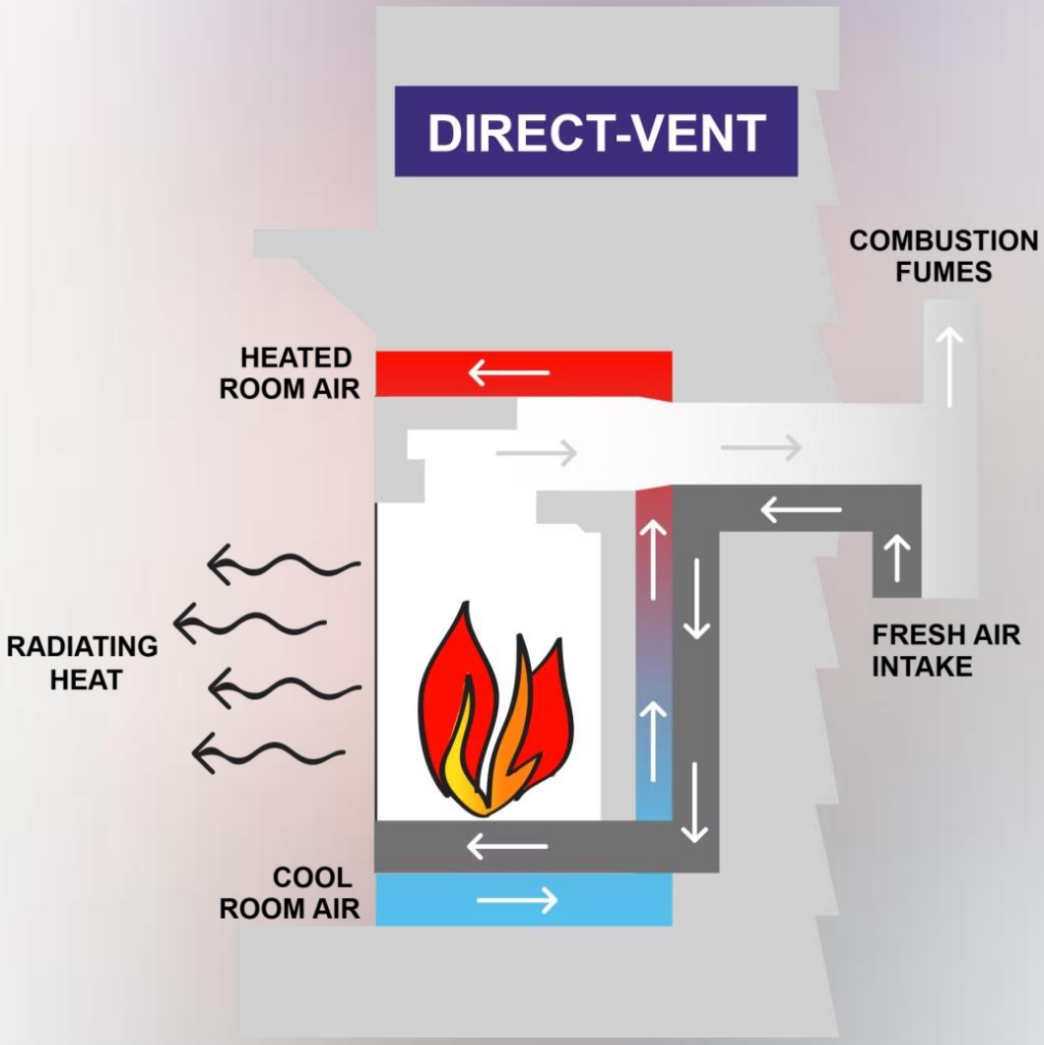
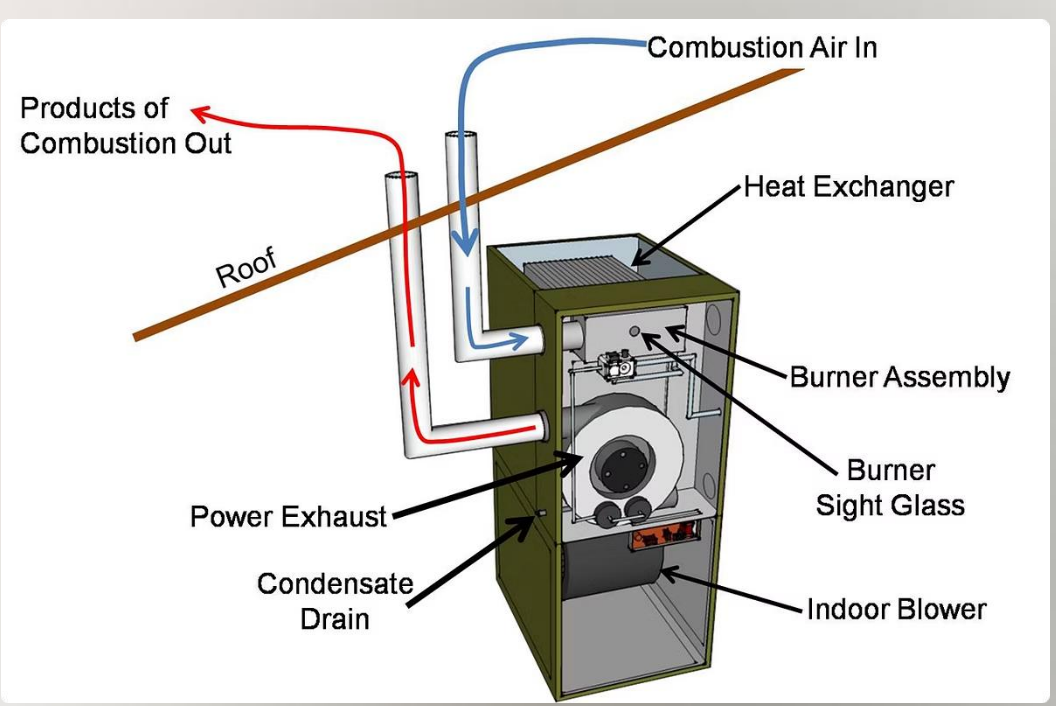



# CSA Unit 9 – Intro to Gas Appliances
# Chapter 1 Venting Systems for Gas Appliances

Venting is the removal of combustion gases and excess air from an appliance to the outdoors and the supply of fresh air to the burner to replace the exhausted air. The vented products vary from innocuous gases that result from complete combustion to toxic gases that result from incomplete combustion. The most important use for venting is to exhaust the combustion products safely to the outside atmosphere without spillage and without water vapour condensing in the appliance or vent unless they are designed for condensing. The use of natural draft, mechanical draft, or a combination of both may help achieve venting.

Created

MK **by Mike Kapin**




# Purpose of a Venting System

## Removal of Flue Gas

Safely removes products of combustion to the outside atmosphere, including carbon dioxide, water vapor, nitrogen, and carbon monoxide.

## Prevention of Condensation Damage

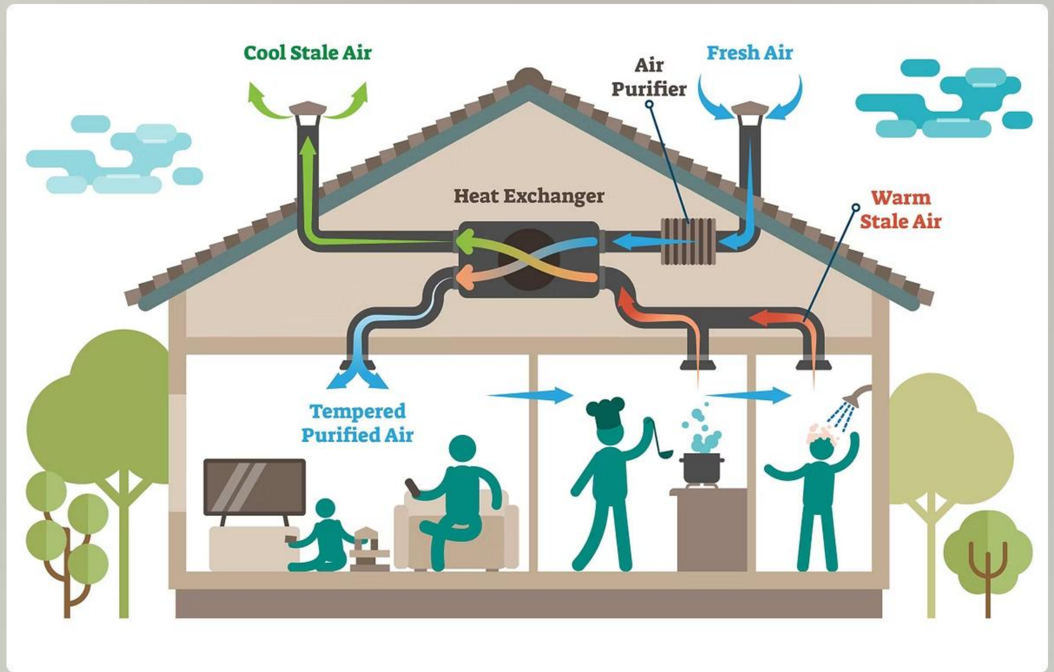
Prevents corrosion inside heat exchangers, flue passages, and vent pipes when water vapor condenses at low temperatures.

## Protection from Fire Hazard

Ensures proper vent material, installation method, and clearance to combustibles to prevent fires from high-temperature flue gases.

## Supply of Fresh Air

Provides essential fresh air to the burner for proper combustion and venting as flue gases exit the appliance.




# Historical Context of Venting

1 **Early Dwellings**

Early peoples built fires at the center of their dwellings and ventilated smoke through a hole in the roof. Ventilation air entered and exited through doors, windows, and other unsealed openings.

2 **Traditional Buildings**

As buildings evolved, more sophisticated heating systems and cooking facilities were developed, requiring more complex venting systems.

3 **Modern Construction**

Today, people spend more time indoors in virtually airtight buildings, requiring advanced venting systems for safety and efficiency.


# Problems Associated with Venting Systems

### CO2 Spillage

Spillage of $CO_2$ inside the building, resulting in potentially serious health effects for the occupants due to reduced levels of oxygen.

### Water Vapor Damage

Spillage of water vapour inside the building, resulting in damage to the building structure.

### CO Poisoning

Spillage of CO, if incomplete combustion is occurring in the appliance, resulting in CO poisoning of the occupants.

### Combustion Issues

Combustion problems that result from the failure to remove the products of combustion from around the flame, which allows fresh combustion air to enter the combustion chamber and results in incomplete combustion of carbon monoxide, soot, and potentially, extinguishing of the flame.

# More Venting System Problems

## Condensation Damage

Condensation of acidic water vapour inside the appliance and/or vent, resulting in damage to the equipment if the appliance and vent are not designed for this condensation.

## Reduced Efficiency

Reduced efficiency of the heat transfer, if removal of the products of combustion occurs at a faster rate of flow than originally designed, resulting in longer cycles and higher heating costs.

## Flame Roll-out

Fire hazards that result from flame roll-out from the combustion chamber due to the failure to provide the proper flow rate of air and flue gases out of the appliance from startup to shutdown of the burner operation.

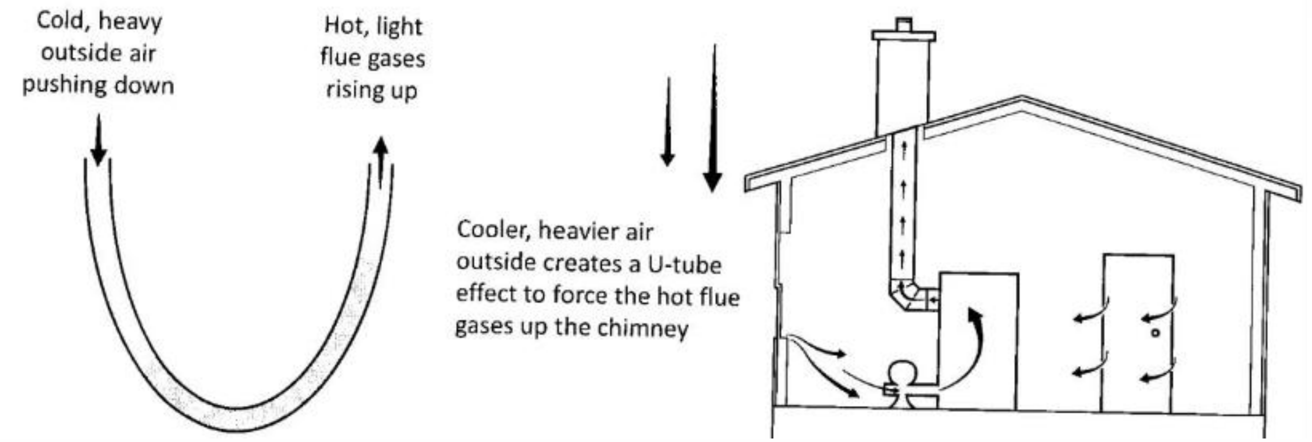
## Combustible Material Ignition

Fire hazards that result from the vent material raising the temperature of combustible material to the point of ignition or drying out the combustible material to the point that it easily ignites.

# Natural Draft Venting System

Natural draft primarily occurs due to the pressure difference between the hot air and gases in a chimney or vent and the cooler, heavier air outside the chimney or vent. The difference in pressure causes the hot gases to rise, thus producing a suction effect in the heat exchanger. This is sometimes what you call thermal draft.

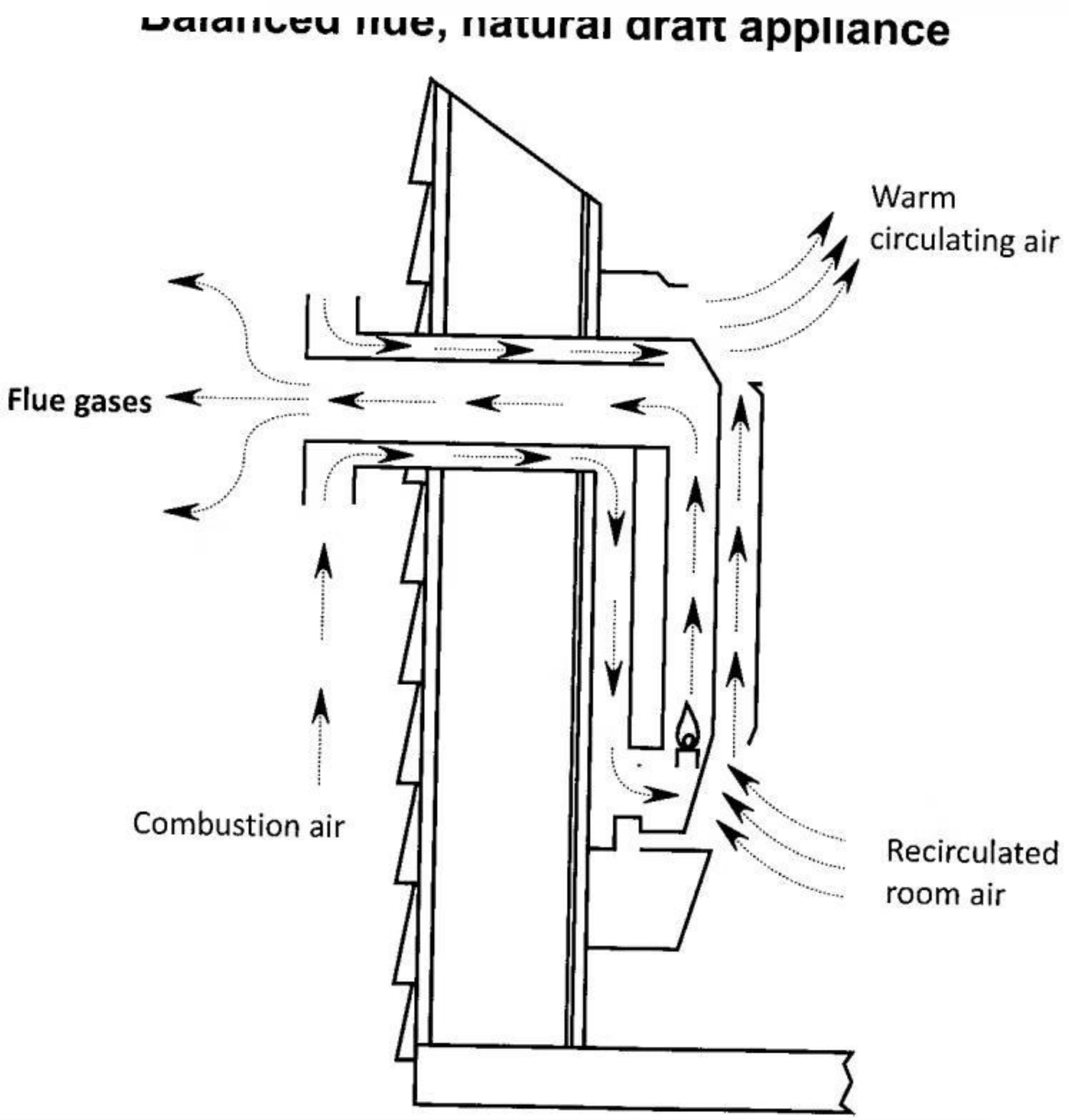
Category 1 appliances that have a negative vent pressure and are less than 83% efficient most commonly use natural draft. These appliances are vented into properly lined chimneys or factory-built vents.




Conventional natural draft venting principles rely on the natural tendency of hot gases to rise. This creates a pressure differential that draws combustion products up through the venting system.

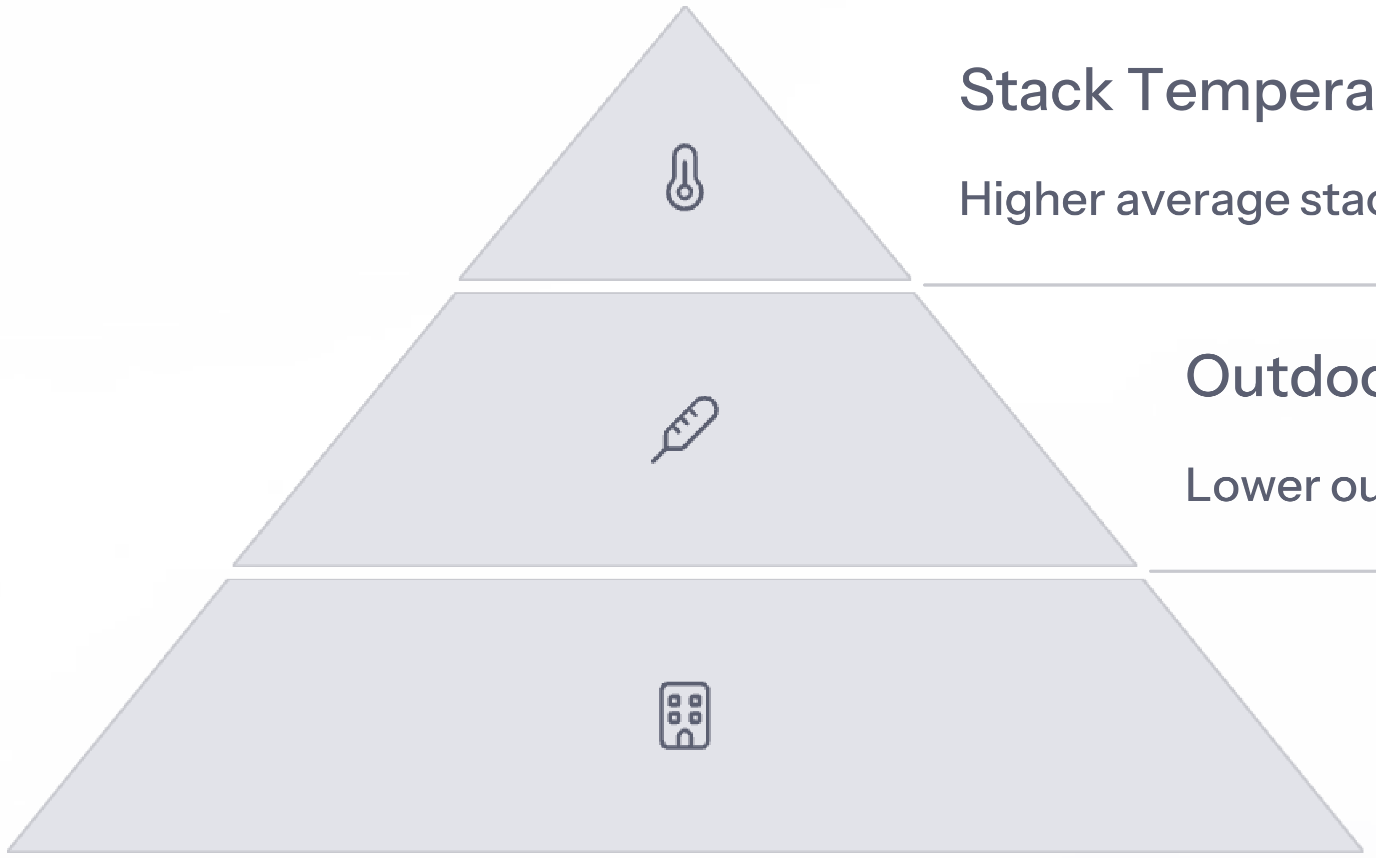
# Balanced Flue Natural Draft Appliances

Balanced flue, direct vent appliances vented into special venting systems that are designed and approved for use with the specific appliance also employ natural draft venting. Although the vent pressure may be slightly negative, the flue gas temperature is well above the dew point temperature (approximately 127-130°F) that would otherwise cause the water vapour to condense.




In both the conventional and balanced flue types of natural draft venting systems, the use of a mechanical device is not necessary to remove flue gases from the appliance to the outdoors.

# Factors Affecting Natural Draft Venting Systems



### Stack Temperature

Higher average stack temperature increases draft

### Outdoor Air Temperature

Lower outdoor temperature increases draft

### Stack Height

Greater stack height increases draft

The quantity of theoretical draft in a stack, measured in inches of water column or in pascals, is directly proportional to the absolute temperature difference between the stack gas and its surroundings, and to the height of the stack. Note that draft does not directly depend on the diameter of the stack.

# Factors Under Technician Control

## Heat Transfer Efficiency

Affected by excess air, heated medium temperature, flow rate, and heat exchanger cleanliness

## Vent Material

Higher insulating value maintains stack temperature throughout travel to outdoors

## Vent Diameter

Proper sizing ensures effective removal of flue gases while maintaining temperature

## Vent Configuration

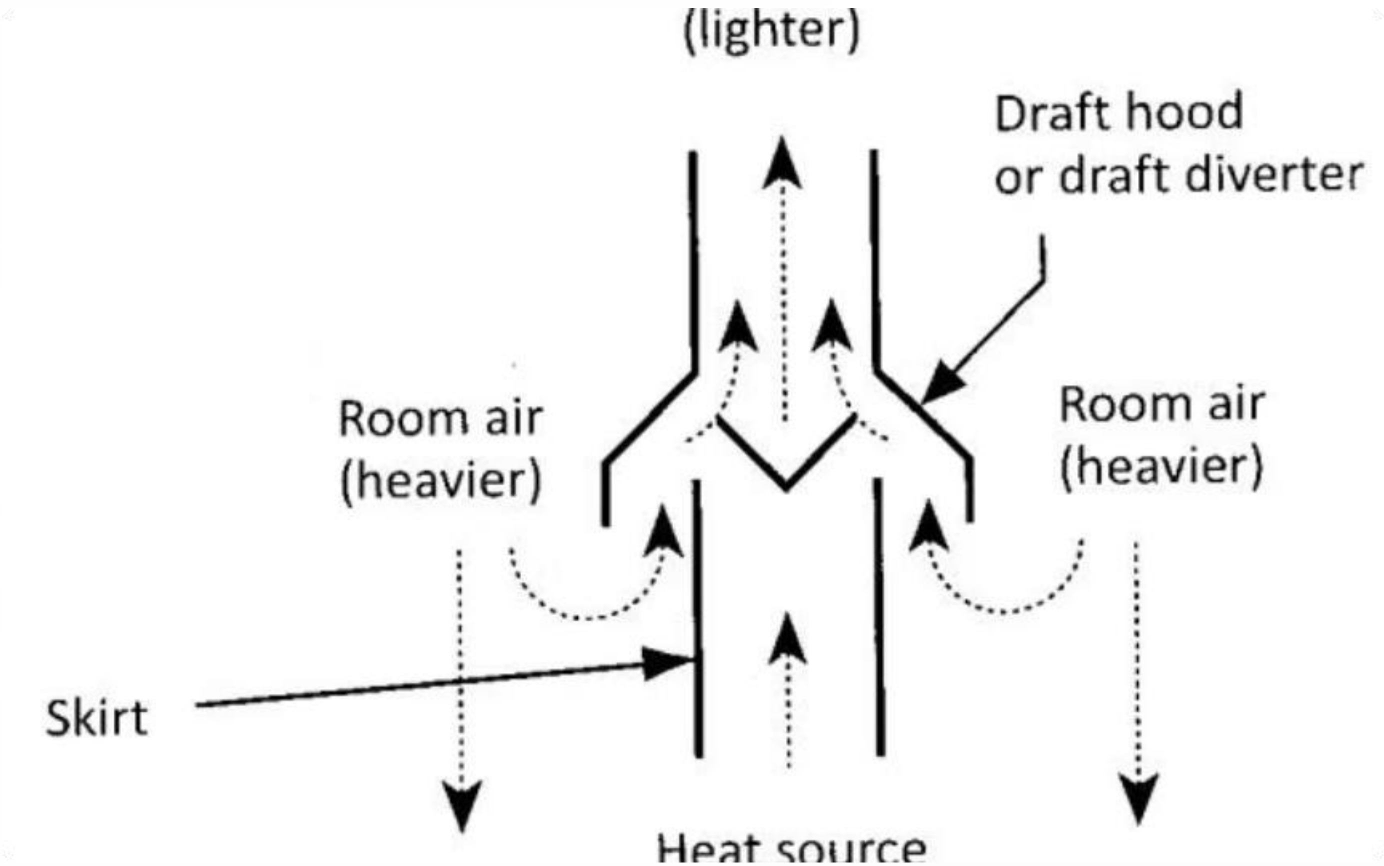
Minimizing resistance to flow by reducing lateral lengths and changes in direction

## Vent Location

Proper placement minimizes heat transfer through vent material

# Draft Control Equipment

For proper venting and combustion efficiency, you must control the amount, and force, of the draft. A draft that is too strong pulls in too much combustion air, thus reducing efficiency. A draft that is too weak smothers the flame and reduces the combustion efficiency. Draft control equipment is therefore an essential part of a natural draft venting system.





