Canadian Gas Technician - Learning Module 15

Control Systems and Sequences

Learning Objectives

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

01

Understand

fundamental control logic types and their applications

02

Analyze

heating control sequences according to CSA B149.1

03

Explain

the operation of combination heating and cooling systems

04

Design

basic zone control systems for residential and commercial applications

05

Configure

advanced control systems including outdoor reset and building automation

01

Troubleshoot

complex control system problems systematically

02

Interpret

control sequences and timing diagrams

03

Verify

proper control system operation and safety interlocks

04

Diagnose

common control system failures

05

Apply

control theory to practical HVAC applications

Introduction

Control systems are the brain of modern HVAC equipment, orchestrating the complex interaction between components to maintain comfort and safety. From simple on-off thermostats to sophisticated building automation systems, gas technicians must understand how controls sequence equipment operation, manage safety interlocks, and optimize system performance.

This chapter explores control theory and practical applications, emphasizing:

Safety sequences mandated by CSA B149.1

Integration of heating and cooling systems

Zone control strategies

Advanced control technologies

Systematic troubleshooting approaches

Understanding control systems enables technicians to:

- Properly commission new equipment
- Diagnose complex system problems
- Optimize system performance
- Ensure safe equipment operation
- Interface with building automation systems

15.1

Basic Control Logic

On-Off Control

Principle of Operation: On-off control, also called two-position or binary control, is the simplest form of automatic control. The controlled device is either fully on or fully off, with no intermediate positions.

Characteristics:

- Simple and reliable
- Low cost
- Easy to understand and troubleshoot
- Some temperature swing inherent
- Cycling wear on components

Components:

1. Sensing Element

- Temperature sensor
- Pressure sensor
- Humidity sensor
- Flow sensor

2. Controller

- Thermostat
- Pressure switch
- Humidistat
- Aquastat

3. Final Control Element

- Gas valve
- Relay contacts
- Damper motor
- Pump/blower

Temperature Control Example:

Setpoint: 20°C (68°F)
Differential: 1°C (2°F)
Heat ON at: 19.5°C (67°F)
Heat OFF at: 20.5°C (69°F)

Advantages:

- Simplicity
- Reliability
- Low initial cost
- Easy maintenance
- Fail-safe operation possible

Disadvantages:

- Temperature swing
- Equipment cycling
- Reduced equipment life
- Less precise control
- Potential comfort issues

Staged Control

Multi-Stage Operation: Staged control provides intermediate capacity levels between off and full capacity, improving comfort and efficiency.

Two-Stage Heating Example:

Stage 1 (Low Fire)

- First stage activates at setpoint minus 0.5°C
- Provides 40-60% of full capacity
- Maintains temperature during mild conditions

Stage 2 (High Fire)

- Activates if temperature continues dropping
- Typically 1-2°C below setpoint
- Provides 100% capacity
- Quick recovery from setback

Staging Methods:

1. Time-Based Staging

- Fixed time delay between stages
- 5-10 minutes typical
- Prevents short cycling
- Simple implementation

2. Temperature-Based Staging

- Based on temperature differential
- More responsive to load
- Better comfort control
- Requires sophisticated thermostat

3. Outdoor Temperature Staging

- Stages based on outdoor temperature
- Prevents unnecessary high fire
- Improves efficiency
- Requires outdoor sensor

Commercial Multi-Stage Example:

4-Stage Rooftop Unit:

Stage 1: 25% capacity at SP-0.5°C
Stage 2: 50% capacity at SP-1.0°C
Stage 3: 75% capacity at SP-1.5°C
Stage 4: 100% capacity at SP-2.0°C

Staging Down:
Stage 4 OFF at SP+0.5°C
Stage 3 OFF at SP+1.0°C
Stage 2 OFF at SP+1.5°C
Stage 1 OFF at SP+2.0°C

Benefits of Staging:

- Improved comfort (smaller temperature swings)
- Better humidity control
- Increased efficiency
- Reduced equipment cycling
- Longer equipment life
- Quieter operation at low fire

Modulating Control

Continuous Capacity Control: Modulating control provides infinite capacity adjustment between minimum and maximum, maintaining precise temperature control.

