CSA Unit 19 - Forced Warm Air Appliances

Chapter 1
Forced-air Furnaces

Gas technicians/fitters are commonly required to install and maintain forced-air furnaces. Correct installation and maintenance require the technician/fitter to understand the operation of the basic components of the furnace, as well as how they fit together into a complete system. The technician/fitter must be familiar with the various Code requirements and other regulations that regulate the installation of these devices.

Created

MK **by Mike Kapin**

Objectives

Code Requirements

Describe Code and other requirements governing installation of forced-air furnaces

Building Types

Distinguish between building types and locate Code requirements governing installation of forced-air furnaces in various building types

Furnace Configurations

Describe common furnace configurations, efficiencies, and types

Venting Requirements

Describe venting requirements for forced-air furnaces

Selection Factors

Describe the factors that must be considered in selecting a furnace

Start-up and Commissioning

Describe start-up and commissioning of a furnace

Key Terminology

Term	Abbreviation (Symbol)	Definition
Annual fuel utilization efficiency	AFUE	Furnace efficiency which take into account losses during steady state burner operating, warm-up, cool-down, and standby periods
Drain, waste and vent system	DWV	The assembly of pipes, fittings, and appurtenances used to convey sewage, clear-water waste, or storm water to a public sewer
Flammable vapours ignition resistant	FVIR	A standard that incorporates new design features to make gas-fired appliances resistant to igniting flammable vapours outside of the appliance
Heating, Refrigeration, and Air-conditioning Institute of Canada	HRAI	A non-profit national trade association representing the HVACR industries
Latent heat of vapourization	Latent heat	Heat that causes a change of state in a substance

CSA Gas Trade Training Materials

The CSA Group Gas Trade Training Materials align with Red Seal requirements, covering essential topics for gas technicians. These materials ensure comprehensive training on various aspects of gas-fired systems, from basic electricity and controls to installation, testing, and maintenance procedures.

Additional Terminology

Term	Abbreviation (Symbol)	Definition
Plenum		A chamber forming part of an air duct system. Typically, the supply and return air plenums are the sheet metal components directly adjacent to the furnace
Special venting system		A venting system certified with the appliance and either supplied or specified by the appliance manufacturer
Thermal Environmental Comfort Association	TECA	A not-for-profit society with a focus on training in the HVACR industries
ULC S636 standard	S636	Underwriters Laboratories of Canada Standard for Type BH gas venting systems

Major Furnace Components

Burner and Control Devices

The components responsible for igniting and regulating the gas flow to create controlled combustion within the furnace.

Combustion Chamber

The enclosed area where the burning of fuel occurs, designed to contain and direct the heat produced.

Heat Exchanger

The component that transfers heat from the combustion gases to the air that circulates through the home.

Blower Compartment

Contains the fan that moves air through the furnace and ductwork system to distribute heated air throughout the building.

Major Furnace Classifications

High Boy

Tall, upright furnaces that can be configured as up-flow or down-flow units.

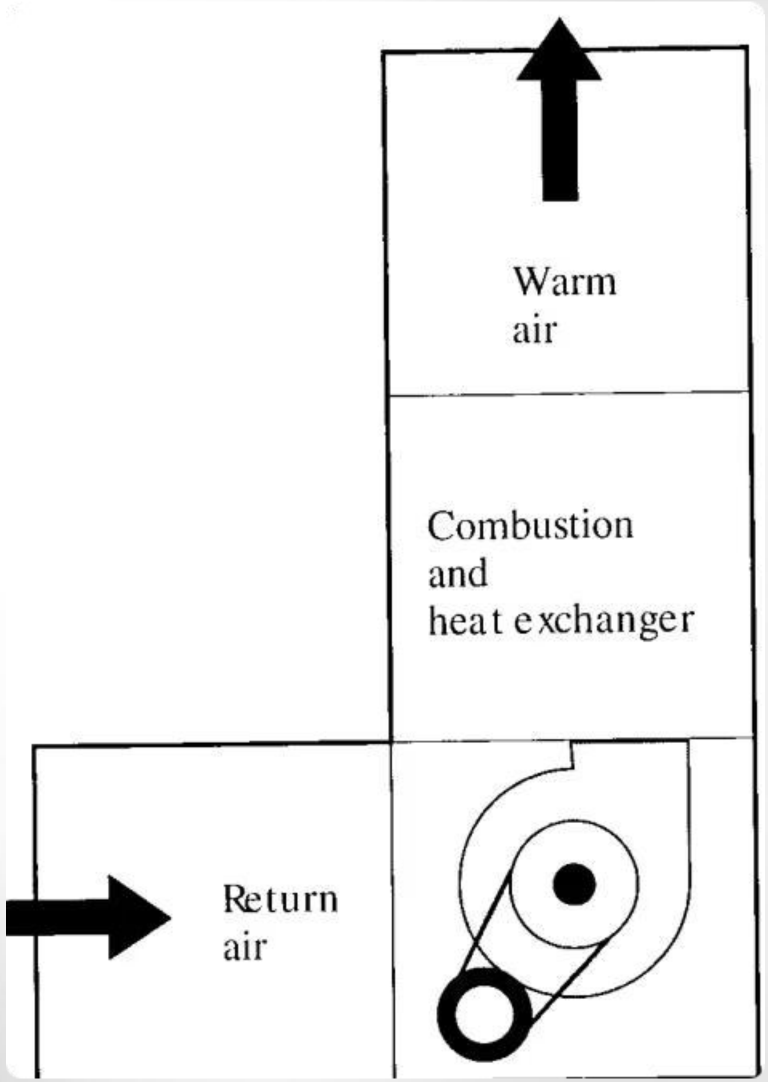
Low Boy

Shorter furnaces with components arranged horizontally, designed for spaces with height limitations.

Horizontal

Furnaces designed to be installed in a horizontal position, often used in crawl spaces or attics.

The end user requirements and the installation site determine the choice of furnace type. Each classification has specific airflow patterns and installation requirements.



High Boy Up-Flow Furnace

1

Return Air Entry

Return air enters the furnace either at the bottom, rear, or one of the sides, depending on where the furnace is located

2

Blower Operation

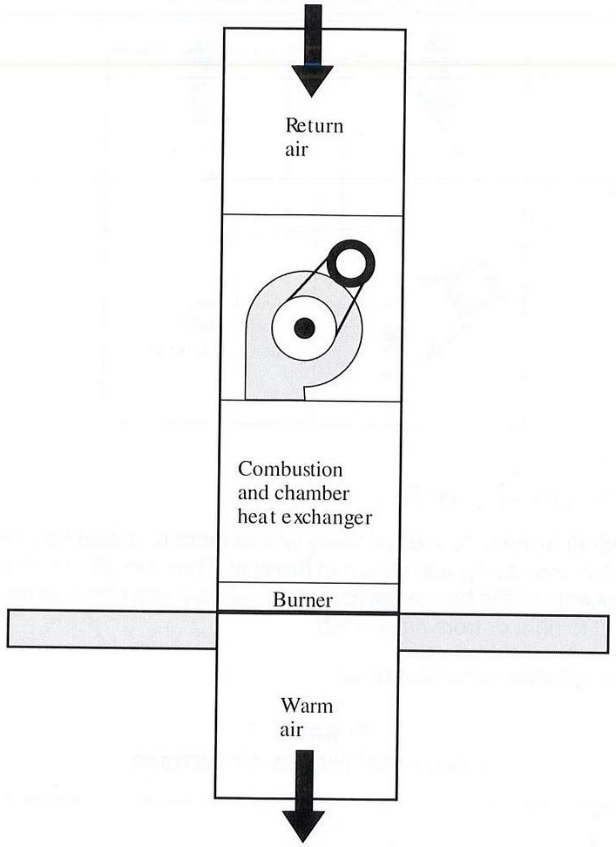
The blower is mounted beneath the heat exchanger and forces the return air up over the heat exchanger

3

Heated Air Distribution

The heated air then leaves through the top of the furnace

The high boy up-flow furnace is the most popular gas-fired furnace and is usually located in basements, although it may also be located in first floor utility rooms.



High Boy Down-Flow Furnace

1

Return Air Entry

Return air enters the top of the furnace and is forced down over the heat exchanger

2

Heat Exchange

Air passes over the heat exchanger, gaining thermal energy from the combustion process

3

Heated Air Distribution

The heated air is then blown out the bottom of the furnace

These furnaces have an additional limit switch placed above the heat exchanger for sensing the rising warm air and to turn the burner off. If the furnace did not have this switch, the air filter and/or motor would quickly overheat.

Down-Flow Furnace Installation Note

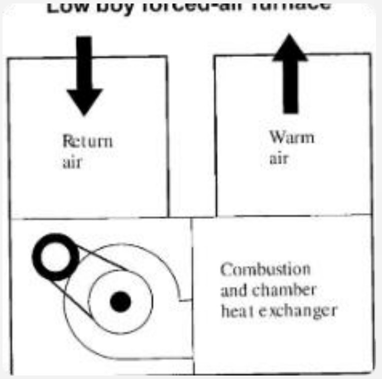
Installation Caution

Some down-flow furnaces have been certified for installation on a non-combustible floor only.

Combustible Flooring

These furnaces should not be installed on combustible flooring unless installed on a special base that has been specifically certified for this purpose.

The high boy down-flow furnace is also known as the high boy counter-flow furnace. These furnaces are normally installed in first floor utility rooms or slab constructed buildings. The air is distributed through crawl spaces.



Low Boy Forced-Air Furnace

1

Air Intake

The blower pulls in air through the top of the furnace

2

Heat Exchange

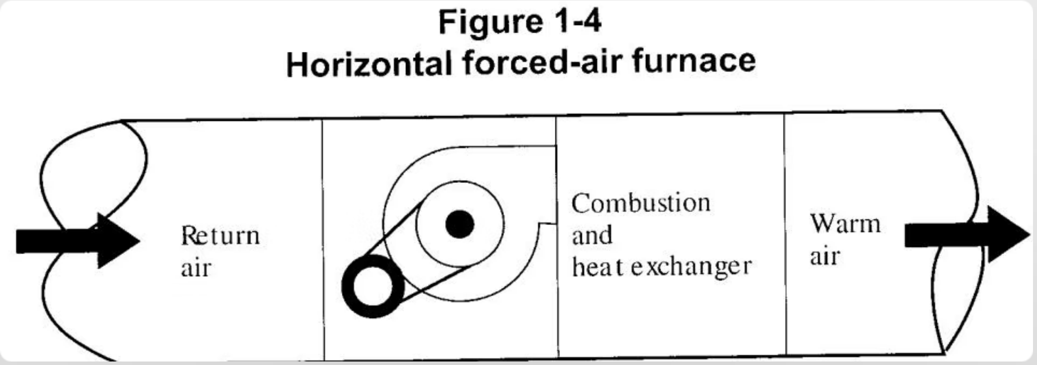
The blower pushes air over the heat exchanger

3

Air Distribution

The heated air then leaves through the top of the furnace

Low boy forced-air furnaces are used mainly in basements. In this type of low boy furnace, the blower is placed next to the heat exchanger. The gas-fired low boy furnace design is fast disappearing from the marketplace since new compact high-boy designs can accommodate the height spacing left behind from the removal of an old low boy furnace.



Horizontal Forced-Air Furnace

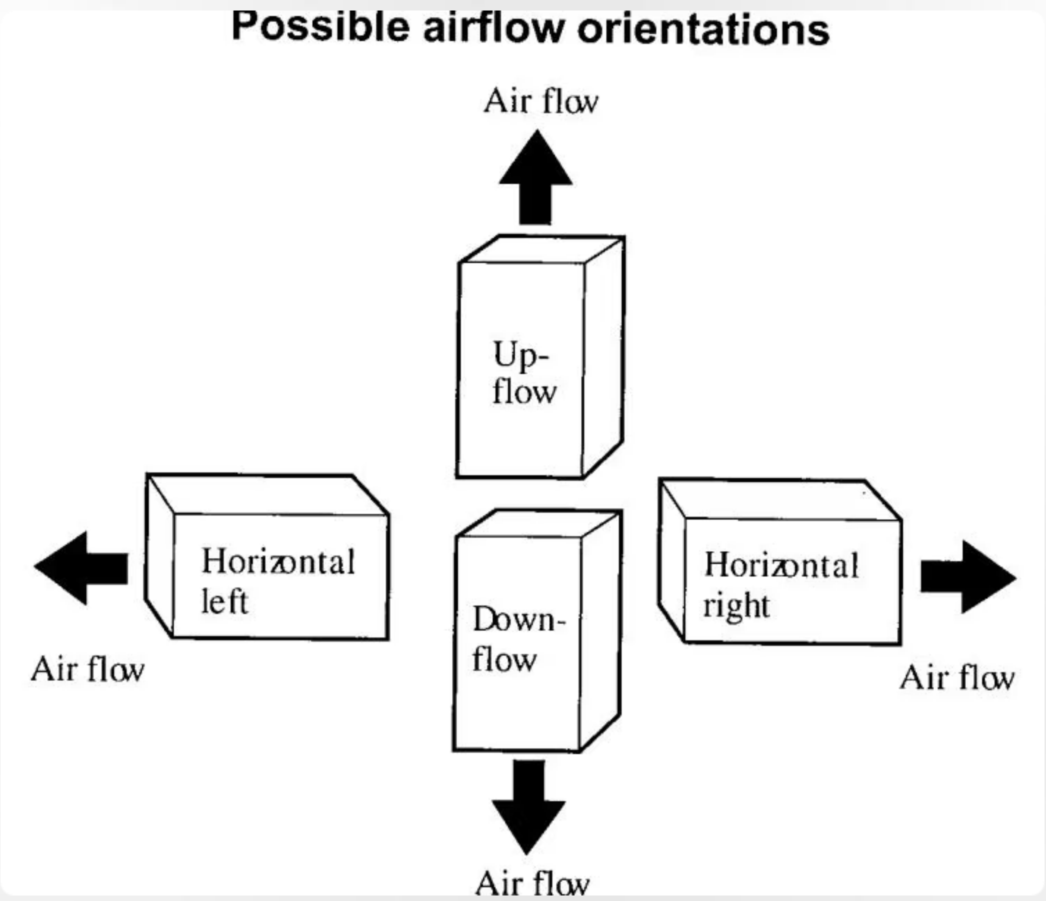
The horizontal forced-air furnace is used in areas where there is limited head room, or where it can be suspended from the ceiling and be out of the way. They are often used in automotive garages, crawl spaces, and attics.

Flexible Configuration

The components in a horizontal furnace can often be rearranged so that the air can move from left to right or from right to left.

Space Efficiency

Designed specifically for installation in areas with height restrictions where vertical furnaces cannot fit.



Multi-Position Forced-Air Furnace

Some furnaces are designed so they can be installed in any one of several positions. The orientation of the components will change as the position changes.

Upflow Configuration

Air enters at the bottom and exits at the top, ideal for basement installations.

Downflow Configuration

Air enters at the top and exits at the bottom, suitable for installations on main floors or in closets.

Horizontal Configuration

Air flows horizontally through the unit, perfect for attics, crawlspaces, or other areas with limited headroom.

Furnace Efficiency Classifications

Conventional/Low Efficiency

Below 78% efficient

Medium/Mid Efficiency

78% to 89% efficient

High Efficiency/Condensing

90% efficient and above

Energy Star

95% efficient and above

Natural Resources Canada (NRCan) Energy Efficiency regulations mandate the efficiency of furnaces. Since 2010, the minimum AFUE efficiency for residential furnaces (65.92kW/225,000 Btu/h using single-phase electric current) has been 90%. Although there are furnaces installed with different efficiencies, only high-efficiency furnaces are currently manufactured and sold in Canada.

Low-Efficiency Furnace Characteristics

Standing Pilot

Continuously burning pilot light that wastes energy when heating is not required

Natural-Draft Burners

Rely on the natural rise of hot gases for combustion air flow

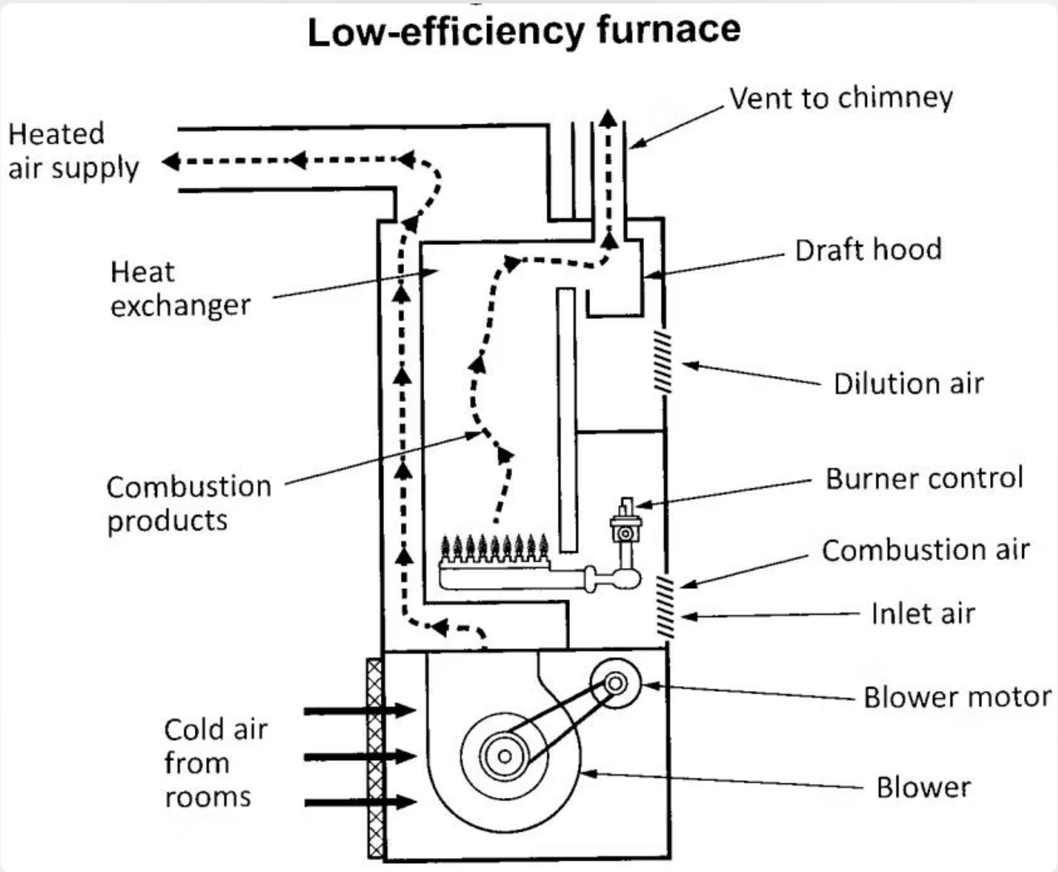
Draft Hoods

Control the draft influence on the combustion chamber

High Flue Temperatures

Temperatures well above the dew point ensure no condensation in heat exchanger or venting

These models represent most central furnaces sold prior to the mid-1980s. They typically had a belt-drive blower assembly and electro-mechanical type safety and operating controls.



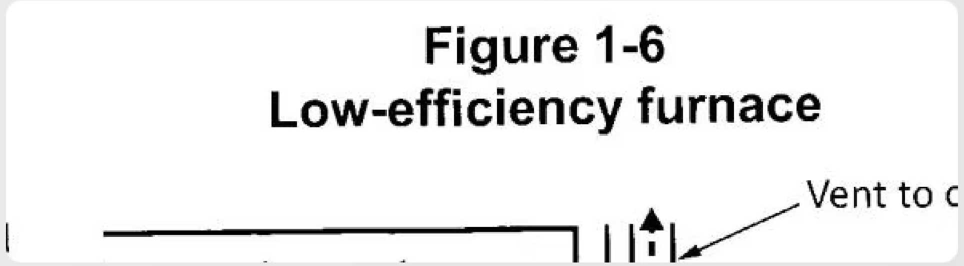


Figure 1-6
Low-efficiency furnace

Mid-Efficiency Furnace Characteristics

Electronic Ignition

Replaced standing pilots, requiring a control module (circuit board) for operation

Redesigned Heat Exchanger

Constructed of thinner material with multiple passes for better heat transfer

Draft-Inducing Fan

Helps draw the products of combustion from the burner to the venting system

Efficiency Range

Generally achieve AFUEs of 78-82%

High-Efficiency Furnace Characteristics

Condensing Technology

Products of combustion are purposely cooled below the dew point by advanced heat transfer methods

Dual Heat Exchangers

Utilizes primary and secondary heat exchangers for maximum efficiency

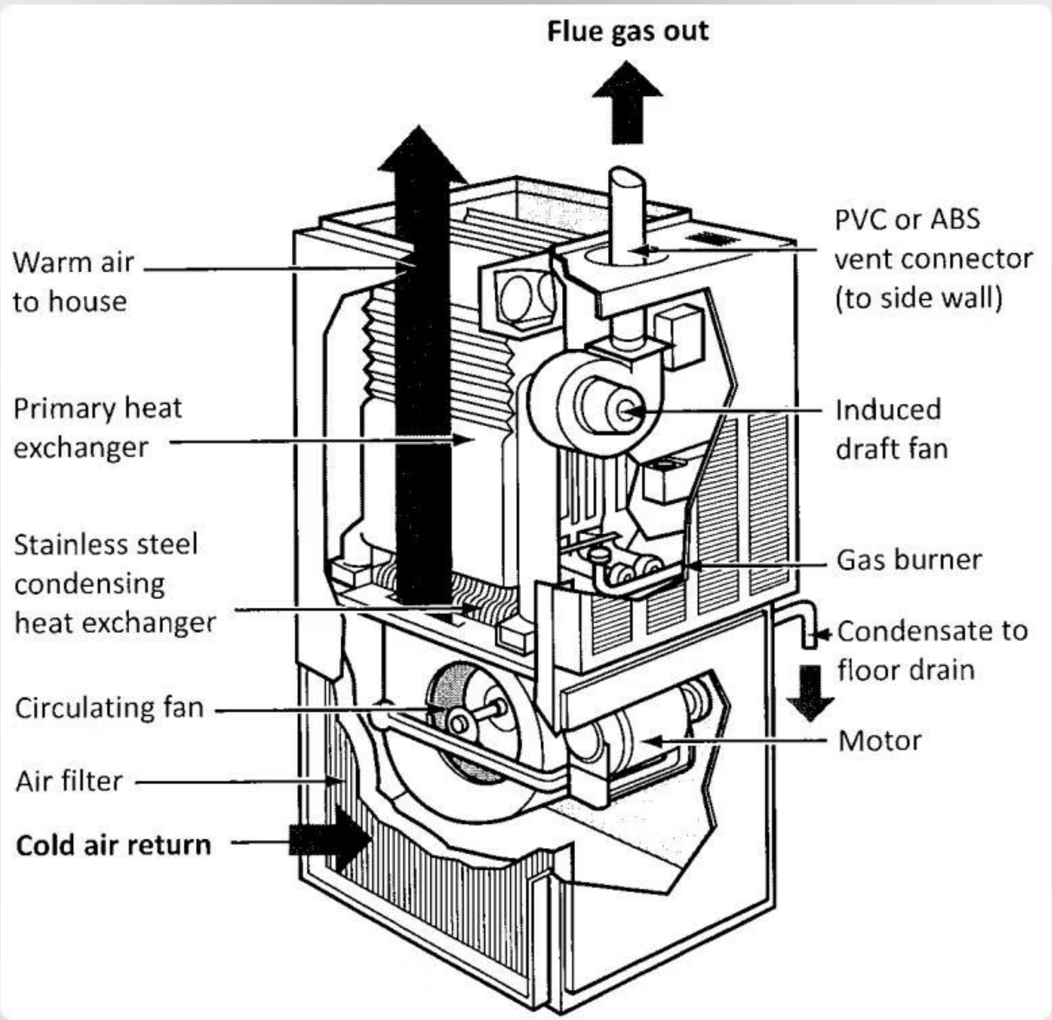
Condensate Management

Requires proper drainage systems for the acidic condensate produced

High AFUE Rating

Efficiency levels well into the 90% range

Since January 1st, 2012, all gas-fired furnaces sold in Canada are required to be high efficiency (90% and above) as determined by the AFUE testing guidelines.



Furnace Categories

Category	Vent Static Pressure	Flue Loss	Type and Efficiency
Category I	Non-positive (zero or negative)	Not less than 17% (maximum 83% efficient)	Medium-efficiency furnaces with draft hood-equipped or fan-assisted for venting into Type B vents
Category II	Non-positive (zero or negative)	Less than 17% (84% or greater efficiency)	High-efficiency furnaces (90-98%) with condensation that must be properly disposed
Category III	Positive	Not less than 17% (maximum 83% efficient)	Most are medium-efficiency furnaces
Category IV	Positive	Less than 17% (84% or greater efficiency)	High-efficiency furnaces (90-98%) with condensation that must be properly disposed

Vent gas condenses below a certain temperature (127–130°F). Furnace categories are based on whether or not condensing occurs and whether there is positive vent pressure. Vents for a particular furnace category are then designed from this information.

Installation Requirements Overview

The gas technician/fitter can be expected to work on conventional Category I furnaces as well as high-efficient Category IV appliances. The installation of modern furnaces can be much more complex than older appliances. A modern high-efficiency furnace could work as a stand-alone heat source or could be used as a companion to other HVACR equipment. For example, a furnace can be a single-stage, two-stage, or multi-stage (modulating) model and can be combined with a heat pump, solar system, air-conditioning, or any other alternate heating or cooling source. This can be challenging for installers and service technicians, so a strong understanding of all the components and installation requirements is required.

Code Requirements

Professional Installation

A forced-air furnace requires professional installation, maintenance, and repair according to CSA B149.1 and local ordinances.

Installer Responsibility

The gas technician/fitter is responsible for installing and maintaining forced-air furnaces and must know what these requirements are.

Compliance Verification

Before leaving installations, installers shall ensure that the appliance, accessory, component, equipment, or piping and tubing they installed complies with the Code requirements, and that the appliance is in safe working order.

In CSA B149.1, Clause 4.3 clearly describes the responsibilities of the installer.

Key Terms for Furnace Installation

- Appliance
- Automatic Vent Damper Device
- Condensate
- Direct-Vent Appliance
- Draft and Draft Control Device
- Furnace and Floor Furnace
- Indirect Fired Appliance
- Mobile Housing
- Vent and Venting System

These terms can be found in CSA B149.1, Clause 3, Definitions.

Electrical Installation Requirements

Permit Requirements

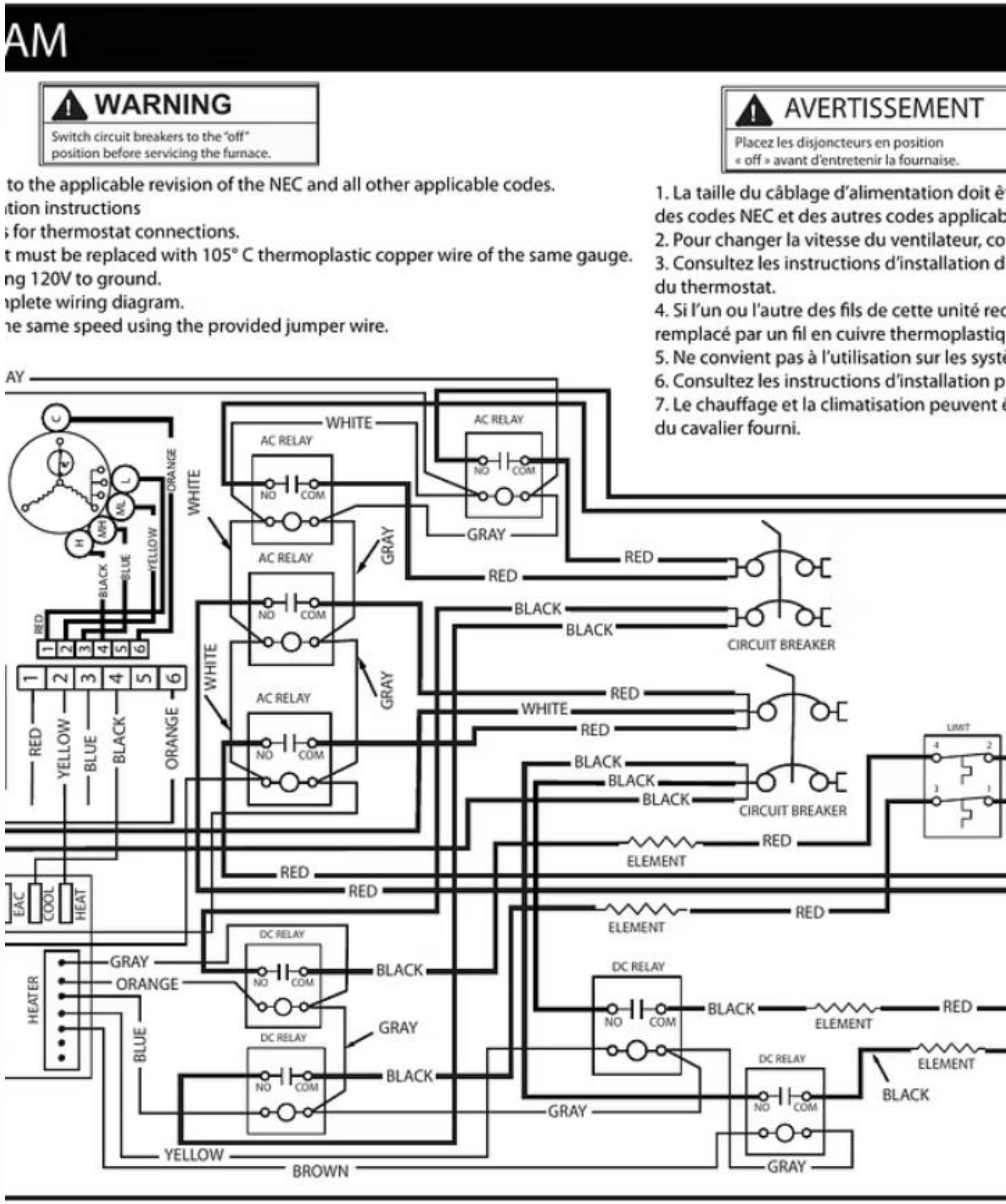
Before work begins on the installation, repair, or alteration of a forced-air furnace, certain jurisdictions require a permit for electrical work from the inspection department of the authority having jurisdiction.

Code Compliance

All wiring and electrical connections must be done in accordance with the latest Canadian Electrical Code, and with local regulations that apply.

Wiring Diagram

Any wiring done must be in accordance with the wiring figure provided by the manufacturer.



Furnace Installation Guidelines

Follow Manufacturer's Instructions

Install a forced-air furnace according to the manufacturer's instructions. However, if these instructions differ with the Code or with local regulations, follow the instructions of the Code or local regulations unless the differences have been approved by the authority having jurisdiction.

Used Appliance Installation

Install used appliances with particular care to ensure they are safe for use.

Specific Requirements

Refer to specific sections of CSA B149.1 for different furnace set-ups: Clause 7.12 Furnaces used with cooling units; Clause 7.13 Central furnaces; Clause 7.14 Downflow furnaces; and Clause 7.16 Horizontal furnaces.

Accessibility Requirements

Furnaces must be installed so that they are accessible for servicing. Requirements for accessibility are outlined in CSA B149.1, Clause 4.14.1.

Area	Requirement
Opening to the crawl space	Be 24 by 30 inches (600 by 750 mm)
Height and width of the crawl path	Be 36 by 36 inches (900 by 900 mm)
Service clearance on the burner and controls side	Be at least 24 inches (600 mm) or more

Note: A cold air return is not allowed in the crawl space.

Standard Clearances to Combustible Material

Area	Clearance
Top	6 inches (150 mm)
Back, sides, and bottom	6 inches (150 mm)
Burner side	24 inches (600 mm)

If not marked on the rating plate, these standard clearances to combustible material should be maintained. For installations on a combustible floor material where the furnace is not certified for this use, two options are available: use the furnace manufacturer's special base; or prepare the surface with two courses of 4-inch hollow block laid flat, with sheet metal on top, extending 6 inches wider than the furnace.

Attic and Rooftop Installation Requirements

Attic Installation

If a horizontal furnace is to be installed in an attic:

- The rating plate should state that the furnace is approved for attic installation
- A permanent substantial walkway should be installed to the control side of the furnace

Rooftop Access Requirements

Roof height	Requirement
0 to 13 ft (0 to 4 m)	No access requirements
13 to 26 ft (4 to 8 m)	Fixed access
26 ft (8 m) and over	Stairway or stairway leading to ladder which is 4 m (13 ft) maximum

Rooftop furnaces must be 2 m (6 ft) away from the edge of the building.

