Canadian Gas Technician

Learning Module 13: Heating Systems

Comprehensive Training for Installation, Service, and Troubleshooting

Learning Objectives

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

01

Identify and explain the operation of forced air furnace components

02

Install furnaces according to manufacturer specifications and CSA B149.1

03

Understand furnace control sequences and troubleshoot control problems

04

Design and install hydronic heating systems with proper components

01

Configure radiant heating systems for various applications

02

Integrate dual fuel heat pump systems with gas furnaces

03

Perform complete commissioning procedures on heating systems

04

Apply systematic troubleshooting techniques to diagnose heating problems

05

Calculate heating loads and equipment sizing

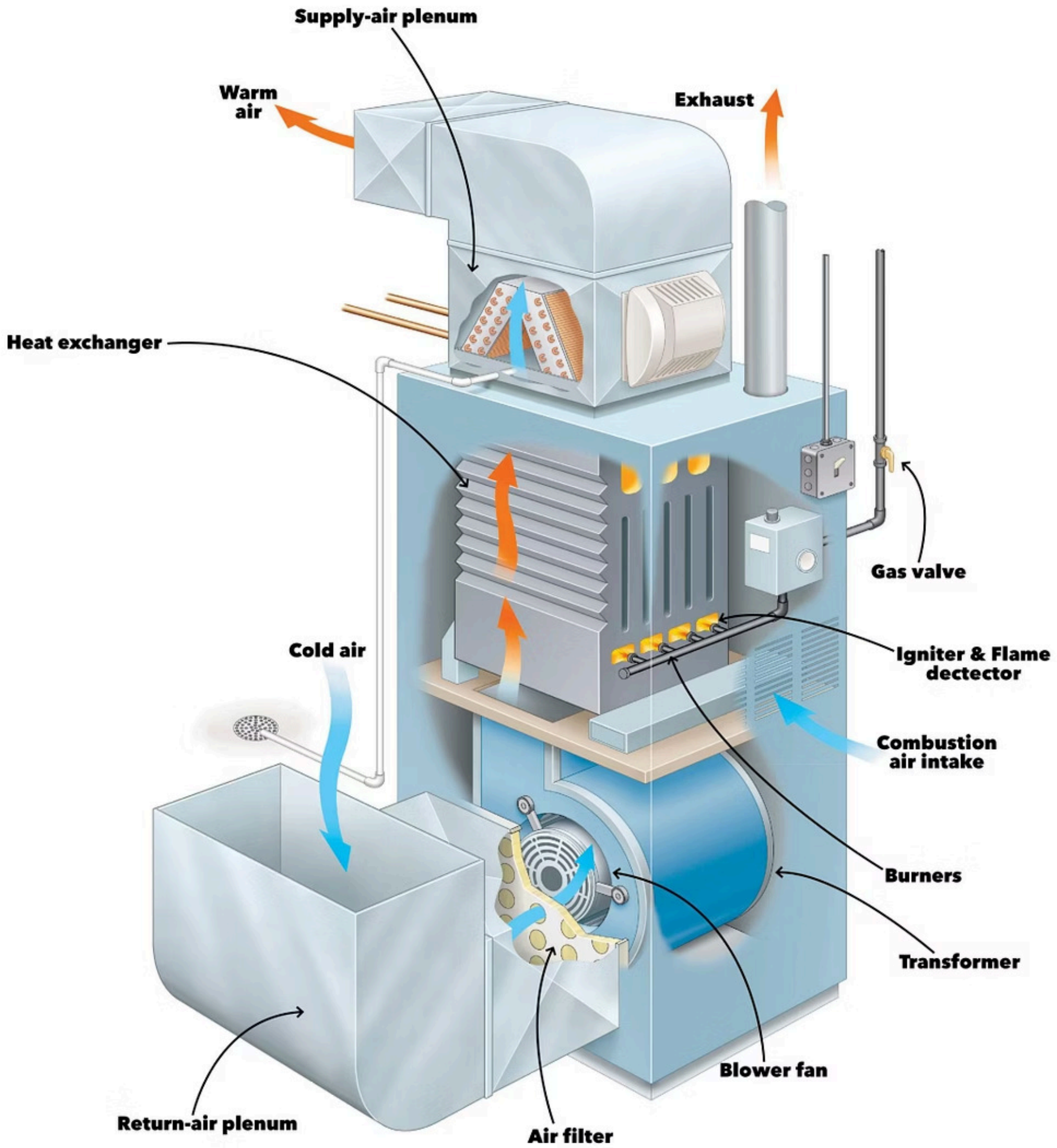
06

Document installation and service work properly

Section 13.1

Forced Air Furnaces

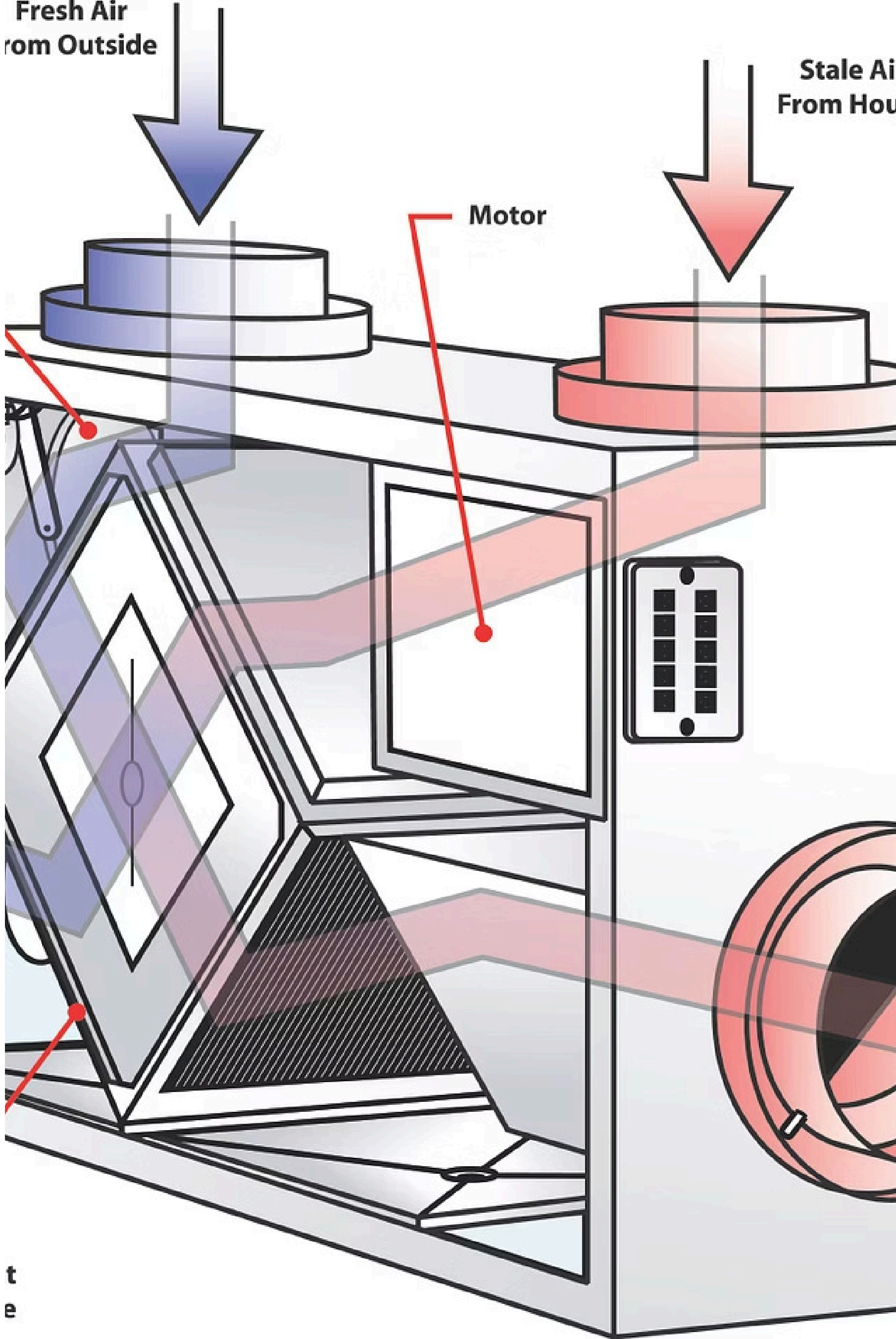
Forced air furnaces are the most common residential heating systems in Canada, providing efficient heat distribution through ductwork.



