CLAS Safety Seminar 2015

Saturday, March 28, 2015

Propane

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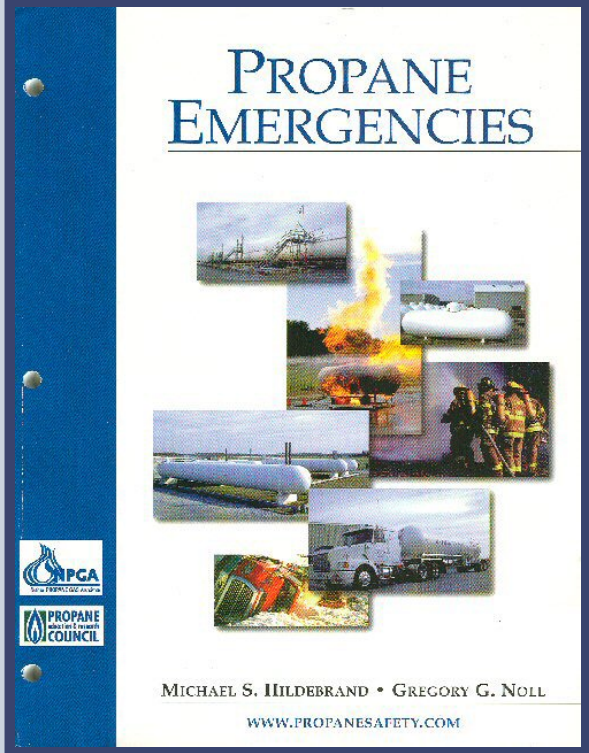
CLAS 2015 Safety Seminar
March 28, 2015

Source Materials



- Propane Emergencies
  - Hildebrand & Noll
  - NPGA, PE&RC, Publisher
  - www.propanesafety.com
- Introduction to Chemical Engrg. Thermodynamics
  - Smith & Van Ness
  - McGraw-Hill, Publisher
- www.propane101.com

Outline

- Common misconceptions about propane
- Explanations and background for each
- Promise – no equations!
- “Tour” of propane physical properties
- Implications for safety in ballooning
- ***Quiz – must pass for BFA credit***
- Jokes – warning…may be lame

What the talk is *not* about

- Regulations
  - ANSI, NFPA, ASME
  - DOL (OSHA), DOT
  - Will mention informally
- In-flight issues, accidents
  - But, just to maintain focus…

What the talk* is *REALLY* about

- What is risk?
  - Risk = Uncertainty × Exposure
    - Uncertainty: what I *can sometimes* influence
    - Exposure: what I *can always* influence - choice
- Safety is the opposite of risk
  - Safety = 1 – Risk
  - Safety = 1 - Uncertainty × Exposure

** and most of the others today*

“Game Show”

- Some questions and answers about propane…

Question #1

True or False:

- Propane C_3H_8 is what's in my tank
  - FALSE!
  - Commercial "propane" or LPG (liquefied petroleum gases) is a mixture of **propane**, C_3H_8 and **propylene**, C_3H_6
  - In warmer climates, it may also contain **butane**, C_4H_{10} (more about temperature later…)

Question #2

True or False:

- Propane is both liquid and gas in my tank
  - TRUE!
  - You can't burn liquid propane directly, only vapor ("gas")
  - What would it look like inside your tank if it were glass?

Question #3

True or False:

- Propane has a nasty smell
  - FALSE!
  - Actually, propane is colorless and has a mild, “sweetish” odor
  - Regulations demand an odor/stench agent, ethyl mercaptan

Question #4

True or False:

- Propane is cold
  - FALSE!
  - What is the temperature of propane in the tank?
  - When we see propane escape, or touch it (ouch!), it certainly *seems* cold
  - The substance that forms on surfaces when propane escapes is not propane, but ICE

Question #5

True or False:

- My 10 gal tank has a volume of 10 gal
  - FALSE!
  - A 10gal tank has a volume of about 12.5gal
  - A 20% head space is to allow liquid expansion
  - Tanks are typically labeled with the weight of water they can hold, so a 10 gal propane tank would be labeled 100 lb!

Question #6

- Why propane C_3H_8?
  - Why not methane CH_4? Ethane C_2H_6? Butane C_4H_{10}?
  - Methane is supercritical at ambient T, *i.e.*, always a gas. Energy density too low
  - Ethane is subcritical but needs lots of pressurization. Would need regulator on tank
  - Butane works in hot climates, not enough *vapor pressure* in colder weather

Physical properties of propane

- Colorless, almost odorless (before stench agent added)
- Liquid under modest pressure (5-10 atm)
  - density ~4.2 lb/gal, about half that of water
  - a full 10 gal Al tank should float in water!
- Vapor at ambient T & P
  - density ~ 1/270 of liquid at room temperature
  - heavier than air (44 *vs.* 29) – “pools” near ground

Hazards

See MSDS in online handout materials

http://www.unitoops.com/clas2015.htm

- Inhalation – awareness!
  - Low conc: dizziness, headache, nausea, lack of coordination
  - High conc: asphyxiaton (without awareness)
- Fire & explosion – prevention!
- Contact – protection!

