CHAPTER 13

Heating Systems

Learning Objectives

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

1. Identify and explain the operation of forced air furnace components
2. Install furnaces according to manufacturer specifications and CSA B149.1
3. Understand furnace control sequences and troubleshoot control problems
4. Design and install hydronic heating systems with proper components
5. Configure radiant heating systems for various applications
6. Integrate dual fuel heat pump systems with gas furnaces
7. Perform complete commissioning procedures on heating systems
8. Apply systematic troubleshooting techniques to diagnose heating problems
9. Calculate heating loads and equipment sizing
10. Document installation and service work properly

13.1 Forced Air Furnaces

Forced air furnaces are the most common residential heating systems in Canada, providing efficient heat distribution through ductwork.

System Components

Understanding each component's function is essential for proper installation and service.

Heat Exchanger

Primary Heat Exchanger:

- Separates combustion products from circulated air
- Constructed of aluminized steel, stainless steel, or cast iron
- Transfers combustion heat to supply air
- Must maintain separation integrity
- Life expectancy: 15-30 years

Types of Heat Exchangers:

1. **Tubular:**

- Individual tubes or cylinders
- Serpentine design common
- Good heat transfer
- Moderate cost
- Easy to manufacture

2. **Clamshell:**
    - Stamped steel sections
    - Welded or crimped seams
    - Compact design
    - Lower cost
    - Common in older units
3. **Drum:**
    - Cylindrical design
    - Heavy gauge steel
    - Durable construction
    - Higher cost
    - Less common today

Secondary Heat Exchanger (Condensing):

- Stainless steel construction (typically 439SS or 29-4C)
- Extracts latent heat from flue gases
- Produces condensate
- Increases efficiency to 90%+
- Requires condensate management

Burner Assembly

Components:

- Burner tubes or ribbon burners
- Orifices (spuds)
- Manifold
- Gas valve
- Crossover/carryover tubes

Burner Types:

1. **In-shot Burners:**
    - Most common design
    - Gas and primary air mix in venturi
    - Individual burner tubes
    - Natural draft or induced draft
    - 30,000-40,000 BTU per burner typical
2. **Ribbon/Matrix Burners:**
    - Metal fiber mat design

- Large surface area
- Lower NOx emissions
- Quieter operation
- Higher cost

3. **Pre-mix Burners:**
    - Gas and air mixed before combustion
    - Precise control required
    - Used in modulating systems
    - Higher efficiency potential
    - Complex controls

Blower Assembly

Blower Types:

1. **PSC (Permanent Split Capacitor):**
    - Single-speed or multi-speed
    - Simple control
    - Lower cost
    - 60-70% electrical efficiency
    - Speed taps for adjustment
2. **ECM (Electronically Commutated Motor):**
    - Variable speed capability
    - Constant airflow delivery
    - 80-85% electrical efficiency
    - Soft start/stop
    - Advanced diagnostics

Blower Specifications:

- CFM rating (typically 400 CFM per ton)
- Static pressure capability (0.5" - 1.0" W.C.)
- Horsepower (1/3 to 1 HP residential)
- Voltage (120V or 240V)
- Speed options

Control Systems

Integrated Furnace Control (IFC):

- Microprocessor-based
- Manages all furnace operations
- Diagnostic capabilities
- Safety monitoring
- Communication protocols

Control Functions:

- Ignition sequence
- Blower operation
- Safety monitoring
- Fault detection
- User interface

Airflow Principles

Proper airflow is critical for comfort and equipment longevity.

Airflow Requirements

Design Parameters:

- Heating: 400 CFM per ton typical
- Cooling: 350-450 CFM per ton
- Temperature rise: 30-70°F (check nameplate)
- External static pressure: 0.5" W.C. maximum typical

Calculating Required Airflow:

```
CFM = Output BTU/hr / (1.08 × Temperature Rise)
```

Example:

- 80,000 BTU/hr output
- 50°F temperature rise
- CFM = 80,000 / (1.08 × 50) = 1,481 CFM

Static Pressure

Components of Static Pressure:

Component	Typical Pressure Drop
Clean filter	0.10" - 0.15" W.C.
Dirty filter	0.25" - 0.50" W.C.
Supply ductwork	0.05" - 0.15" W.C.
Return ductwork	0.05" - 0.10" W.C.
Registers/grilles	0.03" - 0.05" W.C.
Cooling coil	0.20" - 0.30" W.C.

Measuring Static Pressure:

1. Drill test holes in supply and return plenums
2. Insert manometer probes
3. Measure with system running
4. Total External Static = Supply + Return (absolute values)
5. Compare to blower capability

Duct Design Considerations

Proper Sizing:

- Use ACCA Manual D or equivalent
- Account for all fittings
- Consider future additions
- Balance supply and return

Common Problems:

- Undersized returns (most common)
- Excessive elbows
- Flex duct compression
- Poor transitions
- Inadequate registers

Heat Exchanger Types

Different heat exchanger designs affect efficiency and application.

Primary Heat Exchangers

Aluminized Steel:

- Most common material
- Good corrosion resistance
- Moderate cost
- 15-20 year typical life
- Aluminum coating on steel

Stainless Steel:

- Superior corrosion resistance
- Higher cost
- 20-30+ year life
- Better for condensing
- Various grades (409, 439, 316L)

Cast Iron:

- Excellent durability
- High thermal mass
- Slow response time
- Heavy weight
- Mainly boilers now

Secondary Heat Exchangers

Purpose:

- Extract latent heat
- Cool flue gases below dew point
- Increase efficiency 10-15%
- Produce condensate

Construction:

- Stainless steel required
- Finned tubes common
- Counter-flow design
- Condensate collection
- Corrosion resistant

Condensing vs. Non-Condensing

Understanding the differences helps with selection and service.

Non-Condensing Furnaces

Characteristics:

- 78-83% AFUE typical
- Exhaust temperature 300-500°F
- No condensate production
- Natural or induced draft
- Type B venting typical

Advantages:

- Lower initial cost
- Simple installation
- No condensate management
- Proven technology
- Easy service

Disadvantages:

- Lower efficiency
- Higher operating cost
- Heat lost in exhaust
- May require chimney

Condensing Furnaces

Characteristics:

- 90-98% AFUE
- Exhaust temperature 100-140°F
- Produces acidic condensate
- Positive pressure venting
- PVC venting typical

Advantages:

- High efficiency
- Lower operating costs
- Utility rebates available
- Flexible venting
- Quieter operation

Disadvantages:

- Higher initial cost
- Condensate management
- More complex
- Freeze protection needed
- Regular maintenance critical

Efficiency Ratings

Understanding efficiency metrics helps with equipment selection.