## Draft Hood

Many domestic gas burners are of the atmospheric type and require a neutral over fire draft in the combustion chamber. The draft hood maintains this neutral pressure over the fire by allowing dilution air into the venting system.

## Barometric Damper

Used on gas appliances that operate with a controlled negative over fire draft in the combustion chamber. They regulate dilution air, down-draft, and spillage.

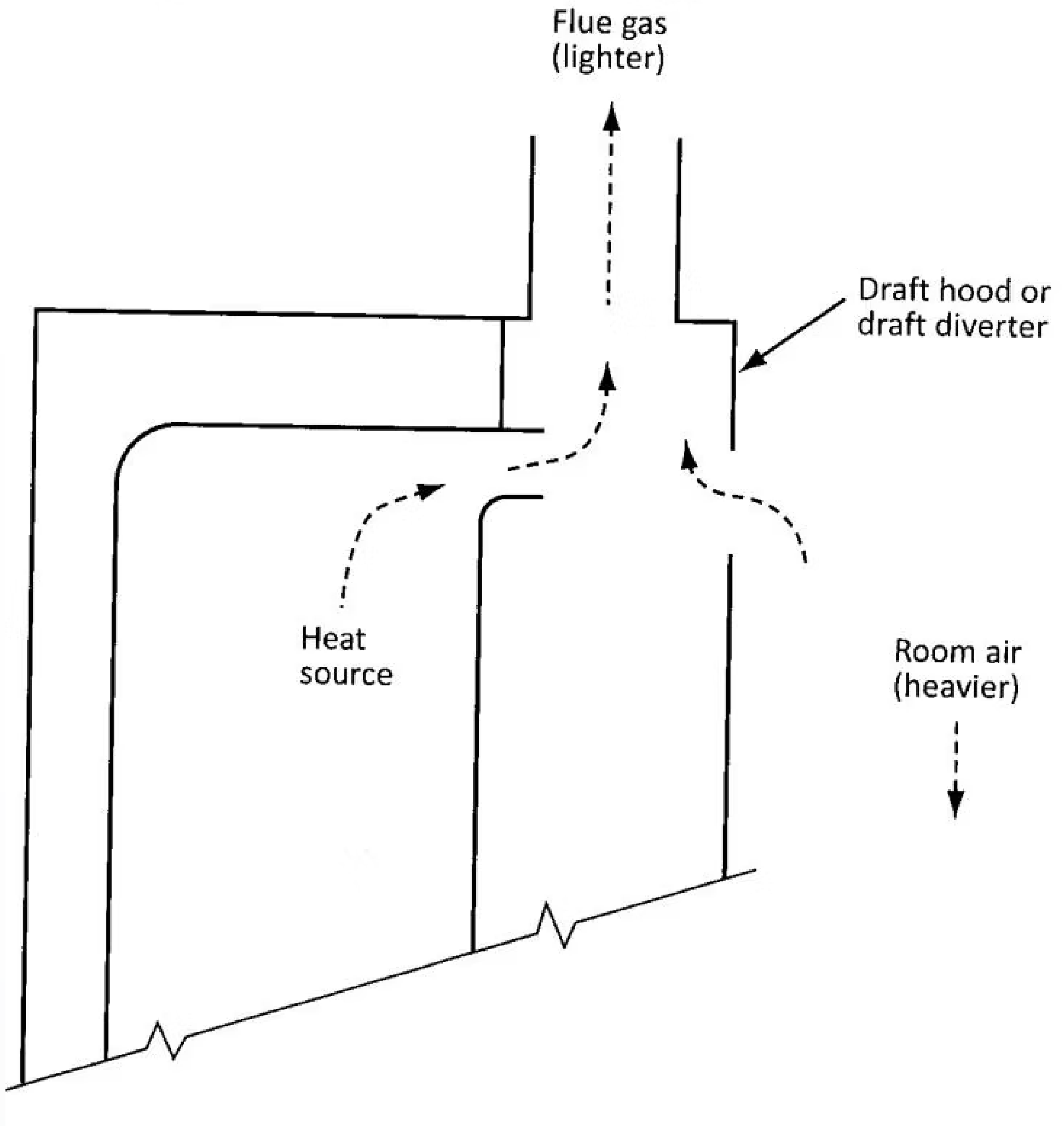
# Draft Hood Function

The draft hood serves several important functions in a natural draft venting system:

- Maintains neutral pressure over the fire
- Prevents excessive negative pressure in the combustion chamber
- Allows dilution air into the venting system
- Decouples the venting system from the appliance

When there is no draft, a back draft, or a blockage beyond the draft hood, the flue gases exit out of the draft hood, causing spillage. When there is an updraft in the venting system, the draft hood permits dilution air to enter the draft hood.

**Operation of a horizontal draft hood**




A hood is either built into the gas appliance or is part of the vent connector. You should never alter or modify one. Installing a different draft hood or altering the skirt length changes the

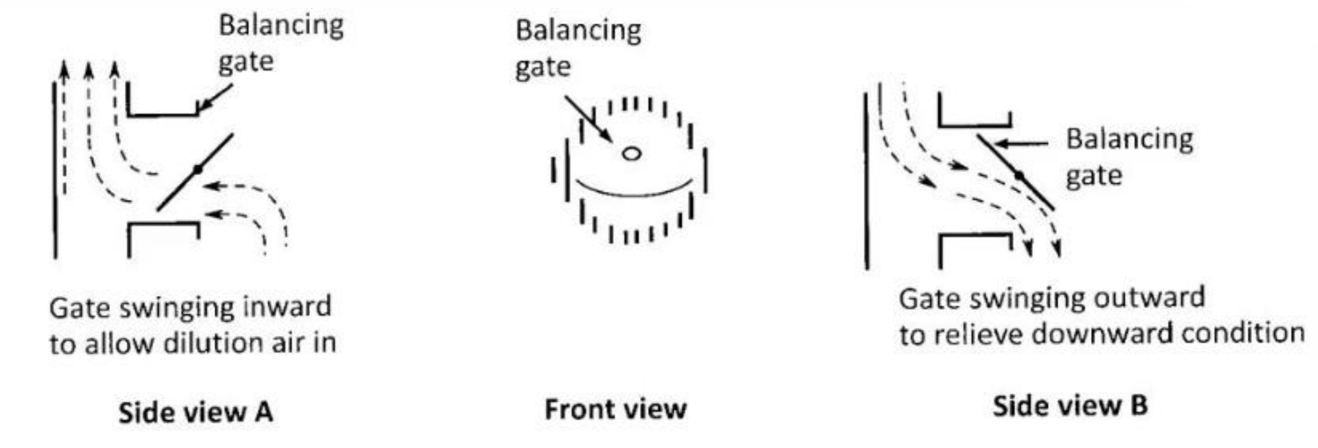
# Barometric Dampers

## Single-Acting Barometric Damper

Has a gate that only swings in to regulate the stack draft and closes shut when a down-draft is present to prevent soot or ashes from entering the room. Not typically used on gas equipment, except in some jurisdictions on gas-fired incinerators.

## Double-Acting Barometric Damper

Can open both inward and outward. Opens inward to regulate dilution air and opens outward to relieve down-draft and spillage.

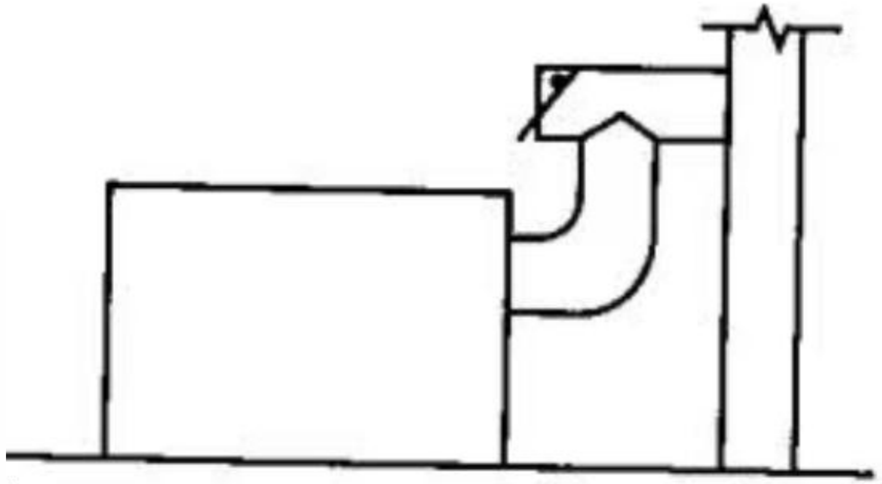


# Location of Barometric Dampers

In a correct installation, the flue gases are not directed toward the gate during normal up draft conditions, but they are so directed during a down draft condition.

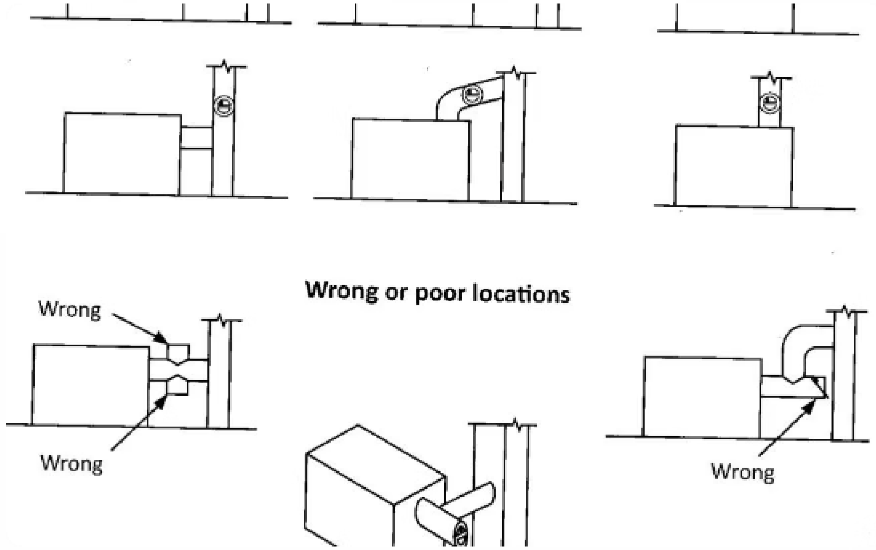

## Correct Installation

Proper positioning ensures effective operation of the barometric damper during both normal and abnormal draft conditions.



## Best Locations for Gas

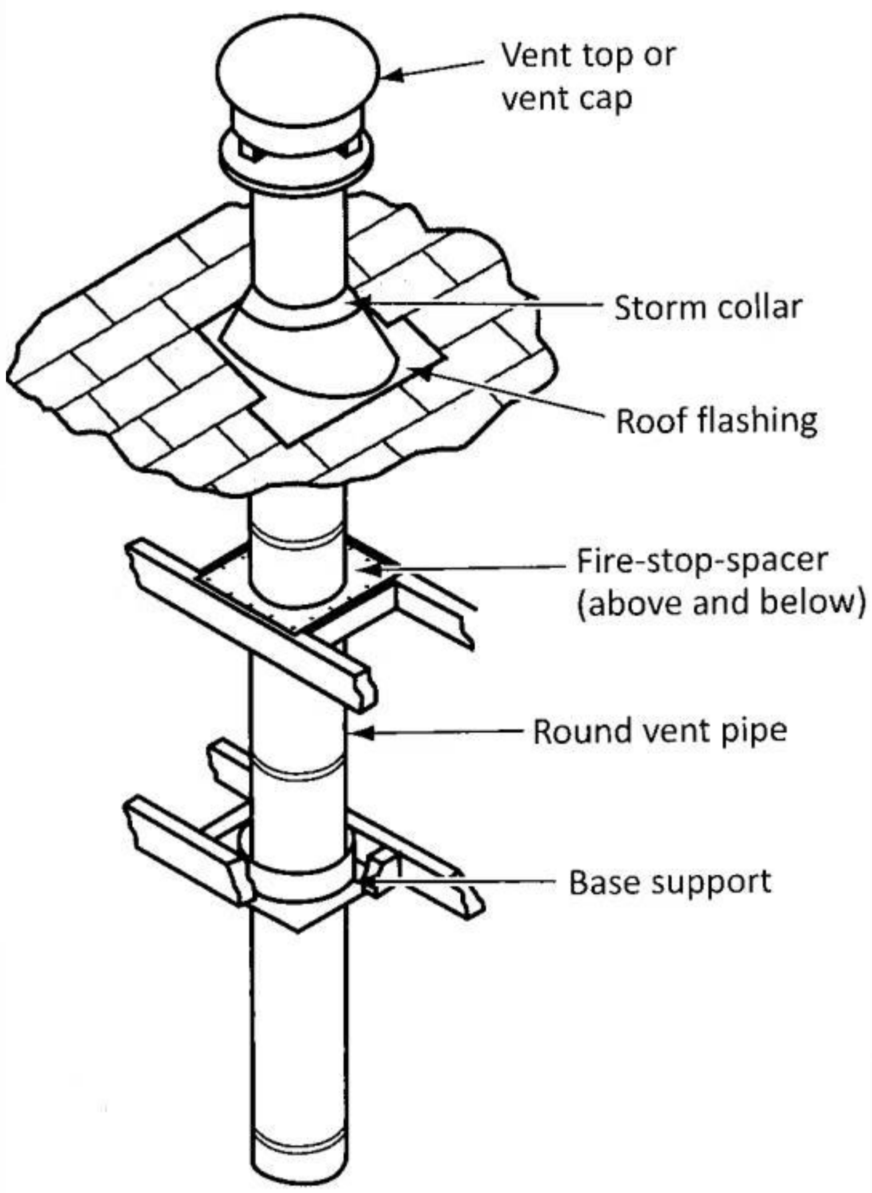
Optimal placement for gas appliance barometric dampers to ensure proper function and safety.




## Best Locations for Oil or Solid Fuels

Recommended positioning for barometric dampers on oil or solid fuel appliances differs from gas applications.

# Components of a Natural Draft Venting System




### Vent Pipe Support

Venting materials must have adequate support to maintain proper clearances. The vent supports must be separate from the appliance since the appliance cannot support the length and weight of its vents.

### Fire Stop Spacer

The fire stop spacer blocks the stack effect during a fire. This helps to contain the fire and prevent it from spreading.

### Roof Flashing

Roof flashings are fitted around the gas vent to prevent rain and snow from entering the vent where it joins the roof.

### Storm Collar

The storm collar is an addition to the roof flashing. It prevents water from following the vent pipe down the roof flashing to seep into the dwelling area.

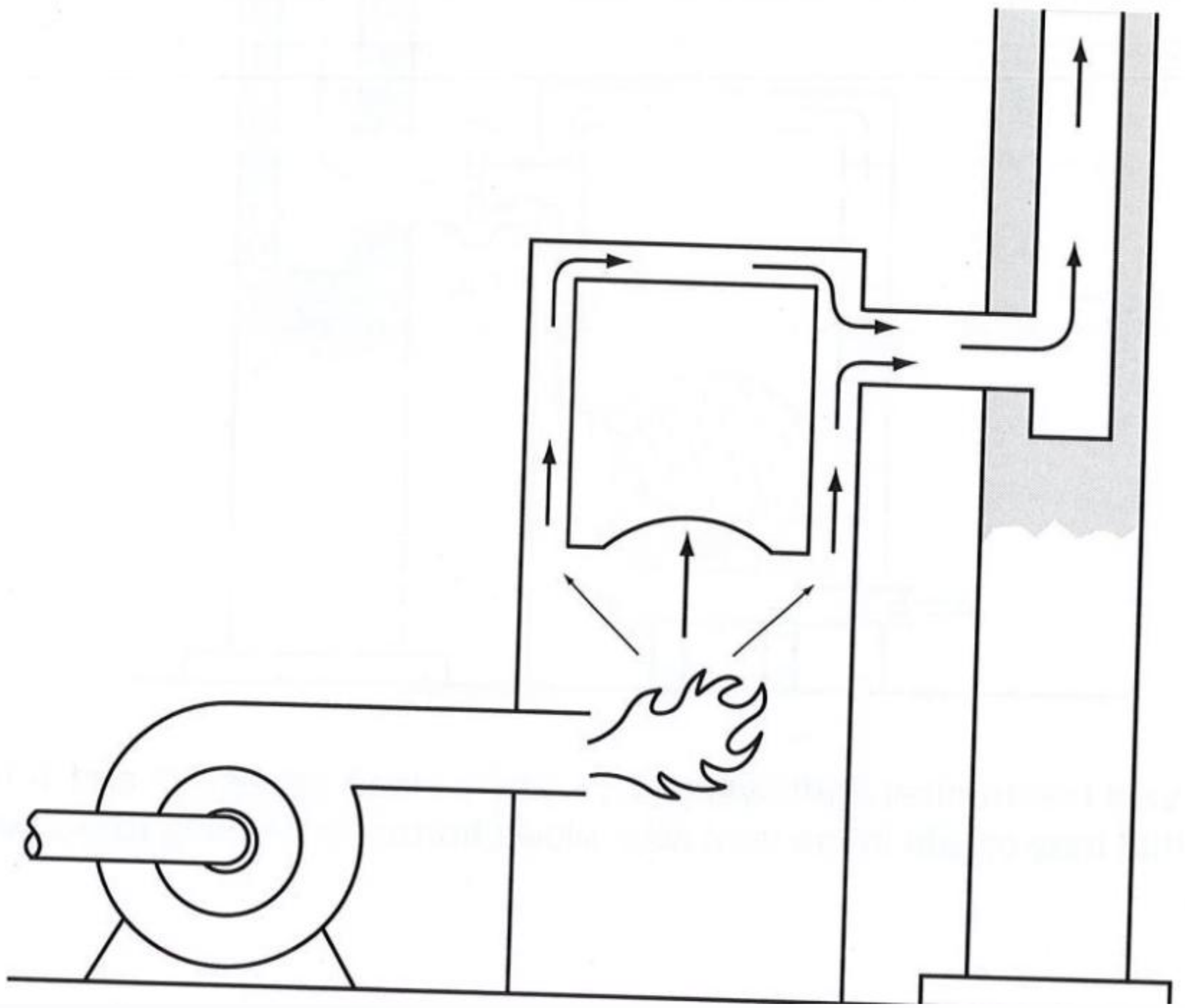
### Vent Cap or Vent Top

The vent cap or vent top prevents weather elements and foreign objects from entering the vent at its external opening. An approved cap or top is also designed to reduce down draft due to wind.

# Mechanical Draft Venting Systems

A mechanical draft is a draft that a fan, blower, or other mechanical device produces. A mechanical draft is either a forced draft or an induced draft.

- A forced draft is a mechanical draft that results from the introduction of air or gas under pressure at the inlet of the appliance.
- An induced draft is a mechanical draft that a device located downstream of the appliance combustion zone produces.



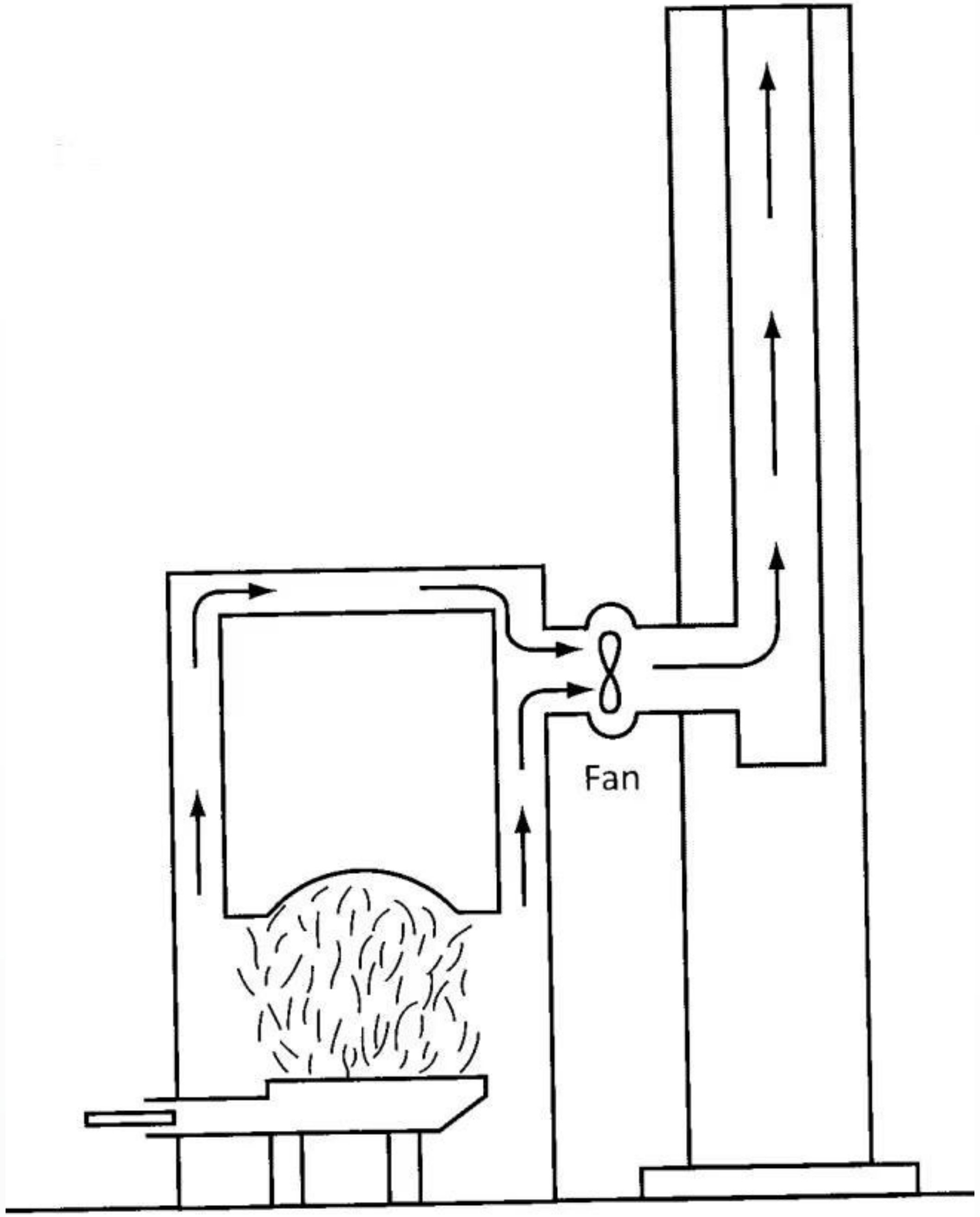
Although mechanical draft systems can be vented vertically, they also allow for horizontal venting to sidewall locations, providing more installation flexibility.

# Mechanical vs. Natural Draft

It is important not to confuse mechanical venting systems with mechanical burner systems—which you may know as forced draft burners or fan-assist burners.

A mechanical device may be used to introduce air into the burner and/or cause the flue gases to pass through the appliance, but this device might not participate in venting. In these cases, the forced draft burner or fan-assist burner depends on a natural draft venting system to move the products of combustion to the outdoors.