Handling propane

- Refueling
  - Always wear gloves (freeze burns)
  - Ignition risk (static, synthetic fabrics)
- Sniff and listen
- 4 of the 5 senses can be on alert
- Watch out for distractions
  - Overfilling hazard

Boiling water in a pot

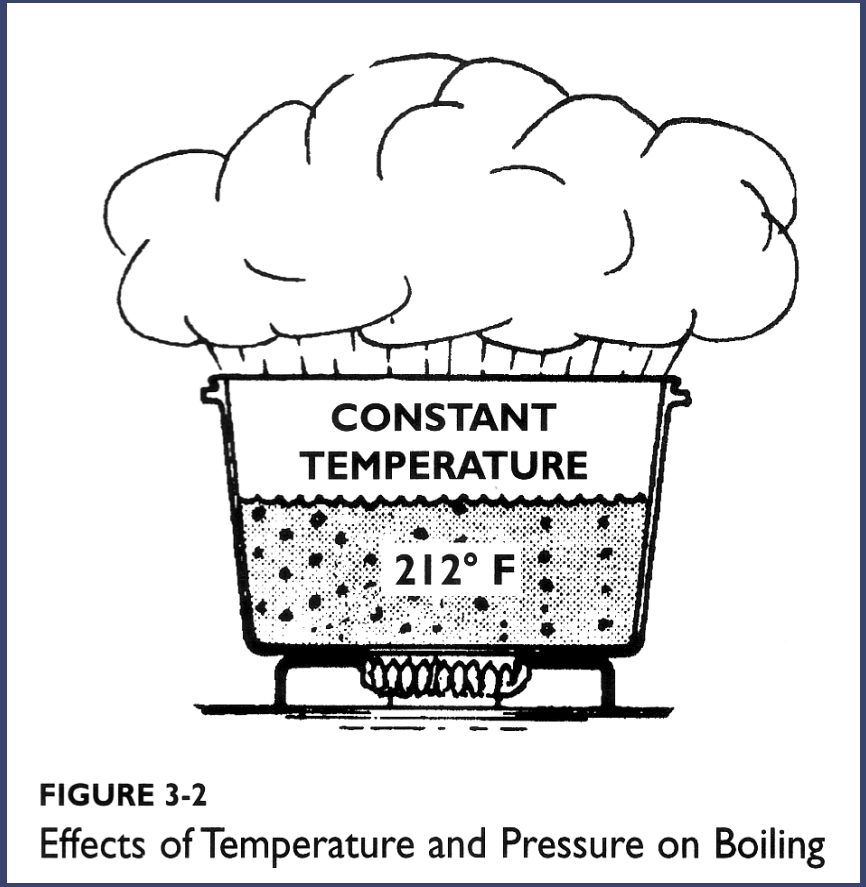


FIGURE 3-2
Effects of Temperature and Pressure on Boiling

- Boils at 212 F at sea level
- At less than 212 F if we're higher up

  (you can't get a decent cup of tea in Colorado!)
- Temperature stays the same until all water is gone
- Applying heat, but not getting "hotter" – *latent heat*
- Where we "live," water likes to be a liquid

