CHAPTER 5

Properties of Propane (LP Gas)

Learning Objectives

Upon completion of this chapter, students will be able to:

1. Describe the chemical composition and structure of propane
2. Explain the relationship between liquid and vapor states of propane
3. Understand vapor pressure and its relationship to temperature
4. Calculate vapor withdrawal rates for propane tanks
5. Compare propane properties to natural gas properties
6. Explain appliance conversion requirements between natural gas and propane
7. Understand propane storage requirements including the 80% fill rule
8. Describe DOT and TC cylinder specifications
9. Differentiate between single-stage and two-stage pressure regulation
10. Apply safety considerations specific to propane installations

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5.1 Composition and Characteristics

Chemical Structure

Propane: C_3H_8

Propane is a three-carbon hydrocarbon molecule:

- 3 carbon atoms
- 8 hydrogen atoms
- Molecular weight: 44.1
- Member of the paraffin series (alkanes)
- Saturated hydrocarbon (single bonds only)

Structural Formula:

```
    H   H   H
    |   |   |
H - C - C - C - H
    |   |   |
    H   H   H
```

Three carbon atoms in a chain, each surrounded by hydrogen atoms.

LP Gas vs. Propane

LP Gas (Liquefied Petroleum Gas):

- Generic term for propane, butane, or mixtures
- In Canada and USA, "LP gas" typically means propane or propane-dominant mixtures
- Commercial propane may contain small amounts of other hydrocarbons

HD-5 Propane (Standard Grade):

- Minimum 90% propane
- Maximum 5% propylene (C_3H_6)
- Maximum 2.5% butane and heavier
- Remainder: ethane and lighter
- Standard for appliance fuel in North America
- Consistent properties for equipment operation

Commercial Propane:

- May vary slightly in composition
- Still meets minimum standards
- Primarily propane with minor components

Propane vs. Butane:

Property	Propane (C_3H_8)	Butane (C_4H_{10})
Molecular Weight	44.1	58.1
Boiling Point	-42°F (-42°C)	32°F (0°C)
Vapor Pressure (70°F)	127 PSIG	17 PSIG
Use in Canada	Year-round	Limited (freezes in winter)

Why Propane in Canada:

- Low boiling point allows winter use
- Adequate vapor pressure in cold weather
- Butane unusable below freezing
- Propane standard for all seasons

Physical Properties

State at Normal Conditions:

- Liquid when under moderate pressure or refrigerated

- Gas when released to atmospheric pressure
- Transitions easily between states
- Stored as liquid, used as vapor

Color:

- Colorless as liquid
- Colorless as vapor
- No visual indication of presence

Odor:

- Naturally odorless (like natural gas)
- Ethyl mercaptan added as odorant
- Distinctive "rotten egg" smell
- Required for safety

Toxicity:

- Non-toxic (propane itself not poisonous)
- Asphyxiant (displaces oxygen)
- Anesthetic effect at high concentrations
- Carbon monoxide from incomplete combustion is highly toxic

Flammability:

- Highly flammable within explosive range
- Lower Explosive Limit (LEL): 2.1% by volume in air
- Upper Explosive Limit (UEL): 9.5% by volume in air
- Auto-ignition temperature: 920-1,020°F (493-549°C)
- Wider flammable range than natural gas (more easily explosive)

Weight Relative to Air:

- **Heavier than air**
- Specific gravity: 1.52 (vapor at 60°F)
- **Sinks and accumulates in low areas**
- Critical safety consideration
- Different behavior than natural gas

5.2 Liquid vs. Vapor States

Understanding propane's dual nature is fundamental to working with LP gas systems.

Liquid Propane Properties

Density:

- Liquid propane weighs approximately 4.24 lbs per gallon at 60°F
- Changes with temperature (expands when heated)
- Less dense than water (water = 8.34 lbs/gallon)
- Floats on water

Volume:

- 1 gallon of liquid = 36.39 cubic feet of vapor at 60°F
- Approximately 270:1 expansion ratio (liquid to vapor)
- Small liquid leak creates large vapor volume
- This is why propane is stored as liquid (efficiency)

Temperature Effects on Liquid:

- Liquid expands significantly when heated
- Approximately 1.5% volume increase per 10°F
- Must not completely fill containers (ullage space required)
- Pressure increases with temperature in closed container

Boiling Point:

- -42°F (-42°C) at atmospheric pressure
- Boiling point increases with pressure
- In pressurized tank, remains liquid above -42°F

Vapor Propane Properties

Specific Gravity (Vapor):

- 1.52 relative to air
- Heavier than air
- Sinks to lowest point
- Accumulates in basements, pits, low areas

Vapor Density:

- 0.1162 lbs per cubic foot at 60°F
- Air = 0.0765 lbs per cubic foot
- About 1.5 times heavier than air

Behavior:

- Released vapor sinks
- Flows like water seeking lowest level
- Does not readily disperse upward
- Can travel long distances at ground level
- Critical for leak response and ventilation

Heating Value (Vapor):

- Approximately 2,500 BTU per cubic foot of vapor
- About 2.5 times more than natural gas
- 91,500 BTU per gallon of liquid
- High energy density

Vaporization Process

How Liquid Becomes Vapor:

1. **Heat Absorption:**
   - Liquid propane absorbs heat from surroundings
   - Heat energy breaks molecular bonds
   - Molecules escape liquid surface as vapor
   - This is evaporation/vaporization
2. **Latent Heat of Vaporization:**
   - 184 BTU per pound required to vaporize propane
   - Heat must come from somewhere (air, ground, water)
   - Vaporization cools the remaining liquid
   - Tank surface may frost in high-demand situations
3. **Continuous Process:**
   - As vapor withdrawn, liquid vaporizes to replace it
   - Tank pressure maintained (if vaporization rate adequate)
   - Heat continuously absorbed from environment

Factors Affecting Vaporization Rate:

1. **Temperature:**
   - Warmer = faster vaporization
   - Colder = slower vaporization
   - Winter = reduced capacity
   - Critical in northern Canada
2. **Tank Surface Area:**
   - Larger surface = more vaporization
   - Liquid level affects surface area (less liquid = less surface)
   - Tank design affects capacity
   - Horizontal tanks better than vertical for vaporization
3. **Tank Size:**
   - Larger tanks have more surface area

    - But also store more liquid
    - Proper sizing critical
4. **Demand Rate:**
    - High demand may exceed vaporization rate
    - Causes pressure drop
    - May cause "freeze-up"
    - Requires proper tank sizing

Weathering:

- As propane vaporizes, heavier components remain
- Butane and heavier hydrocarbons stay liquid longer
- Over time, liquid becomes "heavier"
- Affects heating value and vapor pressure
- Eventually may not vaporize properly in cold weather
- Reason to refill rather than "use to empty"

5.3 Vapor Pressure and Temperature Relationships

Vapor pressure is the pressure exerted by propane vapor in a closed container.

Understanding Vapor Pressure

Definition:

- Pressure of vapor in equilibrium with liquid
- In closed tank, vapor and liquid coexist
- Pressure depends on temperature
- Independent of tank size (full or partially full)

Key Concept:

- Propane vapor pressure is ONLY dependent on temperature
- 10% full tank has same pressure as 90% full tank (at same temperature)
- Pressure gauge shows temperature, not quantity

Temperature-Pressure Relationship

Propane Vapor Pressure Table:

Temperature	Vapor Pressure	Temperature	Vapor Pressure
-40°F (-40°C)	5 PSIG	50°F (10°C)	71 PSIG
-30°F (-34°C)	9 PSIG	60°F (16°C)	91 PSIG

Temperature	Vapor Pressure	Temperature	Vapor Pressure
-20°F (-29°C)	14 PSIG	70°F (21°C)	112 PSIG
-10°F (-23°C)	20 PSIG	80°F (27°C)	135 PSIG
0°F (-18°C)	27 PSIG	90°F (32°C)	161 PSIG
10°F (-12°C)	35 PSIG	100°F (38°C)	189 PSIG
20°F (-7°C)	44 PSIG	110°F (43°C)	219 PSIG
30°F (-1°C)	54 PSIG	120°F (49°C)	252 PSIG
40°F (4°C)	66 PSIG	130°F (54°C)	287 PSIG

PSIG = Pounds per Square Inch Gauge (pressure above atmospheric)

Observations:

- Pressure increases rapidly with temperature
- Non-linear relationship (exponential)
- Approximately 10 PSI increase per 10°F rise
- At -42°F (boiling point), pressure = 0 PSIG
- At 130°F, pressure approaches 300 PSIG

Practical Implications

Winter Operation:

- Cold temperatures = lower pressure
- May be inadequate for appliance operation
- Vaporization rate reduced
- Tank may "freeze up" (frost formation)
- Larger tanks or vaporizers may be needed

Summer Operation:

- High temperatures = high pressure
- Increased vaporization
- Relief valve may operate if excessive
- Adequate capacity for demand

System Design:

- First-stage regulator inlet pressure varies with temperature
- Must design for coldest expected temperature
- Appliance regulators see constant pressure after regulation
- Second-stage typically delivers 11" W.C. (residential) or 13" W.C. (mobile home)

Safety Considerations:

- Pressure relief valve required on all tanks
- Typically set at 250-375 PSIG
- Vents if temperature causes excessive pressure
- Prevents tank rupture
- Never block or plug relief valve

Tank Pressure as Temperature Indicator:

- Gauge reading indicates approximate temperature
- Cannot determine liquid level from pressure
- Common misconception
- Use gauge or weight to determine quantity

5.4 Propane vs. Natural Gas

Understanding differences between propane and natural gas is essential for conversions and proper installations.

Property Comparison

Property	Natural Gas	Propane
Chemical Formula	CH_4 (primarily)	C_3H_8
Specific Gravity (vapor)	0.60	1.52
Heating Value	~1,000 BTU/ft³	~2,500 BTU/ft³
Wobbe Index	1,250-1,400	~2,100
Weight Relative to Air	Lighter (rises)	Heavier (sinks)
LEL	5%	2.1%
UEL	15%	9.5%
Auto-ignition Temp	1,004°F	920-1,020°F
Storage	Gas in pipes	Liquid in tanks
Supply Pressure (typical)	5-7" W.C.	11" W.C. (residential)
Manifold Pressure (typical)	3.5" W.C.	10" W.C.