Garage Installation Requirements

Storage Garage Clearance

Minimum clearance above-grade-level of any component of a forced-air furnace is 18 inches (450 mm) for a storage garage.

Repair Garage Clearance

Minimum clearance above-grade-level of any component of a forced-air furnace is 4.5 ft (1400 mm) for a repair garage.

FVIR Exception

The 18 inch requirement for storage garages does not apply if the appliance is certified as flammable vapours ignition resistant (FVIR).

Physical Protection

The furnace in a garage should be adequately protected against damage.

In CSA B149.1, Clause 4.16.4 requires that the installation of a forced-air appliance in a garage be in accordance with local building codes or in the absence of local codes, the NBC.

Minimum Clearances for Central Furnaces

1

inch

From the top of the plenum

6

inches

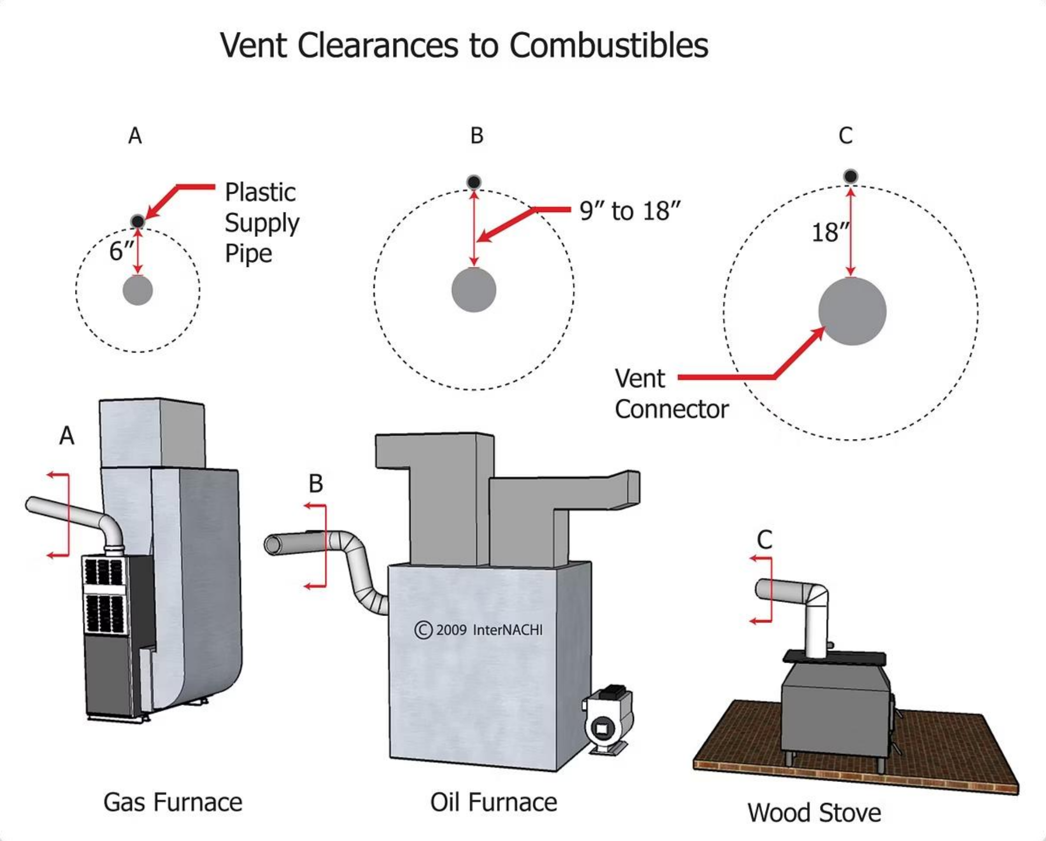
From the sides and rear

24

inches

From the front

These are the minimum clearances from combustible material allowed for a central furnace. Furnaces in mobile homes and recreational vehicles have specific requirements covered in the Mobile homes and Recreational vehicles sections.



Combined Heating Systems

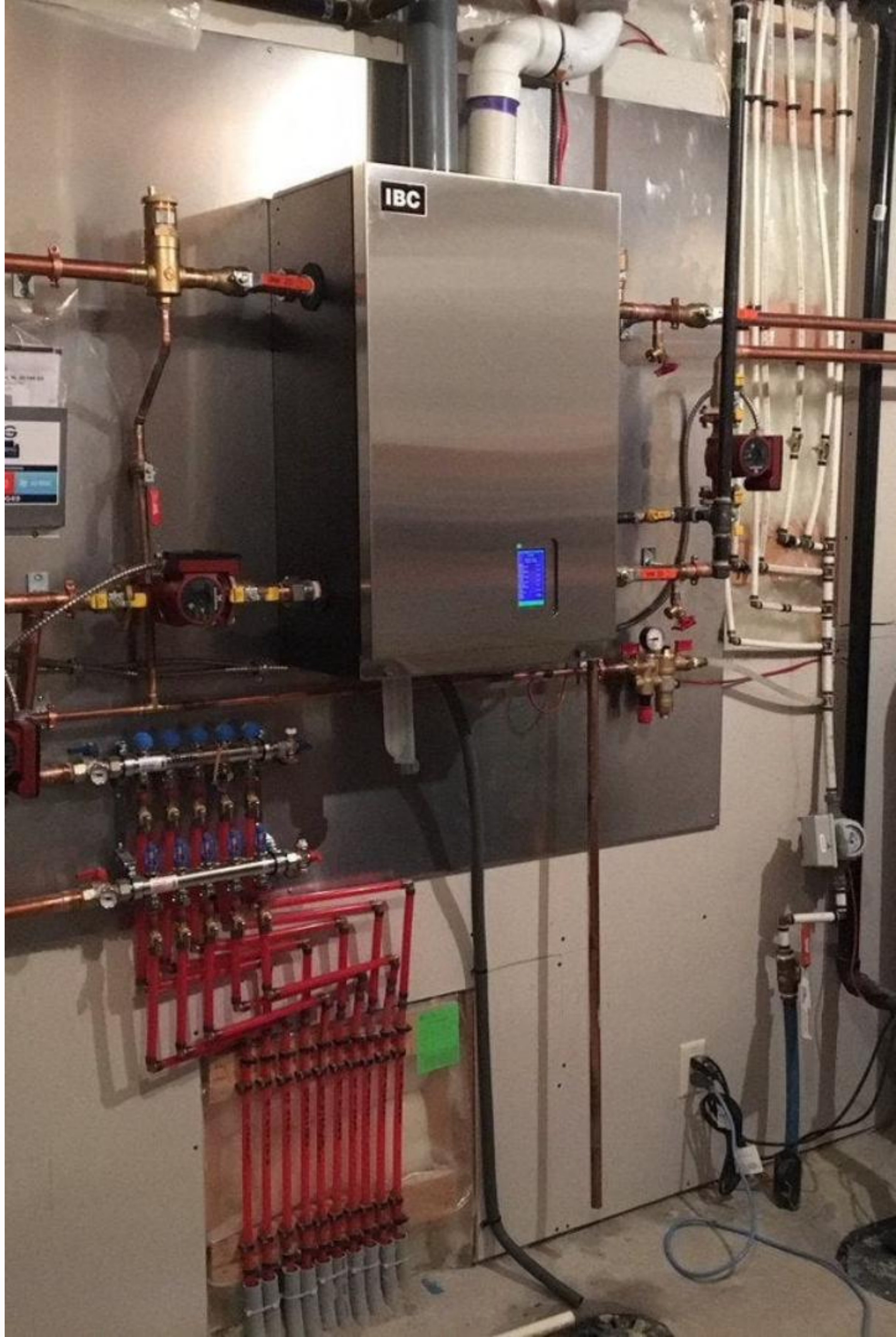
Do not pipe air heated by the combustion of a solid fuel-fired appliance into the ductwork of a gas-fired appliance, unless the furnace is certified as a combined heating system or a certified, solid fuel-fired appliance downstream add-on furnace is installed. This is covered in CSA B149.1, Clause 4.18.

Certification Requirement

The furnace must be specifically certified as a combined heating system to be used with solid fuel heating.

Add-on Option

A certified, solid fuel-fired appliance downstream add-on furnace may be installed with proper certification.



Heating Residences Under Construction

Use Approved Construction Heater

To heat a residence under construction, install an approved construction heater.

Proper Furnace Installation

If installing a furnace for future use, place it on a finished concrete floor, a proper concrete slab, or suspend it safely.

Follow Code Requirements

Pipe and vent the furnace according to CSA B149.1 Sections 6 and 8.

Protect Air Plenums

Fit the furnace with warm air and return air plenums protected against waste material.

Many manufacturers recommend that their furnace not be used during construction since drywall dust and dirt can coat the heat exchanger causing premature failure. The furnace warranty may be voided if the furnace is improperly used for construction heat.

Mobile Home Installation Requirements

Code References

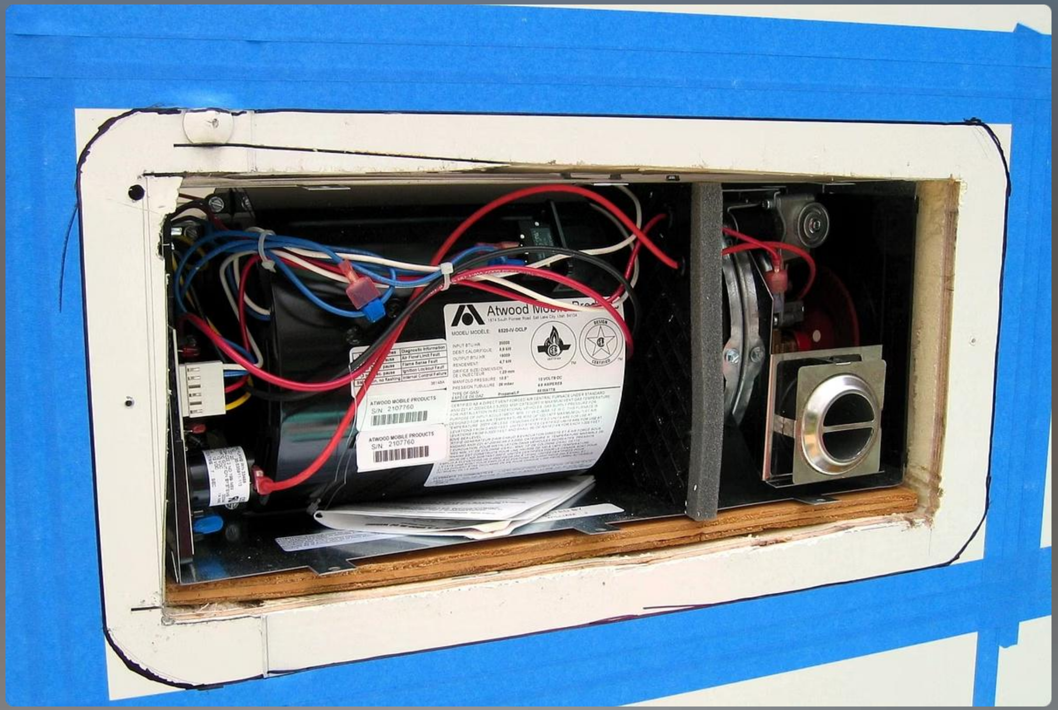
Before installing a forced-air furnace in a mobile home, refer to CSA B149.1, Clause 4.8 and CSA Z240.4.1.

Certification Requirement

CSA Z240.4.1 requires the installation of furnaces that are certified for use in mobile homes.

Permanent Placement

If the mobile home has been placed in a permanent fixed position, ensure that the installation of the furnace meets all CSA B149.1 requirements.



Recreational Vehicle Installation Requirements

Code Compliance

When installing a forced-air furnace in a recreational vehicle, comply with the requirements laid down in CSA Z240.4.2.

Certification Requirement

A furnace installed in a recreational vehicle must be certified for use with propane and be of the direct-vent type.

Refueling Safety

Turn off any source of ignition before refuelling the vehicle.

Warning Label

In recreational vehicles using propane, place a warning label in French and English next to the propane container as specified in CSA Z240.4.2.

Figure 1-9
Major installation features of a high-efficiency forced-air furnace
Courtesy Imperial Manufacturing Group

Major Installation Features

A furnace installation includes many components in addition to the gas-fired appliance. A modern furnace heating system needs supply air ducting and return air ducting. It could also include specialized equipment such as a heat recovery ventilator (HRV) and high efficiency particulate air (HEPA) filtration. A gas technician/fitter needs to know how this added equipment works and how it integrates into the furnace heating system.

Furnace Selection Considerations

Configuration

The configuration of the furnace (upflow, downflow, or horizontal) is usually predetermined by on-site considerations.

Heat Loss Calculation

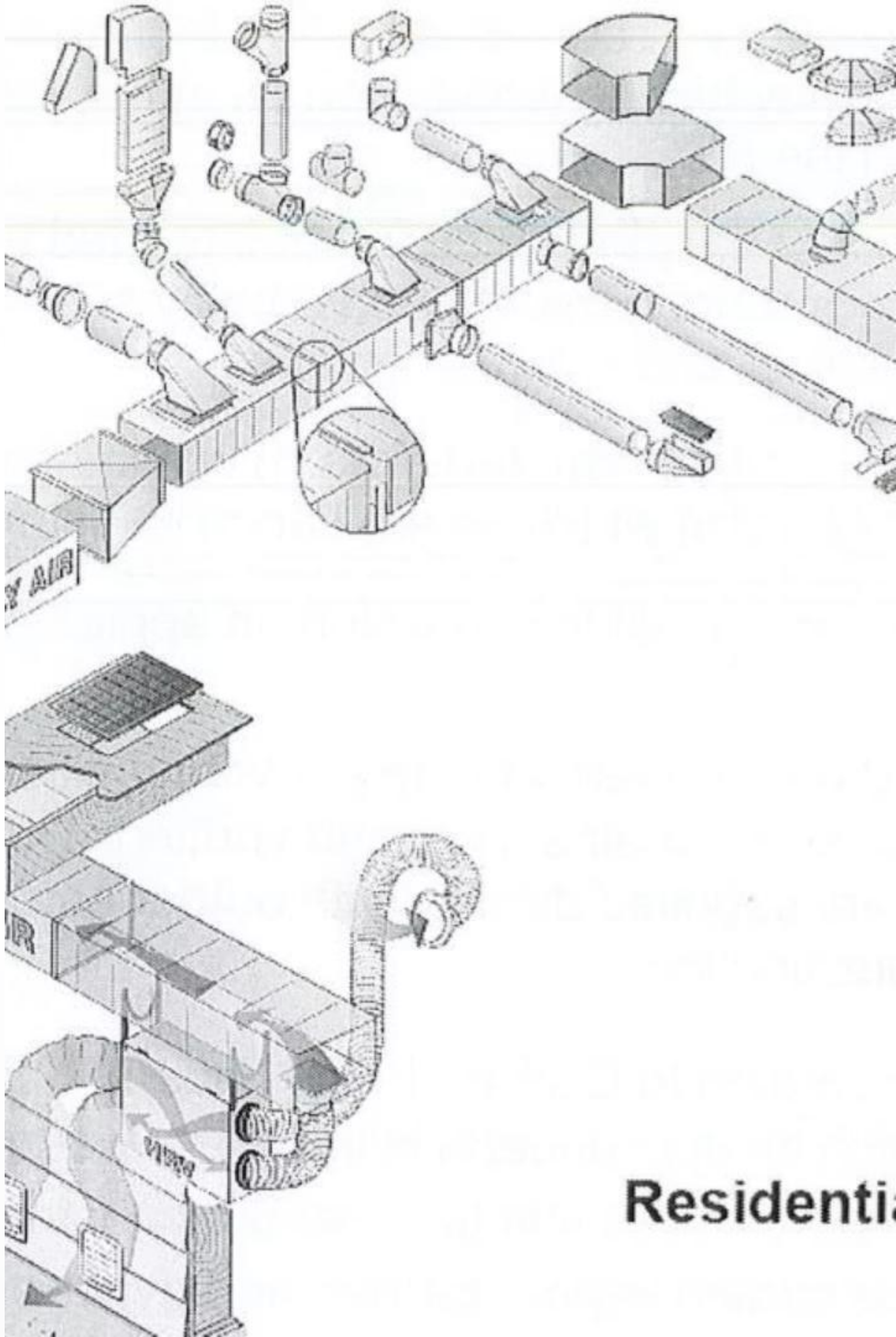
The size of a new furnace or a furnace for a retrofit can only be decided by completing a heat loss calculation.

Building Factors

The home's heating demand is heavily influenced by other energy-related components in the building, as well as any renovations that have been completed.

Homeowner Consultation

The gas technician/fitter must be prepared to discuss any past or future changes to the home with the homeowner.



Building Classifications

Class	Description
Building	A structure or part thereof used or intended for supporting or sheltering persons, animals, or property and classified by its occupancy in accordance with the applicable building code of the authority having jurisdiction or, in the absence of such, in accordance with the NBC.
Dwelling unit	A housekeeping unit used or intended to be used as a domicile by one or more persons, and usually containing cooking, eating, living, sleeping, and sanitary facilities.
Enclosure	A secondary structure (room) within or attached to a structure (building) in which an appliance is installed.
Structure	The entire building in which an appliance is installed.

Outdoor Air Supply Requirements

An outdoor air supply sized according to CSA B149.1, Clause 8.2.2 must be provided to either an enclosure or a structure in which an appliance(s) is installed, when the structure:

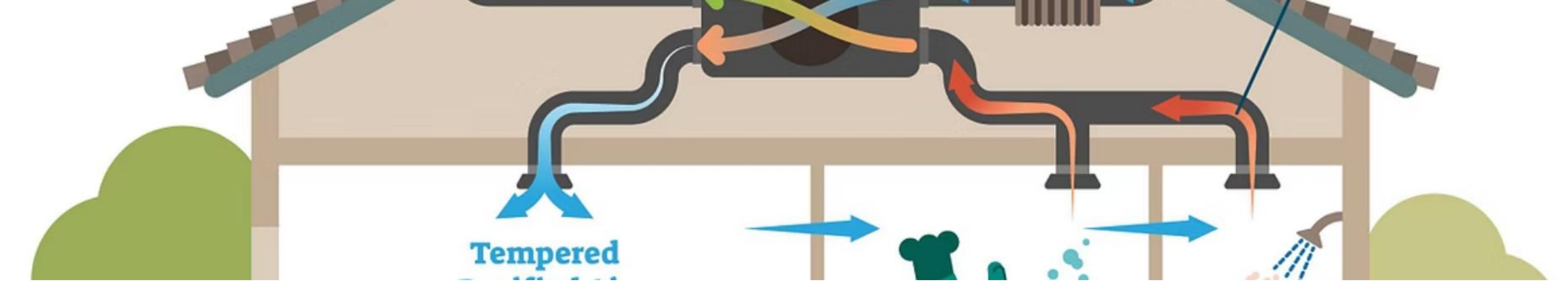
Sealed Construction

Has windows and doors of either close-fitting, or sealed construction, and the exterior walls are covered by a continuous sealed vapour barrier, and gypsum wallboard (drywall), plywood, or similar materials having sealed joints

Limited Leakage Area

Has an equivalent leakage area of 78 square inches (0.05 m^2) or less at a differential pressure of 0.00145 psig (10 Pa) as determined by the recognized Canadian fan depressurization test procedure

Note: Gas technicians/fitters in Ontario, refer to the clause established by the authority having jurisdiction.



Building and Ventilation Considerations

Current provincial and national building codes and standards describe minimum ventilation rates for a building, as well as ventilation methods and criteria for spillage susceptible appliances (including central furnaces).

System Interdependence

Consider that the gas-burning central furnace, the building construction, and the ventilation system are interdependent.

Depressurization Limits

Most standards and codes include criteria for limiting depressurization levels in buildings containing spillage susceptible appliances.

Ventilation Methods

Certain building ventilation methods (e.g., exhaust-only systems) are permitted only when there are direct-vent type appliances installed in the building; spillage susceptible appliances are not permitted.

Supply and Return Sheet Metal Ducting

The sheet metal system for a furnace includes many individual components such as plenums, ducts, boots, collars, shoes, grilles, etc. Most jurisdictions in Canada require that qualified workers install the sheet metal components of the furnace heating system.

Proper Sizing

The gas technician/fitter would need to have some basic knowledge of sizing ducted systems to ensure the existing ducting is the correct size when completing a furnace retrofit.

Air Flow Requirements

Most high-efficiency furnaces need more cubic feet per minute (CFM) of air flow than existing furnace systems.

External Static Pressure

The gas technician/fitter should always complete an external static pressure (ESP) reading to determine whether the ductwork and fittings require modifications.

Balancing Dampers

A register (or diffuser) that includes a louvred damper, or alternatively an inline damper, are used to balance the supply air flow from each individual branch run into the heated space.

Damper Construction

A balancing damper is made from a piece of metal shaped to match the inside of the duct. It is used to restrict the air flow in the duct and is operated manually with a handle.

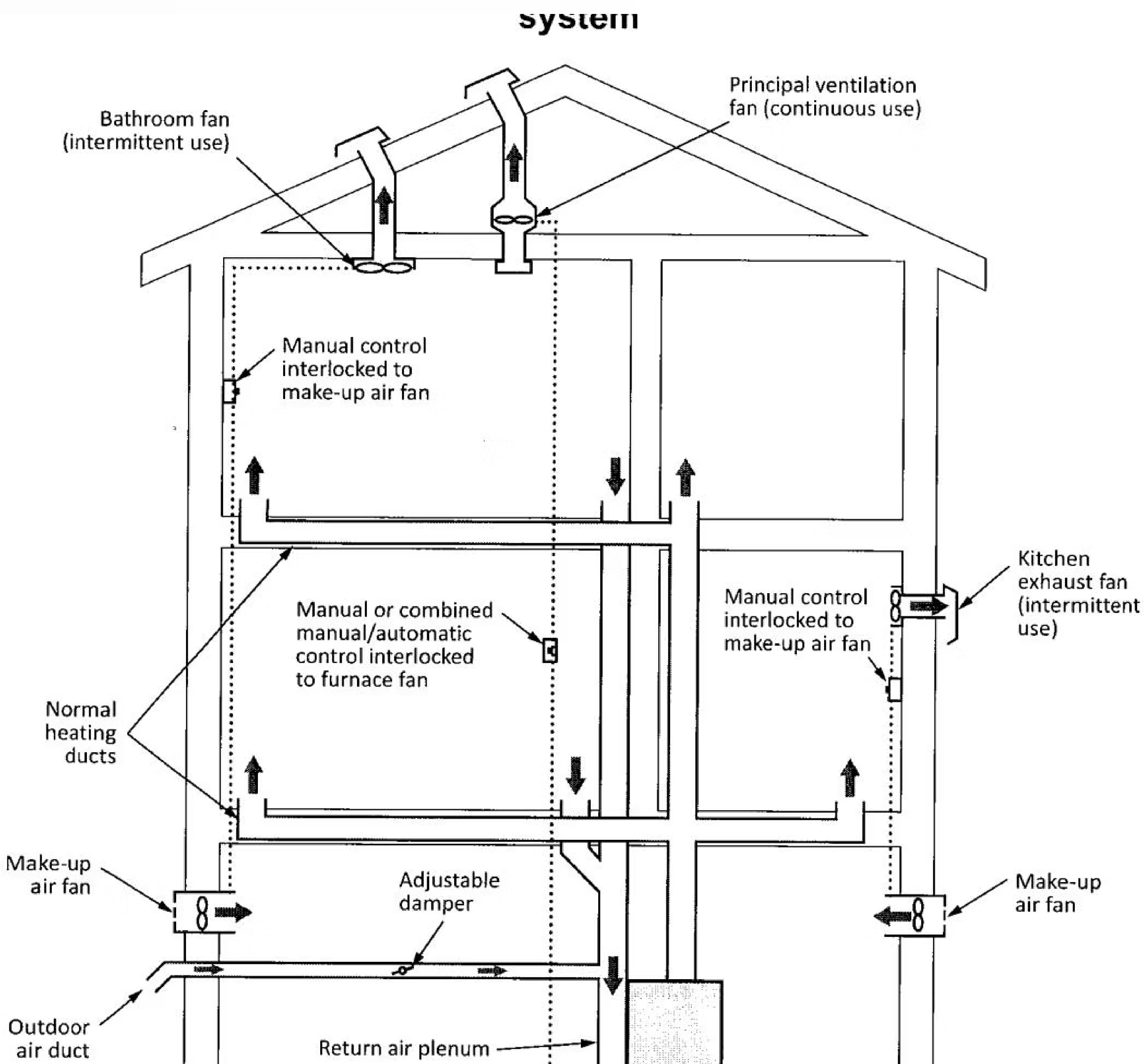
Placement

Each branch of the ductwork should have a damper to control the air flow to each room. The damper should be placed near the main duct line to reduce the noise due to the air flow in the room.

System Balancing

Dampers are adjusted during the commissioning of a system and should be fixed in place after a formal system balancing has taken place as changing one setting can affect the entire system.

Heat Recovery Ventilators



HRV Integration with Forced-Air System

This figure shows an HRV integrated with the furnace. The ducted forced-air heating system used in combination with the HRV must also have a furnace air circulating fan set to run continuously to ensure the distribution of the ventilation system supply air.

Heat Recovery

The HRV transfers heat from exhaust air to incoming fresh air, improving energy efficiency.

Balanced Ventilation

The system provides balanced ventilation by exhausting stale air while bringing in fresh air.

Whole-House Distribution

Using the furnace ductwork allows for distribution of fresh air throughout the entire home.

Figure 1-10
Possible configuration of a ventilation system coupled with a forced-air heating system

Ventilation System Configuration

This figure shows a possible configuration of a ventilation system using a heat recovery ventilator coupled with a forced-air heating system. The integration of these systems requires careful planning and proper installation to ensure optimal performance.

Airflow Paths

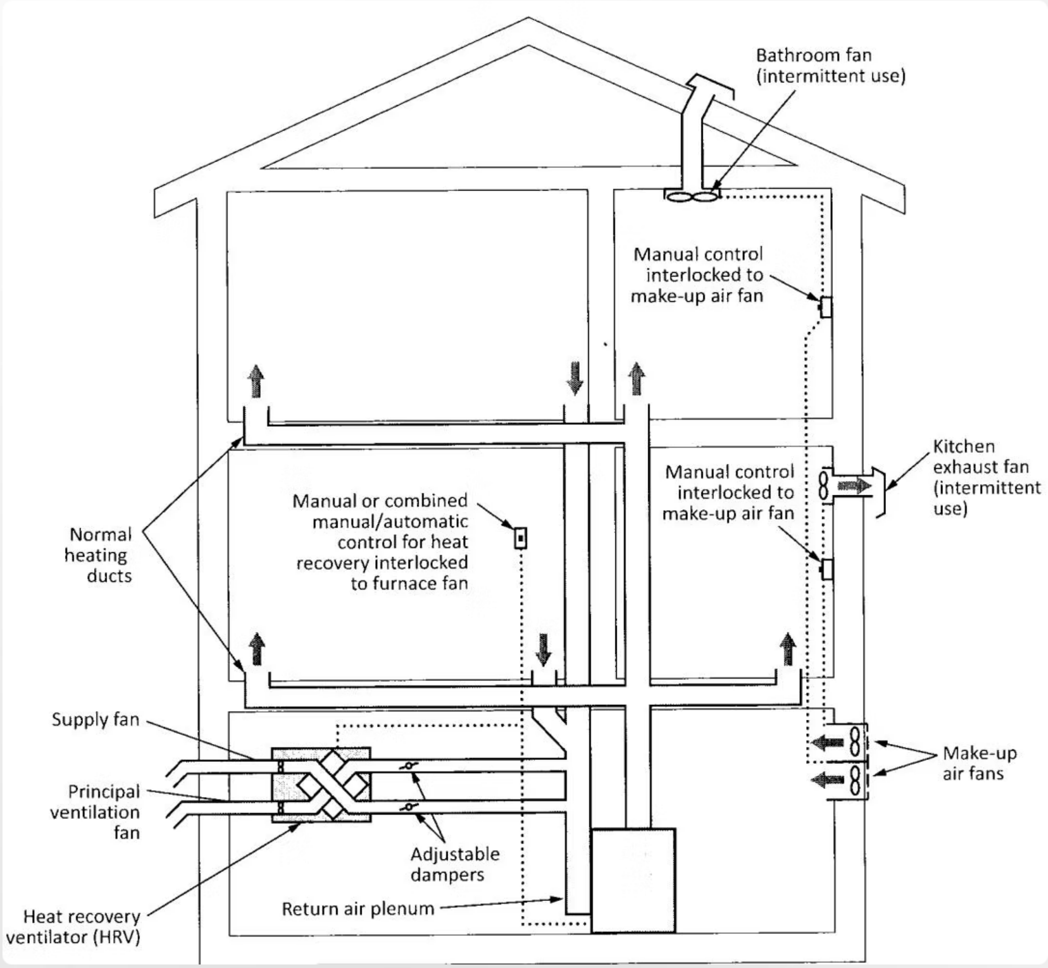
The diagram shows the various airflow paths through the integrated system, including fresh air intake, exhaust air, and distribution through the home.

Component Integration

The HRV is integrated with the furnace ductwork to provide a complete ventilation and heating solution.

Temperature Control

The system allows for temperature-controlled fresh air to be distributed throughout the home.



Control Systems: Thermostats

Modern high-efficiency furnaces match their heating output to building heating demand more precisely than older single-stage appliances. This can improve occupant comfort and increase energy savings.

Wireless Technology

A modern furnace installation could include a wireless thermostat connected to equipment interface module (EIM) which operates the furnace.

Building Management

Direct Digital Control (DDC) systems are used on more complex installations such as industrial, commercial, and institutional projects and integrate the heating appliances into a building management system.

Communication Requirements

To fully achieve comfort and efficiency benefits, the new thermostats must be able to communicate different heating levels to the furnace and the wiring must also be matched.

Wireless HVAC Control System

This figure shows a wireless system for the HVAC equipment. Modern control systems offer enhanced functionality and convenience for both homeowners and technicians.

Wireless Communication

The system uses wireless technology to communicate between components, reducing the need for complex wiring.

Remote Access

Many modern systems allow for remote monitoring and control via smartphone applications.

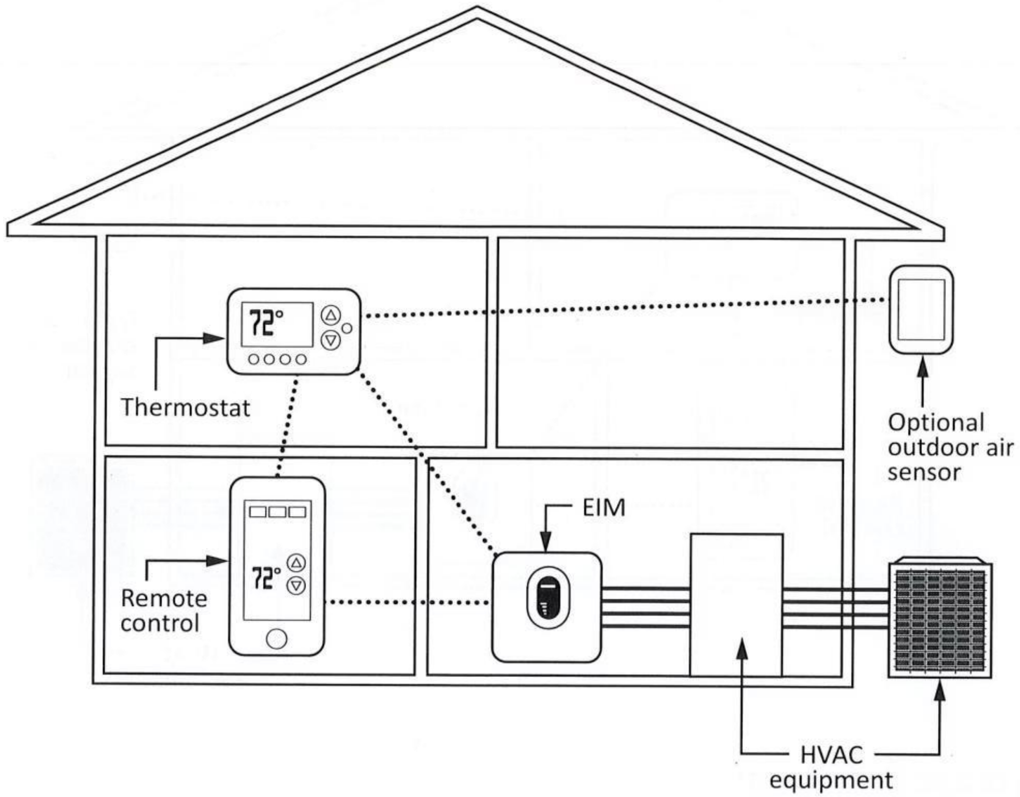
Data Collection

Advanced systems can collect usage data to optimize performance and energy efficiency.