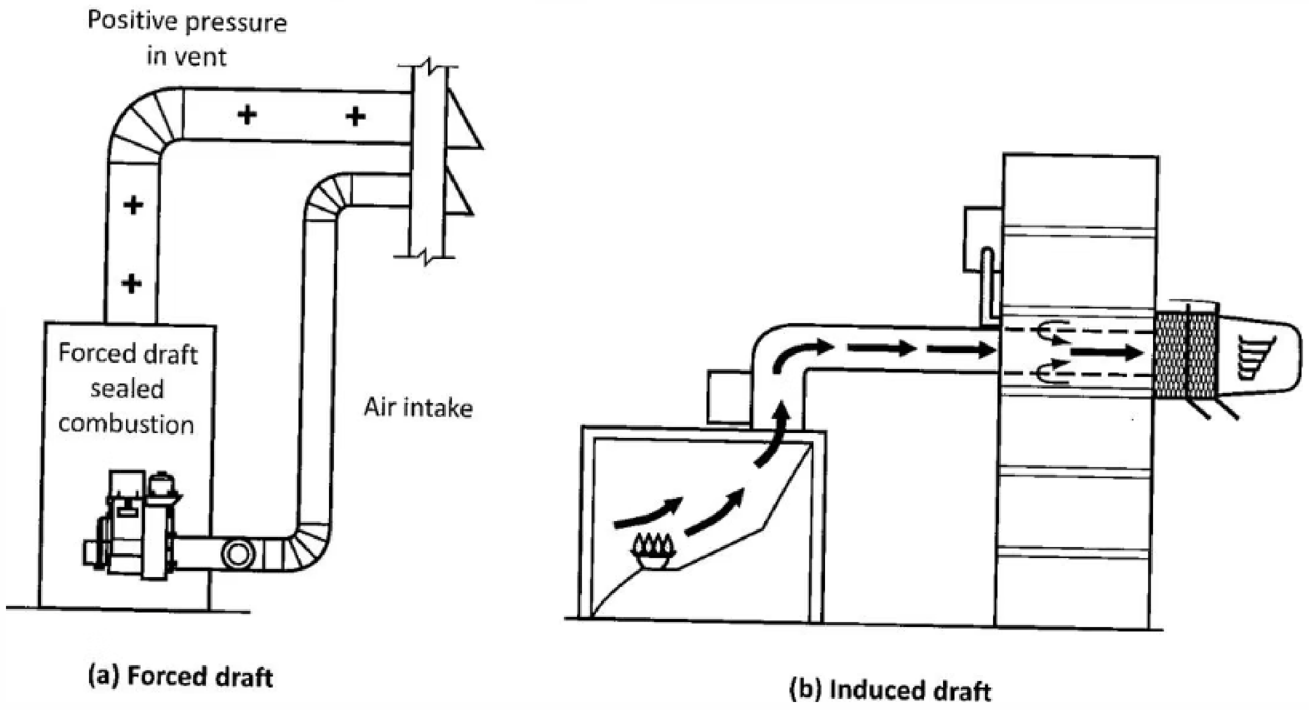
**Figure 1-10**
**Induced draft**



# Sidewall Vented Mechanical Draft Systems

Mechanical draft systems allow for greater flexibility in appliance and vent placement. Unlike natural draft systems that typically require vertical venting, mechanical draft systems can be vented horizontally through sidewalls.

This flexibility is particularly valuable in installations where vertical venting is impractical or impossible, such as in buildings without suitable chimney access or in retrofit applications.

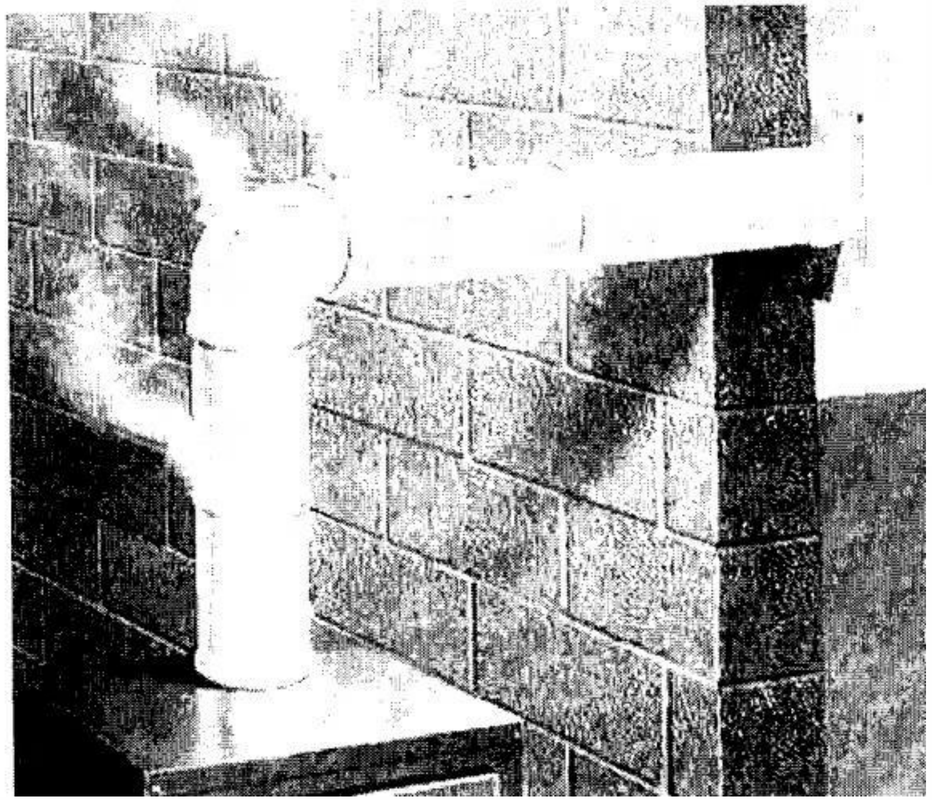



Sidewall venting must be installed according to manufacturer specifications and code requirements to ensure safe operation and prevent issues with flue gas recirculation or building entry.

# Forced Draft Venting Systems

Forced draft venting systems must be completely sealed because the vent pressure is positive from the inlet to the vent termination outside. Any leak or crack in the venting system causes flue gas spillage indoors.

All forced draft systems are special venting systems that are designed and approved with the specific appliance. The appliance manufacturer specifies the type of vent material and the method of installation in its certified installation instructions.

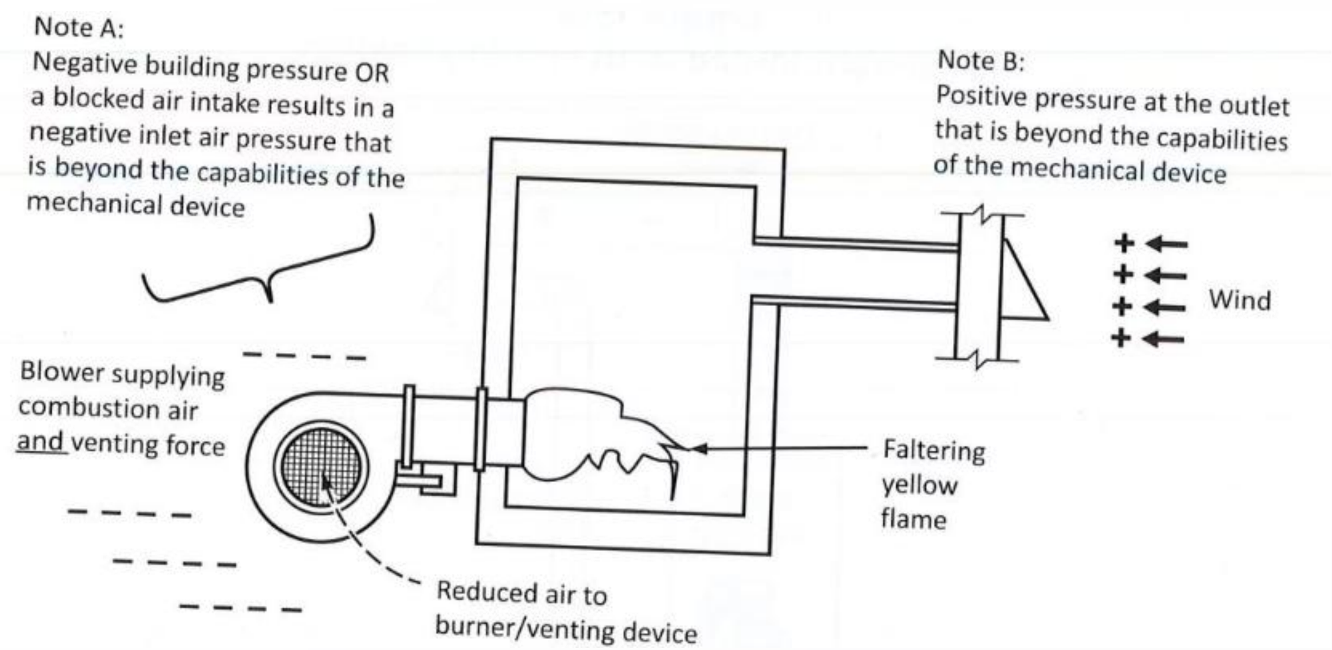


It is critical that the technician/fitter who is installing or maintaining a forced draft venting system read and comply with the manufacturer's instructions as well as applicable code requirements.

# Factors Affecting Forced Draft Venting

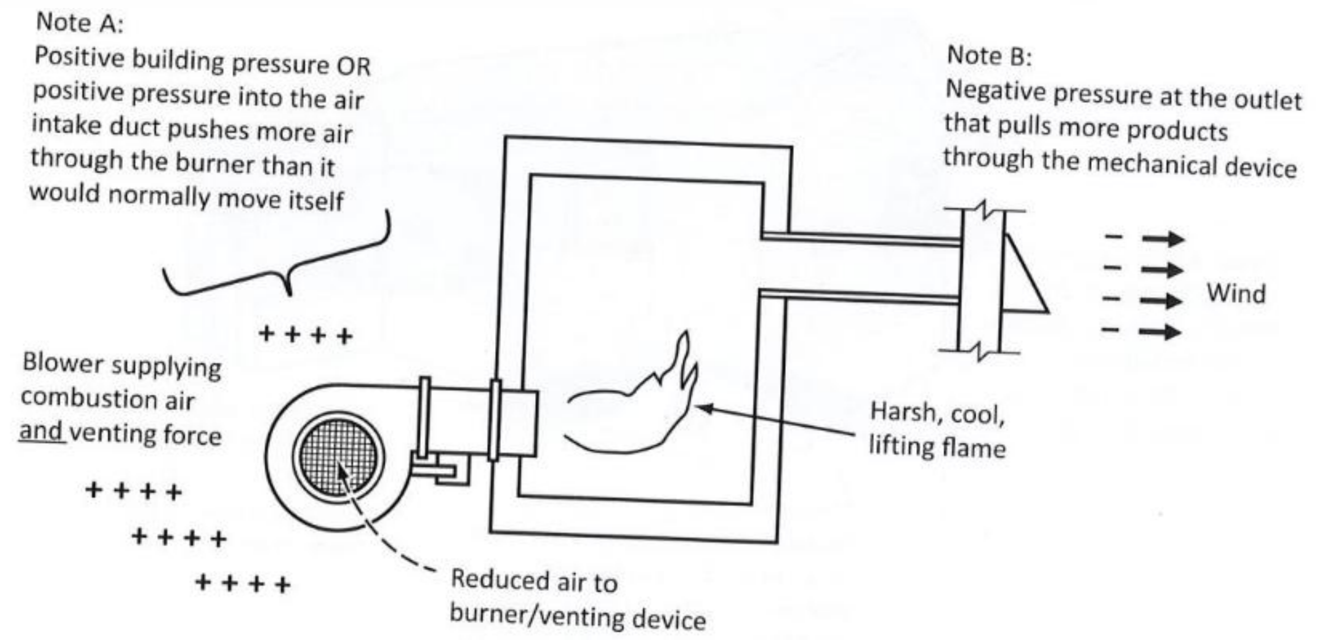
## Reduced Venting Action

If there is insufficient air (caused by a negative building pressure or restriction of the air intake duct or filter to the mechanical device) that exceeds the suction ability of the mechanical venting device, venting action can be reduced, stopped, or reversed. The same problem can occur as a result of positive pressure (caused by wind) at the vent termination.




## Increased Venting Action

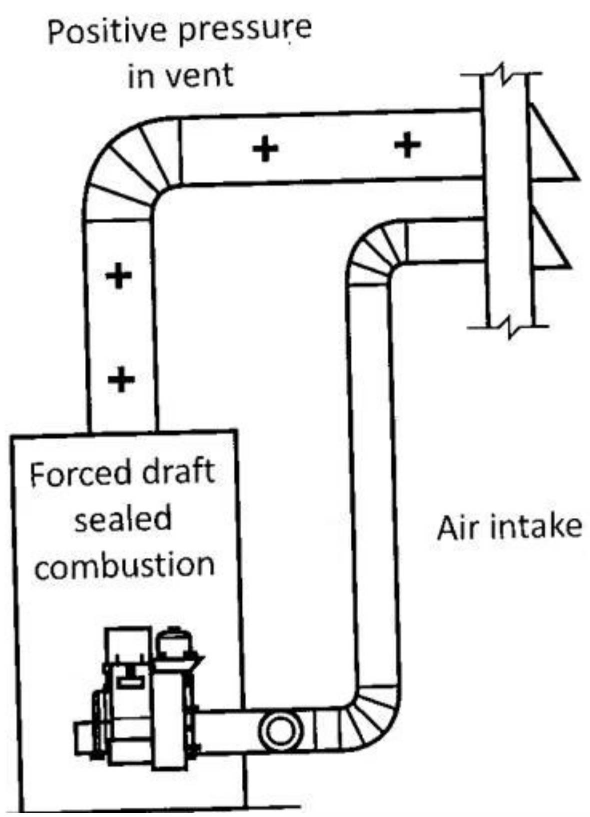
If the inlet pressure is positive (caused by a positive building pressure or suction on the air intake duct) and exceeds the static pressure ability of the mechanical device, venting action can increase. The same problem can occur as a result of negative pressure (caused by wind) at the vent termination.



# Direct-Vent Forced Draft Systems

You can minimize the adverse effects of positive or negative pressures at the burner inlet by employing a direct vent air supply duct if the appliance manufacturer offers this option.

Indoor air pressures that are susceptible to change do not affect a direct-vent forced draft system, making it more reliable in buildings with variable pressure conditions.



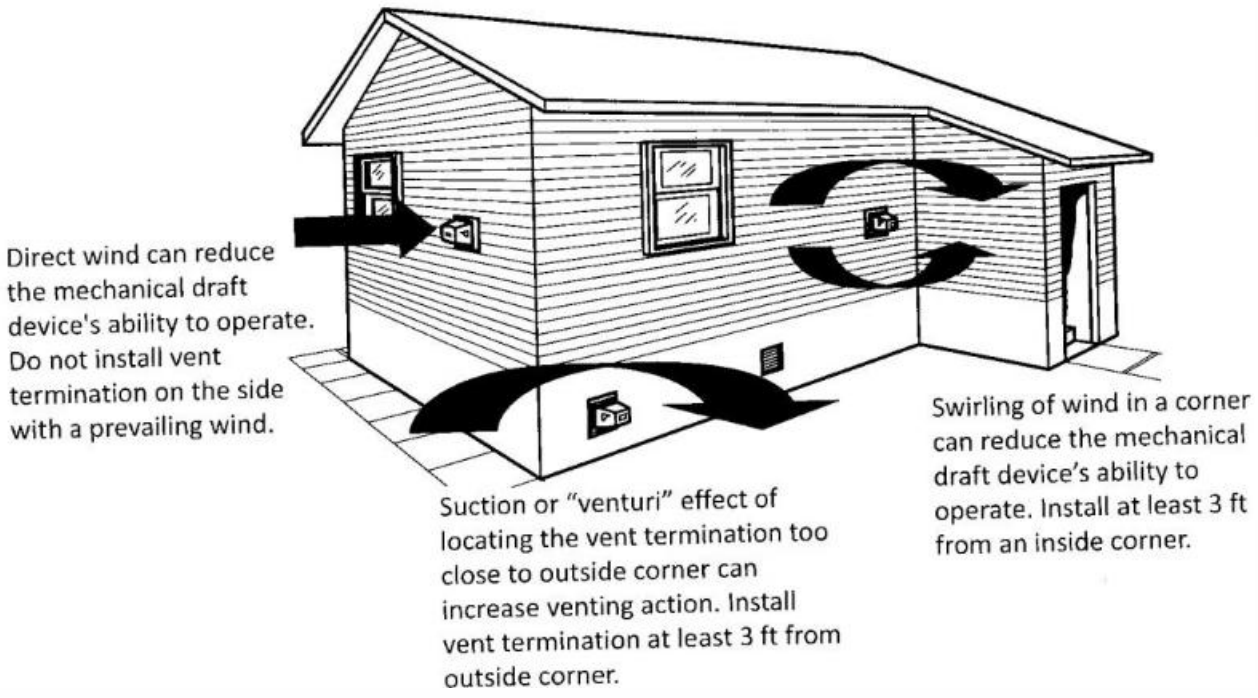

You can minimize the adverse effects of positive or negative pressure at the vent termination by following the manufacturer's instructions regarding the location of the vent termination and the proper vent termination cap.

# Sidewall Vent Termination

Proper positioning of sidewall vent terminations is critical for safe operation of mechanical draft venting systems. The location must comply with both manufacturer's instructions and code requirements.

Key considerations include:

- Distance from doors, windows, and air intakes
- Height above grade
- Clearance from corners, overhangs, and adjacent structures
- Protection from snow accumulation
- Prevention of flue gas recirculation

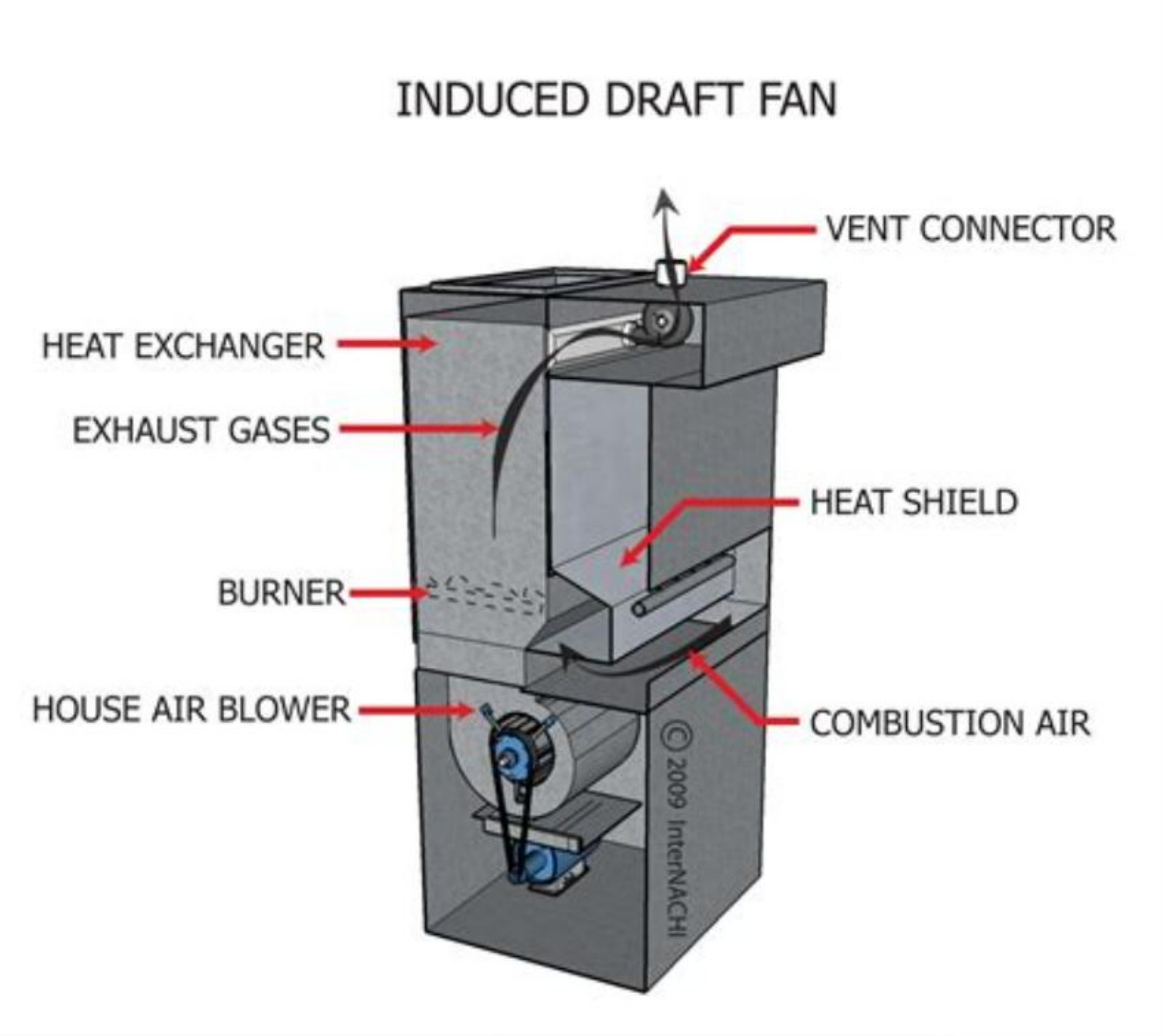



Improper vent termination can lead to serious safety hazards, including carbon monoxide entering the building, damage to surrounding materials, or improper appliance operation.

# Induced Draft Venting Systems

An induced mechanical draft device pulls the products of combustion through the vent. The vent upstream of the device is under negative pressure and, if a vent is installed downstream of the device, it is under positive pressure.

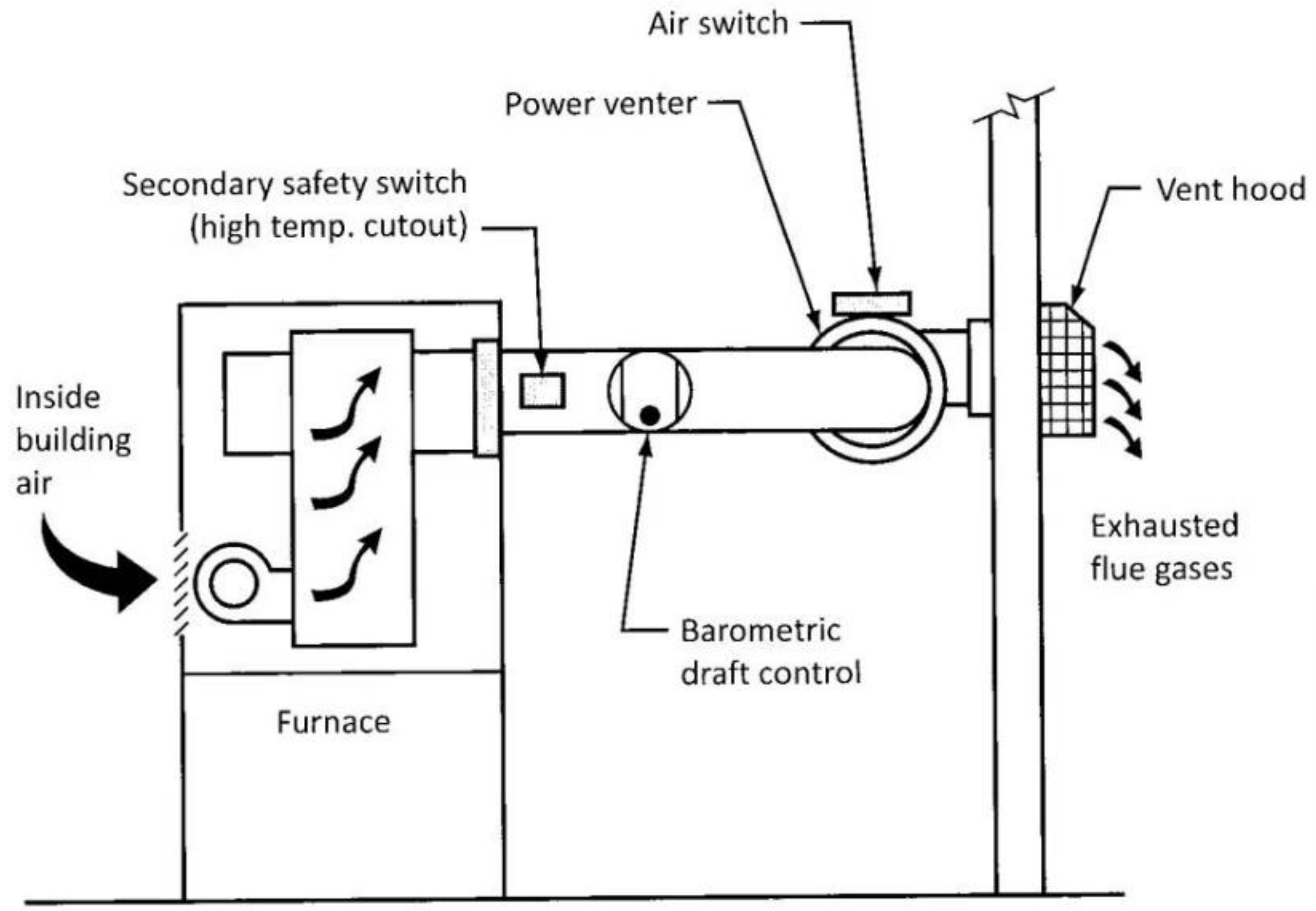
If the mechanical device is at the vent termination, the entire vent is under negative pressure. The appliance may have a draft hood or the vent may need to have a barometric damper. This type of induced draft system is what you often call a power venter.




Power venters provide flexibility in installation and can improve the efficiency and safety of appliances that might otherwise have venting challenges.

# Indoor-Mounted Induced Draft Systems

If the mechanical device is mounted indoors, the pressure upstream (i.e., on the appliance side) is negative and the downstream side (i.e., toward the sidewall) is under positive pressure. You must seal the positive pressure side of the vent system to prevent flue gas leakage indoors.




The induced draft device operates in conjunction with a temperature control device to ensure proper sequencing of operation and safe venting.