AFUE (Annual Fuel Utilization Efficiency)

Definition:

- Ratio of annual heat output to annual fuel input
- Expressed as percentage
- Includes cycling losses
- Seasonal average

Categories:

Efficiency Level	AFUE Range	Technology
Standard	78-80%	Non-condensing
Mid-efficiency	80-83%	Non-condensing, improved
High-efficiency	90-98%	Condensing
Ultra-high	95-98%	Modulating condensing

Steady-State Efficiency

Definition:

- Efficiency during continuous operation
- Higher than AFUE
- Doesn't include cycling losses
- Laboratory measurement

Typical Values:

- Non-condensing: 80-85%
- Condensing: 92-98%
- Difference from AFUE: 2-5%

Input vs. Output

Understanding Ratings:

- Input: Gas consumed (BTU/hr)
- Output: Heat delivered (BTU/hr)
- Output = Input × Efficiency

Example:

- Input: 100,000 BTU/hr
- Efficiency: 95%
- Output: 95,000 BTU/hr

Multi-Stage and Modulating Systems

Advanced systems provide improved comfort and efficiency.

Two-Stage Furnaces

Operation:

- Low fire: 40-70% capacity
- High fire: 100% capacity

- Automatic staging
- Longer run times
- Better comfort

Benefits:

- Quieter operation on low fire
- Better temperature control
- Improved humidity control
- Higher efficiency
- Reduced cycling

Control Methods:

- Two-stage thermostat
- Timed staging
- Outdoor temperature
- Smart controls

Modulating Furnaces

Operation:

- Variable capacity 40-100%
- Continuous adjustment
- Matches heat loss precisely
- Advanced controls required

Components:

- Modulating gas valve
- Variable-speed blower
- Advanced control board
- Communicating thermostat
- Multiple sensors

Benefits:

- Optimal comfort
- Maximum efficiency
- Minimal temperature swing
- Quiet operation
- Superior humidity control

Modulation Control:

- Room temperature feedback
- Supply air temperature
- Return air temperature
- Outdoor temperature
- PID control algorithms

13.2 Furnace Installation

Proper installation ensures safe operation, optimal performance, and code compliance.

Location Requirements

Selecting the appropriate location affects performance and serviceability.

Code Requirements

CSA B149.1 Specifications:

- Not in sleeping quarters
- Not in bathrooms
- Not in clothes closets
- Not blocking exits
- Accessible for service

Exceptions:

- Direct vent furnaces in bedrooms (some jurisdictions)
- Sealed combustion units
- Special occupancies
- With additional protection

Preferred Locations

Basement Installation:

- Central location ideal
- Easy duct distribution
- Service accessibility
- Combustion air available
- Condensate drainage simple

Utility Room:

- Dedicated space

- Sound isolation
- Good for main floor
- Requires proper sizing
- Door requirements

Attic Installation:

- Saves floor space
- Special requirements apply
- Overflow protection needed
- Access platform required
- Insulation considerations

Crawl Space:

- Horizontal furnaces available
- Moisture concerns
- Access requirements
- Support requirements
- Special venting needs

Clearances per Code

Maintaining proper clearances ensures safety and service access.

Minimum Clearances

Standard Requirements:

Location	Minimum Clearance
Front (service)	24 inches
Sides	1 inch (or per manufacturer)
Back	0 inches typical
Top (plenum)	1 inch
Vent connector	6 inches (single wall)
Combustibles	Per manufacturer

Alcove Installation:

- Minimum width: Furnace + 3 inches
- Minimum depth: Per manufacturer
- Door if required: Louvered
- Combustion air provisions

Service Clearances

Access Requirements:

- Burner removal space
- Blower service access
- Control compartment access
- Filter replacement clearance
- Minimum 30" × 30" work space

Platform Requirements:

- Attic installations: 30" × 30" minimum
- Load capacity: 200 lbs minimum
- Permanent light required
- Switch at entry
- Walkway if needed

Return Air Considerations

Proper return air design ensures adequate airflow and comfort.

Sizing Requirements

Calculation Method:

```
Return Area (sq in) = CFM / Face Velocity
Face Velocity = 400-600 FPM typical
```

Example:

- Required CFM: 1,200
- Face velocity: 500 FPM
- Area = (1,200 / 500) × 144 = 346 sq in
- Duct size: 18" × 20" or equivalent

Return Air Locations

Recommended Placement:

- Central location
- High on walls for cooling
- Low for heating only
- Away from supply registers
- Not in bathrooms/kitchens

Multiple Returns:

- Improved air circulation
- Better comfort
- Reduced noise
- Lower velocity
- Balanced pressures

Combustion Air from Returns

When NOT Permitted:

- Solid fuel appliances present
- Commercial kitchens
- Contaminated air possible
- Paint booths
- Chemical storage areas

Requirements When Allowed:

- Volume calculations per code
- No exhaust fans impact
- Sealed returns
- No garage air
- Clean environment

Filter Access

Proper filter installation and access ensures maintenance.

Filter Locations

Options:

1. **Furnace Cabinet:**
    - Standard location
    - Easy replacement
    - Size limitations
    - Check clearance
2. **Return Air Drop:**
    - Larger filters possible
    - Better accessibility
    - Quieter operation
    - Higher capacity
3. **Return Grille:**
    - Most accessible
    - Multiple locations possible
    - Size flexibility

- Customer friendly

Filter Types and Ratings

MERV Ratings:

MERV Rating	Efficiency	Application
1-4	<20%	Basic protection
5-8	20-85%	Standard residential
9-12	85-95%	Better air quality
13-16	95-99%+	Hospital/clean room

Pressure Drop Considerations:

- Higher MERV = Higher restriction
- Size appropriately
- Check blower capability
- Monitor static pressure

Gas Piping Connections

Proper gas connections ensure adequate supply and safety.

Pipe Sizing

Determining Size:

1. Calculate total BTU load
2. Measure pipe length
3. Use CSA B149.1 tables
4. Account for fittings
5. Verify at meter

Example Calculation:

- Furnace input: 100,000 BTU/hr
- Distance from meter: 30 feet
- From table: 3/4" pipe required

Connection Requirements

Installation Steps:

1. Install shut-off valve within 6 feet
2. Install union for service

3. Install sediment trap (drip leg)
4. Use approved joint compound
5. Pressure test at 10 PSIG
6. Check for leaks

Component Details:

- Manual shut-off: Ball valve required
- Union: For equipment removal
- Sediment trap: 3" minimum nipple
- Flex connector: Listed for gas, 3 feet maximum

Electrical Connections

Proper electrical installation ensures safe operation.

Power Requirements

Voltage Options:

- 120VAC most common
- 240VAC for larger units
- 15 or 20 amp circuit typical
- Dedicated circuit recommended

Wire Sizing:

- Based on furnace nameplate
- Maximum circuit ampacity
- 14 AWG minimum typically
- 12 AWG for 20 amp circuit

Control Wiring

Thermostat Wiring:

Terminal	Function	Wire Color (typical)
R	24V power	Red
C	Common	Blue
W	Heat call	White
Y	Cool call	Yellow
G	Fan	Green

Installation Requirements:

- 18 AWG thermostat wire minimum
- Separate from line voltage
- Proper routing
- Strain relief
- Color coding

Combustion Air Provisions

Adequate combustion air ensures safe, efficient operation.