System Integration

The wireless control system can integrate with other home automation systems for comprehensive control.

Figure 1-12
Wireless system for HVAC



Zoning Systems

Traditional furnace heating systems use only one thermostat to control the appliance burner. These systems have manual dampers on the individual duct runs to provide system balancing. This system is hard to balance and with limited choices for blower fan speed it is critical to get the air flow correct for customer comfort.

Multiple Zones

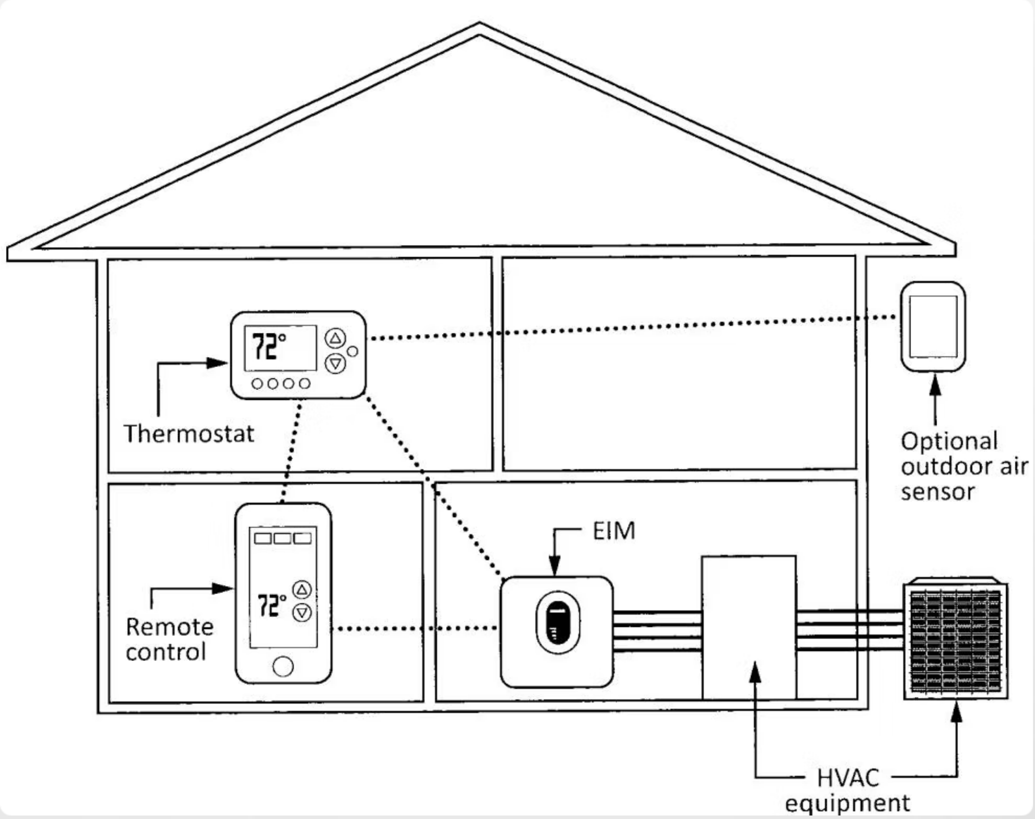
Zoning is a solution that compensates for variations in load throughout a home by creating multiple independently controlled areas.

Motorized Dampers

Zoning adds motorized dampers to each supply air duct so that multiple zones using multiple thermostats can be used.

Air Flow Management

A zoned furnace heating system would need a variable speed fan or a bypass damper to ensure the air flow (volume and velocity) from each register is appropriate.



Air Conditioning Integration

Air conditioning is a common addition to a furnace heating system. A cased coil would be added downstream of the furnace but could have a significant effect on the operation of the appliance. A gas technician/fitter would need to have a basic understanding of the air conditioning system and the associated components.

Cooling Coil

The evaporator coil is installed in the supply air plenum to cool the air as it passes through.

Outdoor Unit

The condensing unit is installed outside and connected to the indoor coil via refrigerant lines.

Temperature Control

The same thermostat that controls the furnace typically also controls the air conditioning system.

Figure 1-13
Air-conditioning system in furnace heating system

Air Conditioning System Components

This figure shows a simple air-conditioning system installed with a furnace heating system. The integration of these systems requires proper sizing and installation to ensure optimal performance.

Indoor Components

The indoor unit includes the evaporator coil and air handler (often the furnace blower).

Outdoor Components

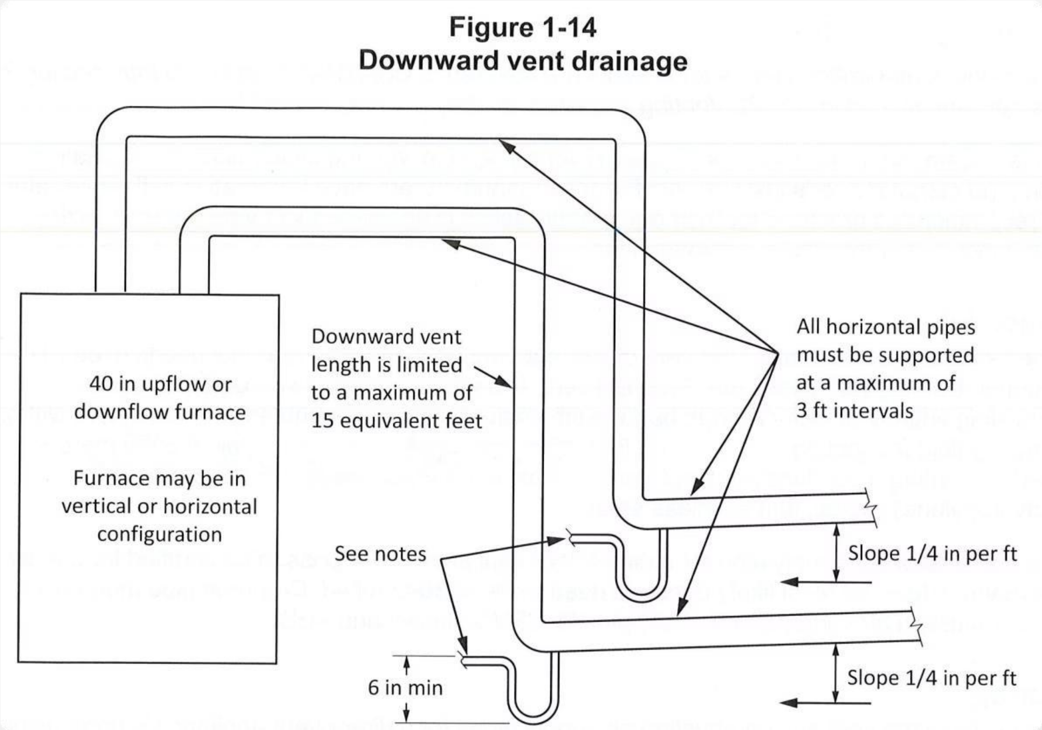
The outdoor unit contains the compressor and condenser coil.

Refrigerant Lines

Copper lines connect the indoor and outdoor units, carrying refrigerant between them.

Condensate Drainage

The cooling process creates condensation that must be properly drained away from the system.



Condensate Removal

Condensate drain piping is used to drain all liquid waste produced by the combustion process. Manufacturers of condensing furnaces incorporate condensate collection into the appliance design but there are some vent pipe installations that may require additional condensate drainage.

Drain Tee Installation

Install a drain tee or inline fitting in the vent pipe to provide a means for condensate removal that may form in the venting system.

Proper Grading

Grade all vent piping toward the appliance and condensate removal fitting which must be as close to the appliance as possible.

Cold Area Protection

If the vent piping runs through an unheated section of the building, insulate the piping to prevent freezing.

Condensate Drainage Requirements

Drainage Path

Condensate piping from the appliance slopes downward and terminates into the DWV system.

Pump Requirements

If there is no floor drain near the furnace then a condensate pump, or sump pump, may be required to pump the condensate to a drain.

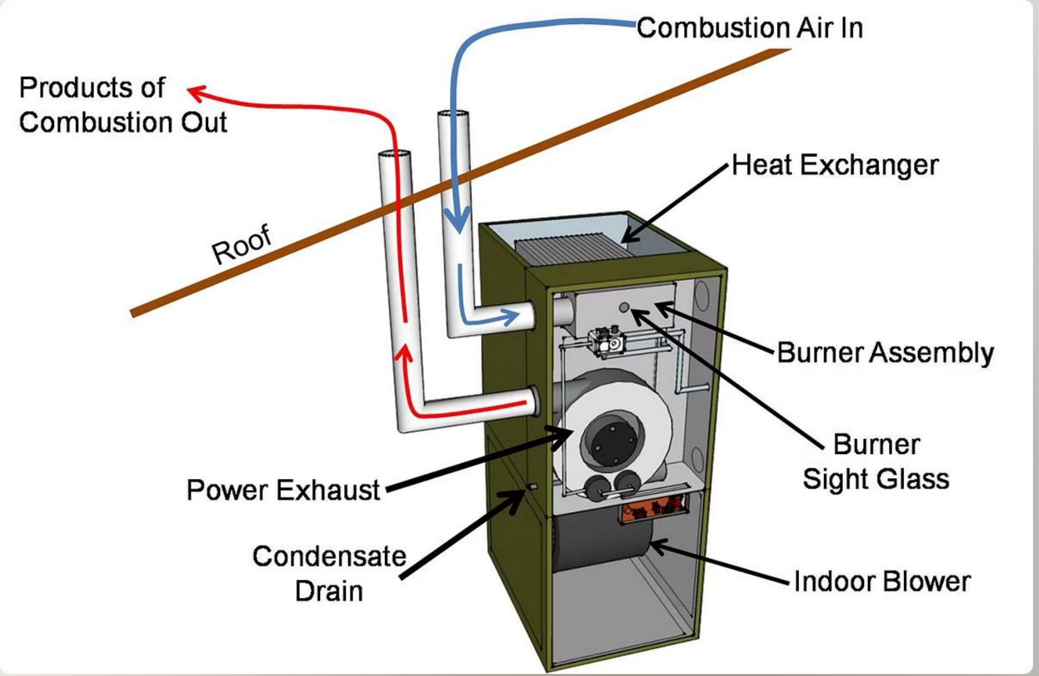
Neutralizer Installation

Due to the potential corrosive effects of condensate on a drain waste and vent (DWV) system, local jurisdictions may require that a neutralizer be installed.

Trap Requirements

On high-efficiency furnaces, there must be a condensate trap to separate the pressure of the vent system from the drain system.

If the condensate trap is improperly installed, or there are two condensate traps, an air pocket between the traps quickly prevents draining of the system.



Venting Practices

Sizing and configuration criteria for B-vents are covered in CSA B149.1, in Unit 9 Introduction to gas appliances, and in Unit 22 Venting practices. Modern Category IV furnaces use Type BH vent or special venting systems and are installed using the manufacturer's instructions.

Manufacturer Guidelines

Furnace manufacturers have information in their literature on recommended practices for their equipment.

Installation Requirements

Proper vent material, sizing, installation, and termination are critical for safe and efficient operation.

Vent Material Selection

BH Vent Material

When selecting a material for the vent of a direct-vent appliance the material needs to be BH vent material complying with ULC S636.

Common Materials

The typical S636 materials used for venting a condensing direct-vent appliance are PVC plastic, CPVC plastic, PP (polypropylene) plastic, and stainless steel.

Combustion Air Supply

The combustion air supply pipe for a direct-vent appliance only needs to be certified for use by the manufacturer so most likely does not need to be S636-certified. Common pipe materials for the combustion air supply can be PVC plastic, CPVC plastic, and ABS.

Vent Sizing and Installation

Sizing Guidelines

The sizing of the vent and combustion air supply pipes for a direct-vent appliance is done using information in the manufacturer's literature. Each pipe size will have a maximum length to ensure the operation of the appliance is not affected.

Equivalent Length

Each fitting installed on the vent or combustion air piping must be accounted for as an equivalent length of pipe.

Installation Requirements

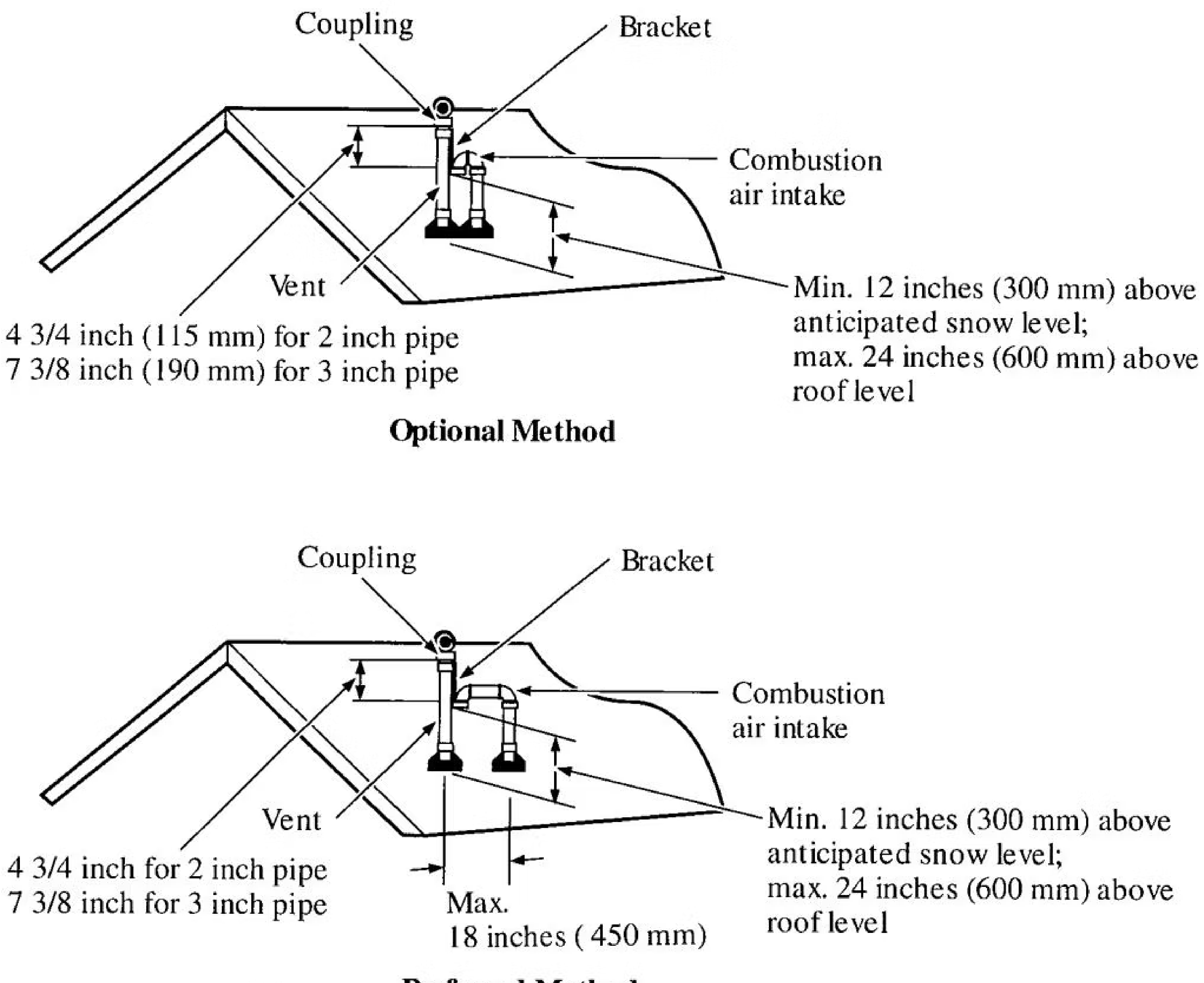
Pipe grade and pipe support requirements are very important to the long-term operation of the appliance. All materials expand and contract as they heat and cool so this movement must be accommodated.

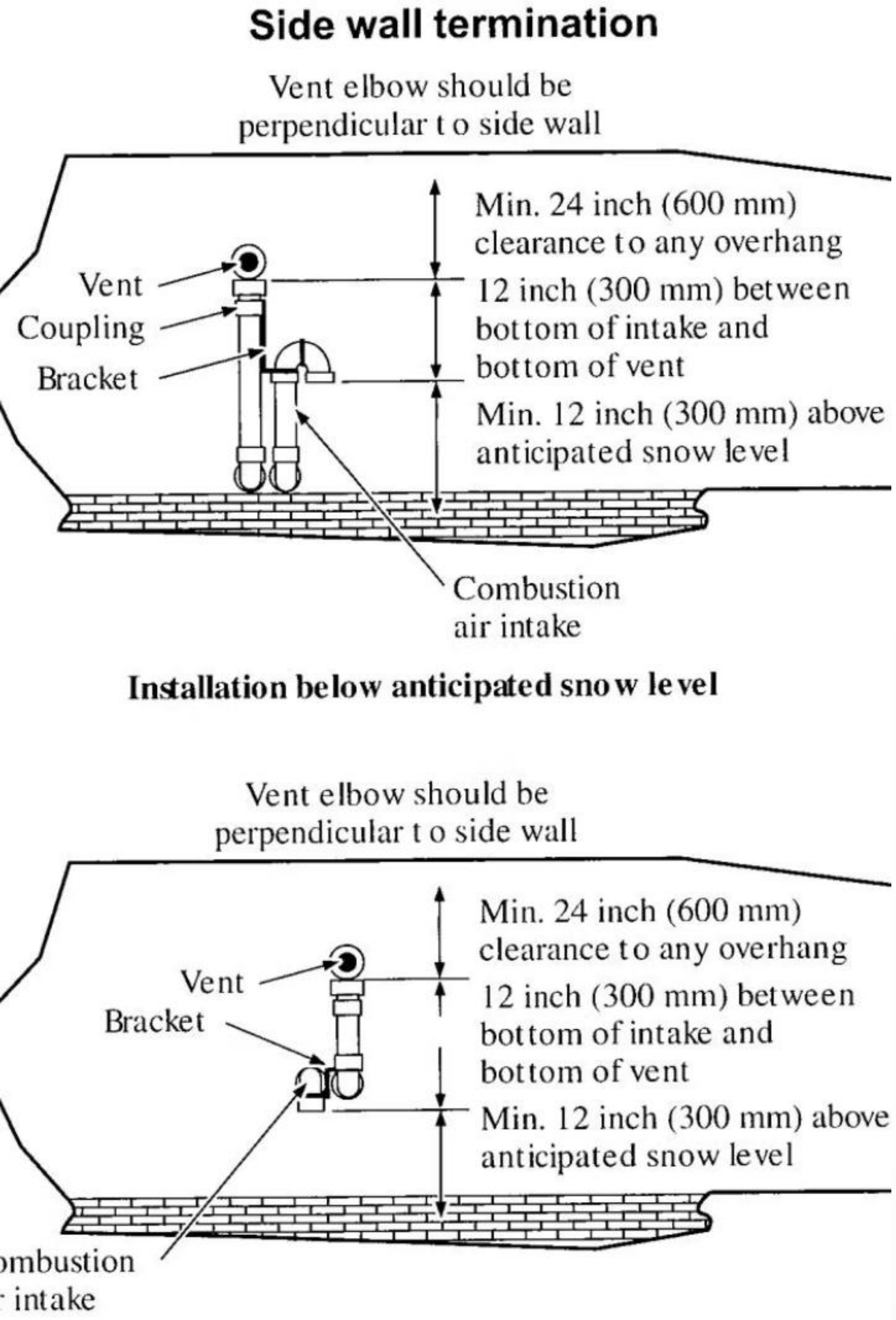
Primer and Cement

Canadian applications require primer and cement that are from a single system manufacturer. Pipe manufacturers include guidelines on the correct primer and cement for each type of material.

Vent Terminations

Figure 1-15
Rooftop termination
Courtesy of News Publishing Co.





Side Wall Vent Termination

This figure shows a manufacturer's preferred arrangement for a Category IV furnace's side wall vent termination. Manufacturer's certified installation instructions should be referenced to confirm compliance regarding the snorkel of a vent termination that rises to meet Code requirements.

Height Requirements

The termination must be installed above anticipated snow level to prevent blockage during winter months.

Clearance Requirements

Proper clearances must be maintained from windows, doors, corners, and other building features.

Exhaust Direction

The termination should be positioned to direct exhaust away from the building and prevent re-entry of combustion products.

Application and Approval Process

Some municipalities require that a heat loss calculation accompany the application for a building permit for a new building. Heat loss calculations can be done by the gas technician/fitter if trained in this practice.

Certification Requirements

Some jurisdictions require a certificate proving competency in heat loss/heat gain calculations. Gas technicians/fitters can take additional 3rd party training to receive this certification.

Code Compliance

The furnace must be installed in accordance with the codes, unless the authority having jurisdiction has approved an alteration from the codes.

Appliance Certification

The appliance must be certified by a recognized certification organization (e.g., CSA Group). Confirm with the authority having jurisdiction that the furnace has an acceptable certification mark.

Gas Conversion

The appliance may need to be converted for another type of gas. The requirements for conversion are discussed in Unit 9 Introduction to gas appliances.

Heat Loss Coefficient is Heat Loss Parameter per unit area

Floor	U_{floor}	A_{floor}	$U_{floor} * A_{floor}$
Roof	U_{roof}	A_{roof}	$U_{roof} * A_{roof}$

Sizing a Forced-Air Furnace

As part of correctly sizing a forced-air furnace, the gas technician/fitter must understand how heat is transferred and the rate of transfer. Otherwise the system may be:

Incorrect Sizing	Which may
Undersized	Lead to problems in heating areas
Oversized	Create inefficient energy usage
Directed to incorrect areas	Create uneven heating

Note: Heat loss or gain can vary considerably during a day. Also, a temperature that feels comfortable when people are active might not feel comfortable when they are resting.

Heat Loss and Heat Gain Factors

Heat is a form of energy, and so cannot be created or destroyed. It can only be transferred from one place to another.

Building Materials

The insulation values and thermal properties of construction materials affect heat transfer rates.

Infiltration Factors

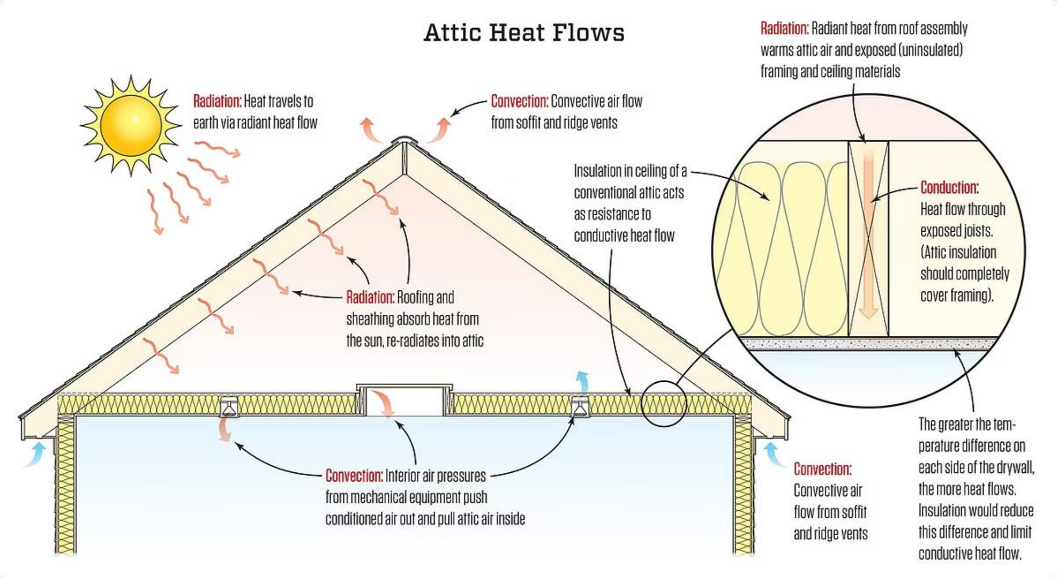
Air leakage through cracks, gaps, and openings in the building envelope contributes to heat loss.

Occupancy

The number of building occupants and their activities generate internal heat gains.

Equipment Capacity

The capacity of heating and cooling equipment being used must match the building's requirements.



The calculation of heat loss and gain, and requirements for heat transfer in various types of buildings are discussed in detail in Unit 24 Air handling.

Furnace Replacement Considerations

The gas technician/fitter is usually required to change the furnace currently in operation in a building rather than redesign a whole system. This could involve replacing an electric furnace with a gas furnace, an oil burning furnace with a gas furnace, or an older gas furnace with a more efficient furnace.

Heat Loss Calculation

Before replacing an electric furnace, an oil-fired furnace, or an older gas-fired furnace with a higher efficiency gas furnace, a heat loss calculation must be done.

Building Upgrades

This is important, as the old furnace might not have been sized properly, or the home may have been upgraded after the furnace was installed.

Code Compliance

The heat loss calculations must be completed in accordance with the relevant codes and standards using acceptable methods of practice as recognized by the authority having jurisdiction.

Venting Considerations for Furnace Replacement

When updating to a more efficient furnace the gas technician/fitter needs to evaluate the other gas-fired appliances that may be dependent on the existing furnace system for venting.

Orphaned Appliances

These can include B-vented hot water tanks and other equipment related to the home HVAC system.

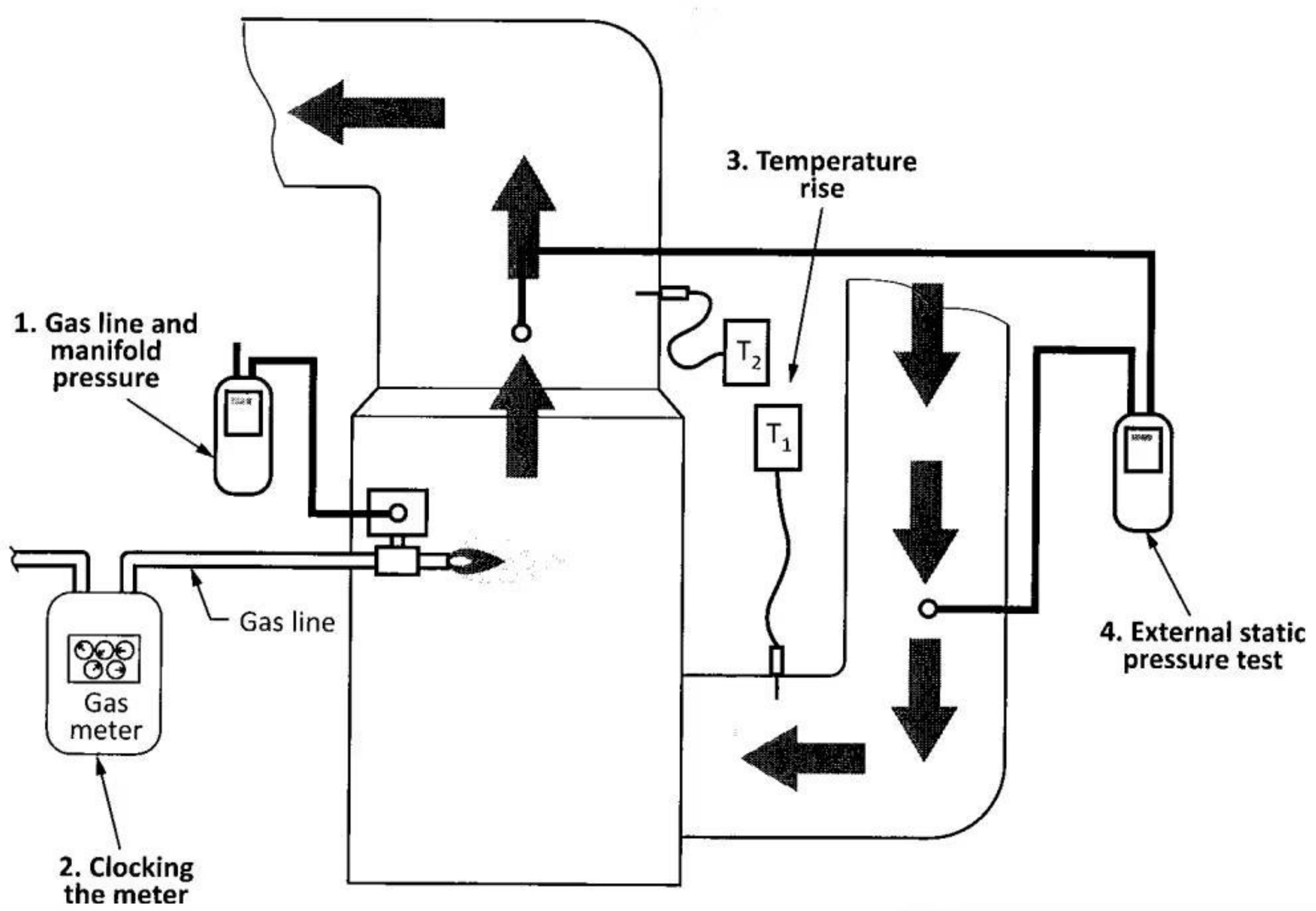
Vent Evaluation

A B-vented hot water tank vent that is combined with a furnace vent must be evaluated after the new furnace is installed to determine whether venting changes are required.

Resizing Requirements

After checking the size of the vent, it may be determined that the existing old common vent is oversized and will need to be resized, typically by installing a liner system.

Start-up and Commissioning a Furnace



Component Inspection

Inspection of individual system components to ensure proper installation.

Performance Testing

Check manifold gas pressure, firing rate, and temperature rise to confirm they meet manufacturer's specifications.

System Adjustments

Make necessary adjustments to blower speed, external static pressure, and other parameters to optimize performance.

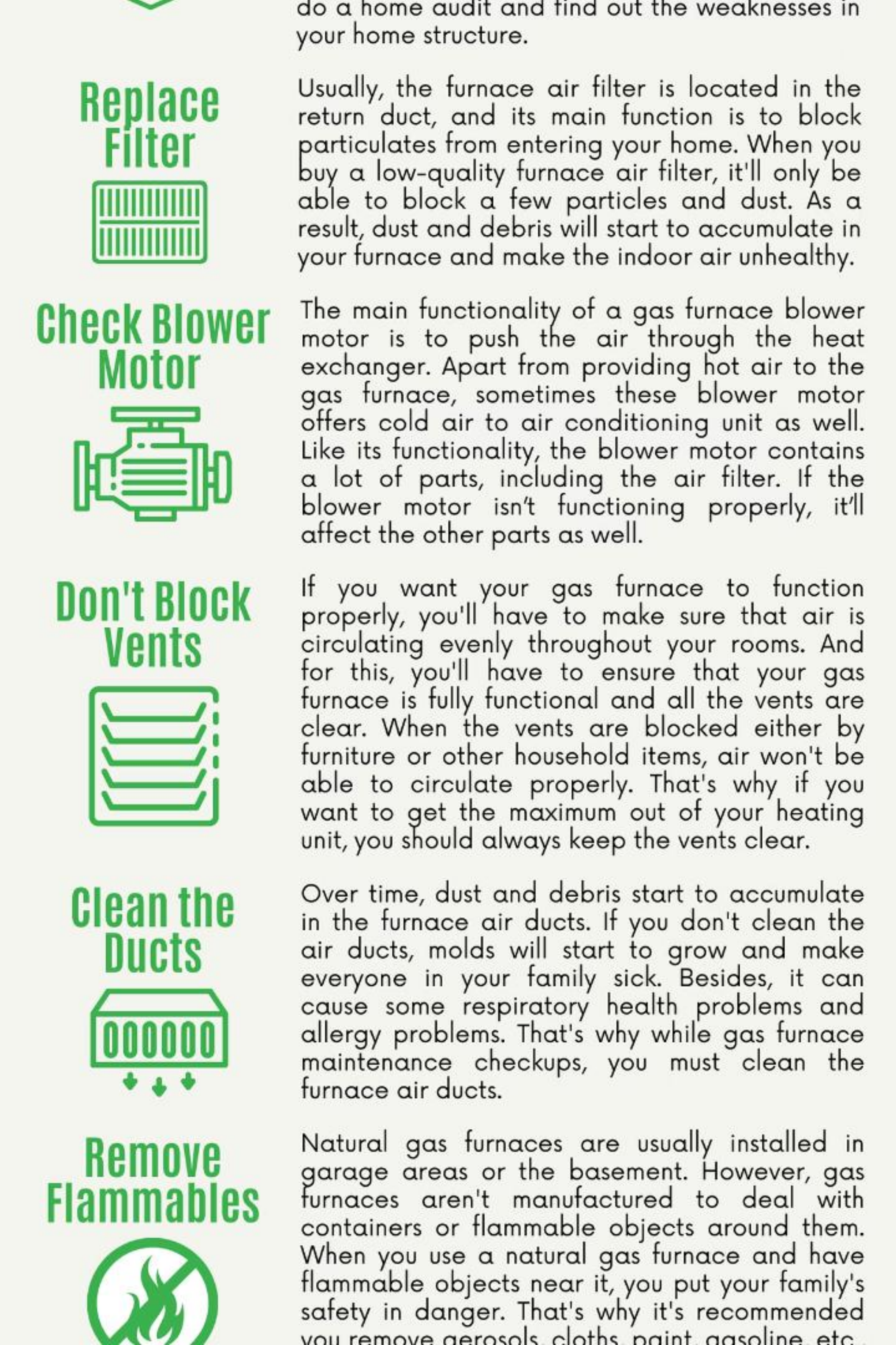
Thermostat Programming

Set-up and program the thermostat to achieve optimal furnace operation and customer comfort.