Types of Modulating Control:

1. Proportional Control

- Output proportional to error
- Simple implementation
- May have offset from setpoint

2. Proportional-Integral (PI)

- Eliminates steady-state error
- More complex tuning
- Common in commercial systems

3. PID (Proportional-Integral-Derivative)

- Fastest response
- Anticipates changes
- Requires careful tuning
- Used in critical applications

Modulating Components:

Modulating Gas Valves:

- 0-10VDC or 4-20mA signal
- Turndown ratio 5:1 to 10:1
- Smooth capacity adjustment
- Electronic feedback

Variable Frequency Drives (VFDs):

- Control motor speed
- Energy savings
- Soft start/stop
- Precise airflow control

Electronic Expansion Valves:

- Precise refrigerant control
- Superheat optimization
- Wide operating range

Control Signals:

- 0-10VDC: Common in HVAC
- 2-10VDC: Allows off position
- 4-20mA: Industrial standard
- PWM: Pulse width modulation
- Digital: BACnet, Modbus

Throttling Range: The temperature range over which the control modulates from minimum to maximum.

Example:

Setpoint: 20°C
Throttling Range: 2°C
Maximum output at: 19°C
Minimum output at: 21°C

Setpoint and Differential

Setpoint: The desired control point for the system.

Types of Setpoints:

1. Fixed Setpoint

- Manually set
- Remains constant

2. Adjustable Setpoint

- User adjustable
- Limited range

3. Remote Setpoint

- Set by BAS
- Can be scheduled

4. Reset Setpoint

- Varies with outdoor temperature
- Optimizes efficiency

Differential (Deadband): The difference between cut-in and cut-out points.

Mechanical Differential:

- Fixed by design
- 1-3°C typical
- Not adjustable

Electronic Differential:

- Adjustable
- 0.5-5°C range
- Optimizable for application

Differential Considerations:

Narrow Differential:

- More precise control
- Increased cycling
- Better comfort
- More equipment wear

Wide Differential:

- Less cycling
- Longer equipment life
- Greater temperature swing
- Potential comfort complaints

Optimal Differential Selection:

Residential: 1-2°C (2-3°F)
Commercial: 2-3°C (3-5°F)
Industrial: 3-5°C (5-10°F)
Storage: 5-10°C (10-20°F)

Anticipation

Purpose: Anticipation prevents overshoot by shutting off heating/cooling before reaching setpoint.

Types of Anticipation:

1

Heat Anticipation

- Small heater in thermostat
- 0.1-1.2A adjustable
- Turns heat off early
- Prevents overshoot

2

Cool Anticipation

- Fixed resistor
- Not adjustable
- Prevents overcooling

3

Electronic Anticipation

- Algorithm-based
- Self-adjusting
- Learns system response
- No physical anticipator

Cycle Rate Adjustment: Number of cycles per hour affects comfort and equipment life.

Recommended Cycles Per Hour (CPH):

Gravity warm air: 1-2 CPH
Low mass radiation: 3-4 CPH
Forced air: 4-6 CPH
Electric heat: 6-9 CPH
High mass radiation: 2-3 CPH

Adaptive Control: Modern thermostats use adaptive algorithms:

- Learn system response time
- Adjust anticipation automatically
- Optimize for comfort and efficiency
- Reduce overshoot and undershoot

15.2

Heating Control Sequences

Simple Thermostat Call for Heat

Basic Sequence of Operation:

01

Thermostat Initiation

- Room temperature drops below setpoint
- Thermostat contacts close (R to W)
- 24VAC signal sent to furnace

02

Control Board Response

- Receives W call
- Initiates safety checks
- Begins ignition sequence

03

Pre-Purge (if applicable)

- Inducer motor starts
- Proves venting path clear
- 15-30 second purge

04

Ignition Sequence

- Ignition source activated
- Gas valve opens
- Flame established

05

Flame Proving

- Flame sensor confirms ignition
- Safety timer satisfied
- System continues operation

01

Blower Operation

- Fan-on delay (30-90 seconds)
- Blower starts on heat speed
- Circulates warm air

02

Continuous Operation

- Maintains flame
- Monitors safety controls
- Cycles on limit if needed

03

Satisfaction

- Thermostat satisfied
- W signal removed
- Gas valve closes

04

Post-Purge

- Inducer continues (15-30 seconds)
- Clears products of combustion

05

Fan-Off Delay

- Blower continues (90-180 seconds)
- Removes residual heat
- Prevents heat exchanger stress

Ignition Sequences per CSA B149.1

CSA B149.1 Requirements:

Mandatory Safety Features:

1. Proof of Closure

- Gas valve must be proven closed
- Before ignition attempt

2. Ignition Trial Time

Maximum trial periods:

- Main burner direct: 15 seconds
- Pilot ignition: 90 seconds
- Direct spark: 15 seconds
- Hot surface: 30-60 seconds

3. Flame Supervision

- Continuous monitoring
- 0.5-4 seconds response
- Immediate gas shutoff on failure

4. Lockout on Failure

- After failed ignition attempts
- Requires manual reset
- Or automatic after timeout