Air Requirements

Calculation Methods:

1. **Standard Method:**
    - 1 sq in per 4,000 BTU/hr (all air from inside)
    - 1 sq in per 4,000 BTU/hr each opening (outside air)
2. **Known Air Infiltration:**
    - 0.40 ACH or greater: No additional air
    - Less than 0.40 ACH: Provide outside air

Example:

- 100,000 BTU/hr furnace
- From inside: 100,000/4,000 = 25 sq in
- Two openings: 12.5 sq in each minimum

Outdoor Air Methods

Two-Opening Method:

- One within 12" of ceiling
- One within 12" of floor
- Size per calculations
- Proper screening
- Dampers not permitted

Single-Opening Method:

- Direct to outdoors
- 1 sq in per 3,000 BTU/hr
- Minimum dimension requirements
- Located properly

Venting Installation

Proper venting ensures safe removal of combustion products.

Non-Condensing Furnace Venting

Type B Vent:

- 1" clearance to combustibles
- Proper support spacing
- Correct termination height
- Listed cap required

Connection Requirements:

- Minimum 1/4" per foot rise
- Maximum horizontal per tables
- Secure all joints
- Fire stops required

Condensing Furnace Venting

PVC/CPVC Venting:

- Follow manufacturer exactly
- Proper support (3-4 feet)
- Slope to furnace (1/4" per foot)
- Prime and cement joints
- Termination clearances

Installation Steps:

1. Plan route
2. Calculate equivalent length
3. Install supports
4. Assemble with proper cement
5. Install termination kit
6. Check slope throughout

13.3 Furnace Controls and Sequences

Understanding control operation is essential for installation and troubleshooting.

Thermostat Operation

Thermostats initiate heating cycles and control comfort levels.

Types of Thermostats

Mechanical Thermostats:

- Bimetallic element
- Mercury switch (older)
- Simple operation
- No power required
- Heat anticipator adjustment

Electronic Thermostats:

- Thermistor sensing
- Digital display
- Precise control (±1°F)
- Battery or hardwired
- Multiple features

Smart Thermostats:

- WiFi connectivity
- Learning algorithms
- Remote access
- Energy reporting
- Integration capabilities

Thermostat Wiring and Signals

Standard Terminals:

Terminal	Function	Operation
R/Rc	Power from transformer	24VAC continuous
W/W1	First stage heat	Closes on heat call
W2	Second stage heat	Two-stage systems
Y/Y1	First stage cooling	A/C compressor
Y2	Second stage cooling	Two-stage A/C
G	Fan	Continuous fan
C	Common	Complete circuit

Anticipator Settings:

- Mechanical only
- Matches gas valve current
- Typically 0.4-0.6 amps

- Affects cycle rate
- Proper setting critical

Blower Control Sequences

Blower operation varies with system type and configuration.

PSC Motor Control

Heating Sequence:

1. Thermostat calls for heat
2. Burner ignites
3. Time delay (30-45 seconds)
4. Blower starts on heat speed
5. Heating cycle continues
6. Thermostat satisfied
7. Burner stops
8. Blower continues (45-90 seconds)
9. Blower stops

Speed Selection:

- Low: Continuous fan
- Medium-Low: Heating
- Medium-High: Cooling (if equipped)
- High: Emergency heat

ECM Motor Control

Constant CFM Operation:

- Motor adjusts to maintain CFM
- Compensates for filter loading
- Multiple comfort profiles
- Soft start/stop
- Delay profiles programmable

Operating Modes:

Mode	CFM Setting	Ramp Time
Heating	100% programmed	30 seconds
Cooling	Adjusted for humidity	30 seconds
Continuous	50% typical	60 seconds
Dehumidification	80% cooling	Variable

Limit Switch Operation

Limit switches prevent overheating and ensure safety.

Primary Limit

Function:

- Monitors heat exchanger temperature
- Opens at high temperature
- Shuts off gas valve
- Auto or manual reset

Typical Settings:

- Open: 160-200°F
- Close: 140-180°F
- Differential: 20-25°F
- Location: Supply plenum

Auxiliary Limits

Secondary Limit:

- Backup protection
- Manual reset typical
- Higher setpoint
- Series with primary

Roll-Out Switch:

- Detects flame roll-out
- Located near burners
- Manual or auto reset
- Multiple switches possible

Ignition Control Modules

Modern ignition systems provide reliable, safe operation.

Hot Surface Ignition (HSI)

Sequence of Operation:

1. Thermostat call
2. Inducer starts (if present)

3. Pressure switch closes
4. Ignitor energizes (30-45 seconds)
5. Gas valve opens
6. Flame sensor detects flame
7. Ignitor de-energizes
8. Main burner continues

Ignitor Types:

- Silicon carbide (older)
- Silicon nitride (current)
- 120V or 24V
- 3-5 year typical life

Direct Spark Ignition (DSI)

Operating Sequence:

1. Call for heat
2. Spark generation starts
3. Pilot valve opens (if used)
4. Main valve opens
5. Flame detected
6. Spark stops
7. Continuous monitoring

Components:

- Ignition module
- Spark electrode
- Flame sensor (may be combined)
- High voltage cable

Integrated Furnace Controls

Modern furnaces use sophisticated integrated controls.

IFC Features

Capabilities:

- Complete sequence control
- Diagnostic LEDs
- Fault history
- Blower speed control
- Safety monitoring

- Communication ability

Typical Inputs:

Input	Function
Thermostat	Heat/cool demand
Pressure switch	Draft proving
Limit switches	Overheat protection
Flame sensor	Flame presence
Roll-out switches	Safety

Outputs:

Output	Function
Inducer motor	Draft creation
Ignitor	Flame ignition
Gas valve	Fuel control
Blower motor	Air circulation
Humidifier	Humidity control

Diagnostic Features

LED Flash Codes:

Code	Meaning	Action
1 flash	Normal operation	None
2 flashes	Pressure switch stuck closed	Check switch
3 flashes	Pressure switch open	Check venting
4 flashes	Open high limit	Check airflow
5 flashes	Flame failure	Check gas/ignition
6 flashes	Roll-out switch	Reset and investigate
7 flashes	Low flame signal	Clean sensor

Communication Protocols

Advanced systems use digital communication.

Types of Communication

Proprietary Systems:

- Manufacturer specific
- Full feature access
- Diagnostic capability
- Limited compatibility
- Examples: Carrier Infinity, Trane ComfortLink

Standard Protocols:

- BACnet
- Modbus
- LON
- OpenTherm
- Wider compatibility

Communicating Components

System Elements:

- Thermostat (user interface)
- Furnace control
- A/C or heat pump
- Zoning system
- Humidifier
- Air cleaner

Information Exchanged:

- Temperature setpoints
- Operating status
- Fault codes
- Energy consumption
- Maintenance reminders
- Weather data

13.4 Hydronic Heating Systems

Hydronic systems use hot water to distribute heat through piping to terminal units.

