity limitations do not appear in the packaging requirements of this subchapter, the permitted gross weight or capacity authorized for a packaging is as shown in the packaging specification or standard in part 178 or 179, as applicable, of this subchapter.

App. B to Part 209 – Penalty Guidelines (Penalty = $5,000)

§173.26 – Loaded beyond gross weight or capacity as stated in specification. (Applies only if quantity limitations do not appear in packaging requirements of part 173). (For tank cars, see §179.13). For gross weight & capacity requirements, see §179.13. §173.26 should be the citation for the violation & civil penalty; §179.13 can be cited as a reference section.

Tank Car Filling Limits

§ 173.24b (a) Outage & Filling Limits

Except as otherwise provided in this subchapter, liquids & liquefied gases must be so loaded that the outage is at least 5% for materials poisonous by inhalation, *or* at least 1% for all other materials, of the total capacity of a cargo tank, portable tank, tank car (including dome capacity), multi-unit tank car tank, or any compartment thereof, at the following reference temperature:

(i) 46°C (115°F) for a noninsulated tank,

(ii) 43°C (110°F) for a tank car having a thermal protection system, incorporating a metal jacket that provides an overall thermal conductance at 15.5°C (60°F) of no more than 0.5 Btu per hour/per square foot/per degree F) temperature differential; *or*

112 J
114 J

(iii) 41°C (105°F) for an insulated tank

Outage Standard Exceptions

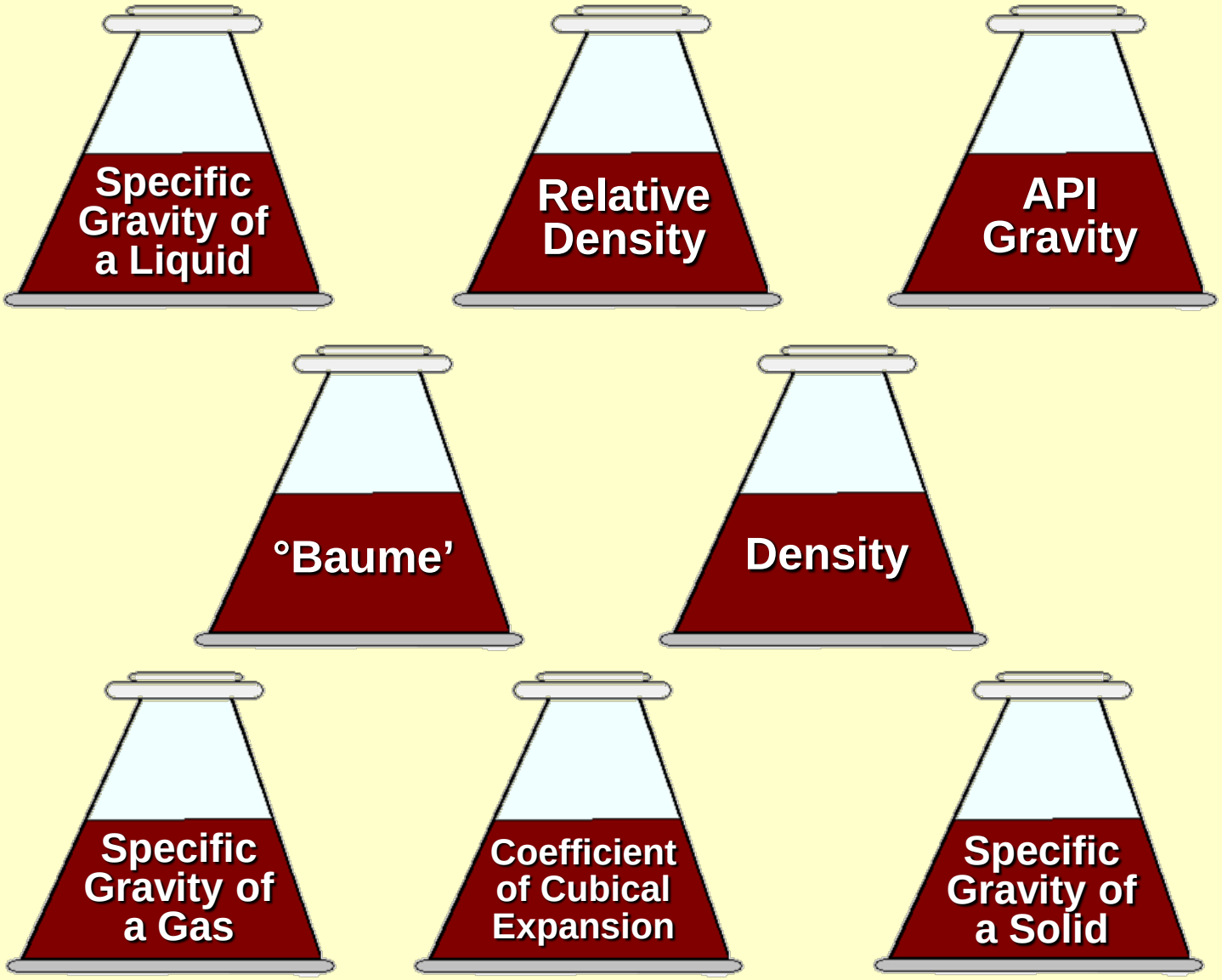
- ✓ **Anhydrous Ammonia** *or* **Ammonia solutions > 50% Ammonia**
  § 173.314(c) – *Note 2* (allows for a 2% outage @ app. ref. temp)
- ✓ **Summer/winter schedule for LPG** *&* **AA** - **§ 173.314(c) – *Note 10***
- ✓ **Filling Density Standards - Applies to only 5 commodities** *(all gases)* **when loaded in tank cars:**

1. Chlorine	3. Hydrogen sulfide	5. Nitrosyl chloride
2. Sulfur dioxide	4. Sulfuryl fluoride	

*** Filling Density is a percent ratio of the weight of liquefied gas in the tank to the weight of water that the tank will hold !**

- ✓ **Cryogenic liquids - § 173.24(h)(2), § 273.319** *&* **§ 173.320**
  Note: ***A cryogenic liquid is a refrigerated liquefied gas having a boiling point colder than -130ºF*** *(-90ºC)* ***at 14.7 psia*** *(1 atm).*
- ✓ **A few special commodity requirements - "B61" Special Provisions for *Hydrocyanic Acid* & "B26" *for Phosphorous***
- ✓ **Compressed gases in cargo tanks & portable tanks - § 173.315**
- ✓ **Non-bulk packagings (includes DOT106A500W tanks) - § 173.24a(d)**

Basic Chemical Properties Terminology



Specific Gravity

Can be divided into 2 categories:

- ✓ **Gas**
- ✓ **Liquid / Liquefied Gas**

(also includes solids)

Specific Gravity of a Gas

Definition: Mass of a gas or vapor compared to an equal volume of air. Sometimes referred to as "Vapor Density". Thus, an abstract number that compares the ratio of density of a gas to the mass of equal volume of air.

Standard: Specific Gravity of Air @ 70ºF = 1

EX: Oxygen weighs .01221 lbs/gal @ 60ºF

Air (dry) @ 60°F = .011 lbs/gal

Sg @ 60ºF = Density @ 60ºF / Air Wt.

Sg @ 60ºF = .01221 / .011 = **1.11**

Thus, the **vapor density** of Oxygen weighs **1.11** times **heavier** than air @ 60ºF.

Specific Gravity of a Gas – cont.

Standard: **Specific Gravity of Air @ 70ºF = 1**

EX: **Chlorine weighs .027335 lbs/gal @ 32ºF**

Sg @ 32ºF = Density @ 32ºF / Air Wt.