System Components

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

Modern forced air furnaces integrate multiple components working together to provide safe, efficient heating. Each component plays a critical role in the overall system performance.



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

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

Types of Heat Exchangers

Tubular

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

Clamshell

- Stamped steel sections
- Welded or crimped seams
- Compact design
- Lower cost
- Common in older units

Drum

- Cylindrical design
- Heavy gauge steel
- Durable construction
- Higher cost
- Less common today

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

PSC (Permanent Split Capacitor)

- Single-speed or multi-speed
- Simple control
- Lower cost
- 60-70% electrical efficiency
- Speed taps for adjustment

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

0.5" - 1.0" W.C. capability

Horsepower

1/3 to 1 HP residential

Voltage

120V or 240V

Speed Options

Multiple speed taps available

Control Systems

Integrated Furnace Control (IFC)

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

Control Functions

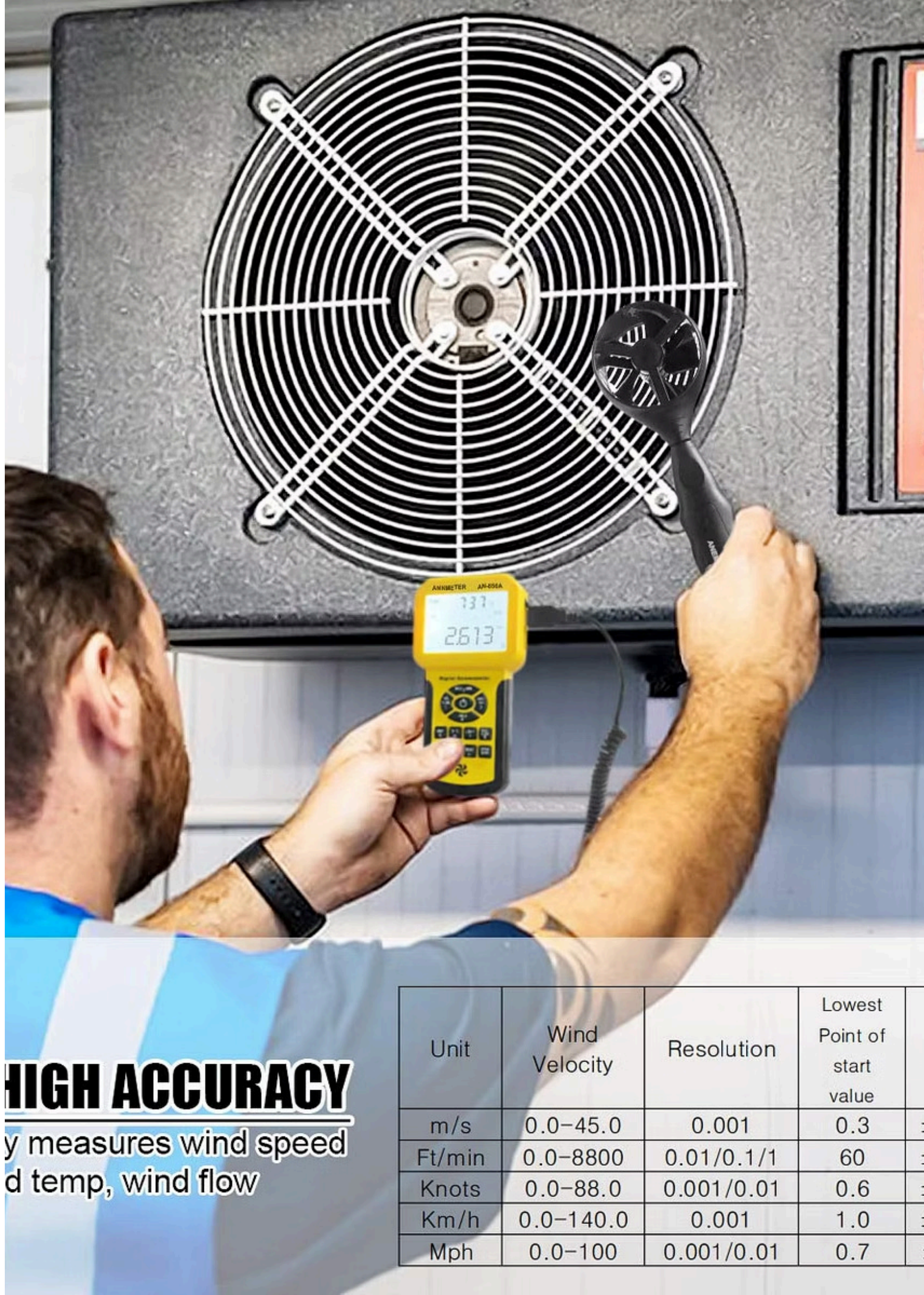
- Ignition sequence
- Blower operation
- Safety monitoring
- Fault detection
- User interface

