

CHAPTER 18

Propane Systems and Installations

Learning Objectives

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

1. Design single-stage and two-stage propane systems for various applications
2. Select and size propane tanks and cylinders according to CSA B149.2 requirements
3. Install and configure propane regulators for proper pressure reduction
4. Size and install propane piping systems with appropriate correction factors
5. Convert natural gas appliances to propane following manufacturer specifications
6. Handle and store propane cylinders safely according to TDG regulations
7. Commission propane systems with proper testing and documentation
8. Calculate propane vaporization rates and system capacities
9. Troubleshoot common propane system problems
10. Apply CSA B149.2 Propane Storage and Handling Code requirements

18.1 Propane System Design

Propane systems require careful design to ensure adequate supply, proper pressure, and safe operation under all conditions.

System Fundamentals

Understanding propane properties is essential for proper system design.

Propane Properties

Physical Characteristics:

- Chemical formula: C_3H_8
- Molecular weight: 44.1
- Specific gravity (gas): 1.52
- Specific gravity (liquid): 0.504
- Boiling point: $-44^{\circ}F$ ($-42^{\circ}C$)
- Vapor pressure at $70^{\circ}F$: 127 psig
- Vapor pressure at $100^{\circ}F$: 196 psig
- Expansion ratio: 270:1 (liquid to gas)
- BTU per gallon: 91,547
- BTU per pound: 21,548
- BTU per cubic foot: 2,516

Vaporization Characteristics:

- Latent heat of vaporization: 184 BTU/lb
- Temperature drop during vaporization
- Frost formation on tanks
- Vaporization rates vary with temperature
- Wetted surface area critical

Safety Properties:

- Flammability limits: 2.15% - 9.6%
- Ignition temperature: 920°F - 1,020°F
- Heavier than air (pools in low areas)
- Odorant added (ethyl mercaptan)
- Non-toxic but asphyxiant

Single-Stage vs. Two-Stage Systems

System configuration depends on application requirements and local codes.

Single-Stage Systems

Applications:

- Small residential systems
- Single appliance installations
- Cylinders under 420 lbs
- Short piping runs
- Moderate flow requirements

Components:

- Tank or cylinder
- Single regulator (tank to 11" W.C.)
- Piping system
- Appliance connections
- Safety devices

Advantages:

- Simple installation
- Lower initial cost
- Fewer components
- Easier troubleshooting
- Minimal maintenance

Disadvantages:

- Pressure variation with temperature
- Limited capacity
- Shorter regulator life
- Less precise pressure control
- Not suitable for large loads

Pressure Characteristics:

- Inlet: Tank pressure (varies)
- Outlet: 11" W.C. nominal
- Variation: ± 2 " W.C. typical
- Lock-up pressure: 14" W.C. maximum
- Temperature effect: Significant

Two-Stage Systems

Applications:

- Large residential systems
- Commercial installations
- Multiple appliances
- Long piping runs
- Critical pressure requirements

Components:

- Tank or multiple tanks
- First-stage regulator (tank to 10 psi)
- Second-stage regulator (10 psi to 11" W.C.)
- Piping systems (high and low pressure)
- Multiple appliances
- Safety and monitoring devices

Advantages:

- Consistent delivery pressure
- Better cold weather performance
- Longer regulator life
- Higher capacity
- More precise control

Disadvantages:

- Higher initial cost
- More complex installation
- Additional components

- More potential failure points
- Requires higher skill level

Pressure Characteristics:

- First stage inlet: Tank pressure
- First stage outlet: 10 psi typical
- Second stage inlet: 10 psi
- Second stage outlet: 11" W.C.
- Variation: ± 1 " W.C. typical

Design Considerations:

- Distance between stages
- Pipe sizing between stages
- Regulator sizing
- Relief valve placement
- System monitoring

Vapor Withdrawal Systems

Most common propane system type for residential and light commercial use.

System Design Principles

Vaporization Capacity:

Tank vaporization depends on:

- Tank size (wetted surface area)
- Liquid level (% full)
- Ambient temperature
- Withdrawal rate
- Tank design (above/below ground)

Vaporization Rates (Continuous):

Tank Size	0°F	20°F	40°F	60°F
100 lb cylinder	8,000	14,000	24,000	36,000
420 lb cylinder	28,000	49,000	84,000	126,000
500 gal tank	168,000	294,000	504,000	756,000
1000 gal tank	308,000	539,000	924,000	1,386,000

Values in BTU/hr at 50% full

Temperature Effects:

- Pressure drops with temperature
- Vaporization reduces tank temperature
- Frost indicates high withdrawal rate
- Ambient temperature critical
- Tank heating sometimes required

System Components:

1. **Storage Tank/Cylinder**
 - Properly sized for load
 - Located for vaporization
 - Protected from damage
 - Accessible for filling
 - Relief valve equipped
2. **Vapor Service Valve**
 - Located in vapor space
 - Excess flow protection
 - Back-check capability
 - Service shutoff
 - Pressure gauge connection
3. **Regulators**
 - Sized for maximum flow
 - Proper inlet/outlet ratings
 - Vent protection
 - Relief valve provisions
 - Lock-up pressure suitable
4. **Piping System**
 - Sized for flow and distance
 - Protected from damage
 - Proper materials
 - Expansion provisions
 - Testing capabilities

Design Calculations:

Example System:

- Total load: 250,000 BTU/hr
- Design temperature: 0°F
- Distance to appliances: 150 feet

Tank Sizing:

- Required vaporization: 250,000 BTU/hr

- 500 gal tank at 0°F: 168,000 BTU/hr
- Need larger tank or multiple tanks
- Select: 1000 gal tank (308,000 BTU/hr at 0°F)

Liquid Withdrawal Systems

Used for high-capacity commercial and industrial applications.

System Applications

When Required:

- Vaporization exceeds tank capacity
- Consistent high flow rates
- Cold climate operations
- Process applications
- Fork truck filling

Components Required:

1. **Liquid Withdrawal Valve**
 - Dip tube to tank bottom
 - Excess flow valve
 - Manual shutoff
 - Hydrostatic relief
 - Back-check valve
2. **Vaporizer**
 - Sized for maximum flow
 - Heat source (electric/steam/water)
 - Temperature controls
 - Safety shut-offs
 - Pressure relief
3. **High-Pressure Piping**
 - Schedule 80 steel
 - Pressure rated fittings
 - Hydrostatic relief valves
 - Proper supports
 - Insulation if required

Vaporizer Types:

Direct-Fired Vaporizers:

- Propane-fired heat source
- 1-2% of vaporized gas used
- Automatic operation

- 100,000 - 10,000,000 BTU/hr
- Stand-alone operation

Electric Vaporizers:

- Immersion heaters
- Precise temperature control
- No combustion products
- 50,000 - 500,000 BTU/hr
- Higher operating cost

Steam/Hot Water Vaporizers:

- Uses available steam/hot water
- Shell and tube design
- No additional fuel cost
- 100,000 - 5,000,000 BTU/hr
- Requires utility source

Ambient Air Vaporizers:

- No external heat source
- Limited by ambient temperature
- Fins for heat transfer
- 50,000 - 250,000 BTU/hr
- Supplemental heat often needed

Safety Requirements:

- Pressure relief valves
- Temperature controls
- High-temperature shut-off
- Low-temperature alarm
- Excess flow protection
- Emergency shutdown
- Ventilation requirements
- Electrical classification

System Component Selection

Proper component selection ensures reliable and safe operation.

Tank/Cylinder Selection Factors

Capacity Requirements:

- Peak hourly demand
- Continuous demand
- Future expansion
- Vaporization capacity
- Storage capacity
- Delivery frequency

Installation Factors:

- Available space
- Access for delivery
- Setback requirements
- Above/below ground
- Local code restrictions
- Aesthetic concerns

Cost Considerations:

- Initial tank cost
- Installation cost
- Rental vs. purchase
- Delivery charges
- Maintenance costs
- Insurance requirements

Regulator Selection

Sizing Factors:

- Maximum flow rate
- Inlet pressure range
- Outlet pressure required
- Pressure drop allowable
- Temperature range
- Accuracy requirements

Types by Application:

Application	First Stage	Second Stage
Residential	10-15 psi	11" W.C.
Commercial	10-20 psi	11-14" W.C.
Industrial	5-125 psi	Various
Fork trucks	Liquid to vapor	Varies

Features to Consider:

- Internal relief valve
- Vent limiting device
- Integral two-stage
- Automatic changeover
- OPSO (over-pressure shut-off)
- UL/CSA listing

Piping Component Selection

Material Options:

- Steel pipe (Schedule 40)
- Copper tubing (Type K or L)
- CSST (Corrugated Stainless Steel Tubing)
- Polyethylene (underground only)
- Stainless steel

Fitting Selection:

- Malleable iron (indoor)
- Forged steel (high pressure)
- Brass (certain applications)
- Flare fittings (copper)
- Compression fittings (limited use)

Valve Selection:

- Ball valves (full port)
- Appliance connectors
- Service valves
- Emergency shutoffs
- Excess flow valves

Pressure Requirements at Appliances

Maintaining proper pressure ensures safe and efficient operation.