Orifice Sizing Differences

Appliances require different orifices for natural gas vs. propane:

Why Different:

- Propane has 2.5× higher heating value
- Need less propane flow for same BTU input

- Smaller orifice required
- Specific gravity affects flow rate
- Wobbe Index difference is significant

Example: 40,000 BTU/hr Burner

Natural Gas:

- Flow needed: 40,000 BTU/hr ÷ 1,000 BTU/ft^3 = 40 ft^3/hr
- Larger orifice
- Lower pressure (3.5" W.C. manifold)

Propane:

- Flow needed: 40,000 BTU/hr ÷ 2,500 BTU/ft^3 = 16 ft^3/hr
- Smaller orifice (typically 60% of natural gas orifice size)
- Higher pressure (10" W.C. manifold)

Conversion Requirements:

- Change all orifices
- Adjust or change gas valve spring (for proper manifold pressure)
- Verify primary air adjustment
- Update appliance labeling
- Document conversion
- Some appliances have conversion kits; others not convertible

Drill Number Sizes:

- Natural gas orifice might be #42 drill (0.0935")
- Propane orifice might be #54 drill (0.0550")
- Always verify manufacturer specifications
- Never guess or estimate

Combustion Differences

Air Requirements:

Natural Gas:

- Stoichiometric: 9.5:1 (air:gas)
- Practical: 13-15:1 with excess air

Propane:

- Stoichiometric: 23.8:1 (air:gas)

- Practical: 30-35:1 with excess air
- Requires 2.5× more air per unit volume

Flame Characteristics:

Natural Gas:

- Blue flame
- Higher flame speed
- Less luminous

Propane:

- Blue flame with slight luminosity
- Slower flame speed
- May show slight yellow tipping (acceptable if minimal)
- Higher flame temperature potential

Products of Combustion:

Complete Combustion (Propane): $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ + Heat

Propane produces:

- More CO_2 per unit volume of fuel (3 molecules vs. 1 for methane)
- More water vapor (4 molecules vs. 2 for methane)
- More flue gas volume per unit fuel
- Slightly higher CO_2 percentage in ideal combustion (10-12% vs. 8-10%)

Venting Differences

Generally Similar Requirements:

- Same vent categories apply
- Same clearances
- Same sizing principles

Differences:

- Propane produces more flue gas per BTU input
- May require slightly larger vents (check tables)
- Same vent material specifications
- Higher water vapor production (more condensation in condensing appliances)

Safety Differences

Natural Gas:

- Lighter than air (rises)
- Disperses upward
- Accumulates at ceiling level
- Easier to ventilate

Propane:

- **Heavier than air (sinks) - CRITICAL**
- Flows to lowest point
- Accumulates in basements, pits, crawlspaces
- Harder to disperse
- Can travel long distances at ground level
- Greater explosion risk in confined low areas

Installation Implications:

- No propane tanks in below-grade areas
- No propane appliances in pits without special ventilation
- Floor drains may need sealing
- Ventilation must be from floor level (not ceiling)
- Leak response more critical

5.5 Propane Storage and Handling

Tank Types and Sizes

ASME Tanks (Stationary):

- Built to American Society of Mechanical Engineers code
- Permanent installation
- Above-ground or underground
- Various capacities

Common Residential Sizes:

- **120 gallon (420 lb):** Small homes, seasonal
- **250 gallon (880 lb):** Small homes, backup heat
- **500 gallon (1,760 lb):** Average home, primary heat
- **1,000 gallon (3,520 lb):** Large homes, high demand
- Larger for commercial/agricultural

Tank Capacity Ratings:

- "Water capacity" = total internal volume
- **NOT the usable propane capacity**
- Actual fill limited to 80% (discussed below)

Example: 500 Gallon Tank

- 500 gallons = water capacity
- 500 × 0.80 = 400 gallons maximum propane fill
- 400 gal × 4.24 lbs/gal = 1,696 lbs propane capacity

DOT/TC Cylinders (Portable):

- Department of Transportation (USA) or Transport Canada specifications
- Portable, movable
- Various sizes
- Must be transported upright
- Subject to re-certification requirements

Common Cylinder Sizes:

- **20 lb (5 gallon):** BBQ cylinders, most common
- **30 lb (7.5 gallon):** RVs, larger portable
- **40 lb (10 gallon):** Forklifts
- **100 lb (25 gallon):** Temporary construction heat
- Larger cylinders for special applications

Cylinder Markings (typical):

- DOT or TC specification (e.g., DOT-4BA240)
- Date of manufacture (month/year)
- Re-test date (every 10-12 years typically)
- Tare weight (empty weight)
- Water capacity
- Service pressure rating

The 80% Fill Rule

Propane expands significantly when heated. Tanks must have space for expansion.

Why 80%:

- Liquid propane expands about 1.5% per 10°F temperature rise
- From 0°F to 130°F = 19.5% expansion
- 80% fill allows adequate expansion space (20% ullage)
- Prevents overfilling
- Allows for pressure relief valve to handle temperature extremes

Maximum Fill (by weight):

For any container:

- Water capacity (gallons) × 4.24 lbs/gal × 0.80 = Maximum fill (lbs)

Example: 500 Gallon ASME Tank

- 500 gal × 4.24 lbs/gal × 0.80 = 1,696 lbs maximum
- Never exceed this amount
- Typically filled to 80% by volume or 42% by gauge

Fixed Liquid Level Gauge:

- Indicates when tank is 80% full
- Bleeder valve
- Opens when liquid reaches 80%
- Liquid (not vapor) sprays out when 80% reached
- Filling stops
- Required on all ASME tanks

Percentage Gauges:

- Dial gauge showing 0-100%
- Indicates liquid level
- Reading of 80% = full by volume
- Actually about 42% by weight (due to ullage space at top)
- Common on residential tanks

Overfill Prevention Device (OPD):

- Required on portable cylinders (DOT/TC)
- Prevents filling beyond 80%
- Triangular hand wheel identifies OPD valve
- Float mechanism inside valve
- Automatically stops fill at 80%

Consequences of Overfilling:

- No room for expansion
- Excessive pressure
- Relief valve operates
- Propane venting (waste and hazard)
- Potential tank damage
- Illegal and dangerous

Tank Installation Requirements (CSA B149.2)

Setback Distances (Minimum):

Distances from ASME tanks to buildings, property lines, and other features per CSA B149.2:

From Buildings:

- Water capacity < 2,000 L (530 gal): 3 meters (10 ft) minimum
- Larger tanks: Increased distances
- From doors, windows, and ventilation openings: minimum 3 meters
- From above-ground non-fireproof structure: minimum 3 meters

From Property Line:

- Minimum 3 meters (10 ft) to adjoining property
- Greater if larger tank
- Consider neighboring buildings

From Other Features:

- Sources of ignition: 3 meters minimum
- Air conditioning equipment: 3 meters
- Heat pumps: 3 meters
- Other propane containers: specified distances

Relief Valve Discharge:

- Must point vertically upward for above-ground
- Must terminate away from buildings
- Minimum heights specified
- Away from openings
- Unobstructed

Underground Installation:

- Minimum depth of cover
- Corrosion protection required
- Must be locatable
- Electrical bonding requirements
- Fill and gauge access above grade

Cylinder Storage:

- Outdoor only (except during use)
- Upright position

- Protected from tampering
- Away from heat sources
- Secure from falling
- Minimum distances from buildings

Tank Sizing Considerations

Factors in Sizing:

1. **Total Appliance Load:**
    - Sum of all appliance inputs (BTU/hr)
    - Consider simultaneous operation
    - Peak demand conditions
2. **Vaporization Capacity:**
    - Tank must vaporize enough propane to meet demand
    - Depends on tank size, surface area, and temperature
    - Critical in cold climates
3. **Refill Frequency:**
    - How often customer accepts delivery
    - Storage capacity between fills
    - Winter consumption higher than summer
4. **Ambient Temperature:**
    - Coldest expected temperature
    - Reduced vaporization in cold weather
    - May need larger tank or multiple tanks
5. **Delivery Access:**
    - Truck access
    - Hose reach
    - Terrain considerations

Vaporization Rates (Approximate):

BTU/hr continuous capacity at various temperatures:

Tank Size	-20°F	0°F	20°F	40°F
120 gal	50,000	85,000	130,000	190,000
250 gal	90,000	150,000	230,000	340,000
500 gal	140,000	240,000	370,000	550,000
1,000 gal	210,000	370,000	570,000	850,000

(Values are approximations; actual varies with tank design and conditions)

Observation:

- Capacity drops dramatically in cold weather

- 500-gallon tank at -20°F provides only 140,000 BTU/hr continuously
- Same tank at 40°F provides 550,000 BTU/hr
- Winter sizing critical in Canada

Rule of Thumb:

- Tank should provide 2-3 times peak demand at coldest temperature
- Prevents pressure drop
- Prevents "freeze-up"
- Maintains system pressure

Multiple Tanks:

- Manifolding tanks increases vaporization capacity
- Two 500-gal tanks provide nearly double capacity
- Common for high-demand applications
- Must be properly manifolded and regulated

Vaporizers:

- Electric or indirect-fired
- Supplement natural vaporization
- Required for very high demands
- Commercial/industrial applications
- Add heat to increase vaporization rate

5.6 Pressure Regulation

Propane systems require pressure regulation to deliver gas at proper pressure to appliances.

Single-Stage vs. Two-Stage Systems

Single-Stage System:

- One regulator reduces tank pressure directly to appliance pressure
- Simple, fewer components
- Less common in modern installations
- Used for small loads only

Two-Stage System:

- First-stage regulator at tank reduces to intermediate pressure (typically 10 PSI)
- Second-stage regulator at building reduces to appliance pressure (11" W.C. residential or 13" W.C. mobile home)

- Modern standard
- Better pressure control
- Protects against tank pressure variations

First-Stage Regulation

Location:

- At or near tank
- Often integral with tank service valve
- Protected from weather

Function:

- Reduces tank pressure (varies with temperature) to constant 10 PSI
- Handles varying inlet pressure (20-250+ PSIG depending on temperature)
- Outlet pressure constant regardless of inlet

Outlet Pressure:

- **10 PSI (27.7" W.C.) typical**
- Sometimes 15 PSI for longer runs
- Allows piping to second stage with smaller pipe
- Higher pressure means less pressure drop in piping

Relief Valve:

- Integral or separate
- Vents to atmosphere if over-pressure
- Protects piping downstream
- Must point away from building

Lock-Up Pressure:

- Pressure when no flow
- Should not exceed 20 PSI (approximately)
- Test requirement

Second-Stage Regulation

Location:

- At or just outside building
- Before entering structure
- Protected from weather
- Accessible for service

Function:

- Reduces 10 PSI to appliance pressure
- Final pressure control
- Protects appliances

Outlet Pressure:

- **11" W.C. (0.40 PSI) for residential dwellings**
- **13" W.C. (0.47 PSI) for mobile/manufactured homes**
- Constant pressure to appliances
- Appliance regulators further reduce to manifold pressure (10" W.C.)