Airflow Principles

Proper airflow is critical for comfort and equipment longevity.

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

Formula

$$CFM = \frac{Output\ BTU/hr}{1.08 \times Temperature\ Rise}$$

Example Calculation

Given:

- 80,000 BTU/hr output
- 50°F temperature rise

Solution:

CFM = 80,000 / (1.08 × 50) = 1,481 CFM

This calculation determines the required airflow to achieve the desired temperature rise across the heat exchanger.

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

- Drill test holes in supply and return plenums
- Insert manometer probes
- Measure with system running
- Total External Static = Supply + Return (absolute values)
- 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 Materials

Aluminized Steel

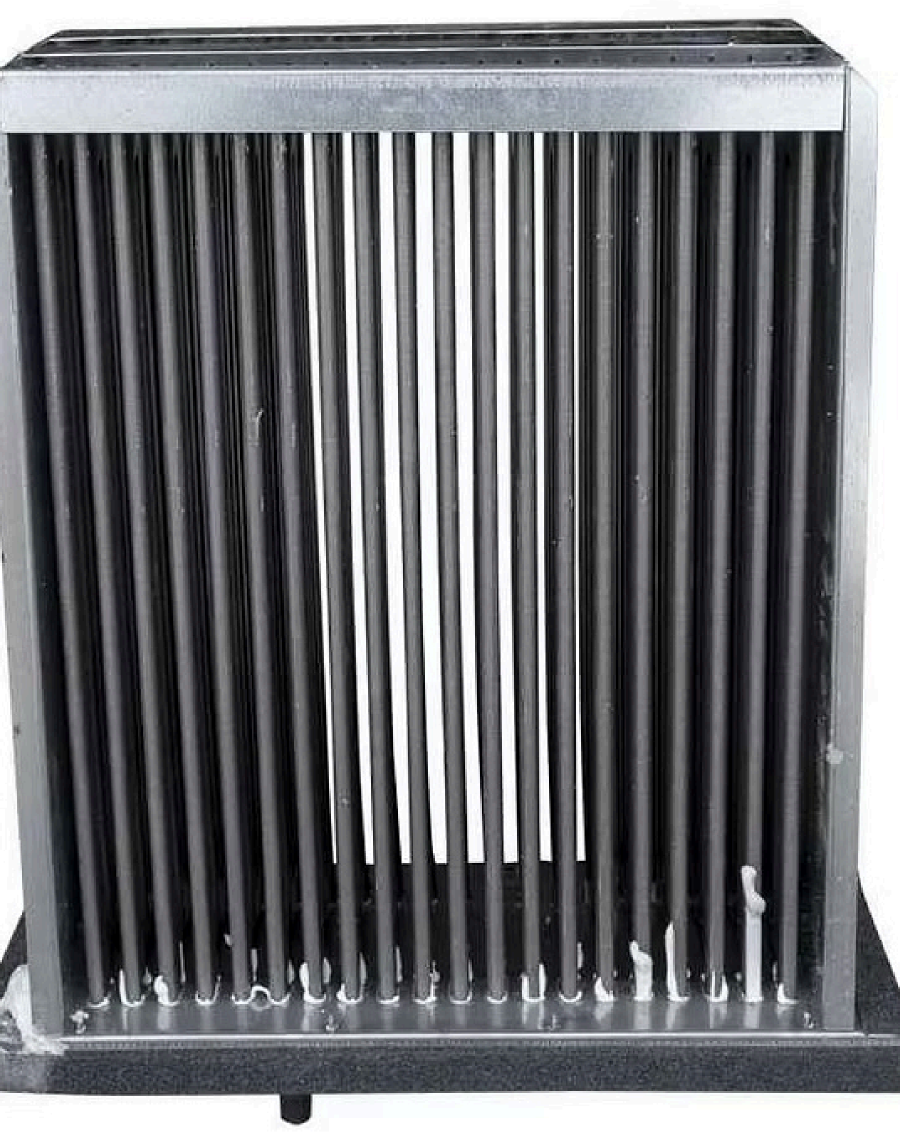
- Most common material
- Good corrosion resistance
- Moderate cost
- 15-20 year typical life
- Aluminum coating on steel