CSA Unit 19

Chapter 2
Servicing of Mechanical Components

The gas technician/fitter must be familiar with the components of the furnace and the way in which it operates. Regular maintenance procedures must be understood and followed to ensure safe operation of the furnace. The use of diagnostic equipment to check mechanical components must be understood since repair of the furnace is frequently the responsibility of the gas technician/fitter.



Objectives

Describe Major Components

Understand the major components of a forced-air furnace

Understand Diagnostic Equipment

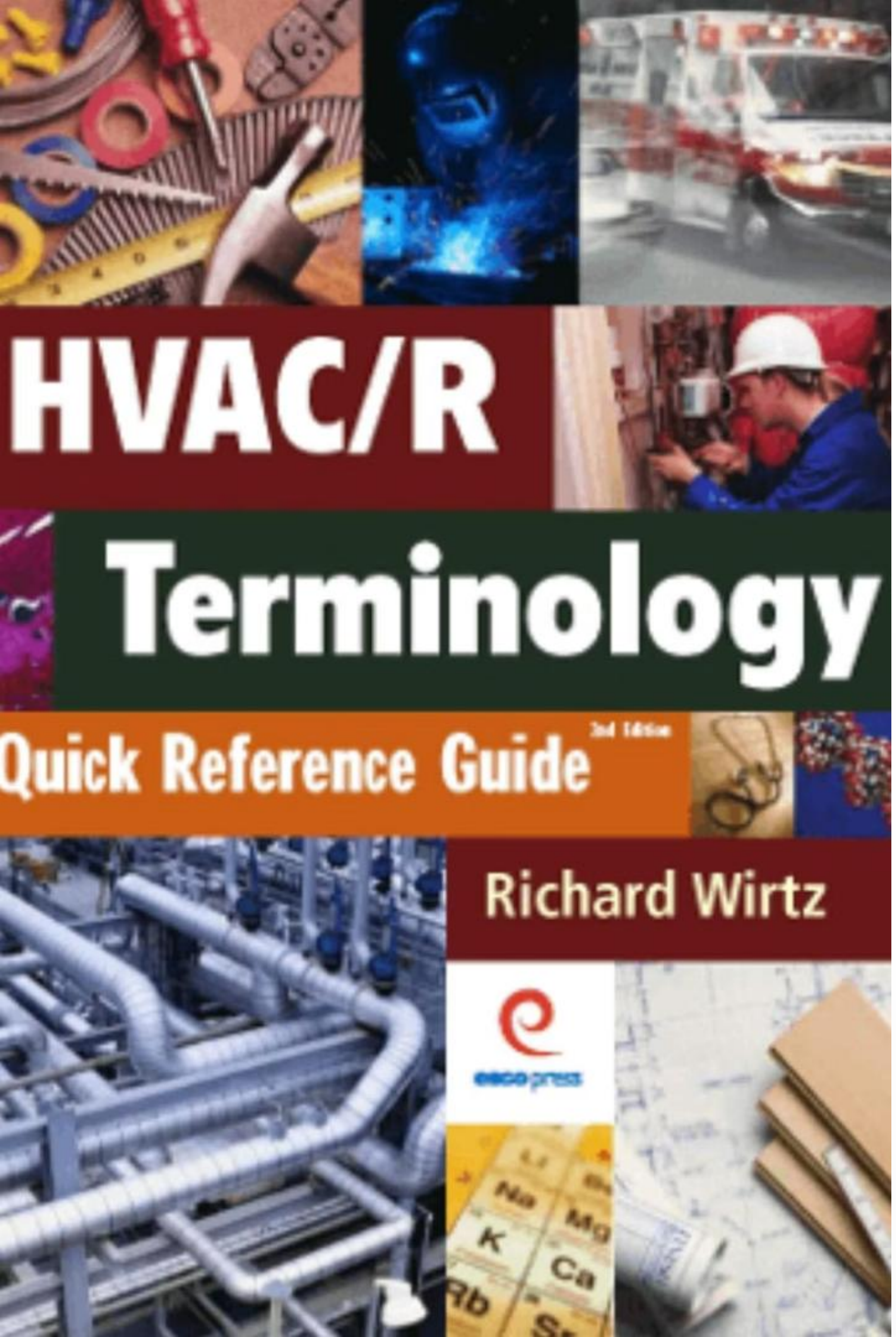
Describe the operation of diagnostic equipment used in troubleshooting forced-air furnaces

Cleaning and Adjustment

Describe cleaning and adjustment procedures for major furnace components

Component Checking

Describe procedures for checking mechanical components



Key Terminology

Term	Abbreviation (Symbol)	Definition
Heat exchanger		Any device that transfers energy from one substance to another without allowing the two substances to mix
Return air		Air drawn into the furnace, heated and then supplied by ducts to those areas requiring heating
Squirrel cage		The blower (or fan) inside the furnace that moves air through the furnace and across the heat exchanger to the building

Diagnostic Equipment Overview

An annual inspection and service is recommended for furnaces. This generally occurs prior to the start of the heating season. To properly service a gas-fired, forced-air furnace, the gas technician/fitter needs to have access to several diagnostic and test tools.

Common Diagnostic Equipment

- Draft gauge
- Manometers (U-tube, inclined, electronic)
- Combustion analyzers
- Thermometers
- Digital multimeters

Diaphragm Draft Gauge

Figure 2-1
Draft gauge
Image courtesy of Terry Bell.

The draft gauge is used to determine the flue draft. This test is done to ensure that the furnace is venting properly. Drafts should be checked after the burner has been operating for a long enough time that the flue temperature has reached a normal operating temperature.

1 Operation Steps

Check the draft gauge for free needle movement

2 Placement

Place the draft gauge on a level surface

3 Calibration

Adjust the draft gauge to zero

Draft Gauge Maintenance

Maintenance Guidelines

- Do not oil the gauge
- Protect the gauge from shock, vibration, and exposure to excessively high temperatures

Important Notes

- There are different types of draft gauges, but they all operate in the same manner
- The draft tube can become very hot after testing, so it should be handled carefully

U-Tube Manometer

Purpose

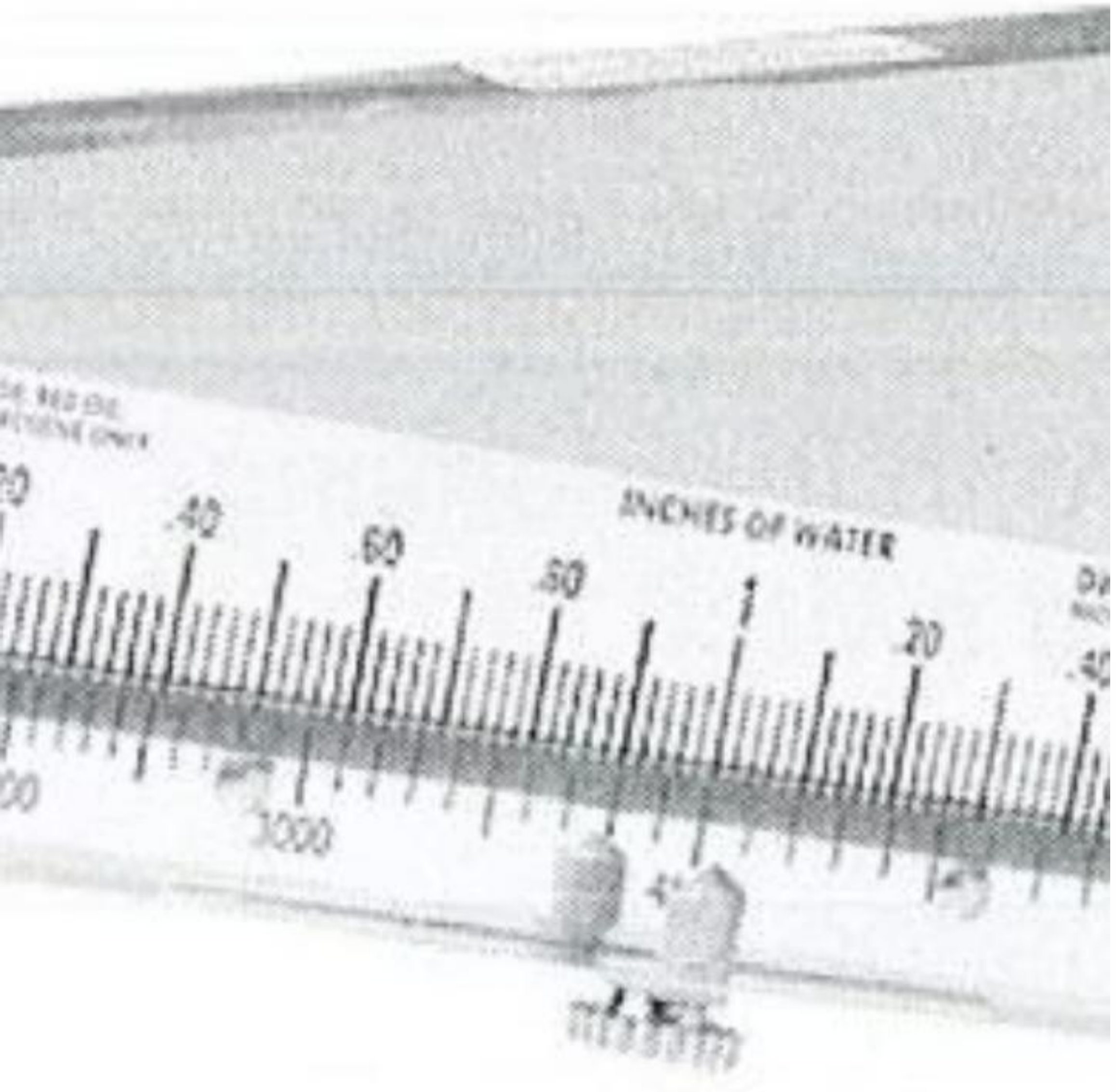
The "U" tube manometer is used to measure the pressure in the gas piping and burner manifold, or static pressure in the duct.

Static pressure drop in the duct reduces the pressure and volume of the air as it moves along the duct.

Measurement Method

The pressure is measured by drilling a small hole in the side of the duct and inserting the tube from one side of the manometer.

For detailed operation information, refer to Unit 2 Fasteners, tools, and testing instruments.



Inclined Manometer

An inclined manometer is also used to measure the static pressure in a duct. It is more accurate than a "U" tube manometer, as a small change in pressure is easier to measure on the incline manometer because it is used in a semi-horizontal position (incline) and requires less pressure to influence the fluid change.

Measurement Applications

Duct pressure to ensure correct conditions or identify faults

Air Flow Measurement

Air flow directly (with pitot tube)

Blower Pressure

Pressure produced by a draft inducer blower

When to Use an Inclined Manometer

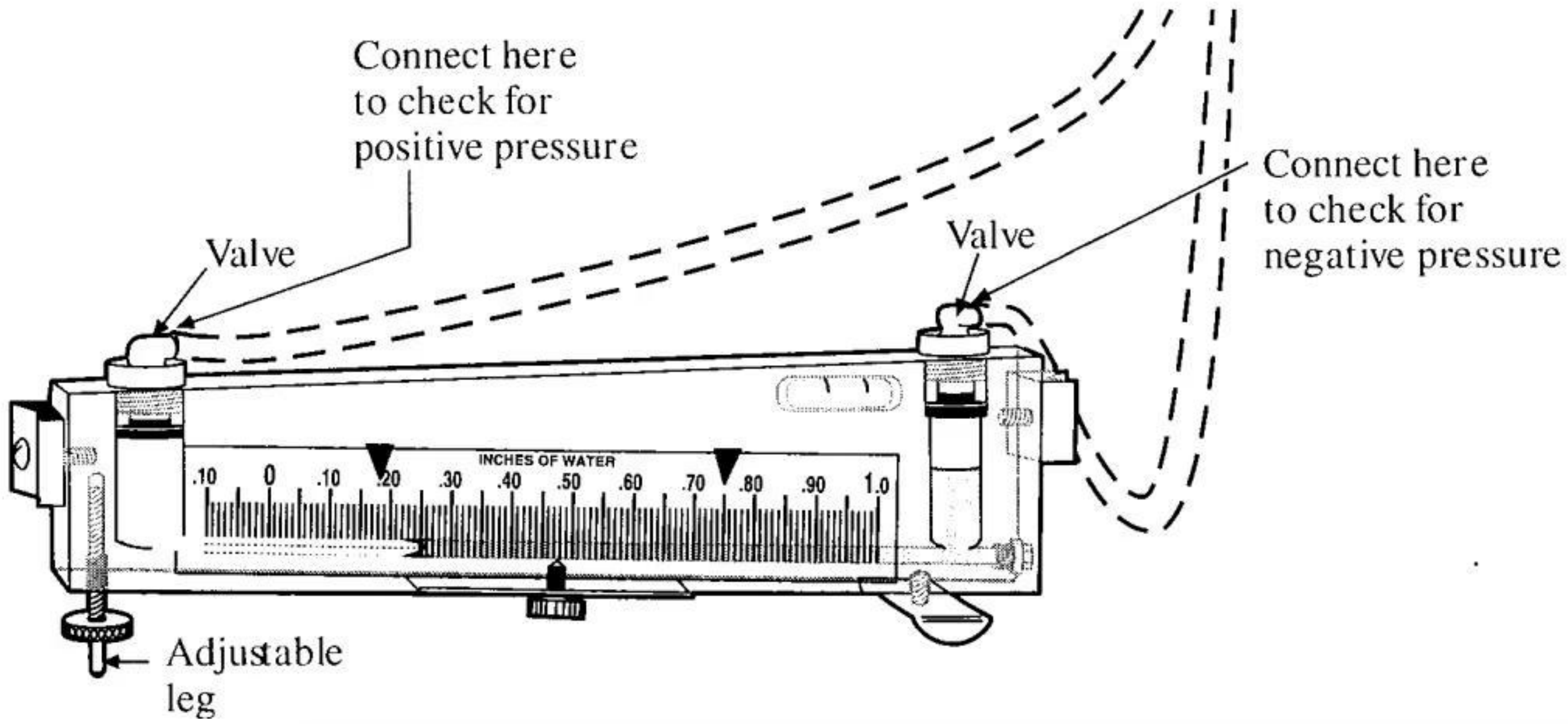
Installation Scenarios

- After installing a furnace or add-on air conditioning
- When troubleshooting a duct system for cause of insufficient air flow

Testing Scenarios

- When using a pitot tube to test air flow in a system or system part
- When a furnace pressure switch fails to close when the induced draft blower is running

Inclined Manometer Tests



To test	Then	Reading
An air conditioning coil for dirt on fins	Test the difference between the inlet and outlet of the coil.	A reading greater than 0.10 inch w.c. indicates a blocked coil (also check the manufacturer's specifications).
For a supply air restriction	Test the pressure downstream of the air conditioning coil and a second point downstream in the supply duct.	A reading greater than 0.15 inch w.c. indicates a restriction in the supply air system.
For a restriction in the return air system	Test the pressure upstream of the furnace and a second point upstream in the return duct.	A reading greater than 0.10 inch w.c. indicates a restriction.
Air flow using a pitot tube	The differential pressure is measured across the two parts of the pitot tube.	The reading is located on a table to determine air velocity. Once the area of the duct at that point is determined, the air flow can be calculated by multiplying the velocity times the duct area [i.e., velocity (ft/min) x area (ft^2) = ft^3/min(cfm)].

Inclined Manometer Operation

Prepare the Instrument

Open both the valves on top of the instrument at least one turn

Level the Manometer

Place the manometer on a flat surface and adjust the legs so that it is level

Calibrate to Zero

Slide the scale so that the zero mark is in line with the top of the oil column

Connect Hoses

Attach one end of each hose to each of the two valves on top of the instrument

Take Readings

Take the readings on the scale in line with the meniscus (curved upper surface of liquid column)

Finish

After taking the readings, remove the hoses and close the valves to avoid fluid loss

Electronic Manometer

Digital manometer
Courtesy of Camosun College, John Gordon

Features

Electronic (or digital) manometers read both positive and negative pressures in inches of water column as well as a variety of other scales (Pascals, millibars, inches, or mercury and pounds per square inch).

Advantages

- Can accurately measure relatively higher pressures found in residential gas piping
- Can measure low pressures in a venting system
- Smaller and more portable
- Can be used in any position (no need for levelling)
- Do not require fluid that can freeze or spill out

They are not good for measuring rapidly fluctuating pressures like what may happen in some appliance venting systems and during troubleshooting. A true non-electric monometer is the most accurate and useful to use during initial activations and troubleshooting of all appliances.

Combustion Analyzers

There are several types of combustion analyzers. These are identified in Unit 2 Fasteners, tools, and testing instruments. The image shows an electronic flue gas analyzer.

Measurement Parameters

- Carbon dioxide (CO_2) percentage
- Oxygen (O_2) percentage
- Flue gas temperature
- Carbon monoxide (CO) levels

When to Test for CO

- When a customer complains of headaches, nausea, vomiting, dimness of vision, disorientation, or other signs of CO poisoning
- When CO is suspected due to visual appearance of the flame or smell of aldehydes during firing
- When indicated by the history of a particular type or line of equipment
- Whenever a conversion burner is installed, inspected, or has its settings modified

CO Safety Protocols

Recognize Danger

If a customer is showing any signs of CO poisoning

Shut Down

Shut down the furnace immediately

Evacuate

Safely remove everyone from the building including yourself

Call for Help

Contact medical and emergency services

Ventilate

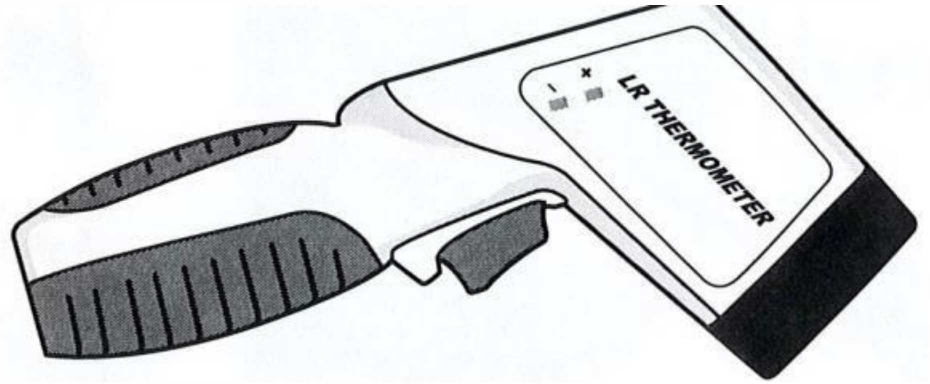
Ventilate the building thoroughly

Analyze

Conduct a complete analysis of the flue products and supply air

CAUTION! A high CO level can be fatal. Shut down the burner if the test level is high, and then determine the fault.

Thermometers



Importance

An accurate thermometer is an essential tool for any troubleshooting. By measuring air and system temperatures, the gas technician/fitter has a good indication if there is a problem with a furnace.

The thermometer is used to test for flue efficiency. The heat loss to the atmosphere can be determined with the measured flue gas temperature combined with the result of a combustion analysis.

Digital Infrared Thermometers

Digital infrared thermometers provide fast, accurate, and easy temperature readings even from a distance. These units can be helpful reading duct temperatures on ducts that are located out of reach.

The temperature readings from an infrared thermometer are very unreliable and must never be used to determine proper operating parameters of an appliance or venting system.

Thermometers should be utilized to confirm temperature rise across a furnace, check limit settings during safety checks, and assist with duct balancing.

Digital Multimeters (DMMs)

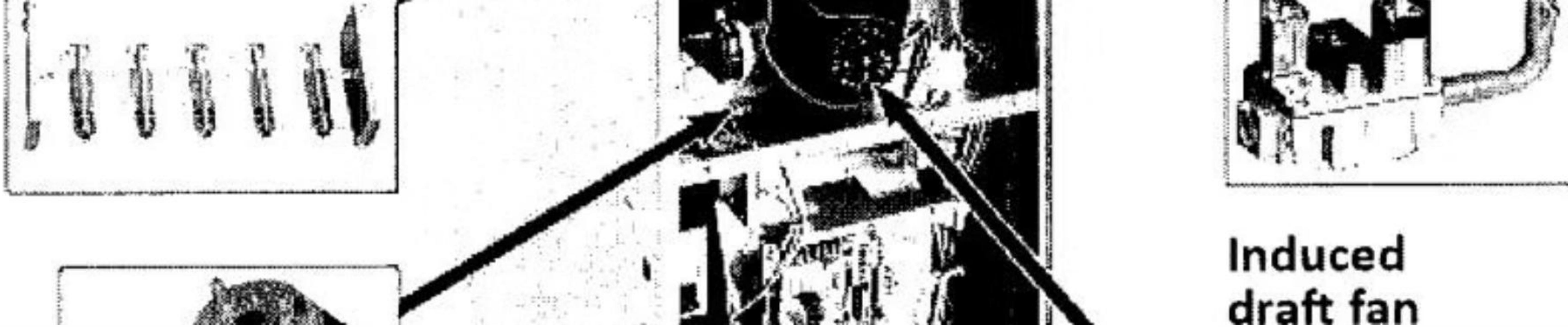
Functionality

DMMs (digital multimeters) combine the features of an ammeter, a voltmeter, and an ohmmeter into one unit. Most models also have an option to measure temperature using a thermocouple.

Applications

The gas technician/fitter will need to use a DMM during the annual service to:

- Verify electrical voltages
- Test the flame rectification system in appliances incorporating electronic ignition systems
- Check continuity of safety circuits
- Measure resistance of components



Furnace Components Overview

To properly service a gas-fired, forced-air furnace, the gas technician/fitter needs to know the purpose and operating principles of the furnace's major components and how to service them. The image shows the major components of a furnace.

Since the components that make up the furnace appliance are covered in detail in other units, the content below only covers the maintenance and service of these components. Since the components of a low-efficiency furnace are much different than the components of a high-efficiency appliance, some clarification will be included in the description of each item.

Furnace Operation Sequence

Call for Heat

Call for heat from a thermostat or sensor

Circuit Board Activation

The circuit board is energized

Safety Check

Safety check is initiated (limit switches, roll out switches)

Induced Draft Fan

Induced draft fan comes on

Pressure Switch

Pressure switch closes to confirm induced draft fan is operating

Ignition

Direct spark ignition begins to spark

Gas Valve

Gas valve opens

Combustion

Gas is ignited at burners

Flame Sensing

Flame sensor senses flame

Air Circulation

Blower motor comes on after preset time moving return air across the heat exchanger

Cycle Completion

Furnace runs until the call for heat is satisfied

General Furnace Service Checklist

Safety Components

- Safety limit controls
- Temperature set points
- Pressure switches and vent blower
- Flame rollout/temperature switches

Operational Components

- Operation of thermostat
- Blower assembly and motor bearings
- Burners
- Gas valve
- Automatic vent dampers

System Performance

- Venting system and termination
- Flame rectification
- Combustion analysis
- Temperature difference between supply and return plenums
- Manifold gas pressure
- Input

Safety Limit Controls

High-Limit Control

The high-limit control can be an electro-mechanical fan/limit control (older furnaces) or a temperature snap-disc (modern furnace) and is usually located on the partition panel of the appliance.

The high-limit monitors the heat exchanger compartment temperature and is a normally closed, automatic reset, temperature-activated switch. The high limit guards against overheating as a result of insufficient air passing over the heat exchanger.

Flame Rollout/Temperature Switches

These switches protect the burner area from unusually high temperatures. These switches are located in the burner compartment and are wired in series with the control circuit of the gas furnace.

When an excessive high temperature (usually above 200°F [93°C]) occurs in the burner area, the switch opens to shut down the control circuit.

Testing the High-Limit Control

Disconnect Fan

Disconnect power supply to the fan motor at the fan switch or control module

Call for Heat

Set the thermostat to call for heat

Observe Burner

The burner should come on and then turn off in a very short period of time

Check Temperature

Insert a thermometer into the supply plenum to verify temperature does not exceed requirements

Verify Switch Operation

Use a voltmeter to ensure that the high-limit has opened its contacts

If the burner does not turn off as expected, shut off the power to the furnace. Failure to shut down the system can damage the heat exchanger by overheating.

Testing Flame Rollout Switches

Power Off

Disconnect power to the furnace

Access Switch

Locate the flame rollout switch in the burner compartment

Disconnect Wires

Remove the wires from the switch terminals

Measure Resistance

Use a DMM to measure for resistance between the two switch terminals

Interpret Results

If you measure no resistance, the switch is closed and does not need to be replaced. If you measure any amount of resistance, the switch is faulty and must be replaced.

Reset if Needed

If the switch is open and has a reset option, reset the switch by depressing the reset button

If a switch has opened, determine the cause and make all necessary repairs or adjustments.

Temperature Setpoints

Older Furnaces

Older furnaces (low-efficiency and mid-efficiency) may have a combination high-limit/fan control that contains a normally open fan switch on the left side and a normally closed high-limit switch on the right side.

Located on the front dial of the combination high-limit/fan control are a temperature scale and three adjustable tabs:

- Fan-off setpoint: Temperature that the fan switch opens and de-energizes the fan motor
- Fan-on setpoint: Temperature at which the fan switch closes its contacts and energizes the fan motor
- High-limit setpoint: Temperature that the high-limit opens its contacts

Newer Furnaces

Newer furnaces utilize an integrated control module. These furnaces do not have a temperature adjustment function.

They use time-actuated fan switches that are built into the control module. The control module may or may not have an adjustable fan-on time.

The choice of settings is dependent on comfort or economy:

- Fan on sooner/off later: Most heat distributed but may circulate cooler air
- Fan on later/off sooner: Warmer air circulated but less economical

Thermostat Maintenance

Older Electro-Mechanical Thermostats

- Clean bimetal strips and contacts using air or a small brush
- Ensure terminal screws are tight
- Verify proper seasonal setting (heating or cooling)
- Check that mercury switch thermostats are level
- Handle mercury thermostats carefully to avoid breaking glass bulb
- Properly recycle devices containing mercury

Modern Electronic Thermostats

- Check battery strength and replace if necessary
- Ensure terminal connections are secure
- Verify proper seasonal setting (heating or cooling)
- Check programming if applicable
- Clean display and housing as needed

The HRAI thermostat recovery program has information on mercury switch thermostats for proper disposal.

Blower Motor Lubrication

Direct Drive Motors

Every forced-air furnace has a blower motor attached to a fan that circulates the air. Newer model direct drive motors have the motor attached directly to the fan blower.

Many, but not all, direct drive motors have sealed bearings and require no lubrication. Check manufacturer specifications to determine if lubrication is needed.

Belt Drive Motors

Older belt-drive style motors typically require regular maintenance.

Virtually all belt drive fan motors must be lubricated. Use 2 to 3 drops of SAE 20W oil (non-detergent) annually if the blower motor requires lubrication.

Older belt-drive systems may use bearings with grease ports for the squirrel cage shaft. These bearings require a small amount of grease annually.

Blower Assembly Cleaning

Preparation

De-energize the furnace completely before beginning inspection or cleaning

Inspection

Inspect the blades of the squirrel cage for dust and debris build-up

Removal

If cleaning is needed, remove the bolts or nuts holding the blower assembly in place, disconnect the motor wiring, and slide the blower assembly out of the furnace

Cleaning

Use a moist rag or vacuum to remove dust and dirt from the air scoops or vanes of the blower wheel

Deep Cleaning

If excessively dirty, remove from the unit and thoroughly wash using a high-pressure hose (remove the motor first)

Reassembly

Make sure all components are completely dry before reassembly and operation

The fan and motor should be cleaned at least annually. Check the fan motor amperage against the amperage on the rating plate. Excessive amperage could mean that the motor is dirty or that the bearings are worn.

Blower Speed and Operation

Modern Furnaces

Modern furnaces have a circuit board with fan connection terminals. The circuit board will be designed for either:

- PSC multi-speed fan motor: Connected to the appropriate terminal depending on the fan speed required for heating, cooling, and possibly continuous operation
- ECM variable speed fan motor: Programmed through the control board for different operating modes

Any speeds that are not required are connected to the terminals marked "Unused" or "Park".

Belt Drive Blowers

The speed on older belt drive blowers can only be adjusted by changing one of the sheave sizes:

- Making the drive sheave larger would increase the rotations per minute (RPMs)
- Making the driven sheave bigger would decrease the RPMs

The belt also needs to be checked for wear and adjustment. The belt should be tight enough that it does not slip, but not overly tight that it causes stress on the motor bearings.

Pressure Switches and Vent Blower

Pressure Switch Function

Pressure switches sense pressure created by the operation of the inducer fan and are usually normally open (other than high pressure switches), single-throw switches.

Depending on which side of the inducer fan that they sense, they can be either closed by positive pressure or a vacuum.

These switches guard against insufficient airflow (combustion air and flue products) through the heat exchanger and/or blocked condensate drain conditions.

Common Issues

A problem with a pressure switch could be caused by:

- Faulty switch
- Problem with the inducer fan
- Plugged hoses
- Lack of differential across the inducer fan (loose on shaft or damaged)
- Condensate in the housing

Confirm the switch is in good condition using a DMM and then inspect the inducer fan housing and the blower assembly to ensure they are in good condition.

Burner Inspection and Cleaning

Pilot Adjustment

If equipped with a pilot, the flame should surround 3/8 inches to 1/2 inches of the flame rod, thermocouple or thermopile

Main Burner Check

Allow the furnace to run for approximately 10 minutes then inspect the main burner flames

Flame Inspection

Check for stable, quiet, soft blue flames without solid yellow tips

Cleaning Process

If needed, remove burners, tap lightly to dislodge dirt, and vacuum the burner ports

Surface Cleaning

Clean lint from burner surface (a venturi brush can be used)

It should not be necessary to clean the burners more than once a year (this always depends on site conditions). If burners are found in poor condition, check and correct the cause and/or recommend a more frequent cleaning.

Venting System Inspection

Draft Hood Inspection

Spillage from an appliance equipped with a draft hood is a major concern for a gas technician/fitter.

Check for signs of discoloration, moisture, and over-heating near the draft hood as indications that spillage has occurred.

Vent Material Inspection

- B-vented systems: Look for corrosion and signs of moisture
- Plastic vented systems: Look for stress cracking, distortion, discoloration, and melting

Any deterioration of the venting system could result in a CO safety hazard in homes, causing personal injury to the occupants.

Non-S636 plastic venting may be present on existing appliances but, depending on the authority having jurisdiction (AHJ), may not require action until replacement of the appliance. The AHJ may have a process for testing the existing system to ensure the integrity of the pipe and fittings.

Flame Rectification Testing

How It Works

Flame rectification is a method of flame sensing whereby the flame sensor (flame rod or element) is located in the pilot or burner flame and a current applied to the sensor flows through the flame to the pilot assembly or the burner head and then to ground.

Dirt, corrosion, or bad connections in the flame sensing circuit can cause the controller to think the flame did not ignite, causing it to shut down the gas valve prematurely.

Testing Procedure

A gas technician/fitter can measure the current through the flame rod by connecting an ammeter in series with the flame rod.

The expected results from this test would be in the range of 2-5 micro-amps DC so the test equipment (ammeter) must be capable of measuring this low range of micro-amps DC.