Vent:

- Second-stage regulators are vented
- Vent to atmosphere
- Must terminate outside (except for Vent Limiting Devices)
- Minimum distances from openings per code
- Protected from insects and weather

Lock-Up Pressure:

- Pressure when no flow
- Should not exceed 14" W.C. (residential) or 16" W.C. (mobile home)
- Test requirement per CSA B149.2

Automatic Changeover Regulators

For Cylinder Systems:

- Automatically switches between two cylinders
- Continuous supply when one cylinder empties
- Indicator shows which cylinder in use
- Common for cylinder installations

Operation:

- Regulates from cylinder supplying gas
- When that cylinder empties (pressure drops), automatically switches to full cylinder
- Indicator moves to show switchover
- Allows empty cylinder replacement without interrupting service

First-Stage Function:

- Integral first-stage regulation

- Reduces cylinder pressure to 10 PSI
- Requires second-stage at building

Line Pressure Regulators

Two-Stage Integral:

- Single device combining first and second stage
- Mounted at tank or on building
- Direct reduction to appliance pressure
- Simpler installation
- Common on smaller systems

Installation Considerations:

- Cannot have excessive pressure drop between regulator and appliances
- Piping must be sized adequately
- Limited run length
- Not suitable for complex piping systems

Regulator Venting

Why Regulators Vent:

- Diaphragm-operated regulators use atmospheric pressure as reference
- Internal chamber must be vented to atmosphere
- Vent allows regulator to sense outlet pressure correctly
- Small gas amounts may vent during operation

Vent Location Requirements (CSA B149.2):

- **Outdoors**
- Minimum 3 meters (10 ft) from any source of ignition
- Minimum 1.5 meters (5 ft) from mechanical ventilation intakes
- Minimum 3 meters (10 ft) from doors, windows, and ventilation openings
- Protected from precipitation
- Screened against insects

Vent Limiting Devices (VLD):

- Special internal vent design
- Allows indoor installation of second-stage regulator in some cases
- Limits gas release if diaphragm fails
- Must meet specific standards
- Not common in Canada

5.7 Propane Piping

Materials

Approved Materials (per CSA B149.2):

- Black steel pipe (most common)
- Brass pipe
- Copper tubing (Type K or L, properly joined)
- Corrugated stainless steel tubing (CSST)
- Polyethylene (PE) for underground only, with proper transitions
- Flexible appliance connectors (approved lengths)

Not Approved:

- Galvanized steel pipe (internal coating flakes off)
- PVC, ABS, or other plastics above ground
- Aluminum (except specific appliance components)
- Copper soft tubing (for permanent piping)

Sizing Considerations

Propane vs. Natural Gas:

- Propane has higher specific gravity (1.52 vs. 0.60)
- More pressure drop for same pipe size and flow
- Must use propane-specific sizing tables
- Cannot use natural gas tables directly

Correction Factor:

- If using natural gas table: $CF = \sqrt{(0.60 \div 1.52)} = 0.628$
- Multiply natural gas capacity by 0.628 to get propane capacity
- Or use propane-specific tables in CSA B149.2

Example:

- 1/2" pipe, 20 ft, 0.5" W.C. drop
- Natural gas capacity from table: 175 ft^3/hr (CFH)
- Propane capacity: $175 \times 0.628 = 110$ CFH
- In BTU: $110 \times 2{,}500 = 275{,}000$ BTU/hr

Pressure Drop:

- Higher pressure = less percentage drop
- 11" W.C. supply (vs. 7" W.C. for natural gas) helps
- Still must calculate pressure drop
- CSA B149.2 tables account for this

Underground Piping

Polyethylene (PE):

- Yellow jacket (propane identification)
- Minimum depth per code (typically 18" below frost)
- Protected from rocks and sharp objects
- Installed on sand bed if rocky soil
- Tracer wire for locating
- Transition to steel above grade

Steel Pipe Underground:

- Coated and wrapped
- Cathodic protection may be required
- More expensive than PE
- Higher maintenance
- Less common for new installations

Transitions:

- PE to steel transition above grade (minimum 12" above)
- Proper fittings
- Dielectric union may be required
- Accessible for inspection

5.8 Appliance Conversion

Converting appliances between natural gas and propane is common but must be done correctly.

Conversion Requirements

When Conversion Allowed:

- Appliance manufacturer provides conversion kit or instructions
- Appliance designed for conversion
- Proper documentation available

When Conversion NOT Allowed:

- No manufacturer conversion kit available
- Appliance not designed for conversion
- Instructions unavailable
- Appliance too old (parts unavailable)
- Sealed combustion chamber (some models)

Conversion Procedure

1. Verify Convertibility:

- Check manufacturer specifications
- Obtain proper conversion kit
- Review conversion instructions
- Verify appliance model compatibility

2. Change Orifices:

- Turn off gas supply
- Remove burner orifices
- Install orifices for new gas type
- Typically smaller for propane
- ALL orifices must be changed (including pilot)

3. Adjust/Replace Gas Valve:

- Change gas valve spring (if required)
- Some valves need complete replacement
- Adjust manifold pressure to:
    - Natural gas: 3.5" W.C.
    - Propane: 10" W.C.