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

Condensing Furnaces

Characteristics

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

Advantages and Disadvantages

Non-Condensing 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 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.

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%

Example Calculation

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

Output = Input × Efficiency

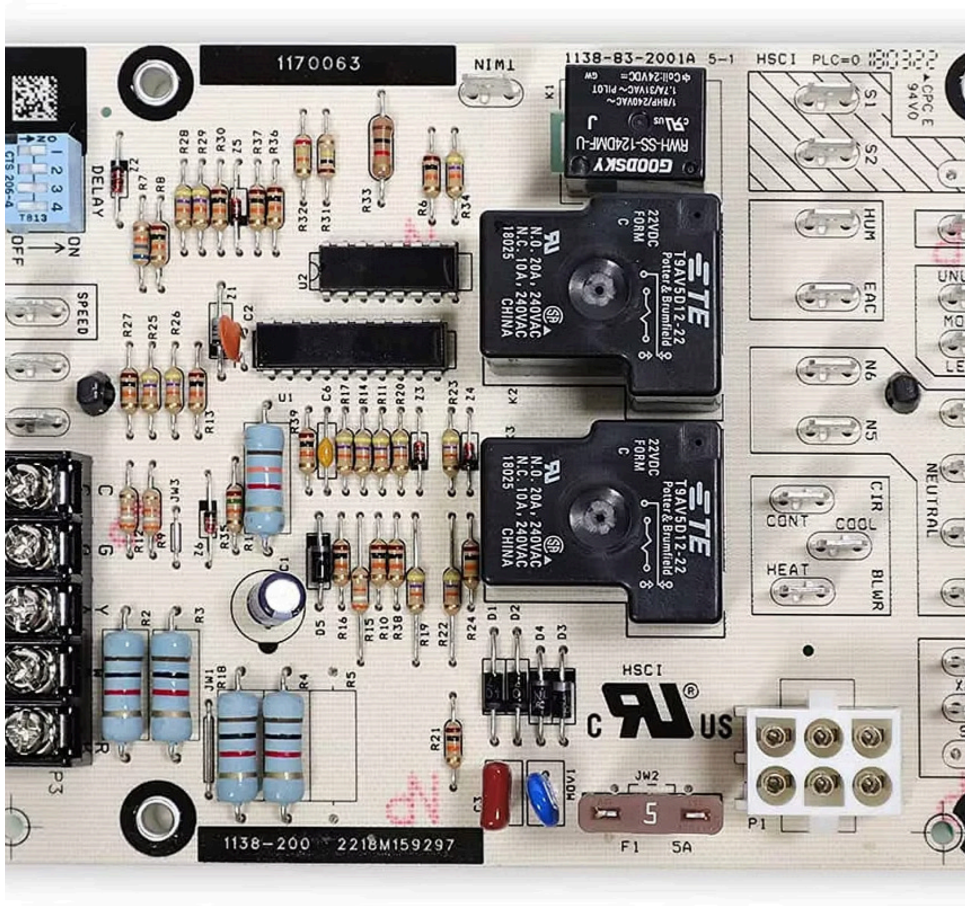
Multi-Stage and Modulating Systems

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



Two-Stage Benefits

Quieter Operation

Operates on low fire most of the time, reducing noise levels

Better Temperature Control

Longer run times minimize temperature swings

Improved Humidity Control

Extended operation time better manages indoor humidity

Higher Efficiency

Reduced cycling losses improve overall efficiency

Reduced Cycling

Less wear on components extends equipment life

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**

Modulating Benefits

Optimal Comfort

Precise capacity matching eliminates temperature swings

Maximum Efficiency

Operates at ideal capacity for conditions

Minimal Temperature Swing

Continuous operation maintains steady temperatures

Quiet Operation

Low-capacity operation reduces noise

Superior Humidity Control

Extended run times manage moisture effectively

Modulation Control

Modulating furnaces use sophisticated control algorithms to optimize performance.