Sg @ 32ºF = .027335 / .011 = 2.49

Thus, the vapor density of Chlorine weighs 2.49 times heavier than air @ 32ºF.

EX: **Ethylene weighs .010758 lbs/gal @ 32ºF**

Sg @ 32ºF = Density @ 32ºF / Air Wt.

Sg @ 32ºF = .010758 / .011 = .978

Thus, the vapor density of Ethylene weighs .978 times lighter than air @ 32ºF.

Specific Gravity of a Liquid / Liquefied Gas

Specific Gravity (Sg) - **Mass of liquids & solids at a given temperature compared to the mass of an equal volume of water at the same temperature.**
Sometimes referred to as "relative density" !

Sg = 1 equals Water Wt. @ 60°F *or* **8.32828 lbs/gal** ~ §173.314(c) - note 1
Sg = .85 means that the product weight is 85% of the weight of water.
Sg = 1.25 means that the product wt. is 125% of the weight of water.

EX: **Sulfuric Acid weighs 15.33 lbs/gal @ 60º F**

Sg @ 60º F = Density @ 60º F / Water Wt.

Sg @ 60º F = 15.33 lbs/gal / 8.32828 lbs/gal = 1.8407

***Thus*, Sulfuric Acid is 1.8407 times heavier than water @ 60º F**

Is the following a possibility *(liquid or liquefied gas)* ?

Sg @ 60°F of product A = .5900

Sg @ 105°F of product A = .6100

Specific Gravity *vs.* Density

Density is the ratio of the mass of a substance to its volume (*i.e.*, lbs/gal, lbs./cu.ft., kg/m^3, g/cm^3, *etc.*). If the "Density" of a substance is known, then the "Specific Gravity" of the substance can be calculated & visa versa !

Specific Gravity = Density / Water Wt.

Density = Specific Gravity X Water Wt.

Weight of water @ 60ºF = 8.32828 lbs/gal

EX#1: **Given: Density of Anhydrous Ammonia @ 105ºF = 4.828 lbs/gal**
Determine its Specific Gravity at that temperature?

Sg @ 105ºF = 4.828 lbs/gal / 8.32828 lbs/gal = .5797

EX*#2*: Given: Specific Gravity of Sodium Hydroxide Solution (50%) @ 68ºF = 1.525 Determine its Density at that temperature?

Density @ 68ºF = 1.525 X 8.32828 lbs/gal = 12.70 lbs/gal

Specific Gravity *vs.* API Gravity

The American Petroleum Institute (API) utilizes a different scale to express specific gravities for liquids and gases.

Specific Gravity @ given temp = 141.5 / (131.5 + API Gravity @ given temp)

API Gravity @ given temp = (141.5 / Sg @ given temp) – 131.5

EX#1: **Given: Sg of Butane @ 60☜F = .5849** **Determine the API Gravity?**

API Gravity @ 60ºF = (141.5 / .5849) – 131.5 = 110.42

EX#2: **Given: Sg of Xylene @ 60☜F = .8710** **Determine the API Gravity?**

API Gravity @ 60ºF = (141.5 / .8710) – 131.5 = 30.96

Note: **The higher the API gravity, the lower the specific gravity !**

AMERICAN PETROLEUM INSTITUTE

Specific Gravity *vs.* ºBaume'

Baume' (ºBe') – Commonly used to measure the density of acids using calibrated hydrometer scales (2) for liquids that are heavier than water & lighter than water.

Baume' in degrees for liquids *heavier* than water:

ºBe' = 145 – (145 / Sg @ 60º F)

Sg @ 60º F = 145 / (145 - ºBe')

Baume' in degrees for liquids *lighter* than water:

ºBe = 146 / (Sg @ 60º F – 136)

Sg @ 60º F = 146 / (136 + ºBe')

°Baume' Hydrometers

Example:

Given: Sulfuric Acid *(80% solution)* **@ 60º F = 65.2 °Baume'**

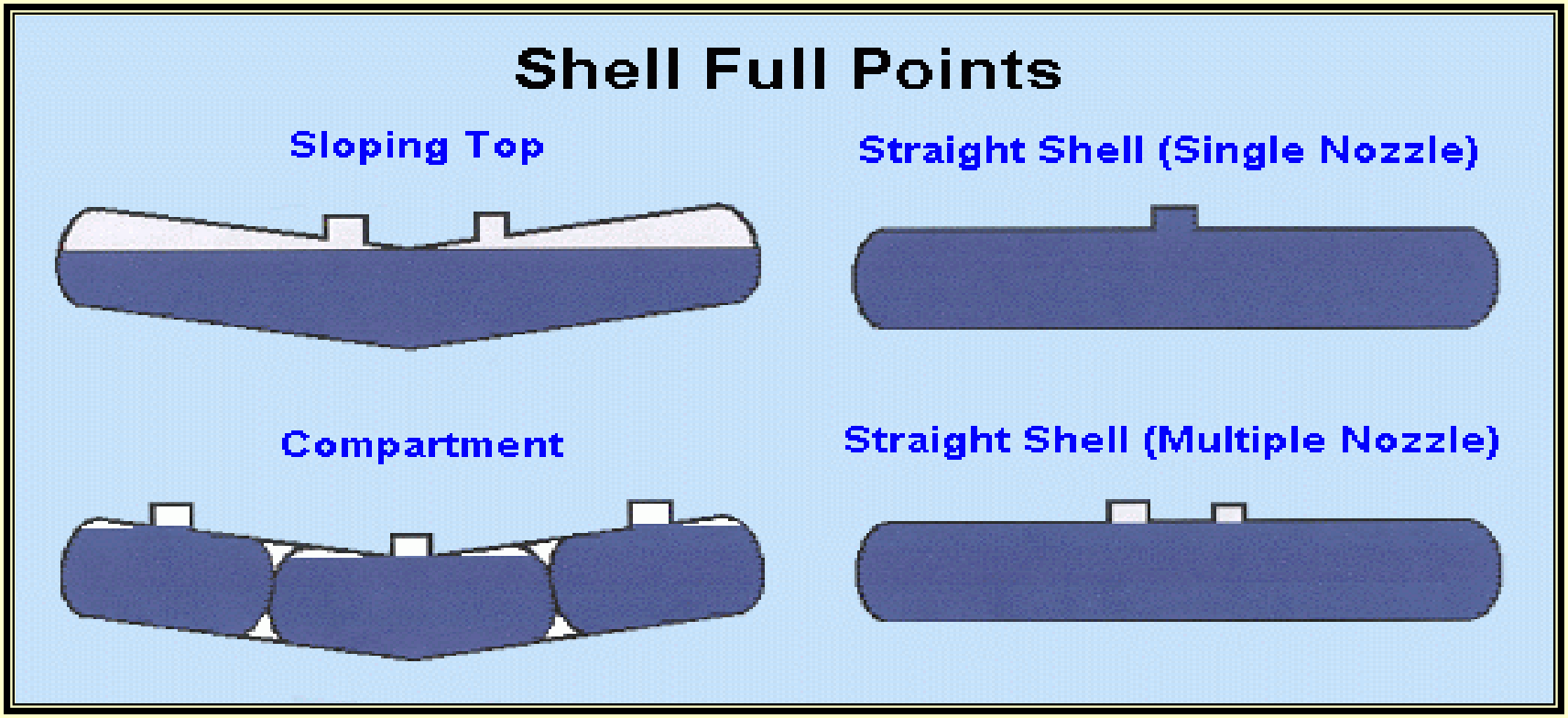
Since Sulfuric Acid is *heavier* than water:

Sg @ 60º F = 145 / (145 - ºBe') = 145 / (145 – 65.2) = 1.817

When is a tank considered to be "shell-full"?