4. Adjust Primary Air:

- May require adjustment
- Propane needs more air per unit volume
- Verify proper flame characteristics

5. Verify Venting:

- Check vent sizing (may be adequate for both)
- Verify clearances unchanged
- Confirm proper draft

6. Test and Adjust:

- Pressure test all connections

- Light appliance and verify operation
- Check manifold pressure
- Perform combustion analysis
- Adjust burner for proper flame
- Verify all safeties operate

7. Update Labeling:

- Remove old gas type label
- Install new gas type label
- CSA requires proper labeling
- Include conversion date
- Technician identification

8. Document:

- Record conversion in service records
- Provide customer with documentation
- Include new operating specifications
- List converted components

Common Conversion Mistakes

Incomplete Orifice Change:

- Missing pilot orifice change
- Missing one burner
- Results in improper combustion

Wrong Manifold Pressure:

- Using natural gas pressure with propane orifices (too rich)
- Using propane pressure with natural gas orifices (too lean)
- Both dangerous

Missing Pressure Adjustment:

- Forgot to adjust gas valve
- Incorrect pressure
- Poor combustion or over-firing

Inadequate Testing:

- Skipping combustion analysis
- Not checking all safety controls
- Assuming conversion successful without verification

Improper Labeling:

- Confuses future service technicians
- May lead to incorrect service
- Code violation

5.9 Safety Considerations

Heavier Than Air

Critical Safety Difference from Natural Gas:

- Propane sinks to lowest point
- Accumulates in basements, crawlspaces, pits, low areas
- Does not readily disperse
- Can travel long distances along ground
- Remains concentrated longer

Installation Implications:

- No propane tanks in below-grade locations
- No cylinders in basements
- Appliances in basements require adequate ventilation
- Floor drains may need traps or sealing
- Ventilation from floor level (not ceiling)

Leak Response:

- Evacuate immediately
- Ventilate from low areas
- Propane may have traveled far from source
- Check all low areas
- Use gas detector from floor level up

Cold Burns

Liquid propane is extremely cold:

- Boils at -42°F
- Contact causes frostbite instantly
- Skin damage similar to thermal burns
- Eye exposure can cause blindness

When Risk Exists:

- Rapid liquid releases (line breaks)
- Tank overfilling
- Relief valve discharge
- Connecting/disconnecting fittings
- Filling operations

Protection:

- Safety glasses (always)
- Gloves when handling connections
- Proper clothing
- Know emergency procedures
- First aid for cold exposure

Tank Safety

Relief Valve:

- Never plug, cap, or block
- Operates at 250-375 PSIG typically
- Vents excess pressure
- Must discharge upward and away from people
- Check operation during tank inspection

Fire Exposure:

- Tanks exposed to fire can rupture catastrophically (BLEVE)
- Extremely dangerous
- Call fire department immediately
- Evacuate far distance (1/2 mile recommended)
- Never approach tank involved in fire

Physical Damage:

- Inspect tanks for damage (dents, rust, cracks)
- Damaged tanks may fail
- Report damage to supplier
- Never use damaged tank

Overfilling:

- Strictly enforce 80% rule
- Never override safety devices
- Overfilled tank is extreme hazard
- Relief valve will vent (waste and danger)

Leak Detection

Electronic Detectors:

- Most effective for propane
- Check from floor level upward
- Propane specific detectors available
- More sensitive than human nose

Soap Solution:

- Works well for pinpointing
- Bubbles show leak location
- Safe method
- Apply to all connections

Odor:

- Mercaptan provides warning
- But never rely on odor alone
- Some people cannot smell
- Odorant can fade
- Always use detection equipment

Leak Response Protocol:

1. Evacuate building
2. Call fire department (911) and propane supplier
3. Shut off tank if safe to do so
4. Keep people away
5. No ignition sources
6. Ventilate (open doors/windows from outside)
7. Do not re-enter until cleared
8. Professional leak investigation required

Chapter Summary

Propane (C_3H_8) is stored as a liquid and used as a vapor, with properties significantly different from natural gas. With specific gravity of 1.52, propane is heavier than air and sinks to low areas—a critical safety consideration. The heating value of approximately 2,500 BTU/ft^3 is 2.5 times higher than natural gas, requiring smaller orifices and different manifold pressure (10" W.C. vs. 3.5" W.C.).

Vapor pressure increases with temperature, varying from about 27 PSIG at 0°F to 189 PSIG at 100°F. The 80% fill rule prevents dangerous overfilling, allowing space for liquid expansion. Tank sizing must account for vaporization capacity, which decreases dramatically in cold weather.

Two-stage pressure regulation is standard: first stage at tank reduces to 10 PSI, second stage at building reduces to 11" W.C. (residential) or 13" W.C. (mobile home). Conversion between natural gas and propane requires changing all orifices, adjusting manifold pressure, testing combustion, and updating labeling.

Safety considerations include propane's tendency to accumulate in low areas, cold burn hazards from liquid propane, proper tank setbacks per CSA B149.2, and appropriate emergency response procedures. Understanding propane's unique properties enables safe, efficient installations and effective troubleshooting.