Standing Pilot Sequence:

1. Pilot Valve Opens

- Thermocouple must be proven
- 750°C minimum temperature
- 25-30 mV typical

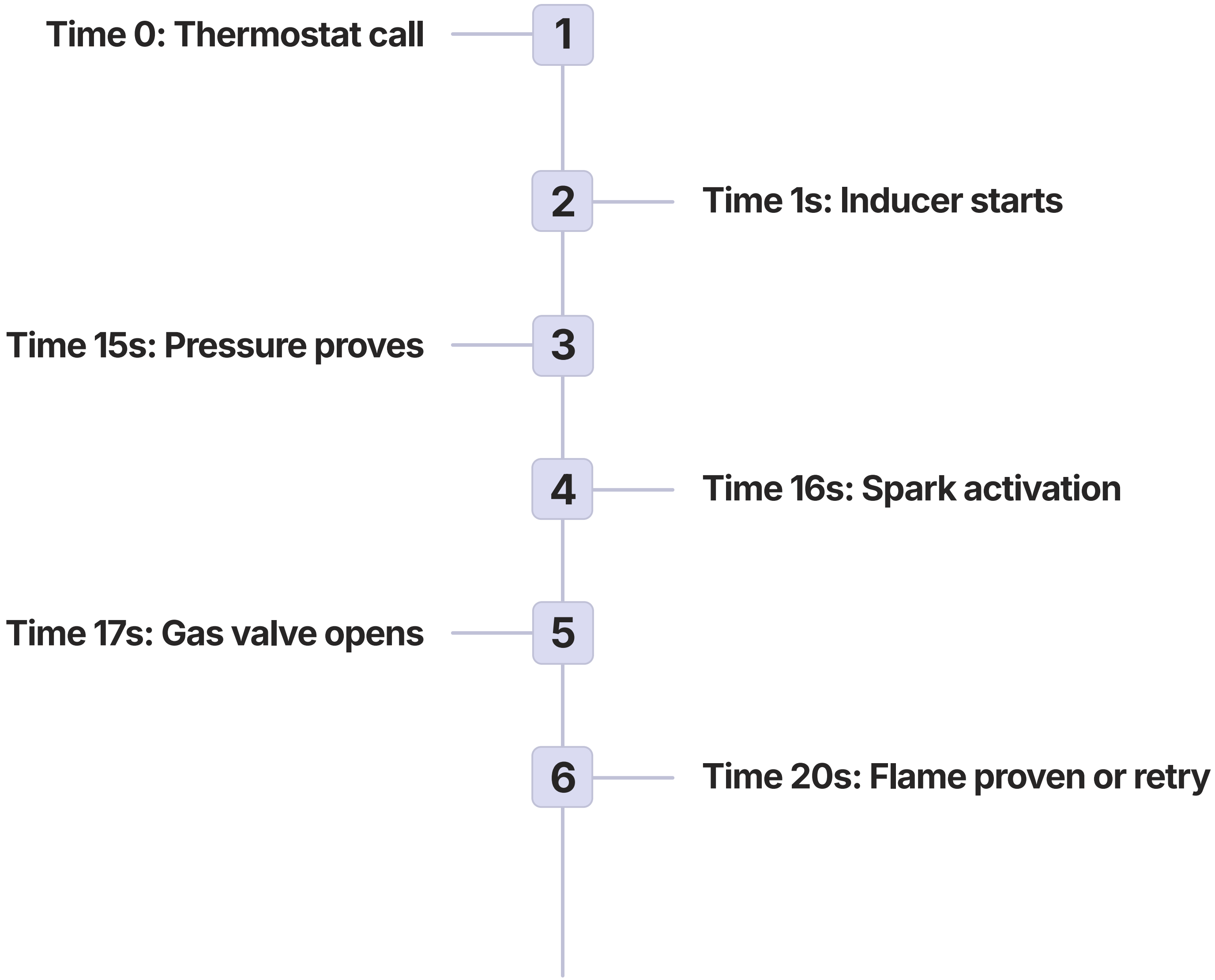
2. Main Valve Operation

- Only after pilot proven
- Continuous supervision
- Immediate shutdown on failure

Intermittent Pilot Sequence (IPI):

Time 0	Thermostat call (W)
Time 1s	Inducer starts (if present)
Time 15s	Pressure switch proves
Time 16s	Spark starts
Time 17s	Pilot valve opens
Time 20s	Spark stops (flame proven)
Time 21s	Main valve opens
Continuous	Flame monitoring
On failure	Immediate gas shutoff
After 3 failures	Lockout (manual reset)