“Shell – Full” Standard

“The liquid volume at the transition point at which air or vapor becomes entrapped in a location that is not in direct communication with all top fittings.” - ***Specifications for Tank Cars, M1002- Section C-III***

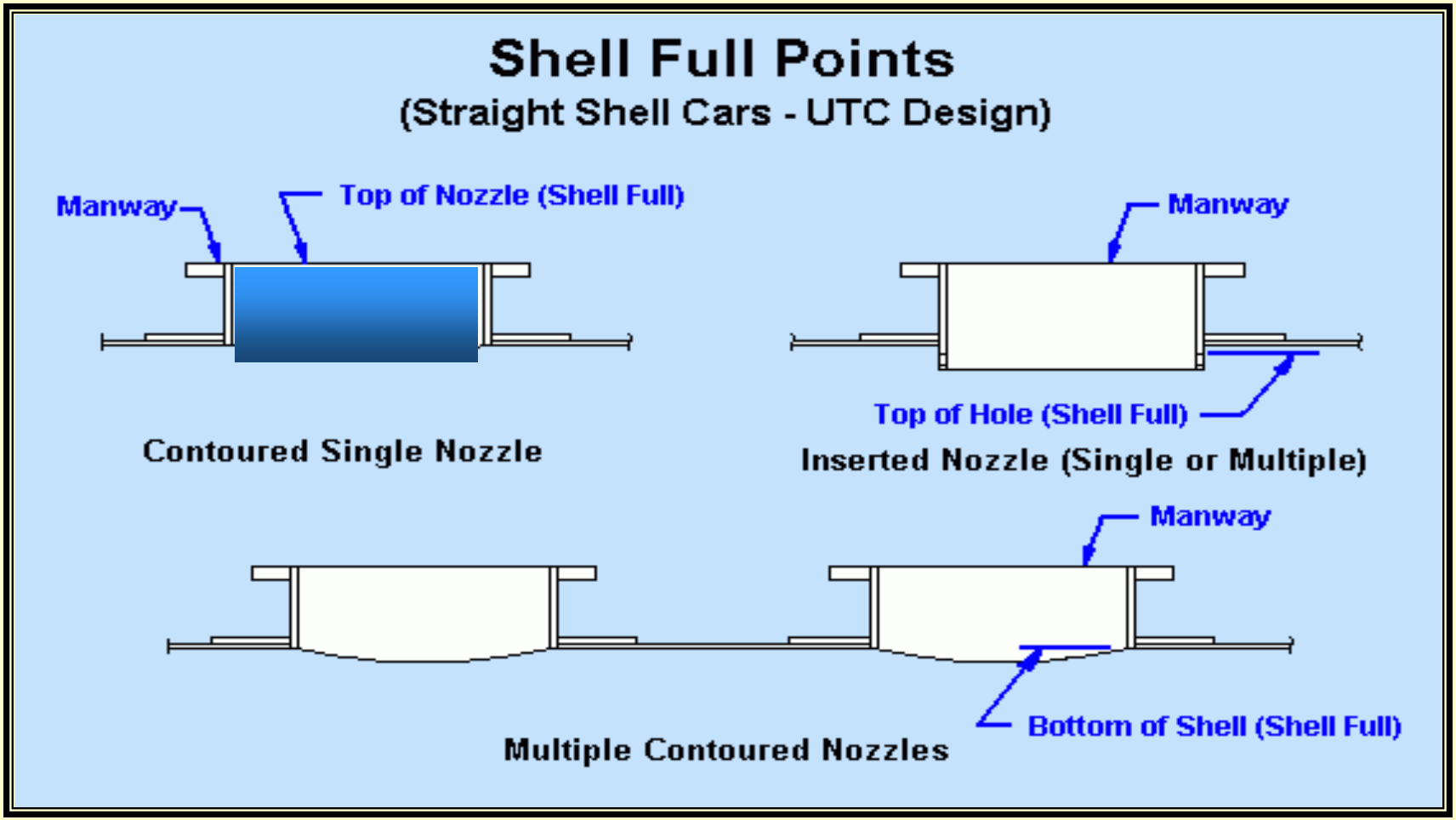


Gauging tables are assigned to certain tank cars, based on “estimated” tank designs if the shell capacity is within 0.1% of the shell-full capacity used in the design. ***- Spec. for T/C, M1002 – Section C-III***

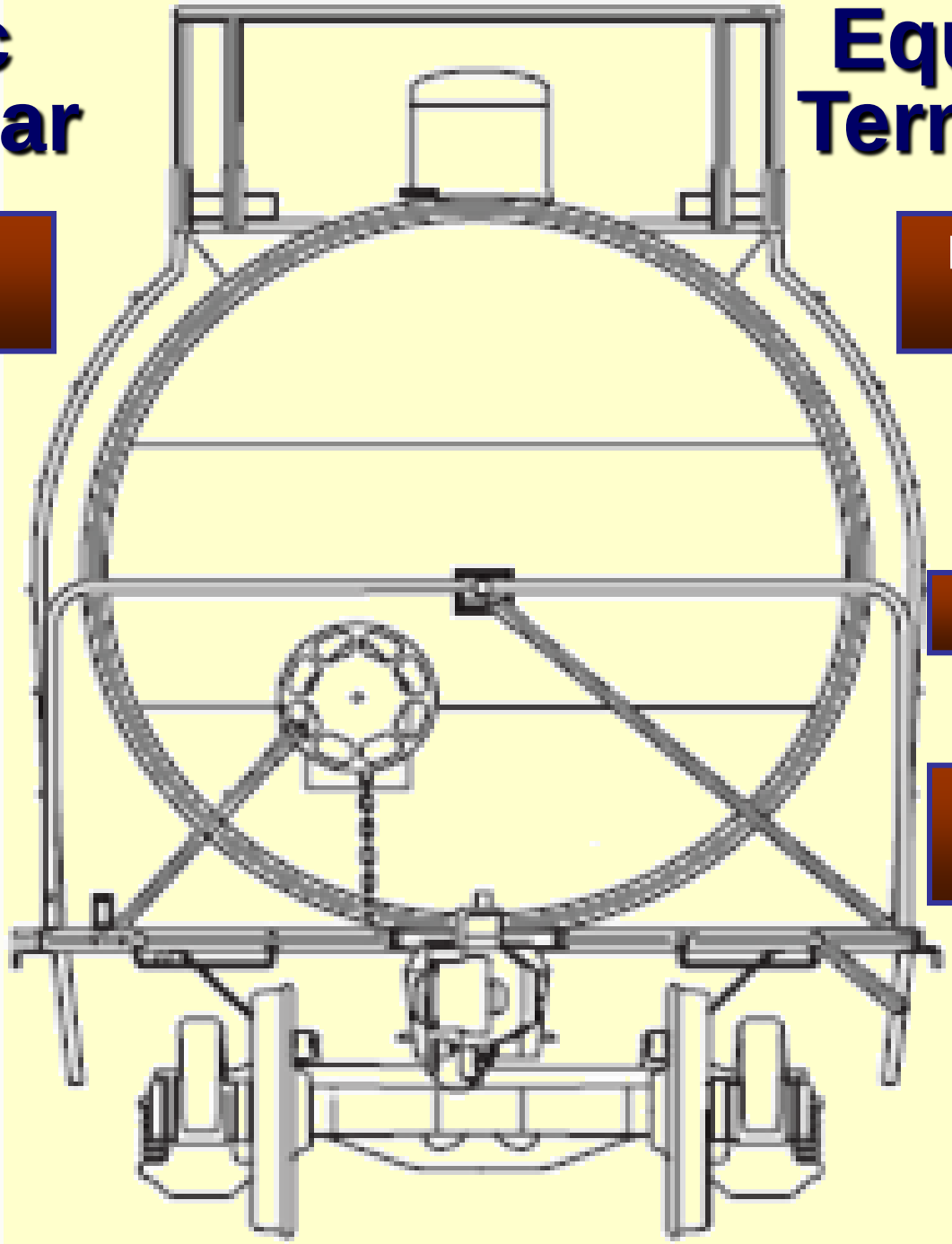
“Shell – Full” Standard

An Outage/Innage table shows the tank capacity for the liquid level measured at the reference gauge point downward from the shell-full (zero-outage) level. Capacities are rounded to the nearest 10 gals.