# Power Venter Operation Sequence

### Temperature Control Call

The temperature control device, such as a thermostat or aquastat, calls for heat.

### Power Venter Activation

The demand activates a relay that triggers the power venter.

### Pressure Verification

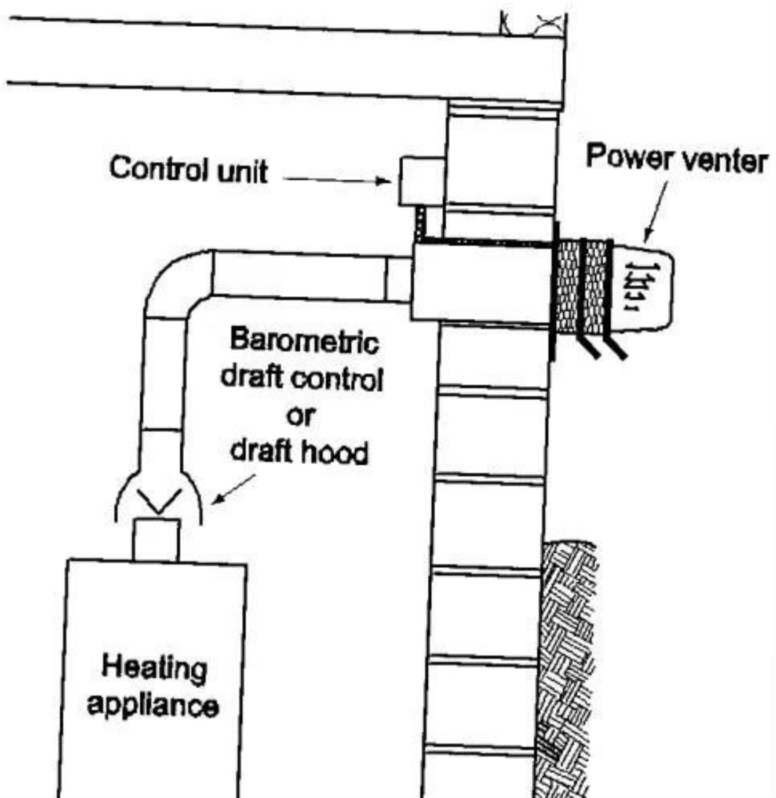
After the power venter has brought the system to a negative pressure, or to the required draft level, the pressure sensing contacts close.

### Burner Ignition

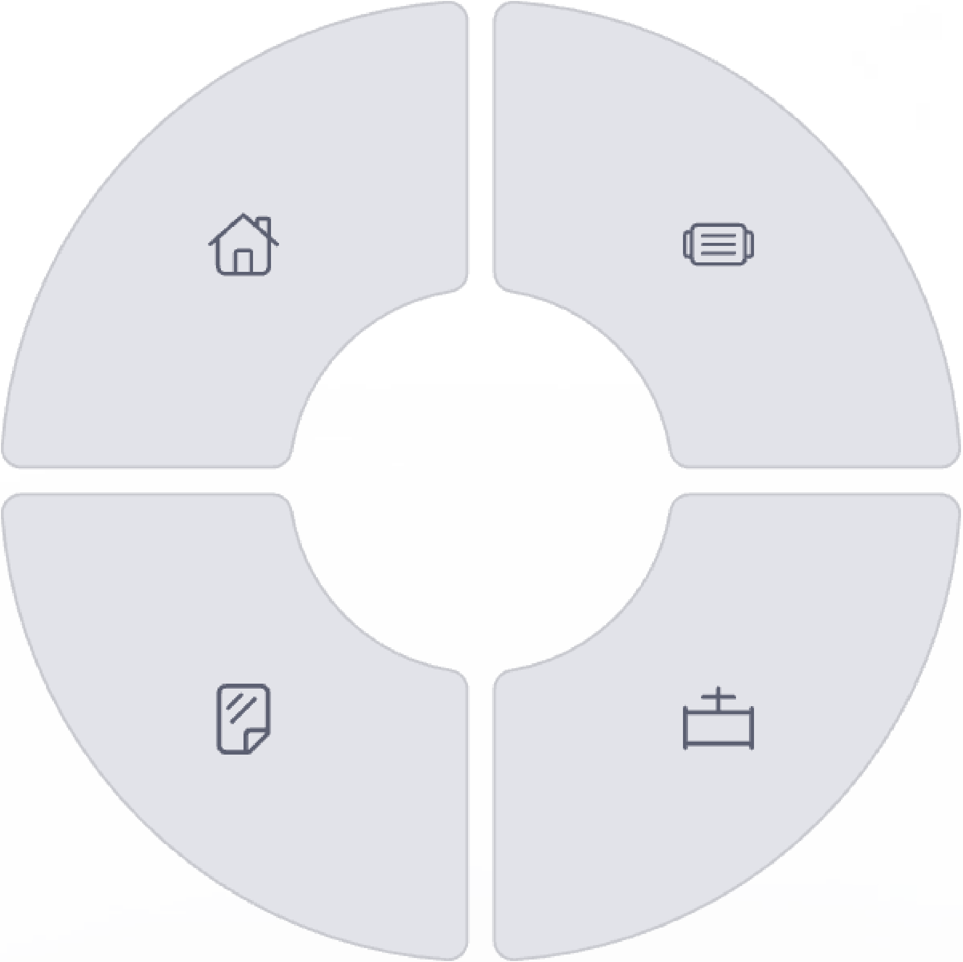
The closed pressure contacts allow the burner to light.

### Shutdown Sequence

Following the satisfaction of the appliance demand, the contacts open and stop the power venter.



# Types of Gas Vents



### Chimneys (Type A)

For high-temperature flue gases, often used with oil or solid fuel appliances

### Type B Vents

Double-wall construction for gas appliances, including BW and L variants

### Type BH Vents

Special metallic or plastic pipe for high-efficiency appliances

### Single-Wall Vents (Type C)

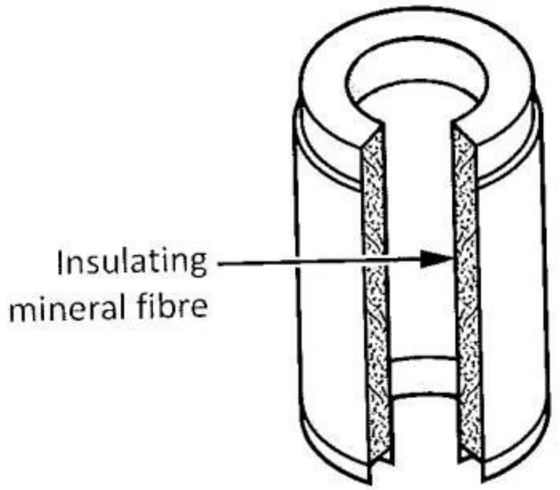
Basic galvanized steel vents with specific clearance requirements

Since there are so many gas fired appliances available, one general type of gas vent is insufficient for all appliance types. CSA B149.1, engineering practices, and manufacturer's specifications determine the type of vent required, along with installation procedures for appliances.

# Chimneys (Type A Vents)

Chimneys help vent oil or solid fuel appliances that have flue temperatures that exceed 470°F (243°C). Because of the high temperatures, these vents are made of such heat-resistant materials as masonry or factory-built insulated metal chimneys.

When solid-fuel or oil appliances are converted to gas-fired appliances that do not produce high temperature flue gases, the existing chimney may need modification to prevent condensation and ensure proper venting.




Manufactured insulated metal chimneys are designed to safely handle high-temperature flue gases while maintaining proper clearances to combustible materials.

# Chimney Conversion Challenges

## Temperature Difference

Solid-fuel or oil appliances produce high temperature flue gases and a strong draft. The temperature that gas-fired appliances produce is not as hot and the draft is drastically reduced to the point where a back-draft may be produced.

## Condensation Risk

Large, cold chimneys require large amounts of heat to warm them enough to stop condensation. Gas-fired appliances may not provide enough heat to prevent condensation.

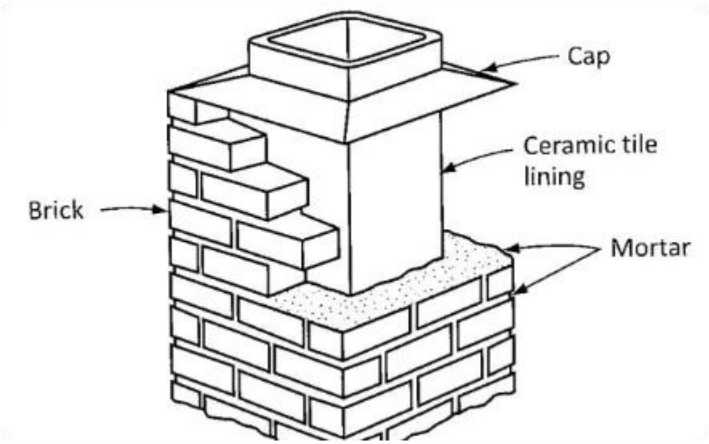
## Corrosion Concerns

Corrosion occurs when the condensed water vapour mixes with carbon dioxide and forms carbonic acid. This acid attacks mortar joints and bricks and accelerates their deterioration.

## Liner Requirement

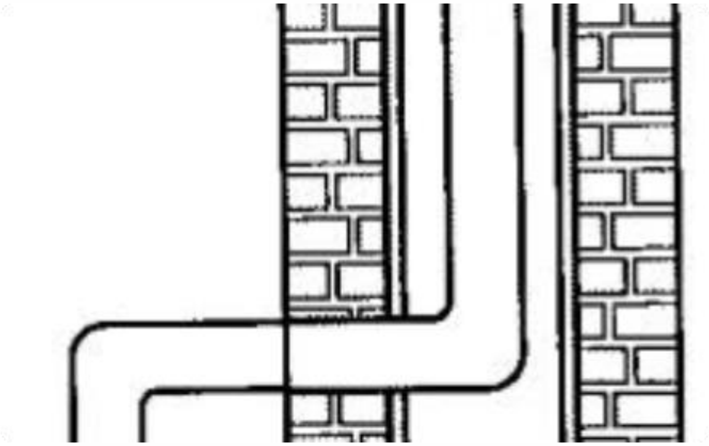
For such reasons, unlined chimneys must be modified. As per CSA B149.1, all chimneys must be lined for use with gas fired appliances.

# Chimney Liner Types



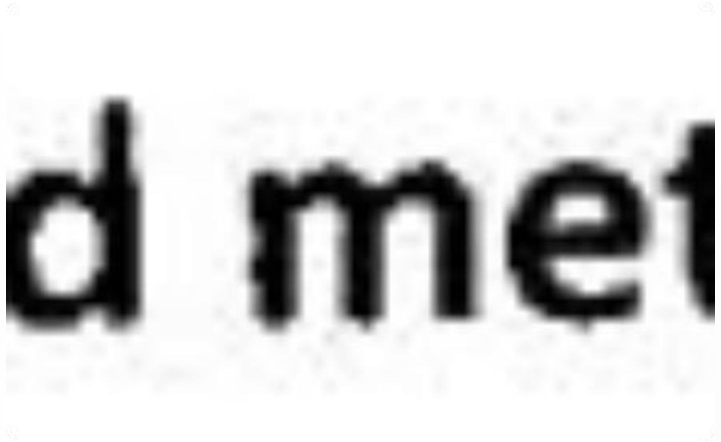

### Clay or Ceramic Tile Liner

Traditional rigid liner material that provides good insulation and durability but can be difficult to install in existing chimneys.



### Rigid Metal Liner

Provides excellent protection against condensation and corrosion, typically made of stainless steel for durability.



### Flexible Metal Liner

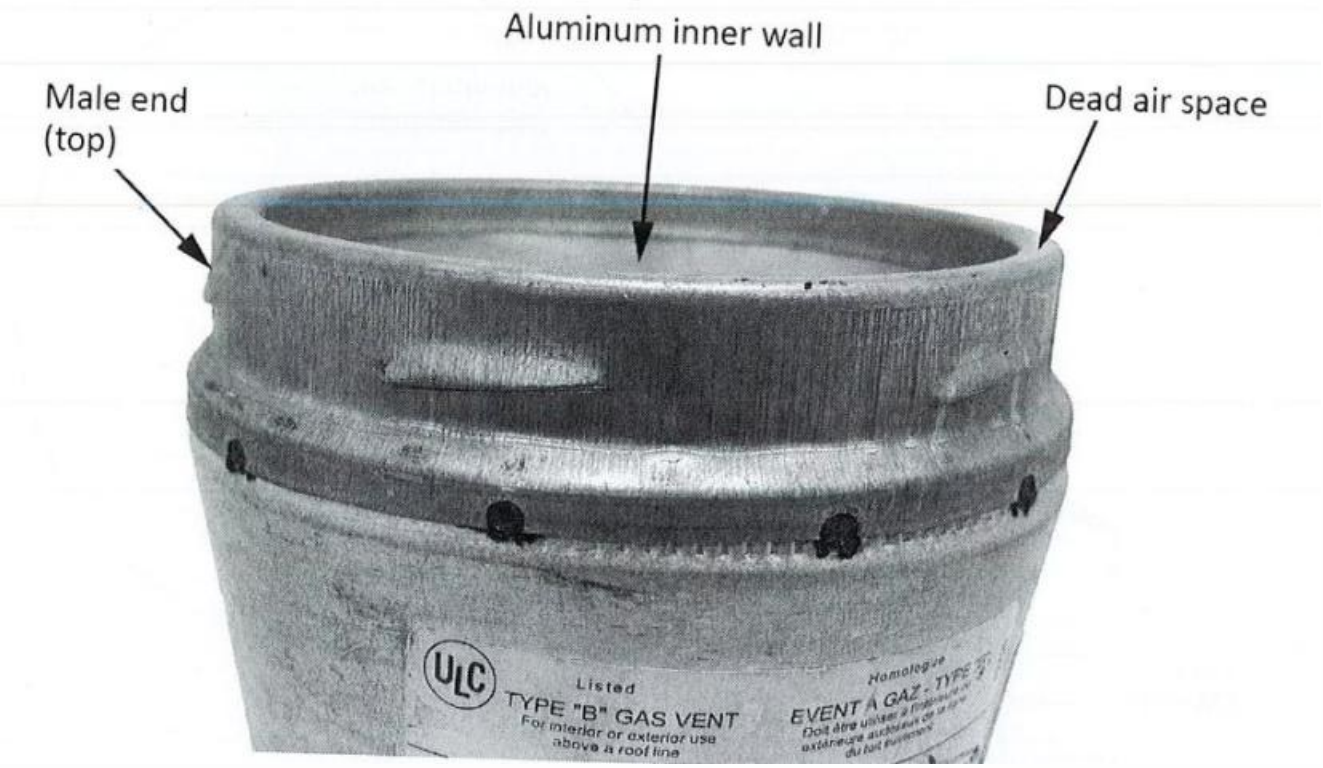
Easier to install in existing chimneys with offsets or bends, while still providing necessary protection against condensation.

# Type B Vent

Type B vents are only approved for handling low temperature gases from gas appliances. They are of a double wall construction that encloses an insulating (dead air) space. The outer wall is galvanized metal and the inner wall is aluminum.

Since the insulating quality of Type B vent is less than that of Type A vent, you must place it inside an insulated structure up to the roof line to maintain the temperature of the flue gases and reduce the effects of low outdoor temperatures that can reduce venting action.

**Figure 1-22**
**Type B vent for gas-fired appliances**
**Image courtesy of Terry Bell**

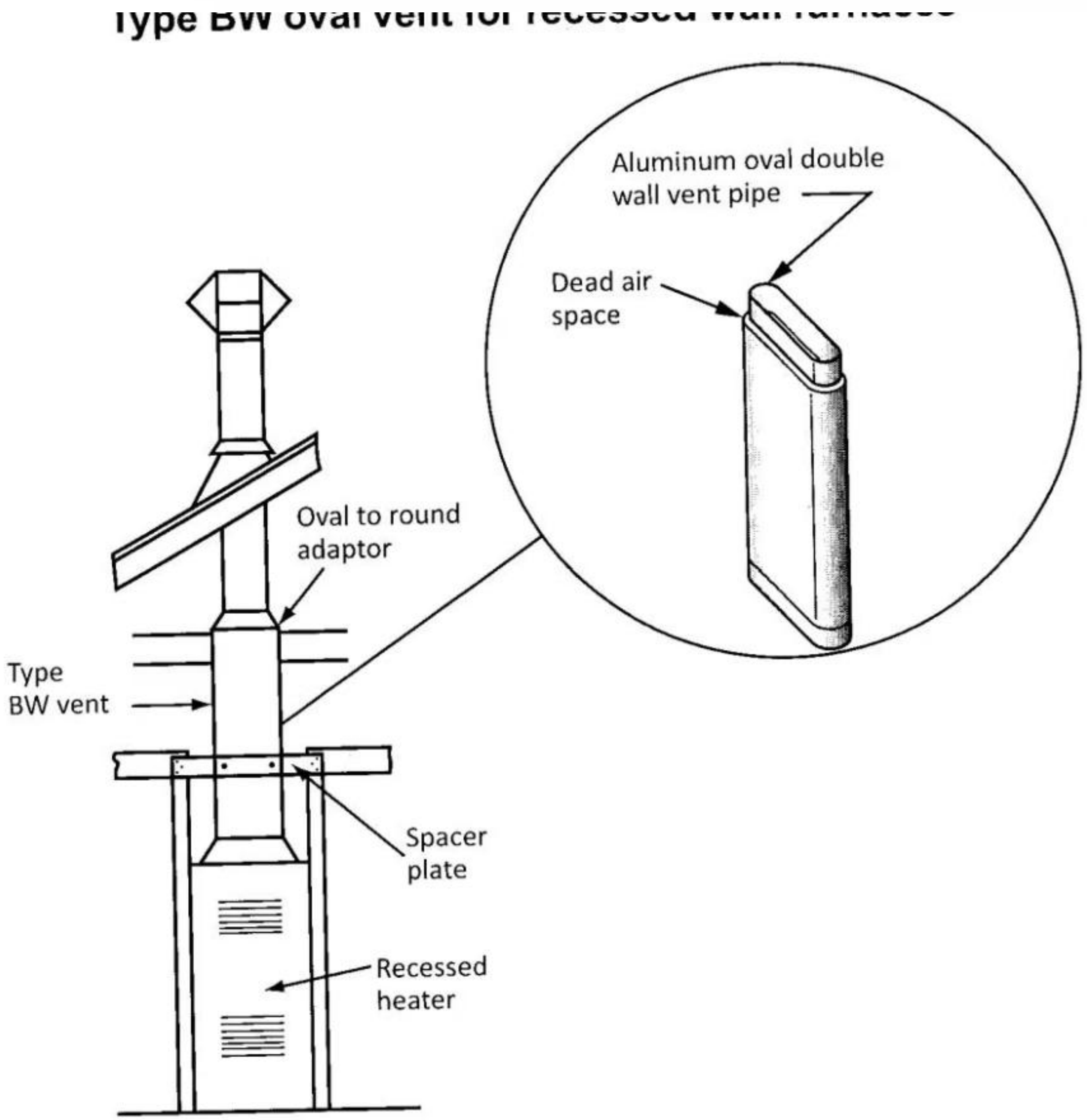



Type B vent must be kept at least 1 in (2.5 mm) away from combustible material in accordance with the manufacturer's instructions and the Gas Code.

# Type BW Vent

Type BW vent is similar in construction to Type B vent, except that it is oval instead of round. BW vent is approved for recessed wall furnaces where you can install the oval shape inside a 2 × 4 stud wall.

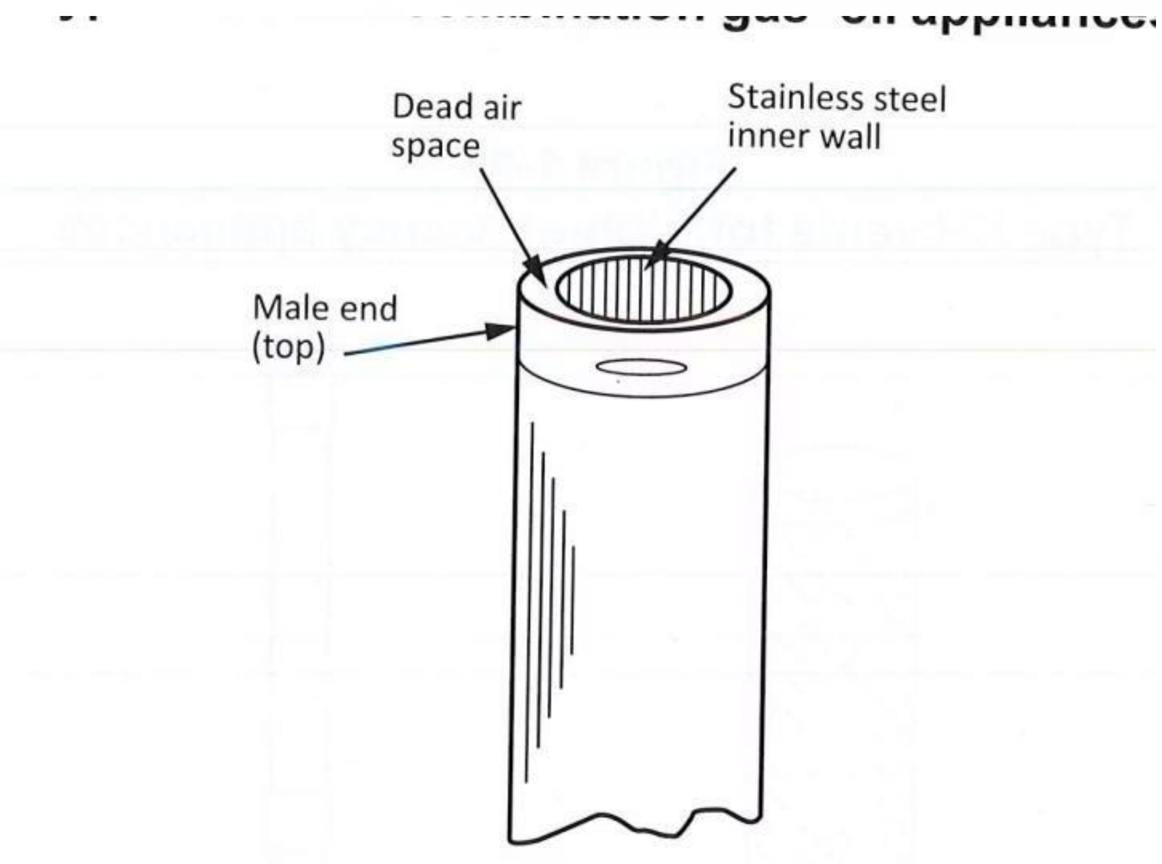
This specialized vent type allows for installation of heating appliances in wall cavities while maintaining proper venting and clearances to combustibles.



# Type L Vent

Type L vent is also very similar to Type B vent, except that the inner wall is stainless steel. This makes the vent more heat and corrosion resistant.

You may use Type L vent instead of Type B vent; however, they are more expensive. Therefore, they are usually only installed where the application specifically requires them (e.g., in a combination gas/oil system) or to solve a specific problem.

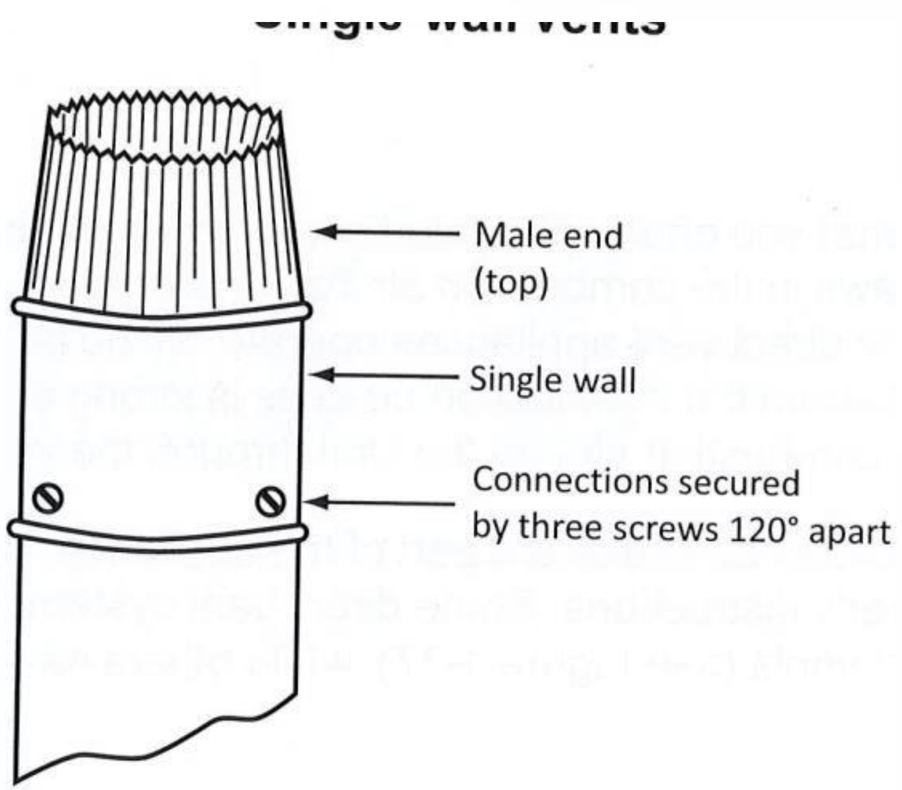



The stainless steel inner wall of Type L vent provides superior resistance to corrosion, making it suitable for applications where condensation might occur or where higher flue gas temperatures are expected.

