CHAPTER 11

Gas Valves and Safety Controls

Learning Objectives

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

1. Identify and properly select manual gas valves for specific applications
2. Understand the operation and application of automatic gas valves
3. Install and test safety shut-off systems per CSA B149.1 requirements
4. Configure and troubleshoot limit controls
5. Diagnose and service flame safeguard systems
6. Install and adjust pressure and airflow switches
7. Interpret valve wiring diagrams and sequences of operation
8. Apply proper testing procedures for all safety controls
9. Understand redundancy requirements and fail-safe principles
10. Troubleshoot complex control system failures

11.1 Manual Gas Valves

Manual gas valves are the fundamental control devices in gas systems, providing positive shut-off and flow control. Understanding their construction, operation, and proper application is essential for safe gas system design and maintenance.

Ball Valves

Ball valves are the most common manual shut-off valves in modern gas installations. Their quarter-turn operation and reliable sealing make them ideal for gas service.

Construction

Components:

- Ball: Stainless steel or brass sphere with port through center
- Seats: PTFE (Teflon) or reinforced PTFE
- Body: Brass, steel, or stainless steel
- Stem: Connected to ball, extends through packing
- Handle: Lever or butterfly type
- Packing: Prevents leakage around stem

Types:

- Full Port: Port diameter equals pipe diameter (minimal pressure drop)
- Standard Port: Port diameter smaller than pipe (reduced flow, lower cost)
- Three-Way: Diverting or mixing applications
- Vented Ball: Small hole in ball for downstream venting

Operating Principles

Ball valves operate by rotating a ball with a port through it 90 degrees. In the open position, the port aligns with the pipeline allowing full flow. In the closed position, the solid portion of the ball blocks flow completely.

Advantages:

- Quick operation (1/4 turn)
- Tight shut-off
- Low pressure drop when fully open
- Visual indication of position
- Minimal maintenance
- Long service life
- Bubble-tight shut-off

Disadvantages:

- Not suitable for throttling
- More expensive than some alternatives
- Can trap pressure in center cavity
- Handle can be accidentally operated

Installation Requirements

CSA B149.1 Requirements:

- Must be rated for gas service
- Certified to CAN/CSA-6.18 or CSA 6.32
- Yellow handle or marked "GAS"
- Installed in accessible location
- Handle parallel to pipe when open
- Handle perpendicular when closed

Installation Best Practices:

1. Verify flow direction (if applicable)
2. Install with handle in accessible position
3. Support valve to prevent stress on connections

4. Use approved pipe compound or tape
5. Do not over-tighten connections
6. Test for leaks after installation
7. Ensure full open/close operation
8. Lock in position if required

Applications

Typical Uses:

- Main gas shut-off
- Equipment isolation
- Branch line shut-off
- Appliance shut-off
- Test point isolation
- Emergency shut-off

Where Not to Use:

- Throttling service
- Frequent operation (thousands of cycles)
- Extreme temperature variations
- Contaminated gas streams

Plug Valves

Plug valves, also called cock valves or gas cocks, use a tapered or cylindrical plug to control flow. They were once the standard in gas service but have largely been replaced by ball valves.

Construction

Components:

- Plug: Tapered or straight, with port through center
- Body: Cast iron, brass, or steel
- Seat: Machined into body or replaceable
- Stem: May be integral with plug
- Lubricant system: Some models have lubricant injection
- Stop plate: Limits rotation to 90 degrees

Types:

- Lubricated: Lubricant seals and reduces friction
- Non-lubricated: PTFE sleeve or coating
- Eccentric: Plug moves away from seat when opening
- Multi-port: Three-way or four-way configurations

Operating Characteristics

Advantages:

- Simple, rugged construction
- Quick quarter-turn operation
- Can handle slurries and solids
- Available in multi-port configurations
- Fire-safe design available
- Good for high-temperature service

Disadvantages:

- Higher operating torque than ball valves
- Requires periodic lubrication (lubricated type)
- Can seize if not operated regularly
- Tapered plugs can bind
- More pressure drop than ball valves

Installation and Maintenance

Installation:

1. Check for proper taper engagement
2. Ensure proper orientation for gravity drain
3. Install with adequate clearance for handle
4. Apply appropriate lubricant if required
5. Work valve several times after installation
6. Pressure test in both directions

Maintenance:

1. Operate periodically to prevent seizing
2. Lubricate per manufacturer schedule
3. Adjust taper nuts if leaking
4. Check for wear on plug and seats
5. Replace seals as needed

Gate Valves

Gate valves use a sliding gate or wedge to control flow. While not recommended for gas throttling service, they are sometimes found in older installations and specific industrial applications.

Construction

Components:

- Gate/Wedge: Solid, flexible, or split wedge
- Body: Cast iron, steel, or brass
- Bonnet: Bolted, welded, or screwed
- Stem: Rising or non-rising
- Seats: Integral or replaceable
- Packing: Prevents stem leakage

Types:

- Rising Stem: Visual indication of position
- Non-Rising Stem: Compact, stem threads inside
- Solid Wedge: Most common, good seal
- Flexible Wedge: Compensates for seat wear
- Split Wedge: Self-aligning

Operating Principles

Gate valves operate by raising or lowering a gate perpendicular to the flow path. When fully open, the gate is completely out of the flow path, providing minimal pressure drop.

Advantages:

- Minimal pressure drop when fully open
- Bi-directional flow capability
- No flow path offset
- Available in large sizes
- Good for slurry service

Disadvantages:

- Slow operation (multi-turn)
- Poor throttling characteristics
- Gate can vibrate in partially open position
- Seats susceptible to wear
- Can trap pressure in bonnet
- Requires large installation space

Applications and Limitations

Acceptable Applications:

- Isolation service (fully open/closed)
- Infrequent operation
- Where minimal pressure drop required

- Large diameter pipelines

Not Recommended For:

- Throttling service
- Frequent operation
- Rapid cycling
- Where quick shut-off required

Applications and Limitations Summary

Valve Type	Best Applications	Limitations	Typical Locations
Ball Valve	Quick shut-off, Main isolation	Not for throttling	Equipment shut-offs, Main lines
Plug Valve	Multi-port applications	Higher torque	Older systems, Industrial
Gate Valve	Large lines, Infrequent use	Slow operation	Main distribution

Installation Requirements

General Requirements (CSA B149.1)

All Manual Valves Must:

- Be certified for gas service
- Have adequate pressure rating
- Be accessible for operation
- Be properly supported
- Have clear identification
- Be tested for leaks after installation

Location Requirements:

1. **Readily Accessible:**
   - Maximum 6 feet (1.8m) above floor
   - Clear access path
   - No obstructions to handle operation
   - Adequate lighting
2. **Outside Equipment:**
   - Upstream of all controls
   - Before entering building (where required)
   - Protected from damage
   - Clear identification
3. **Emergency Shut-off:**
   - Clearly marked
   - Red handle or identification
   - Unobstructed access

    - Known to all personnel

Installation Procedures

Step-by-Step Installation:

1. **Preparation:**
    - Verify valve rating and certification
    - Check for damage
    - Ensure proper size and connection type
    - Confirm flow direction (if applicable)
2. **Installation:**
    - Clean pipe threads
    - Apply approved compound/tape
    - Install valve in proper orientation
    - Support valve weight
    - Tighten connections properly
    - Do not exceed torque specifications
3. **Testing:**
    - Pressure test at operating pressure
    - Soap test all connections
    - Operate valve full cycle
    - Verify proper operation
    - Check for internal leakage
4. **Documentation:**
    - Record valve location
    - Note manufacturer and model
    - Document test results
    - Update system drawings

Identification and Labeling

CSA B149.1 Requirements

Mandatory Marking:

- Gas service valves must be identified
- Yellow handles or tags
- "GAS" marking visible
- Flow direction arrows where applicable
- Pressure rating visible

Valve Tags Should Include:

- Valve number/identification
- System served

- Normal position (open/closed)
- Date of installation
- Last service date

Color Coding Standards

Service	Handle Color	Tag Color	Notes
Natural Gas	Yellow	Yellow	"GAS" marking required
Propane	Yellow	Yellow	"PROPANE" if specific
Emergency	Red	Red	"EMERGENCY SHUT-OFF"
Main Shut-off	Yellow/Red	Yellow/Red	Building entrance

Labeling Best Practices

1. **Permanent Labels:**
    - Engraved tags
    - Stamped plates
    - Weather-resistant materials
    - Secured with wire or chain
2. **Temporary Labels:**
    - During maintenance
    - Testing procedures
    - Out-of-service notation
    - Date and signature
3. **Valve Charts:**
    - Posted in mechanical room
    - Shows all valve locations
    - Indicates normal positions
    - Emergency contact information

11.2 Automatic Gas Valves

Automatic gas valves provide controlled gas flow without manual intervention, responding to electrical signals, pressure changes, or temperature variations. These valves are essential components in modern gas equipment control systems.

Solenoid Valves

Solenoid valves use electromagnetic force to open or close a valve mechanism. They are widely used for fast-acting shut-off and safety applications.

Construction and Operation

Components:

- Solenoid coil: Creates magnetic field when energized
- Plunger/Armature: Ferrous metal core that moves in magnetic field
- Valve body: Contains seat and flow passages
- Return spring: Closes valve when de-energized
- Manual override: Some models include manual open feature

Operating Principle: When electrical current flows through the coil, it creates a magnetic field that pulls the plunger upward, opening the valve. When current stops, the spring forces the plunger down, closing the valve.

Types:

1. **Direct-Acting:**
   - Plunger directly opens/closes orifice
   - Works with zero pressure differential
   - Limited to smaller pipe sizes
   - Fast response time
2. **Pilot-Operated:**
   - Uses line pressure to assist operation
   - Handles larger flow rates
   - Requires minimum pressure differential
   - More complex construction
3. **Normally Closed (NC):**
   - Closed when de-energized
   - Most common in gas service
   - Fails safe on power loss
4. **Normally Open (NO):**
   - Open when de-energized
   - Special applications only
   - Not typically used for gas

Electrical Characteristics

Voltage Ratings:

- 24VAC (most common in HVAC)
- 120VAC (commercial/industrial)
- 12VDC or 24VDC (special applications)
- Millivolt (thermopile powered)

Power Consumption:

- In-rush current: 2-3 times holding current
- Holding current: Varies by size (typically 0.2-2.0 amps)

- Power factor considerations
- Heat generation in continuous duty

Coil Protection:

- MOV (Metal Oxide Varistor) surge protection
- Diode protection for DC coils
- Proper grounding essential
- Arc suppression on contacts

Installation Requirements

Mounting Position:

- Vertical with coil up (preferred)
- Horizontal acceptable for most models
- Check manufacturer requirements
- Consider service access

Piping Considerations:

- Install strainer upstream
- Proper pipe support
- Avoid stress on valve body
- Direction arrow must be observed

Electrical Connections:

- Use proper wire gauge
- Secure connections
- Weatherproof if exposed
- Proper grounding

Diaphragm Valves

Diaphragm valves use a flexible diaphragm to control gas flow, operated by pressure differential or mechanical actuators.

Types and Construction

Main Types:

1. **Pressure-Operated:**
    - Uses control pressure on diaphragm
    - Pilot circuit controls main valve
    - Large flow capacity

    - Smooth opening characteristics
2. **Mechanically-Operated:**
    - Manual or motorized actuator
    - Direct diaphragm control
    - Used for modulation
    - Precise flow control

Components:

- Diaphragm: Fabric-reinforced rubber or synthetic material
- Valve body: Cast iron or aluminum
- Pilot system: Controls operating pressure
- Bleed orifice: Equalizes pressure
- Manual reset: Where required for safety

Operating Characteristics

Advantages:

- Smooth opening/closing
- Minimal pressure drop
- Good for modulating service
- Can handle some contamination
- Large flow capacity
- Quiet operation

Disadvantages:

- Diaphragm can fail
- Temperature limitations
- Requires minimum pressure differential
- More complex than solenoid valves
- Regular inspection needed

Redundant Valve Systems

Redundant gas valve systems use two automatic shut-off valves in series to provide double block safety shut-off as required by CSA B149.1 for certain applications.

Code Requirements

When Required (CSA B149.1):

- Inputs over 400,000 BTU/hr (117 kW)
- All power burners
- Commercial/industrial equipment

- Where specified by manufacturer
- Institutional occupancies

Configuration Requirements:

- Two automatic valves in series
- Independent operators
- Both must close on safety shutdown
- Proof of closure systems (where required)
- Manual reset (where required)

Typical Configurations

1. **Double Solenoid:**
    - Two separate solenoid valves
    - Wired in parallel
    - Common in retrofit applications
    - Easy to service
2. **Redundant Gas Valve (Combined):**
    - Two valves in one body
    - Common actuator or separate
    - Compact design
    - Factory assembled and tested
3. **Solenoid + Diaphragm:**
    - Fast-acting solenoid
    - Slow-opening diaphragm
    - Reduces ignition stress
    - Common in larger equipment

Valve Proving Systems

Purpose: Valve proving systems verify that safety shut-off valves are fully closed before allowing startup, detecting internal valve leakage that could create hazardous conditions.

Types:

1. **Pressure Switch Method:**
    - Monitors pressure between valves
    - Detects rise indicating upstream leak
    - Detects no drop indicating downstream leak
    - Simple and reliable
2. **Electronic Valve Proving:**
    - Automated test sequence
    - Times pressure changes
    - Provides diagnostics
    - Required for some applications

Test Sequence:

1. Close both valves
2. Vent inter-valve space
3. Monitor for pressure rise (upstream leak)
4. Pressurize inter-valve space
5. Monitor for pressure drop (downstream leak)
6. Pass/fail determination
7. Proceed to ignition or lockout

Slow-Opening Valves

Slow-opening valves provide controlled gas flow increase to prevent ignition shock and equipment damage.