- Specifications for Tank Cars, M1002- Section C-III



Basic Tank Car Equipment Terminology



- Load Limit (LD LMT)
- Non-insulated Tank
- GWR
- Quasi-insulated Tank
- Insulated Tank
- UMLER
- Light Weight (LT WT)
- Journal Weight Limits
- Tare Weight

Load Limit (LD LMT)

Definition: **Difference between the total weight on rail for the journal size and the scale light weight *(tare weight)* of the car. Thus, it is the maximum permissible weight on the journal that can be loaded into the car!**

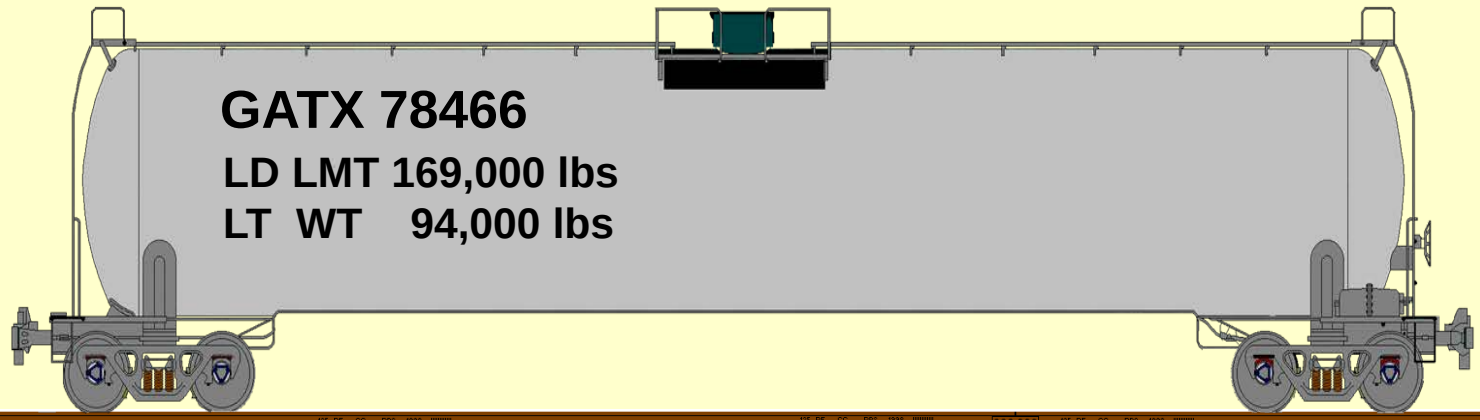
Example:

Journal size = 6 ½ " X 12"

Total wt. on rail for the journal : 263,000 lbs.

(less) **Light wt. *(* LT WT *)*** **- 94,000 lbs.**

Load Limit **169,000 lbs.**



Light Weight (LT WT)

- ✓ **AAR Field Manual, Rule 70 requires that the stenciled lightweight *(tare weight)* of a newly built tank car be within the nearest 100 lbs.**
- ✓ **Subsequent lightweighing is required if the weight is altered by 500 lbs.**

How can I locate scale tickets on cars weighed by the railroad?

Major Rail Carrier's Overload Desks

UP - *Omaha, NE* **(800) 243-0890** *option #1*

BNSF - *Topeka, KS* **(785) 676-4866** *or* **(888) 428-2673** *option #2*

CSXT - *Jacksonville, FL* **(904) 279-5546**

NS - *Atlanta, GA* **(404) 589-6697 / 6698** *After hours:* **(404) 589-6017**

KCS - *Kansas City* **(816) 983-1588**

CN - *Pontiac, MI* **(248) 740-6057** *or* *Chicago, IL* **(708) 332-6757**

CP - *Minneapolis, MN* **(612) 904-6073** *or* **(612) 904-6066**

ALS - *E. St. Louis, IL* **(618) 482-7708**

BNSF SCALE TICKET / WEIGHT TICKET
DATE WEIGHED August 30, 2009 TIME – 16.14
THE WEIGHTS * CAR WEIGHED CAR INIT GATX *
SHOWN HEREON HAVE * UNCOUPLED AT GALESBURG, IL NUMBER 6494*
BEEN ASCERTAINED *271000 GROSS * DRY … RAIN …SNOW …SLEET …
ONLY TO DETERMINE * 63000 TARE * DATE OF TARE …19 …TEMP.FIXTS ..
TO BE ASSESSED, * 208000 NET * GR. DOORS… REFUSE… ICE IN TANKS
AND THEIR USE IS * * RACKS … BLOCKING … DUNNAGE …
GOVERNED BY * * CAPACITY …..... LD LMT
PUBLISHED WEIGHING * SIGNATURE OF SWORN WEIGHMASTER

What do we need to know about insulation ?