Before connecting any meter to the flame sensing circuit, determine first if the system uses a separate flame rod or uses a combination igniter/sensing rod.

Hot Surface Ignition Systems

Separate Flame Rod Systems

Hot surface ignition systems typically have the flame rod separated from the hot surface igniter.

These can be tested with a microammeter to measure flame current.

Combination Systems

Some systems use the same hot surface igniter for sensing and ignition.

Many amps go through the hot surface igniter during the ignition cycle, so the flame sensing current cannot be checked until after the hot surface igniter has switched over to perform the function of a flame sensing rod.

In practice, very few meters can conduct both very high and very low currents without mechanical switches.

In this case the hot surface igniter is usually only tested for resistance when it is cold and the furnace is not firing.

Consult the manufacturer's literature for the appropriate ohm reading when testing hot surface igniters.

Combustion Analysis

When working on gas appliances, it is imperative to perform a combustion analysis during routine service or any time changes are made that will affect the combustion process.

Safety Verification

Verify the safety of the appliance prior to and after service

Efficiency Determination

Determine the combustion efficiency of the appliance

Conformance Verification

Verify that the operation of the furnace is within the conformance requirements of the manufacturer's guidelines

A combustion analysis should be measured before any draft control devices where the stack temperature and the CO_2 are at the highest level and the O_2 is at its lowest level.

Combustion Analysis Parameters

O_2 Percentage

Measures oxygen content in flue gases

CO_2 Percentage

Indicates combustion efficiency

Stack Temperature

Helps determine heat loss through flue

Draft Measurement

Ensures proper venting

CO Parts Per Million

Critical safety parameter

Net Temperature

Differential of flue temperature minus ambient temperature

Excess Air Percentage

Indicates air-fuel ratio

Efficiency Calculation

Overall combustion efficiency

Expected Combustion Analysis Results

	Atmospheric draft appliance	Induced draft appliance	Condensing appliance (90%+)	Power burner
O_2	4% - 9%	7% - 9%	5% - 7%	3% - 6%
CO_2	6.5% - 8%	6.5% - 8%	7% - 8.5%	8.5% - 11%
Stack temp.	163°C - 204°C (325°F - 400°F)	163°C - 204°C (325°F - 400°F)	<52°C (125°F)	160°C - 299°C (320°F - 570°F)
Draft	-0.02 w.c. - 0.04 inch w.c.	-0.02 w.c. - 0.04 inch w.c.	As per manufacturer's specifications	As per manufacturer's specifications
CO	< 50 ppm air-free	< 50 ppm air-free	< 50 ppm air-free	< 100 ppm air-free

Depending on the type of furnace, a certain amount of heat must go out of the flue to prevent the gases from condensing. With high-efficiency furnaces, condensing is desirable because of the additional heat extracted from the flue gases. Stack temperature is used to determine an appliance's efficiency.

Temperature Rise Measurement

Procedure

The manufacturer's temperature rise range can be found on the rating plate.

Determine the temperature rise by subtracting the return air temperature from the supply air temperature.

A blower speed must be selected that will provide a temperature rise through the furnace that is within the limits specified by the manufacturer without exceeding the maximum external static pressure (ESP).

Calculation

The required CFM for a particular temperature rise can be calculated based on the following formula:

CFM = (Btu/h output) ÷ (1.08 × temperature rise)

The constant 1.08 is derived from the fact that it takes 0.018 Btu's to raise 1 ft^3 of air by 1°F times 60 minute in 1 hour.

Gas Piping Inspection

Inspection Methods

All gas piping fittings and connections should be checked by an approved method such as:

- Combustible gas leak detector
- Chloride-free soap and water
- Equivalent non-flammable solution

Action Required

Repair or replace any part(s) of the system that may be found defective.

Ensure all connections are tight and properly sealed.

Verify proper gas pressure at the appliance.

Air Filter Maintenance

Procedure

Remove the air filter and clean or replace it as required.

When replacing filters, consult the manufacturer's literature as some high-efficiency filters have a high pressure drop which could be beyond the limitations of the manufacturer.

Important Considerations

Many furnace manufacturers have a filter chart in their literature that will specify the size and type of filter required.

Some furnaces may contain more than one filter.

Using the wrong filter type can restrict airflow and cause system problems.

Gas Valve Conversion

Orifice Replacement

The orifices at the burners need to be resized based on which fuel will be used

Pilot Adjustment

If the furnace ignition system includes a pilot, the orifice in this assembly needs to be changed as well

Pressure Adjustment

The manufacturer will include a method to change the combination gas valve outlet pressure (manifold pressure)

Spring Replacement

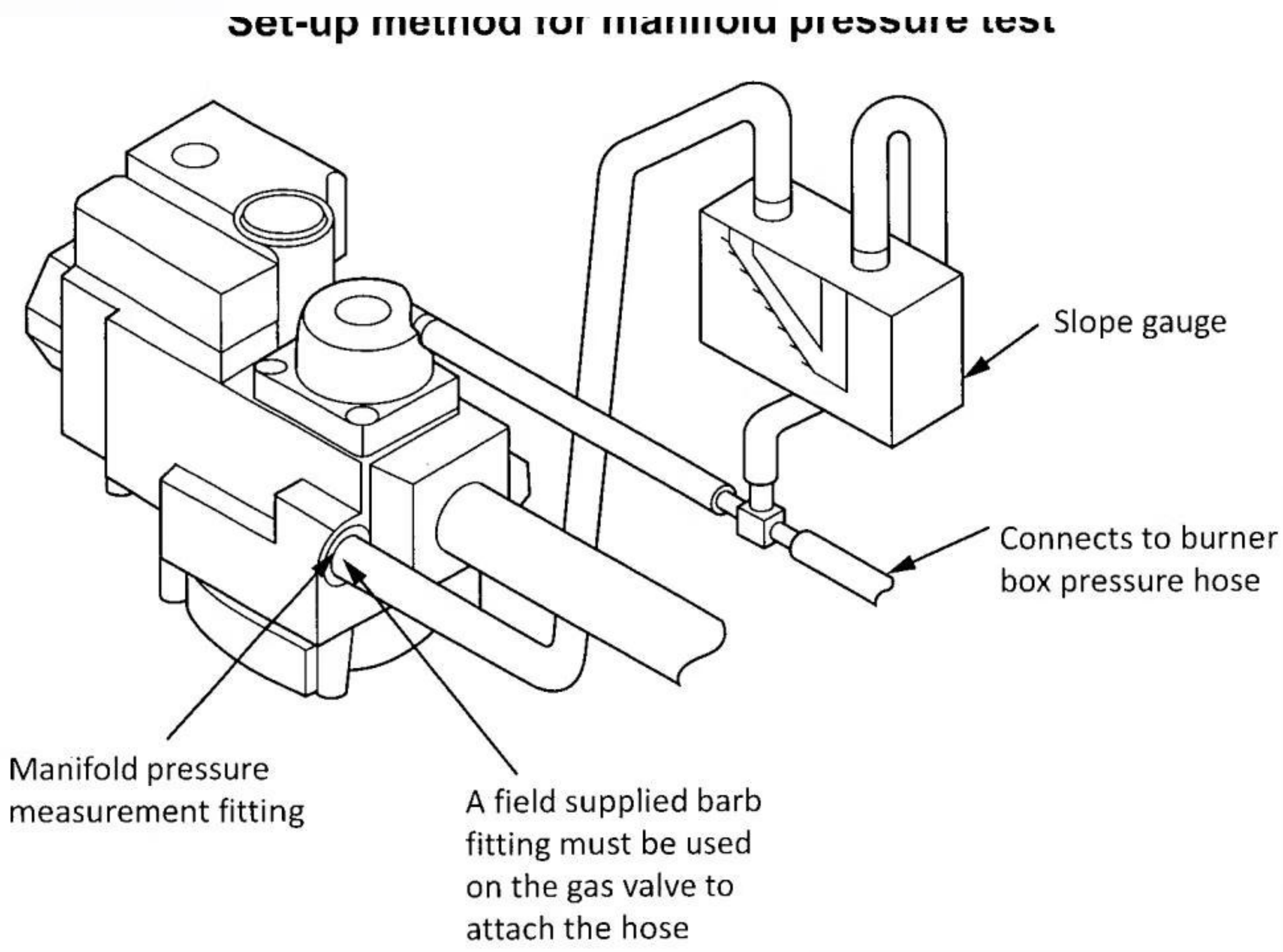
This is usually as simple as replacing a spring in the servo-regulator

Verification

Once the conversion has been completed, check the input rate and temperature rise to ensure the furnace is operating within the design parameters

Propane orifices are smaller than natural gas orifices and, if not supplied by the manufacturer, can be sized using Table 1.3 of CSA B149.1.

Manifold Gas Pressure Check



Power Off

Make sure that the power is off

Gas Supply Off

Turn off the gas supply at the furnace

Access Pressure Tap

Remove the plug from the gas valve outlet pressure tap (manifold pressure tap)

Combustion Air Supply

Direct-Vent Sealed-Combustion Appliances

Modern direct-vent sealed-combustion appliances take their air directly from outdoors to the combustion chamber and vent directly to the outdoors.

These furnaces must have their air supply and venting sized and installed according to the manufacturer's literature.

Natural Draft Appliances

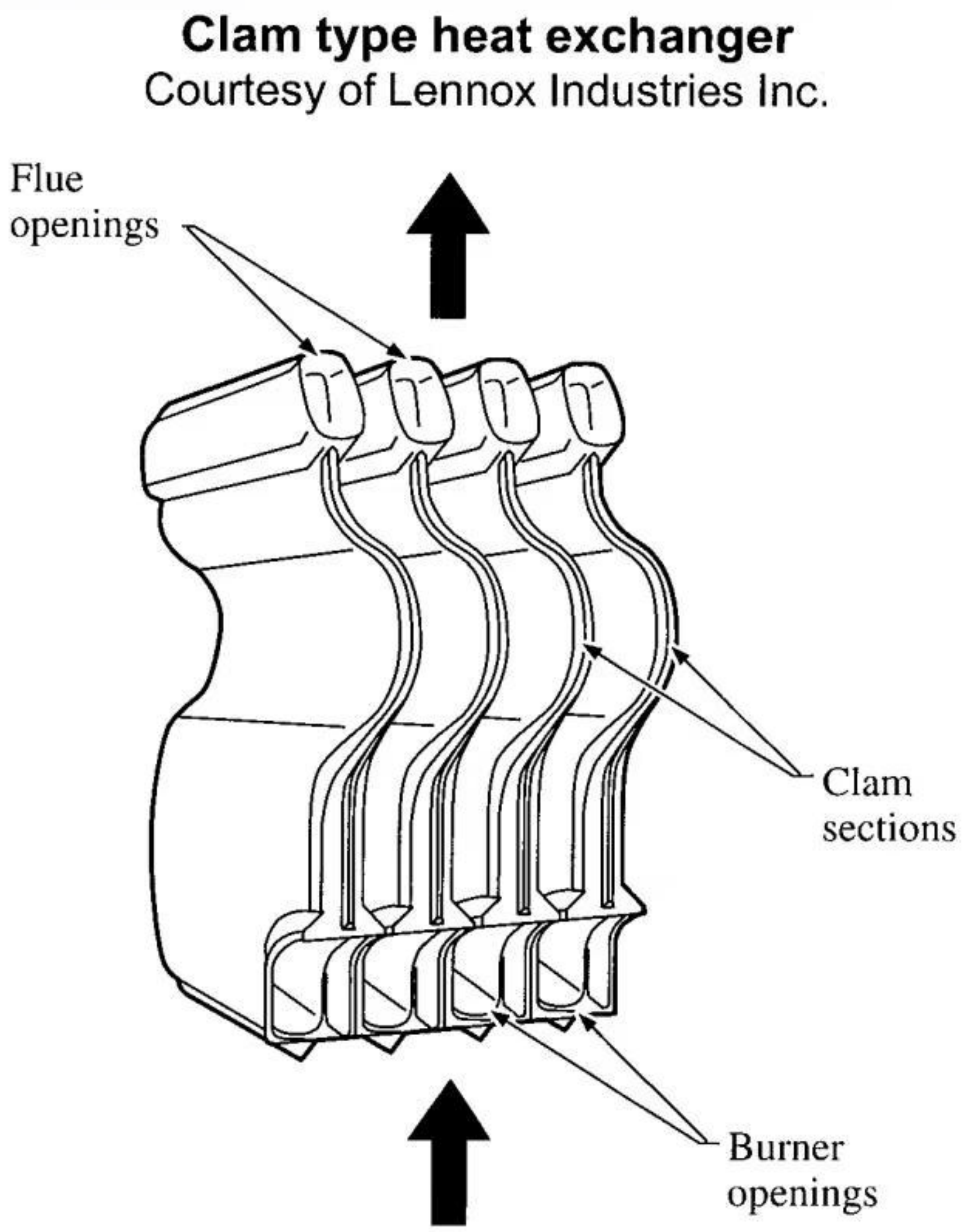
Older natural draft appliances must be supplied with combustion, excess and, if required, dilution air.

This air supply is sized by Clauses 8.2, 8.3, and 8.4 of CSA B149.1.

It may be necessary to check the sizing of a combustion air supply (pipe or duct) of an existing appliance if a combustion analysis indicates concerns with the combustion process.

Combustion air pipes or ducts can become blocked or damaged at any time, so a thorough check of the entire system is required during annual servicing.

Heat Exchanger Overview



A heat exchanger is any device that transfers energy from one substance to another without allowing the two substances to mix.

High-Efficiency Furnace Heat Exchangers

Clam Type Heat Exchanger

Heat Exchanger Design

Design Features

- Each clam has an opening in the bottom for a gas burner
- An opening at the top of the clam allows flue gas to escape
- Multiple clams are joined together to make up the heat exchanger

Construction Benefits

- Curved to protect from damage during expansion and contraction
- Presents more surface area to the supply air
- Does not interfere with airflow during expansion/contraction
- Usually made of stainless steel or aluminized steel
- Often coated with vitreous enamel for corrosion resistance

The heat exchanger must be made of a durable material so that it will not crack. If it cracks, the products of combustion (which can be toxic) will mix with the supply air, causing a dangerous situation in the building.

Heat Exchanger Temperature Rise

Standard Temperature Rise

Most heat exchangers should cause an air temperature rise of between 45°F (25°C) and 100°F (56°C).

Temperature rises on newer high-efficiency furnace models are usually lower than on standard or mid-efficiency units.

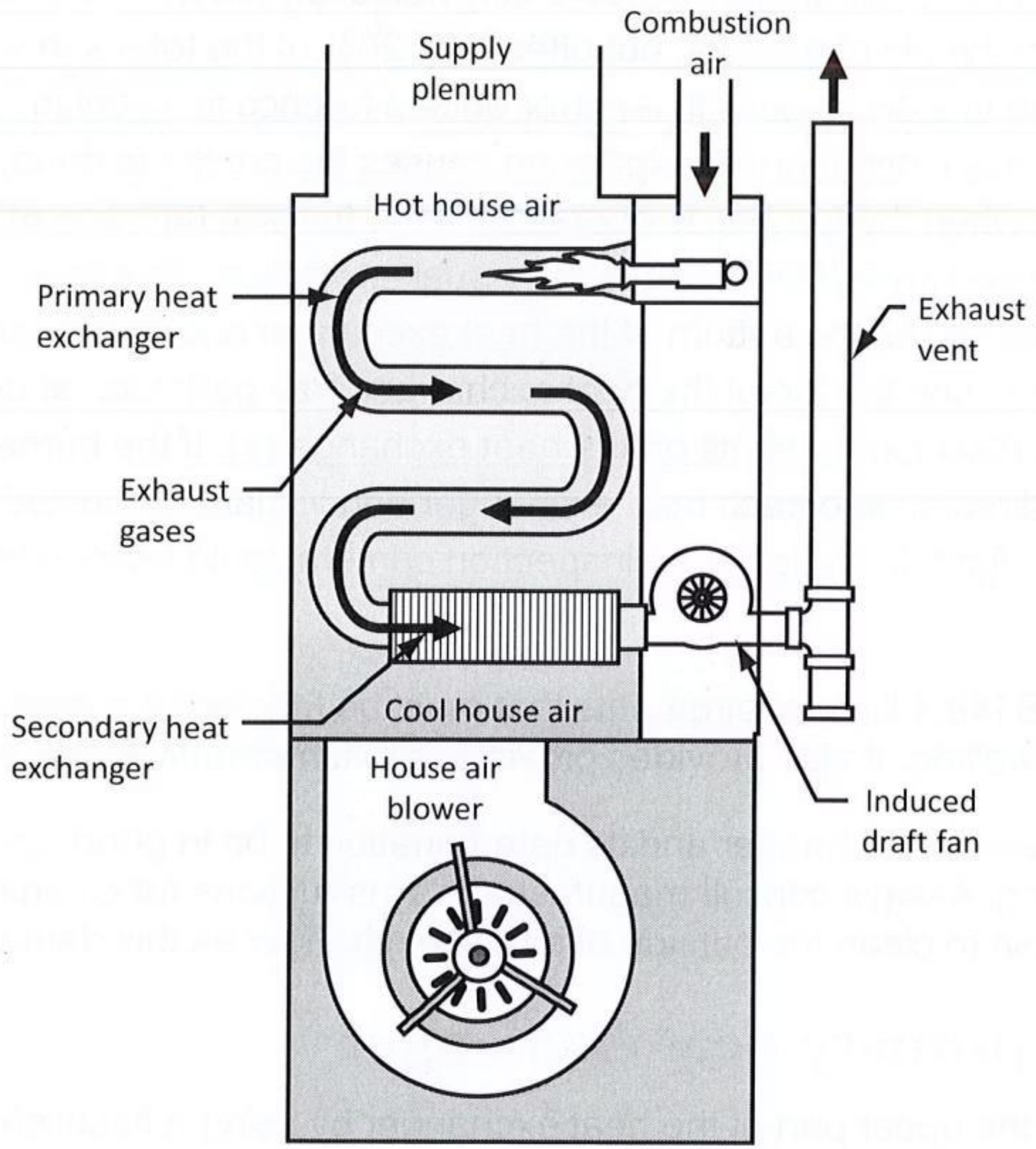
Always check the manufacturer's specifications for temperature rise.

Secondary Heat Exchanger

The secondary heat exchanger is a condensing heat exchanger. It is used to draw off the heat from the combustion products that have been vented from the primary heat exchanger.

In a high-efficiency furnace, the heat that would normally be lost is transferred to the return air, allowing efficiencies greater than 90%.

High-Efficiency Furnace Operation



Primary Combustion

Fuel gas is ignited in the primary heat exchanger, heating it

Flue Gas Transfer

Heat Exchanger Inspection

Flame Disturbance Check

Start the furnace and observe any changes in the flame pattern as the circulating air blower starts operating

CO Level Measurement

Measure CO levels in return air and supply air to check for differences

O_2 Level Measurement

Measure O_2 levels in the vent and observe for significant increases when the circulating fan is energized

Visual Inspection

Look for holes, cracks, or damage, paying particular attention to welds, seams, joints, and discolored spots

Clause 4.21 of CSA B149.1 lists requirements that must be followed if a heat exchanger is found to be defective in a dwelling. It also provides provisions to temporarily repair a heat exchanger.

Primary Heat Exchanger Cleaning

Inspection

Check for dirt in the upper part of the heat exchanger by using a flashlight and a mirror

Vacuum Setup

Attach the exhaust pipe from a vacuum to the flue outlet of the heat exchanger

Dislodge Dirt

Blow any dirt at the top of the exchanger to the bottom burner area

Bottom Cleaning

Use a wire brush to clean the bottom of the heat exchanger and then use a vacuum cleaner to remove all the loose dirt

Exterior Cleaning

Use a soft brush to clean the outside of the heat exchanger

Never use a wire brush to clean the outside of a heat exchanger as this damages the exchanger.

Secondary Heat Exchanger Cleaning

A blocked secondary coil surface may cause the furnace to cycle on and off on the high-limit control and reduce furnace heating effectiveness and efficiency.

Exterior Cleaning

Clean the outside of a secondary heat exchanger using a soft brush

Removal

Remove the heat exchanger from its casing for interior cleaning

Preparation

Plug either the inlet or outlet pipe

Filling

Fill the heat exchanger with hot water and plug the other pipe

Agitation

Shake it vigorously, and then drain the exchanger

Flushing

Finally, flush the exchanger with a hard stream of water

Reassembly and Testing

Reassembly Guidelines

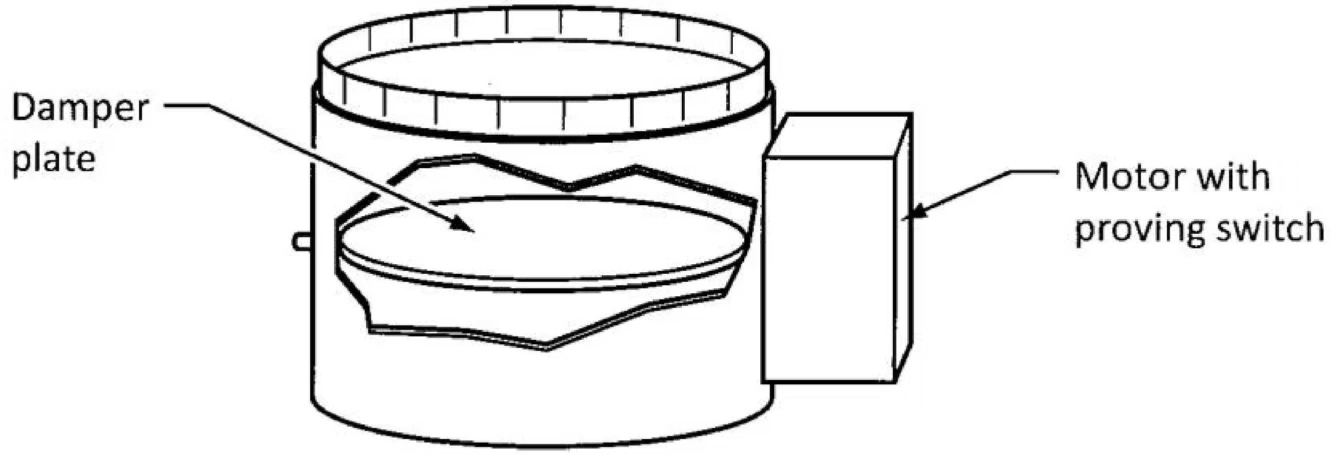
- Ensure that the burner assembly is put back together properly after cleaning
- Verify all components have been reconnected correctly
- Check all electrical connections are secure
- Ensure all access panels are properly replaced

Post-Maintenance Testing

- Perform an operational check of the furnace
- Conduct a flue gas analysis
- Verify temperature rise is within specifications
- Check for proper ignition and flame characteristics
- Ensure all safety controls are functioning properly

Automatic Vent Dampers

Figure 2-11
Automatic vent damper



Purpose and Location

Automatic vent damper devices are used to reduce heat loss up the vent on mid-efficient appliances.

Although popular on boilers because of the large mass, some furnace manufacturers install these components on furnaces.

The automatic vent dampers are located downstream of the draft hood.

Operation Methods

Method	Uses
Electrical	Electricity to open/close
Thermal	The heat of vent gas to open

Dampers are neither needed nor used on high-efficiency furnaces.

Vent Damper Operation

Call for Heat

Thermostat signals heating needed

Damper Opens

Damper automatically opens

Burner Ignites

Burner lights after damper opens

Heating Cycle Ends

Thermostat is satisfied

Damper Closes

Damper automatically closes

Heating system efficiency is increased because the closed damper reduces the loss of residual appliance heat and heated room air through the draft diverter.

Checking Vent Damper Operation

Power On

Turn on the power supply

Thermostat Setup

If using a thermostat, set the heat anticipator at 0.13 A

Call for Heat

Set the thermostat or controller to 10°F (6°C) above room temperature to call for heat

Verify Opening Sequence

Check that the damper opens before the gas valve opens and the pilot or main burner ignites

End Heating Cycle

Turn the thermostat or controller 10°F (6°C) below the room temperature

Verify Closing

Check that the damper closes

Cycle Testing

Cycle the heating system at least three times using the thermostat or controller to assure the system is operating safely

Condensate Drain System Inspection

System Components

Condensing furnaces have several condensate drain points within the cabinet of the appliance as well as externally, on vents and piping to the DWV system.

Some installations also include accessory equipment such as neutralizers and pumps.

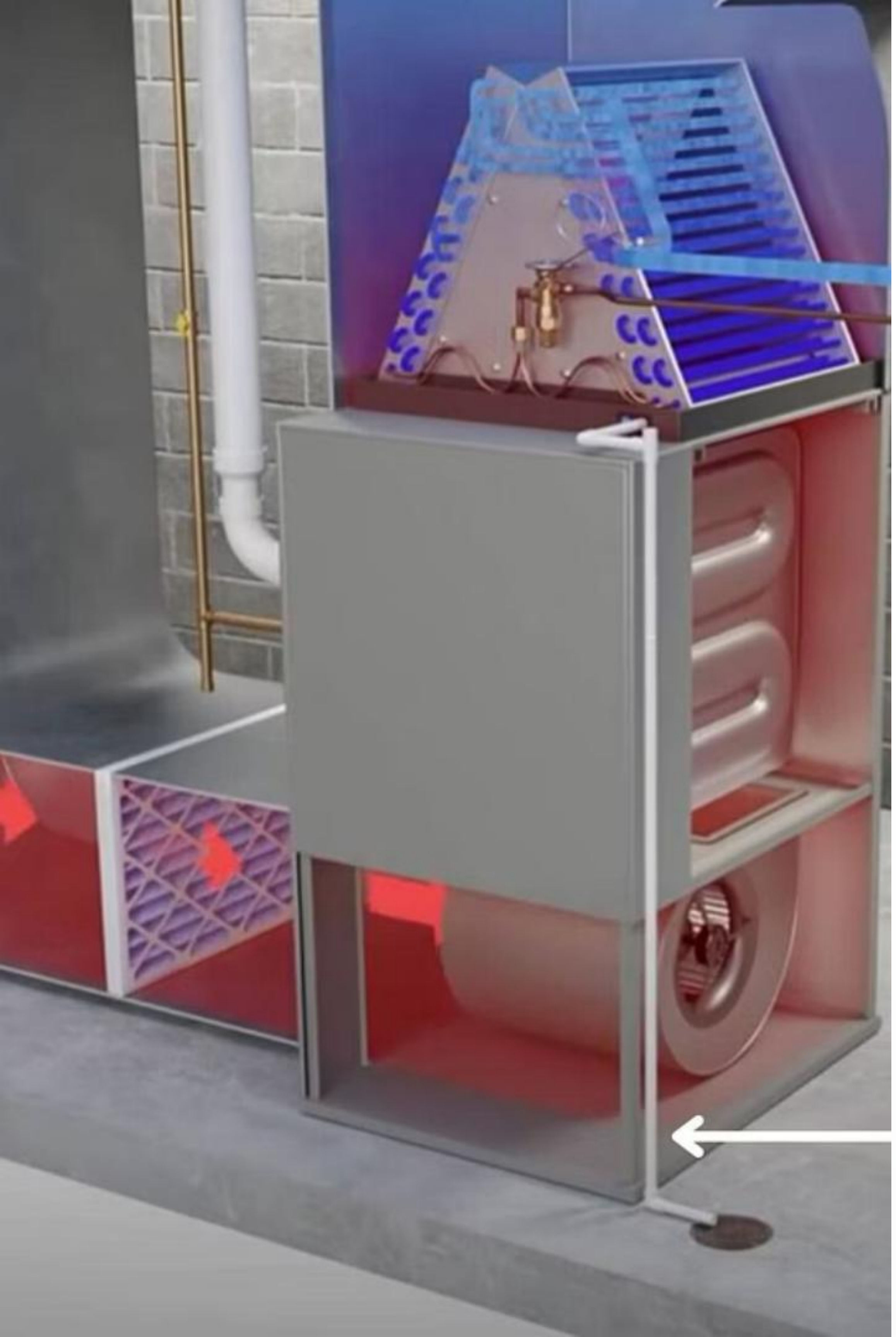
All the piping, tubing, and accessory equipment needs to be inspected and cleaned/repaired as necessary.

pH Neutralizers

Since some older DWV piping cannot accommodate the low pH (high acidity) associated with the condensate, some municipalities require condensate from furnaces to be passed through a pH neutralizer prior to entering the drain network.

These neutralizer cartridges require recharging with new pellets in order to keep them working at peak levels.

Make sure to properly size the neutralizer for the capacity of condensate that can be produced by the appliance.



Condensate Pumps

When Required

A condensate pump may be required if the lowest drain point on the appliance cannot drain by gravity to the DWV system.

Installation Requirements

- A corrosion resistant condensate pump must be used
- It must be installed with provisions to prevent winter freeze-up of the condensate drain line
- Frozen condensate blocks drains, resulting in possible furnace shutdown if the pump has a high-level alarm interlocked with the furnace control system

Freeze Prevention

An option to prevent freezing of drain lines is to install self-regulating or thermostatically-controlled heat tape.

Flexible condensate tubing is used for internal drains (outside the furnace cabinet) need to be rigid PVC piping to maintain grade to the DWV system.

Combination Units

Integrated Solutions

Condensate pumps and acid neutralizers can be sold separately or combined into one unit.

These combination units offer space-saving installation and simplified maintenance.

Maintenance Considerations

- Check and clean the pump reservoir regularly
- Replace neutralizer media according to manufacturer's schedule
- Test pump operation by adding water to the reservoir
- Verify that check valves are functioning properly
- Ensure all connections are secure and not leaking

quality management.

Annual Maintenance Schedule

Pre-Season Inspection

Complete full system inspection before heating season begins

Regular Filter Changes

Replace or clean filters every 1-3 months depending on conditions

Mid-Season Check

Verify system operation and clean components as needed

End of Season Service

Complete thorough cleaning and maintenance after heating season

An annual inspection and service is recommended for furnaces. This generally occurs prior to the start of the heating season to ensure safe and efficient operation throughout the winter months.

Technician Safety Precautions

Electrical Safety

Always disconnect power before servicing electrical components

Gas Safety

Shut off gas supply before working on gas components

Ventilation

Ensure adequate ventilation when working with combustion appliances

Personal Protection

Wear appropriate PPE including gloves, safety glasses, and respiratory protection when needed

CO Monitoring

Always carry a personal CO detector when working on combustion equipment

Documentation and Record Keeping

Service Documentation

Maintain detailed records of all service performed, including:

- Date of service
- Components inspected and serviced
- Measurements taken (temperatures, pressures, etc.)
- Parts replaced
- Adjustments made

Customer Communication

Provide customers with:

- Summary of work performed
- Recommendations for future maintenance
- Any safety concerns identified
- Efficiency improvement suggestions
- Expected timeline for next service

Thorough documentation helps track the furnace's performance over time and provides a history that can be valuable for troubleshooting future issues.

Customer Education

Basic Maintenance Tasks

- How and when to change filters
- Signs that indicate service is needed
- Proper thermostat operation

Safety Information

- Carbon monoxide safety and detector placement
- What to do if gas odors are detected
- Emergency shutdown procedures

Efficiency Tips

- Optimal thermostat settings
- Benefits of programmable thermostats
- Importance of keeping vents unobstructed

Explain to the homeowner that a yearly inspection by a trained, experienced service technician is necessary for safe, efficient operation of the furnace and its components. The homeowner should check for deterioration from corrosion or other sources between service technician calls.