Direct Spark Ignition (DSI):



Trial time: 15 seconds maximum

Retries: 3-5 attempts

Lockout: After final failure

Hot Surface Ignition (HSI):

Time 0
Thermostat call

Time 1s
Inducer starts

Time 15s
Pressure proves

Time 16s
Igniter energizes

Time 45s
Igniter at temperature (870°C)

Time 46s
Gas valve opens

Time 50s
Flame proven

Time 51s
Igniter de-energizes

If no flame: Close valve, retry
Maximum trials: 3-4 attempts

Flame Sensing Methods:

1. Flame Rectification

- AC applied to sensor
- Flame conducts DC component
- 0.5-10 microamps DC typical
- Most common method

2. Flame Rod Requirements

- Minimum 1 µA for proof
- 2-10 µA typical reading
- Ground area 4x rod area
- Proper positioning critical

3. UV Sensors

- Ultraviolet detection
- Commercial/industrial
- Self-checking capability
- Fail-safe design

4. Infrared Sensors

- Detects IR radiation
- High-temperature applications
- Less affected by contamination

Blower Control (Heating Mode)

Fan Control Methods:

1. Temperature-Activated

- Bimetal fan switch
- Opens at 38°C (100°F)
- Closes at 49°C (120°F)
- Simple and reliable

2. Time-Delay Control

- Electronic timer
- Fixed or adjustable delay
- 30-90 seconds on
- 90-240 seconds off

3. Integrated Control Board

- Programmed delays
- Multiple speed control
- Diagnostic capability
- Variable timing

Blower Speed Selection:

Heating Speed:

- Lower CFM than cooling
- 350-400 CFM per ton typical
- Prevents cold drafts
- Increases temperature rise

Speed Tap Selection:

PSC Motor Typical:

Black: High (cooling)
Blue: Medium-high
Yellow: Medium-low (heating)
Red: Low
White: Common

Temperature Rise Calculation:

ΔT = (Output BTU/h) / (1.08 × CFM)

Example:
80,000 BTU/h furnace
1200 CFM airflow
ΔT = 80,000 / (1.08 × 1200) = 62°F

Acceptable Temperature Rise:

- Manufacturer specifications
- Typically 30-70°F (17-39°C)
- Higher rise = lower CFM
- Must stay within limits

Limit Control Operation

Primary Limit Switch:

Purpose:

- Prevent overheating
- Protect heat exchanger
- Ensure safe operation
- Manual reset type

Operation:

1. Normal: Closed circuit
2. Over-temperature: Opens at setpoint
3. Stops gas flow immediately
4. Requires manual reset
5. Investigate cause before reset

Typical Settings:

Residential Furnace:

Open: 200°F (93°C)

Manual reset required

Location: Above heat exchanger

Secondary/Auxiliary Limits:

Auto-Reset Limits:

- Open: 160-180°F
- Close: 130-140°F
- Automatic reset
- Cycling protection

Rollout Switches:

- Detect flame rollout
- Multiple locations
- Manual or auto reset
- 200-300°F typical

Location Requirements:

- Hottest air location
- Not in direct radiant path
- Proper airflow sensing
- Accessible for service

Testing Limit Switches:

1. Continuity when cold
2. Opens at rated temperature
3. Proper reset function
4. Secure mounting
5. Proper location

Safety Lockout Procedures

Types of Lockout:

1. Soft Lockout

- Automatic reset
- After time period (1-3 hours)
- Or power cycle
- Minor faults

2. Hard Lockout

- Manual reset required
- Safety-critical faults
- Requires investigation
- Reset button/power cycle

Common Lockout Conditions:

Ignition Failure Lockout:

Sequence:

1st attempt: 15-30 seconds trial
2nd attempt: After 30s wait
3rd attempt: After 30s wait
4th attempt: Final try
Lockout: No flame after all attempts
Reset: Manual after 1-3 hours

Flame Failure Lockout:

- Flame loss during operation
- Immediate gas valve closure
- Retry attempts (1-3)
- Lockout if continuous failure

Limit Switch Lockout:

- Primary limit open
- Manual reset only
- Must investigate cause

Check for:

- Dirty filter
- Blocked vents
- Blower failure
- Overfire condition

Pressure Switch Lockout:

Typical sequence:

5 attempts to prove pressure
2-minute wait between attempts
Lockout after 5 failures

Check:

- Blocked vents
- Inducer operation
- Pressure tubing
- Switch calibration

Lockout Reset Procedures:

1. Identify Fault

- Check diagnostic LEDs
- Read fault codes
- Review sequence

2. Correct Problem

- Clear blockages
- Replace failed parts
- Verify operation

3. Reset Method

- Press reset button (hold 1-2 seconds)
- Or power cycle (off 30 seconds)
- Clear fault memory if needed

4. Verify Operation

- Complete heating cycle
- No fault recurrence
- Document repair

Diagnostic LED Codes:

Common Patterns:

1 flash	System lockout
2 flashes	Pressure switch stuck closed
3 flashes	Pressure switch open
4 flashes	Open limit
5 flashes	Flame sense failure
6 flashes	Rollout switch open
7 flashes	Gas valve error
Continuous	Normal operation

15.3

Combination Systems

Heating and Cooling Integration

Dual-Function Systems: Modern HVAC systems integrate heating and cooling functions, requiring careful control coordination to prevent simultaneous operation and ensure efficient changeover.

Common Terminal Designations:

R: 24V power from transformer
C: Common (24V return)
W/W1: First stage heat
W2: Second stage heat

Y/Y1: First stage cooling
Y2: Second stage cooling
G: Fan
O: Reversing valve (cool)
B: Reversing valve (heat)

System Integration Requirements:

1. Single Transformer

- Powers both heating and cooling
- 40-75VA typical
- Sized for maximum load

2. Interlock Controls

- Prevent simultaneous heat/cool
- Thermostat logic
- Time delays between modes

3. Blower Speed Control

- Different speeds for heat/cool
- Automatic switching
- Relay or electronic control

Control Board Integration: Modern integrated control boards manage:

- Mode selection
- Safety interlocks
- Blower speeds
- Staging sequences
- Diagnostic functions
- Communication protocols

Furnace with Air Conditioning

System Components:

1. Furnace (Heating)

Gas burner system

- Heat exchanger
- Integrated blower
- Control board

2. Air Conditioner (Cooling)

- Outdoor condensing unit
- Indoor evaporator coil
- Refrigerant lines
- Condensate management

Control Sequence - Cooling Mode:

01

Thermostat calls for cooling (Y)

02

Furnace control receives signal

03

Blower relay energizes (high speed)

04

Y signal passed to outdoor unit

05

Compressor contactor pulls in

06

Condenser fan starts

07

Compressor starts (time delay)

08

Continuous operation until satisfied

09

Thermostat satisfied (Y off)

10

Outdoor unit stops

11

Blower continues (90 seconds)

12

System off

Control Sequence - Heating Mode:

1. Thermostat calls for heat (W)
2. Standard heating sequence initiates
3. Inducer starts (if present)
4. Ignition sequence
5. Gas valve opens
6. Flame established
7. Blower on (low/medium speed)
8. Continuous operation
9. Thermostat satisfied
10. Gas valve closes
11. Blower off delay

Blower Speed Configuration:

DIP Switch Settings (Typical):

2.0	60,000	+10%
2.5	75,000	Normal
3.0	90,000	-10%
3.5	105,000	-20%

Airflow Requirements:

- Cooling: 400 CFM/ton
- Heating: Based on temperature rise
- Continuous fan: Medium speed
- Dehumidification: -15% CFM

Heat Pump with Gas Backup

Dual-Fuel Systems: Combines heat pump efficiency with gas heating reliability.

Components:

1. Heat pump outdoor unit
2. Gas furnace with coil
3. Dual-fuel thermostat
4. Outdoor temperature sensor
5. Fossil fuel kit (control module)

Operating Modes:

Heat Pump Only (Above Balance Point)

Outdoor > 35°F (2°C):

- Heat pump primary heat
- High efficiency operation
- No gas usage

Dual Operation (Transition)

20-35°F (-7 to 2°C):

- Heat pump with gas auxiliary
- Based on outdoor temperature
- Or time/temperature algorithm

Gas Only (Below Balance Point)

Below 20°F (-7°C):

- Gas furnace only
- Heat pump locked out
- Maximum heating capacity

Control Logic:

Balance Point Determination:

- Heat loss calculation
- Heat pump capacity curve
- Intersection point
- Adjustable in thermostat

Switchover Methods:

1. Outdoor Temperature

- Fixed setpoint
- 25-40°F typical
- Simple control

2. Economic Balance

- Compares operating costs
- Real-time pricing
- Optimizes for cost

3. Comfort Priority

- Switches on recovery time
- Maintains temperature
- User preference

Wiring Configuration:

Dual-Fuel Terminal Usage:

R: 24V power
C: Common
Y1: Compressor stage 1
Y2: Compressor stage 2
W1: Gas heat (backup)
W2: Gas heat stage 2
O/B: Reversing valve
G: Fan
E: Emergency heat
S1/S2: Outdoor sensor

Lockout Logic:

- Heat pump OFF when gas runs
- Prevents compressor damage
- Time delay between modes
- Emergency heat override

Changeover Controls

Automatic Changeover: System automatically switches between heating and cooling based on temperature.