Room Temperature Feedback

Supply Air Temperature

Return Air Temperature

Outdoor Temperature

PID Control Algorithms

Section 13.2

Furnace Installation

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

Location Requirements

Selecting the appropriate location affects performance and serviceability.

CSA B149.1 Specifications

Not Permitted In:

- Sleeping quarters
- Bathrooms
- Clothes closets
- Blocking exits

Must be accessible for service

Exceptions:

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

Preferred Locations

1

Basement Installation

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

2

Utility Room

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

3

Attic Installation

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

4

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

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 and Service Clearances

Alcove Installation

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

Service Clearances

- 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

$$Return\ Area\ (sq\ in) = \frac{CFM}{Face\ Velocity}$$

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.

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

Calculate total BTU load

Measure pipe length

Use CSA B149.1 tables

Account for fittings

Verify at meter

Example Calculation

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

Gas 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 for quick, reliable shutoff

Union

For equipment removal and service access

Sediment Trap

3" minimum nipple to catch debris and protect valve

Flex Connector

Listed for gas, 3 feet maximum length

Electrical Connections

Proper electrical installation ensures safe operation.

Power Requirements

- 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

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

Control Wiring Installation

- 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.

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

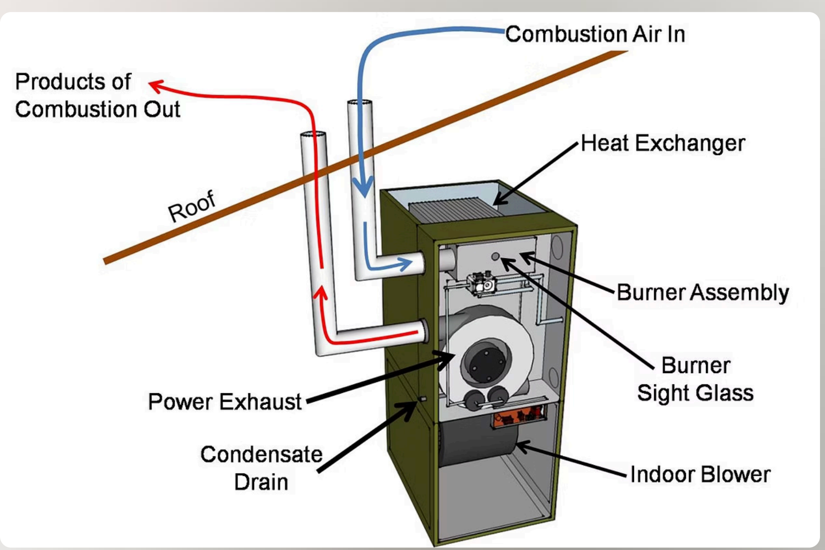
Outdoor Air Methods

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

01

Plan route

02

Calculate equivalent length