Types

1. **Stepped Opening:**
   - Initial small opening (pilot rate)
   - Delay period
   - Full opening
   - Reduces ignition impact
2. **Motorized Valves:**
   - Motor-driven actuator
   - Adjustable opening rate
   - Can provide modulation
   - Position feedback available
3. **Hydraulic Dampening:**
   - Oil-filled dashpot
   - Controls opening speed
   - Temperature compensated
   - Reliable operation

Applications

Where Used:

- Large burners
- Power burners
- Prevent furnace pulsation
- Reduce noise
- Protect heat exchangers
- Smooth light-off

Pressure Regulating Valves

While pressure regulators are covered in detail in Chapter 9, some automatic gas valves incorporate pressure regulation.

Combination Regulators/Valves

Features:

- Inlet pressure regulation
- Outlet pressure regulation
- Shut-off capability
- Single device solution

Applications:

- Appliance pressure regulation
- Equipment protection
- Space savings
- Simplified piping

Combination Gas Valves

Combination gas valves integrate multiple functions into a single valve body, simplifying installation and reducing potential leak points.

Typical Functions Included

1. **Manual Shut-off:**
    - On/off knob or lever
    - Service and emergency shut-off
    - Lockout capability
2. **Pressure Regulator:**
    - Maintains outlet pressure
    - Adjustable spring
    - Atmospheric vent
3. **Safety Shut-off:**
    - Redundant operators
    - Thermocouple connection
    - Manual reset (where required)
4. **Pilot Valve:**
    - Separate pilot outlet
    - Pilot adjustment
    - Pilot filter
5. **Main Valve:**
    - Servo-regulated
    - Diaphragm operated
    - Slow-opening feature

Common Types

Standing Pilot Valves:

- Used in older equipment
- Continuous pilot flame
- Thermocouple safety
- Manual pilot lighting

Intermittent Pilot Valves:

- Electronic pilot ignition
- Pilot lights with main burner
- No standing pilot
- Energy efficient

Direct Ignition Valves:

- No pilot flame
- Direct burner ignition
- Electronic flame sensing
- Most efficient

Wiring and Controls

Typical Connections:

- 24VAC power supply
- Thermostat circuit
- Limit controls
- Flame sensor
- Ignition module
- Pressure switches

Terminal Designations:

Terminal	Function	Typical Wire Color
TH	Thermostat Hot	Red
TR	Transformer Hot	Black
C	Common	White/Blue
MV	Main Valve	Brown
PV	Pilot Valve	Orange
GND	Ground	Green

11.3 Safety Shut-Off Systems

Safety shut-off systems are critical components that prevent gas flow during unsafe conditions. These systems must comply with strict code requirements and provide reliable fail-safe operation.

Manual Reset Requirements

Manual reset ensures human intervention before restarting after a safety shutdown, preventing automatic restart in potentially dangerous conditions.

When Required (CSA B149.1)

Mandatory Manual Reset:

- High limit trips
- Flame failure on inputs > 400,000 BTU/hr
- Combustion air proving failure
- Blocked vent detection
- Low water cutoff (boilers)
- Any condition requiring inspection

Reset Mechanism Requirements:

- Must be manually operated
- Cannot be held in reset position
- Clearly identified
- Located at equipment
- Requires deliberate action

Types of Manual Reset

1. **Mechanical Reset:**
    - Push button on control
    - Must be physically pressed
    - Spring return
    - Cannot be bypassed easily
2. **Electrical Reset:**
    - Remote reset button
    - Momentary contact
    - Still requires physical presence
    - Can be located for best access
3. **Valve Reset:**
    - Reset on gas valve itself
    - Mechanical linkage
    - Often combined with pilot lighting

- Common on water heaters

100% Shut-Off Criteria

Complete gas shut-off is required for safety conditions to prevent any gas flow to burners.

Definition

100% Safety Shut-Off means:

- All gas flow stopped
- Both automatic valves closed (redundant systems)
- No bypass around safety valves
- Pilot and main gas stopped
- Cannot be overridden

Code Requirements

Equipment Requiring 100% Shut-Off:

- All power burners
- Equipment > 400,000 BTU/hr
- Unvented equipment
- Commercial cooking equipment
- Industrial process equipment
- Hazardous locations

Conditions Requiring 100% Shut-Off:

- Flame failure
- Limit control trip
- Combustion air failure
- Power failure
- Safety interlock open
- Manual emergency stop

Proving Systems

Proving systems verify safe conditions exist before allowing gas valve operation.

Types of Proving

1. **Valve Proving:**
    - Verifies valve closure
    - Detects internal leakage
    - Required for certain applications

    - Automatic test cycle
2. **Pilot Proving:**
    - Confirms pilot flame establishment
    - Mercury flame sensor
    - Thermocouple/thermopile
    - Electronic flame detection
3. **Air Proving:**
    - Confirms combustion air flow
    - Differential pressure switch
    - Sail switch
    - Current sensing (motors)
4. **Purge Proving:**
    - Verifies pre-purge completion
    - Timer circuits
    - Air flow verification
    - Required for power burners

Proving System Sequence

Typical Proof Sequence:

1. System call for heat
2. Valve proving test (if equipped)
3. Pre-purge period
4. Pilot valve energized
5. Ignition activated
6. Pilot flame proved
7. Main valve energized
8. Main flame proved
9. Normal operation
10. Post-purge on shutdown

Redundancy Requirements per Code

Redundancy provides backup safety in case of single component failure.

CSA B149.1 Redundancy Requirements

Double Block Required:

- Two automatic valves in series
- Equipment > 400,000 BTU/hr
- All forced draft burners
- Multiple burner systems
- Industrial equipment

Control Circuit Redundancy:

- Independent safety controls
- Separate limit switches
- Multiple flame sensors (where required)
- Backup safety systems

Redundant System Design

Design Principles:

1. **Independence:**
    - Separate operators
    - Independent power
    - No common failure modes
    - Different sensing methods
2. **Diversity:**
    - Different valve types
    - Various manufacturers
    - Multiple technologies
    - Reduced common cause failure
3. **Testing:**
    - Individual valve testing
    - Proof of closure
    - Leak testing
    - Regular maintenance

Pilot Safety Valves

Pilot safety valves prevent pilot gas flow when flame is not established, using various sensing methods.

Thermocouple Systems

Operating Principle:

- Two dissimilar metals joined
- Heat generates millivolts (25-35mV typical)
- Powers electromagnetic safety valve
- Self-powered system
- Fails safe on flame loss

Components:

- Thermocouple: Generates power
- Pilot burner: Heats thermocouple

- Safety valve: Electromagnetic operator
- Reset mechanism: Manual reset button

Troubleshooting:

Problem	Possible Cause	Solution
Won't hold	Low thermocouple output	Replace thermocouple
	Poor connection	Clean and tighten
	Weak magnet	Replace valve
	Incorrect thermocouple position	Adjust position
Slow dropout	Normal operation	30-180 seconds typical
Won't reset	No pilot flame	Light pilot
	Thermocouple open	Replace

Mercury Flame Sensors

Note: Mercury flame sensors are being phased out due to environmental concerns but may still be encountered in existing equipment.