# Single-Wall Vent

Single-wall vents are made of a single wall of galvanized steel. You must secure sections by three screws at each joint. The screws are positioned 120° apart.

Not being insulated, single-wall vents must not penetrate any floors, ceilings, or concealed areas of the building structure. CSA B149.1 designates the minimum clearances from combustibles.

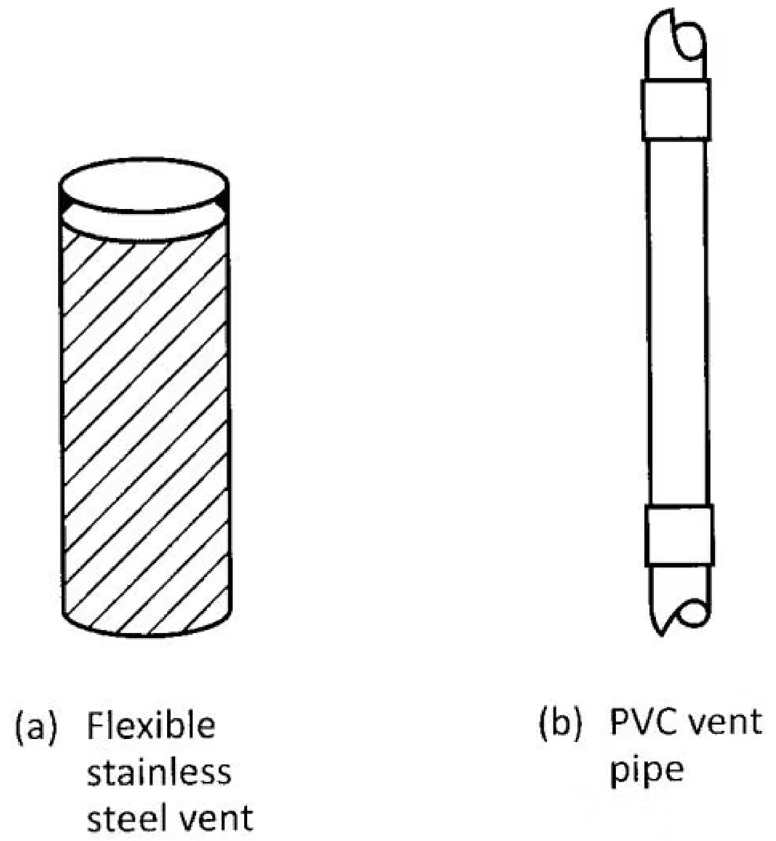



Single-wall vents are typically used for vent connectors within the same room as the appliance, where they can be easily inspected and maintained.

# Type BH Vent

Gas technicians/fitters use Type BH vents with high efficiency appliances that produce low flue temperatures and positive vent pressures or with other appliances that produce positive vent pressures and require "BH only" venting.

The low flue temperatures create abundant water vapour, and for this reason, the venting system must be made of corrosion resistant and leak-proof material.




A thin wall of flexible stainless steel pipe or plastic piping certified to ULC Standard S636 is capable of withstanding the condensation of the water vapour and a positive vent pressure.

# ULC S636 Plastic Venting

## Regulatory Acceptance

Before the regulatory acceptance of ULC S636, Standard for Type BH Gas Venting Systems, in 2007, plastic materials used for venting included ABS as well as "ordinary" PVC/CPVC that was not tested and certified to any Standard.

## Current Requirements

Although existing installations of non-certified plastic venting may still be in use, any new installations of plastic piping must employ certified S636 venting systems.

## Certification Purpose

The ULC S636 standard ensures that plastic venting materials can withstand the temperatures, pressures, and condensate exposure associated with high-efficiency appliances.

## Safety Considerations

Certified venting materials reduce the risk of vent failure, which could lead to carbon monoxide leakage or other hazardous conditions.

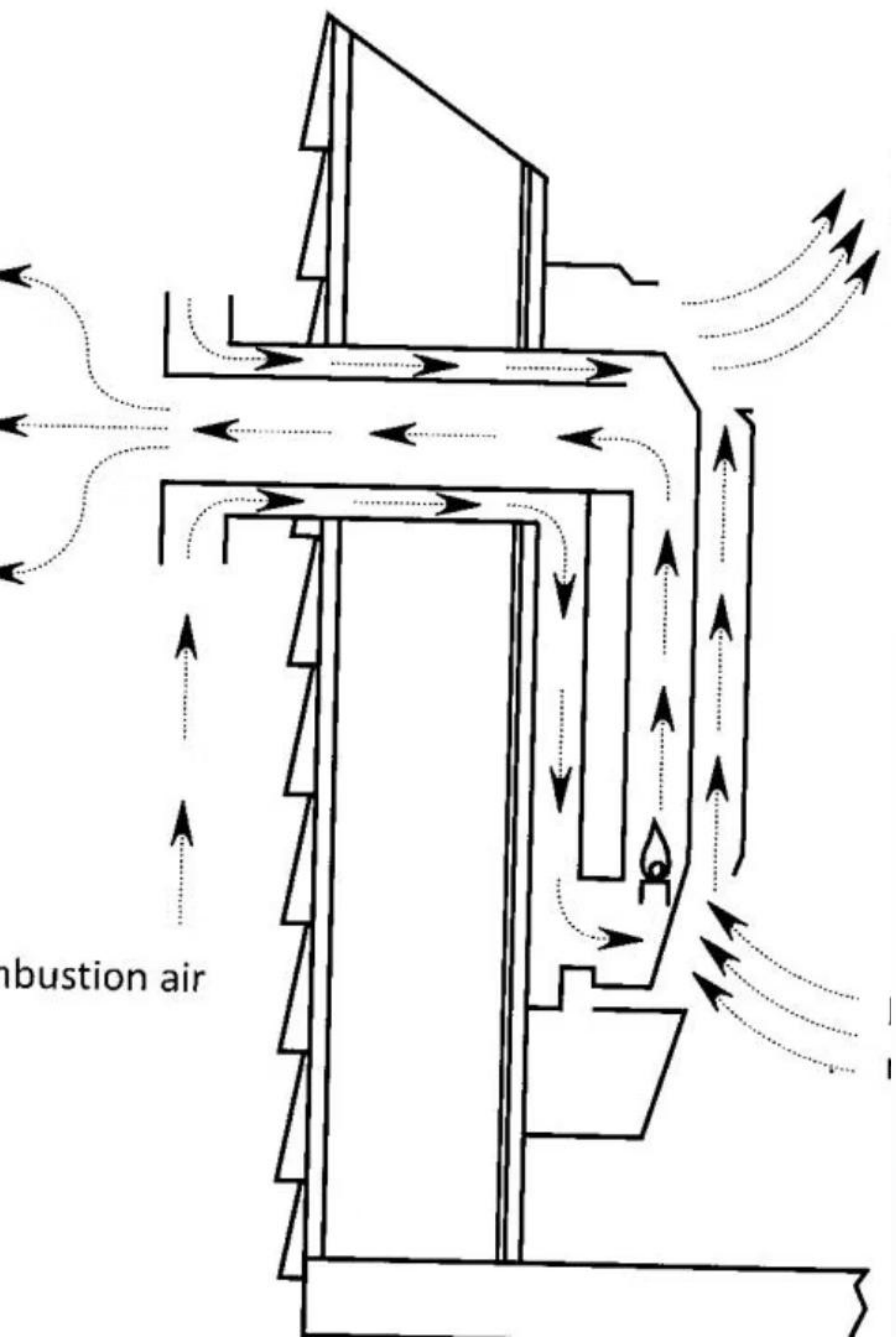
# Direct Vent Systems

Direct vent appliances are what you often call sealed combustion appliances. This venting system both draws in the combustion air from the outside and vents all flue gas directly to the outdoors.

Many direct vent appliances operate on the natural draft principle, whereby the draft that results from the combustion process is strong enough to vent the products of combustion and draw the combustion air into the unit through the vent/air intake system.

**Figure 1-27**
**Direct vent draws in combustion air and emits flue gas from the same vent/air intake system**

Both the vent and the combustion air intake are part of the appliance, and you must install them according to the manufacturer's instructions. Some direct vent systems are configured with concentric air intake/exhaust vents, while others have separate air intake and exhaust pipes.




# Benefits of Direct Vent Systems

### Negative Pressure Environments

It may be beneficial to use a direct vent appliance when the building could experience a negative pressure that might otherwise affect conventional venting.

### Hazardous Atmospheres

Direct vent systems are ideal when a hazardous atmosphere exists within the building, as they isolate the combustion process from indoor air.

### Improved Efficiency

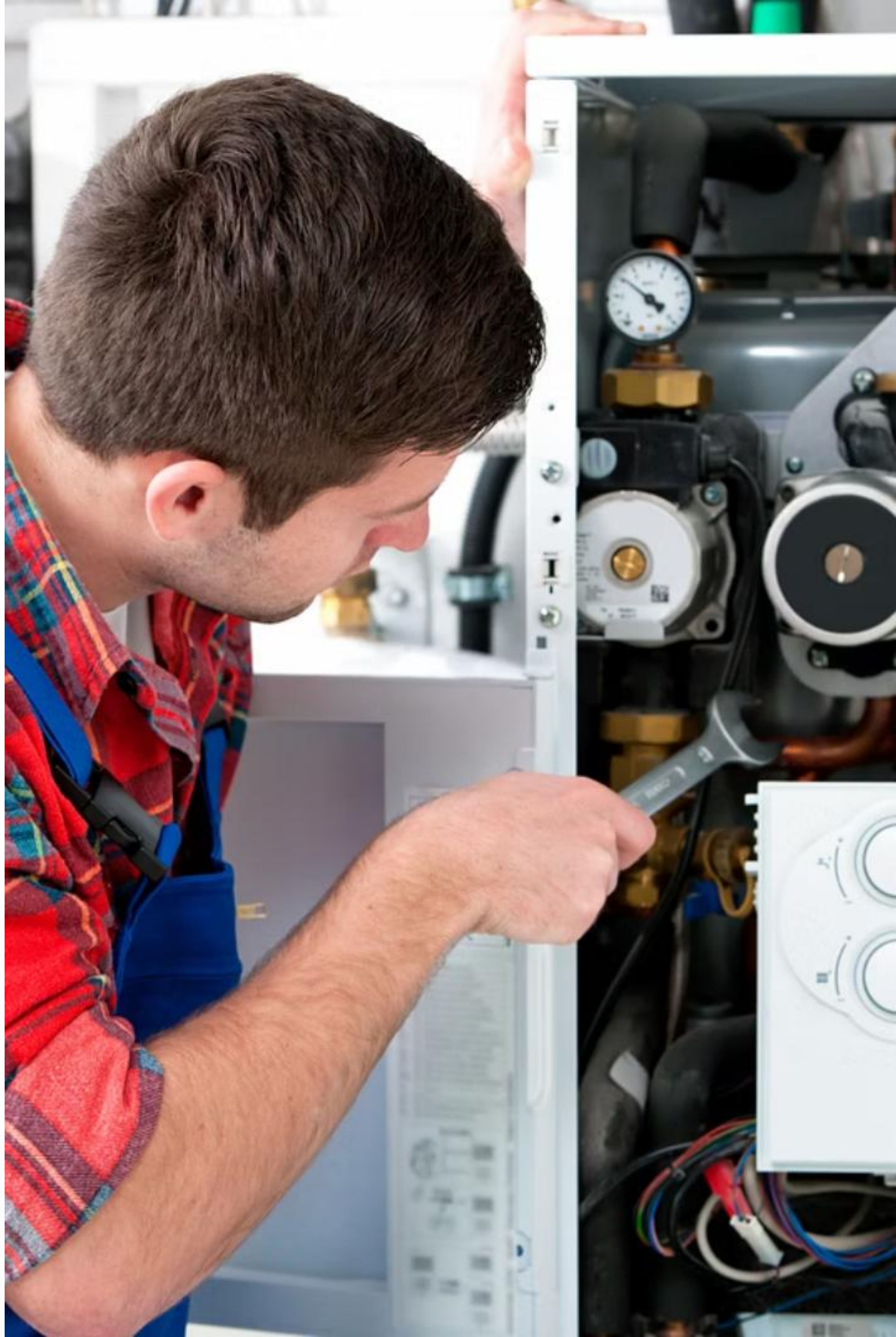
By drawing in outdoor air directly, these systems can improve combustion efficiency, especially in well-sealed buildings.

### Installation Flexibility

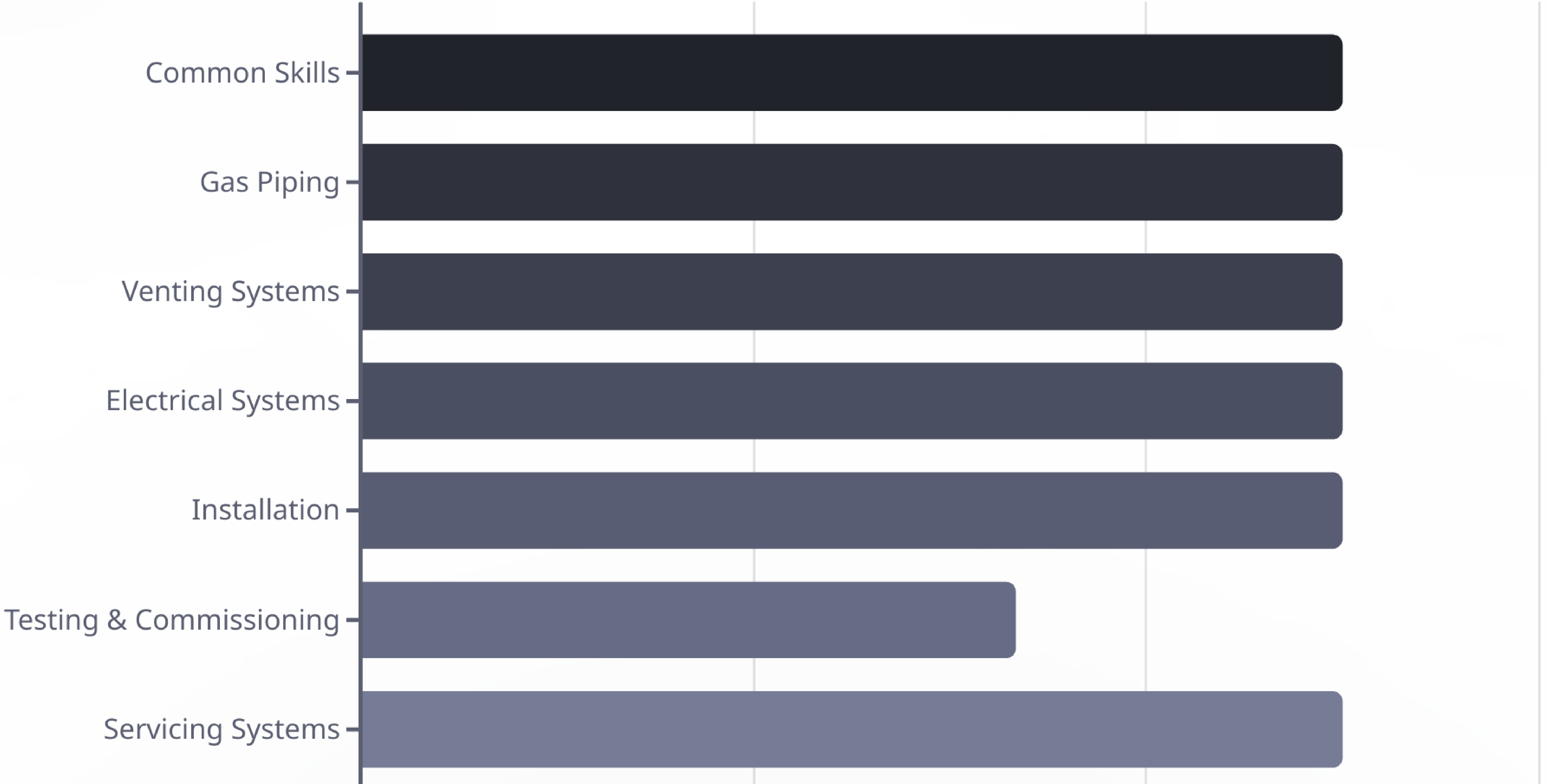
Direct vent systems often allow for installation in locations where conventional venting would be impractical.

# Red Seal Gas Trade Unit Overview

| Red Seal | CSA Gas Trade Unit | Title |
|---|---|---|
| 1 | 1 | Safety |
| 2 | 2 | Fasteners, Tools and Testing Instruments |
| 3 | 3 | Properties, Characteristics, Fuel Gases |
| 4 | 4 | Utilization Codes, Acts and Regulations |
| 4A | | Utilization Codes, Acts, and Regulations Ontario Supplement |
| 5 | 5 | Introduction to Electricity |
| 6 | 6 | Technical Manuals, Specifications, Drawings and Graphs |
| 7 | 7 | Customer Relations |
| 8 | 8 | Introduction to Piping and Tubing Systems |
| 9 | 9 | Introduction to Gas Appliances |



# Red Seal Block Tasks



# Venting System Objectives

### Explain Venting Purpose

Understand why venting systems are essential

### Explain Natural Draft Systems

Comprehend how thermal draft principles work

### Explain Mechanical Draft Systems

Understand forced and induced draft operations

### Describe Gas Vent Types

Identify and understand different venting materials

At the end of this Chapter, you will be able to explain the purpose of a venting system, explain natural draft venting systems, explain mechanical draft venting systems, and describe types of gas vents.

# Venting Terminology

| Term | Abbreviation (symbol) | Definition |
|---|---|---|
| Flue gas | | Products of combustion |
| Natural draft | | Pressure difference between the hot air and gases in a chimney or vent and the cooler, heavier air outside the chimney or vent, causing the hot gases to rise |
| Mechanical draft | | Draft that a mechanical device such as a fan or blower produces |
| Thermal draft | | See Natural draft |

# Flue Gas Components

### Carbon Dioxide ($CO_2$)

Does not support combustion, but when dissolved in water vapour, forms carbonic acid that corrodes steel venting pipes

### Water Vapour ($H_2O$)

A 100,000 Btu/h furnace produces approximately 200 $ft^3$/h of water vapour

### Carbon Monoxide (CO)

Product of incomplete combustion that remains combustible; must be vented from the building because it is deadly

### Nitrogen ($N_2$)

Colourless, odourless gas that constitutes 78% of the atmosphere; not harmful nor used for heating purposes

# Heat Transfer Efficiency Factors

### Excess Air

Lower excess air improves flame temperature and efficiency

### Medium Temperature

Proper temperature of heated medium affects heat transfer

### Flow Rate

Appropriate flow rates improve heat transfer effectiveness

### Heat Exchanger Cleanliness

Clean heat exchangers ensure effective heat transfer

The heat transfer efficiency of the appliance is designed by the manufacturer but affected by factors under the technician/fitter's control. These factors directly impact stack temperature and venting effectiveness.

sity calculation

| mation | Correlation |
|---|---|
| article volume | $\mu_{nf}=\mu_{bf}(1+2.5\emptyset)$ |
| ate particle tration ed from Einstein al particles | $\mu_{nf}=\mu_{bf}\frac{1}{(1-\emptyset)^{2.5}}$ |
| herical particle an motion ic structure | $\mu_{nf}=\mu_{bf}(1+2.5\emptyset+6.2$ |
| ater | $\mu_{nf}=\mu_{bf}(1+7.3\emptyset+123$ |
| ater | $\mu_{nf}=\mu_{bf}(1+7.3\emptyset+123$ |
| ater | $\mu_{nf}=\mu_{bf}+\frac{\rho_{np}u_m d^2}{72C\delta}$ <br> $\delta=\sqrt[3]{\frac{\pi}{6\emptyset}}d$ |
| valid for ater nanofluid s nanoparticle concentration, ature and layer effect | $\frac{\mu_{nf}}{\mu_{bf}}=\exp\left[m+\alpha\left(\frac{T}{T_0}\right)+\beta(\emptyset_h)\right.$ |

# Vent Material Considerations

## Insulating Value

The higher the insulating value of the vent material, the higher you can maintain the stack temperature throughout its travel to the outdoors. A proper vent cap holds the heat in the vent and prevents cold air from entering the vent.

## Vent Diameter

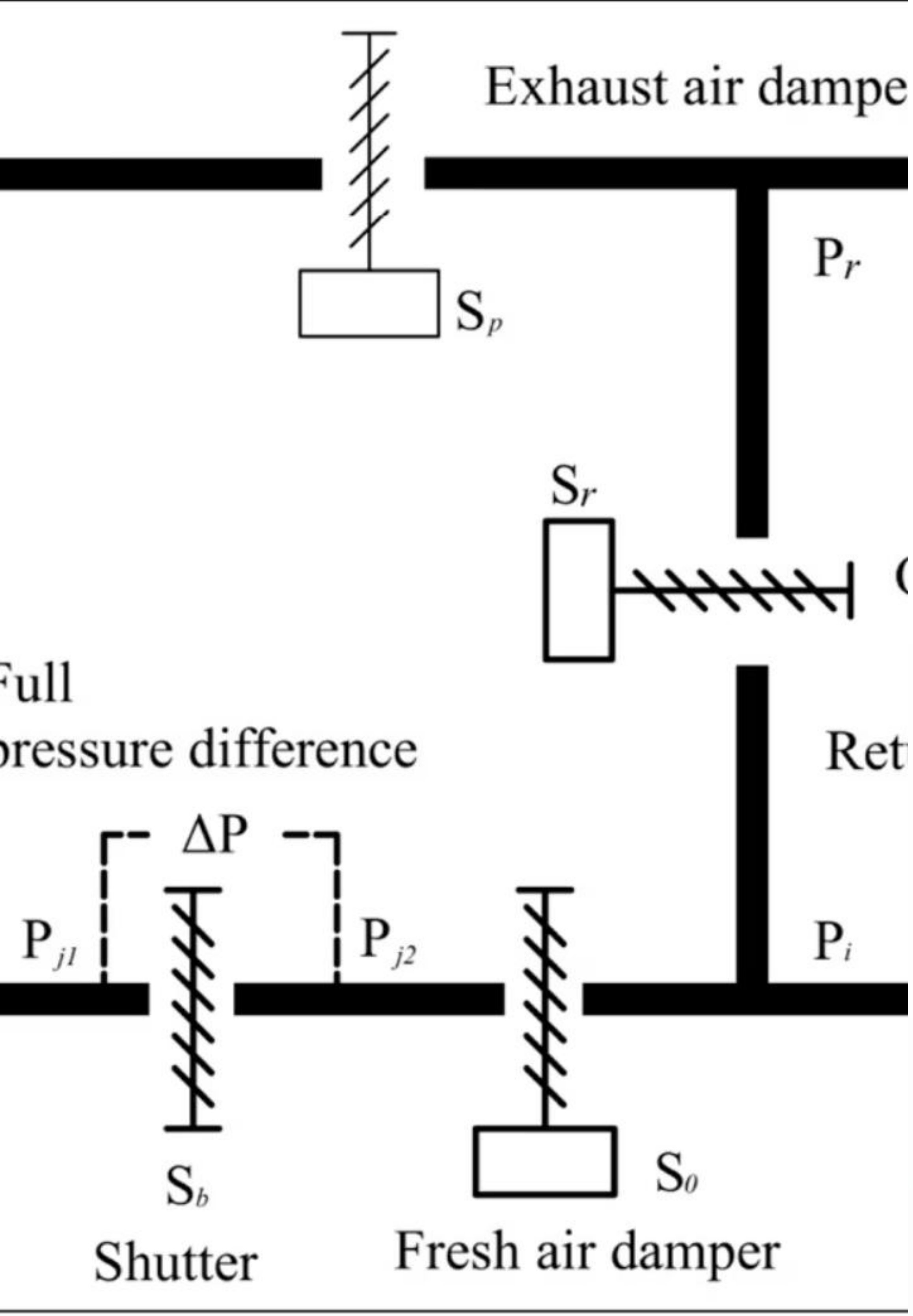
The closer the vent diameter is to that required for the effective removal of the volume of flue gases, the higher the flue gas temperature. A too small vent diameter restricts the flue gases, while a too large vent diameter reduces the stack temperature and inhibits venting action.

## Vent Configuration

The configuration of the venting must minimize resistance to flow by reducing lateral vent lengths, changes in direction, and restrictive fittings. A tall vertical vent with no elbows maximizes stack temperature and venting action.

## Vent Location

The location of the vent must minimize heat transfer through the vent material. Vents located outdoors or in contact with outside temperatures reduce stack temperature and venting action.




# Double-Acting Barometric Damper Regulation

| Feature | Function |
|---|---|
| Dilution air | When the vent draw increases, the atmospheric pressure on the outside of the damper pushes against the gate, allowing extra dilution air in to reduce the draft draw. |
| Down-draft | If the pressure increases inside the venting system, the gate swings out to relieve a down-draft. |
| Spillage | In the event of a blockage in the venting system, the gate swings out to allow spillage. You should adjust barometric dampers according to the manufacturer's instructions. Adjustments depend on the type of burner, combustion chamber, and available draft. |

# Induced Draft Device Operation

### Temperature Control Call

The temperature control device, such as a thermostat or aquastat, calls for heat.