Hot Water Boilers

Boilers heat water for distribution through the heating system.

Boiler Types

Fire-Tube Boilers:

- Hot gases pass through tubes
- Water surrounds tubes
- Cast iron or steel
- High water content
- Slower response

Water-Tube Boilers:

- Water in tubes
- Hot gases surround tubes
- Faster response
- Lower water content
- Higher efficiency possible

Condensing Boilers:

- Aluminum or stainless steel
- 90-98% efficiency
- Low water content
- Fast response
- Requires condensate management

Construction Materials

Cast Iron:

- Sectional construction
- Long life (30+ years)
- Resistant to thermal shock
- Heavy weight
- Slow response time

Steel:

- Welded construction
- Lighter than cast iron
- Faster response
- Prone to corrosion
- 15-25 year life typical

Aluminum/Stainless:

- Used in condensing units
- Corrosion resistant

- Light weight
- High efficiency
- Sensitive to water quality

System Components

Hydronic systems require various components for proper operation.

Circulators (Pumps)

Types:

1. **Wet Rotor:**
    - Water lubricated
    - Quiet operation
    - Maintenance free
    - Limited head capability
    - Residential standard
2. **Dry Rotor:**
    - External motor
    - Higher head capability
    - Requires maintenance
    - Commercial applications
    - Louder operation

Sizing Considerations:

```
GPM = BTU/hr / (ΔT × 500)
```

Where ΔT = Temperature drop (typically 20°F)

Example:

- Heat load: 50,000 BTU/hr
- Temperature drop: 20°F
- GPM = 50,000 / (20 × 500) = 5 GPM

Expansion Tanks

Function:

- Accommodate water expansion
- Maintain system pressure
- Prevent relief valve discharge
- Air elimination point

Types:

1. **Steel Compression Tank:**
   - Air cushion above water
   - Requires air control
   - Larger size
   - Lower cost
   - Maintenance required
2. **Diaphragm Tank:**
   - Rubber diaphragm separation
   - Pre-charged with air
   - Smaller size
   - No air absorption
   - Maintenance free

Sizing:

```
Tank Volume = System Volume × Expansion Factor × Safety Factor
```

Typical Sizes:

- Residential: 2-5 gallons
- Light commercial: 5-15 gallons
- Based on system volume
- Temperature range considered

Zone Valves

Purpose:

- Control flow to zones
- Individual temperature control
- Energy savings
- Comfort improvement

Types:

1. **Two-Way Valves:**
   - On/off control
   - Motorized actuator
   - Spring return or power open/close
   - 24V typical
2. **Three-Way Valves:**
   - Diverting or mixing
   - Continuous flow
   - Temperature control

    - Manual or automatic

Installation:

- Proper flow direction
- Accessible location
- Wire to zone controller
- Manual override feature
- Isolation valves recommended

Piping Configurations

Different piping arrangements suit various applications.

Series Loop

Characteristics:

- Simplest system
- Single path for water
- No zone control
- Lowest cost
- Temperature drops through loop

Applications:

- Single zone
- Small homes
- Garages
- Low budget

One-Pipe System

Features:

- Main loop with branches
- Special tees required
- Some temperature drop
- Moderate cost
- Limited zoning

Monoflo Tees:

- Create pressure differential
- Force flow through radiators
- Proper sizing critical

- Specific installation orientation

Two-Pipe Direct Return

Characteristics:

- Separate supply and return
- Parallel flow paths
- Better temperature control
- Higher cost
- Easier balancing

Balancing Required:

- Closest radiators favor flow
- Balancing valves needed
- Time-consuming setup
- Better comfort

Two-Pipe Reverse Return

Features:

- Equal pipe lengths
- Self-balancing
- Highest material cost
- Best performance
- Professional preference

Design Principle:

- First supplied, last returned
- Equal resistance paths
- Minimal balancing needed
- Uniform heating

Temperature Controls

Precise temperature control ensures comfort and efficiency.

Aquastat Controls

Functions:

- Maintain boiler temperature
- Control circulator operation

- Provide high limit protection
- Enable/disable burner

Types:

1. **Single Aquastat:**
    - High limit only
    - Simple control
    - Constant circulation
    - Lower cost
2. **Triple Aquastat:**
    - High limit
    - Low limit
    - Differential control
    - Maintains minimum temperature

Settings Example:

- High limit: 180-200°F
- Low limit: 140-160°F
- Differential: 10-15°F

Outdoor Reset Controls

Purpose:

- Adjust water temperature with outdoor temperature
- Improve efficiency
- Enhance comfort
- Reduce cycling

Operation:

- Sensor measures outdoor temperature
- Controller calculates required water temperature
- Mixing valve or boiler modulation
- Continuous adjustment

Reset Curve:

- Design temperature points
- Slope adjustment
- Parallel shift capability
- Building-specific tuning

Boiler Installation Requirements

Proper installation ensures safe, efficient operation.

Location Requirements

Code Specifications:

- Not in sleeping rooms
- Not in bathrooms
- Not in closets
- Adequate clearances
- Service access

Mechanical Room:

- Preferred location
- Combustion air provisions
- Drainage available
- Electrical supply
- Ventilation required

Piping Connections

Near Boiler Piping:

1. **Supply Side:**
    - Pressure relief valve
    - Air eliminator
    - Expansion tank connection
    - Temperature/pressure gauge
    - Isolation valve
2. **Return Side:**
    - Circulator
    - Fill valve
    - Backflow preventer
    - Drain valve
    - Strainer

Installation Sequence:

1. Position boiler
2. Install relief valve
3. Connect expansion tank
4. Install circulator
5. Connect zones
6. Fill and purge system
7. Test operation

CSA B149.1 Specific Requirements for Boilers

Code requirements ensure safety and proper installation.

Relief Valve Requirements

Specifications:

- ASME rated
- Set pressure ≤ 30 PSI residential
- Capacity ≥ boiler input
- No valve between boiler and relief
- Discharge piped to safe location

Low Water Cutoff

When Required:

- Steam boilers (always)
- Hot water over 400,000 BTU/hr
- Cast iron boilers recommended
- Manufacturer requirement

Types:

- Float type
- Probe type
- Flow switch
- Manual reset available

Combustion Air

Requirements:

- Same as furnaces
- Mechanical room considerations
- Louvers sized properly
- Direct vent option
- No dampers permitted

13.5 Radiant Heating

Radiant heating provides comfort through infrared radiation rather than air movement.

In-Floor Heating Systems

In-floor radiant provides even, comfortable heat distribution.