Operation:

- Mercury expands when heated
- Completes electrical circuit
- Fast response
- Reliable operation

Safety Considerations:

- Contains mercury (hazardous material)
- Special disposal required
- Do not break bulb
- Replace with electronic type when possible

Electronic Pilot Safety

Modern Systems:

- Electronic flame detection
- Microprocessor control
- Diagnostic capabilities
- Faster response
- More precise control

Advantages:

- No mercury
- Programmable timing
- Self-diagnostics
- Remote monitoring capable
- Integration with BMS

11.4 Limit Controls

Limit controls monitor operating parameters and shut down equipment when unsafe conditions exist. They are critical safety devices that prevent equipment damage and hazardous conditions.

Temperature Limits

Temperature limit controls are the most common safety devices in gas equipment, preventing overheating and potential fires.

Types of Temperature Limits

1. **Bimetallic Disc:**
    - Two metals with different expansion rates
    - Snaps open/closed at setpoint
    - Simple and reliable
    - Fixed or adjustable setpoint
    - Auto or manual reset
2. **Rod and Tube:**
    - Brass tube expands more than steel rod
    - Operates mechanical switch
    - Adjustable setpoint
    - Surface or insertion mounting
    - Common on water heaters
3. **Liquid-Filled Bulb:**
    - Remote bulb with capillary tube
    - Liquid expansion operates switch
    - Can sense average temperature
    - Long capillary possible
    - Used in ovens and boilers
4. **Electronic:**
    - Thermistor or RTD sensor
    - Electronic switching
    - Precise control
    - Digital display available
    - Communication capability

High Limit vs. Operating Limit

Understanding the distinction between high limits and operating controls is crucial for proper system design and safety.

High Limit (Safety Limit):

- Primary safety device
- Prevents unsafe conditions
- Set above operating control
- Usually manual reset
- Opens safety circuit
- Cannot be bypassed

Operating Limit (Control):

- Normal cycling control
- Maintains operating temperature
- Auto-reset
- Controls burner operation
- Part of normal sequence

Typical Settings:

Equipment Type	Operating Limit	High Limit	Notes
Warm Air Furnace	140-180°F	200-250°F	Depends on design
Hot Water Boiler	160-180°F	210-220°F	Below steam point
Steam Boiler	2-5 PSI	12-15 PSI	Low pressure
Water Heater	120-140°F	180-210°F	ECO function
Unit Heater	140-180°F	200-220°F	Air temperature

Installation and Location

Proper Location Critical:

- Hottest point in system
- Good thermal contact
- Representative temperature
- Accessible for service
- Protected from damage

Warm Air Furnaces:

- Supply plenum
- Above heat exchanger
- 12-18" from heat exchanger
- Not in line of sight to heat exchanger

- Centered in airstream

Boilers:

- Immersion well in vessel
- Top of boiler
- Supply manifold
- Per manufacturer specifications

Water Heaters:

- ECO (Energy Cut-Off) location
- Upper thermostat position
- Immersion or surface mount
- Good thermal contact essential

Pressure Limits

Pressure limits prevent over-pressurization of vessels and systems.

Types

1. **Pressure Switches:**
    - Diaphragm operated
    - Adjustable setpoint
    - Electrical contacts
    - Manual or auto reset
    - SPST or SPDT contacts
2. **Pressure Relief Valves:**
    - Mechanical relief
    - No electrical connection
    - Last resort protection
    - Must vent safely
    - Regular testing required

Applications

Steam Boilers:

- Operating pressure control
- High pressure limit
- Safety relief valve
- Multiple levels of protection

Hot Water Systems:

- System pressure monitoring
- Expansion tank pressure
- Pump operation
- Fill pressure

Gas Pressure:

- High gas pressure switch
- Low gas pressure switch
- Vent pressure monitoring

Spill Switches

Spill switches detect combustion products escaping from draft hoods or barometric dampers, indicating backdraft conditions.

Construction and Operation

Thermal Type:

- Bimetallic sensor
- Located at draft hood
- Opens on temperature rise
- Manual or automatic reset
- 160-210°F typical setpoint

Installation Requirements:

- Centered over draft hood opening
- 1-4" above opening
- Not affected by room drafts
- Accessible for reset
- Proper wire routing

Testing Procedures

1. **Functional Test:**
    - Block draft hood
    - Run appliance
    - Switch should trip in 2-5 minutes
    - Verify shut-down
    - Clear blockage and reset
2. **Calibration Check:**
    - Use heat gun or match
    - Apply heat to sensor
    - Verify trip point

    - Check reset function

Blocked Vent Switches

Blocked vent switches detect restricted venting that could cause combustion products to spill into occupied space.

Types

1. **Pressure Switch:**
    - Monitors vent pressure
    - Detects excessive positive pressure
    - Adjustable setpoint
    - More sensitive than thermal
2. **Thermal Switch:**
    - Temperature-based detection
    - Similar to spill switch
    - Located in vent connector
    - Detects hot conditions

Applications

Required Locations:

- Category I fan-assisted appliances
- Power vent water heaters
- Induced draft furnaces
- Where specified by manufacturer

Installation:

- Per manufacturer specifications
- Proper tube routing (pressure type)
- Avoid condensate traps
- Regular inspection required

Manual vs. Automatic Reset

The choice between manual and automatic reset affects safety and operation.

Manual Reset

Advantages:

- Requires investigation
- Prevents repeated cycling

- Indicates problem exists
- Safer for critical limits

Disadvantages:

- Requires service call
- Can't restart remotely
- Occupant inconvenience

When Required:

- High limit trips
- Flame failure (>400,000 BTU/hr)
- Repeated safety trips
- Critical safety functions

Automatic Reset

Advantages:

- Automatic restart
- No service call for transient conditions
- Convenient operation

Disadvantages:

- Can mask problems
- Repeated cycling possible
- May not identify issues

Acceptable Uses:

- Operating controls
- Minor limits
- Non-critical functions
- Where code permits

11.5 Flame Safeguard Controls

Flame safeguard controls detect the presence or absence of flame and control gas valves accordingly. They are critical safety components that prevent unburned gas accumulation.

Thermocouple Systems (Millivolt)

Thermocouples are self-powered flame detection devices used extensively in standing pilot systems.

Principle of Operation

Thermoelectric Effect:

- Two dissimilar metals joined at tip
- Temperature difference generates voltage
- Typical output: 25-35 millivolts
- No external power required
- Direct operation of safety valve

Metals Used:

- Hot junction: Chromel-Alumel
- Cold junction: Copper
- Special alloys for temperature range
- Protective sheath

Components and Construction

Thermocouple Assembly:

- Sensing tip (hot junction)
- Extension lead
- Cold junction connection
- Protective tubing
- Mounting bracket

Power Characteristics:

- Open circuit voltage: 25-35 mV
- Closed circuit current: 15-30 mA
- Coil resistance: 200-500 milliohms
- Response time: 15-45 seconds heat-up
- Dropout time: 30-180 seconds

Installation Requirements

Proper Position Critical:

- Tip in pilot flame
- Upper 3/8" to 1/2" of flame
- Blue flame contact
- Secure mounting

- Proper thread engagement

Connection Requirements:

- Clean connections essential
- Proper torque (hand tight + 1/4 turn)
- No pipe dope on threads
- Copper tubing to reduce resistance
- Avoid sharp bends

Troubleshooting Procedures

Testing Thermocouple Output:

1. **Open Circuit Test:**
    - Disconnect from gas valve
    - Light pilot flame
    - Measure with millivolt meter
    - Should read 25-35 mV
    - Less than 20 mV - replace
2. **Closed Circuit Test:**
    - Thermocouple connected
    - Measure across coil terminals
    - Should read 12-15 mV minimum
    - Tests under load condition

Common Problems:

Symptom	Possible Cause	Solution
Low output	Dirty tip	Clean with steel wool
	Wrong position	Reposition in flame
	Weak pilot	Adjust pilot flame
	End of life	Replace thermocouple
Won't hold	Bad connection	Clean and tighten
	Weak magnet coil	Replace gas valve
	Low gas pressure	Adjust pressure
Intermittent	Loose connection	Secure all connections
	Pilot flame unstable	Clean pilot orifice
	Drafts affecting pilot	Shield pilot area

Thermopile Systems

Thermopiles generate more power than single thermocouples by connecting multiple thermocouples in series.