Standard Pressure Requirements

Residential Appliances:

- Design pressure: 11" W.C.
- Minimum: 10" W.C.
- Maximum: 13" W.C.
- Measured at appliance inlet
- Full flow conditions

Commercial Equipment:

- Standard: 11" W.C.
- Some equipment: 14" W.C.
- Others: 2 psi or higher
- Manufacturer specifications
- Dedicated regulators possible

Pressure Drop Calculations

Allowable Pressure Drop:

- Residential: 0.5" W.C. maximum
- Commercial: 1" W.C. typical
- Industrial: Per design
- High pressure: 10% of initial
- Between stages: 10% maximum

Factors Affecting Pressure:

1. Pipe Friction

- Length of run
- Pipe diameter
- Flow rate
- Specific gravity
- Pipe roughness

2. Fitting Losses

- Equivalent lengths
- Valve restrictions
- Direction changes
- Diameter changes
- Connection types

3. Elevation Changes

- 0.5" W.C. per 100 ft rise
- Affects low pressure systems
- Negligible in high pressure
- Consider in design

4. Temperature Effects

- Gas density changes
- Regulator performance
- Tank pressure variation
- Vaporization rates
- Material expansion

Verification Methods:

- Manometer testing
- Digital pressure gauges
- Chart recorders
- Data loggers
- Remote monitoring

Testing Conditions:

- All appliances operating
- Maximum flow conditions
- Cold weather testing
- Documentation required
- Annual verification

18.2 Propane Tanks and Cylinders

Proper tank and cylinder selection, installation, and maintenance ensure safe propane storage.

DOT/TC Cylinder Specifications

Cylinders are manufactured and certified to Department of Transportation (DOT) or Transport Canada (TC) specifications.

Cylinder Types and Sizes

Common Cylinder Sizes:

Size	Water Capacity	Propane Capacity	Dimensions	Weight (Empty)
20 lb	47.6 lbs	20 lbs	18"H × 12"D	18 lbs
30 lb	71.4 lbs	30 lbs	24"H × 12"D	25 lbs
40 lb	95.2 lbs	40 lbs	29"H × 12"D	29 lbs
100 lb	238 lbs	100 lbs	48"H × 15"D	67 lbs
420 lb (100 gal)	1000 lbs	420 lbs	53"H × 30"D	209 lbs

Cylinder Specifications:

- Material: Steel or aluminum
- Design pressure: 240-312 psig
- Test pressure: 480 psig minimum
- Safety factor: 4:1
- Relief valve: 375 psig typical

Cylinder Markings:

- TC or DOT specification

- Serial number
- Manufacture date
- Test date
- Tare weight
- Water capacity
- Requalification marks

Requalification Requirements:

- Visual inspection: 5, 10, or 12 years
- Depends on cylinder type
- Hydrostatic testing if required
- Stamping of new date
- Must be current for filling

Valve Types:

POL Valve (obsolete):

- Left-hand thread
- No excess flow protection
- Being phased out
- Not on new cylinders

ACME/Type 1 Valve:

- Right-hand thread
- External ACME thread
- Internal POL thread
- Excess flow protection
- Thermal protection

Quick-Connect Valve:

- Push-to-connect
- Automatic shut-off
- Common on RV cylinders
- Various styles
- Safety features built-in

ASME Tank Specifications

ASME tanks are designed for stationary installations.

Tank Sizes and Capacities

Common Tank Sizes:

Nominal Size	Water Capacity	Propane Capacity	Dimensions
120 gal	499 lbs	96 gal	54"D × 44"L
250 gal	1040 lbs	200 gal	30"D × 94"L
500 gal	2080 lbs	400 gal	37"D × 119"L
1000 gal	4160 lbs	800 gal	41"D × 192"L
2000 gal	8320 lbs	1600 gal	48"D × 293"L

Tank Construction:

- Material: Carbon steel
- Wall thickness: 1/4" minimum
- Heads: Dished or hemispherical
- Design pressure: 250 psig
- Test pressure: 325 psig

Required Appurtenances:

1. **Fill Valve**
 - 1¼" or 1¾" ACME
 - Back-check valve
 - Excess flow protection
 - Double back-check available
2. **Relief Valve**
 - Sized per code
 - 250 psig start-to-discharge
 - Full relief at 375 psig
 - Rain cap required
 - Annual inspection
3. **Service Valve**
 - Vapor or liquid withdrawal
 - Excess flow protection
 - Manual shutoff
 - Pressure gauge port
4. **Fixed Liquid Level Gauge**
 - 80% maximum fill
 - Dip tube design
 - Bleed valve operation
 - Used during filling
5. **Float Gauge**
 - Percentage indication
 - Magnetic or mechanical
 - Remote reading available
 - Not for filling

Underground Tank Requirements:

- Coating: Epoxy or polyurethane
- Cathodic protection required
- Minimum 6" cover
- Concrete anchors if required
- Special valves and dome
- Access risers needed
- Leak detection considered

Tank Sizing Methods

Proper tank sizing ensures adequate supply without excessive cost.

Sizing Calculations

Factors to Consider:

1. **Peak Load**
 - Maximum hourly demand
 - All appliances operating
 - Future additions
 - Safety factor (1.25)
2. **Vaporization Rate**
 - Ambient temperature
 - Tank wetted surface
 - Continuous vs. intermittent
3. **Storage Capacity**
 - Days between deliveries
 - Seasonal variations
 - Emergency reserve
 - Delivery availability

Sizing Methods:

Method 1: Vaporization Limited

Example:

- Peak load: 200,000 BTU/hr
- Design temperature: -10°F
- Continuous operation

Calculation:

- 500 gal tank at -10°F: 100,000 BTU/hr

- Need multiple tanks or vaporizer
- Select: Two 500 gal tanks manifolded

Method 2: Storage Limited

Example:

- Average daily use: 50 gallons
- Delivery frequency: Monthly
- Reserve required: 20%

Calculation:

- Monthly use: $50 \times 30 = 1,500$ gallons
- Add reserve: $1,500 \times 1.2 = 1,800$ gallons
- Tank capacity at 80%: $1,800/0.8 = 2,250$ gallons
- Select: 2000 gal tank or larger

Method 3: Combined Approach

- Check both vaporization and storage
- Select larger requirement
- Consider cost optimization
- Future expansion capability
- Local delivery practices

Load Diversity Factors:

Application Diversity Factor

Single family 1.00

2-4 units 0.85

5-10 units 0.75

11-20 units 0.65

Over 20 units 0.60

Fill Limits and Ullage

Proper fill limits ensure safe tank operation under all conditions.

Maximum Fill Regulations

CSA B149.2 Requirements:

- Maximum fill: 80% by volume
- Allows for liquid expansion

- Temperature correction required
- Fixed liquid level gauge used
- Automatic fill stop available

Volume Correction Factors:

Liquid Temp Correction Factor

-40°F	0.867
-20°F	0.893
0°F	0.919
20°F	0.946
40°F	0.973
60°F	1.000
80°F	1.029
100°F	1.058

Example Calculation:

- 500 gal tank
- Liquid temperature: 30°F
- Correction factor: 0.960
- Maximum gallons: $500 \times 0.80 \times 0.960 = 384$ gallons

Ullage Space Functions:

- Liquid expansion space
- Vapor space for withdrawal
- Safety margin
- Pressure relief operation
- Prevents liquid relief

Overfilling Hazards:

- Liquid discharge from relief valve
- Hydraulic tank rupture possible
- No vapor for vapor service
- Increased fire hazard
- Environmental damage

Prevention Methods:

- Fixed liquid level gauge
- Automatic stop-fill valves
- Percentage gauges

- Delivery procedures
- Driver training

Tank Placement Requirements per CSA B149.2

Proper tank placement ensures safety and accessibility.