Review Questions

Multiple Choice

1. Propane has the chemical formula:
   - a) CH_4
   - b) C_2H_6
   - c) C_3H_8
   - d) C_4H_{10}
2. The specific gravity of propane vapor is approximately:
   - a) 0.60
   - b) 1.00
   - c) 1.52
   - d) 2.50
3. One gallon of liquid propane produces approximately how many cubic feet of vapor?
   - a) 9.5 ft^3
   - b) 36.4 ft^3
   - c) 92.0 ft^3
   - d) 270 ft^3
4. Propane tanks are filled to a maximum of what percentage?
   - a) 60%
   - b) 70%
   - c) 80%
   - d) 90%
5. The typical manifold pressure for propane appliances is:
   - a) 3.5" W.C.
   - b) 7" W.C.
   - c) 10" W.C.
   - d) 11" W.C.

6. A first-stage propane regulator typically reduces tank pressure to:
    - a) 11" W.C.
    - b) 5 PSI
    - c) 10 PSI
    - d) 20 PSI
7. The second-stage outlet pressure for a residential dwelling is typically:
    - a) 7" W.C.
    - b) 10" W.C.
    - c) 11" W.C.
    - d) 13" W.C.
8. The Lower Explosive Limit (LEL) for propane is:
    - a) 1.5%
    - b) 2.1%
    - c) 5.0%
    - d) 9.5%
9. When converting from natural gas to propane, the orifice size must be:
    - a) Increased
    - b) Decreased
    - c) Kept the same
    - d) Removed entirely
10. Propane is heavier than air, which means it will:
    - a) Rise and disperse quickly
    - b) Mix evenly with air
    - c) Sink and accumulate in low areas
    - d) Float on water

True or False

11. Propane and natural gas have the same Wobbe Index and are directly interchangeable.
12. The 80% fill rule exists because liquid propane expands significantly when heated.
13. Propane tank pressure indicates how much propane is in the tank.
14. A 500-gallon propane tank can safely hold 500 gallons of liquid propane.
15. Second-stage propane regulators must be vented to the outdoors.

Short Answer

16. Explain why propane is stored as a liquid but used as a vapor. Include the expansion ratio and its significance. (4 marks)
17. Describe the difference between single-stage and two-stage pressure regulation systems for propane. (4 marks)
18. Why is propane's heavier-than-air property a critical safety consideration? List three specific implications. (5 marks)
19. Explain the relationship between temperature and vapor pressure in propane tanks. Why does this matter for system design? (5 marks)
20. What is "weathering" in propane tanks and why does it matter? (3 marks)

Long Answer

21. A customer wants to install a propane furnace rated at 100,000 BTU/hr input in a location where winter temperatures can drop to -20°F. Explain how you would determine the proper tank size. Include:
    - Calculation of propane consumption rate
    - Vaporization capacity considerations
    - Temperature effects
    - Safety factors
    - Your recommendation with justification (12 marks)
22. Describe the complete procedure for converting a natural gas furnace to propane operation. Include:
    - Pre-conversion verification
    - All components that must be changed or adjusted
    - Testing procedures
    - Safety checks
    - Documentation requirements
    - Common mistakes to avoid (15 marks)
23. Compare and contrast propane and natural gas in terms of:
    - Physical properties (specific gravity, heating value, Wobbe Index)
    - Storage and distribution
    - Safety considerations
    - Appliance requirements
    - Environmental factors Explain why these differences require different installation practices and equipment. (15 marks)

Practical Exercises

Exercise 1: Vapor Pressure Calculations

Using the temperature-pressure table:

1. What is the tank pressure at -10°F?
2. What is the tank pressure at 70°F?
3. If tank pressure reads 91 PSIG, what is the approximate temperature?
4. Why can't you determine quantity from pressure alone?

Exercise 2: Tank Capacity Calculations

Calculate for various tank sizes:

1. Water capacity in gallons
2. Maximum fill at 80% (gallons)

3. Maximum fill weight (pounds)
4. Vapor volume at 60°F
5. Total BTU content

Exercise 3: Vaporization Rate Analysis

For a 500-gallon tank:

1. Find vaporization capacity at -20°F
2. Find vaporization capacity at 40°F
3. Calculate percentage reduction in cold weather
4. Determine if adequate for 150,000 BTU/hr furnace at each temperature
5. Explain implications for cold climate installations

Exercise 4: Piping Sizing for Propane

Using CSA B149.2 tables:

1. Size pipe for 200,000 BTU/hr, 50 ft run
2. Compare to natural gas sizing for same load
3. Calculate pressure drop
4. Verify adequate pressure at appliance
5. Document design

Exercise 5: Conversion Procedure

On training appliance (if available) or detailed written procedure:

1. Identify current gas type
2. List all components requiring change
3. Obtain proper orifices
4. Describe pressure adjustment procedure
5. Create step-by-step checklist
6. Describe combustion testing process
7. Prepare proper labeling
8. Complete documentation

Exercise 6: Leak Detection Practice

On test propane system with known leak:

1. Use electronic detector to locate general area
2. Use soap solution to pinpoint exact leak
3. Estimate leak severity
4. Recommend repair method
5. Document findings

6. Describe safety procedures followed

Exercise 7: Tank Setback Calculations

Given site plan:

1. Identify proposed tank location
2. Measure distances to building, property lines, ignition sources
3. Verify compliance with CSA B149.2
4. Identify any violations
5. Recommend compliant location if needed
6. Document with sketches

Case Studies

Case Study 1: Winter Freeze-Up

Scenario: A customer calls in February complaining their furnace "keeps shutting down" and they "can't keep the house warm." Outdoor temperature is -25°F. They have a 250-gallon propane tank that shows 40% on the gauge. The 125,000 BTU/hr furnace runs for a few minutes, then shuts down on limit. When you arrive, you notice frost on the lower half of the propane tank.