Propane in open container

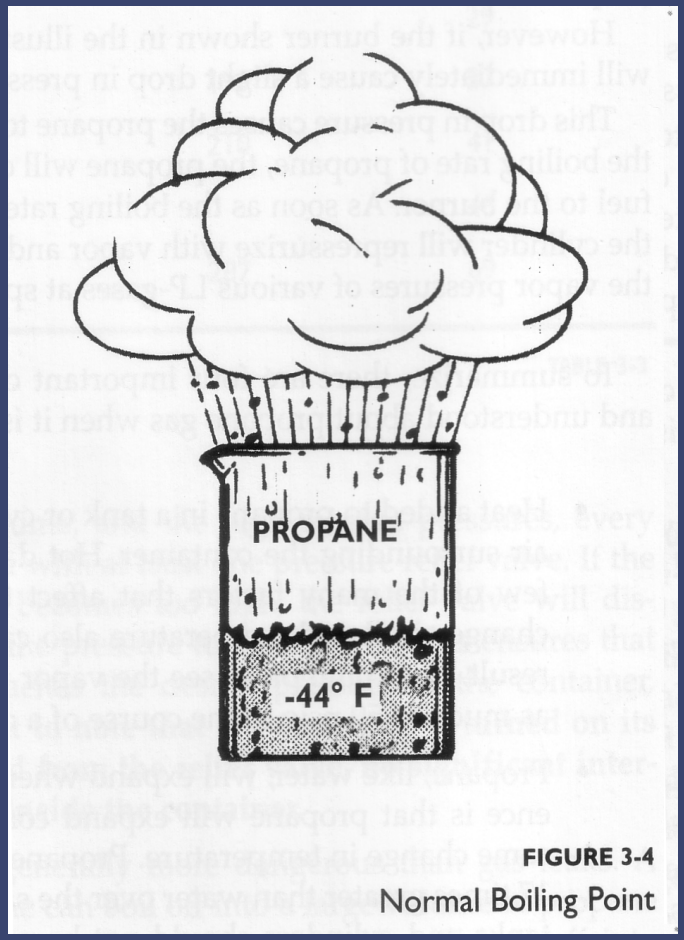
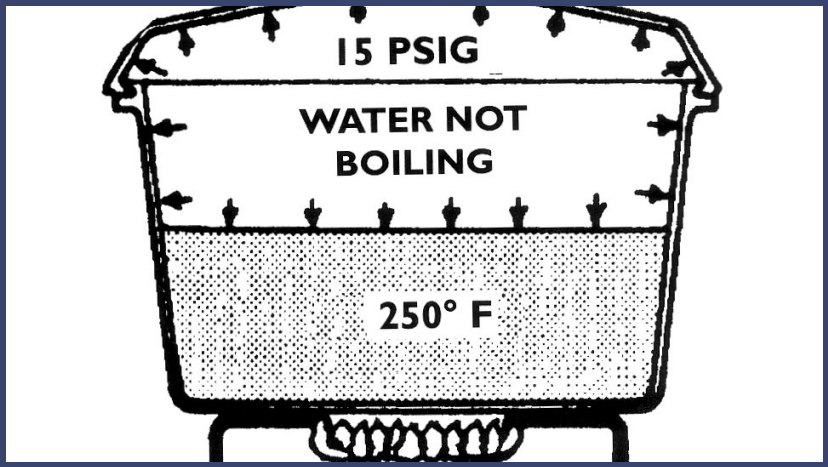


FIGURE 3-4
Normal Boiling Point

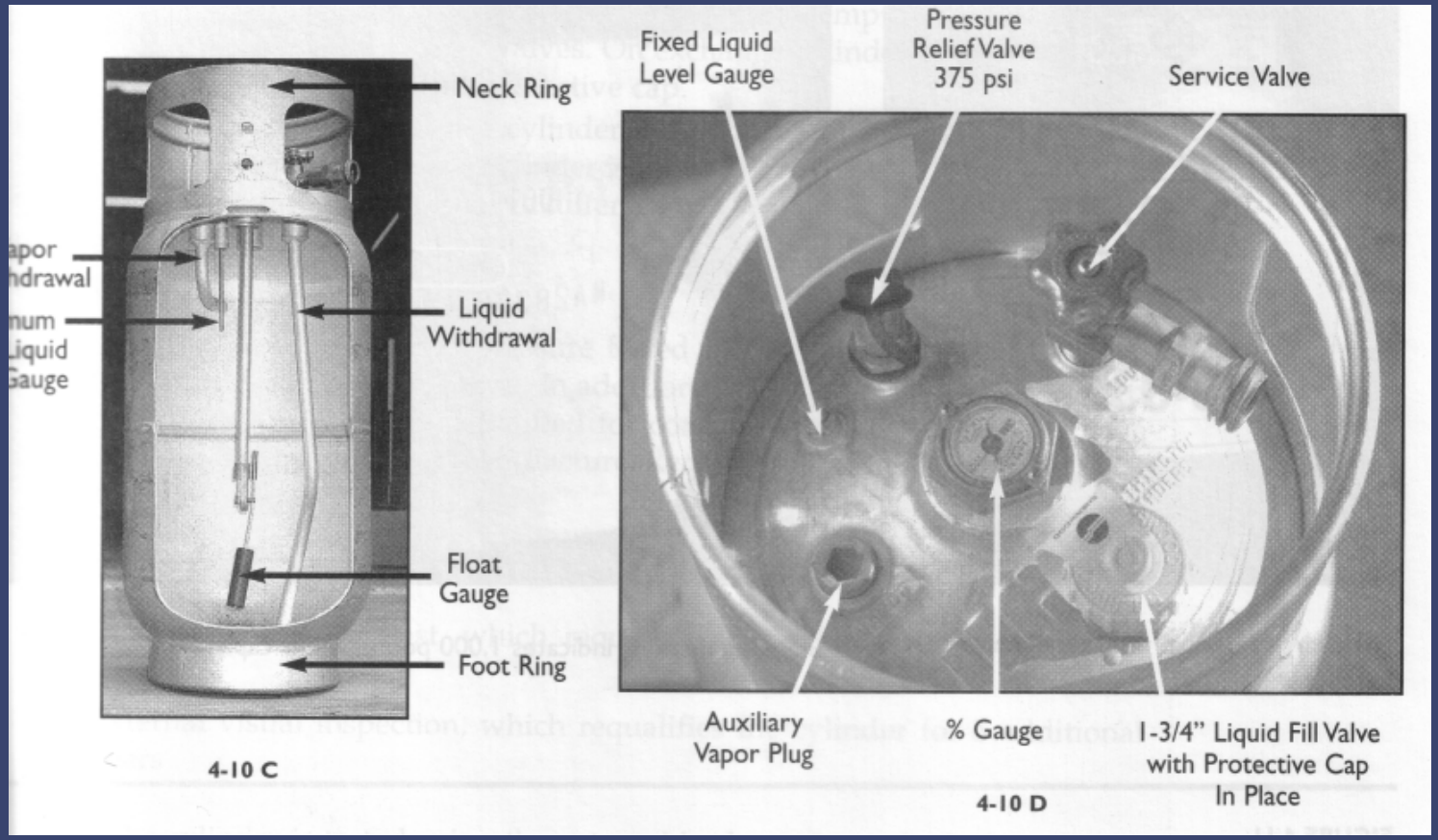
- Boils at -44 F at sea level
- Temperature stays the same until all propane is gone
- That happens *very quickly!!*
- Where we live, propane likes to be a gas