Requirements:

- Auto mode on thermostat
- Deadband between modes
- Time delays
- Temperature averaging

Changeover Deadband:

Example Settings:

Heat setpoint: 68°F (20°C)
Cool setpoint: 75°F (24°C)
Deadband: 7°F (4°C)

Operation:
Heat ON below 68°F
All OFF 68-75°F
Cool ON above 75°F

Manual Changeover: User manually selects heating or cooling mode.

Advantages:

- Prevents unwanted switching
- User control
- Energy savings
- Simpler control

Commercial Changeover:

Often based on outdoor temperature:

Outdoor > 65°F: Cooling only
55-65°F: Auto changeover
Outdoor < 55°F: Heating only

Emergency Heat

Purpose: Backup heating when heat pump fails or cannot maintain temperature.

Activation Methods:

1. Manual Selection

- EM HEAT switch
- Bypasses heat pump
- Direct gas/electric heat
- User activated

2. Automatic Activation

- Heat pump failure
- Low pressure lockout
- Defrost malfunction
- Compressor fault

Control Sequence:

1. Emergency heat selected/activated
2. Heat pump locked out
3. W2 or E terminal energized
4. Auxiliary heat operates
5. Higher energy consumption
6. Alert indicator activated

Staging with Emergency Heat:

- Stage 1: Auxiliary heat only
- Stage 2: Additional elements/capacity
- No heat pump operation
- Full backup capacity

Return to Normal:

1. Manual: Switch back to normal
2. Automatic: After fault cleared
3. Time delay before compressor
4. Verify heat pump operation

15.4

Zone Control Systems

Multiple Zone Damper Systems

System Components:

1. Zone Control Panel

- Central brain
- Receives thermostat inputs
- Controls dampers
- Manages equipment

2. Zone Dampers

- Motorized dampers
- Spring return or power close
- End switches
- Various sizes

3. Zone Thermostats

- Individual zone control
- Standard wiring
- Programmable options

4. Bypass Damper

- Pressure relief
- Barometric or motorized
- Prevents high static

5. Equipment Interface

Staging control

- Speed control
- Safety interlocks

Zone Panel Operation:

Priority Logic:

First Priority: Any heating call
Second Priority: Any cooling call
Third Priority: Fan only call
Staging: Based on number of zones

Typical 3-Zone Sequence:

Zone 1 calls for heat:

1. Zone panel receives W signal
2. Opens Zone 1 damper
3. Closes Zones 2 & 3 dampers
4. Damper end switches prove
5. Sends W to equipment
6. Normal heating sequence
7. Zone 1 satisfied
8. Equipment stops
9. Dampers return to normal

Multiple Zone Calling:

Zones 1 & 2 call for heat:

1. Both dampers open
2. Zone 3 closes
3. Equipment operates
4. First zone satisfies
5. Its damper closes
6. Bypass opens partially
7. Second zone continues
8. All satisfied system off

Multiple Circulator Systems

Hydronic Zone Control: Each zone has dedicated circulator pump.

Components:

1

Boiler

- Central heat source
- Aquastat control
- Multiple temperature capability

2

Zone Circulators

- Individual pumps
- 1/12 to 1/6 HP typical
- Isolation valves

3

Zone Controls

- Relay panels
- Thermostat inputs
- Pump outputs
- Priority control

Control Methods:
Zone Relay Panel:

Typical 4-Zone Panel:

- 4 thermostat inputs (T1-T4)
- 4 pump outputs (C1-C4)
- Boiler demand contact
- Priority capabilities
- LED indicators

Operation Sequence:

01 Zone thermostat calls

02 Relay panel energized

03 Zone circulator starts

04 Boiler demand made

05 Boiler fires

06 Water circulates in zone

07 Zone satisfied

08 Circulator stops

09 Last zone satisfied

10 Boiler demand removed

Zone Valve Alternative:

- Single circulator
- Multiple zone valves
- 2-way or 3-way valves
- End switch feedback
- Similar control logic

Control Strategies

Temperature Control Strategies:

1. Single Setpoint

- All zones same temperature
- Simple control
- Limited flexibility

2. Individual Setpoints

Each zone independent

- Maximum comfort
- Energy savings potential

3. Scheduled Setpoints

- Time-of-day control
- Occupied/unoccupied
- Night setback

4. Adaptive Control

- Learns zone characteristics
- Anticipates demand
- Optimizes runtime

Equipment Staging Strategies:

Demand-Based Staging:

1 zone calling: Stage 1 (40%)
2 zones calling: Stage 1 (40%)
3 zones calling: Stage 2 (70%)
4+ zones calling: Stage 3 (100%)

Time-Based Staging:

- Fixed time delays
- Prevents short cycling
- 5-10 minute stages

Temperature-Based Staging:

- Based on supply temperature
- Or return temperature
- Or outdoor temperature

Load Matching:

Modern systems modulate capacity:

- Variable speed equipment
- Matches exact load
- Maximum efficiency
- Optimal comfort

Bypass Requirements (Air Systems)

Purpose of Bypass: Maintains minimum airflow when zones close.

Types of Bypass:

1. Barometric Bypass

Weighted damper

- Opens on pressure
- Self-regulating
- No power required

2. Motorized Bypass

- Controlled by static pressure
- Variable position
- Better control
- Requires power

3. Dump Zone

- Always open zone
- Common area
- Hallway/basement
- No damper required

Bypass Sizing:

Bypass CFM = Total CFM - Minimum Zone CFM

Example:

System: 1200 CFM
Smallest zone: 400 CFM
Bypass needed: 800 CFM
Bypass duct: ~14" round

Static Pressure Control:

- Monitor with manometer
- 0.5" W.C. maximum typical
- Adjust bypass damper
- Verify all conditions

Problems Without Bypass:

1. High static pressure
2. Reduced airflow
3. Icing of coil
4. Compressor damage
5. Heat exchanger stress
6. Noise issues
7. Comfort problems

Bypass Installation:

Location: Supply to return
Before zones: After coil
After zones: Before return drop
Distance: Minimum 10 feet
Damper type: Barometric/motorized

Alternative: Variable Speed Blower

- ECM motor
- Constant CFM
- Adjusts to static
- Eliminates bypass need
- Higher initial cost
- Better comfort

15.5

Advanced Controls

Outdoor Reset Controls

Principle: Adjusts supply water temperature based on outdoor temperature - warmer water when mild, hotter water when cold.

Benefits:

- Improved efficiency (10-30%)
- Better comfort
- Reduced cycling
- Lower return temperatures
- Condensing boiler optimization

Reset Curve:

-20°C (−4°F)	82°C (180°F)
-10°C (14°F)	71°C (160°F)
0°C (32°F)	60°C (140°F)
10°C (50°F)	49°C (120°F)
15°C (59°F)	38°C (100°F)

Reset Ratio: Temperature change ratio between outdoor and supply.

Reset Ratio = ΔSupply / ΔOutdoor

Example:
Supply changes 60°F (180-120)
Outdoor changes 40°F (-4 to 36)
Ratio = 60/40 = 1.5:1

Control Components:

1

Outdoor Sensor

- North wall mounting
- Away from sun/exhaust
- 10K thermistor typical
- Weather resistant

2

Supply Sensor

- Strapped to pipe
- Under insulation
- 12" from boiler
- Good thermal contact

3

Reset Controller

- Analog or digital
- Adjustable curve
- Min/max limits
- Display capabilities

Programming Parameters:

- Design outdoor temperature
- Design supply temperature
- Warm weather shutdown
- Minimum supply temperature
- Maximum supply temperature
- Reset curve shape

System Types:

Boiler Reset:

- Most common application
- Works with any boiler
- Best with condensing
- Requires mixing valve protection

Mixing Valve Reset:

- Boiler constant temperature
- Valve modulates
- Good for cast iron boilers
- Protects against condensation

Injection Pumping:

- Variable speed injection
- Primary/secondary piping
- Precise control
- Complex installation

Boiler Management Systems

Multi-Boiler Control:

Purpose:

- Stage multiple boilers efficiently
- Rotate lead boiler
- Optimize efficiency
- Provide redundancy

Staging Strategies:

1. Sequential Staging

- Fixed order
- Simple logic
- Uneven wear

2. Rotation Staging

- Lead boiler rotates
- Even wear
- Daily/weekly rotation

3. Efficiency Staging

- Most efficient first
- Based on load
- Optimizes fuel usage

Control Parameters:

Stage 1 ON: 20% load
Stage 2 ON: 40% load
Stage 3 ON: 60% load
Stage 4 ON: 80% load

Stage delays: 10 minutes
Stage differential: 10°F
Rotation: Weekly

Advanced Features:

Outdoor Reset Integration:

- Common outdoor sensor
- Coordinated supply temps
- System optimization

Warm Weather Shutdown:

- Boilers off above 65°F
- DHW priority
- Summer/winter modes

Parallel Positioning:

- All boilers modulate together
- Equal loading
- Maximum efficiency
- Complex control

Fault Management:

- Automatic isolation
- Backup activation
- Alarm notification
- Runtime balancing

Building Automation Basics

BAS Overview: Building Automation Systems integrate HVAC, lighting, security, and other systems.