Professional Development

Continuous Learning

Stay updated on new technologies, codes, and best practices

Certification

Maintain and upgrade professional certifications

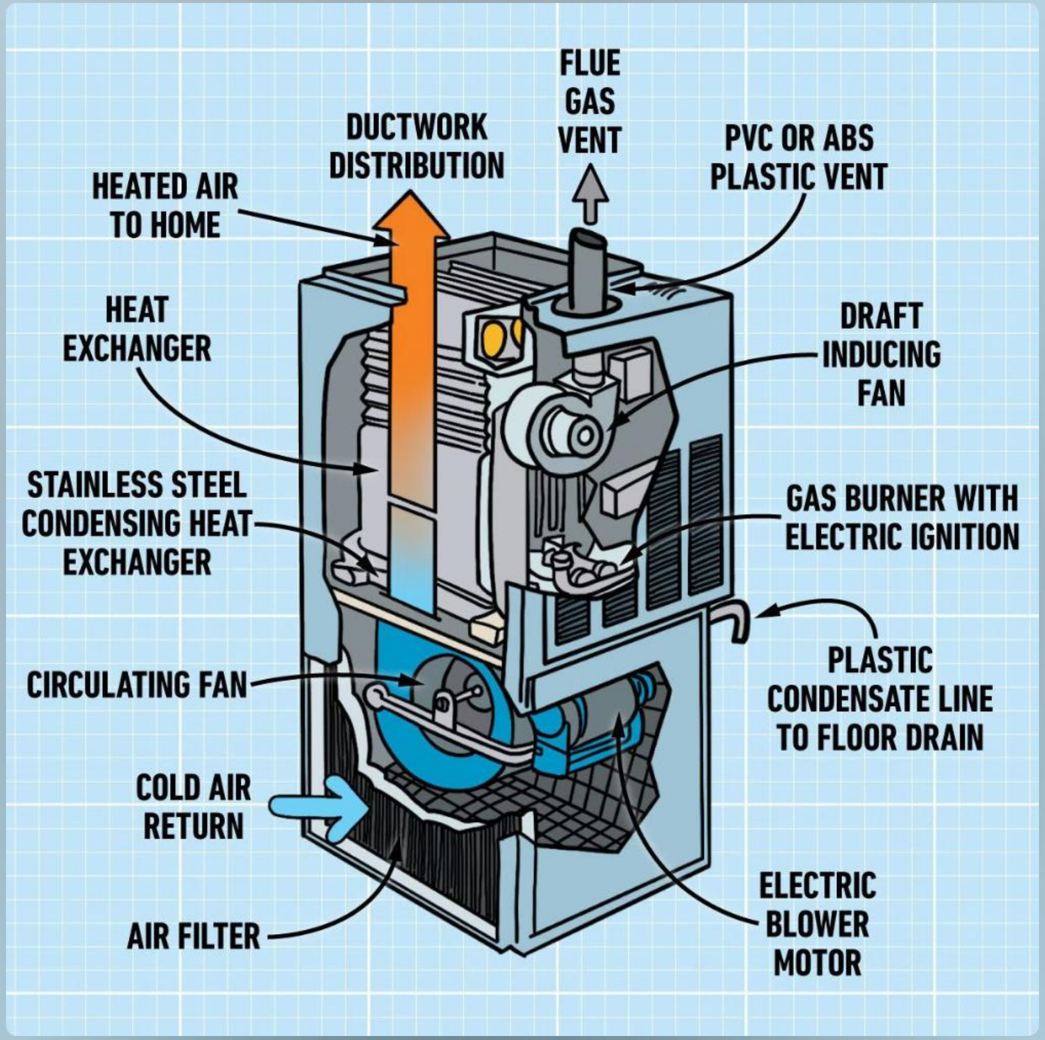
Industry Networking

Connect with peers to share knowledge and experiences

Practical Experience

Apply knowledge in the field and learn from each installation

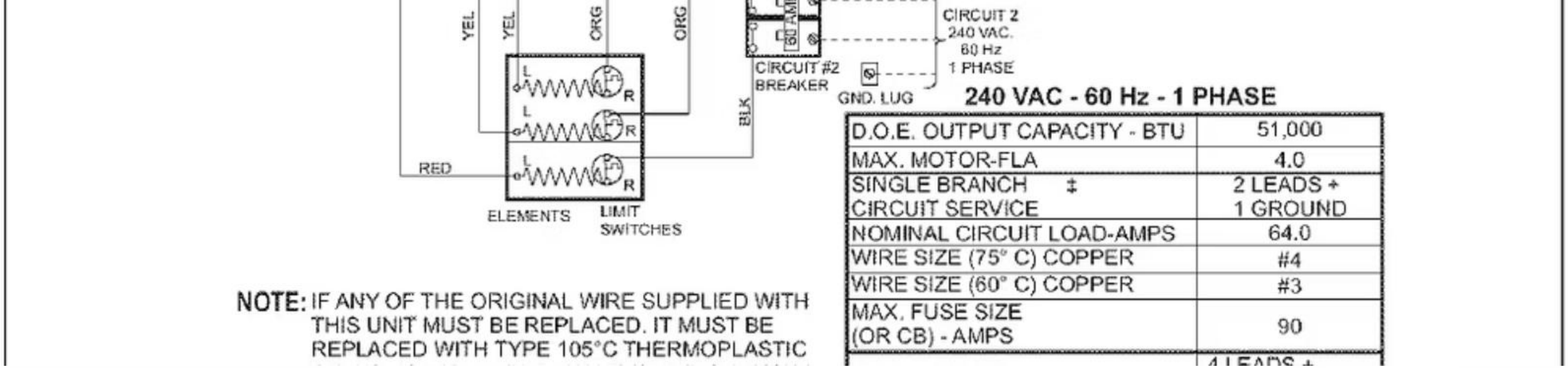
Gas technicians/fitters must continuously update their skills and knowledge to keep pace with evolving furnace technologies, especially as high-efficiency systems become more prevalent. Professional development ensures technicians can properly service all components of modern furnaces while maintaining safety standards.



CSA Unit 19

Chapter 3 Electrical Circuits and Components in Gas Furnaces

Gas furnaces are controlled by electrical circuits with various components that control the operation of the blower and determine when the furnace will fire. Safety circuits prevent unsafe operation. As furnace technology has evolved, the components have improved, with modern high-efficiency furnaces using electronic controls.



D.O.E. OUTPUT CAPACITY - BTU	51,000
MAX. MOTOR-FLA	4.0
SINGLE BRANCH ‡ CIRCUIT SERVICE	2 LEADS + 1 GROUND
NOMINAL CIRCUIT LOAD-AMPS	64.0
WIRE SIZE (75° C) COPPER	#4
WIRE SIZE (60° C) COPPER	#3
MAX. FUSE SIZE (OR CB) - AMPS	90

Understanding Furnace Control Circuits

Control Circuits

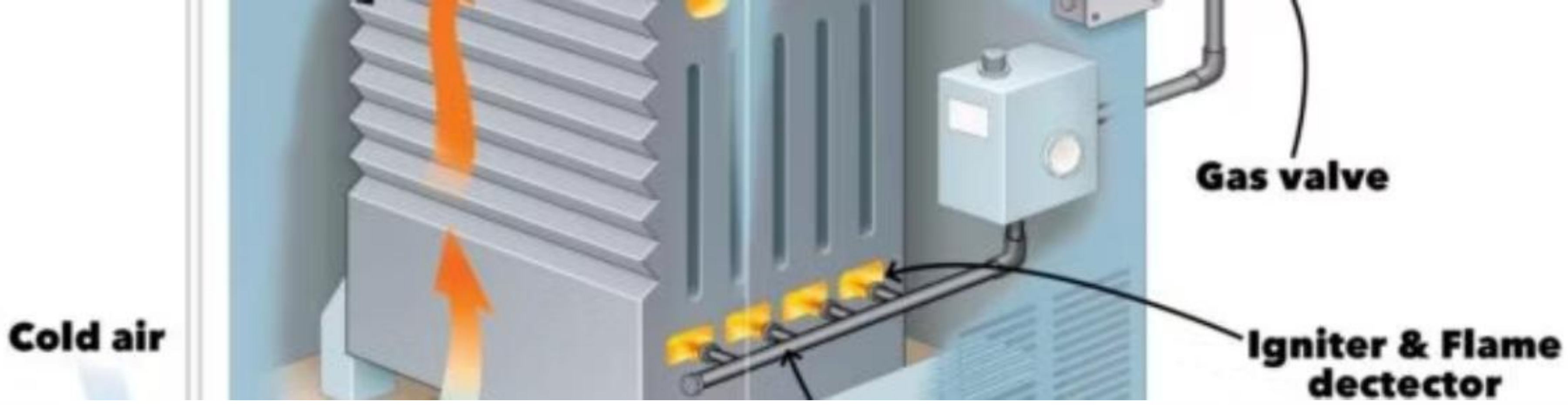
Electrical components that determine when and how the furnace operates, controlling the blower and firing sequence.

Safety Circuits

Specialized components that prevent unsafe operation by monitoring temperature, pressure, and proper combustion.

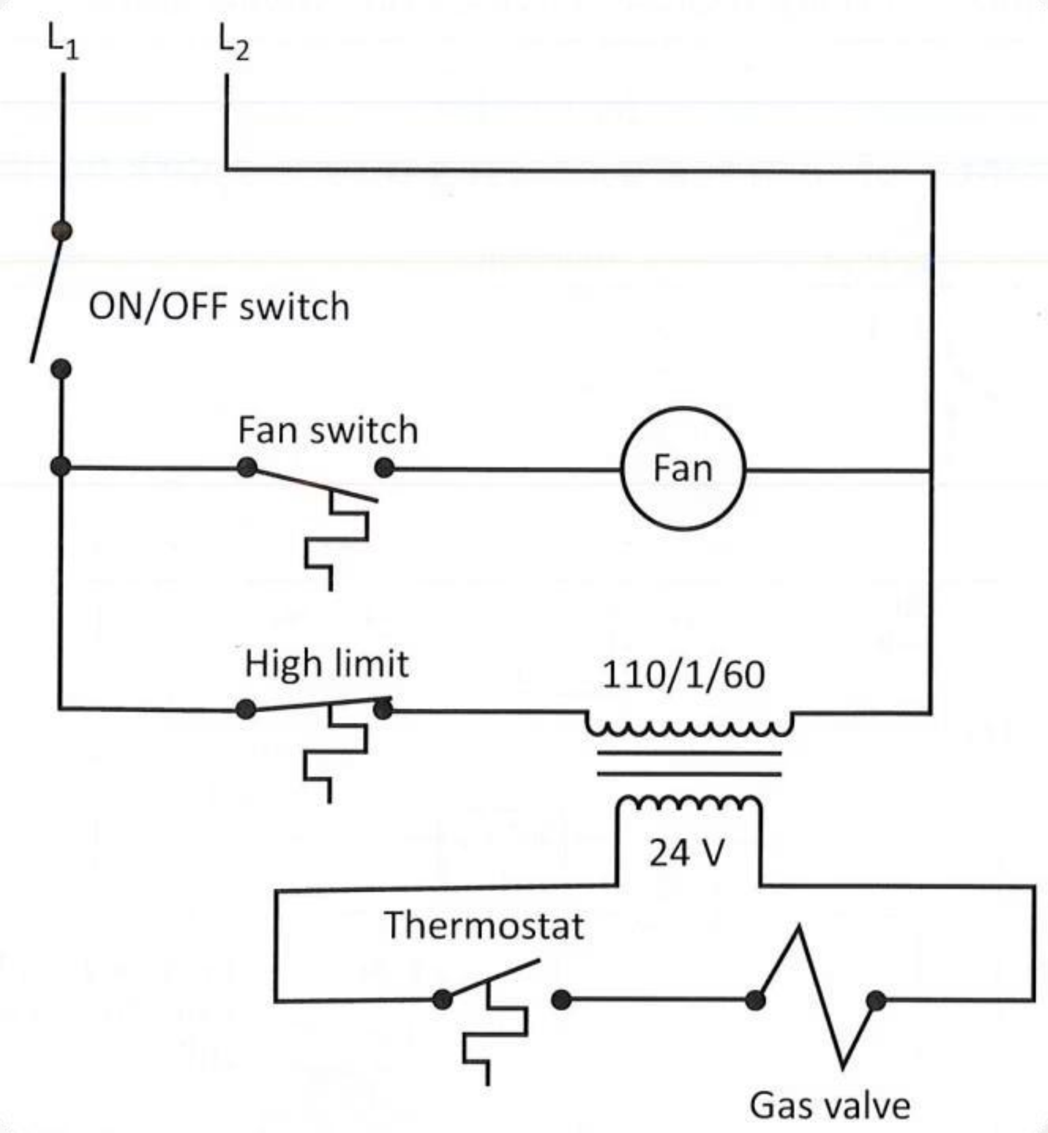
Evolution

From electro-mechanical controls in older furnaces to sophisticated electronic controls in modern high-efficiency models.



Key Terminology in Furnace Systems

Term	Abbreviation (Symbol)	Definition
External static pressure	ESP	The difference in pressure between the return air plenum entering the furnace and the supply plenum leaving the furnace
Furnace air flow		The cubic feet per minute (CFM) of air flow required to pass through a furnace heat exchanger to ensure the temperature rise stays within specifications
Integrated furnace control	IFC	Electronic control used to control most operations for newer gas furnaces including flame safety control, circulating fan control, inducer control, and safety sensors



Low-Efficiency Furnace Control Circuit

The schematic above shows a simple control circuit for a furnace that uses a continuous (standing) pilot. These older electro-mechanical controls were used before electronic systems became readily available and reliable. Although these older furnaces are not installed anymore, many still exist in homes and require regular service and maintenance.

Thermostat Call for Heat

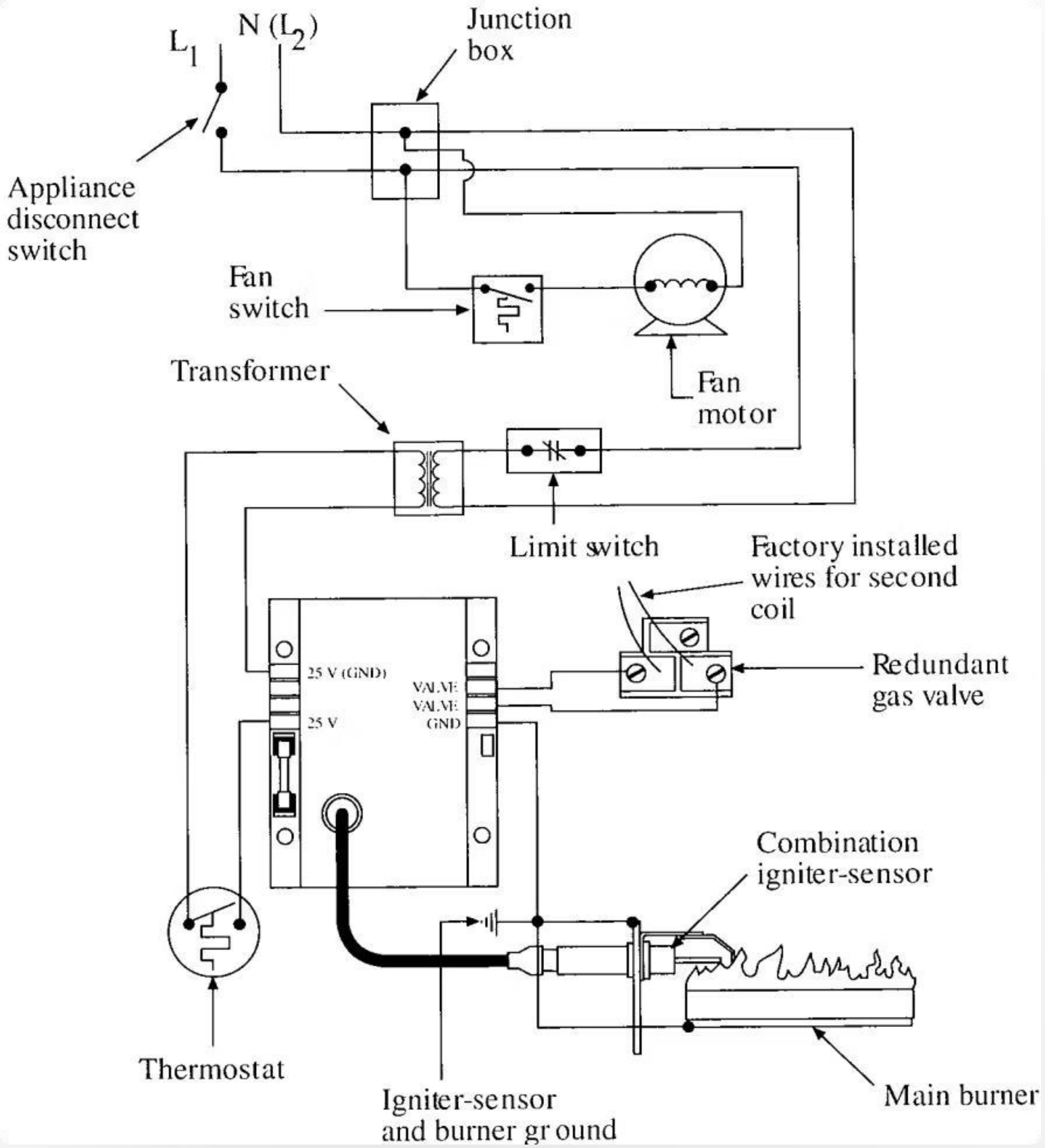
On a call for heat, the thermostat contacts close to complete the control circuit.

Gas Valve Activation

The gas valve is energized and opens, allowing gas flow to the burners.

Ignition and Fan Operation

Gas is ignited by the standing pilot, heat from the exchanger operates the fan control, and the indoor blower circulates warm air through the ducting.



Mid-Efficiency Furnace Control Circuit

This schematic shows a furnace that uses direct-spark ignition. Mid-efficiency furnaces used some electro-mechanical controls as well as electronic control of the ignition system. Manufacturers could have also used an intermittent pilot or hot-surface ignition.

1

Thermostat Initiates

Thermostat contacts close to complete the control circuit.

2

Control Module Activates

The control circuit energizes the control module through the "25V" terminals.

3

Ignition Sequence

The module energizes the flame sensor, igniter, and main gas valve, then proves and monitors the flame.

4

Blower Operation

The fan switch closes after sufficient heat is generated, and the indoor blower distributes warm air until the cycle ends.

Fan Control for Older Furnaces

Temperature-Actuated Control

Uses a temperature-activated switch that responds to heat from either a 24-V heater or directly from the furnace. The fan starts when the heat exchanger is hot and stops after the furnace shuts down but before the air is cooled.

The temperature differential between FAN ON and FAN OFF settings is normally about 25°F (14°C).

Timer-Actuated Control

Uses an electronic timer to control fan operation. When there's a call for heat, the gas valve opens and the timer starts. After a preset time, the fan comes on and continues to run until the gas valve closes. Then the timer starts again and turns the fan off after the timed cycle.

Unlike temperature-actuated controls, timer controls will bring the fan on even during a "no-heat" situation, potentially blowing cold air.

Fan Control Operation

Heat Generation

Burners fire and begin heating the heat exchanger

Fan Activation

Fan switch closes when temperature reaches set point

Shutdown

Fan continues running after burners stop to cool heat exchanger

Air Circulation

Blower distributes warm air throughout the home

The fan control differential (difference between FAN ON and FAN OFF temperatures) is normally about 25°F (14°C). If the differential is less than this, the fan will cycle on and off continuously over too short a period. If greater, the system will not be very efficient.

Combination High-Limit/Fan Control

Components

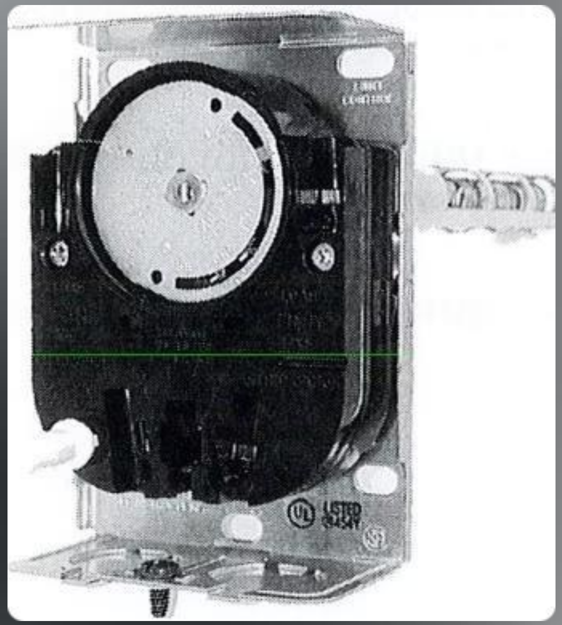
Contains a normally open fan switch on the left side and a normally closed high-limit switch on the right side, connected together with a jumper.

Operation

As temperature rises, the bimetal first closes the fan switch to start the blower. If overheating occurs, the bimetal continues to warp until it opens the limit switch, interrupting the circuit and closing the main gas valve.

Location

Positioned by the manufacturer to best sense temperature rise. If replacement is needed, use the same design in the same location.



Fan Control Board

To improve reliability and efficiency, manufacturers replaced the electro-mechanical fan control with a fan control board that times the fan to turn on and off at a set time period after the gas valve has been energized and de-energized.

Electronic Timing

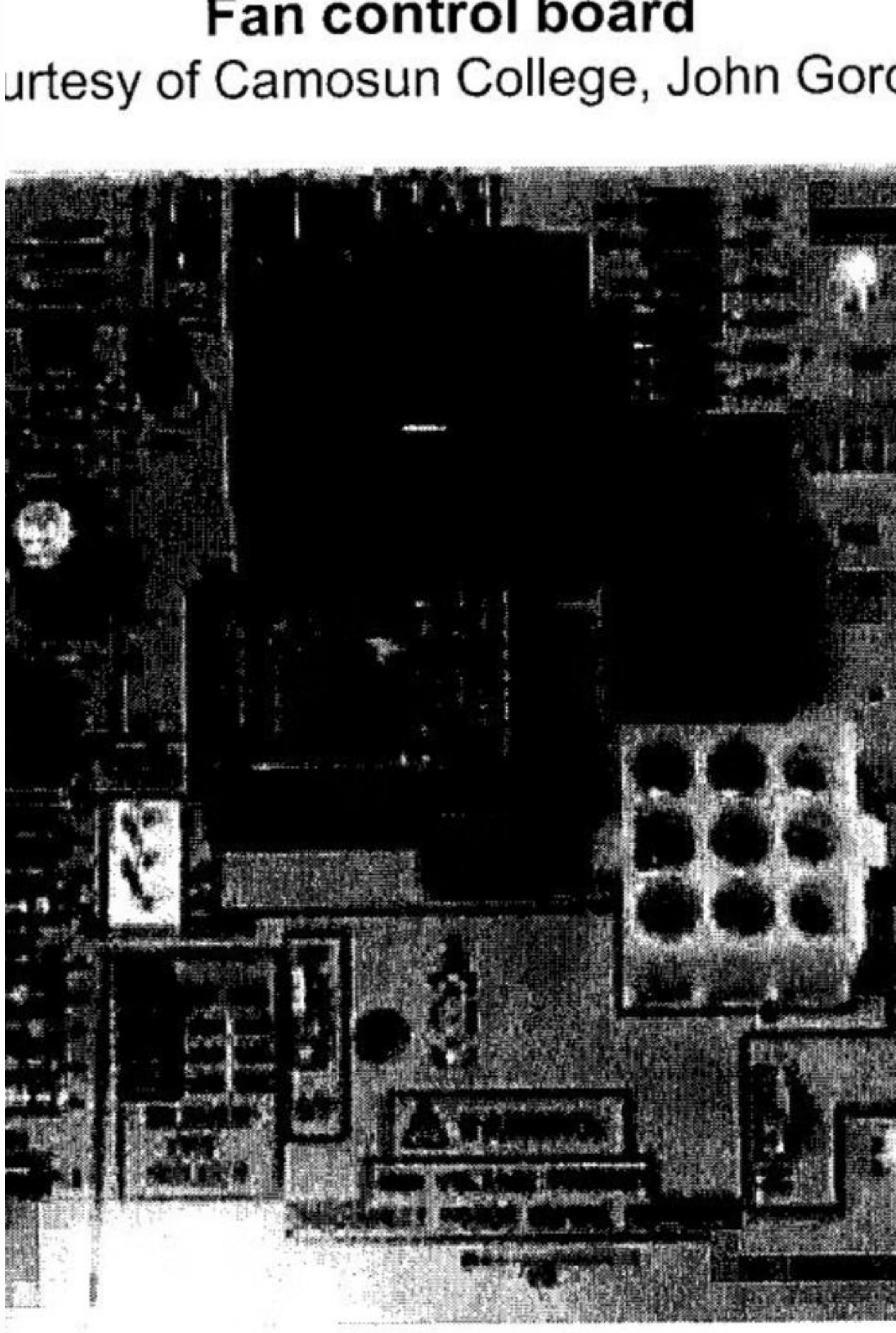
Provides more precise control over fan operation than mechanical systems

Adjustable Settings

Allows for customization of fan on/off timing to optimize comfort and efficiency

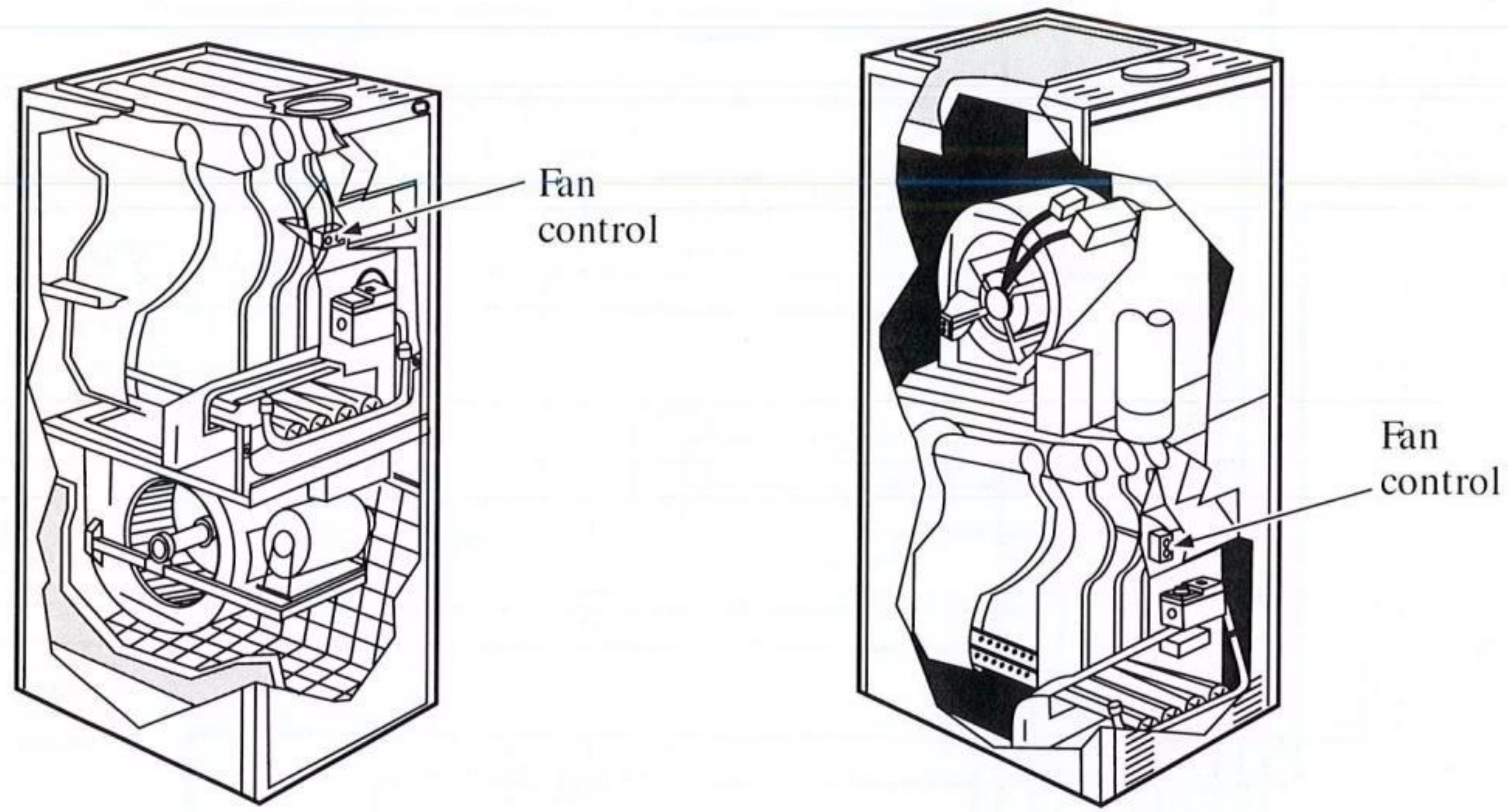
Improved Reliability

Fewer mechanical parts means less wear and longer service life



Fan Control Location

Figure 3-5
Locating the fan control
Courtesy of Lennox Industries Inc.



Up-flow furnace **Down-flow application**

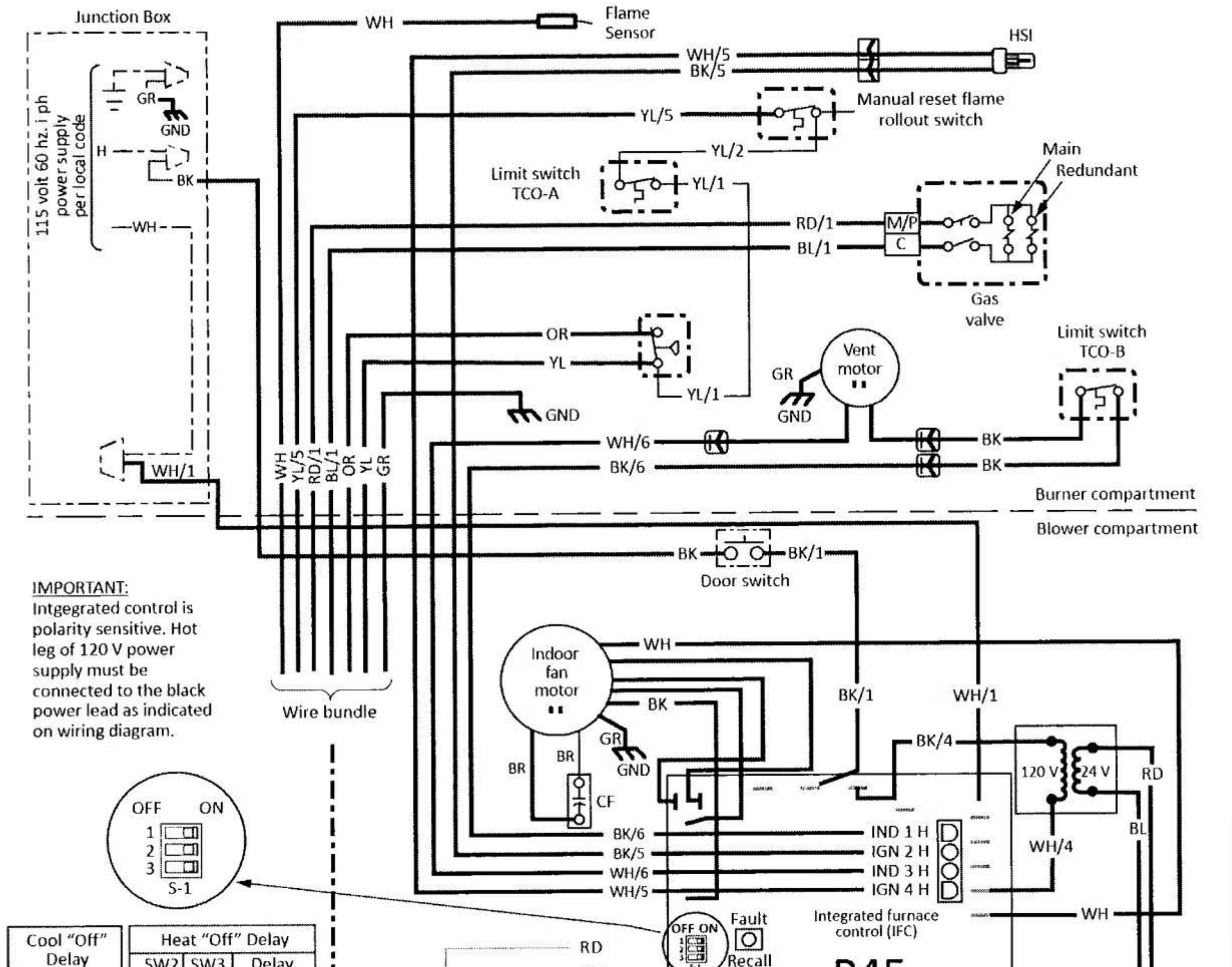
Up-Flow Furnace

In an up-flow furnace, the fan control is typically located in the upper portion of the furnace cabinet, where it can effectively sense the temperature of the heated air as it rises through the heat exchanger.

Down-Flow Furnace

In a down-flow furnace, the fan control is positioned differently to account for the reversed airflow direction, ensuring it can still accurately detect temperature changes and control the fan appropriately.

High-Efficiency Furnace Control Circuit



Advanced Furnace Options

Single-Stage Furnace

Basic operation with one heating level. The furnace is either on at full capacity or completely off.