Heating water under pressure



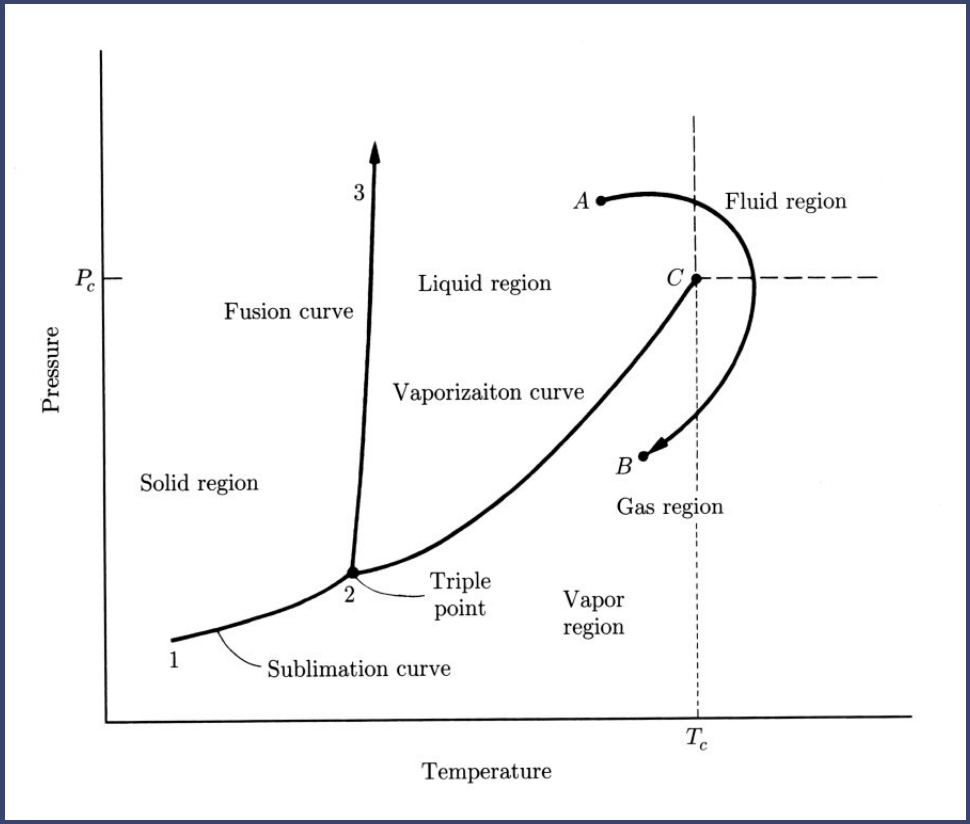
- Higher pressure moves the boiling point *higher*
- Under 1 atmosphere (15 psig) excess pressure, water is still not boiling at 250 F
- Eventually, you get to the boiling point temperature for any pressure.
- The boiling point in an open container, *i.e.,* at 1 atm pressure, is called the *normal boiling point*