Construction and Output

Design:

- Multiple thermocouples in series
- Common hot junction
- Separate cold junctions
- Higher voltage output
- Can power control circuits

Specifications:

- Output voltage: 250-750 millivolts
- Current capacity: 100-300 milliamps
- Can operate relays
- Powers control circuits
- Self-powered systems

Applications

Where Used:

- Millivolt heating systems
- Remote locations without power
- Wall heaters
- Decorative appliances
- Pool heaters
- Self-powered systems

System Components:

- Thermopile generator
- Millivolt thermostat
- Gas valve (millivolt type)
- Pilot burner assembly
- Safety shutdown

Advantages Over Thermocouples

Benefits:

- Higher power output
- Can operate multiple devices
- Powers thermostats
- No external power needed
- Simple wiring

- Reliable operation

Limitations:

- More expensive
- Larger physical size
- Longer response time
- Standing pilot required

Flame Rectification Systems

Flame rectification uses the electrical conductivity and rectifying properties of flame to detect presence.

Principle of Operation

How It Works:

1. AC voltage applied between sensor and ground
2. Flame conducts electricity
3. Flame acts as rectifier (diode)
4. Creates DC component
5. Electronics detect DC current
6. Proves flame presence

Key Concepts:

- Flame is conductive (ionized gas)
- Unequal electrode areas create rectification
- Sensor rod: small area
- Ground (burner): large area
- Ratio should be 4:1 minimum

System Components

Flame Rod (Sensor):

- High-temperature ceramic insulator
- Stainless steel or Kanthal rod
- Positioned in flame
- Electrical isolation critical
- Proper positioning essential

Ignition Module:

- Provides AC voltage to sensor

- Detects DC microamp signal
- Typical sensitivity: 0.5-1.5 μA
- Safety shutdown on low signal
- Diagnostic indicators

Grounding:

- Clean ground essential
- Burner must be grounded
- Low resistance path
- Separate from sensor
- Critical for operation

Installation and Adjustment

Sensor Position:

- In strong part of flame
- Not touching burner
- 1/2" to 3/4" into flame
- Avoid flame impingement
- Stable flame area

Critical Measurements:

- Flame signal: 1-10 microamps typical
- Minimum signal: 0.5-1.5 μA
- Sensor insulation: > 50 megohms
- Ground resistance: < 5 ohms
- AC voltage: 24-120 VAC typical

Troubleshooting

Testing Flame Signal:

1. Connect microamp meter in series
2. Run burner normally
3. Read DC microamps
4. Should exceed minimum
5. Stable reading important

Common Issues:

Problem	Cause	Solution
No signal	Dirty/cracked sensor	Clean or replace
	Poor ground	Clean ground connection

Problem	Cause	Solution
	Sensor position	Reposition sensor
	Wire leakage	Check insulation
Weak signal	Carbon on sensor	Clean with steel wool
	Small flame	Adjust gas pressure
	Poor combustion	Adjust air/gas ratio
Unstable	Flame lifting	Reduce gas pressure
	Drafts	Shield flame area
	Loose connections	Secure all wiring

Electronic Flame Safeguard Modules

Modern electronic modules provide sophisticated flame monitoring with diagnostic capabilities.

Types and Features

Integrated Ignition Modules:

- Spark ignition control
- Flame detection
- Valve sequencing
- Safety timing
- Diagnostic LEDs
- Fault codes

Universal Modules:

- Multiple sensor types
- Configurable timing
- Various input voltages
- Relay outputs
- Communication capable

Smart Modules:

- Microprocessor controlled
- Self-diagnostics
- Fault history
- Communication protocols
- Remote monitoring
- Predictive maintenance

Sequence of Operation

Typical Heating Cycle:

1. **Thermostat Call:**
   - 24VAC signal received
   - Safety circuit check
   - Control powered
2. **Pre-Purge:**
   - Inducer starts (if equipped)
   - Air proving switch closes
   - Timer period (0-30 seconds typical)
3. **Ignition Trial:**
   - Ignitor activated
   - Warm-up period (HSI: 15-45 seconds)
   - Gas valve energized
4. **Flame Proving:**
   - Flame sensor monitored
   - Signal must exceed minimum
   - Proving period (2-10 seconds)
5. **Main Burner Operation:**
   - Ignition source may turn off
   - Continuous flame monitoring
   - Normal heating operation
6. **Shutdown:**
   - Thermostat satisfied
   - Gas valve closes
   - Post-purge if required
   - System ready for next cycle

Lockout Conditions

Lockout prevents continued operation after repeated failures, requiring manual intervention.

Soft Lockout

Characteristics:

- Automatic retry after time delay
- Typically 1-3 hour wait
- Limited retry attempts
- Power cycle may reset
- Used for minor faults

Typical Causes:

- Single ignition failure
- Transient flame loss

- Temporary sensor issue
- Limit trip (auto-reset type)

Hard Lockout

Characteristics:

- Requires manual reset
- Power cycle won't clear
- Investigation required
- Indicates serious problem
- Safety protection

Typical Causes:

- Multiple ignition failures
- Flame failure during run
- Open safety circuit
- Internal module fault
- Exceeded retry limit

Diagnostic Features

LED Indicators:

- Steady on: Normal operation
- Slow flash: Normal standby
- Fast flash: Call for heat
- Error codes: Specific flash patterns

Flash Code Examples:

Flashes	Meaning	Action Required
1	Normal operation	None
2	System lockout	Reset and investigate
3	Pressure switch	Check venting/pressure
4	Open high limit	Check airflow/limit
5	Flame failure	Check gas/ignition
6	Soft lockout	Wait or reset
7	Low flame signal	Clean sensor

Advanced Diagnostics:

- Digital displays

- Fault history
- Run time counters
- Cycle counters
- Communication ports
- Remote monitoring

11.6 Pressure and Air Flow Switches

Pressure and air flow switches ensure proper combustion air supply and safe venting conditions. These switches are critical safety components in forced-air gas equipment.

Differential Pressure Switches

Differential pressure switches measure the pressure difference between two points, commonly used to verify induced draft fan operation.