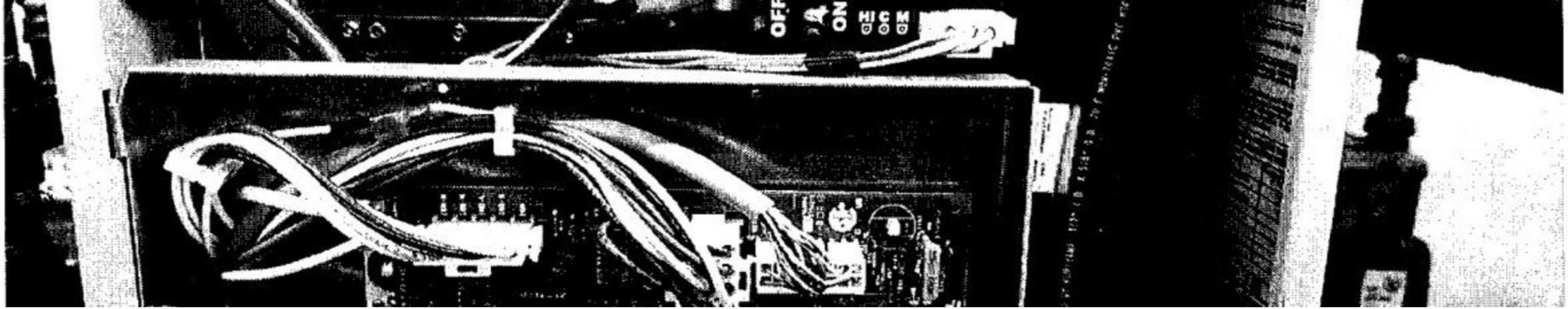
Two-Stage Furnace

Incorporates a longer, slower heating cycle to eliminate rapid warming. Uses a two-stage gas valve, 2nd stage inducer relay, and multi-speed indoor blower motor.

Modulating Furnace

Fully modulates between approximately 40% and 100% of capacity in 1% increments. Uses a modulating gas valve, variable speed inducer, and variable speed indoor blower motor.

These advanced options provide improved comfort by better matching the heating output to the home's needs at any given time.



Integrated Control Modules

The brain of most modern furnaces uses an integrated circuit board to control many sophisticated processes. These integrated controllers can also perform self-diagnostics providing codes similar to the diagnostic computer in your car.

The integrated circuits continuously monitor the furnace's operation and the operation of the integrated control module itself. If a failure occurs, light emitting diodes (LEDs) can indicate a failure code. These codes are listed in the owner's manual and are often displayed on the furnace door.

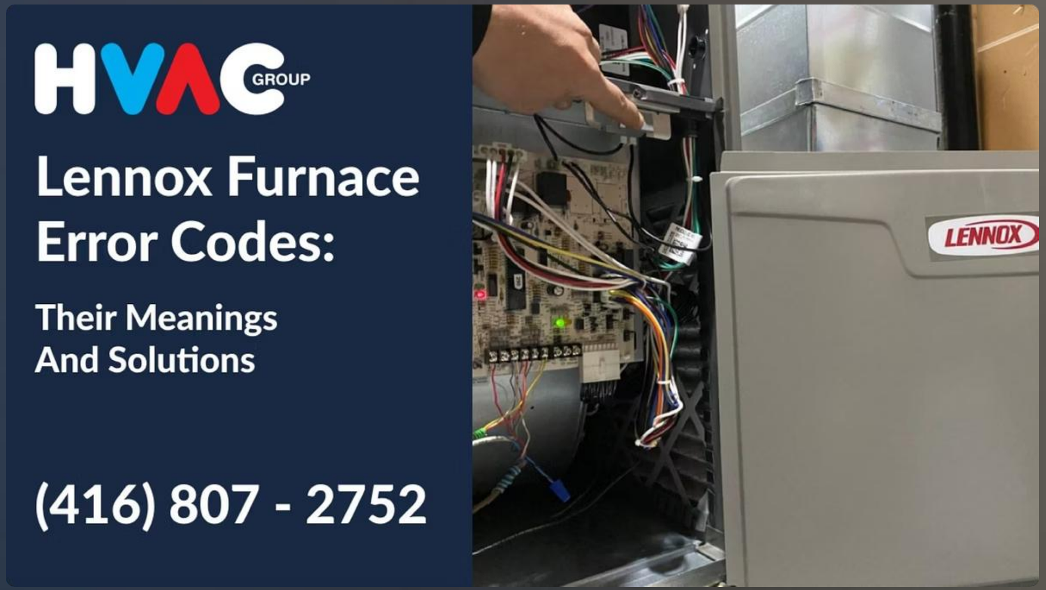
IFC Error Flash Codes

Flash Pattern	Meaning
Flashing slow	Normal - no call for heat
Flashing fast	Normal - call for heat
Continuous ON	Replace IFC
Continuous OFF	Check power
2 flashes	System lockout (retries or recycles exceeded)
3 flashes	Pressure switch error
4 flashes	Open high limit device
5 flashes	Flame sensed when no flame should be present

More IFC Error Flash Codes

Flash Pattern	Meaning
6 flashes	115 Volt AC power reversed or poor grounding
7 flashes	Gas valve circuit error
8 flashes	Low flame sense signal
9 flashes	Igniter relay fault

These diagnostic codes help technicians quickly identify issues with the furnace, making troubleshooting more efficient and reducing repair time.



Fan Control for High-Efficiency Furnaces

The wide variety of applications and installations of furnaces throughout the country makes it impossible to factory-select indoor blower speeds that will provide proper operation for all installations. This means that the blower speeds for both heating and cooling must be field-selected by the installer for each application.

1. ## Determine Required CFM

Calculate using the formula: CFM = (Btu/h output) ÷ (1.08 × temperature rise)

2. ## Select Blower Speed

Use manufacturer's tables based on the furnace model to select appropriate indoor blower speed

3. ## Perform ESP Test

Ensure the appliance is operating within its temperature rise and External Static Pressure specifications

4. ## Set Fan Timing

Configure the IFC module for appropriate fan-ON delay and fan-OFF period

Calculating Required CFM

Manufacturers of furnaces specify temperature rise as well as a maximum external static pressure (ESP). Temperature rise is the difference between the return air temperature and the supply air temperature. ESP is the difference in pressure between the return air plenum entering the furnace and the supply plenum leaving the furnace.

Use the Formula

CFM = (Btu/h output) ÷ (1.08 × temperature rise)

Check Manufacturer Tables

Reference CFM vs. temperature rise tables

Verify Selection

Ensure CFM maintains temperature rise within specifications

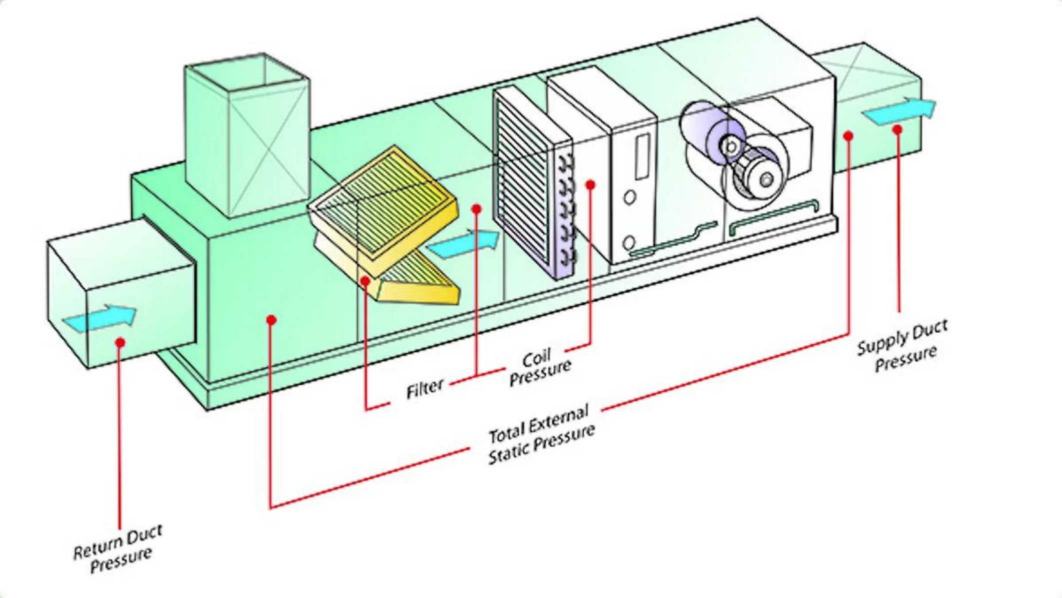
Example: For a furnace with an output of 72,000 Btu/h and a temperature rise of 55°F, the calculation would be: CFM = 72,000 ÷ (1.08 × 55) = 1,212 CFM

CFM vs. Temperature Rise

Furnace Airflow vs. External Static Pressure

Once the required CFM has been determined, the gas technician would use tables from the manufacturer, based on the furnace model, to select an indoor blower speed that can deliver that airflow at the expected external static pressure.

Model	Speed tap	0.10	0.20	0.30	0.40	0.50
UC1-B040A9241-A	4 - HIGH - Black	1043	992	930	885	812
	3-MED. HIGH - Blue	940	895	841	791	726
	2 - MED. LOW - Yellow	837	798	752	705	649
	1 -- LOW - Red	729	694	657	600	545



IFC Fan Control Settings

Fan Start Timing

The blower start is usually fixed at approximately 45 seconds after ignition. This delay allows the heat exchanger to warm up before circulating air, preventing cold air from blowing into the living space.

Fan-OFF Period

Field-selectable via a user interface menu with options like 60, 100, 140, or 180 seconds. The factory setting is usually approximately 100 seconds. This allows the heat exchanger to cool down gradually and extracts remaining heat.

For heating mode, the blower speed is pre-set to be approximately 50% of the cooling speed but could have a user-determined selectable range. This procedure is usually the same whether the furnace uses a PSC or an ECM motor, but always check the manufacturer's literature.

Thermostats: Control and Safety Circuits

The thermostat is used to control the operation of the furnace. The simplest thermostat measures the room temperature and starts and stops the burner so that the temperature is maintained at the set level. It needs to be well placed so that the furnace will operate correctly.

Proper Location

Must be placed to sense average room temperature, not exposed to hot or cold drafts or spots on the wall, and located to best sense the average temperature of the entire room.

Installation Requirements

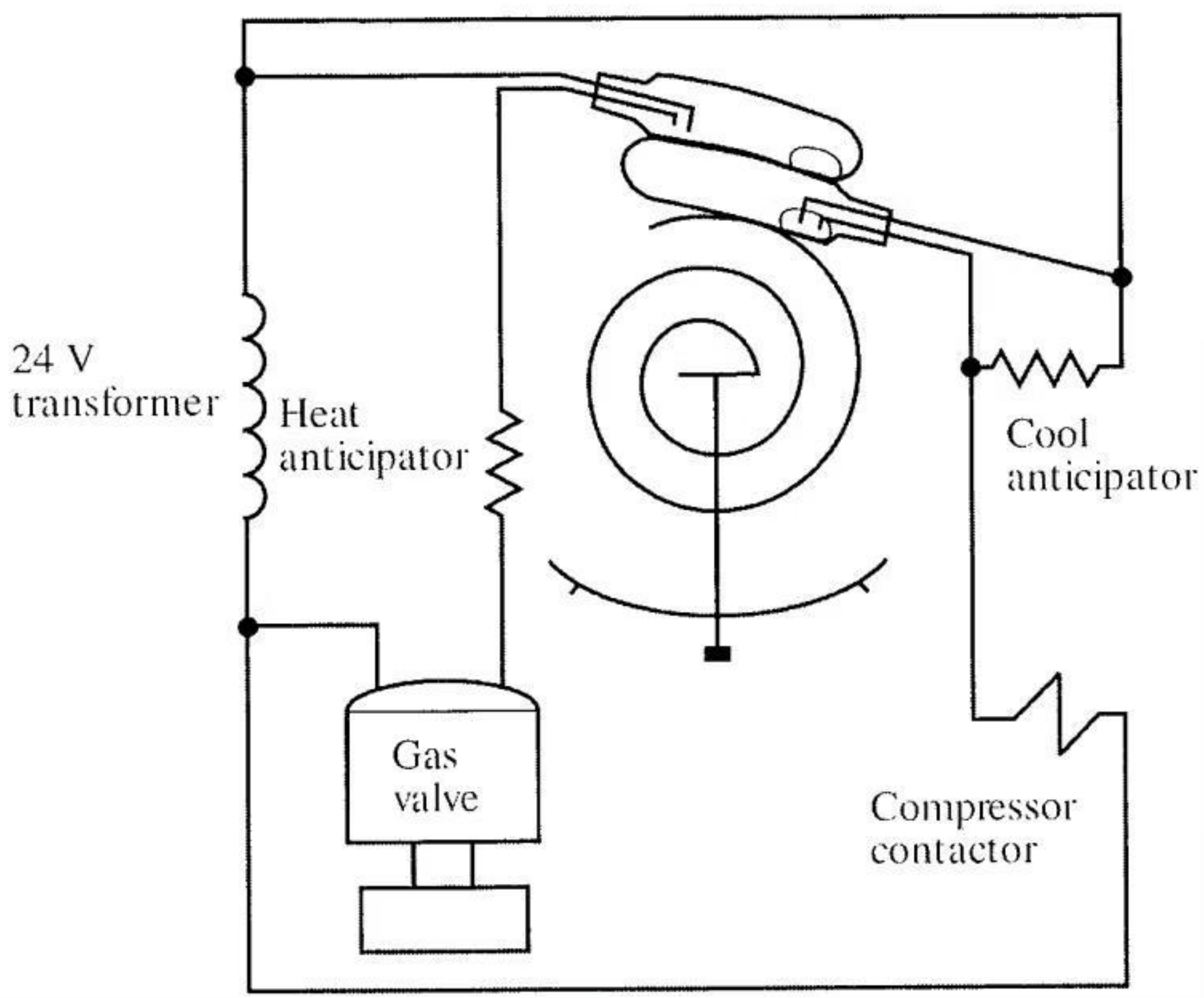
Since older thermostats use a mercury switch, they must be properly levelled when mounted and placed in an area free from vibration.

Modern Alternatives

Electronic programmable thermostats are used on modern, high-efficiency furnaces. They are solid state or microprocessor boards that do not use mercury switches and do not require heat anticipation.

Heating-Cooling Thermostat

Figure 3-9
Two-bulb thermostat wiring diagram
Courtesy of Lennox Industries Inc.



When heating and cooling are combined for year-round comfort, a heating-cooling thermostat is used. The bulk and expense of two separate bimetal coils is avoided when two mercury bulbs are mounted on the same bimetal coil, with heating and cooling anticipators mounted near the coil.

Mercury Bulb Design

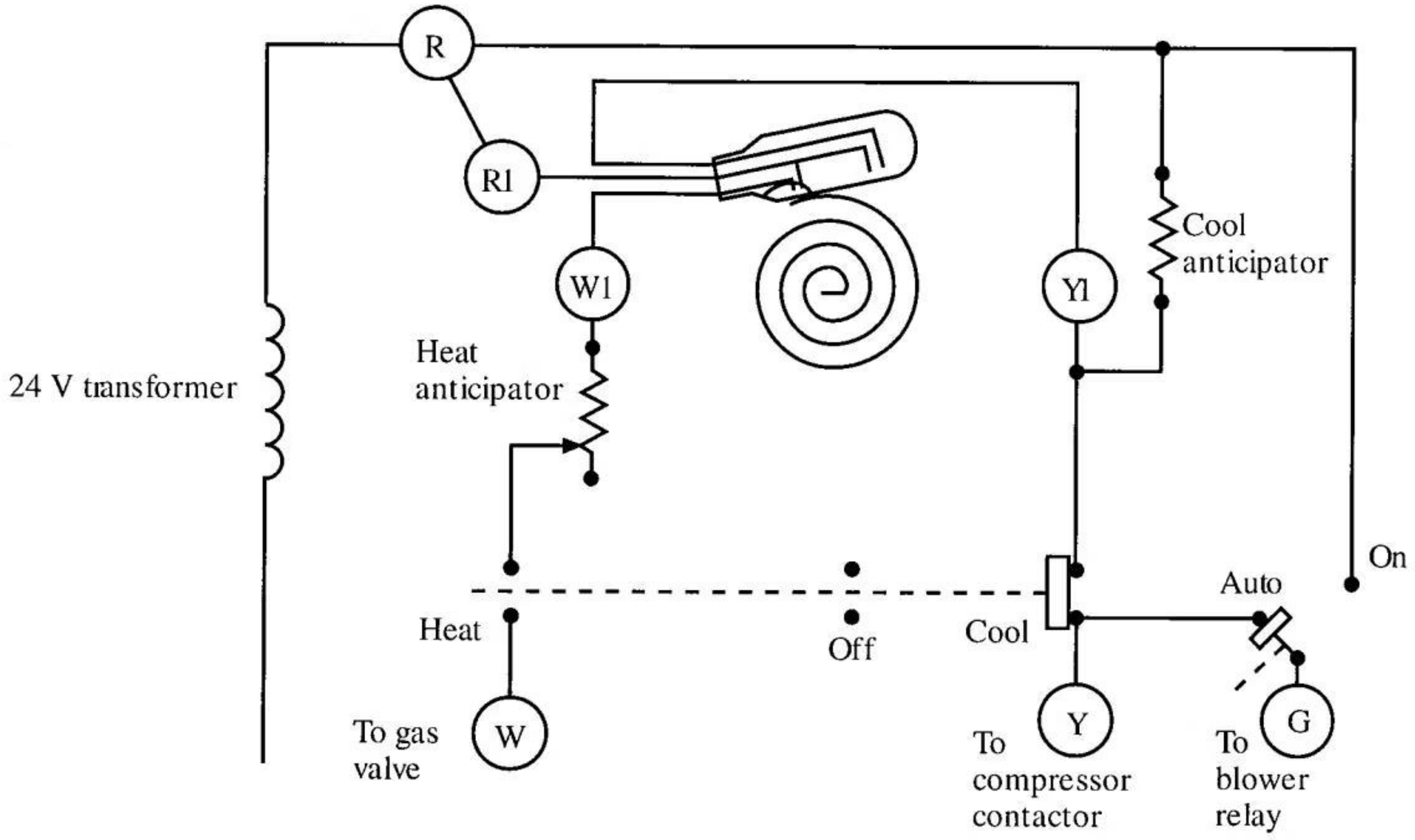
The two mercury bulbs can be combined into one by using one common electrode, one heating electrode,

System Switches

A switch provides a means to activate cooling while disconnecting the heating circuit, or vice versa. When

Thermostat System and Fan Switches

Figure 3-10
Switch diagram with control to cooling
Courtesy of Lennox Industries Inc.



Satisfied

Programmable Thermostats

Electronic programmable thermostats are used on modern, high-efficiency furnaces. They are solid state or microprocessor boards that do not use mercury switches and do not require heat anticipation. Some models even operate wirelessly making for an easier installation.

Field Setup Required

The gas technician must field wire and set up the thermostat for the specific furnace application

Multiple Applications

Can be configured for single-stage, two-stage, or modulating furnaces with various cooling options

Advanced Features

Many offer Wi-Fi connectivity for remote monitoring and control of the heating and cooling system

Mercury Notice

Old mercury-containing thermostats should be properly recycled through the HRAI Thermostat Recovery Program

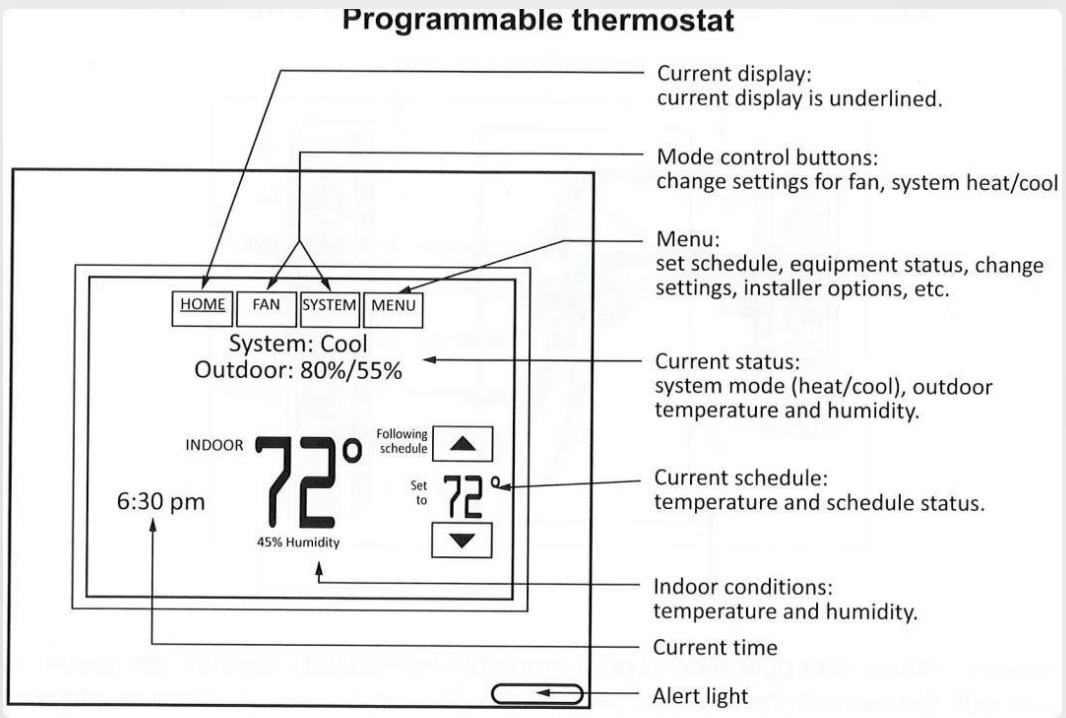


Figure 3-13
Example from a furnace manufacturer’s literature

Thermostat Field Wiring

Field wiring must match the specific combination of furnace, thermostat and any other optional equipment. Furnace manufacturer's literature, thermostat manufacturer's literature and other equipment literature must all be consulted during the set-up of a thermostat.

Single-Stage Applications

Basic wiring for a single-stage furnace with or without single-stage cooling

Two-Stage Applications

More complex wiring for two-stage furnaces with single or two-stage cooling

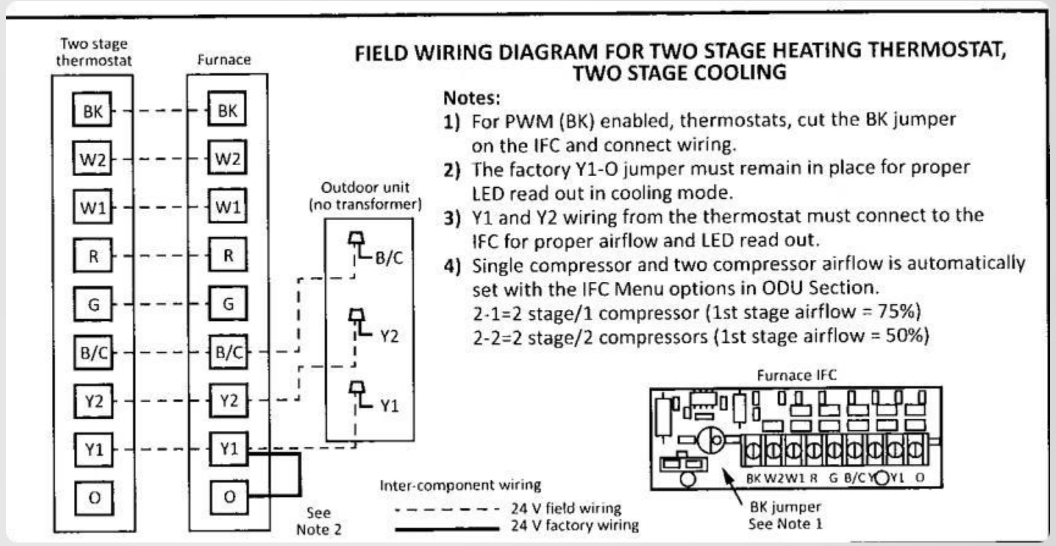
Modulating Systems

Specialized wiring for modulating furnaces with various cooling options or heat pump integration

Multiple Furnace Setup

Twinning two single-stage furnaces using a single-stage thermostat

More Thermostat Wiring Examples



The image shows an example from a thermostat manufacturer's literature, illustrating the proper wiring connections for a specific application. The installation, set-up, and operation of programmable thermostats must be conducted in accordance with the manufacturer's instructions and will involve several programming steps.

Identify Terminal Connections

Match thermostat terminals with corresponding furnace terminals

Connect Wiring

Install appropriate gauge wire between the thermostat and furnace control board

Program Settings

Follow the prompts on the screen to select the appropriate options for your specific system

Additional Thermostat Wiring Example

This image shows another example of thermostat wiring from a manufacturer's literature. To complete the thermostat set-up, follow the prompts on the screen to select the appropriate options for your specific system configuration.

1 Review Wiring Diagram

Carefully study the manufacturer's wiring diagram for your specific equipment combination

2 Identify Wire Functions

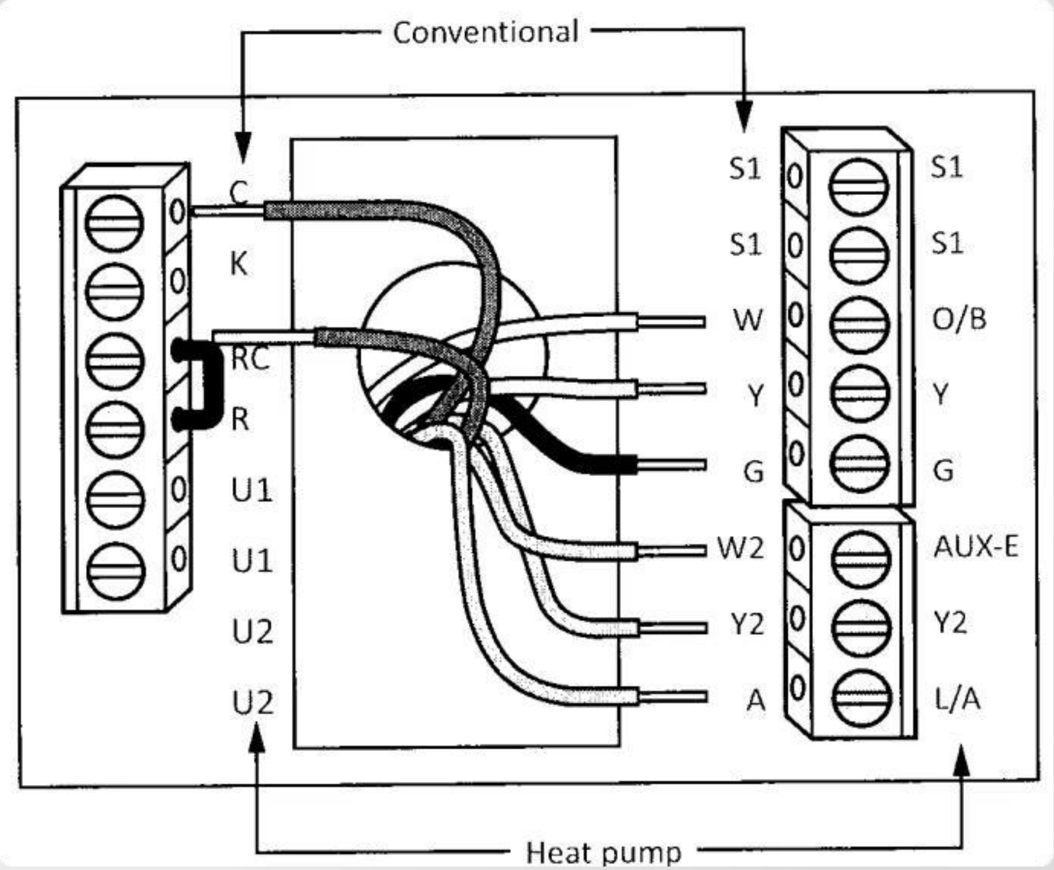
Understand the purpose of each colored wire in the thermostat cable

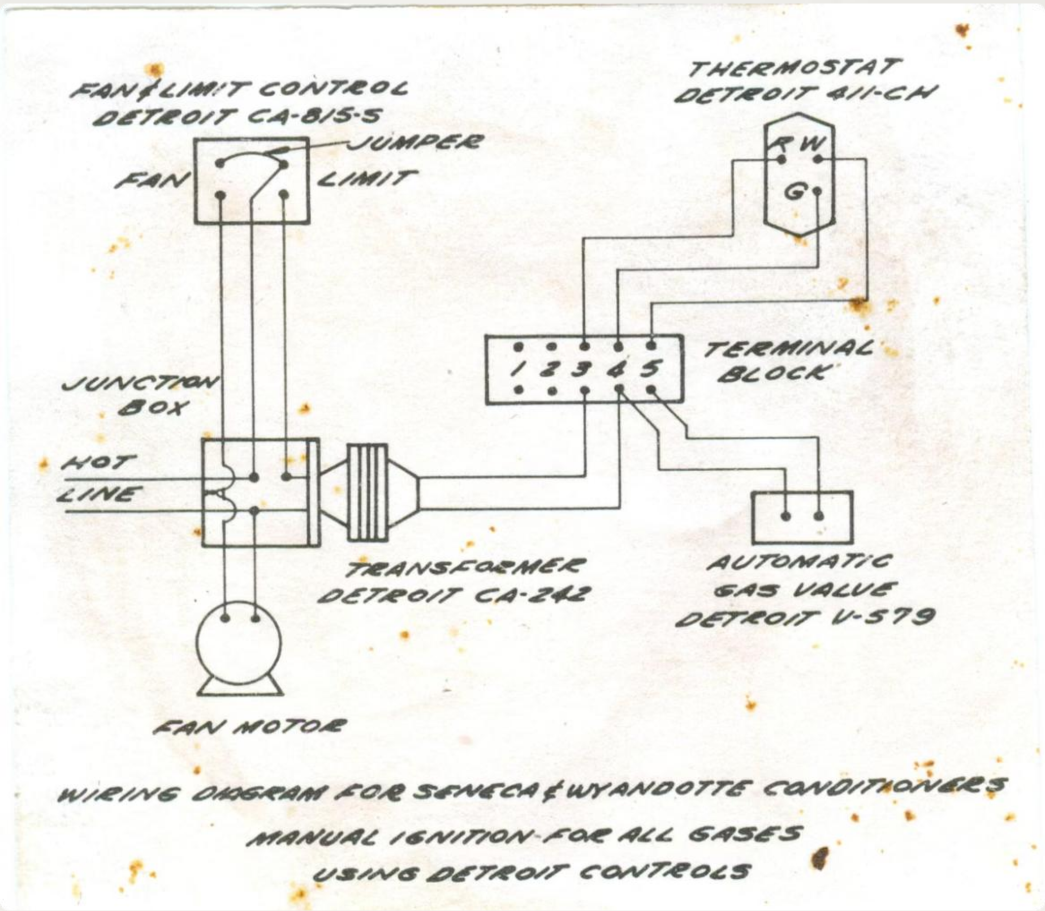
3 Make Proper Connections

Connect each wire to the appropriate terminal on both the thermostat and furnace control board

4 Test Operation

Verify proper system function in all modes (heating, cooling, fan only)





Gas Valves in Furnaces

The operation of gas valves in gas-fired appliances is detailed in Unit 13 Controls: Fundamentals. The same principles are used in forced-air furnaces. In central furnaces, the gas valve forms part of a combination control.

Thermostat Call

Thermostat signals need for heat

Coil Energized

Electrical current flows to valve coil

Valve Opens

Gas flows to burners for ignition

4

Cycle Ends

When satisfied, coil de-energizes and valve closes

Limit and Rollout Switches

There are a number of different switches that are used in furnaces as safety checks. A limit or rollout switch is essentially a bimetal element that is placed in the area in which the temperature must be sensed.

Basic Operation

The switch is normally in the closed position and is connected in the control circuit in series with the gas valve. As the temperature rises, the bimetal bends or capillary expands, until at some point it breaks electrical contact to open the circuit.

Reset Function

Most limit and rollout switches reset automatically as they cool down, but some do need to be manually reset.

Common Triggers

Switches may function due to faulty fuel valve, broken blower belt, blocked air filter, or faulty blower motor. If a limit switch causes the furnace to shut down, the reason must be identified and fixed.

High-Limit Switch

The high-limit switch is a safety device that is used to shut the burner off if the outlet air overheats. It is calibrated by the manufacturer and prevents the air that leaves the furnace from exceeding a set temperature limit.

Types of High-Limit Switches

- Stand-alone safety limit switch
- Combination fan and limit switch

The high-limit switch is in the normally closed position. These switches may use either a bimetal sensing element or a capillary fluid filled sensing element to perform the same function.