System Architecture:

3. Management Level

- Supervisory computers
- Servers
- User interfaces
- Graphics

2. Automation Level

- DDC controllers
- Equipment controllers
- Network controllers

1. Field Level

- Sensors
- Actuators
- VAV boxes
- Local controllers

Benefits:

- Energy optimization
- Central monitoring
- Scheduling
- Trending
- Alarming
- Remote access

Common Functions:

Scheduling:

Occupied: 6:00 AM - 6:00 PM
Unoccupied: 6:00 PM - 6:00 AM
Weekend: Unoccupied
Holidays: Programmed
Override: 2-hour timer

Optimal Start:

- Calculates start time
- Based on outdoor temp
- And indoor temp
- Reaches setpoint on time

Demand Limiting:

- Monitors power usage
- Sheds loads at peak
- Prevents demand charges
- Priority-based shedding

Trending:

- Records data over time
- Temperature trends
- Energy usage
- Equipment runtime
- Troubleshooting tool

Communication Protocols

BACnet (Building Automation and Control Network):

Overview:

- ASHRAE standard
- Open protocol
- Multi-vendor compatible
- Most common in commercial

BACnet/IP:

- Ethernet based
- High speed
- IT infrastructure
- Remote access capable

BACnet MS/TP:

- Master-Slave/Token-Passing
- RS-485 wiring
- Lower cost
- 2-wire communication

Objects and Properties:

- Analog Input (temperature)
- Analog Output (valve position)
- Binary Input (status)
- Binary Output (start/stop)

Modbus:

Overview:

- Industrial protocol
- Simple and robust
- Master/slave architecture
- Wide equipment support

Modbus RTU:

- Serial communication
- Binary protocol
- RS-485 typical
- 2-wire or 4-wire

Modbus TCP/IP:

- Ethernet based
- Higher speed
- Network integration
- Modern systems

Register Types:

- Coils (binary outputs)
- Discrete inputs
- Input registers (analog)
- Holding registers

LON (Local Operating Network):

- Echelon protocol
- Peer-to-peer
- Free topology wiring
- Self-healing

Integration Gateways:

- Protocol converters
- Multi-protocol support
- Web interfaces
- Cloud connectivity

Wireless Protocols:

Wi-Fi:

- Standard 802.11
- High bandwidth
- Existing infrastructure
- Security concerns

Zigbee:

- Low power
- Mesh network
- Self-healing
- Short range

EnOcean:

- Energy harvesting
- No batteries
- Self-powered sensors
- Green technology

15.6

Troubleshooting Control Systems

Systematic Approach

Troubleshooting Methodology:

01

Information Gathering

- Customer complaint
- System history
- Recent changes
- Operating conditions

02

Visual Inspection

- Obvious problems
- Burnt components
- Loose connections
- Physical damage

03

System Understanding

- Review sequence
- Identify components
- Understand normal operation
- Check documentation

04

Problem Isolation

- Which circuit?
- Which component?
- Intermittent or constant?
- Single or multiple issues?

05

Testing and Verification

- Systematic testing
- Document readings
- Compare to specifications
- Verify each component

06

Repair and Retest

- Replace failed parts
- Verify operation
- Check related components
- Complete system test

Documentation:

Service Record:

Date:
Complaint: No heat Zone 2
Found: Open damper motor
Action: Replaced motor
Test: All zones operational
Tech:

Using Wiring Diagrams

Diagram Types for Troubleshooting:

Ladder Diagrams:

- Best for circuit tracing
- Shows electrical path
- Easy voltage tracking
- Clear component relationships

Schematic Diagrams:

- Component connections
- Not physical layout
- Good for understanding
- Complex system overview

Pictorial Diagrams:

- Physical representation
- Component locations
- Wire routing
- Field reference

Connection Diagrams:

- Terminal connections
- Wire colors/numbers
- Board layouts
- Quick reference

Effective Diagram Use:

1. Obtain Correct Diagram

- Model number match
- Serial number range
- Revision level
- Field modifications

2. Mark Test Points

- Expected voltages
- Key connections
- Problem areas
- Test sequence

3. Trace Circuits

- Power source
- Through controls
- To loads
- Return path

4. Document Findings

- Actual voltages
- Open circuits
- Failed components
- Unusual readings