Questions:

1. What is causing this problem?
2. Why is there frost on the tank?
3. What is the tank's vaporization capacity at -25°F?
4. Is 40% adequate liquid level? Why or why not?
5. Why does the furnace shut down on limit?
6. What immediate solution can you provide?
7. What long-term solutions would you recommend?
8. How do you explain this to the customer?

Case Study 2: Improper Conversion

Scenario: You respond to a "no heat" call. The customer just had their natural gas furnace "converted to propane" by an unlicensed friend. The furnace won't light. You find:

- Natural gas orifices still installed
- Natural gas label still on furnace
- Gas valve spring not changed
- No combustion testing performed

- Manifold pressure measures 10" W.C.

Questions:

1. Why won't the furnace light?
2. What's wrong with the manifold pressure?
3. What could happen if it did light with this configuration?
4. What components are incorrect?
5. What is the proper manifold pressure for propane?
6. What is required to properly convert this furnace?
7. What do you tell the customer?
8. What are the safety and legal implications?

Case Study 3: Tank Location Violation

Scenario: You're asked to perform a routine inspection on a propane installation. You find a 500-gallon tank located:

- 2 meters (6.5 ft) from the house
- 1.5 meters (5 ft) from the property line
- Adjacent to the neighbor's heat pump (3 meters away)
- Relief valve pointing toward the house

Questions:

1. What CSA B149.2 violations exist?
2. What are the required minimum setbacks?
3. Why are these distances required?
4. What is wrong with the relief valve orientation?
5. Where should the tank be located?
6. Who is responsible for correction?
7. What if correction is impossible on this property?
8. What documentation/notification is required?

Case Study 4: Basement Accumulation

Scenario: Homeowners smell propane in their basement. They have a propane furnace and water heater in the basement. You arrive and detect propane concentration of 8,000 ppm (0.8%) at floor level in one corner, decreasing with height. No odor at ground level outside. All appliances are off.

Questions:

1. What is the immediate action?
2. Why is propane only in the basement?
3. Why higher concentration at floor level?

4. What is 0.8% in relation to LEL?
5. How would this differ if it were natural gas?
6. What is the likely leak source?
7. How do you locate the leak safely?
8. What ventilation strategy do you use?
9. What recommendations prevent future accumulation?

Case Study 5: Vaporization Capacity

Scenario: A customer wants to add a propane pool heater (400,000 BTU/hr) to their existing 250-gallon tank that supplies their home (furnace: 80,000 BTU/hr, water heater: 40,000 BTU/hr, range: 65,000 BTU/hr). They live in an area where winter temperatures reach -10°F. Current tank shows 60% full.

Questions:

1. What is the peak simultaneous load?
2. What is the tank's vaporization capacity at -10°F?
3. Is the existing tank adequate? Why or why not?
4. What happens if vaporization capacity is exceeded?
5. What solutions are available?
6. Would a larger tank solve the problem?
7. What about two tanks manifolded together?
8. What would you recommend and why?
9. How do summer conditions affect this analysis?

Case Study 6: Overfilled Tank

Scenario: You're called to a home where the propane tank is venting from the relief valve. It's a hot summer day (95°F). The customer mentions the delivery driver "really filled it up good - said he wanted to make sure I had plenty." The gauge reads 95%. Liquid is spraying from the relief valve.

Questions:

1. What has happened?
2. Why is the relief valve operating?
3. What is the immediate danger?
4. What immediate actions are required?
5. How did this occur?
6. What should the maximum fill be?
7. What prevents this normally?
8. How is the problem corrected?
9. Who should be notified?
10. What could happen if the relief valve were blocked?

Key Terms

ASME Tank: Stationary propane tank built to American Society of Mechanical Engineers standards.

Auto-Ignition Temperature: Temperature at which propane ignites spontaneously without external ignition (920-1,020°F).

BLEVE (Boiling Liquid Expanding Vapor Explosion): Catastrophic tank failure when liquid rapidly vaporizes, typically from fire exposure.

DOT Cylinder: Portable propane cylinder meeting Department of Transportation specifications.

First-Stage Regulator: Reduces tank pressure to intermediate pressure (typically 10 PSI).

HD-5 Propane: Standard grade propane containing minimum 90% propane.

LEL (Lower Explosive Limit): Minimum propane concentration in air that will ignite (2.1%).

LP Gas (Liquefied Petroleum Gas): Generic term for propane, butane, or mixtures thereof.

OPD (Overfill Prevention Device): Valve preventing propane cylinder from being filled beyond 80%.

Second-Stage Regulator: Reduces intermediate pressure to appliance supply pressure (11" W.C. residential, 13" W.C. mobile home).

Specific Gravity: Weight of propane vapor relative to equal volume of air (1.52).

TC Cylinder: Portable propane cylinder meeting Transport Canada specifications.

UEL (Upper Explosive Limit): Maximum propane concentration in air that will ignite (9.5%).

Ullage: Space in tank above liquid level; required for liquid expansion (20% minimum).

Vapor Pressure: Pressure exerted by propane vapor in closed container; varies with temperature.

Vaporization: Process of liquid propane converting to vapor by absorbing heat.

Weathering: Preferential vaporization of lighter components, leaving heavier components in liquid.

Wobbe Index: Heating value divided by square root of specific gravity (propane ≈ 2,100).

End of Chapter 5