### Relay Activation

The demand activates a relay that triggers the power venter.

### Negative Pressure Creation

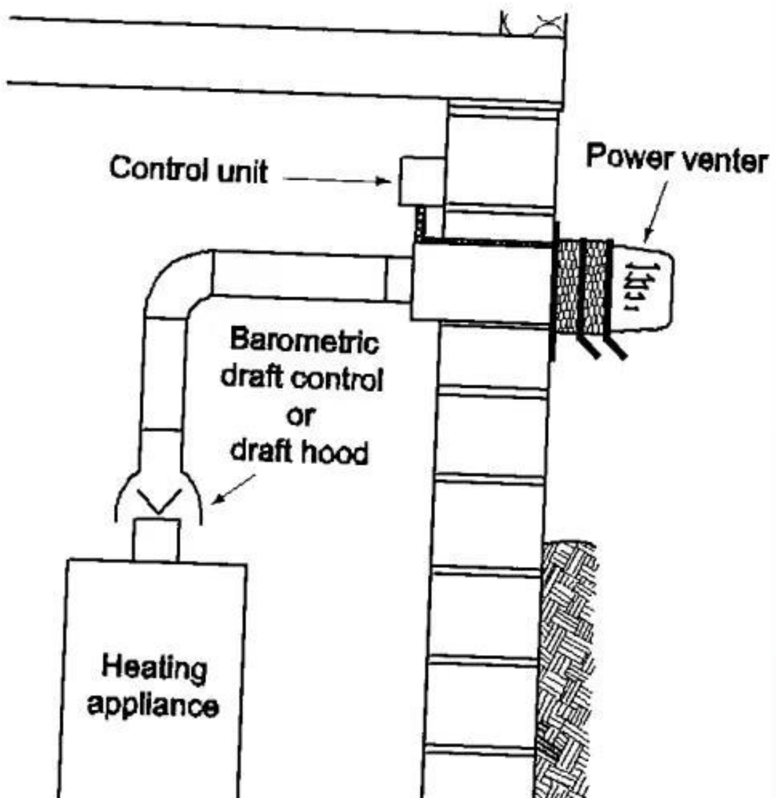
After the power venter has brought the system to a negative pressure, or to the required draft level, the pressure sensing contacts close.

### Burner Operation

The closed contacts allow the burner to light and operate.

### System Shutdown

Following the satisfaction of the appliance demand, the contacts open and stop the power venter.




# Gas Technician 3 Role in Venting

## Identify Problems

Recognize signs of venting issues during inspection or maintenance

## Notify Qualified Personnel

Alert more qualified technicians/fitters about identified venting problems

## Assist with Corrections

Help more qualified personnel correct venting issues when appropriate

## Proper Installation

Prevent problems by correctly installing venting systems according to codes and manufacturer specifications

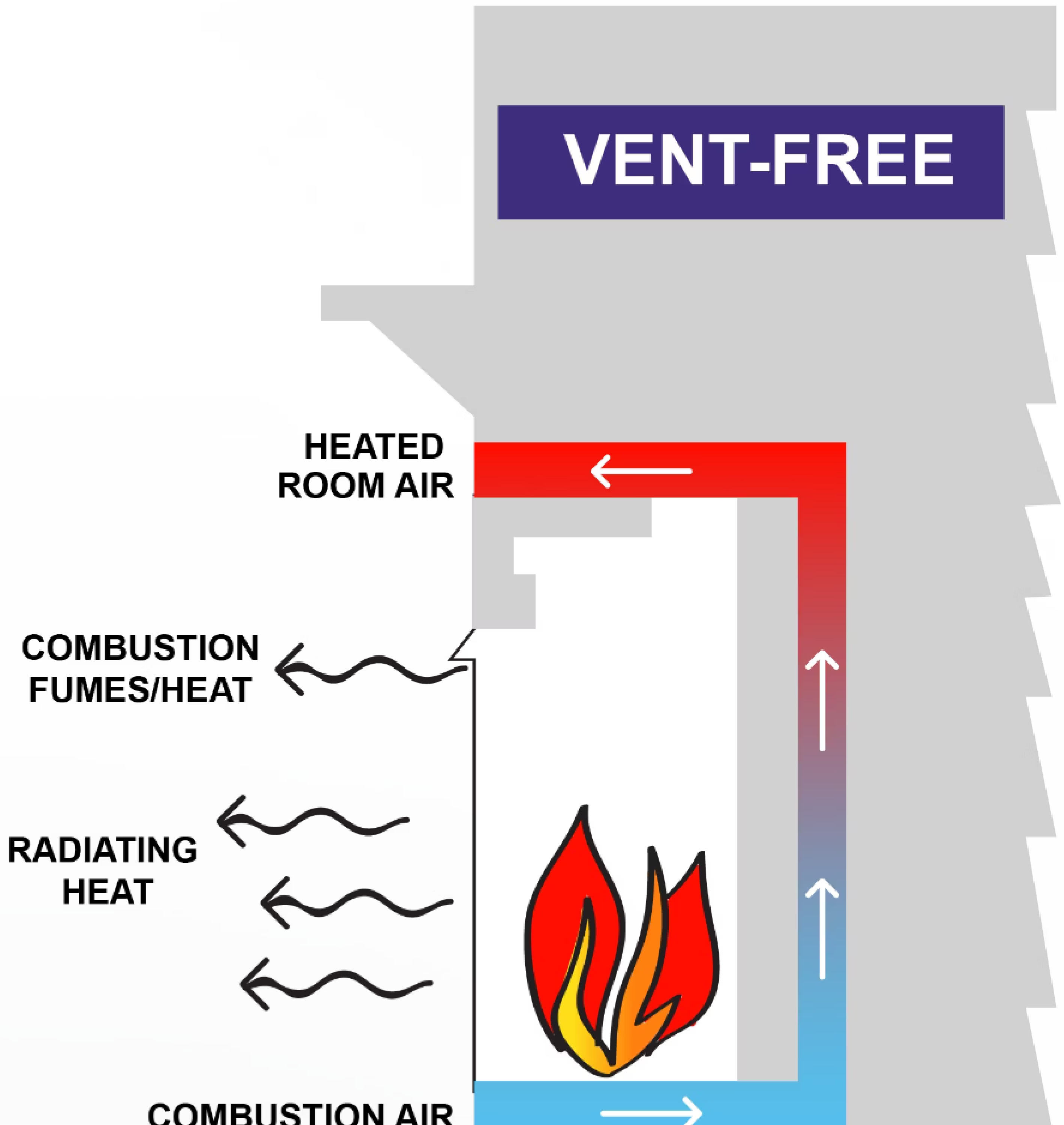
The role of a Gas Technician 3 is, primarily, to identify venting problems and notify or assist more qualified technicians/fitters to correct those problems or prevent them from occurring in the first place by properly installing venting systems.

# Understanding Venting Principles

To complete their role effectively, a gas technician/fitter must understand the basic principles of natural draft and mechanical draft venting systems and the components employed in those systems.

This understanding includes:

- How thermal draft is created and maintained
- How mechanical draft systems operate
- The differences between forced and induced draft
- The characteristics of various vent materials
- The importance of proper installation techniques
- The safety implications of venting system failures



# Flue Gas Temperature Considerations

## 40°C

### Minimum Temperature

For properly setup high efficiency (condensing) appliances

## 260°C

### Maximum Temperature

For low efficiency or improperly setup appliances

## 127°C

### Dew Point

Approximate temperature below which water vapor condenses

The flue gas temperature in the vent can range from 100°F (40°C) for properly setup high efficiency appliances (condensing appliances) to 500°F (260°C) for low efficiency or improperly setup appliances. The vent material, installation method, and clearance to combustibles must meet the requirements of CSA B149.1 and the manufacturer's certified instructions to prevent a fire due to venting.

# Mechanical vs. Natural Draft Venting

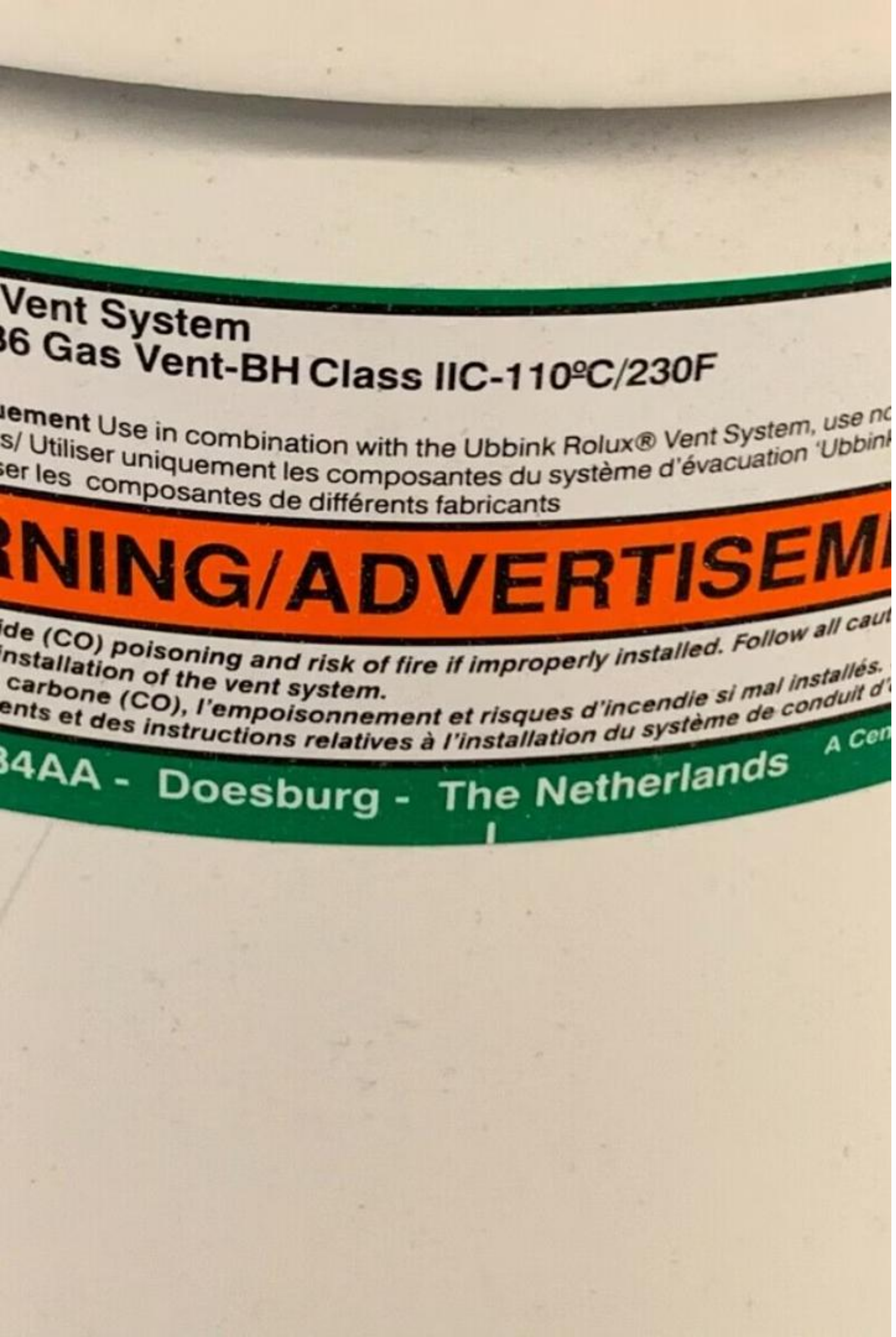
## Natural Draft Systems

- Rely on thermal buoyancy of hot gases
- More susceptible to external factors
- Require proper sizing and configuration
- Typically have fewer safety devices
- Installation decisions more critical

## Mechanical Draft Systems

- Use mechanical devices to move flue gases
- More resistant to external influences
- Usually have more safety monitoring devices
- More explicit installation instructions
- Can still fail if improperly installed

The level and type of risk posed varies depending largely on the type of venting system. Natural draft venting systems are more susceptible to all the previously mentioned problems compared to mechanical draft systems due to their principles of operation and the need to rely on the installer to make decisions.




# Plastic Venting Requirements

1

## Pre-2007

Before regulatory acceptance of ULC S636, plastic materials used for venting included ABS as well as "ordinary" PVC/CPVC that was not tested and certified to any Standard.

2

## 2007

ULC S636, Standard for Type BH Gas Venting Systems, was accepted by regulatory authorities.

3

## Current Requirements

Although existing installations of non-certified plastic venting may still be in use, any new installations of plastic piping must employ certified S636 venting systems.

# Direct Vent Applications

## Negative Pressure Buildings

It may be beneficial to use a direct vent appliance when the building could experience a negative pressure that might affect conventional venting.

## Hazardous Atmospheres

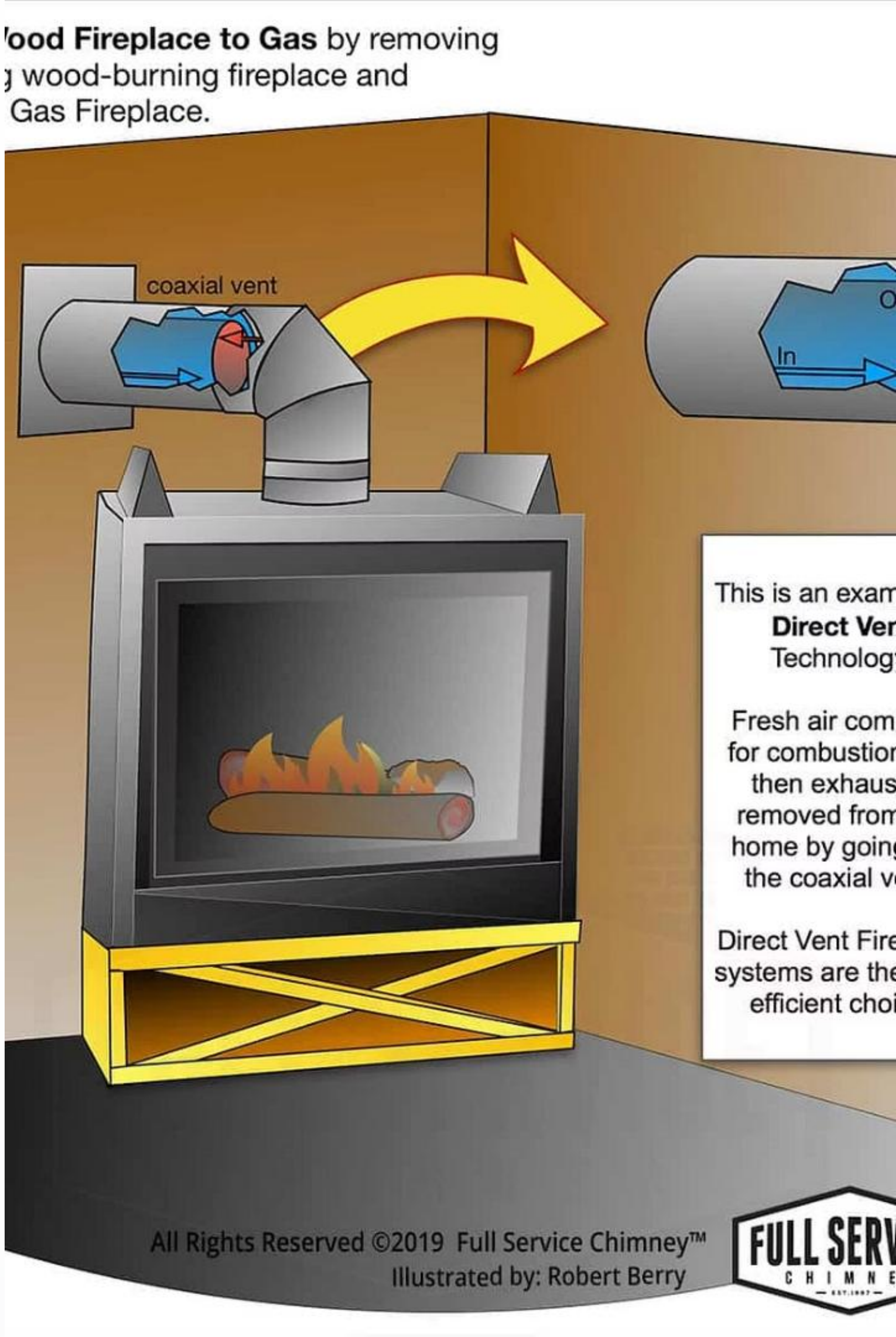
Direct vent systems are ideal when a hazardous atmosphere exists within the building, as they isolate the combustion process from indoor air.

## Tightly Sealed Buildings

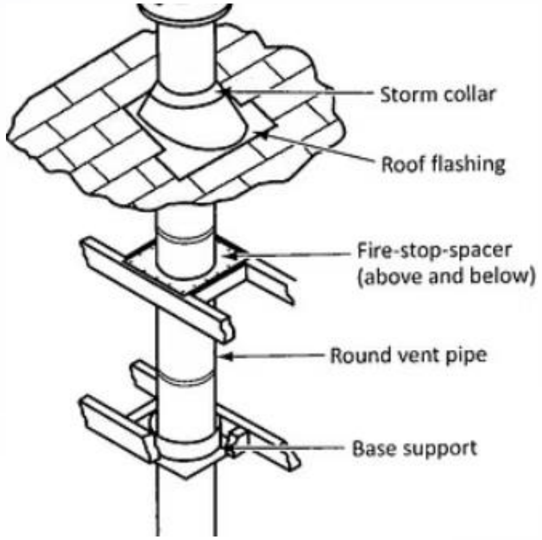
Modern energy-efficient homes with minimal air infiltration benefit from direct vent systems that don't rely on indoor air.

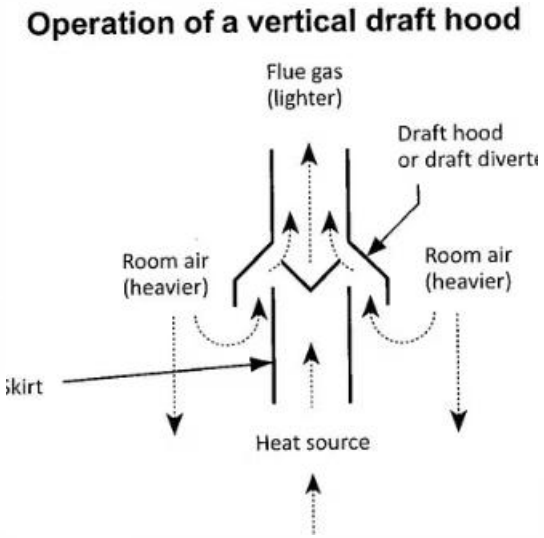
## Limited Space Applications

When conventional venting is impractical due to building constraints, direct vent systems offer alternative installation options.

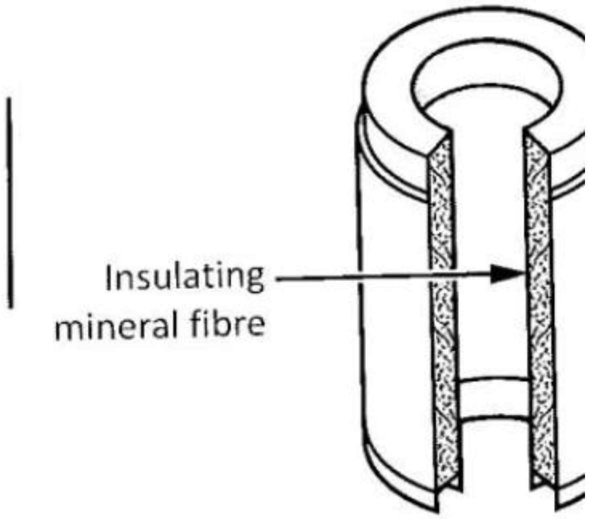


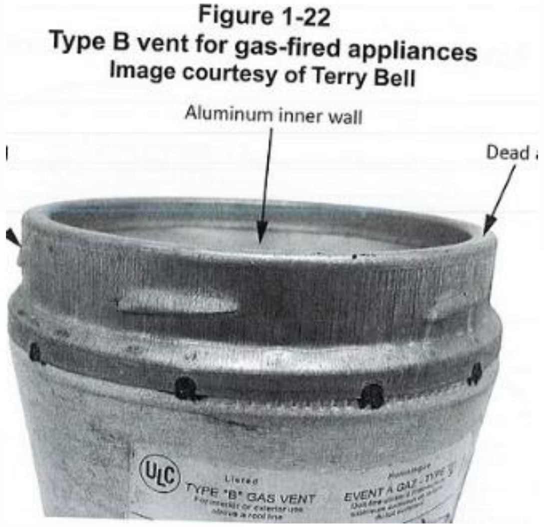
# Venting System Components

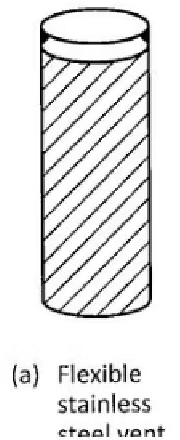


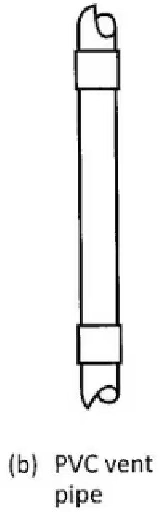








Various components make up complete venting systems, including vent pipe supports, fire stop spacers, roof flashings, storm collars, vent caps, draft hoods, barometric dampers, and the venting material itself. Each component serves a specific purpose in ensuring safe and effective venting.

# Venting System Safety Considerations

### Regular Inspection

Check for blockages, corrosion, and proper connections

### Proper Maintenance

Clean components and replace damaged parts

### Manufacturer Instructions

Adhere to specific installation requirements

### Code Compliance

Follow all applicable codes and standards

Safety is paramount when working with venting systems. Improper venting can lead to carbon monoxide poisoning, fire hazards, and appliance malfunctions. Always follow manufacturer instructions and applicable codes when installing, inspecting, or maintaining venting systems.

# Condensation Prevention in Venting Systems

When flue gas temperature is low, the water vapour (in the flue products) condenses. Condensation can cause corrosion inside the heat exchanger, flue passages, and vent pipes, unless the appliance and its venting system are designed and properly installed for the collection and removal of this condensation.