03

Install supports

04

Assemble with proper cement

05

Install termination kit

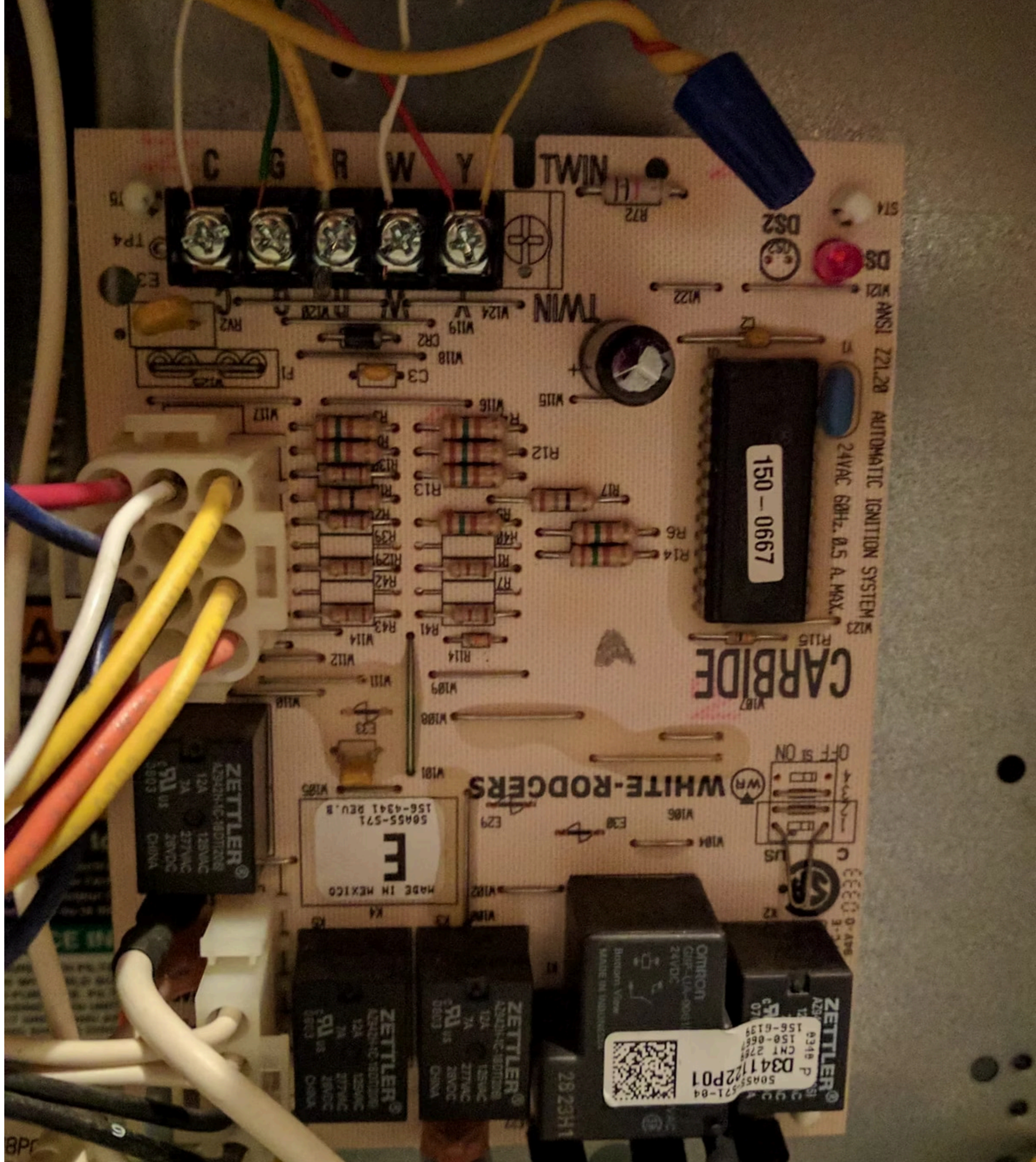
06

Check slope throughout

Section 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.

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

1. Thermostat satisfied
2. Burner stops
3. Blower continues (45-90 seconds)
4. Blower stops

Speed Selection and ECM Control

PSC 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

ECM 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

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 and DSI

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 and Capabilities

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

Typical Inputs

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

IFC Outputs and Diagnostics

Outputs

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

LED Flash Codes

Code	Meaning
1 flash	Normal operation
2 flashes	Pressure switch stuck closed
3 flashes	Pressure switch open
4 flashes	Open high limit
5 flashes	Flame failure
6 flashes	Roll-out switch
7 flashes	Low flame signal

Communication Protocols

Advanced systems use digital 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

- 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

Section 13.4

Hydronic Heating Systems

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

Module 13 Continues...

This presentation covers the first major sections of Chapter 13: Heating Systems from the Canadian Gas Technician training program.

Topics Covered

Forced Air Furnaces

Components, airflow principles, heat exchangers, efficiency ratings, and multi-stage systems

Furnace Installation

Location requirements, clearances, return air, gas piping, electrical connections, combustion air, and venting

Furnace Controls

Thermostat operation, blower sequences, limit switches, ignition systems, and integrated controls

Hydronic Systems Introduction

Hot water boilers and system components overview

The remaining sections covering hydronic systems, radiant heating, heat pumps, commissioning, and troubleshooting would continue in additional presentation modules to complete the full chapter content.