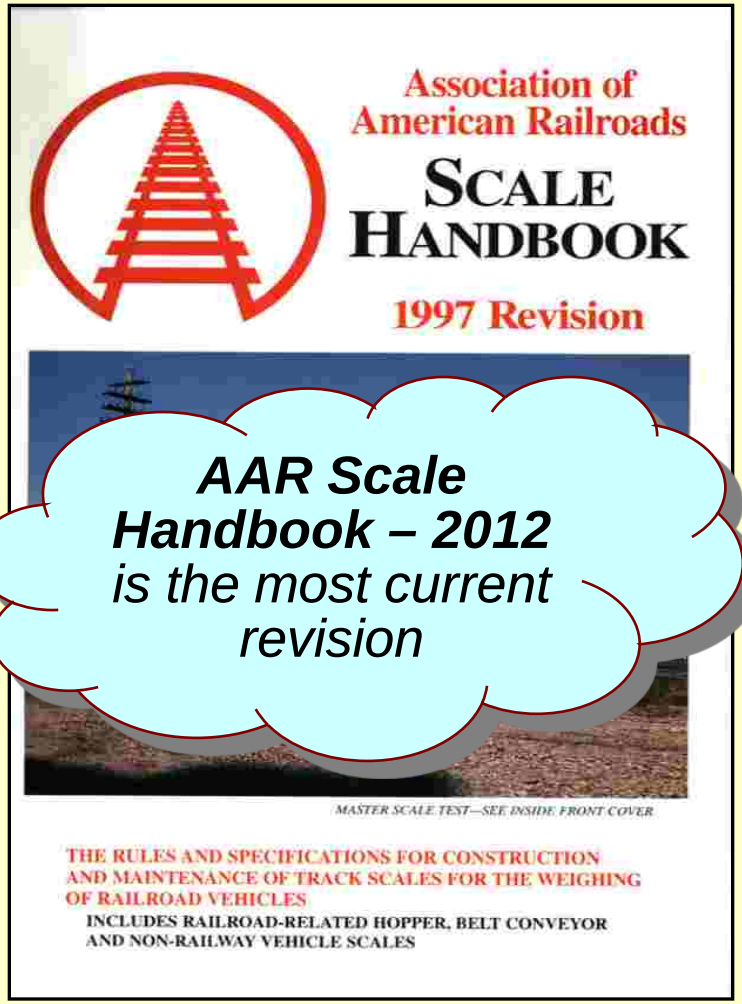
Insulated Tank Car Tank Standards

49 CFR References & Insulation Performance Standard

Tank Type (Insulation)	Tank Car Specification	49 CFR Reference	U-Value *CFR Reference*	R-Value *R=1/U*
Pressure (Full Insulation)	DOT 105 / DOT 120	179.101-1 179.100-4	.075	13.3
Pressure (Quasi-Insulated)	DOT 112J / DOT 114J	173.24b(a)(1)(ii)	.50	2.0
Non-Pressure (Insulated)	DOT 111A100W3 DOT 115 / AAR206W	179.201-1 179.200-4	.225	4.44
Non-Pressure (Insulated)	DOT 111A100W4	179.201-1 179.201.11	.075	13.3
Cryogenic liquid tanks (low pressure, generally < 25 psig)	DOT 113A60W / AAR204W DOT 113C120W	179.400-4 179.401.1	.097 .4121	10.31 2.43
Non-Pressure (Noninsulated) *Note: A few DOT 111 & AAR 211 cars may be insulated per 179.200-4*	DOT 103 / AAR 203W DOT 111A***W1,W2,W5,W6 *or* W7 AAR 211W / DOT 107 DOT 112 A,S *or* T / DOT114 A,S *or* T	179.201-1	*n/a*	*n/a*
Special Commodity Requirements	171.102 (Special Prov.): B26 (Phosphorus,etc), B61 (Hydrocyanic acid)			

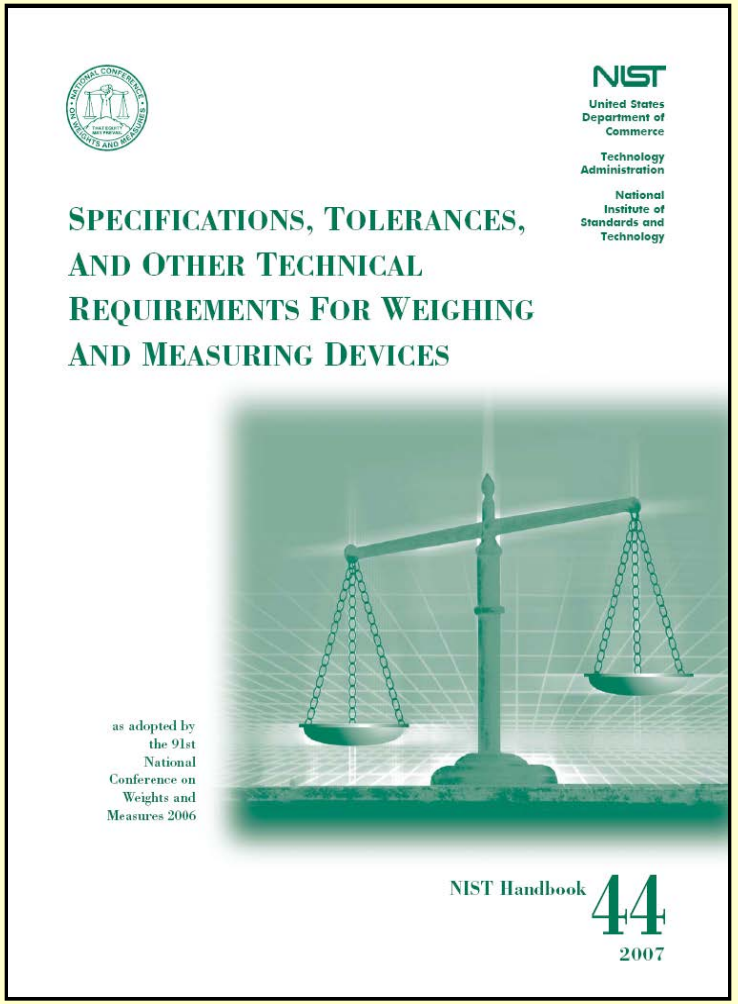
How accurate are R.R. track scales ?

Excerpt from BNSF Weighing Book 9300-A, Item 500 (Rules for Weighing Loaded Cars) –
"**Scales used for determining weights for the assessment of freight charges or for determining actual tare weight of freight cars shall be maintained, tested and operated in accordance with NIST Handbook 44 and AAR Scale Handbook**".



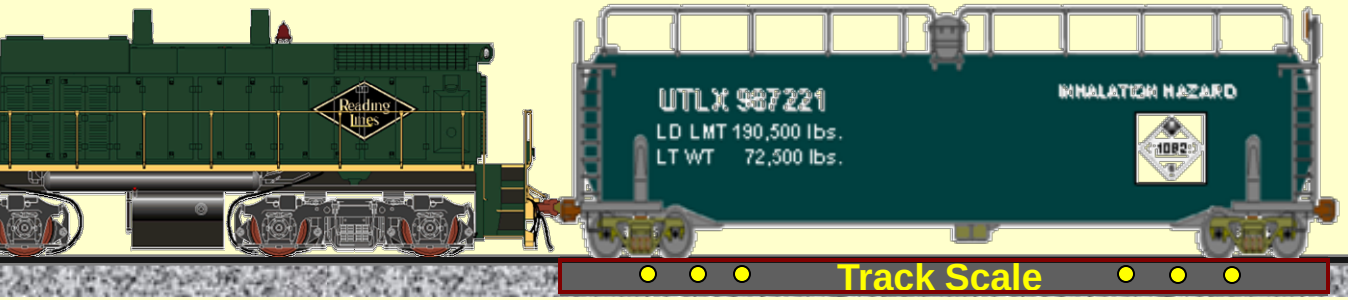
AAR Scale Handbook – 2012 *is the most current revision*

Association of American Railroads



National Institute of Standards & Technology

Track Scale Weight Tolerances



How precise does it have to be ?

Most railroad track scales are calibrated to be within .2 of 1% (*i.e.*, 2 lbs per 1000) for an uncoupled rail car, thus a tank car with a gross weight of 263,000 lbs would be "in tolerance" within + or – 526 lbs. For a coupled-in-motion weight, the tolerance is .6 of 1% (*i.e.*, 6 lbs per 1000), thus a 263,000 lb. tank car would be "in tolerance" within + or - 1,578 lbs.

Note: Most R.R. track scales are set on either 50 lb. or 100 lb. increments.

***Relative to FRA Movement Approvals*, is there a tolerance provided on track scale weights for the movement of overloaded tank car shipments?**

FRA's policy on HM tank cars that exceed the allowed Gross Weight on Rail *(GWR)*

United States Department of Transportation
Federal Railroad Administration

Dangerous Goods / Hazardous Materials Program
Office of Safety Assurance and Compliance
1120 Vermont Avenue, Mail Stop 25
Washington, D.C. 20590

File: ADM 08-2001

June 16, 2001

Colleagues:

At the March 2001 Bureau of Explosives Steering Committee Meeting in Jacksonville, Florida. I discussed FRA's policy with respect to the total allowable weight on rail of tank cars containing a hazardous material. Currently, FRA allows only a 1000-pound tolerance on the actual scale weight. The Association of American Railroad's Scale Handbook and AAR Field Manual Rule 91, relative to weigh-in-motion scales (both coupled and uncoupled-in-motion scales), allows a 1% tolerance.

Based on the AAR allowable tolerance, I am changing the Federal Railroad Administration's (FRA) Movement Approval Policy. Effective today, FRA no longer requires movement approval for any tank car that is 1% or less of the allowable total weight on rail, rounded up to the next 100 pounds, on weigh-in-motion scales. For static scales, the current policy of a 1000-pound tolerance still applies. This policy is necessary since there is no degree of certainty that any tank car measured on a scale within the AAR allowable scale tolerance for accuracy is in fact over weight.