Tanks



- Ballooning tanks have spit valve for liquid level detection

P-T diagram



- All substances work like this
- Propane in context

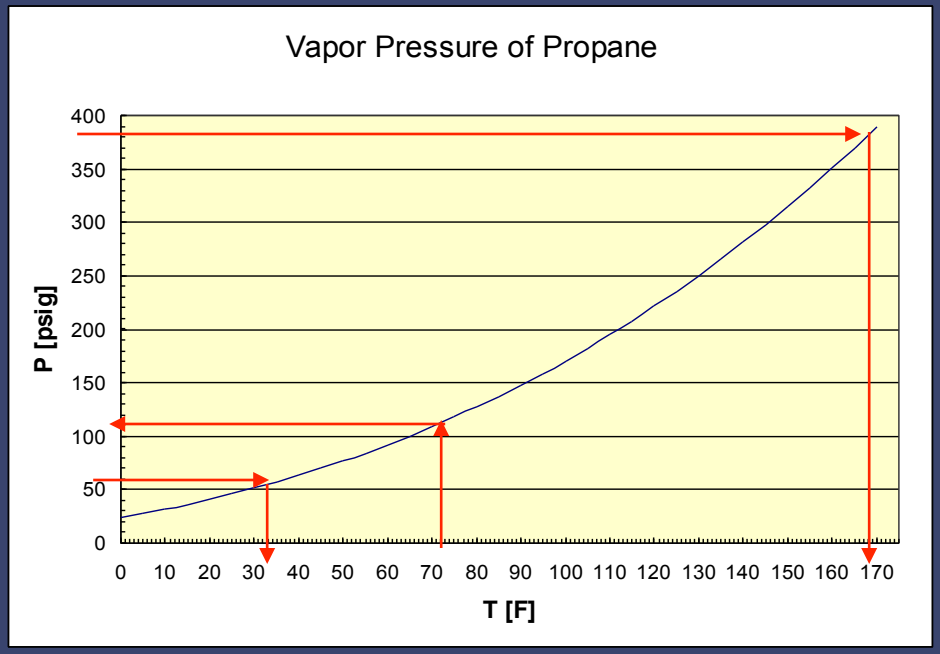
T_C = 518 F (point C on graph)
P_C = 625 psi (42.5 bar)

T_t = -306 F (point 2 on graph)
P_t = 169 μPa (almost zero)

- 1-2 is solid/vapor boundary
- 2-3 is solid/liquid boundary
- 2-C is liquid/vapor boundary

- We live in the middle of the line 2-C for propane

Vapor Pressure



- Vapor pressure rises exponentially with temperature
- Most balloon makers require at least 60 psig to be legal for flight, or around 35-40 F
- We typically heat our tanks to at least 70 F in winter, or about 110 psig (less piping losses)
- Tank pressure relief valves are typically set at 375 psig, or around 165 F

Propane tanks in action

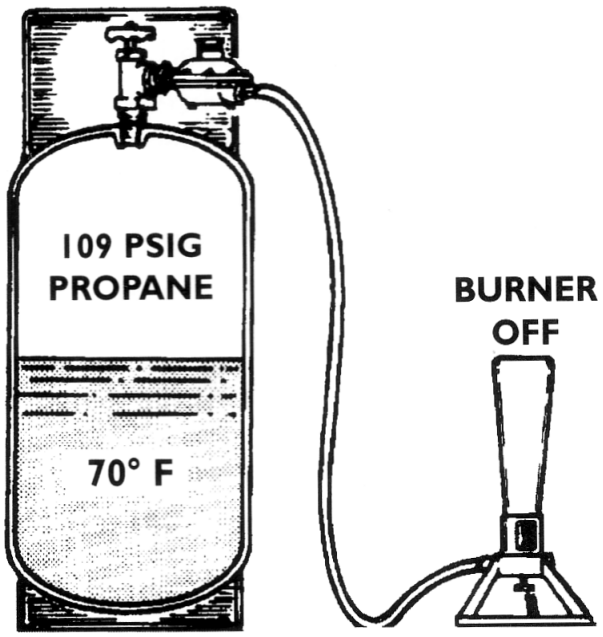


FIGURE 3-5
No Demand

- Liquid and vapor in equilibrium
- Picture shows vapor burner *i.e.,* pilot light
- Most modern burners have liquid pilot lights
- For blast, liquid comes from the bottom, and through burner coils first to provide preheat
- If pressure > 375 psig, pressure relief valve opens and vents propane vapor