System Design

Heat Output:

- 25-35 BTU/hr/sq ft typical
- Based on floor construction
- Surface temperature limits
- 85°F maximum floor temperature

Tubing Layout:

1. **Serpentine Pattern:**
   - Simple installation
   - Temperature variation
   - Good for small areas
   - Single path
2. **Reverse Return:**
   - Balanced temperatures
   - Even heat distribution
   - More complex
   - Preferred method

Spacing:

- 6" on center: High heat areas
- 9" on center: Standard
- 12" on center: Low heat areas
- Closer at perimeter

Installation Methods

Concrete Slab:

- Tubing tied to wire mesh
- 2" concrete cover minimum
- Insulation below essential
- Edge insulation required
- Thermal mass benefit

Thin Slab (Overpour):

- 1.5" lightweight concrete

- Over existing floor
- Faster response
- Less weight
- Special additives used

Staple-Up:

- Under subfloor installation
- Aluminum heat transfer plates
- Insulation below
- Access required
- Lower output

Suspended Tube:

- Between joists
- No floor contact
- Lowest output
- Easiest retrofit
- Requires higher water temperature

Materials and Components

Tubing Types:

1. **PEX (Cross-linked Polyethylene):**
   - Most common
   - Flexible
   - 25-year warranty typical
   - Various connection methods
   - Temperature rating: 200°F
2. **PERT (Polyethylene Raised Temperature):**
   - Similar to PEX
   - No cross-linking
   - Repairable
   - Lower cost
   - Good flexibility

Manifolds:

- Flow balancing valves
- Individual loop control
- Temperature gauges
- Air vents
- Isolation valves

Panel Radiators

Modern panel radiators provide efficient space heating.

Types

Steel Panel Radiators:

- Single or double panel
- With or without convectors
- Wall or floor mounted
- Various sizes
- Painted or stainless finish

Cast Iron Radiators:

- Traditional appearance
- High thermal mass
- Slow response
- Decorative options
- Refurbished units available

Sizing

Heat Output Factors:

- Water temperature
- Room temperature
- Radiator size
- Air flow across unit

Calculation:

```
Output = Surface Area × U-value × ΔT
```

Typical Outputs:

- 150-200 BTU/hr per sq ft
- At 180°F water temperature
- 70°F room temperature

Installation

Mounting:

- Wall brackets required

- Level installation
- Clearances maintained
- Behind furniture avoided
- Under windows preferred

Piping:

- Thermostatic radiator valves
- Balance valves
- Air vents
- Flexible connections
- Proper support

Unit Heaters

Unit heaters provide localized heating for commercial/industrial spaces.

Types

Horizontal Unit Heaters:

- Ceiling mounted
- Downward discharge
- Wide coverage
- Various sizes
- 10,000-400,000 BTU/hr

Vertical Unit Heaters:

- Floor or wall mounted
- Upward discharge
- Compact design
- Good for doorways
- Destratification capable

Cabinet Unit Heaters:

- Attractive enclosure
- Wall or ceiling mount
- Quiet operation
- Residential appearance
- Filtered air

Applications

Typical Uses:

- Garages
- Warehouses
- Workshops
- Entry vestibules
- Loading docks

Advantages:

- Quick heat
- Spot heating
- Low installation cost
- Individual control
- Simple maintenance

Installation Considerations

Proper installation ensures optimal performance.

Piping Design

Flow Rates:

- Calculate based on heat load
- Size pipes accordingly
- Consider pressure drop
- Velocity limits (4 fps typical)

Expansion Compensation:

- Expansion loops
- Flexible connections
- Swing joints
- Proper anchoring
- Allow for movement

Controls

Zone Control:

- Individual thermostats
- Zone valves or pumps
- Outdoor reset
- Time scheduling
- Setback capability

Mixing Valves:

- Protect floor surfaces
- Maintain safe temperatures
- Manual or automatic
- Three-way or four-way
- Outdoor reset capable

Control Strategies

Effective control maximizes comfort and efficiency.

Constant Circulation

Method:

- Pump runs continuously
- Temperature varies
- Even heat distribution
- No on/off cycling

Benefits:

- Stable temperatures
- Quiet operation
- Reduced expansion noise
- Even floor temperatures

Intermittent Operation

Method:

- Pump cycles with demand
- Fixed water temperature
- Traditional control
- Simple implementation

Considerations:

- Temperature swings
- Expansion noise
- Energy savings questionable
- Simpler controls

Outdoor Reset

Benefits:

- Optimal efficiency
- Improved comfort
- Reduced cycling
- Lower return temperatures
- Condensing boiler compatible

Implementation:

- Outdoor sensor required
- Reset controller
- Mixing valve or modulation
- Proper curve selection
- Fine-tuning period

13.6 Heat Pump Systems (Dual Fuel)

Dual fuel systems combine heat pumps with gas furnaces for optimal efficiency.

Integration with Gas Furnaces

Proper integration ensures seamless operation between heating sources.

System Configuration

Components:

- Heat pump outdoor unit
- Gas furnace indoor
- Dual fuel thermostat
- Outdoor temperature sensor
- Control integration

Operating Modes:

1. **Heat Pump Only:**
    - Above balance point
    - Most efficient
    - Typical above 30-40°F
    - Electric heating
2. **Dual Operation:**
    - Near balance point
    - Heat pump primary
    - Furnace supplements
    - Improved capacity

3. **Furnace Only:**
    - Below balance point
    - During defrost
    - Emergency heat
    - Coldest weather

Control Wiring

Terminal Connections:

Terminal	Function	Operation
O/B	Reversing valve	Heat/cool changeover
Y	Compressor	Heat pump call
W2/AUX	Auxiliary heat	Gas furnace
E	Emergency heat	Furnace only
C	Common	24V return
R	Power	24V supply

Fossil Fuel Kit:

- Prevents simultaneous operation
- Locks out heat pump
- Temperature-based switching
- Field-installed option

Changeover Controls

Changeover determines when to switch between heat sources.

Balance Point

Definition:

- Outdoor temperature where heat pump capacity equals heat loss
- Typically 25-40°F
- Building specific
- Adjustable setting

Determining Balance Point:

```
Balance Point = 65°F - (Heat Pump Capacity / Building Heat Loss Rate)
```

Example:

- Heat pump capacity at 30°F: 30,000 BTU/hr

- Building heat loss: 40,000 BTU/hr at 0°F
- Loss rate: 1,000 BTU/hr per degree
- Balance point = 65 - (30,000/1,000) = 35°F

Temperature-Based Control

Outdoor Sensor Method:

- Simple installation
- Fixed changeover point
- No utility rate consideration
- Common approach

Settings:

- Changeover: 30-40°F typical
- Differential: 2-5°F
- Defrost lockout: 25°F
- Emergency heat: Manual

Economic Balance Point

Cost-Based Switching:

- Compares operating costs
- Requires rate inputs
- More complex setup
- Optimal savings

Calculation:

```
Economic Balance = Temperature where:
Heat Pump Cost/BTU = Gas Cost/BTU
```

Factors:

- Electric rate ($/kWh)
- Gas rate ($/therm)
- Heat pump COP
- Furnace efficiency

Efficiency Considerations

Understanding efficiency metrics optimizes system selection and operation.