Stand-Alone Safety Limit Switch

This is purely a safety switch used to shut down the burner if the supply air in the plenum exceeds a certain set temperature, normally about 200°F (93°C). When this type of limit switch is used, a separate switch controls the operation of the fan.

The limit set pointer on the limit controls is preset by the manufacturer and must not be adjusted.

Secondary Limit Control

Down-flow and horizontal furnaces make use of secondary limit controls — sometimes called auxiliary limit controls. The secondary limit control protects the fan motor, which is on top of the unit, from damage.

Purpose

When the fan is off, heat rises to the top of the furnace. The high-limit switch does not detect this heat, so an additional switch protects the motor and air filters from this rising heat.

Location

Installed above the heat exchanger, near or in the supply air inlet.

Operation

Connected in series with the high-limit switch. If the temperature rises above the set level, the switch opens and the burners shut down. Typically set to open at a point below the high-limit switch setting.

Exhaust Limit Switch

The exhaust limit switch is used to shut down the burner if the temperature of the flue gas exceeds a certain limit. This may happen if there is a soot buildup inside the heat exchangers, or if there is a lint buildup on the secondary heat exchanger.

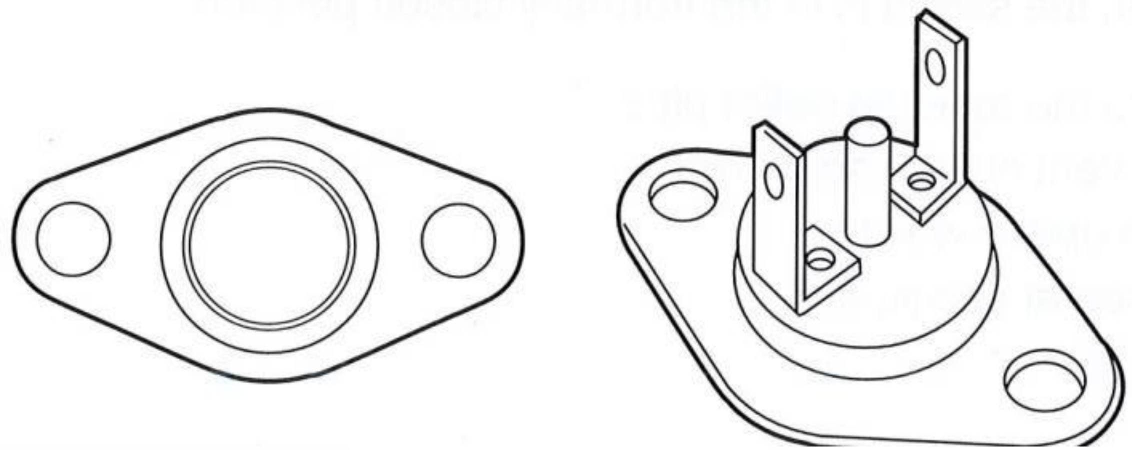
Purpose

Prevents overheating due to restricted heat transfer from the heat exchangers. If this occurs, the heat exchangers must be cleaned.

Location and Operation

Typically located on the exhaust blower housing. The switch is normally closed and opens when temperature rises above a set limit, closing the gas valve and shutting down the burner. It resets automatically when temperature falls below the set level.

Rollout Switch



This switch is used to sense problems in the flow of combustion products. These problems may be caused by blockages in the heat exchangers and flue or may be a failure of a combustion air blower or exhaust blower to function properly, which could lead to flame rollout.

Purpose

If flame rollout is sensed, the switch causes the burner to shut down. If this has occurred, the blockages must be removed, and the cause of the problem corrected.

Location

Located on the burner shield where it can detect flame rollout conditions.

Operation

A normally closed, snap disc type switch or a capillary type switch. When high temperatures are sensed, the switch opens, breaking contact to the burner control system. Some require manual reset while others reset automatically.

A flame rollout safety switch must never be jumped. If the switch does shut the furnace down, a check must be made for the reason for the shutdown.

Vent Outlet Pressure Switches

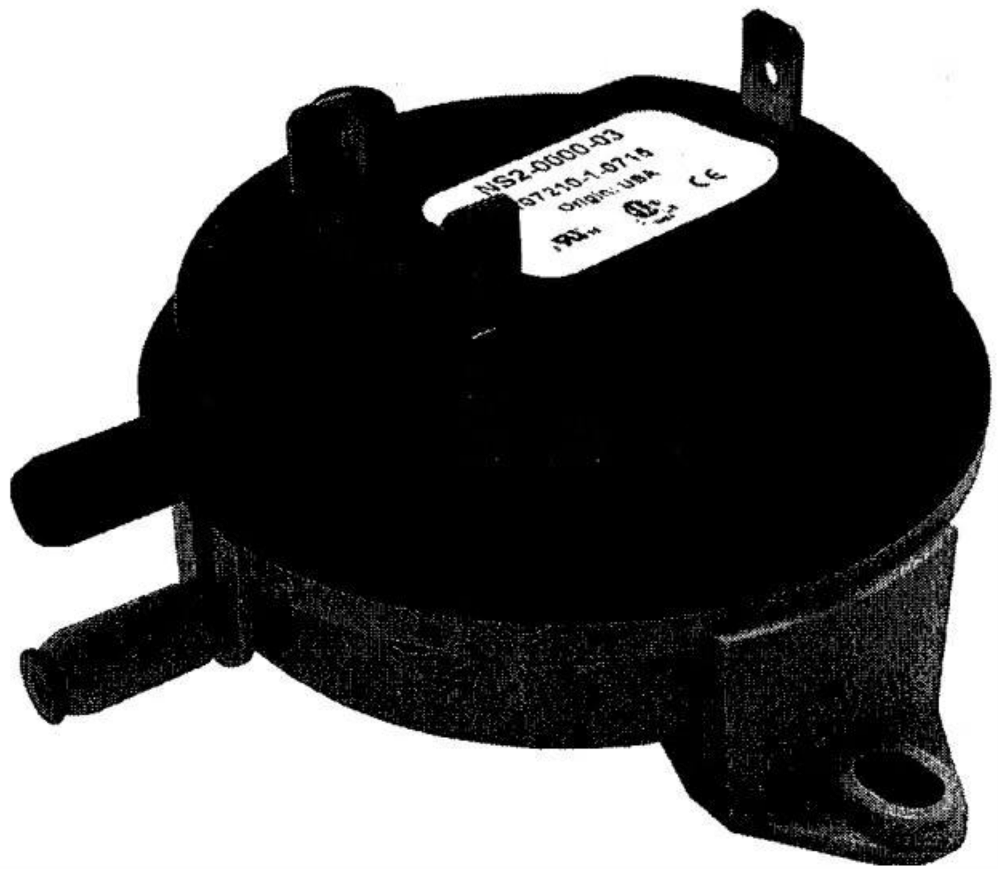


Figure 3-16
Pressure switch
Image courtesy of Terry Bell

A vent outlet pressure switch is used to shut the burner down if there is a blockage of some form in the vent outlet or internal flue gas passages. It will also shut the burner down if there is a failure of the combustion air fan or motor.

Location

Normally located at the appliance flue outlet where it can effectively monitor pressure conditions.

Operation in Standard Furnace

Connected in series to the thermostat circuit. In a furnace without a power venter, the switch is normally closed. If there is a blockage in the exhaust outlet pipe, the pressure rises and the switch opens, shutting down the burner.

Pressure Switch Operation in Power-Vented Furnaces

In furnaces with mechanical draft systems, the pressure switch operation differs from standard furnaces.

Normal State

The switch is in a normally open position when the system is at rest

Call for Heat

When there is a call for heat, the mechanical draft blower motor activates

Switch Closure

Once proper draft is established, the pressure switch closes, allowing the ignition sequence to proceed

Safety Function

If the mechanical draft fails or a blockage occurs, the switch will open, shutting down the burner

The mechanical draft blower motor is equipped with a differential pressure switch. If the required pressure differential is not sensed, the switch will not close and the burner cannot operate, because the switch is interlocked with the burner.

Combustion Safety Controls

A combustion safety control is used to shut down the burner if it malfunctions. The combustion safety control monitors firing to make sure that ignition occurs and that the flame remains on when there is a call for heat.

Flame Sensing

Monitors presence of flame during operation

Ignition Verification

Confirms successful ignition during startup

Safety Shutdown

Stops gas flow if flame issues detected

Automatic Reset

Most systems attempt restart after temporary failures

Troubleshooting Furnace Systems

The gas technician/fitter must be able to successfully troubleshoot electrical problems in order to fix a forced-air furnace. To do this it is necessary to be able to read electrical wiring diagrams.

Testing supply voltage, amperage draw, 24-V systems, thermocouple systems, and flame rectification is detailed in Unit 12 Basic electricity for gas fired equipment and in Unit 13 Controls: Fundamentals.

Note that faults with mechanical parts of the furnace may impact on the electrical components, and faults with electrical components of the furnace may impact on the mechanical parts. The gas technician/fitter must take this into account when troubleshooting a furnace.

Troubleshooting Electrical Problems

Observe the Furnace

Compare to the customer's description of the problem

Read the Electrical Drawing

Determine the sequence of operation

Identify Problem Circuit

Test for voltage at its load

Conduct Voltage Tests

Work around the circuit to locate the problem

Verify Findings

Check against known normal values of resistance, pressure, temperature, etc.

Replace and Test

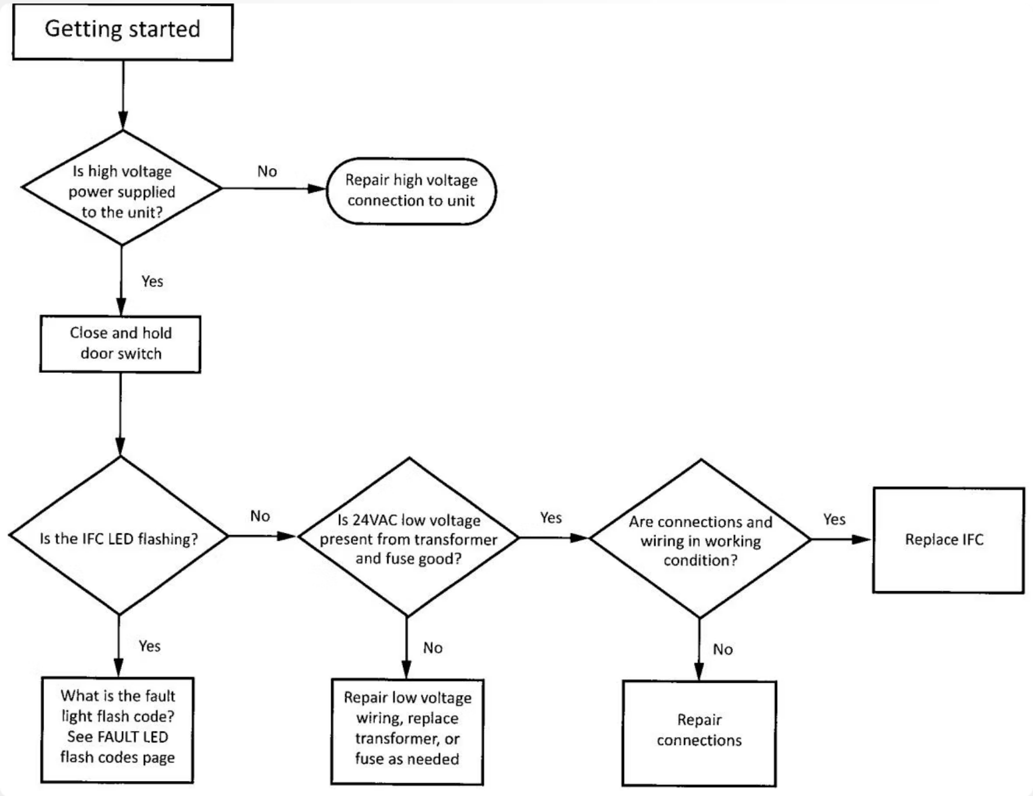
Replace the faulty device and observe operation

Common Furnace Faults and Corrections

Fault	Symptom	Correction
Low gas pressure	Pilot goes out when the main burner valve is energized	Check supply and piping system
Open thermostat	No noise or action from the furnace; Fan comes on when manual switch activated	Check for loose connections; burned heat anticipator
Inoperable draft inducer motor	Motor is warm; Slight humming sound; No other action	Check for obstruction or low voltage; Replace if necessary
Open transformer winding	Transformer is cool; Fan comes on when manual fan switch activated	Check with ohmmeter; Determine cause of failure; Replace

More Furnace Faults and Corrections

Fault	Symptom	Correction
High-limit inoperable when fan fails	Burners do not shut off when fan is disabled	Check electrical connections; Replace if necessary
Unit cycles off high-limit	Fan is running constantly; Burners cycle on-off and an open high-limit switch is verified with voltage test	Correct air flow problem; Check for oversized furnace or undersized ductwork
Rollout or spillage switch activated	Symptoms depend on manufacturer's electrical design	Determine cause of rollout
Erratic fan cycling	Fan cycles on-off during burn period and/or runs for a very short period after burners de-activate	Set fan-off setting so plenum temperature is 90-100°F (32-38°C)



Troubleshooting Flow Chart

Most furnace manufacturers offer troubleshooting solutions in their literature. The image shows an example of a troubleshooting flow chart that guides technicians through a systematic process to identify and resolve furnace issues.

These flow charts typically start with the most common or basic issues and progress through more complex possibilities, helping technicians efficiently diagnose problems without missing important steps in the troubleshooting process.

Understanding Low-Efficiency Furnace Operation

Thermostat Call

Thermostat contacts close to complete the control circuit

Gas Valve Activation

Gas valve is energized and opens

Ignition

Gas is ignited at the burners by the standing pilot

Heat Exchange

Heat from the exchanger operates the combination high-limit/fan control

Air Circulation

Fan motor is energized and indoor blower circulates warm air

Mid-Efficiency Furnace Operation

1. ### Thermostat Call
   Thermostat contacts close to complete the control circuit
2. ### Control Module Activation
   Control circuit energizes the control module through the "25V" terminals
3. ### Ignition Sequence
   Module energizes flame sensor, igniter, and main gas valve; proves and monitors flame
4. ### Fan Operation
   Fan switch closes after sufficient heat is generated; blower distributes warm air
5. ### Cycle Completion
   Run cycle continues until call for heat is satisfied; blower runs until fan switch opens

High-Efficiency Furnace Operation

Thermostat Signal

R-W contacts close on the thermostat sending 24VAC to the W low voltage terminal of the IFC

Self-Check and Inducer Start

IFC performs self-check routine, confirms pressure switch is open and limit switch is closed, then energizes the vent motor

Pressure Switch and Ignition

Pressure switch closes, hot surface ignitor warms up, gas valve is energized, and flame sensor confirms ignition

Blower and Accessory Operation

After 45 seconds, indoor blower starts, followed by humidifier and electronic air cleaner activation if applicable

Cycle Completion

When thermostat is satisfied, gas valve closes, inducer stops, and blower continues to run to remove residual heat

Two-Stage Furnace Operation

A two-stage furnace is an option that may help eliminate the kind of rapid warming that many people find uncomfortable from a single-stage furnace as it incorporates a longer, slower heating cycle.

Control System

Uses a proprietary algorithm in the IFC programming to allow the furnace to initiate second-stage input when needed. The control circuit includes:

- A two-stage gas valve
- A 2nd stage inducer relay for the multi-speed inducer
- A multi-speed indoor blower motor

Operation Sequence

The furnace starts in first stage for initial heating. If the thermostat continues to call for heat after a predetermined time, or if the temperature differential is large, the system activates second stage for increased heating capacity.

Note: 2nd stage heating cannot operate without 1st stage operation.

Modulating Furnace Operation

A modulating furnace is an advanced option that provides the most precise temperature control. This design will fully modulate between approximately 40 and 100% of capacity in 1% increments.

Startup Sequence

Typically, the furnace lights at approximately 65% capacity

Modulation Control

Will modulate up or down based on thermostat feedback and proprietary algorithm

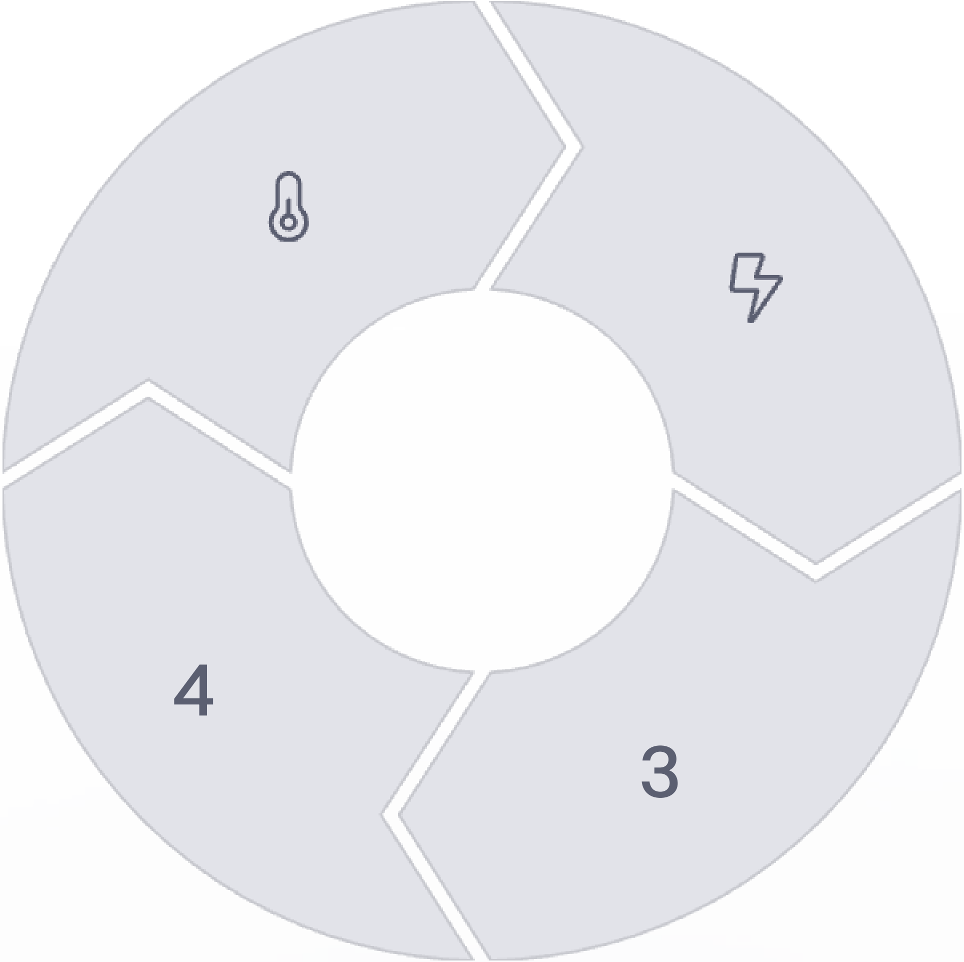
Gas Control

Uses a modulating gas valve for precise fuel delivery

Air Movement

Employs variable speed inducer and indoor blower motors that adjust to demand

Temperature-Actuated Fan Control



Heating Cycle Begins

Thermostat calls for heat, gas valve opens, burner fires

Heater Activation

24-V heater starts heating temperature-activated switch

Fan Start

After about 40 seconds, switch closes and fan starts

Cycle End

Thermostat satisfied, power to heater stops, fan runs until switch cools

Timer-Actuated Fan Control

Call for Heat

Thermostat contacts close

Burner Ignition

Gas valve opens, furnace fires

Timer Starts

Electronic timer begins "timed on" period

4

Fan Activation

At end of timed setting, fan comes on

5

Heating Ends

Thermostat satisfied, gas valve closes

Fan Off Timer

Timer starts "timed off" cycle

7

Fan Stops

At end of timed cycle, fan turns off

Calculating Furnace Airflow

Manufacturers specify temperature rise and maximum external static pressure (ESP) for their furnaces. The gas technician must select a fan speed that maintains the temperature rise within the manufacturer's parameters.

Use the Formula

CFM = (Btu/h output) ÷ (1.08 × temperature rise)

Check Manufacturer Tables

Reference CFM vs. temperature rise tables if available

3

Select Blower Speed

Choose appropriate speed tap based on required CFM and ESP

4

Verify Performance

Perform ESP test to confirm proper operation

Example: For a 72,000 Btu/h output furnace with a 55°F temperature rise, the calculation would be: CFM = 72,000 ÷ (1.08 × 55) = 1,212 CFM

Thermostat Applications for Modern Furnaces

Single-Stage Applications

Single-stage furnace using a single-stage thermostat

Single-stage furnace with single-stage cooling

Two-Stage Applications

Two-stage furnace with single-stage cooling using a single-stage thermostat

Two-stage furnace with single or two-stage cooling using a two-stage thermostat

Advanced Applications

Modulating furnace using a smart thermostat

Modulating furnace combined with single speed cooling or heat pump

Special Configurations

Twinning two single-stage furnaces using a single-stage thermostat

Wi-Fi enabled programmable thermostat with remote monitoring

Limit Switch Safety Functions

Prevent Overheating

Stops burner if air temperature exceeds safe limits

Prevent Fire Hazards

Shuts down system before dangerous conditions develop

Indicate System Problems

Activation signals underlying issues requiring attention

Limit switches are used as safety controls to prevent runaway temperatures that can cause a fire hazard. If a limit control functions to shut off the burner, the condition should be assessed to determine the cause and corrective action taken.

Rollout Switch Safety Function

Purpose and Function

The rollout switch senses problems in the flow of combustion products that could lead to flame rollout. These problems may be caused by:

- Blockages in the heat exchangers
- Blockages in the flue
- Failure of a combustion air blower
- Failure of an exhaust blower

Operation and Safety

The rollout switch is a normally closed, snap disc type or capillary type switch located on the burner shield. When high temperatures are sensed, the switch opens, breaking contact to the burner control system.

A flame rollout safety switch must never be jumped. If the switch shuts down the furnace, the cause must be identified and corrected before resetting the system.

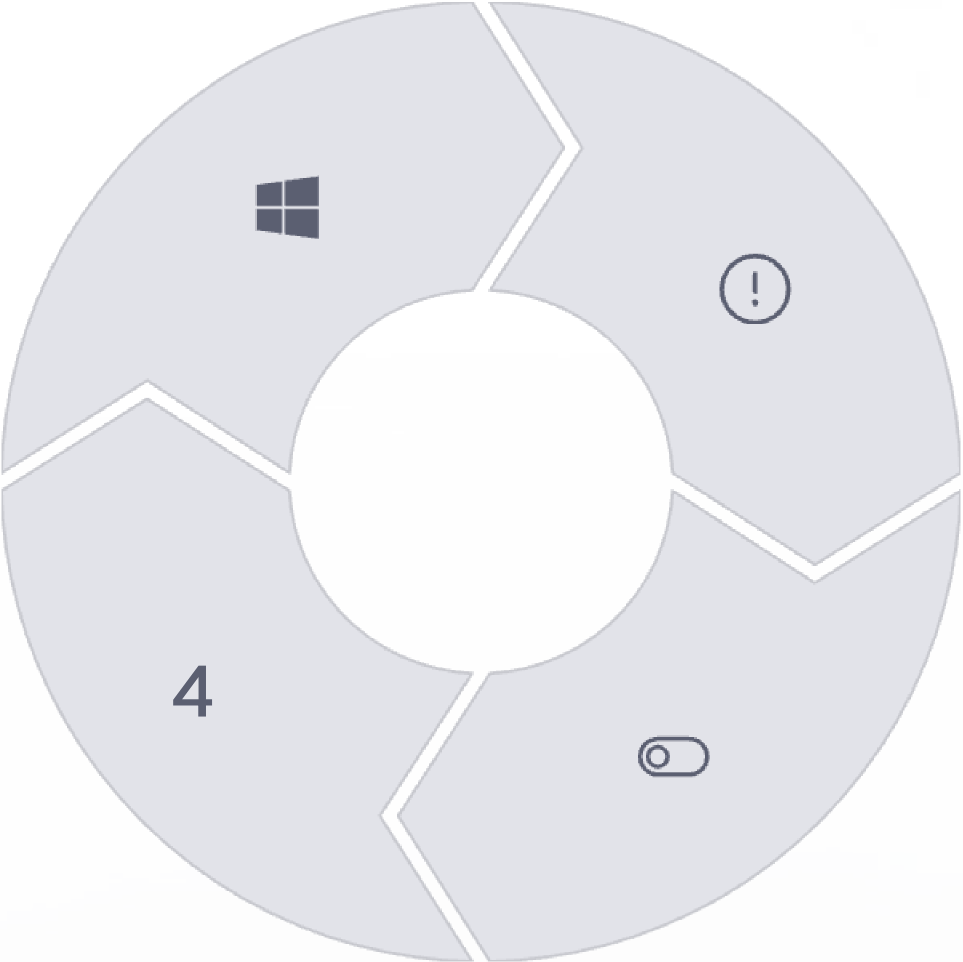
Vent Pressure Switch Operation

Normal Operation

Proper venting maintains normal pressure

Blockage Occurs

Obstruction in vent causes pressure change



System Shutdown

Gas valve closes, preventing unsafe operation

Switch Activates

Pressure switch detects abnormal condition

In furnaces without a power venter, the switch is normally closed and opens on high pressure. In mechanically drafted systems, the switch is normally open and closes when proper draft is established.

Integrated Furnace Control (IFC) Functions

Flame Safety Control

Monitors ignition and flame presence

Circulating Fan Control

Manages blower timing and speed

Inducer Control

Regulates draft motor operation

Safety Sensor Monitoring

Processes input from limit and pressure switches

Self-Diagnostics

Provides error codes for troubleshooting

System Coordination

Integrates all furnace operations

Furnace Airflow Considerations

0.50	40-70°F	1.08
Maximum ESP	**Temperature Rise**	**Calculation Constant**
Typical maximum external static pressure (inches w.c.)	Typical manufacturer's specified range	Used in CFM formula (derived from air properties)

A typical furnace is designed to operate at a maximum of 0.50 inch w.c. external static pressure. The gas technician must select a fan speed that maintains the temperature rise within the manufacturer's parameters while not exceeding this ESP limit.

Furnace Airflow Selection Process

Calculate Required CFM

Use formula or manufacturer's tables to determine needed airflow

Reference Speed Tables

Check manufacturer's data for your specific furnace model

Select Speed Tap

Choose appropriate connection based on required CFM and ESP

Measure Temperature Rise

Verify actual temperature difference is within specifications

Check Static Pressure

Confirm ESP is below maximum allowable value

Furnace Safety Circuit Integration

Primary Safety Controls

High-limit and rollout switches

Airflow Safety

Pressure switches and inducer monitoring

Combustion Safety

Flame sensors and gas valve control

Electronic Monitoring

IFC self-diagnostics and error detection

Modern furnaces integrate multiple layers of safety controls that work together to prevent unsafe operation. These systems are designed with redundancy to ensure that if one safety mechanism fails, others will still protect the home and occupants.

Evolution of Furnace Control Technology

Electro-Mechanical Era

Simple controls with standing pilots and mechanical switches

2

Electronic Control Introduction

Mid-efficiency furnaces with electronic ignition and basic circuit boards

3

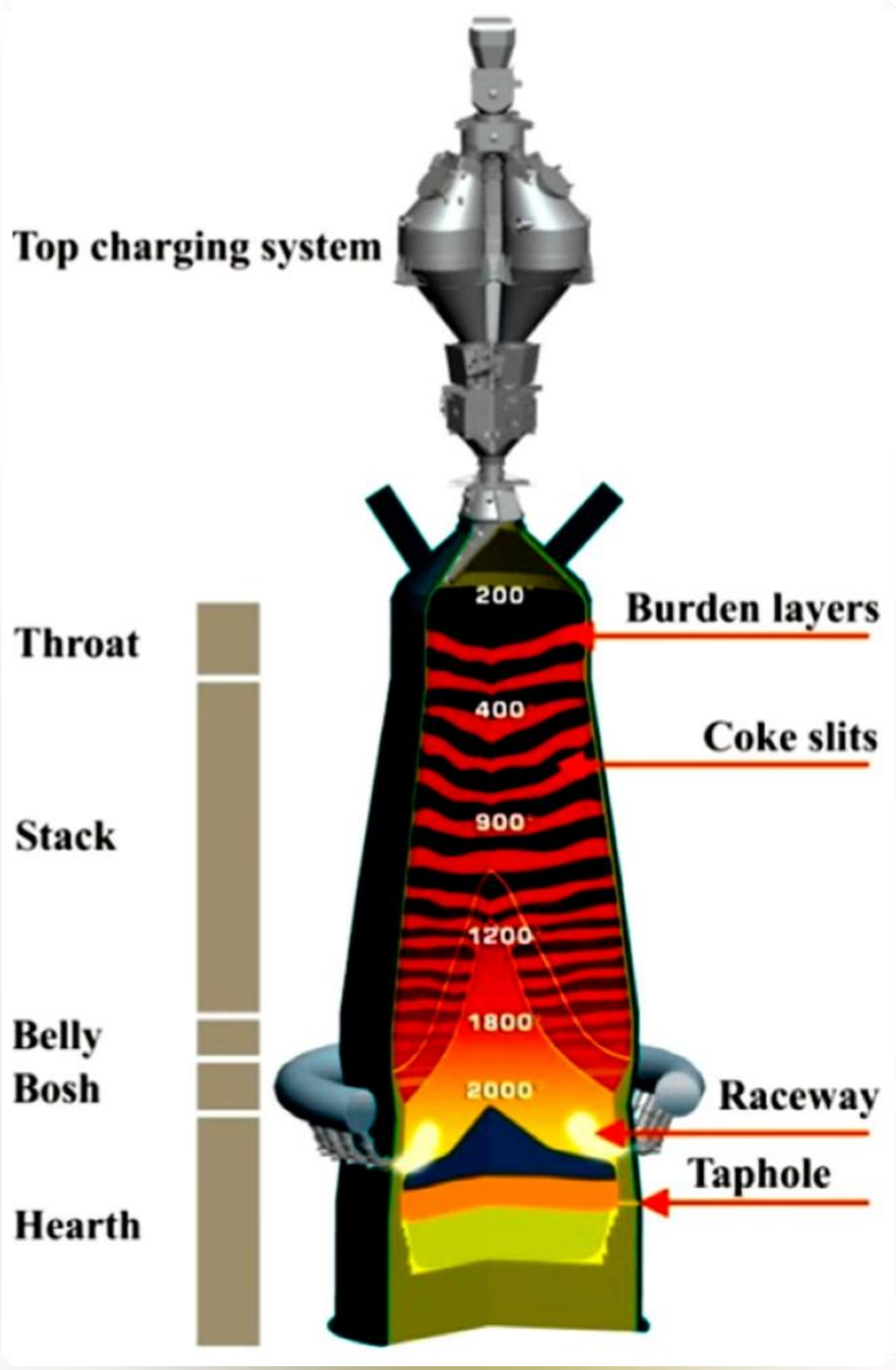
Integrated Control Systems

High-efficiency models with comprehensive IFC modules

Smart Connected Systems

Modern furnaces with remote monitoring and advanced diagnostics

As furnace technology has evolved, the components that control operation have improved dramatically, from simple electro-mechanical controls to sophisticated electronic systems that optimize performance and safety.



Furnace Maintenance and Troubleshooting Best Practices

Regular Inspection

Check all safety switches, electrical connections, and control components annually

Systematic Diagnosis

Follow manufacturer's troubleshooting guides and flow charts when problems occur

Proper Testing

Use appropriate tools to measure voltage, resistance, pressure, and temperature

Documentation

Record all maintenance and repairs, including error codes and corrective actions

Effective furnace maintenance and troubleshooting requires a thorough understanding of both the mechanical and electrical components and how they interact. Always prioritize safety and follow manufacturer guidelines when servicing equipment.

Summary: Electrical Circuits and Components in Gas Furnaces

Evolution of Technology

From simple electro-mechanical controls in older furnaces to sophisticated electronic systems in modern high-efficiency models

Control Circuits

Electrical components that determine when and how the furnace operates, controlling the blower and firing sequence

Safety Circuits

Critical components that prevent unsafe operation by monitoring temperature, pressure, and proper combustion

Troubleshooting Skills

Gas technicians must understand these circuits and be able to use diagnostic equipment to identify and resolve issues

Understanding the operation of control and safety circuits in both older and modern furnaces is essential for proper installation, maintenance, and troubleshooting of gas-fired heating equipment.