Propane tanks in action

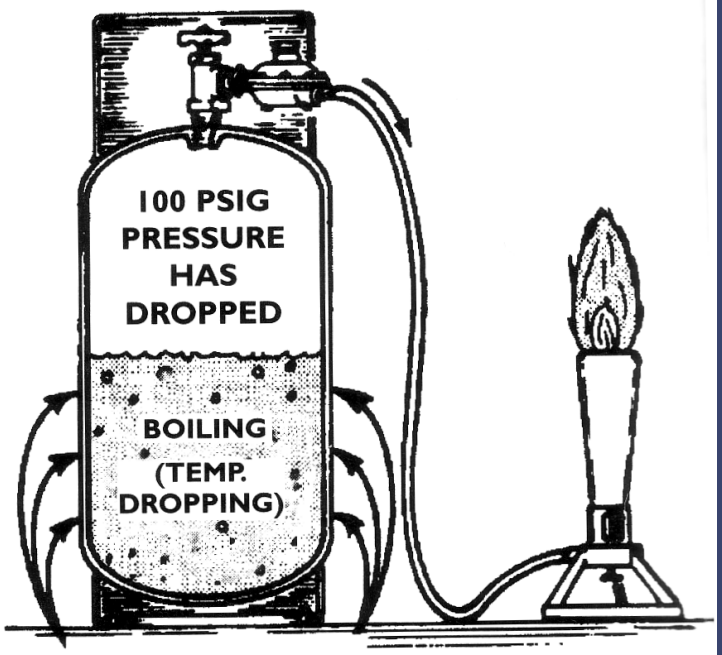


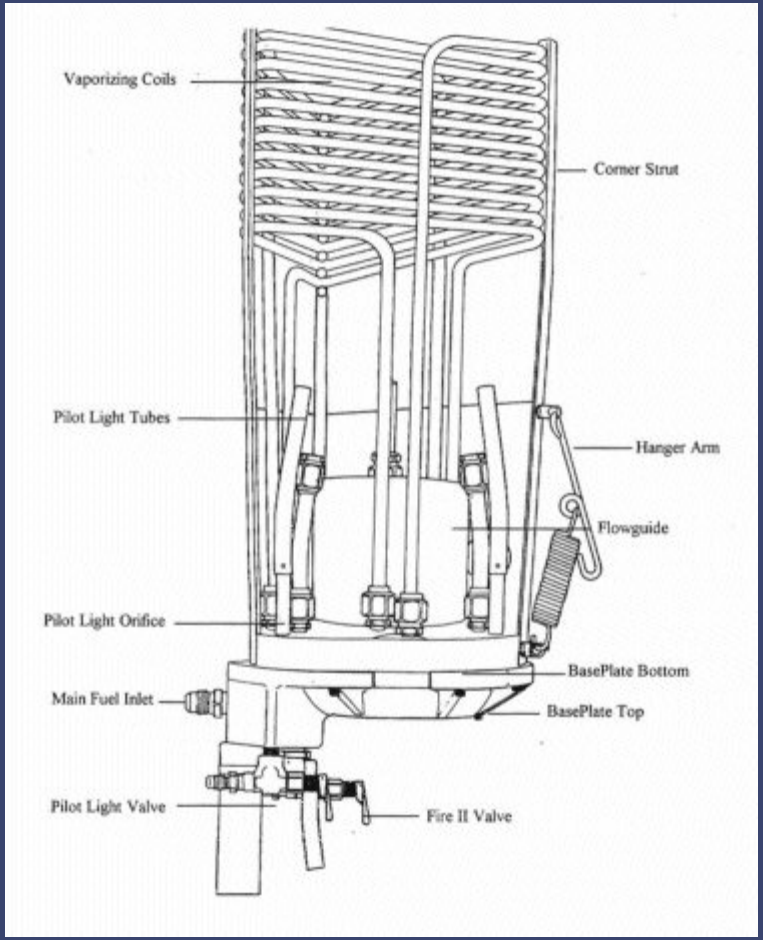
FIGURE 3-6
LP-Gas and Boiling Points

- We're withdrawing vapor
- To keep equilibrium, liquid vaporizes
- Vaporization requires heat, so the liquid starts cooling, drawing heat from outside
- Cooler liquid means lower vapor pressure, so slower flow of vapor
- As flight continues, vapor pilot lights become a little less powerful
- Safety implications N_2 pressurization: vapor becomes less propane and more N_2 as flight progresses

How fast does it vaporize?

- Rate of vaporization
  - depends on how fast it can pull heat from the environment
  - At 0 F, about 0.3 MBtu/hr from 50 gal tank
- Answer
  - enough for home heating
  - not enough for a hot air balloon burner!
- Need external heat input

Implications for burners



- Need preheat to vaporize
- Winter inflation – fireball
- Fuel usage – rough estimates
  - ~91,650 BTU/gal heat available
  - 15 MBTU/hr => 150 gal/hr
  - 12 gal/hr => 2/25 of the time
  - *i.e.,* 5 sec burn per minute

Freezing

- Vaporization requires heat
- Open liquid valve or a leak means *lots* of vaporization
  - Takes so much heat from environment, *i.e.,* tank fittings, *etc.,* that they get very cold
  - Frost forms
  - Can make O-rings brittle, leaky
- Tissue freeze burn hazard

How readily will propane burn?