Heat Pump Efficiency

HSPF (Heating Seasonal Performance Factor):

- Seasonal heating efficiency
- BTUs per watt-hour
- Higher is better
- Range: 7.7-13+ HSPF

COP (Coefficient of Performance):

- Instantaneous efficiency
- Varies with temperature
- Decreases as temperature drops
- 3.0 COP = 300% efficient

Temperature Impact:

Outdoor Temp	Typical COP	Capacity
47°F	3.5-4.0	100%
35°F	2.8-3.2	80%
25°F	2.2-2.6	60%
17°F	1.8-2.2	45%

System Optimization

Best Practices:

- Size heat pump for cooling load
- Use furnace below balance point
- Optimize changeover temperature
- Regular maintenance both systems
- Monitor performance

Control Strategies:

- Adaptive recovery
- Intelligent defrost
- Staged operation
- Load matching
- Utility demand response

13.7 Commissioning Heating Systems

Proper commissioning ensures systems operate safely and efficiently from day one.

Start-up Procedures

Systematic start-up prevents problems and ensures proper operation.

Pre-Start Checklist

Mechanical:

- [ ] Gas piping complete and tested
- [ ] Venting properly installed
- [ ] Condensate drain connected
- [ ] Ductwork connected and sealed
- [ ] Filters installed
- [ ] Access panels secure

Electrical:

- [ ] Power supply verified
- [ ] Proper voltage confirmed
- [ ] Disconnect installed
- [ ] Control wiring complete
- [ ] Thermostat configured
- [ ] Grounding verified

Safety:

- [ ] Gas leak test passed
- [ ] Venting clear
- [ ] Combustion air adequate
- [ ] Area clear of combustibles
- [ ] Carbon monoxide detector installed

Initial Start-up Sequence

1. **Power Application:**
    - Turn on disconnect
    - Check control voltage (24VAC)
    - Verify LED status
    - Check error codes
2. **Gas Supply:**
    - Open manual valve slowly
    - Purge air from line
    - Check inlet pressure
    - Verify no leaks
3. **First Ignition:**
    - Set thermostat to call

    - Observe ignition sequence
    - Verify flame establishment
    - Check for proper combustion
4. **System Operation:**
    - Verify blower operation
    - Check all safeties
    - Monitor temperatures
    - Listen for unusual noises

Temperature Rise Checks

Proper temperature rise ensures efficient heat transfer and equipment longevity.

Measuring Temperature Rise

Procedure:

1. Install thermometers in supply and return plenums
2. Operate furnace 10-15 minutes
3. Record temperatures simultaneously
4. Calculate difference
5. Compare to nameplate range

Acceptable Ranges:

- Standard furnace: 30-60°F typical
- Condensing furnace: 35-65°F typical
- Check manufacturer nameplate
- Adjust blower speed if needed

Adjusting Temperature Rise:

- Too high: Increase blower speed
- Too low: Decrease blower speed
- Check for restrictions
- Verify ductwork adequate

Calculating Airflow

From Temperature Rise:

```
CFM = Output BTU/hr / (1.08 × ΔT)
```

Example:

- Output: 76,000 BTU/hr

- Temperature rise: 55°F
- CFM = 76,000 / (1.08 × 55) = 1,279 CFM

Combustion Testing Requirements

Combustion analysis ensures safe, efficient operation.

Required Tests

CSA B149.1 Requirements:

- CO measurement (< 100 ppm air-free)
- Draft verification
- Gas pressure check
- Spillage test

Complete Analysis:

Parameter	Acceptable Range	Action if Outside
CO	< 100 ppm air-free	Adjust combustion
O_2	5-9%	Adjust air/gas
CO_2	7-10% (natural gas)	Check burners
Stack Temp	300-500°F (non-condensing)	Check heat exchanger
Draft	-0.02" to -0.05" W.C.	Check venting

Adjustment Procedures

Gas Pressure:

1. Connect manometer to manifold tap
2. Operate furnace
3. Check against nameplate
4. Adjust if necessary
5. Typical: 3.5" W.C. natural gas

Combustion Adjustment:

1. Clean burners if needed
2. Check orifice sizes
3. Verify primary air openings
4. Test and document
5. Re-test after adjustments

Airflow Verification

Proper airflow ensures comfort and equipment protection.

Static Pressure Testing

Measurement Points:

- Supply plenum (positive)
- Return plenum (negative)
- Total external static
- Compare to blower curve

Acceptable Values:

- Total external: < 0.5" W.C. typical
- Higher with accessories
- Check manufacturer specifications

Airflow Measurement Methods

Temperature Rise Method:

- Simple calculation
- Described above
- Approximate value
- Good for verification

Velocity Traverse:

- Pitot tube or anemometer
- Multiple readings
- Calculate average
- More accurate
- Time consuming

Flow Hood:

- Direct measurement
- Register by register
- Total all registers
- Most accurate
- Professional tool

Control Verification

Verify all controls operate properly.

Safety Control Testing

Limit Switch:

1. Block return air partially
2. Monitor temperature rise
3. Verify shutdown before danger
4. Clear blockage
5. Verify auto restart

Pressure Switch:

1. Block vent partially
2. Verify shutdown
3. Check switch contacts
4. Clear blockage
5. Test restart

Flame Sensor:

1. Disconnect sensor wire
2. Call for heat
3. Verify shutdown timing
4. Reconnect sensor
5. Test normal operation

Operating Control Testing

Thermostat:

- Heating operation
- Cooling (if equipped)
- Fan operation
- Programming functions
- Temperature accuracy

Staging Controls:

- First stage operation
- Second stage timing
- Outdoor sensor (if used)
- Proper sequencing

Documentation Requirements

Proper documentation protects all parties and ensures traceability.

Start-up Report

Required Information:

- Date and technician
- Equipment model/serial
- Installation address
- Test results
- Adjustments made

Test Data:

Parameter	Reading		Acceptable	Pass/Fail
Gas pressure	___	"W.C.	3.2-3.8"	___
Temperature rise	___	°F	35-65°	___
CO level	___	ppm	<100	___
Static pressure	___	"W.C.	<0.8"	___
Amp draw	___	A	<FLA	___

Customer Documentation

Provide to Customer:

- Operation manual
- Warranty information
- Maintenance requirements
- Emergency contacts
- Service records

Review with Customer:

- Thermostat operation
- Filter maintenance
- Emergency shutdown
- Normal sounds
- Service schedule

13.8 Troubleshooting Heating Systems

Systematic troubleshooting efficiently identifies and resolves heating system problems.

No Heat Calls

When the system doesn't respond to thermostat calls, systematic diagnosis finds the cause.