Above-Ground Installation Requirements

Minimum Distances from Buildings:

Tank Size	From Buildings	From Property Line	Between Tanks
<125 gal	10 feet	10 feet	3 feet
125-500 gal	10 feet	10 feet	3 feet
501-2000 gal	25 feet	10 feet	3 feet
2001-30,000 gal	50 feet	25 feet	5 feet

Distances from Ignition Sources:

- Air intakes: 10 feet minimum
- Direct vent appliances: 10 feet
- Windows/doors: 10 feet
- Electrical sources: 10 feet
- Property lines: 10 feet minimum

Special Considerations:

- Measured from relief valve
- Horizontal distance
- May be reduced with barriers
- Local codes may vary
- Insurance requirements

Support Requirements:

- Concrete pad preferred
- Level and stable
- Saddles for horizontal tanks
- Legs for vertical tanks
- Frost protection

Protection Requirements:

- Vehicle impact protection
- Security fencing considered

- Tampering prevention
- Visibility for delivery
- Emergency access maintained

Setback Distances from Buildings and Property Lines

Critical safety distances must be maintained.

Factors Affecting Setbacks

Tank Capacity:

- Larger tanks = greater distance
- Based on water capacity
- Aggregate capacity for multiple tanks
- Relief valve capacity considered
- Fire exposure calculations

Building Factors:

- Occupancy type
- Construction type
- Fire rating
- Openings present
- Height considerations

Reduction Methods:

Fire Walls:

- 2-hour rating minimum
- Extends 1 foot beyond tank
- Height per code
- No openings
- Reduces distance 50%

Underground Installation:

- Eliminates some distances
- Cover requirements
- Vehicular traffic protection
- Special equipment needed
- Higher installation cost

Special Locations:

Schools and Churches:

- Increased distances
- 50 feet typical minimum
- Local regulations vary
- Additional protection
- Emergency planning

Hospitals and Assemblies:

- Maximum distances
- Special permits
- Emergency shutoffs
- Fire department input
- Risk assessment required

Mobile Home Parks:

- Individual tank restrictions
- Central system preferred
- Special setbacks
- Additional safety measures
- Tenant education required

Underground Tank Installations

Underground installations offer advantages but require special considerations.

Installation Requirements**Excavation:**

- Depth: 6" minimum cover
- Width: Tank diameter + 2 feet
- Length: Tank length + 4 feet
- Stable soil required
- Dewatering if needed

Bedding:

- 6" sand or pea gravel
- Compacted base
- No rocks or debris
- Level surface
- Drainage considered

Tank Preparation:

- Coating inspection
- Soap test for leaks
- Anodes installed
- Risers attached
- Valves protected

Placement:

- Crane or excavator
- Careful lowering
- Proper orientation
- No coating damage
- Temporary supports

Backfilling:

- Clean fill material
- 6" lifts compacted
- No damage to coating
- Risers plumb
- Proper cover depth

Corrosion Protection**Coating Systems:**

- Epoxy coating
- Polyurethane coating
- Fiberglass wrapping
- Multiple coats
- Holiday testing required

Cathodic Protection:**Sacrificial Anodes:**

- Magnesium anodes common
- Connected to tank
- 30-year life typical
- Testing required
- Replacement possible

Impressed Current:

- External power source
- Permanent anodes
- Adjustable protection
- Monitoring required
- Professional design

Testing Requirements:

- Initial testing
- Annual monitoring
- -850 mV criterion
- Records maintained
- Professional testing

Special Considerations**High Water Table:**

- Anchoring required
- Concrete deadmen
- Calculation required
- Buoyancy prevention
- Extra excavation

Vehicular Traffic:

- Minimum 3 feet cover
- Concrete slabs possible
- Load calculations
- Warning markers
- Protection barriers

Access Requirements:

- Dome covers at grade
- Riser extensions
- Service accessibility
- Filling access
- Emergency access

Advantages:

- No distance requirements
- Protected from impact
- Temperature stable
- Aesthetic benefits

- Security advantages

Disadvantages:

- Higher installation cost
- Corrosion concerns
- Difficult inspection
- Leak detection harder
- Removal expensive

18.3 Propane Regulators

Regulators reduce and control propane pressure for safe appliance operation.

Regulator Fundamentals

Understanding regulator operation ensures proper selection and installation.

Operating Principles**Basic Components:**

- 1. Diaphragm**
 - Flexible membrane
 - Separates chambers
 - Transmits force
 - Various materials
 - Size affects capacity
- 2. Loading Spring**
 - Provides set force
 - Adjustable or fixed
 - Determines outlet pressure
 - Spring rate critical
 - Temperature compensated
- 3. Orifice and Seat**
 - Controls gas flow
 - Precision machined
 - Various materials
 - Replaceable design
 - Size affects capacity
- 4. Relief Valve**
 - Internal or external
 - Protects downstream
 - Set above outlet pressure
 - Vents to atmosphere
 - Required by code

Operating Sequence:

1. Spring force opens orifice
2. Gas flows through regulator
3. Downstream pressure builds
4. Pressure opposes spring
5. Equilibrium reached
6. Flow variations compensated

Performance Characteristics:

- Droop: Pressure decrease with flow
- Lock-up: No-flow outlet pressure
- Hysteresis: Pressure difference
- Accuracy: ± 1 " W.C. typical
- Temperature effect: Varies

First-Stage Regulators (High Pressure to 10 psi)

First-stage regulators handle tank pressure variations.

Specifications and Selection

Pressure Ratings:

- Inlet: 250 psig maximum
- Outlet: 10 psi typical
- Relief: 30 psi typical
- Temperature: -40°F to 140°F
- Materials: Aluminum or zinc

Capacity Ratings:

Orifice Size Capacity (BTU/hr)

3/32"	150,000
1/8"	300,000
3/16"	675,000
1/4"	1,200,000
5/16"	1,875,000

Features:

- Inlet filter screen
- Vent limiting device
- Integral relief valve

- Pressure tap
- Adjustable outlet

Installation Requirements

Location:

- At tank or nearby
- Protected from damage
- Accessible for service
- Above snow line
- Vent pointed down

Orientation:

- Vent downward
- Level installation
- Flow arrow observed
- Proper support
- Service space

Venting Requirements:

- Point away from openings
- Minimum 5 feet from intakes
- Protected from blockage
- Screen if required
- Regular inspection

Piping Connections:

- Proper thread sealant
- No overtightening
- Union recommended
- Flexible connector
- Excess flow valve upstream

Cold Weather Considerations

Freezing Issues:

- Moisture in gas
- Regulator icing
- Reduced capacity
- Lock-up problems
- Relief valve freezing

Prevention Methods:

- Methanol injection
- Heat tape (approved type)
- Protective housing
- Regular maintenance
- Quality propane

Capacity Derating:**Temperature Capacity Factor**

60°F	100%
32°F	90%
0°F	75%
-20°F	60%
-40°F	45%

Second-Stage Regulators (10 psi to 11" W.C.)

Second-stage regulators provide final pressure reduction to appliances.

Types and Applications**Single Second-Stage:**

- Inlet: 10 psi
- Outlet: 11" W.C.
- Capacity: Various
- Relief: Internal
- Adjustable: Yes

Integral Two-Stage:

- Combined unit
- Compact design
- Single vent
- Cost effective
- Limited capacity

Line Regulators:

- Individual appliance
- 2 psi systems
- Special applications
- Compact size

- Various pressures

Selection Criteria

Sizing:

- Total connected load
- Simultaneous use factor
- Future expansion
- Minimum inlet pressure
- Maximum pressure drop

Example:

- Connected load: 350,000 BTU/hr
- Diversity: 0.7
- Design load: 245,000 BTU/hr
- Select: 1/2" regulator (300,000 BTU/hr)

Features to Consider:

- Vent limiting device
- Over-pressure protection
- Integral relief
- Token relief
- Screen protection

Installation Best Practices

Location:

- Protected from weather
- 5 feet from air intakes
- Above grade
- Accessible location
- Not in confined spaces

Support:

- Independent support
- No pipe stress
- Unions recommended
- Flexible connections
- Proper alignment

Protection:

- Regulator covers
- Vent protection
- Screen installation
- Lock provisions
- Vandalism prevention

Integral Two-Stage Regulators

Combines both stages in single housing.