- Limit of flammability/explosive limit
  - Different names for same thing
  - 2.4% - 9.6% propane by volume
- Ignition temperature
  - 900-1,100 F
  - Lighted match can reach 3,000 F
  - Static discharge *may* ignite propane
- $C_3H_8 + 5\ O_2 = 4\ H_2O + 3\ CO_2$

Overfilling or overheating)

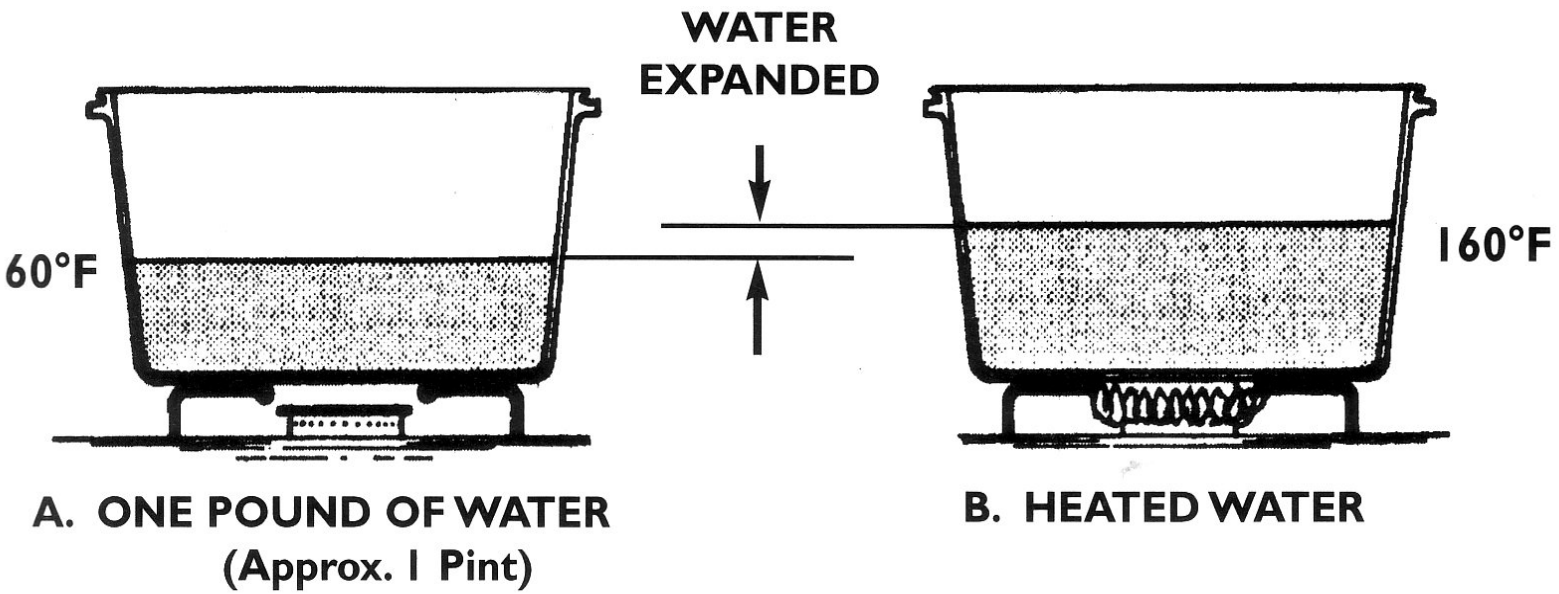


FIGURE 3-1A & B
Effects of Heat on Water

Overfilling (contd.)

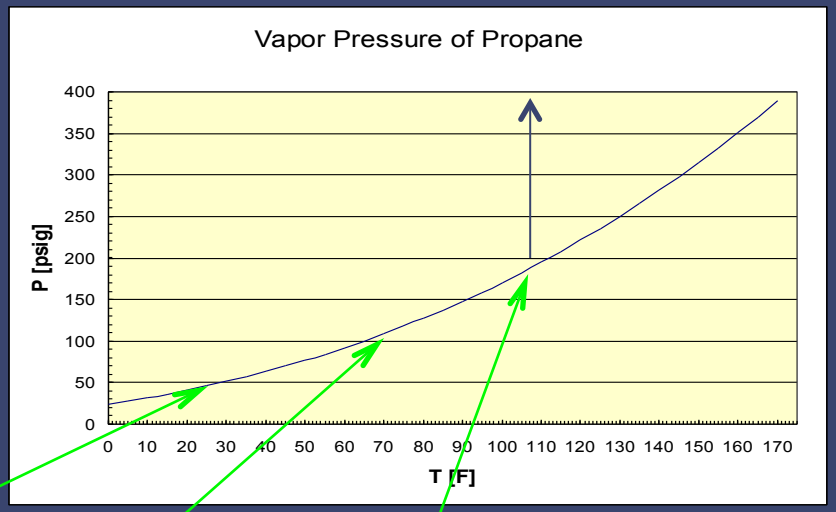
- Head space is to allow for liquid expansion
  - about 15% between 50 F and 120 F
- As long as we have both liquid and vapor, pressure *vs.* temperature is vapor pressure
- BUT…if tank is filled (no more vapor), we are now heating a liquid in a closed tank
- Liquid tries to expand…
  - …ever put a full bottle of water in a freezer?