Diagnostic Sequence

Step 1: Verify Power

- Check disconnect/breaker
- Test transformer output (24VAC)
- Check fuse on control board
- Verify door switch closed
- Test voltage at furnace

Step 2: Check Thermostat

- Verify settings correct
- Test batteries (if used)
- Jump R to W at furnace
- Check wire connections
- Test thermostat operation

Step 3: Safety Circuit

- Check limit switches
- Test pressure switches
- Verify rollout switches
- Check door switch
- Test each component

Step 4: Control Board

- Check diagnostic LEDs
- Test control outputs
- Verify input signals
- Check for fault codes
- Test or replace board

Common Causes and Solutions

Problem	Symptoms	Solution
No power	Dead display, no response	Check breaker, disconnect
Bad transformer	No 24V	Replace transformer
Open limit	LED code, no ignition	Check airflow, reset
Thermostat issue	No call signal	Replace batteries, check wiring
Control board	Various codes	Diagnose and replace
Door switch	No response when closed	Adjust or tape temporarily

Inadequate Heat

System runs but doesn't maintain temperature.

Causes and Diagnosis

Undersized Equipment:

- Heat loss calculation
- Check on design day
- Verify proper sizing
- Consider additions/changes

Low Gas Pressure:

- Measure manifold pressure
- Check with all appliances on
- Verify orifice size
- Adjust if needed

Airflow Problems:

- Dirty filter (most common)
- Closed registers
- Blocked returns
- Duct leakage
- Blower issues

Heat Exchanger Issues:

- Cracked/failed exchanger
- Plugged exchanger
- Soot buildup
- Poor combustion

Testing Procedures

1. **Measure Temperature Rise:**
    - Should be within range
    - Too high indicates low airflow
    - Too low indicates high airflow
2. **Check Gas Input:**
    - Clock meter if possible
    - Calculate actual BTU
    - Compare to nameplate
3. **Verify Airflow:**

    - Measure static pressure
    - Check all registers
    - Inspect ductwork

Short Cycling

Furnace starts and stops frequently without satisfying thermostat.

Causes

Oversized Furnace:

- Heats too quickly
- Poor comfort
- Reduced efficiency
- Equipment wear

Thermostat Issues:

- Poor location
- Anticipator setting
- Loose connection
- Defective thermostat

Airflow Restrictions:

- Dirty filter
- Closed registers
- Blocked return
- Undersized ducts

Control Problems:

- Limit switch tripping
- Pressure switch cycling
- Flame sensor marginal
- Control board issue

Diagnostic Steps

1. **Time the Cycles:**
    - Note on/off times
    - Should run 5-15 minutes minimum
    - Check against thermostat calls
2. **Monitor Temperatures:**
    - Watch temperature rise

    - Check limit operation
    - Verify not overheating
3. **Check Thermostat:**
    - Verify location appropriate
    - Check anticipator (if mechanical)
    - Test for loose connections

Noisy Operation

Unusual noises indicate problems requiring attention.

Types of Noises

Rumbling:

- Dirty burners
- Improper combustion
- Delayed ignition
- Low gas pressure

Whistling:

- Dirty filter
- Restricted airflow
- Undersized ducts
- Register issues

Banging/Popping:

- Delayed ignition
- Duct expansion
- Dirty burners
- Backfire

Scraping/Squealing:

- Blower bearing failure
- Belt issues (if used)
- Inducer motor problems
- Debris in blower

Resolution Procedures

Noise Type	Diagnostic Test	Solution
Rumbling	Visual burner inspection	Clean burners

Noise Type	Diagnostic Test	Solution
Whistling	Static pressure test	Replace filter, check ducts
Banging	Observe ignition	Clean burners, check pressure
Scraping	Isolate source	Lubricate or replace component

Safety Lockouts

System locks out requiring manual reset or power cycle.

Common Lockout Causes

Ignition Failure:

- No gas supply
- Bad ignitor
- Valve failure
- Control issue

Flame Failure:

- Dirty sensor
- Sensor position
- Grounding issue
- Weak flame

Limit Trip:

- Overheating
- Airflow restriction
- Limit failure
- Heat exchanger issue

Pressure Switch:

- Blocked vent
- Failed inducer
- Switch failure
- Tube problems

Reset Procedures

1. **Identify Cause:**
    - Read fault codes
    - Check diagnostic LEDs
    - Test failed component

2. **Correct Problem:**
   - Fix root cause
   - Don't just reset
   - Test thoroughly
3. **Reset System:**
   - Power cycle if soft lockout
   - Manual reset if required
   - Clear fault history
   - Test operation

Systematic Diagnostic Approach

Professional troubleshooting follows logical sequences.

Troubleshooting Methodology

1. **Information Gathering:**
   - Customer complaint
   - System history
   - Recent changes
   - Symptoms observed
2. **Visual Inspection:**
   - Overall condition
   - Obvious problems
   - Safety hazards
   - Installation quality
3. **Operational Test:**
   - Run complete cycle
   - Note sequence
   - Identify where fails
   - Document findings
4. **Component Testing:**
   - Test suspect components
   - Use proper procedures
   - Verify with meters
   - Replace if defective
5. **Verification:**
   - Test after repair
   - Run multiple cycles
   - Check all operations
   - Document work

Diagnostic Tools

Essential Equipment:

- Multimeter
- Manometer
- Combustion analyzer
- Temperature probes
- Amp clamp

Helpful Tools:

- Diagnostic chart
- Wiring diagrams
- Sequence charts
- Manufacturer literature
- Smart phone apps

Chapter Review

Summary

This chapter covered comprehensive heating system knowledge:

Forced Air Furnaces:

- Component functions and types
- Efficiency ratings and technologies
- Multi-stage and modulating benefits
- Airflow principles critical
- Proper sizing essential

Installation Requirements:

- Location and clearance requirements
- Return air design critical
- Combustion air provisions
- Proper venting essential
- Electrical connections per code

Control Systems:

- Thermostat types and operation
- Integrated furnace controls
- Safety and operating limits
- Communication protocols emerging
- Diagnostic capabilities valuable

Hydronic Systems:

- Boiler types and materials
- Piping configurations important
- Component selection critical
- Temperature control strategies
- Code requirements specific

Radiant Heating:

- In-floor provides comfort
- Various installation methods
- Control strategies affect efficiency
- Proper design essential

Dual Fuel Systems:

- Heat pump integration beneficial
- Changeover control critical
- Economic optimization possible
- Efficiency considerations complex

Commissioning:

- Systematic start-up required
- Testing validates installation
- Documentation protects all parties
- Customer education important

Troubleshooting:

- Systematic approach essential
- Common problems predictable
- Proper tools required
- Safety always priority

System Design Exercises

Exercise 1: Furnace Sizing

Given:

- Heat loss: 65,000 BTU/hr
- Location: Toronto
- Fuel: Natural gas

Solution:

1. Add safety factor: 65,000 × 1.25 = 81,250 BTU/hr
2. Select furnace: 80,000 BTU/hr input
3. At 95% efficiency: 76,000 BTU/hr output
4. Adequate capacity confirmed

Exercise 2: Airflow Calculation

Given:

- Furnace output: 60,000 BTU/hr
- Temperature rise: 45°F

Calculate CFM:

```
CFM = 60,000 / (1.08 × 45) = 1,235 CFM
```

Exercise 3: Hydronic Flow Rate

Given:

- Zone heat loss: 30,000 BTU/hr
- Temperature drop: 20°F

Calculate GPM:

```
GPM = 30,000 / (20 × 500) = 3 GPM
```

Installation Planning

New Furnace Installation Checklist

Pre-Installation:

- [ ] Load calculation completed
- [ ] Equipment selected
- [ ] Permits obtained
- [ ] Materials ordered
- [ ] Customer notified

Installation Day:

- [ ] Old equipment removed
- [ ] New furnace positioned
- [ ] Gas piping connected

- [ ] Venting installed
- [ ] Electrical connected
- [ ] Condensate routed
- [ ] Ductwork modified

Commissioning:

- [ ] Gas pressure set
- [ ] Temperature rise verified
- [ ] Combustion tested
- [ ] Static pressure checked
- [ ] Controls verified
- [ ] Documentation complete

Combustion Analysis Interpretation

Sample Analysis Results

Readings:

- CO: 45 ppm air-free
- O_2: 7.5%
- CO_2: 8.2%
- Stack: 385°F
- Efficiency: 82%

Interpretation:

- CO acceptable (< 100 ppm)
- Combustion good
- Efficiency appropriate for equipment
- No adjustment needed

Diagnostic Scenarios

Scenario 1: No Heat - Morning Only

Symptoms:

- No heat first thing morning
- Works fine rest of day
- Condensing furnace
- Outdoor temperature below freezing

Diagnosis:

- Condensate drain frozen
- Pressure switch open
- Overnight freezing

Solution:

- Reroute drain indoors
- Heat trace if necessary
- Insulate drain line

Scenario 2: Runs Constantly

Symptoms:

- Furnace never stops
- House stays cold
- High gas bills
- No error codes

Testing:

- Temperature rise: 70°F (too high)
- Static pressure: 0.9" W.C. (high)
- Filter: Completely blocked

Solution:

- Replace filter
- Check all registers open
- Educate customer on maintenance

Scenario 3: Random Shutdowns

Symptoms:

- Intermittent operation
- No pattern
- Various error codes
- Works after reset

Investigation:

- Loose wire connection found
- Board connection corroded
- Vibration causing intermittent

Solution:

- Clean connections
- Apply dielectric grease
- Secure all wiring

Scenario 4: Loud Bang on Start

Symptoms:

- Loud bang on ignition
- Otherwise normal operation
- Getting worse over time
- Black marks visible

Diagnosis:

- Delayed ignition
- Dirty burners
- Gas accumulation before ignition

Solution:

- Clean burners thoroughly
- Check gas pressure
- Verify ignitor position
- Test ignition timing

Scenario 5: Poor Second Floor Heating

Symptoms:

- First floor comfortable
- Second floor cold
- Single zone system
- Furnace cycles normally

Testing:

- Airflow measurement shows imbalance
- Static pressure normal
- Temperature rise acceptable

Solution:

- Balance dampers

- Partially close first floor registers
- Consider zoning system
- Check return air paths

Laboratory Exercises

Lab 1: Temperature Rise Measurement

Equipment:

- Digital thermometers (2)
- Operating furnace
- Calculator

Procedure:

1. Install thermometers in supply and return
2. Run furnace 10 minutes
3. Record temperatures
4. Calculate rise
5. Compare to nameplate
6. Adjust blower if needed

Lab 2: Static Pressure Testing

Equipment:

- Manometer
- Drill and bits
- Test probes
- Tape

Procedure:

1. Drill test holes
2. Zero manometer
3. Measure supply static
4. Measure return static
5. Calculate total external
6. Compare to specifications
7. Document findings

Lab 3: Combustion Analysis

Equipment:

- Combustion analyzer
- Drill and bits
- Operating furnace

Procedure:

1. Warm up analyzer
2. Zero in fresh air
3. Insert probe in vent
4. Record all readings
5. Compare to standards
6. Make adjustments if needed
7. Retest after adjustments

Lab 4: Control Circuit Diagnosis

Equipment:

- Multimeter
- Wiring diagram
- Non-functioning furnace

Procedure:

1. Check power supply
2. Test transformer output
3. Verify thermostat signal
4. Check safety switches
5. Test control board outputs
6. Identify failed component
7. Document diagnosis

Key Terms

AFUE: Annual Fuel Utilization Efficiency - seasonal efficiency rating including cycling losses.

Air Handler: Blower section that moves air through ductwork system.

Aquastat: Temperature control device for hydronic boilers maintaining water temperature.

Balance Point: Outdoor temperature where heat pump capacity equals building heat loss.

CFM: Cubic Feet per Minute - measurement of airflow volume.

Circulator: Pump that moves water through hydronic system.

Combustion Analysis: Testing of flue gases to verify proper burning.

Condensing Furnace: High-efficiency furnace that extracts latent heat from flue gases.

Delta T (ΔT): Temperature difference between supply and return air or water.

ECM Motor: Electronically Commutated Motor providing variable speed operation.

Expansion Tank: Vessel accommodating water expansion in hydronic systems.

Flame Sensor: Device detecting presence of flame using rectification or thermocouples.

Heat Exchanger: Component separating combustion products from heated air or water.

HSPF: Heating Seasonal Performance Factor measuring heat pump efficiency.

Hydronic: Heating system using hot water as distribution medium.

IFC: Integrated Furnace Control managing all furnace operations.

Inducer: Fan creating draft through heat exchanger and venting system.

Limit Switch: Safety device preventing overheating by shutting off gas.

Manifold: Distribution header for multiple zones or burners.

Modulating: Variable capacity operation matching output to load.

MERV: Minimum Efficiency Reporting Value for air filter effectiveness.

Orifice: Precision opening metering gas flow to burners.

PSC Motor: Permanent Split Capacitor motor, standard blower type.

Radiant Heat: Heating through infrared radiation rather than air movement.

Return Air: Air drawn back to furnace for reheating.

Static Pressure: Resistance to airflow in duct system, measured in inches W.C.

Temperature Rise: Difference between supply and return air temperatures.

Thermocouple: Safety device generating millivolts from flame heat.

Two-Stage: Furnace operating at two capacity levels for better comfort.

Zone: Separately controlled area in heating system.

End of Chapter 13

This comprehensive chapter on Heating Systems provides the essential knowledge for installing, commissioning, and servicing modern heating equipment. Understanding these systems ensures safe, efficient, and comfortable heating for Canadian homes and businesses.

Students should be able to size and select appropriate equipment, perform proper installation following codes and manufacturer requirements, commission systems correctly, and troubleshoot problems systematically. Regular maintenance and proper operation of these systems ensures long life and optimal performance.

The integration of different heating technologies, from traditional furnaces to modern heat pumps and radiant systems, offers flexibility in meeting diverse comfort needs while maximizing efficiency. As technology continues to advance, the fundamental principles covered in this chapter remain the foundation for working with heating systems.