This change also modifies FRA Memorandum HM-99-01, *"FRA Movement Approvals,"* page 4, and my earlier e-mail dated 5/25/01 concerning "FRA Policy on Tank Cars That Exceed the Allowed GWR."

If you have any questions, please contact me.

James H. Rader
Director, Hazardous Material Program

Weigh(t) Agreements

✓ The **shipper** has the option to make a **weigh agreement** with the carrier, that will allow the shipper to provide weights from their own **certified scales** or from **estimated weights** based on calculations. ~ ICC Uniform Freight Classification 6000-J, Rule 35

Do Not Weigh

✓ The **shipper** has the right to weigh a car prior to loading to ascertain the lightweight *(tare)* & use the tare wt. in lieu of the marked tare. ~ ICC Tariff SWFB 9426-E Item 230

✓ The **carrier** has the right to verify calculated weights on compressed gases in tank cars by weighing cars on their own scales. ~ § 173.314 (e)


Carrier's
Requirements
8702
8702
in handling
Overloaded Shipments

How can the railroad handle overloaded hazmat shipments?

1. **Must NOT accept for transportation a shipment that is known to be overloaded *!*** *~ §174.3*
2. **Utilize the FRA's track scale tolerance without securing an FRA Movement Approval:**
   - ✓ **1,000 lbs for static track scales**
   - ✓ **1% for weigh-in-motion scales**
     - applies to both coupled & uncoupled
3. **Obtain** *(or have the shipper obtain)* **an FRA Movement Approval from the Associate Administrator for Railroad Safety, FRA, Wash. D.C.** *~ §174.50*
4. **Arrange for the safe transfer of the product overage before continuing the shipment in transportation.**
5. **Work with their customers to reduce overloads !**

Shipper's Responsibilities

for handling overloaded shipments during transportation

Shipper's Options for handling overloaded shipments during transportation

1. **Arrange** *(with the carrier)* **for the safe transfer of the product overage before continuing the shipment in transportation.**
2. **Obtain an FRA Movement Approval from the Associate Administrator of Railroad Safety, FRA.**

FRA Movement Approvals

Emergency Telephone: *(24 hrs/day)*

National Response Center, Washington, D.C.

(800) 424-8802 or (202) 267-2675

FRA Website Address:

FRA Home Page - www.fra.dot.gov

FRA Hazmat Approval Information & Form –

www.fra.dot.gov/o/safety/hazmat/apprfax.htm

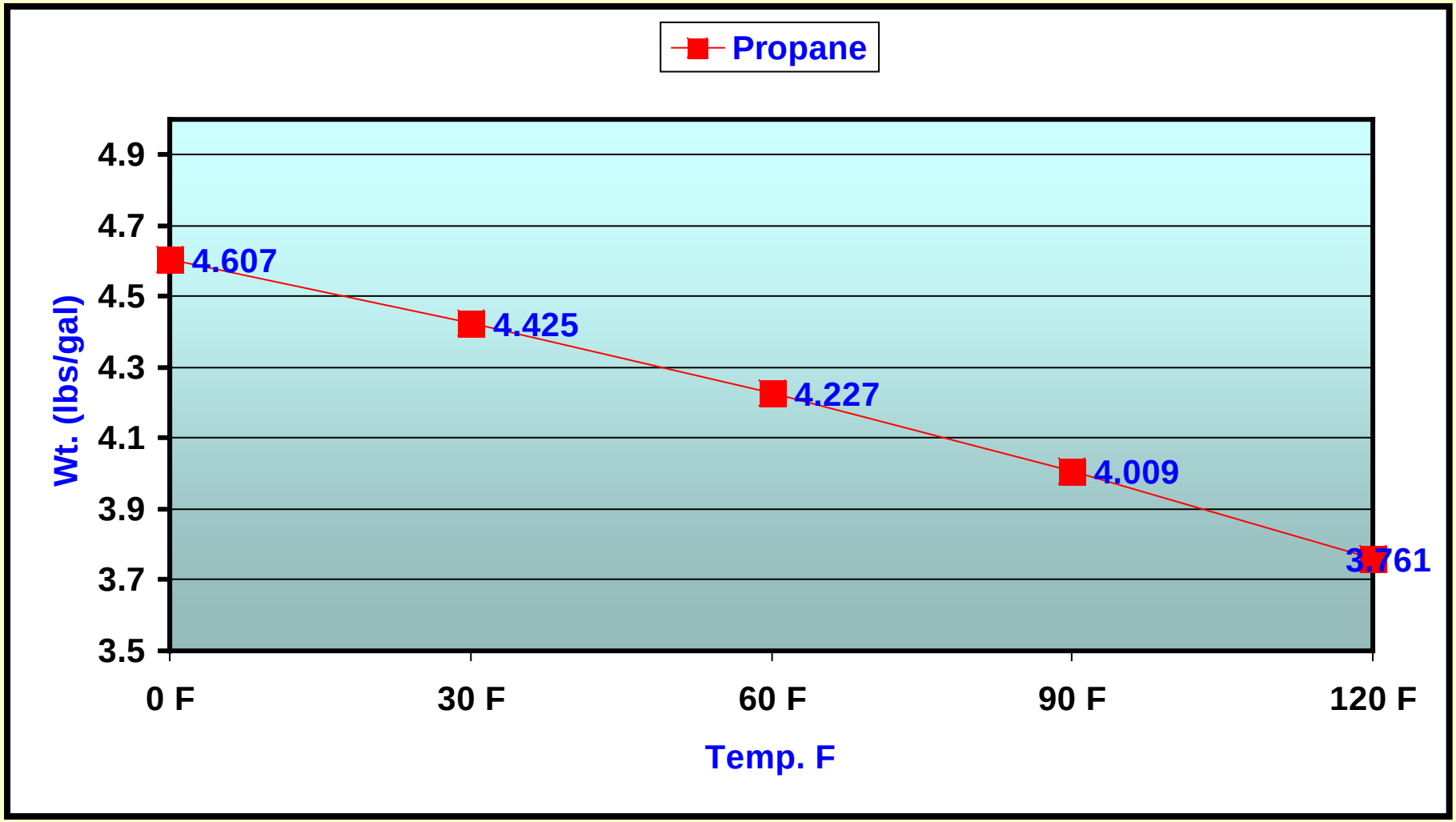
FRA Mailing Address *(hazmat)*:

Federal Railroad Administration
RRS-25 Mail Stop 25
1200 New Jersey Ave., SE
Washington, D.C. 20590

A leaking bulk package containing hazmat may be moved without repair or approval "only so far as necessary to reduce or to eliminate an immediate threat of harm to human health or the environment, when it is determined its movement would provide greater safety than allowing the package to remain in place". In the case of a liquid leak, measures must be taken to prevent the spread of the liquid. ***~ §174.50***

Using Coefficient of Cubical Expansion Method

Density *vs.* Temperature – linear relationship



Since the relationship between a chemical's density & its temperature is generally linear & somewhat predicable, it formulates the basis for Coefficients of Cubical Expansion. Not suitable for all products !

Coefficient of Cubical Expansion of some common liquids

Chemical Name	Coefficient per ☜F	Coefficient per ☜C
Acetone	.00085	.00153
Alcohol (Ethyl)	.00062	.00112
Alcohol (Methyl)	.00072	.00130
Benzene	.00071	.00128
Bromine	.00063	.00110
Calcium Chloride *(50%)*	.00028	.00054
Ethylene Oxide	.00088	.00161
Gasoline	.00080	.00144
Pentane	.00093	.00168
Sulfuric Acid *(50%)*	.00045	.00081
Sulfuric Acid *(96%)*	.00053	.00095
Toluene	.00063	.00113
Vinyl Acetate		.00137
Water	.00012	.00022

Measuring Cubical Expansion

Coefficient of cubical expansion of a liquid – is the ratio of change in volume per degree rise in temperature.