Advantages

Benefits:

- Single unit installation
- Compact design
- Single vent location
- Cost effective
- Simplified piping
- Consistent performance
- Factory adjusted
- Reduced leak potential

Applications:

- Residential systems
- Small commercial
- Limited space
- Single tank systems
- Replacement installations

Limitations

Disadvantages:

- Limited capacity
- Both stages fail together
- Less flexibility
- Difficult troubleshooting
- Higher replacement cost

Capacity Limits:

- Typically under 1,000,000 BTU/hr
- Single tank applications
- Shorter distances

- Fewer appliances
- Standard pressures only

Installation Considerations

Mounting:

- At tank common
- Vertical orientation
- Proper support
- Weather protection
- Service access

Venting:

- Single vent point
- Proper termination
- Screen protection
- Regular inspection
- Clear of obstructions

Testing:

- Inlet pressure
- Interstage pressure
- Outlet pressure
- Lock-up test
- Relief valve test

Automatic Changeover Regulators

Provides continuous supply from multiple cylinders.

Operation and Features

Operating Principle:

1. Service side supplies gas
2. Pressure drops at depletion
3. Automatic switch to reserve
4. Indicator shows changeover
5. Empty cylinder replaced
6. System resets

Components:

- Two-stage regulator
- Changeover valve
- Check valves
- Indicator system
- Pigtails
- Mounting bracket

Specifications:

- Capacity: 200,000 BTU/hr typical
- Inlet: Two cylinders
- Outlet: 11" W.C.
- Changeover: 10 psig typical
- Indicator: Red/Green

Applications

Residential:

- Continuous supply required
- Remote locations
- Vacation homes
- Critical heating
- Customer convenience

Commercial:

- Restaurants
- Small businesses
- Emergency systems
- Process applications
- Backup systems

RV and Marine:

- Dual cylinder systems
- Extended trips
- Convenience
- Safety backup
- Space limitations

Installation Requirements

Cylinder Connections:

- High-pressure pigtails

- Proper length
- No kinks
- Regular inspection
- Replacement schedule

Mounting:

- Secure bracket
- Level installation
- Accessible location
- Protected position
- Clear indicator view

Operation:

- Initial setup
- Indicator monitoring
- Cylinder replacement
- Pressure testing
- Customer training

Relief Valve Requirements

Relief valves protect system components from overpressure.

Code Requirements

CSA B149.2 Requirements:

- Required on all regulators
- Internal or external
- Sized for capacity
- Set pressure specified
- Annual inspection

Relief Valve Settings:

System Component Relief Setting

First stage outlet 30 psi

Second stage outlet 2 psi

Appliance regulator 1 psi

Two-stage integral 2 psi

Types of Relief Valves

Internal Relief:

- Built into regulator
- Token relief common
- Limited capacity
- Factory set
- Non-adjustable

External Relief:

- Separate component
- Full capacity
- Replaceable
- Testable
- Various settings

Token Relief:

- Minimal flow
- Prevents damage
- Indicates problem
- Not full relief
- Warning function

Sizing Requirements**Capacity Calculation:**

- Based on regulator size
- Orifice area
- Set pressure
- Full flow conditions
- Safety factor

Relief Capacity Table:**Regulator Size Required Relief (CFH)**

3/8"	500
1/2"	800
3/4"	1,500
1"	2,500
1¼"	3,500

Vent Termination:

- Outside building
- 5 feet from openings
- Down orientation
- Protected location
- No blockage possible

Regulator Venting

Proper venting ensures safe operation and prevents gas accumulation.

Vent Requirements

Code Requirements:

- Must terminate outdoors
- Away from ignition sources
- Protected from blockage
- Accessible for inspection
- Proper materials

Distances:

- 5 feet from openings
- 10 feet from air intakes
- 3 feet from grade
- Away from alcoves
- Clear of snow line

Vent Piping

Materials:

- Copper tubing
- Steel pipe
- Flexible tubing (limited)
- Corrosion resistant
- Proper support

Sizing:

- Minimum 5/16" tubing
- Based on relief capacity
- Maximum 30 feet
- Minimal elbows
- No traps

Installation:

- Continuous slope
- No low points
- Secured properly
- Protected from damage
- Labeled if required

Vent Protection Devices**Vent Limiting Devices:**

- Limits gas escape
- Required in some areas
- Various designs
- Automatic reset
- Manual types available

Vent Protectors:

- Weather protection
- Screen protection
- Prevents blockage
- Removable for service
- Various designs

Common Problems:

- Spider webs
- Mud dauber nests
- Ice formation
- Paint blockage
- Corrosion

Maintenance:

- Annual inspection
- Clear obstructions
- Test operation
- Replace screens
- Document condition

18.4 Propane Piping

Proper piping design and installation ensure safe and adequate gas delivery.

Material Selection per CSA B149.2

Code-approved materials ensure system integrity.

Approved Materials

Steel Pipe:

- Schedule 40 minimum
- Black or galvanized
- ASTM A53 or A106
- Threaded or welded
- Most common material

Applications:

- Above ground
- Below ground (coated)
- High pressure
- Commercial/industrial
- Long runs

Copper Tubing:

- Type K or L
- No Type M allowed
- Flare fittings required
- Limited to 100 psig
- Common in residential

Applications:

- Above ground
- Below ground
- Residential systems
- Flexible installation
- Corrosion resistant

CSST (Corrugated Stainless Steel Tubing):

- Certified systems only
- Special fittings
- Lightning protection
- Flexible installation
- Labor saving

Applications:

- Interior only
- Residential/commercial
- Retrofits
- Earthquake zones
- Limited pressure

Polyethylene (PE):

- Underground only
- SDR 11 minimum
- Special fittings
- Tracer wire required
- Long life

Applications:

- Underground mains
- Distribution systems
- Yard lines
- Non-metallic preferred
- Corrosion immune

Prohibited Materials**Not Acceptable:**

- Cast iron pipe
- PVC pipe
- Aluminum tubing
- Galvanized steel (underground)
- Lead pipe
- Rubber hose (except listed)

Sizing Propane Piping

Proper sizing ensures adequate pressure at all appliances.

Sizing Methodology**Design Factors:**

1. **Total Load**
 - All connected appliances
 - Future additions

- Diversity factors
- Peak demand
- 2. **Allowable Pressure Drop**
 - 0.5" W.C. residential
 - 1.0" W.C. commercial
 - 10% high pressure
- 3. **Pipe Length**
 - Measured length
 - Fitting equivalents
 - Total equivalent length
- 4. **Specific Gravity**
 - Propane: 1.52
 - Correction required
 - From natural gas tables

Sizing Tables (11" W.C. System)

Capacity in CFH (Propane) - Schedule 40 Pipe:

Pipe Size	20 ft	40 ft	60 ft	80 ft	100 ft
1/2"	235	160	129	110	98
3/4"	490	336	273	234	208
1"	925	636	516	443	393
1¼"	1,900	1,305	1,060	910	807
1½"	2,750	1,890	1,535	1,318	1,169
2"	4,500	3,093	2,513	2,157	1,913

High Pressure Sizing (10 psi System):

Pipe Size	50 ft	100 ft	200 ft	300 ft	400 ft
1/2"	5,890	3,980	2,680	2,130	1,810
3/4"	12,400	8,380	5,640	4,480	3,810
1"	23,500	15,800	10,600	8,460	7,190
1¼"	48,200	32,500	21,900	17,400	14,800

Specific Gravity Correction Factors

Propane requires correction from natural gas sizing tables.

Correction Formula:

Propane Capacity = Natural Gas Capacity $\times \sqrt[0.60/1.52]{}$ Propane Capacity = Natural Gas Capacity $\times 0.63$

Application:

Example:

- Natural gas table: 1,000 CFH
- Propane correction: $1,000 \times 0.63$
- Propane capacity: 630 CFH

Pressure Correction:

Different pressures require additional corrections:

Inlet Pressure Pressure Drop Multiplier

11" W.C.	0.5" W.C.	1.00
2 psi	3.5" W.C.	2.04
5 psi	1 psi	3.23
10 psi	1 psi	4.47

Temperature Correction:

Gas Temperature Correction Factor

32°F	1.07
50°F	1.00
70°F	0.93
90°F	0.87

Vapor Piping vs. Liquid Piping

Different requirements for vapor and liquid service.