Construction and Operation

Components:

- Diaphragm or bellows sensor
- Two pressure ports
- Snap-action switch
- Adjustment spring
- Electrical contacts

Operating Principle:

1. Pressure applied to both sides of diaphragm
2. Differential pressure causes diaphragm movement
3. Movement operates switch contacts
4. Contacts close/open at setpoint
5. Hysteresis prevents chattering

Specifications:

- Range: 0.05" to 10" W.C. typical
- Accuracy: ±10% typical
- Contacts: SPST or SPDT
- Rating: 1-5 amps @ 24-120VAC
- Temperature rating: -40 to 200°F

Installation Requirements

Mounting:

- Vertical position typically required
- Level for accurate operation
- Vibration-free location
- Accessible for service
- Protected from moisture

Tubing Connections:

- Proper tube size (typically 1/4" or 5/16")
- Downward slope to prevent condensate
- No kinks or restrictions
- Secure connections
- Proper port identification

Electrical Connections:

- Proper terminal identification
- NO (Normally Open) common for proving
- Secure connections
- Proper wire routing
- Moisture protection

Air Proving Switches

Air proving switches verify combustion air flow before allowing burner operation.

Purpose and Applications

Why Required:

- Ensures adequate combustion air
- Prevents incomplete combustion
- Verifies fan operation
- Required by code for certain equipment
- Safety interlock function

Equipment Types:

- Induced draft furnaces
- Power burners
- Unit heaters
- Boilers with forced draft
- Commercial equipment

Types

1. **Differential Pressure:**
   - Most common type
   - Measures across fan
   - Or across heat exchanger
   - Sensitive to small changes
   - Adjustable setpoint
2. **Sail Switch:**
   - Paddle in airstream
   - Simple operation
   - Visual indication
   - Less precise
   - Position sensitive
3. **Current Sensing:**
   - Monitors motor current
   - Indirect air proving
   - No pressure tubing
   - Electronic relay
   - Used in some equipment

Draft Safeguard Switches

Draft safeguard switches monitor proper venting to prevent spillage of combustion products.

Applications

Natural Draft Equipment:

- Monitors draft at outlet
- Detects blocked vent
- Detects backdraft conditions
- Safety shutdown function

Power Vent Equipment:

- Proves vent fan operation
- Monitors vent pressure
- Prevents operation without venting
- Required safety device

Setting Requirements

Typical Settings:

- Natural draft: -0.02" to -0.05" W.C.

- Induced draft: -0.3" to -1.5" W.C.
- Power vent: +0.2" to +1.0" W.C.
- Must exceed all conditions
- Safety margin required

Installation and Adjustment

Proper Installation Procedures

Step-by-Step Installation:

1. **Location Selection:**
    - Per manufacturer specifications
    - Representative pressure point
    - Avoid turbulence
    - Accessible location
    - Protected from damage
2. **Mounting:**
    - Use proper fasteners
    - Level if required
    - Secure mounting
    - Vibration isolation
    - Proper orientation
3. **Tubing Installation:**
    - Cut tubing square
    - Proper length (no excess)
    - Downward slope
    - Secure routing
    - Label connections
4. **Electrical Connection:**
    - Verify voltage rating
    - Proper terminal selection
    - Secure connections
    - Proper polarity if required
    - Safety circuit wiring
5. **Initial Adjustment:**
    - Start at minimum setting
    - Run equipment
    - Gradually increase setpoint
    - Find operating point
    - Add safety margin

Adjustment Procedures

Field Adjustment Method:

1. **Equipment Preparation:**
    - Normal operating conditions
    - Warmed up completely
    - All registers open
    - Clean filters
    - Proper gas pressure
2. **Measurement:**
    - Connect manometer
    - Measure actual pressure
    - Record reading
    - Test various conditions
    - Note minimum pressure
3. **Setting:**
    - Set to 80% of minimum measured
    - Verify operation
    - Test with reduced airflow
    - Confirm proper shutdown
    - Document settings

Fine Tuning:

- Test with dirty filter (reasonable)
- Verify cold start operation
- Check all firing rates (modulating)
- Confirm consistent operation
- Record final settings

Testing Procedures

Functional Testing

Air Proving Switch Test:

1. **Initial Verification:**
    - Visual inspection
    - Check tubing connections
    - Verify electrical connections
    - Note current settings
2. **Operational Test:**
    - Call for heat
    - Verify switch closes
    - Monitor with meter
    - Time the proving period
    - Confirm normal operation
3. **Safety Test:**
    - Block return air partially

    - Switch should open
    - Verify burner shutdown
    - Clear blockage
    - Verify restart
4. **Documentation:**
    - Record pressure readings
    - Note switch settings
    - Document test results
    - Update equipment records

Calibration Verification

Accuracy Check:

1. Connect manometer in parallel
2. Vary pressure slowly
3. Note switch point
4. Compare to manometer
5. Adjust if necessary
6. Verify both make and break points

Response Time Test:

1. Create sudden pressure change
2. Measure response time
3. Should be < 2 seconds
4. Check for switch bounce
5. Verify consistent operation

11.7 Sequence of Operations

Understanding the sequence of operations is crucial for proper installation, adjustment, and troubleshooting of gas equipment controls.

Pre-Purge Requirements

Pre-purge removes any combustible gases from the combustion chamber before ignition, preventing explosive ignition.

Purpose of Pre-Purge

Safety Functions:

- Removes unburned gas

- Clears combustion chamber
- Verifies air flow
- Tests safety circuits
- Required by code for certain equipment

When Required:

- All power burners
- Induced draft equipment > 400,000 BTU/hr
- Commercial equipment
- Multiple burner systems
- After lockout reset

Timing Requirements

CSA B149.1 Requirements:

- Minimum 4 air changes
- Or manufacturer specification
- Typical 30-60 seconds
- Must run at full speed
- Combustion air proving required

Calculation Method:

```
Pre-purge time = (Chamber Volume × 4 × 60) / CFM
```

Where:

- Chamber Volume in cubic feet
- CFM = Fan capacity
- Result in seconds
- Minimum 30 seconds typical

Pre-Purge Sequence

1. **Call for Heat:**
    - Thermostat closes
    - Control power applied
    - Safety circuit check
2. **Fan Start:**
    - Combustion air fan energized
    - Full speed operation
    - No modulation during purge
3. **Air Proving:**
    - Pressure switch closes

    - Must prove within 30 seconds
    - Maintained throughout purge
4. **Timer Period:**
    - Pre-purge timer runs
    - Fixed or adjustable
    - Cannot be bypassed
    - LED indication
5. **Completion:**
    - Timer expires
    - System proceeds to ignition
    - Or lockout if fault detected

Ignition Trial Timing

The ignition trial period is the time allowed to establish flame before safety shutdown.