EX: **20,000 gallons of Ethylene Oxide in a container @ 45ºF**

Coefficient of Cubical Expansion factor of EO = .00088 per ºF

Thus, if the temperature of EO is increased from 45ºF to **115ºF** *(a 70º rise),* **the volume capacity will increase by a factor = .00088 per ºF**

20,000 gals *X* **.00088 = 17.6 gals per ºF** *X* **70 ºF =** **1,232 gallons expansion**

20,000 gals + 1,232 gals = **21,232 gallons**

Thus, 20,000 gals. of EO will expand to 21,232 gals with an increase of 70ºF !

LPG & Anhydrous Ammonia Summer / Winter Schedules

Summer/Winter Schedule for Liquefied Petroleum Gases & Anhydrous Ammonia

§ 173.314 (c) Authorized gases, filling limits for tank cars

Note 10: **Permits Liquefied Petroleum Gases & Anhydrous Ammonia to be loaded during the winter months** *(Nov. thru March)* **with the following reference temperatures:**

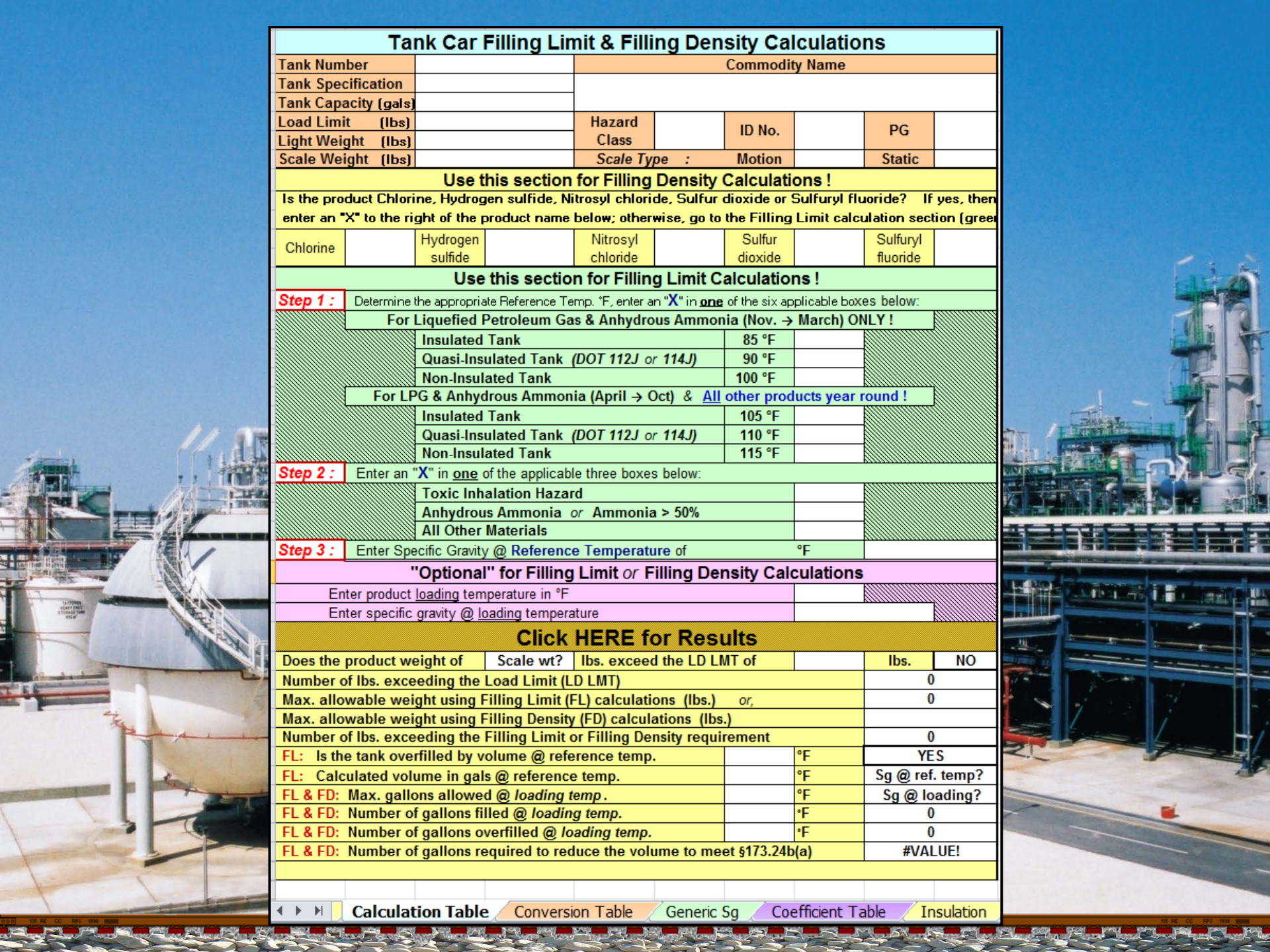
(i) **38°C (100°F) for a noninsulated tank,**

(ii) **32°C (90°F) for a tank car having a thermal protection system, incorporating a metal jacket that provides an overall thermal conductance at 15.5°C (60°F) of no more than 0.5 Btu per hour/per square foot/per degree F) temperature differential; or**

(iii) **29°C (85°F) for an insulated tank**

There are six gases that meet the definition of LPG & carry Special Provision #19:

Butane	**Isobutane**
Butylene	**Isobutylene**
Propane	**Propylene**



Tank Car Filling Limit & Filling Density Calculations

Tank Number		Commodity Name					
Tank Specification							
Tank Capacity (gals)							
Load Limit (lbs)		Hazard Class		ID No.		PG	
Light Weight (lbs)							
Scale Weight (lbs)		*Scale Type :*		Motion		Static	

Use this section for Filling Density Calculations !

Is the product Chlorine, Hydrogen sulfide, Nitrosyl chloride, Sulfur dioxide or Sulfuryl fluoride? If yes, then enter an "X" to the right of the product name below; otherwise, go to the Filling Limit calculation section (green

Chlorine		Hydrogen sulfide		Nitrosyl chloride		Sulfur dioxide		Sulfuryl fluoride	

Use this section for Filling Limit Calculations !

Step 1 : Determine the appropriate Reference Temp. °F, enter an "X" in **one** of the six applicable boxes below:

For Liquefied Petroleum Gas & Anhydrous Ammonia (Nov. → March) ONLY !		
Insulated Tank	85 °F	
Quasi-Insulated Tank *(DOT 112J or 114J)*	90 °F	
Non-Insulated Tank	100 °F	
For LPG & Anhydrous Ammonia (April → Oct) & All other products year round !		
Insulated Tank	105 °F	
Quasi-Insulated Tank *(DOT 112J or 114J)*	110 °F	
Non-Insulated Tank	115 °F	

Step 2 : Enter an "X" in one of the applicable three boxes below:

Toxic Inhalation Hazard	
Anhydrous Ammonia *or* Ammonia > 50%	
All Other Materials	

Step 3 : Enter Specific Gravity @ Reference Temperature of °F

"Optional" for Filling Limit *or* Filling Density Calculations

Enter product loading temperature in °F	
Enter specific gravity @ loading temperature	

Click HERE for Results

Does the product weight of	Scale wt?	lbs. exceed the LD LMT of		lbs.	NO
Number of lbs. exceeding the Load Limit (LD LMT)				0	
Max. allowable weight using Filling Limit (FL) calculations (lbs.) *or,*				0	
Max. allowable weight using Filling Density (FD) calculations (lbs.)					
Number of lbs. exceeding the Filling Limit or Filling Density requirement				0	
FL: Is the tank overfilled by volume @ reference temp.			°F	YES	
FL: Calculated volume in gals @ reference temp.			°F	Sg @ ref. temp?	
FL & FD: Max. gallons allowed @ *loading temp*.			°F	Sg @ loading?	
FL & FD: Number of gallons filled @ *loading temp.*			°F	0	
FL & FD: Number of gallons overfilled @ *loading temp.*			°F	0	
FL & FD: Number of gallons required to reduce the volume to meet §173.24b(a)				#VALUE!	