Vapor Piping Systems

Characteristics:

- Low pressure (under 125 psi)
- Larger pipe sizes
- Standard materials
- Simple installation
- Most common type

Design Considerations:

- Pipe sizing critical
- Pressure drop limits

- Condensation drainage
- Thermal expansion
- Support requirements

Installation:

- Slope for drainage
- Drip legs if required
- Proper supports
- Protection from damage
- Testing requirements

Liquid Piping Systems**Characteristics:**

- High pressure (up to 250 psi)
- Smaller pipe sizes
- Special materials
- Safety considerations
- Limited applications

Design Requirements:

- Hydrostatic relief valves
- Every 50 feet maximum
- Between shutoff valves
- Thermal expansion protection
- Excess flow valves

Materials:

- Schedule 80 steel
- Seamless copper
- Special fittings
- Welded preferred
- Pressure ratings verified

Safety Devices:

- Excess flow valves
- Emergency shutoffs
- Hydrostatic reliefs
- Pressure gauges
- Warning signs

Installation Requirements

Proper installation ensures safety and reliability.

Above-Ground Installation

Support Requirements:

Pipe Size Support Spacing

1/2" - 3/4" 6 feet

1" - 1 1/4" 8 feet

1 1/2" - 2" 10 feet

Over 2" 12 feet

Support Types:

- Pipe hangers
- Brackets
- Straps
- Stands
- Spring hangers

Expansion Provisions:

- Expansion loops
- Offsets
- Flexible connectors
- Swing joints
- Expansion joints

Protection Requirements:

- Vehicle barriers
- Warning signs
- Protective coating
- Insulation if required
- Security measures

Underground Installation

Trenching Requirements:

- Minimum 12" cover
- 18" for vehicular traffic
- 6" sand bedding

- Warning tape
- Proper backfill

Corrosion Protection:

Steel Pipe:

- Wrapped and coated
- Cathodic protection
- Electrical isolation
- Test stations
- Regular monitoring

Copper Tubing:

- Generally not required
- Sacrificial anodes optional
- Dielectric fittings
- Proper bedding
- Quality backfill

PE Pipe:

- No protection required
- Tracer wire mandatory
- Proper bedding
- Snake during installation
- Marking tape

Installation Steps:

1. Excavate trench
2. Prepare bedding
3. Inspect pipe/coating
4. Lower carefully
5. Connect and test
6. Backfill properly
7. Mark location
8. Document as-built

Protection from Damage

Physical protection prevents pipe damage.

Mechanical Protection

Vehicle Protection:

- Bollards
- Barriers
- Curbs
- Fencing
- Warning signs

Above Ground:

- Pipe guards
- Channels
- Sleeves
- Proper height
- Visibility

Underground:

- Adequate depth
- Sleeving
- Concrete slabs
- Warning tape
- Locate services

Sleeving Requirements**Where Required:**

- Wall penetrations
- Floor penetrations
- Under slabs
- Road crossings
- Corrosive soil

Sleeve Specifications:

- Two sizes larger
- Sealed ends
- Vented to atmosphere
- Non-corrosive material
- Proper support

Installation:

- Center pipe in sleeve
- Seal with mastic

- Vent above grade
- Support independently
- Mark locations

Electrical Protection

Bonding Requirements:

- CSST systems
- Lightning protection
- Equipment grounding
- Continuity maintained
- Proper clamps

Dielectric Isolation:

- Underground transitions
- Dissimilar metals
- Cathodic protection
- Test stations
- Regular testing

18.5 Propane Appliance Conversion

Converting appliances between fuel types requires careful attention to safety and performance.

Natural Gas to Propane Conversion

Many appliances can be converted between natural gas and propane.

Conversion Feasibility

Convertible Appliances:

- Most residential furnaces
- Water heaters
- Ranges and cooktops
- Dryers
- Some commercial equipment

Non-Convertible Appliances:

- High-efficiency furnaces (some)
- Sealed combustion units (some)
- Certain imported appliances
- Old equipment

- Units without conversion kits

Manufacturer Requirements:

- Conversion kit available
- Instructions provided
- Certification maintained
- Warranty considerations
- Technical support

Conversion Kit Components:

1. Orifices

- Main burner
- Pilot orifice
- Properly sized
- Brass construction
- Marked with size

2. Springs

- Gas valve springs
- Regulator springs
- Pressure adjustment
- Proper rating

3. Labels

- Conversion label
- Rating plate update
- Instructions
- Warnings
- Date/technician

4. Instructions

- Step-by-step procedure
- Specifications
- Adjustment procedures
- Testing requirements
- Troubleshooting

Orifice Changes

Orifice sizing is critical for proper combustion.

Orifice Sizing Principles

Flow Relationship:

Propane orifices are smaller due to:

- Higher heat content (2,516 BTU/ft³ vs 1,000)
- Higher pressure (11" W.C. vs 7" W.C.)
- Different specific gravity (1.52 vs 0.60)

Size Reduction:

Natural gas to propane:

- Approximately 0.63 area ratio
- 1.5 to 2 drill sizes smaller
- Varies by appliance
- Must use kit orifices

Common Orifice Sizes:

BTU Rating	Natural Gas	Propane
10,000	#42 (0.094")	#54 (0.055")
20,000	#35 (0.110")	#48 (0.076")
30,000	#30 (0.129")	#44 (0.086")
40,000	#26 (0.147")	#41 (0.096")

Orifice Identification:

- Stamped size
- Drill number
- Decimal size
- Color coding
- Part numbers

Installation Procedure

Preparation:

1. Turn off gas supply
2. Turn off electricity
3. Allow cooling
4. Gather tools
5. Review instructions

Main Burner Orifices:

1. Access burner compartment
2. Remove burners if needed
3. Remove old orifices
4. Install new orifices

5. Do not overtighten
6. Check alignment

Pilot Orifice:

1. Remove pilot assembly
2. Replace pilot orifice
3. Adjust pilot bracket
4. Reinstall assembly
5. Check positioning

Common Mistakes:

- Wrong orifice size
- Damaged threads
- Improper sealing
- Lost orifices
- Incorrect installation

Pressure Adjustments

Gas valve adjustments ensure proper operation.

Gas Valve Adjustments

Manifold Pressure:

Fuel Type Manifold Pressure

Natural Gas 3.5" W.C.

Propane 10.0" W.C.

Adjustment Procedure:

1. Connect manometer
2. Remove regulator cap
3. Start appliance
4. Adjust regulator screw
5. Clockwise increases
6. Set to specification
7. Replace cap
8. Verify operation

Multi-Stage Equipment:

- High fire adjustment
- Low fire adjustment

- Modulating controls
- Electronic calibration
- Factory consultation

Pilot Adjustment:

- Flame characteristics
- Thermocouple engulfment
- Proper impingement
- Stable operation
- Safety shutdown test

Electronic Controls:

- DIP switch settings
- Parameter changes
- Combustion settings
- Safety timings
- Diagnostic codes

Vent System Evaluation

Venting requirements may change with fuel conversion.

Venting Considerations**Category I Appliances:**

- Generally no change
- Verify draft
- Check sizing
- Inspect condition
- Clean if needed

High-Efficiency Appliances:

- May require different venting
- Condensate pH different
- Materials compatibility
- Manufacturer specifications
- Professional evaluation

Common Venting:

- Recalculate sizing
- Verify adequate draft

- Check for condensation
- Inspect for corrosion
- May require relining

Draft Testing:

- Measure with all appliances
- Worst-case depressurization
- Spillage testing
- CAZ testing
- Document results

Combustion Testing Post-Conversion

Proper combustion testing verifies safe operation.

Required Tests

Gas Pressure:

- Inlet pressure: 11" W.C.
- Manifold pressure: 10" W.C.
- Verify with manometer
- All burners operating
- Document readings

Combustion Analysis:

Parameter Acceptable Range

CO <100 ppm air-free

O₂ 5-9%

CO₂ 8-11%

Stack temp 350-500°F

Draft -0.02" to -0.04"

Flame Characteristics:

- Blue flame
- Minimal yellow tips
- Stable flame
- No lifting
- No flashback
- Proper impingement

Performance Tests

Temperature Rise:

- Measure supply/return
- Within manufacturer range
- Proper airflow
- Heat exchanger condition
- Document results

Input Verification:

- Clock gas meter
- Calculate BTU input
- Compare to rating
- Adjust if needed
- Within $\pm 5\%$

Safety Tests:

- Spillage test
- CO in space
- Limit operation
- Safety controls
- Proper venting

Documentation:

- Conversion checklist
- Test results
- Photos
- Serial numbers
- Warranty registration

Labeling Requirements

Proper labeling ensures future safety and compliance.