Prevention strategies include:

- Using appropriate vent materials resistant to corrosion
- Maintaining proper flue gas temperatures
- Installing condensate drains where required
- Proper sizing and configuration of venting systems
- Using insulated venting in unconditioned spaces

# Venting System Installation Best Practices

## Read Instructions

Thoroughly review manufacturer's installation instructions and applicable codes

## Proper Sizing

Ensure vent diameter and configuration match appliance requirements

## Adequate Support

Install proper supports to maintain clearances and prevent sagging

## Secure Connections

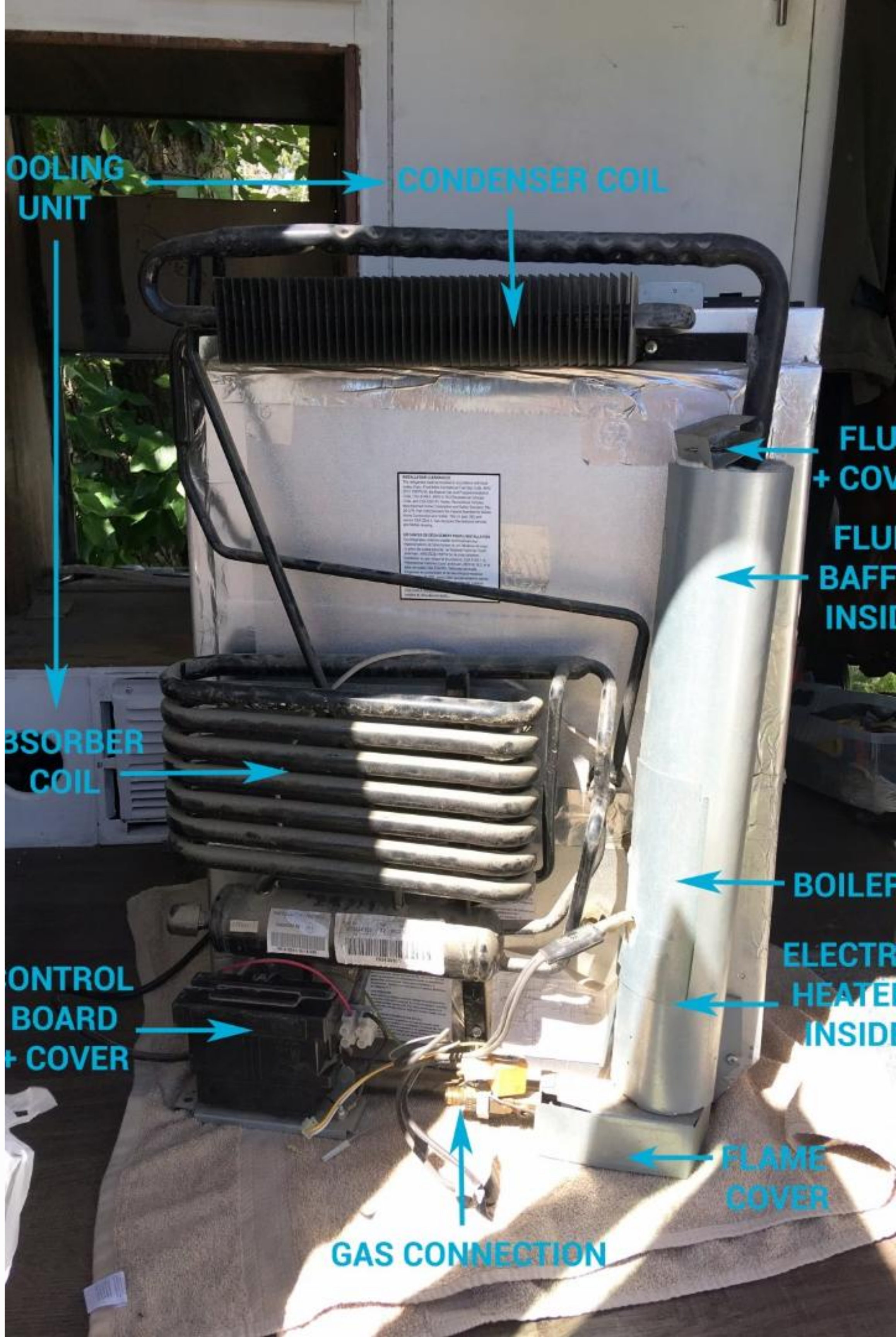
Properly join and seal all connections according to manufacturer specifications

## Verify Operation

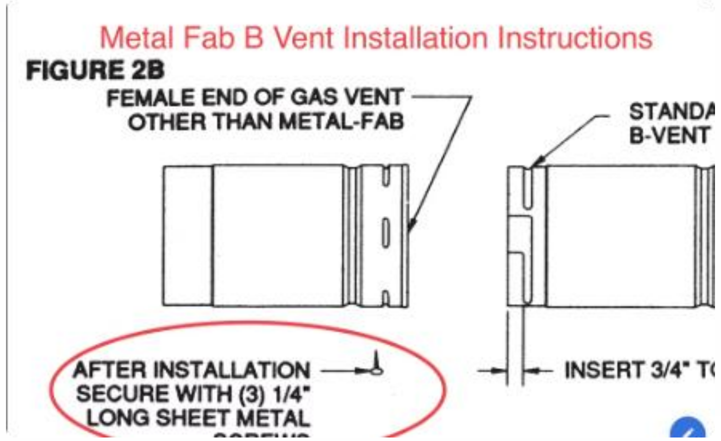
Test the complete system to ensure proper venting under all conditions

# Venting System Troubleshooting

| Problem | Possible Causes | Solutions |
|---|---|---|
| Spillage | Blocked vent, inadequate draft, downdraft | Clear blockage, resize vent, add draft inducer |
| Condensation | Low flue gas temperature, oversized vent | Insulate vent, resize vent, add drain |
| Corrosion | Condensation, improper materials | Use corrosion-resistant materials, prevent condensation |
| Insufficient draft | Too short vent, too many elbows, restrictions | Extend vent, reduce elbows, remove restrictions |
| Excessive draft | Tall chimney, high winds | Install barometric damper, adjust draft hood |



# Venting System Clearances

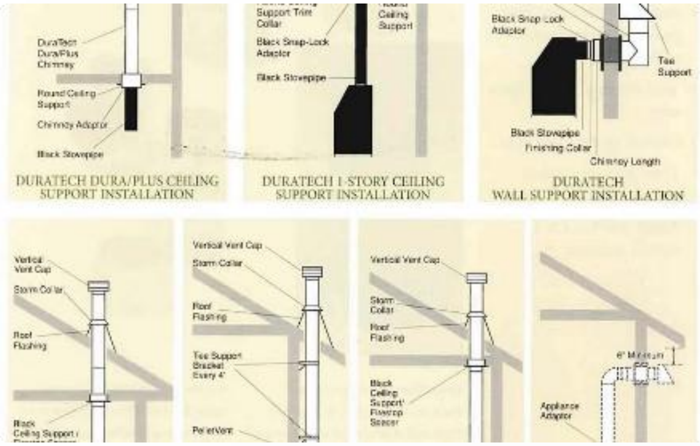



## Type B Vent

Requires minimum 1 inch (25mm) clearance to combustibles. Double-wall construction with insulating air space provides protection against heat transfer.

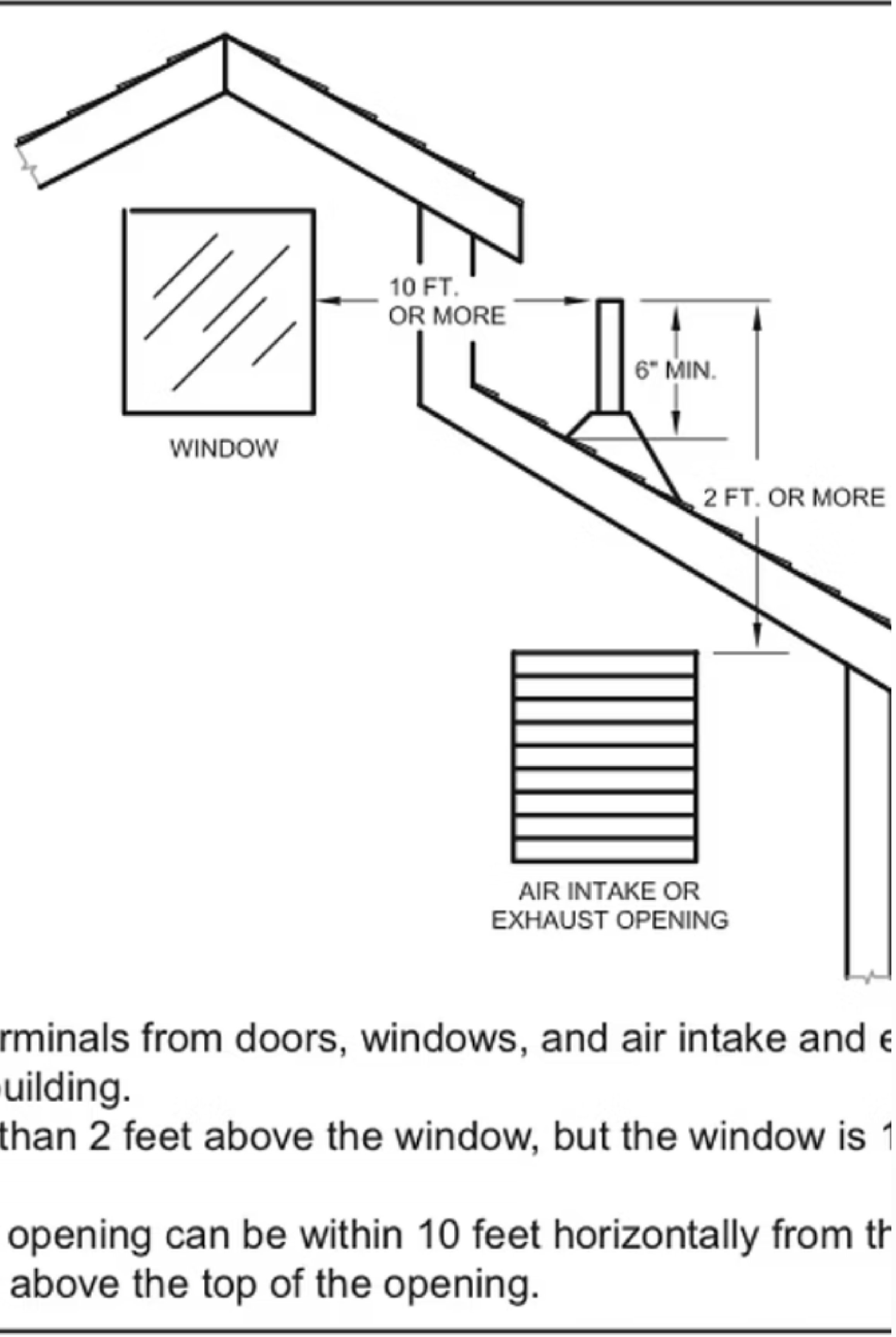
## Single-Wall Vent

Requires greater clearances to combustibles as specified by CSA B149.1. Cannot penetrate floors, ceilings, or concealed spaces due to fire hazard.




## Type A Chimney

Factory-built insulated metal chimneys have specific clearance requirements based on their design and certification. Must be installed according to manufacturer instructions.




# Venting System Termination Requirements

## Vertical Terminations

Must extend above the roof line with specific height requirements based on roof pitch and location. Must include proper cap to prevent weather entry and downdrafts.

## Sidewall Terminations

Must maintain minimum distances from doors, windows, air intakes, corners, and other building features. Location must prevent flue gas recirculation and entry into the building.

## Snow Considerations

Must terminate above anticipated snow levels to prevent blockage during winter conditions.

## Wind Effects

Must be positioned to minimize adverse effects from prevailing winds and building-induced air currents.

# Venting System Maintenance

## Visual Inspection

Check for visible damage, corrosion, improper connections, and clearance issues. Inspect terminations for blockages or damage.

## Operational Testing

Verify proper draft and absence of spillage under normal operating conditions. Test safety devices on mechanical draft systems.

## Cleaning

Remove any accumulated debris, soot, or corrosion products that could restrict flow or create hazards.

## Component Replacement

Replace damaged or deteriorated components with proper parts specified for the venting system.

## Documentation

Record all maintenance activities, findings, and corrective actions taken for future reference.

# Venting System Code Compliance

## CSA B149.1

The primary code governing gas venting systems in Canada. Specifies requirements for materials, installation, clearances, and terminations for various types of venting systems.

## ULC Standards

ULC S636 for plastic venting systems and other ULC standards for metal venting components establish material and performance requirements.

## Local Codes

Provincial and municipal regulations may impose additional requirements or modifications to national codes based on local conditions.

## Manufacturer Instructions

Certified installation instructions from appliance and vent manufacturers must be followed and take precedence when more restrictive than general code requirements.

Compliance with all applicable codes and standards is essential for ensuring the safety and proper operation of gas venting systems. Gas technicians must stay current with code updates and requirements to perform installations and maintenance correctly.

# CSA Unit 9

# Chapter 2
# Operation and Applications of Various Burners

There are countless numbers of burners that provide combustion of fuel gases. A gas technician/fitter encounters many different types. Some designs are simple; some are complex, while the firing rates range from very small to very large. Whatever the purpose of the design, they all must mix fuel and air, ignite and burn it, and then remove the products of combustion (either through natural draft or with the help of a mechanical device).

# Purpose of Burners

### Complete Combustion

The primary purpose of performing combustion analysis must be to determine the completeness of combustion and to test for toxic gases.

### Efficient Operation

Burners must provide complete combustion, stable flames, and quiet operation to ensure efficient and safe appliance performance.

### Heat Distribution

Burners must distribute heat evenly to the heat exchanger or application surface to maximize efficiency and prevent damage.

# Learning Objectives

## Describe Burner Performance Characteristics

Understand what makes a burner operate effectively and efficiently in various applications.

## Describe Various Burner Classifications

Learn the different ways burners are categorized based on their design and operation.

## Describe Atmospheric Burners

Understand the most common type of burner found in residential and commercial applications.

# Key Terminology

## Venturi Effect

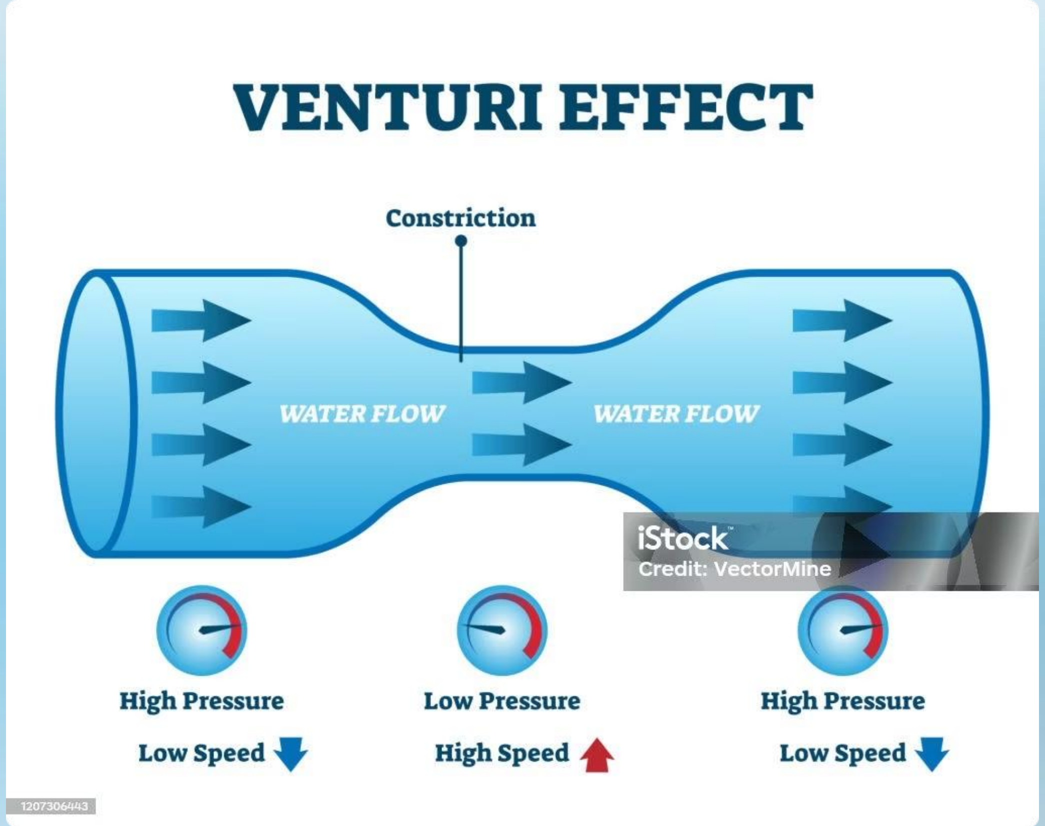
The force of the gas stream from the orifice pulls primary air into a burner as it passes through the centre of a narrowed opening in the burner body.

## Primary Air

The air that mixes with the gas before combustion, typically providing about 50% of the air needed for complete combustion in atmospheric burners.

## Secondary Air

The air that mixes with the gas at the point of combustion, providing the remaining air needed for complete combustion.



# Burner Performance Characteristics

## Complete Combustion

A gas burner must be capable of mixing gas and air together to enable complete combustion of the fuel. Combustion should not produce carbon monoxide or other harmful by-products.

## Rapid Carry-Over of Flames

When ignited, the gas burner flame front must pass smoothly and rapidly over the burner surface. In the case of a multiport burner, the flame front should not delay as it moves from port to port. All ports must ignite.

## Quiet Operation

Burners must ignite quietly either at ignition or during the run cycle. Burner shutdown should also be smooth and quiet, not creating an extinction pop.

# More Performance Characteristics

## Immediate Ignition

There should be no delay in burner ignition.

## Stable Flames

A burner fired at its designed input with correct air adjustment should produce a stable flame. The flames should stay close to the burner ports and not lift off the burner. Also, there should be no burner "flashback." Flashback occurs when a flame front moves back through a burner nozzle, and sometimes back to the air gas mixing point.

## Uniform Heating

A burner must provide uniform heating across its surface. Uneven heating can cause excessive stress on heat exchangers and boiler tubes.


# Turndown Ratio

## Definition

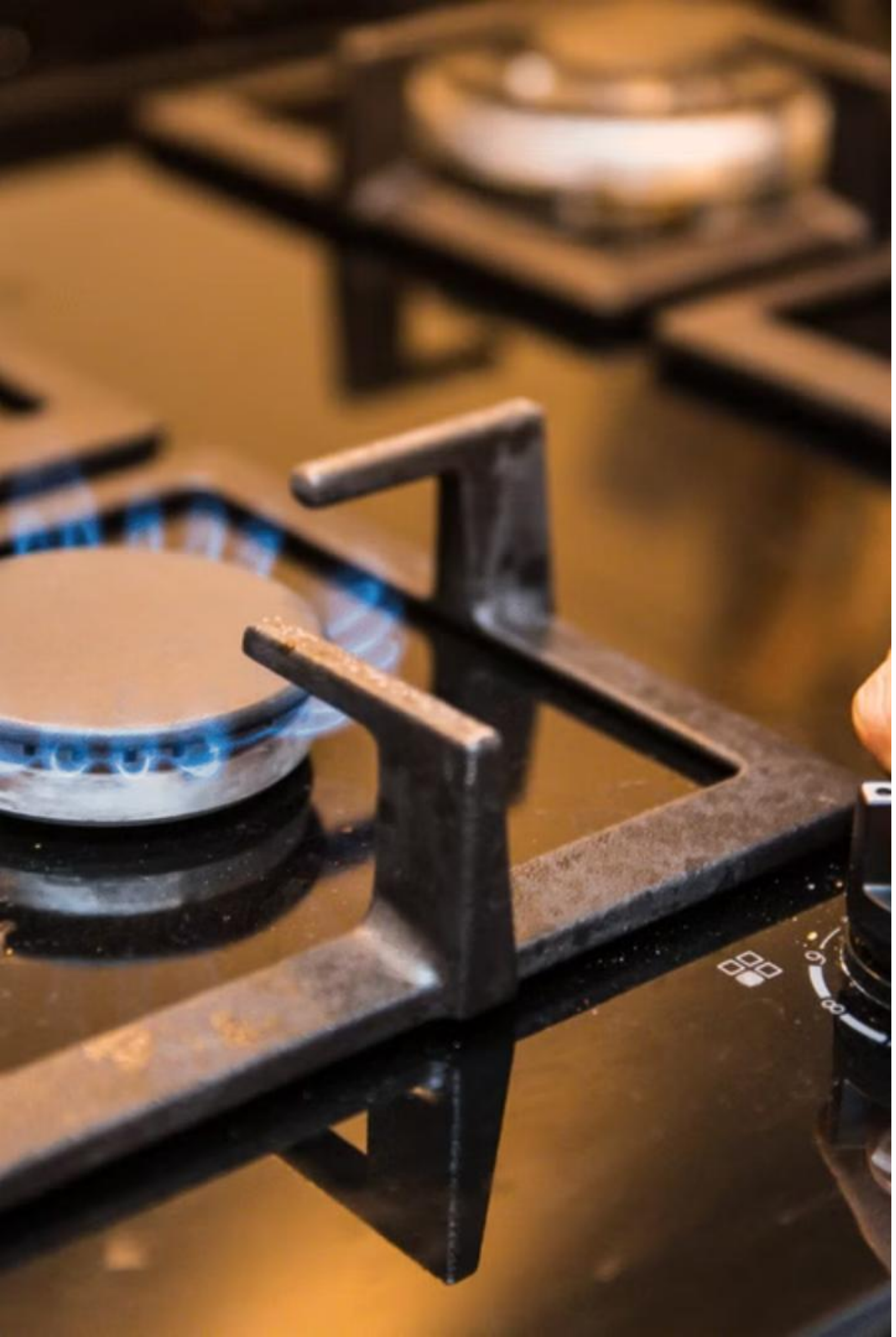
Turndown ratio or turndown rate is the range of inputs for satisfactory combustion.

## Variable Input

Many burners operate at a fixed input. Others, such as range-top burners, must vary their input from high to low.

## Measurement

A turndown rate of 5 to 1 means the burner input can vary from 20% to 100% of maximum rated input and still maintain stable flames at the burner ports.



# Common Burner Problems

| Flame Type | Problem | Remedy |
|---|---|---|
| Flame lifting | Noisy, Incomplete combustion | Reduce primary air, Reduce appliance input |
| Flashback | Burning inside mixing tube | Increase burner input |
| Yellow tipping | Sooting, Incomplete combustion | Increase primary air, Clean primary air opening |
| Extinction pop | Noisy | Reduce primary air |

# More Burner Problems

| Flame Type | Problem | Remedy |
| --- | --- | --- |
| Fluctuating flame | Possible incomplete combustion if flame impinges on cool surfaces | Make sure gas pressure is steady at burner orifice, Clean burner orifice for possible blockage |
| Waving flame | Possible incomplete combustion if flame impinges on a cool surface | Correct draft condition, Possible cracked heat exchanger - replace |
| Floating flame | Severe incomplete combustion, Possible pilot outage | Reduce overfiring of burner, Remove possible vent and flue blockage, Remove soot or dust to increase secondary air supply |

# Flame Roll Out and Normal Flame

| Flame Type | Problem | Remedy |
|---|---|---|
| Flame roll out | Possible fire hazard, Scorch appliance finish, Burn wiring and possible control damage, Possible burner flashback | Reduce overfiring, Remove possible vent and flue blockage, Increase secondary air supply, Employ a 2-step control valve to establish natural draft in appliance before full gas input |
| Normal flame | Complete combustion, Stable flame, High appliance efficiency | Correct primary and secondary air supply, Correct firing rate, Adequate venting and clear flue passages |
| Orange flashing flame | Dust burning in the flame | Clean burner, Ensure a clean air supply to burner |

# Cleaning Burners

### Follow Manufacturer Instructions

You should clean burners according to the manufacturer's instructions.

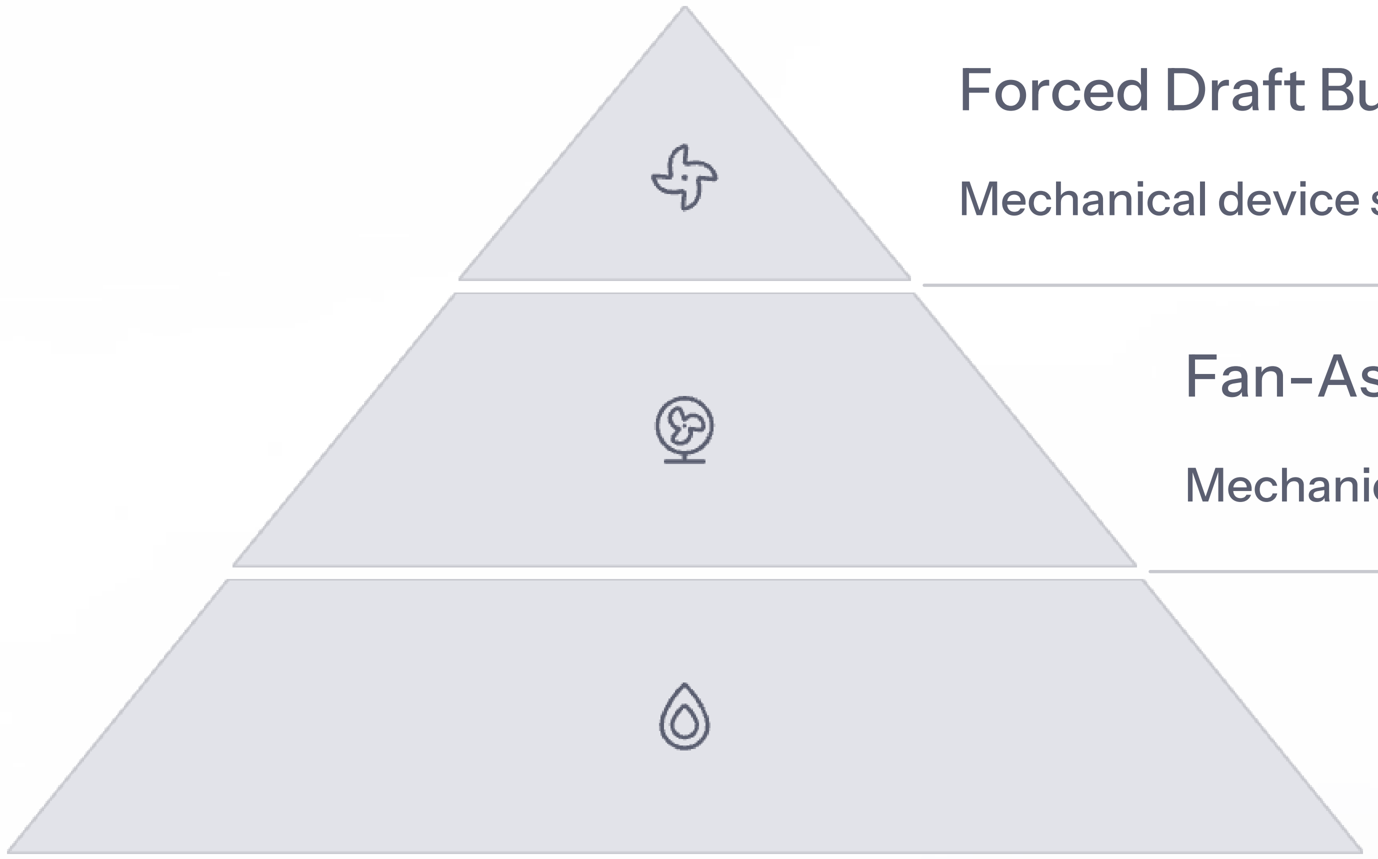
### Regular Maintenance

Regular cleaning prevents many common burner problems like yellow tipping and sooting.

### Safety First

Always ensure the appliance is turned off and cooled before attempting to clean burners.