Calculation Table | Conversion Table | Generic Sg | Coefficient Table | Insulation

Calculating Filling Limit Requirements

Basic Formulas used for Calculating Filling Limits & Filling Densities

Filling Limit & Filling Density Formulas

Explanation of Symbols:

TC	Tank capacity in U.S. Gallons	**Sg**	Specific Gravity of a liquid @ given temp.
Fd	Max. permitted filling density expressed in %	**Wt**	Max. allowable weight of the product
d	Density of a product @ given temp.	**°Be'**	Baume' degrees for liquids
g	Max. filling limit in gals @ given temp.	**API Gravity**	American Petroleum Institute gravity
i	Tank innage, expressed in percent	**Water**	Weight of water @ 60°F= 8.32828 lbs/gal *or* 62.43 lbs/cu.ft.

Maximum allowable weight of the product:

Wt = TC (i) (Sg @ *reference temp*) (Water)
Wt = TC (i) (d @ *reference temp*)
Wt = TC (Fd) (Water)

Wt = g (Sg) (Water)
Wt = g (d)

Specific Gravity of a liquid @ given temperature:

Sg = d @ *same temp* / Water

$$Sg = \frac{141.5}{131.5 + \text{API Gravity}}$$

$$Sg\ @\ 60°F = \frac{145}{145 - °Be'}$$ for liquids ***heavier*** than water

$$Sg\ @\ 60°F = \frac{146}{136 + °Be'}$$ for liquids ***lighter*** than water

American Petroleum Institute Gravity @ given temperature:

API Gravity = (141.5 / Sg) - 131.5

Density of a product @ given temperature:

d @ *given temperature* = Sg @ the *same temp* (Water)

Maximum filling limit in gallons @ given temperature:

g @ given temp = Wt / Sg @ *same temp* (Water)

$$g\ @\ \text{given temp} = \frac{TC\ (Fd)}{Sg\ @\ \textit{same temp}}$$

g @ given temp = Wt / d @ *same temp*

Maximum allowable innage expressed in percent :

I = .95 for PIH; .98 for Anhydrous Ammonia *or* Ammonia solutions > 50%; *and* .99 for all other materials

Baume' in degrees for liquids *heavier* than water:

°Be' = 145 - (145 / Sg @ 60°F)

Baume' in degrees for liquids *lighter* than water:

°Be' = (146 / Sg @ 60°F) - 136

Coefficient of cubical expansion of liquids:

$$\beta = \frac{i}{1 + [a\ (t_1 - t_2)]}$$

g = TC (β)

β = Max. allowable filling limit in % @ temp t
a = Coefficient of cubical expansion per degree temperature
i = Tank innage in percent
t_1 = Reference temperature
t_2 = Actual product temperature of the liquid in the tank

Basic Formulas for Determining Filling Limits

Explanation of Symbols	
Wt	**Max. allowable weight of the product**
TC	**Tank capacity in US gallons**
i	**Tank innage, expressed in % (.95 for PIH, .98 for Anhydrous Ammonia & Ammonia solutions>50% & .99 for all other materials**
Sg	**Specific Gravity of the product @ a given temperature**
g	**Max. allowable gallons @ a given temperature**
Water	**Weight of water @ 60°F = 8.32828 lbs/gal** *or* **62.43 lbs/cu.ft.**

Wt = TC (i) (Sg @ reference temp) (Water)

g @ given temp = Wt / Sg @ same temp (Water)

Collect data on the following:	
Tank Car Specification	**Insulated** *or* **Non-insulated tank**
Capacity in US Gallons	**Scale weight** *(if available)*
Load Limit in lbs (LD LMT)	**Specific Gravity @ reference temp**
Light Weight in lbs (LT WT)	**Specific Gravity @ loading temp**

Ethylene Oxide Filling Limit Example

DOT 105J300W	Insulated Tank	Ethylene Oxide, 2.3 (PIH material), UN1040
LD LMT=177,100 lbs	Scale Wt = 254,000 lbs	
LT WT = 85,900 lbs	Loading temp = 55°F	Sg@ 55°F = .88265
Capy = 24,898 gals	Reference temp=105°F	Sg@ 105°F =.84255

Wt = TC (i) (Sg@ reference temp) (Water)

Wt = 24,898 gals (.95) (.84255) (8.32828 lbs/gal) = 165,974 lbs

Product weight = Scale weight – Light weight

Product weight = 254,000 lbs – 85,900 lbs = 168,100 lbs

Overage = Product weight – Max. allowable Wt

Overage = 168,100 – 165,974 = 2,126 lbs overloaded

Overage in gals @ loading = Overage in lbs / Sg@ loading (Water)

Overage in gals@ loading = 2,126 / .88265 (8.32828) = 289 gals

Propane Shipment Example

DOT 112J340W	Quasi-Insulated Tank	Propane (Loaded in May)
LD LMT=152,000 lbs	Scale Wt = 250,100 lbs	
LT WT = 111,000 lbs	Loading temp = 60°F	Sg @ 60°F = .5076
Capy = 33,514 gals	Reference temp = 110°F	Sg @ 110°F = .4620

Wt = TC (i) (Sg @ reference temp) (Water)

Wt = 33,514 gals (.99) (.4620) (8.32828 lbs/gal) = 127,661 lbs

Product weight = Scale weight – Light weight

Product weight = 250,100 lbs – 111,000 lbs = 139,100 lbs

Overage = Product weight – Max. allowable Wt

Overage = 139,100 – 127,661 = 11,439 lbs overloaded

g @ loading temp of 60°F = Wt / Sg @ same temp (Water)

g @ loading temp of 60°F = 127,661 /.5076 (8.32828) = 30,198 gals

Overage in gals @ loading = Overage in lbs / Sg @ loading (Water)

Overage in gals @ loading = 11,439/ .5076 (8.32828) = 2,706 gals

Calculating Filling Density Requirements

Filling Density Example

Filling Density Formula: Wt = TC (Fd) (Water)

"Fd" represents the Max. permitted filling density expressed in % found in CFR 173.314 (c)……. [Chlorine = 1.25]

*** Note: Filling Density standards do NOT involve reference temperatures!**

DOT105A500W	Chlorine, 2.3, UN 1017	Scale wt = 262,900 lbs
LD LMT = 180,000 lbs	LT WT = 81,300 lbs	Loading temp = 20°F
Capy = 17,386 gals	Sg @ loading temp 20°F = 1.4904	

Wt = TC (Fd) (Water) = 17,386 (1.25) (8.32828) = 180,994 (However, the Load Limit restricts the weight to 180,000, so Wt = 180,000 lbs

Product wt = Scale wt – LT WT = 262,900 – 81,300 = 181,600 lbs

Overage = Product wt – Max. allowable wt = 181,600 – 180,000 = 1,600 lbs

g @ loading temp= Wt/ Sg@ 20°F (Water) = 180,000 / 1.4904 (8.32828) = 14,502 gals

Overage in gal @ loading = Overage in lbs / Sg @ 20°F (Water) = 1600 lbs / 1.4904 (8.32828) = 129 gallons

I’m posed for questions !