Required Labels**Conversion Label:**

Content required:

- "CONVERTED TO PROPANE"
- Date of conversion
- Technician name
- Company name

- Phone number

Location:

- Adjacent to rating plate
- Visible location
- Permanent attachment
- Weather resistant
- Clear and legible

Rating Plate Update:

- Cross out old fuel
- Mark new fuel
- Update input if changed
- New orifice sizes
- Maintain legibility

Additional Labels:

- Gas type at shutoff
- Regulator settings
- Special instructions
- Warning labels
- Service reminders

Documentation Requirements

Conversion Certificate:

- Appliance information
- Conversion kit used
- Test results
- Customer signature
- Copy to customer

Permit Requirements:

- Local permit
- Inspection required
- Code compliance
- Insurance notification
- Utility notification

Warranty Considerations:

- Manufacturer warranty
- Conversion kit warranty
- Installation warranty
- Documentation retained
- Customer informed

18.6 Cylinder Storage and Handling

Safe cylinder handling prevents accidents and ensures code compliance.

Storage Requirements

Proper storage protects cylinders and ensures safety.

Outdoor Storage

Location Requirements:

- Well-ventilated area
- Away from buildings
- No basement storage
- Level surface
- Secured from falling

Distances Required:

Quantity Stored From Buildings From Property Line

<500 lbs	0 feet	0 feet
500-2,500 lbs	10 feet	10 feet
2,500-10,000 lbs	25 feet	25 feet
Over 10,000 lbs	50 feet	50 feet

Storage Arrangements:

- Upright position
- Valve protection
- Separated full/empty
- First in, first out
- Clear access paths

Weather Protection:

- Out of direct sun
- Protected from rain
- Above snow line

- Ventilated enclosure
- No heat sources

Indoor Storage

Prohibited Locations:

- Basements
- Below grade
- Enclosed spaces
- Near exits
- High traffic areas

Special Requirements:

- Ventilated cages
- Explosion-proof electrical
- No ignition sources
- Limited quantities
- Fire-rated construction

Quantity Limits:

Occupancy Type	Maximum Storage
Residential	Two 20 lb cylinders
Commercial	300 lbs
Industrial	Per fire code
Retail display	135 lbs water capacity

Exchange Cage Storage

Requirements:

- Ventilated design
- Lockable
- Non-combustible
- Secured/anchored
- Proper signage

Location:

- Outside building
- Accessible location
- Away from ignition
- Vehicle protection

- Emergency access

Capacity:

- Local regulations
- Insurance requirements
- 500 lbs typical
- Separation distances
- Fire department approval

Transportation Regulations (TDG)

Transportation of Dangerous Goods regulations apply.

TDG Requirements

Classification:

- Class 2.1: Flammable gas
- UN1978: Propane
- Packing group: N/A
- Placarding required >500 kg

Driver Requirements:

Quantity	Requirements
<500 kg	Valid driver's license
>500 kg	TDG certificate
Bulk	Commercial endorsement

Vehicle Requirements:

- Ventilated vehicle
- Secured cylinders
- Upright position
- No smoking
- Fire extinguisher

Documentation:

- Shipping document
- Emergency response info
- 24-hour phone number
- Product identification
- Quantity declaration

Cylinder Transport

In Vehicles:

- Maximum 5 cylinders
- Total 500 kg limit
- Secured upright
- Valve protection
- Ventilation required

Prohibited:

- Closed trunks
- Passenger compartments
- Public transit
- Unattended vehicles
- Without valve caps

Pick-up Trucks:

- Secured in bed
- Upright position
- Not in cab
- Proper restraints
- Warning labels

Trailers:

- Proper placarding
- Secured load
- Safety chains
- Brake requirements
- Light requirements

Emergency Response

Required Equipment:

- 2.3 kg fire extinguisher
- Warning devices
- PPE
- Spill kit (bulk)
- First aid kit

Accident Procedures:

1. Secure scene
2. Eliminate ignition sources
3. Evacuate area
4. Call emergency services
5. Provide TDG information
6. Document incident

Cylinder Filling Procedures

Safe filling procedures prevent overfilling and accidents.

Pre-Fill Inspection

Cylinder Checks:

- Current qualification date
- Visual damage inspection
- Valve condition
- Proper tare weight
- Correct type
- Clean and dry

Reject Cylinders With:

- Expired qualification
- Visible damage
- Fire damage
- Deep rust
- Altered valves
- Unknown history

Filling Equipment

Required Components:

- Certified scale
- Fill hose and nozzle
- Bleed valve
- Emergency shut-off
- Proper lighting
- PPE

Scale Requirements:

- Legal for trade
- Annual certification

- Proper capacity
- Level installation
- Clear display

Filling Procedure

Steps:

- 1. Preparation:**
 - Check cylinder
 - Record tare weight
 - Connect fill hose
 - Open cylinder valve
 - Position on scale
- 2. Filling:**
 - Open dispenser slowly
 - Monitor weight
 - Calculate fill limit
 - Stop at 80% by weight
- 3. Completion:**
 - Close dispenser
 - Close cylinder valve
 - Disconnect hose
 - Check for leaks
 - Install cap/plug

Weight Calculations:

Maximum fill = (Water capacity × 0.42) × 0.80

Example:

- 47.6 lb water capacity
- × 0.42 = 20 lbs propane capacity
- × 0.80 = 16 lbs maximum fill

Documentation:

- Date filled
- Amount dispensed
- Operator name
- Cylinder information
- Customer receipt

Exchange Programs

Cylinder exchange provides customer convenience.

Program Requirements

Cylinder Requirements:

- Uniform cylinders
- Current qualification
- Company ownership
- Proper valves
- Clear markings

Quality Control:

- Regular inspections
- Requalification program
- Valve maintenance
- Paint/labels
- Inventory control

Storage/Handling:

- Secure cages
- Proper signage
- Safety equipment
- Training program
- Emergency procedures

Customer Safety:

- Safety information
- Proper handling
- Transport guidance
- Storage requirements
- Emergency contacts

Logistics

Distribution:

- Route planning
- Vehicle requirements
- Driver training
- Inventory management
- Record keeping

Exchange Procedures:

1. Verify empty cylinder
2. Check condition
3. Exchange for full
4. Document transaction
5. Secure in vehicle

Pricing:

- Exchange fee
- Cylinder lease
- Propane cost
- Delivery charges
- Taxes

Safety in Handling

Safe handling procedures prevent injuries and incidents.

Personal Protective Equipment**Required PPE:**

- Safety glasses
- Gloves (leather/thermal)
- Safety footwear
- Long pants
- No synthetic fabrics

Optional PPE:

- Face shield
- Apron
- Hard hat
- Hearing protection
- Respirator (emergency)

Manual Handling**Lifting Techniques:**

- Bend knees
- Straight back
- Firm grip
- Lift smoothly

- No twisting

Weight Limits:

Cylinder Size Weight Full Two-Person Lift

20 lb	38 lbs	No
30 lb	55 lbs	Optional
40 lb	69 lbs	Recommended
100 lb	167 lbs	Required

Moving Cylinders:

- Hand trucks preferred
- Secured to truck
- Never roll on edge
- No dragging
- Clear path

Cylinder Handling Rules

Do's:

- Keep valves closed
- Use valve caps
- Secure during transport
- Store upright
- Check for damage
- Keep away from heat
- Use proper equipment
- Follow procedures

Don'ts:

- Never drop cylinders
- No valve tampering
- No smoking
- No open flames
- No modification
- No indoor storage
- No excessive heat
- No lying position

Emergency Procedures

Leaking Cylinder:

1. Move to safe area
2. Keep upright
3. Eliminate ignitions
4. Evacuate area
5. Call fire department
6. Do not attempt repair

Fire Exposure:

1. Evacuate immediately
2. Cool with water from distance
3. Let fire burn if safe
4. Call 911
5. Establish perimeter
6. BLEVE potential

Valve Problems:

- Do not force
- No tools on handwheel
- Professional repair only
- Tag out of service
- Document problem

18.7 Propane System Commissioning

Proper commissioning ensures safe system operation and code compliance.

Pre-Commissioning Checks

Verification before system activation.