Trial for Ignition Period

Time Limits (CSA B149.1):

- Pilot ignition: 90 seconds maximum
- Main burner (with proven pilot): 10 seconds
- Direct ignition: 15 seconds maximum
- Power burner: 10-15 seconds
- Must include valve response time

Timing Considerations:

- Starts when gas valve energized
- Includes ignitor warm-up (HSI)
- Must establish stable flame
- Safety margin required
- Shorter is generally safer

Types of Ignition Sequences

Intermittent Pilot:

1. Ignitor activated
2. Pilot valve opens
3. Pilot flame established
4. Flame proved
5. Main valve opens
6. Pilot continues or extinguishes

Direct Spark Ignition:

1. Spark activated
2. Main valve opens
3. Spark continues
4. Flame detected
5. Spark stops
6. Continuous monitoring

Hot Surface Ignition:

1. Ignitor energized
2. Warm-up period (15-45 seconds)
3. Gas valve opens
4. Ignition occurs
5. Flame proved
6. Ignitor de-energized

Retry Sequences

Automatic Retry:

- After failed trial
- Inter-purge period
- Limited attempts (typically 3)
- Lockout after failures
- Reset required

Retry Timing:

- Wait period: 30-60 seconds
- Inter-purge if required
- Full ignition sequence
- Count attempts
- Lockout decision

Main Flame Establishment

Establishing stable main burner flame is critical for safe operation.

Flame Proving Period

Requirements:

- Must prove flame presence
- Within specified time
- Stable flame signal
- Exceeds minimum threshold

- Continuous monitoring

Proof Times:

- Direct ignition: 2-5 seconds
- With pilot: 4-10 seconds
- Must be stable
- No flame flutter
- Strong signal required

Main Valve Sequencing

Typical Sequence:

1. Pilot proven (if used)
2. Main valve energized
3. Slow opening (if equipped)
4. Full flow established
5. Flame signal monitored
6. Normal operation

Modulating Systems:

1. Ignition at low fire
2. Prove flame
3. Drive to high fire
4. Modulation enabled
5. Respond to demand

Post-Purge Requirements

Post-purge continues air flow after burner shutdown to remove residual heat and combustion products.

Purpose

Functions:

- Removes residual heat
- Clears combustion products
- Cools heat exchanger
- Prevents hot spots
- Reduces thermal stress

When Required

Equipment Types:

- Power burners
- Large commercial equipment
- High-temperature applications
- Condensing equipment
- Where specified by manufacturer

Duration:

- Typically 30-180 seconds
- Based on equipment size
- Temperature dependent
- May use thermostat
- Adjustable on some controls

CSA B149.1 Timing Requirements

The Canadian gas code specifies maximum timing for various safety functions.

Summary of Time Limits

Function	Maximum Time	Notes
Pre-purge	As required	Minimum 4 air changes
Pilot trial	90 seconds	Including valve response
Main trial (with pilot)	10 seconds	From pilot proved
Direct ignition trial	15 seconds	Total time
Flame failure response	4 seconds	Power burner
	30 seconds	Atmospheric burner
Post-purge	As required	Equipment dependent
Air proving	30 seconds	To prove air flow
Valve proving	5 minutes	Complete test cycle

Special Requirements

Power Burners:

- Faster response times
- Mandatory pre-purge
- Proven air flow
- Quick flame failure response
- Post-purge typical

High Input Rates (>400,000 BTU/hr):

- Redundant valves
- Manual reset
- Proven closure
- Full safety shutdown
- Qualified startup

Safety Lockout Conditions

Lockout prevents automatic restart after safety faults, requiring investigation and manual reset.

Conditions Causing Lockout

Immediate Lockout:

- High limit trip (manual reset type)
- Repeated ignition failure
- Flame failure during run
- Air proving failure
- Internal control fault

After Retry Attempts:

- Ignition failure (3 attempts typical)
- Weak flame signal
- Unstable flame
- Pressure switch cycling
- Limit cycling

Lockout Types and Reset

Soft Lockout:

- Automatic reset after delay
- 1-3 hour typical
- Power cycle may clear
- Limited occurrences
- Becomes hard lockout if repeated

Hard Lockout:

- Manual reset required
- At equipment location
- Investigation required
- Document cause
- Correct before reset

Remote Reset:

- Permitted for some conditions
- Must be at equipment
- Cannot be automatic
- Requires deliberate action
- Safety investigation still required

Diagnostic Information

Information Available:

- LED flash codes
- Digital displays
- Fault history
- Time stamps
- Cycle counters
- Operating parameters

Typical Fault Codes:

Code	Description	Typical Cause
1-1	Normal operation	No fault
2-2	System lockout	Multiple retry failure
3-3	Pressure switch open	Blocked vent/filter
4-4	Open high limit	Overheating
5-5	Flame failure	Gas or ignition problem
6-6	Soft lockout	Temporary failure
7-7	Low flame signal	Dirty sensor
8-8	Ignitor failure	Open ignitor circuit

Chapter Review

Summary

This chapter covered the critical components of gas valve and safety control systems:

Manual Valves:

- Ball valves are the modern standard
- Proper identification and labeling essential
- Installation must meet code requirements
- Regular operation prevents seizing

Automatic Valves:

- Solenoid valves provide fast response
- Redundant systems required for larger equipment
- Combination valves simplify installation
- Slow-opening features reduce stress

Safety Systems:

- 100% shut-off required for safety
- Manual reset ensures investigation
- Proving systems verify safe conditions
- Redundancy provides backup protection

Limit Controls:

- Temperature limits prevent overheating
- High limits require manual reset
- Proper location critical for function
- Regular testing ensures reliability

Flame Safeguards:

- Multiple detection methods available
- Continuous monitoring required
- Lockout prevents unsafe operation
- Diagnostic features aid troubleshooting

Pressure/Airflow Switches:

- Verify combustion air supply
- Prove proper venting
- Require proper adjustment
- Critical safety components

Sequences:

- Pre-purge removes combustibles
- Timed trials prevent gas accumulation
- Post-purge removes heat
- Lockout requires investigation

Valve Identification Exercises

Exercise 1: Visual Identification

Given a selection of valves, identify:

1. Valve type (ball, plug, gate, etc.)
2. Pressure rating
3. Size and connection type
4. Flow direction (if marked)
5. Certification marks
6. Suitable applications

Exercise 2: Valve Selection

For each scenario, select the appropriate valve:

Scenario A: Main gas shut-off for 100,000 BTU/hr furnace

- Answer: 3/4" ball valve, certified for gas

Scenario B: Equipment over 400,000 BTU/hr

- Answer: Redundant automatic valves with proof of closure

Scenario C: Pilot gas control with thermocouple

- Answer: Combination gas valve with thermocouple connection

Scenario D: Emergency shut-off at building entrance

- Answer: Ball valve with lockable handle, clearly marked

Wiring Diagram Interpretation

Exercise 3: Reading Wiring Diagrams

Given the following wiring diagram symbols, identify components:

```
─||─ : Switch contacts (normally open)
─|/|─ : Switch contacts (normally closed)
─M─ : Motor or valve coil
─●─ : Connection point
──── : Thermal element
─⊏⊐─ : Transformer
```

Exercise 4: Tracing Circuits

Trace the following control circuit sequence:

1. Power from transformer (24VAC)

2. Through thermostat
3. Through limit switches
4. To gas valve
5. Identify safety interruption points
6. Determine fail-safe operation

Sequence Timing Problems

Problem 1: Pre-Purge Calculation

Given:

- Combustion chamber: 8 cubic feet
- Fan capacity: 400 CFM
- Required: 4 air changes

Calculate minimum pre-purge time:

```
Time = (8 × 4 × 60) / 400 = 4.8 seconds
```

However, minimum is typically 30 seconds, so use 30 seconds.