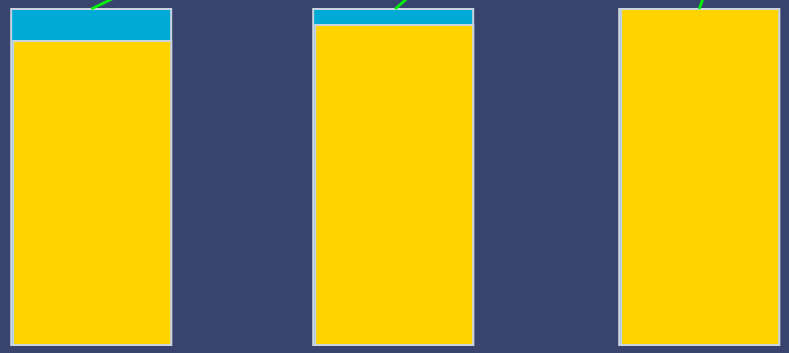
Overfilling (contd.)

$$\frac{\Delta(pressure)}{\Delta(temperature)} = \frac{\beta}{\kappa} = \frac{\text{coefficient of thermal expansion}}{\text{expansivity}}$$

- Bigger for stuff that expands more when heated
- Bigger for stuff that doesn't compress much
- For liquid propane, it's > **50 psig per degree F**

Overfilling (contd.)





BOOM!

Temperature rises

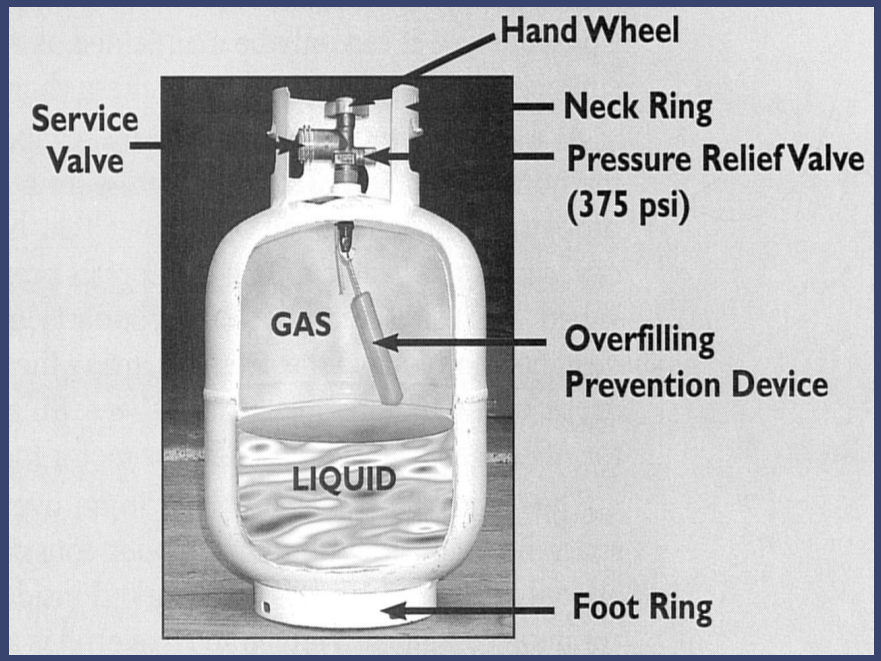
Overfilling (contd.)

- Result: BLEVE
  - boiling liquid expanding vapor explosion
- Pressure relief valve opens, but doesn't relieve pressure; tank may rupture
- Liquid escapes, expanding ~270 times
- Major quantity of flammable material
- Fire, explosion, mechanical damage

Overfilling (contd.)

- Mechanical damage can be great
- Large fire and explosion

Tanks revisited



- Spit valve to detect filling
- BBQ tanks now must have OPD (triangular handle) or will not be filled
  - Help prevent overfilling accidents
  - Next best thing – fill by weight
  - Some people still use for inflation tank

Summary

- Overview - propane chemistry & physics
- Common safety concerns
  - Handling - freezing injuries, fire
  - Pressurization and tank heating issues
  - Overfilling and explosions
  - Flammability and explosion hazards
- http://www.unitoops.com/clas2015.htm
- Questions/Comments?