Documentation Review**Required Documents:**

- Permits issued
- Installation drawings
- Equipment manuals
- Compliance certificates
- Test forms ready

Component Verification:

- Tank/cylinder installation
- Regulator installation

- Piping complete
- Appliances installed
- Controls wired

Visual Inspection:

- Clearances maintained
- Supports adequate
- Protection installed
- Labels/markings
- Access maintained

System Configuration:

- Valves positioned
- Regulators set
- Controls configured
- Safety devices active
- Venting complete

Leak Testing Procedures

Comprehensive leak testing ensures system integrity.

Test Methods**Pressure Drop Test:****Procedure:**

1. Isolate system section
2. Pressurize to test pressure
3. Record initial pressure
4. Wait 15 minutes minimum
5. Record final pressure
6. Calculate drop

Acceptance Criteria:

- No pressure drop
- Gauge accuracy considered
- Temperature stable
- All joints accessible
- Document results

Soap Bubble Test:

Solution Preparation:

- Commercial leak detector
- Or dish soap solution
- No ammonia products
- Fresh solution
- Proper consistency

Application:

- All joints
- Valve stems
- Regulator connections
- Relief valves
- Gauge connections
- Appliance connections

Electronic Leak Detection:

- Combustible gas detector
- Calibrated instrument
- Proper sensitivity
- Systematic coverage
- Document readings

Test Pressures and Duration**Low Pressure Systems (11" W.C.):**

- Test pressure: 15" W.C.
- Duration: 15 minutes
- No pressure drop
- All appliances connected
- Document results

Medium Pressure (2 psi):

- Test pressure: 3 psi
- Duration: 30 minutes
- Gauge: 0-5 psi
- All sections tested
- Recorded results

High Pressure (10 psi):

- Test pressure: 15 psi

- Duration: 60 minutes
- Gauge: 0-30 psi
- Temperature recorded
- Witnessed test

Pressure Testing Requirements

Code-compliant testing procedures.

Test Equipment

Pressure Sources:

- Hand pump
- Compressed air
- Nitrogen
- Initial charge with gas
- Never oxygen

Gauges Required:

System Pressure Test Gauge Range

11" W.C.	0-30" W.C.
2 psi	0-5 psi
10 psi	0-30 psi
Over 30 psi	0-100 psi

Gauge Requirements:

- 1% accuracy
- Current calibration
- Proper range
- Clear reading
- Protected location

Test Procedure

Preparation:

1. Install test gauge
2. Close all valves
3. Cap all outlets
4. Disconnect equipment
5. Open test valves

Testing:

1. Pressurize slowly
2. Check for major leaks
3. Adjust to test pressure
4. Begin timing
5. Monitor pressure
6. Record results

Post-Test:

1. Release pressure safely
2. Reconnect equipment
3. Remove test equipment
4. Open system valves
5. Prepare for purging

Documentation:

- Date and time
- Test pressure
- Duration
- Results
- Technician signature
- Inspector signature

Special Conditions**Temperature Correction:**

Pressure change = 1% per 10°F

Example:

- Start: 70°F, 15 psi
- End: 60°F
- Expected drop: 0.15 psi
- Actual: 0.1 psi
- Pass

Sectional Testing:

- Large systems
- Phased construction
- Different pressures
- Isolation valves

- Complete coverage

Purging Procedures

Safe purging removes air from the system.

Purging Methods

Displacement Purging:

Procedure:

1. Connect purge assembly
2. Open source valve slowly
3. Purge to safe location
4. Monitor with detector
5. Continue until 90% gas
6. Close purge valve

Purge Volumes:

Calculate $1.5 \times$ system volume minimum

Example:

- 100 ft of 1" pipe
- Volume: $100 \times 0.00545 = 0.545 \text{ ft}^3$
- Purge: $0.545 \times 1.5 = 0.82 \text{ ft}^3$

Pressure Purging:

Steps:

1. Pressurize with gas
2. Release to atmosphere
3. Repeat 3 times minimum
4. Test with detector
5. Document cycles

Advantages:

- Less gas used
- Faster process
- Better for long runs
- Effective mixing
- Easier control

Safety Requirements

Purging Safety:

- Outdoor discharge only
- Away from ignition sources
- Controlled release
- Area barricaded
- Fire extinguisher ready
- Gas detection continuous
- No smoking area
- Emergency plan ready

Prohibited:

- Indoor purging
- Near buildings
- Storm sewers
- Uncontrolled release
- Excessive flow rates

Environmental:

- Minimize release
- Consider methane impact
- Local regulations
- Neighbor notification
- Time of day considerations

Appliance Adjustment

Final adjustments ensure proper appliance operation.

Pressure Verification

Check Points:

1. Inlet Pressure:

- At appliance shutoff
- All appliances on
- Minimum 10" W.C.
- Maximum 13" W.C.
- Document reading

2. Manifold Pressure:

- At test port
- Burner operating

- 10" W.C. nominal
- Adjust if needed
- Record setting

Input Verification

Clocking Procedure:

1. Turn off other appliances
2. Run appliance 5 minutes
3. Time dial rotation
4. Calculate CFH
5. Convert to BTU/hr
6. Compare to rating

Calculation:

$$\text{CFH} = (\text{Dial size} \times 3600) / \text{Seconds}$$

Example:

- 1 cubic foot dial
- 36 seconds
- $\text{CFH} = (1 \times 3600) / 36 = 100$
- $\text{BTU/hr} = 100 \times 2,516 = 251,600$

Combustion Adjustment

Air Shutter Adjustment:

- Start at manufacturer setting
- Adjust for blue flame
- Minimal yellow tips
- No lifting
- Stable operation

High Altitude:

- Derate 4% per 1,000 ft
- Orifice change possible
- Consult manufacturer
- Test combustion
- Document changes

Multi-Stage/Modulating:

- High fire first
- Low fire adjustment
- Intermediate settings
- Electronic calibration
- Factory consultation

Documentation

Complete documentation ensures compliance and liability protection.

Required Documentation

Commissioning Report:

Contents:

- Project information
- Date commissioned
- System description
- Test results
- Adjustments made
- Deficiencies noted
- Recommendations
- Sign-offs

Test Certificates:

- Pressure test
- Leak test
- Purge verification
- Combustion analysis
- Input verification

Equipment Records:

- Serial numbers
- Model numbers
- Installation dates
- Warranty registration
- Conversion documentation

Customer Documentation

Operating Instructions:

- System operation

- Safety information
- Emergency procedures
- Maintenance requirements
- Contact information

Handover Package:

- Operating manuals
- Warranty information
- Test certificates
- Permit documents
- Service contacts

Training Provided:

- System operation
- Safety features
- Emergency shutdown
- Basic troubleshooting
- When to call service

Regulatory Documentation**Inspection Records:**

- Permit number
- Inspection dates
- Inspector name
- Deficiencies
- Corrections
- Final approval

Code Compliance:

- CSA B149.2 compliance
- Local code compliance
- Insurance requirements
- Utility requirements
- Environmental compliance

Filing Requirements:

- Owner copy
- Installer copy
- Inspector copy
- Insurance copy

- Utility copy

Chapter Review

Summary

This chapter covered comprehensive propane system knowledge:

System Design:

- Single vs. two-stage systems based on application
- Vapor withdrawal most common
- Liquid systems for high capacity
- Component selection critical
- Proper pressure requirements essential

Tanks and Cylinders:

- DOT/TC specifications for cylinders
- ASME specifications for tanks
- Proper sizing prevents problems
- Fill limits ensure safety
- Placement per code requirements

Regulators:

- First stage reduces tank pressure
- Second stage delivers appliance pressure
- Integral two-stage simplifies installation
- Relief valves required
- Proper venting essential

Piping Systems:

- Material selection per code
- Sizing with specific gravity correction
- Proper installation techniques
- Protection from damage
- Testing requirements

Appliance Conversion:

- Orifice changes required
- Pressure adjustments critical
- Combustion testing mandatory
- Proper labeling required

- Documentation essential

Cylinder Handling:

- Storage requirements strict
- TDG regulations apply
- Filling procedures critical
- Exchange programs common
- Safety paramount

System Commissioning:

- Systematic testing required
- Leak detection mandatory
- Proper purging essential
- Appliance adjustment critical
- Complete documentation

Key Safety Points:

1. Propane heavier than air - accumulates in low areas
2. Odorant added but don't rely solely on smell
3. Proper ventilation critical
4. Regular maintenance essential
5. Emergency procedures established