Problem 2: Ignition Trial Analysis

A direct ignition system has:

- HSI warm-up: 30 seconds
- Gas valve response: 1 second
- Flame establishment: 3 seconds

Total trial time: 34 seconds Maximum allowed: 15 seconds for direct ignition **Problem:** Exceeds code requirement. Need faster ignitor or different sequence.

Troubleshooting Scenarios

Scenario 1: No Heat Call

Symptoms:

- Thermostat calling for heat
- No burner operation
- LED showing pressure switch open

Diagnostic Steps:

1. Check inducer motor operation

2. Verify pressure switch tubing
3. Check for blocked vents
4. Test pressure switch operation
5. Inspect venting system

Solution: Clear blocked condensate drain affecting pressure switch

Scenario 2: Repeated Lockout

Symptoms:

- System locks out after 3 attempts
- Flame lights then goes out
- Fault code indicates flame failure

Diagnostic Steps:

1. Check flame sensor condition
2. Verify sensor position
3. Test flame signal strength
4. Check grounding
5. Inspect gas pressure

Solution: Clean flame sensor, reposition for stronger signal

Scenario 3: Short Cycling

Symptoms:

- Burner cycles on limit
- Short run times
- High temperature at limit

Diagnostic Steps:

1. Check air filter
2. Verify blower operation
3. Test limit switch calibration
4. Inspect heat exchanger
5. Check gas pressure

Solution: Replace restricted air filter, adjust blower speed

Scenario 4: Won't Light After Service

Symptoms:

- New gas valve installed
- Spark present
- No gas flow
- All safeties satisfied

Diagnostic Steps:

1. Verify gas valve wiring
2. Check valve voltage
3. Test manual valve positions
4. Verify gas pressure
5. Check valve proving (if equipped)

Solution: Correct reversed valve wiring

Laboratory Exercises

Lab 1: Thermocouple Testing

Equipment Needed:

- Millivolt meter
- Thermocouple
- Pilot burner
- Gas valve with thermocouple connection

Procedure:

1. Test thermocouple open circuit (25-35 mV)
2. Test closed circuit (12-15 mV minimum)
3. Test dropout time (30-180 seconds)
4. Clean and retest
5. Document results

Lab 2: Flame Signal Measurement

Equipment:

- Microamp meter
- Flame rod
- Operating burner
- Ignition control

Procedure:

1. Connect meter in series with flame rod

2. Establish flame
3. Measure DC microamps (1-10 typical)
4. Test with dirty sensor
5. Clean and retest
6. Verify minimum signal

Lab 3: Pressure Switch Adjustment

Equipment:

- Pressure switch
- Manometer
- Operating furnace
- Hand tools

Procedure:

1. Measure operating pressure
2. Note current switch setting
3. Test switch operation
4. Adjust to 80% of minimum
5. Verify safety shutdown
6. Document settings

Code Reference Summary

Key CSA B149.1 Requirements

Manual Valves:

- Section 5.10: Shut-off valve requirements
- Section 6.22: Identification requirements
- Section 8.4: Accessibility requirements

Safety Controls:

- Section 7.8: Safety shut-off requirements
- Section 7.9: Redundant valve requirements
- Section 7.10: Manual reset requirements
- Section 7.17: Flame safeguard requirements

Time Limits:

- Table 7.1: Maximum trial for ignition times
- Section 7.12: Pre-purge requirements
- Section 7.13: Post-purge requirements

Testing:

- Section 8.14: Control testing requirements
- Section 10: Inspection and testing procedures

Key Terms

Automatic Reset: Control that resets itself after tripping when conditions return to normal.

Ball Valve: Quarter-turn valve using rotating ball with port through center for flow control.

Combination Gas Valve: Single valve body incorporating multiple functions like regulator, safety shut-off, and servo control.

Differential Pressure Switch: Switch that operates based on pressure difference between two measurement points.

Diaphragm Valve: Valve using flexible diaphragm operated by pressure differential for flow control.

Double Block: Two automatic valves in series providing redundant shut-off capability.

Flame Rectification: Flame detection method using flame's ability to conduct electricity and act as electrical rectifier.

Flame Rod: Sensor electrode positioned in flame for flame rectification detection system.

Hard Lockout: Safety shutdown requiring manual reset at equipment location before restart.

High Limit: Safety control that shuts down equipment when temperature exceeds safe maximum.

Hot Surface Ignitor (HSI): Silicon carbide or silicon nitride element that glows when heated electrically to ignite gas.

Ignition Trial: Time period allowed to establish flame before safety shutdown occurs.

Intermittent Pilot: Pilot that lights only when main burner operates, extinguishing when satisfied.

Limit Control: Safety device monitoring temperature, pressure, or other parameters to prevent unsafe conditions.

Manual Reset: Safety control requiring physical reset action before equipment can restart.

Microamp (µA): One millionth of an ampere, unit measuring flame rectification current.

Millivolt: One thousandth of a volt, typical output of thermocouples and thermopiles.

Operating Control: Device controlling normal equipment cycling, typically auto-reset.

Pilot Proving: Verification that pilot flame is established before allowing main gas flow.

Post-Purge: Continued air flow after burner shutdown to remove heat and combustion products.

Pre-Purge: Air flow period before ignition to remove any combustible gases from combustion chamber.

Pressure Switch: Switch operated by gas or air pressure, used for proving and safety functions.

Proof of Closure: System verifying safety valves are fully closed before allowing startup.

Redundant Valves: Two automatic valves in series for safety shut-off per code requirements.

Sail Switch: Air flow switch using paddle or vane in air stream.

Safety Shut-Off: Automatic valve providing 100% gas shut-off during unsafe conditions.

Sequence of Operation: Step-by-step process of equipment startup, operation, and shutdown.

Slow-Opening Valve: Valve with controlled opening rate to reduce ignition shock and noise.

Soft Lockout: Temporary safety shutdown that automatically resets after time delay.

Solenoid Valve: Electrically operated valve using electromagnetic coil to move plunger.

Spill Switch: Thermal switch detecting combustion products spilling from draft hood.

Standing Pilot: Continuous pilot flame maintaining ignition source for main burner.

Thermocouple: Two dissimilar metals joined, generating millivolts when heated for flame detection.

Thermopile: Multiple thermocouples in series generating higher voltage for control power.

Trial for Ignition: Maximum time allowed to establish and prove flame before shutdown.

Valve Proving: Test cycle verifying safety shut-off valves are not leaking internally.

End of Chapter 11

This comprehensive chapter on Gas Valves and Safety Controls provides the foundational knowledge required for proper selection, installation, testing, and troubleshooting of gas control systems. Understanding these components and their interactions is essential for ensuring safe and reliable gas equipment operation in accordance with CSA B149.1 requirements.

Students should be able to identify various valve types, understand safety control operation, properly wire control circuits, interpret sequences of operation, and diagnose control system problems. Regular testing and maintenance of these critical safety components ensures continued safe operation and code compliance.

The next chapter will cover Venting Systems, exploring the principles and practices of removing combustion products safely from gas equipment.