System Design Exercises

Exercise 1: Residential System Design

Given:

- House heat loss: 80,000 BTU/hr
- Water heater: 40,000 BTU/hr
- Range: 65,000 BTU/hr
- Dryer: 22,000 BTU/hr
- Location: Northern climate
- Design temperature: -20°F

Solution:

1. **Total Load:**
 - All appliances: 207,000 BTU/hr
 - Diversity factor: 0.7
 - Design load: 145,000 BTU/hr
2. **Tank Sizing:**

- 500 gal at -20°F: 67,000 BTU/hr
- Need: 1000 gal tank
- Or: 500 gal with vaporizer
- 3. **System Type:**
 - Two-stage recommended
 - Better cold weather performance
 - Consistent pressure
- 4. **Regulator Sizing:**
 - First stage: 250,000 BTU/hr
 - Second stage: 250,000 BTU/hr
 - Located at house

Exercise 2: Commercial System

Given:

- Restaurant equipment: 450,000 BTU/hr
- Space heating: 200,000 BTU/hr
- Water heating: 199,000 BTU/hr
- Continuous operation

Solution:

1. **Total Load:**
 - Peak: 849,000 BTU/hr
 - No diversity
 - Design: 850,000 BTU/hr
2. **Tank Sizing:**
 - Vaporization inadequate
 - Liquid withdrawal required
 - 1000 gal tank
 - Vaporizer: 1,000,000 BTU/hr
3. **System Configuration:**
 - Liquid withdrawal
 - Direct-fired vaporizer
 - Two-stage regulation
 - Multiple regulators

Tank Sizing Calculations

Example 1: Vaporization Limited

Given:

- Load: 300,000 BTU/hr
- Temperature: 0°F

- Continuous operation

Calculation:

- 500 gal at 0°F: 168,000 BTU/hr (insufficient)
- 1000 gal at 0°F: 308,000 BTU/hr (adequate)
- Select: 1000 gallon tank

Example 2: Storage Limited**Given:**

- Daily use: 100 gallons
- Delivery: Bi-weekly
- Reserve: 25%

Calculation:

- Two-week use: $100 \times 14 = 1,400$ gallons
- Add reserve: $1,400 \times 1.25 = 1,750$ gallons
- Tank size: $1,750 / 0.80 = 2,188$ gallons
- Select: 2000 gallon tank (close enough with more frequent delivery)

Piping Calculations with Corrections**Example 1: Low Pressure System****Given:**

- Load: 250,000 BTU/hr
- Pipe length: 100 feet
- Propane at 11" W.C.
- Allowable drop: 0.5" W.C.

Solution:

1. Convert to CFH: $250,000 / 2,516 = 99$ CFH
2. Look up natural gas: 157 CFH requires 1" pipe
3. Apply correction: $157 \times 0.63 = 99$ CFH
4. Select: 1" pipe adequate

Example 2: High Pressure System**Given:**

- Load: 500,000 BTU/hr

- Distance: 200 feet
- System: 10 psi
- Allowable drop: 1 psi

Solution:

1. Convert: $500,000 / 2,516 = 199$ CFH
2. From table: 1¼" pipe = 21,900 CFH at 200 ft
3. Correction: $21,900 \times 0.63 = 13,797$ CFH
4. Adequate capacity confirmed

Installation Planning Scenarios

Scenario 1: New Construction

Project:

- 50-unit apartment complex
- Central propane system
- Individual meters

Planning Steps:

1. **Load Calculation:**
 - Per unit: 150,000 BTU/hr
 - Total connected: 7,500,000 BTU/hr
 - Diversity: 0.4
 - Design: 3,000,000 BTU/hr
2. **Tank Selection:**
 - Multiple tanks required
 - Four 1000 gal tanks
 - Manifold system
 - Liquid withdrawal backup
3. **Distribution:**
 - 2 psi system
 - Underground PE pipe
 - Individual regulators
 - Meter sets

Scenario 2: Conversion Project

Project:

- Convert 100-unit complex from oil
- Natural gas not available
- Maintain central heating

Planning:

- 1. System Analysis:**
 - Existing boiler convertible?
 - Distribution adequate?
 - Venting acceptable?
 - Space for tanks?
- 2. Design Decisions:**
 - Replace boilers
 - High-efficiency units
 - 30,000 gal storage
 - Vaporizer system
- 3. Implementation:**
 - Phased conversion
 - Temporary heat
 - Tenant coordination
 - Permit requirements

Conversion Procedures

Step-by-Step Furnace Conversion

Procedure:

- 1. Preparation:**
 - Obtain conversion kit
 - Review instructions
 - Gather tools
 - Verify model number
 - Check compatibility
- 2. Safety:**
 - Shut off gas
 - Turn off power
 - Lock out/tag out
 - Allow cooling
 - Ventilate area
- 3. Orifice Replacement:**
 - Remove burners
 - Replace main orifices
 - Replace pilot orifice
 - Check alignment
 - Secure properly
- 4. Gas Valve Adjustment:**
 - Install new spring
 - Adjust regulator
 - Set manifold pressure

- Check modulation
- Verify safeties
- 5. **Testing:**
 - Leak check
 - Ignition sequence
 - Flame characteristics
 - Temperature rise
 - Combustion analysis
- 6. **Documentation:**
 - Apply labels
 - Complete certificate
 - Register warranty
 - Customer copy
 - File records

Water Heater Conversion

Special Considerations:

- Pilot assembly change
- Thermocouple position
- Burner orifice
- Different BTU rating
- Venting verification

Range Conversion

Unique Aspects:

- Multiple orifices
- Oven and broiler
- Pilot adjustments
- Simmer settings
- Air shutter adjustments

Troubleshooting Guide

Common Problems and Solutions

Problem	Possible Cause	Solution
Low pressure	Undersized tank	Increase tank size
Regulator freezing	Moisture in gas	Add methanol injection
Yellow flames	Incorrect orifice	Verify proper size
Appliance cycling	Low vaporization	Add vaporizer
Odor in house	Leak	Leak detection/repair

Problem	Possible Cause	Solution
Tank frosting	High withdrawal	Reduce load or add capacity
Won't stay lit	Low pressure	Check entire system

Diagnostic Procedures

Pressure Problems:

1. Check tank level
2. Verify regulator operation
3. Test at multiple points
4. Check for restrictions
5. Verify pipe sizing

Combustion Issues:

1. Check gas pressure
2. Verify orifice size
3. Inspect air adjustments
4. Test with analyzer
5. Check venting

Key Terms and Definitions

ASME: American Society of Mechanical Engineers - tank standards.

BTU: British Thermal Unit - heat measurement.

Cathodic Protection: Corrosion prevention system for underground tanks.

CFH: Cubic Feet per Hour - gas flow measurement.

DOT/TC: Department of Transportation/Transport Canada - cylinder standards.

Excess Flow Valve: Safety device limiting flow if line breaks.

Fixed Liquid Level Gauge: Device showing 80% fill level.

Hydrostatic Relief: Protects from liquid expansion in trapped sections.

Lock-up Pressure: Regulator outlet pressure at no flow.

Manifold Pressure: Gas pressure at appliance burner manifold.

OPD: Overfill Prevention Device on cylinders.

POL: Obsolete left-hand thread valve connection.

Specific Gravity: Density compared to air (propane = 1.52).

TDG: Transportation of Dangerous Goods regulations.

Ullage: Vapor space above liquid in tank (20% minimum).

Vaporization Rate: BTU/hr a tank can supply as vapor.

Water Capacity: Total cylinder volume in pounds of water.

Wetted Surface: Tank area in contact with liquid propane.

End of Chapter 18

This comprehensive chapter on Propane Systems and Installations provides essential knowledge for designing, installing, and servicing propane systems safely and efficiently. Understanding the unique properties of propane and the specific requirements for its storage, handling, and use ensures safe operation of these systems.

Students should be able to design appropriate systems for various applications, properly size all components from tanks to piping, safely handle and store cylinders, convert appliances when appropriate, and commission complete systems to code requirements. The importance of following CSA B149.2 requirements cannot be overstated, as propane's properties create unique hazards requiring specific safety measures.

As propane continues to serve areas without natural gas service and provides backup fuel options, technicians must maintain current knowledge of codes, best practices, and safety procedures. Regular training updates, particularly in cylinder handling and emergency response, ensure continued safe operation of these essential energy systems.