# Burner Classifications by CSA B149.1



### Forced Draft Burners

Mechanical device supplies combustion air at sufficient pressure

### Fan-Assist Burners

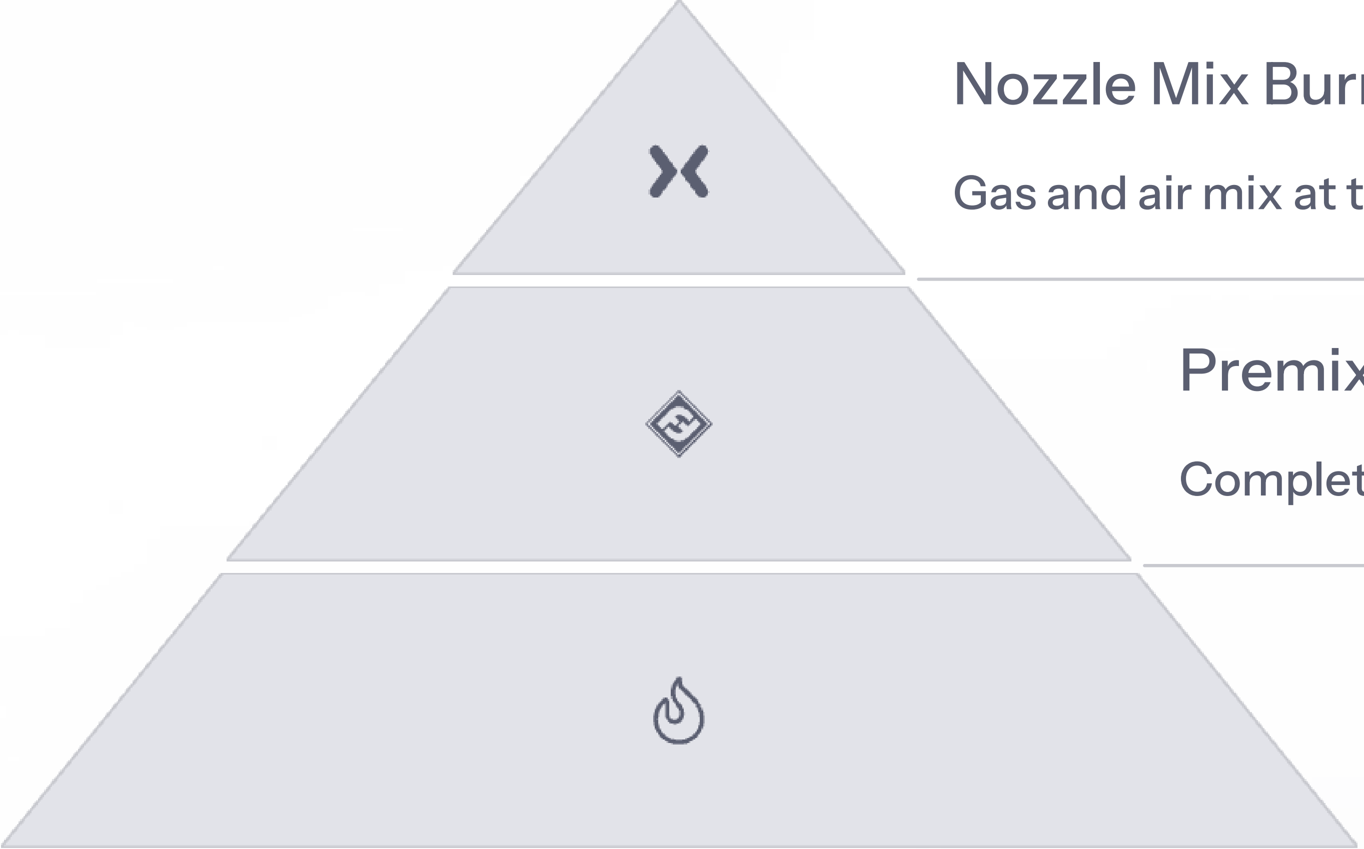
Mechanical device supplies air to overcome burner resistance

### Natural Draft Burners

No mechanical device for supplying combustion air

CSA B149.1 identifies three burner classifications under its definition of burner. These classifications are based on the delivery of combustion air to the burner and on how the combustion gases move through the appliance.

# Common Industry Classifications



### Nozzle Mix Burners

Gas and air mix at the point of combustion

### Premix Burners

Complete mixing of gas and air before combustion

### Atmospheric Burners

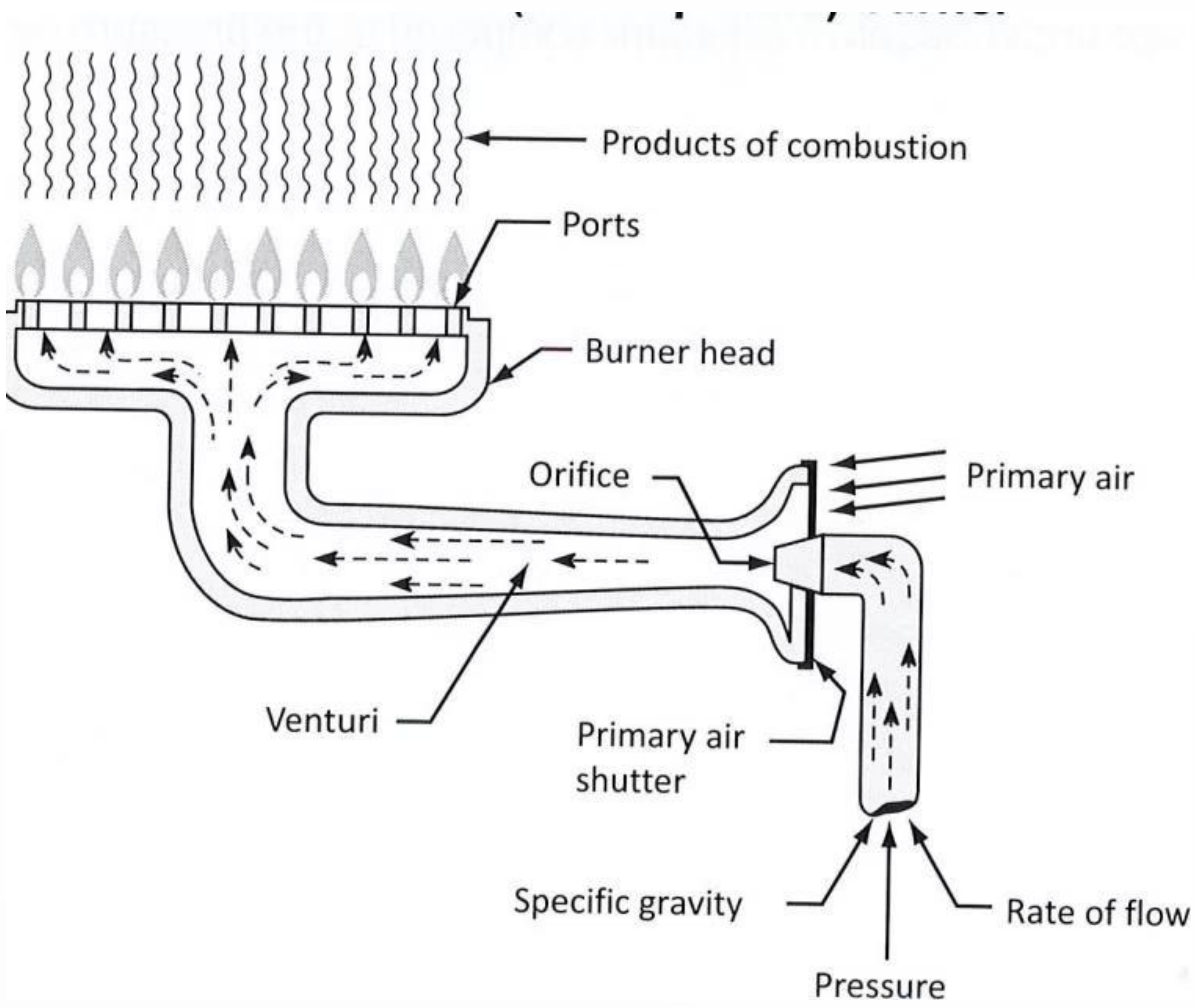
Partial premix of gas and air before combustion

Although these terms are sometimes used in industry literature, a more common method of classification is based on where gas and air are mixed in the combustion process.

# Natural-Draft Burners

A natural-draft burner does not come with a mechanical device for supplying combustion air to the combustion chamber. It is solely dependent on pressure differences that result from natural forces. A natural-draft burner is what you often call an atmospheric burner or inspirating burner.

The force of the gas stream from the orifice pulls primary air into the burner as it passes through the centre of a narrowed opening in the burner body. This venturi effect can entrain approximately 50% of the air required for complete combustion.




The remaining 50% is delivered to the combustion chamber as secondary air in response to the negative pressure that results from hot flue gases rising through the combustion chamber and vent due to natural draft and/or induced draft as discussed in the Venting Chapter.

# Fan-Assist Burners

A fan-assist burner is a burner in which a mechanical device such as a fan or blower supplies the combustion air at sufficient pressure to overcome the resistance of the burner only.

You may place the mechanical device used in a fan-assist burner downstream of the combustion chamber or upstream. In both cases, the combustion chamber and heat exchanger are under negative pressure compared to the pressure outside of the heat exchanger.

**Figure 2-2**
**Fan-assist burner with mechanical air supply fan located downstream of the combustion chamber**

It is important not to confuse mechanical venting systems that help remove the products of combustion with mechanical burner systems that provide air for combustion.

# Fan-Assist Burner with Upstream Blower

In this configuration, the mechanical air supply blower is located upstream of the combustion chamber.

You may use a mechanical device to introduce air into the burner and/or cause the flue gases to pass through the appliance, but this device might not participate in venting. In these cases, the fan-assist burner or forced draft burner depends on a natural draft venting system to move the products of combustion to the outdoors.

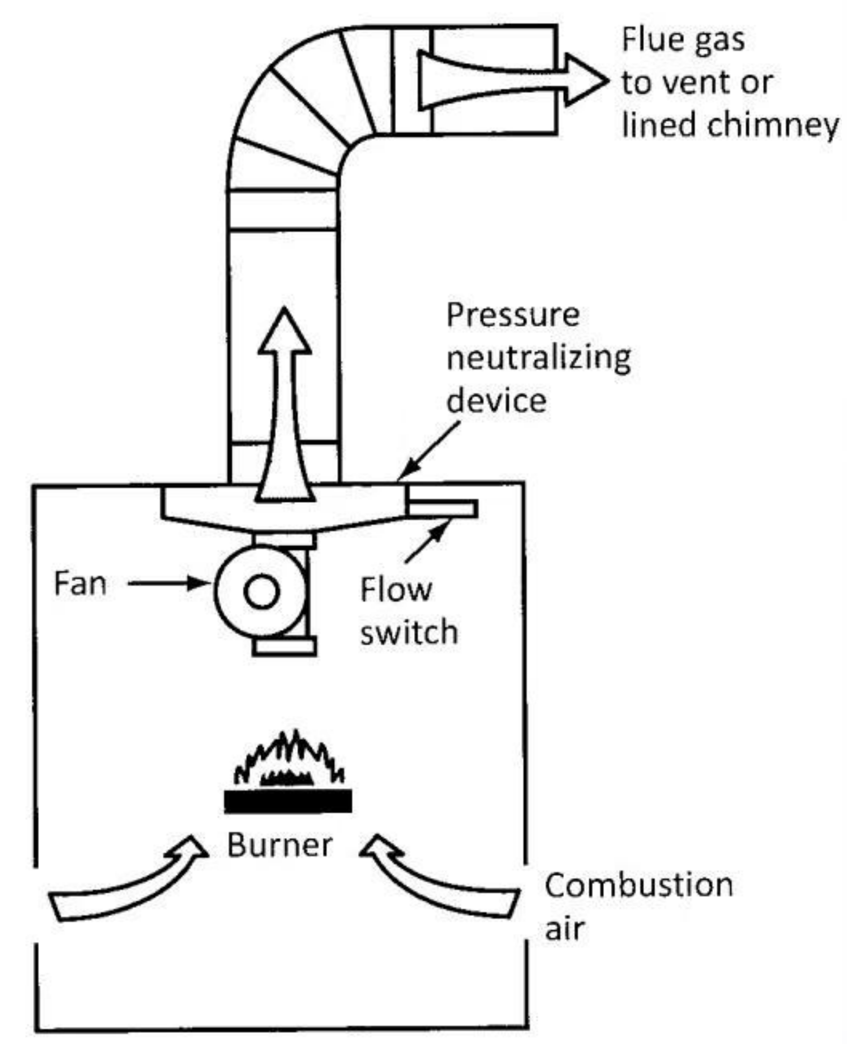
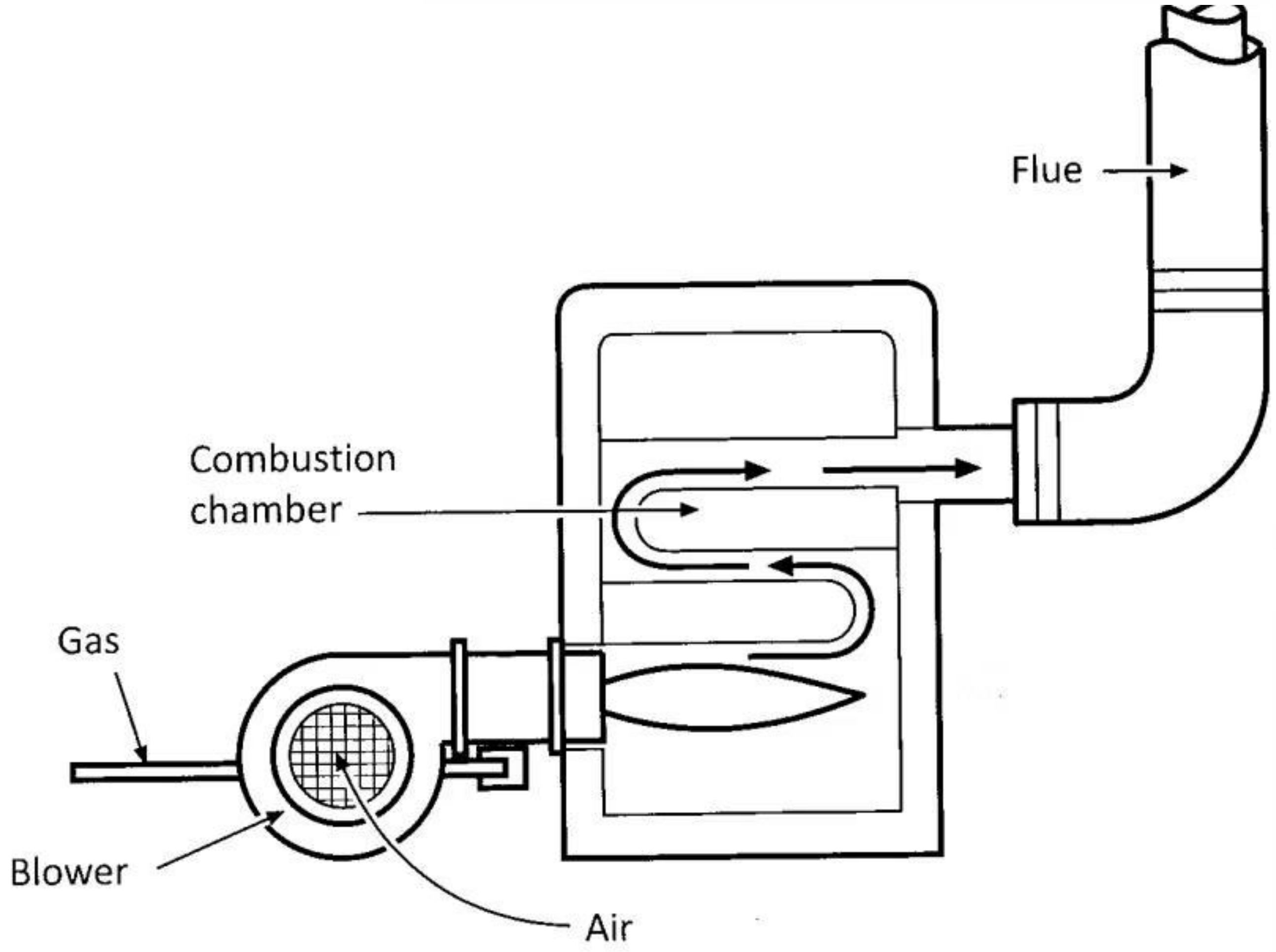



Figure 2-3 Fan-assist burner with mechanical air supply blower located upstream of the combustion chamber

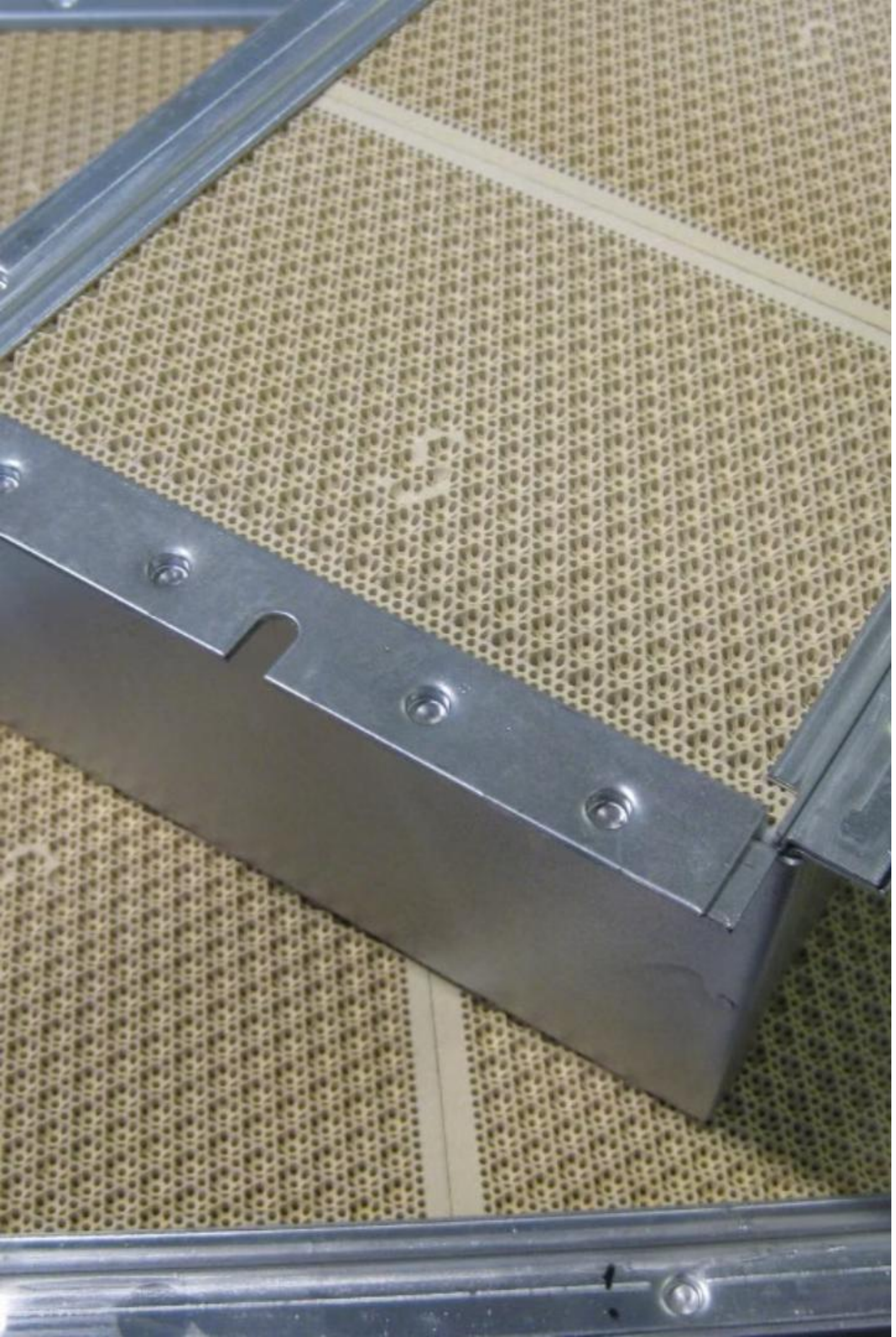
# Forced-Draft Burners

In the design of a forced-draft burner, a fan or blower supplies combustion air at sufficient pressure to overcome the resistance of the burner and the appliance. The location of the fan or blower is upstream of the combustion zone.

A forced draft burner creates a positive pressure in the combustion chamber and throughout the heat exchanger that usually has a high resistance to flow.




In some cases, the design of the blower may be to provide sufficient pressure to overcome the resistance of the venting system as well, in which case you can call it a forced draft burner with a forced draft venting system.



# Atmospheric Burners

### Natural Air Supply

The terms atmospheric burner, inspirating burner, and partial premix burner are interchangeable with the term natural-draft burner.

### Partial Premix

This type of premix burner is in a separate classification from other premix burners that do use mechanical air supply device to highlight the limitations inherent in the natural air supply design.

### Efficiency Limitations

The necessity to supply the remaining 50% as secondary air at the point of ignition and around the flame requires a negative pressure combustion chamber that limits control over excess air, which is important for appliance efficiency.

# Premix Burners

## Definition

Premix burners use a mechanical device to mix the required amounts of air and gas before ignition. People use these burners on high-efficient direct vent residential appliances and in industrial combustion systems that require a short, hot flame with a high heat release.

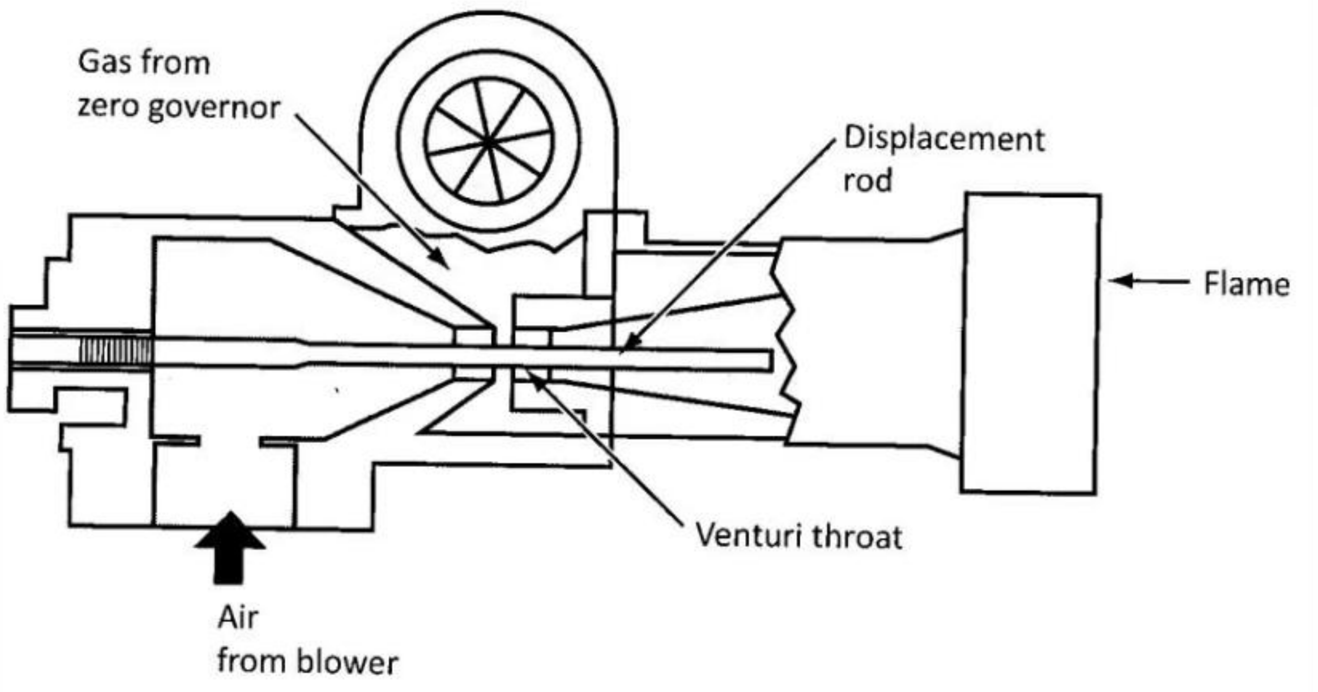
## Two Main Types

1. Aspirator premix burner
2. Blower (or fan) premix burner

# Aspirator Premix Burner

The aspirator type of burner uses air under pressure to entrain gas at atmospheric pressure.

Aspirating burners use a zero governor to regulate the gas supply. As the air pressure increases through the venturi (located in the air-jet mixer), the velocity increases and the pressure drops. The zero governor senses the lowered pressure and opens wider to increase the gas supply.




This allows the air-to-gas ratio to stay the same and provide a consistent flame throughout the firing range of the burner.

# Aspirator Premix Burner with Zero Governor

Industrial aspirator premix burners usually employ a separate component for the zero governor. Residential, or smaller input, appliances usually have the zero governor function incorporated into the combination gas valve.

**Figure 2-5**
**Aspirator industrial premix burner**

Courtesy of Honeywell Inc.

# Zero Governor in Combination Gas Valve

The zero governor function is often incorporated into the combination gas valve in residential or smaller input appliances.

This integrated design simplifies the overall system while still providing the necessary regulation of gas supply based on air pressure changes.

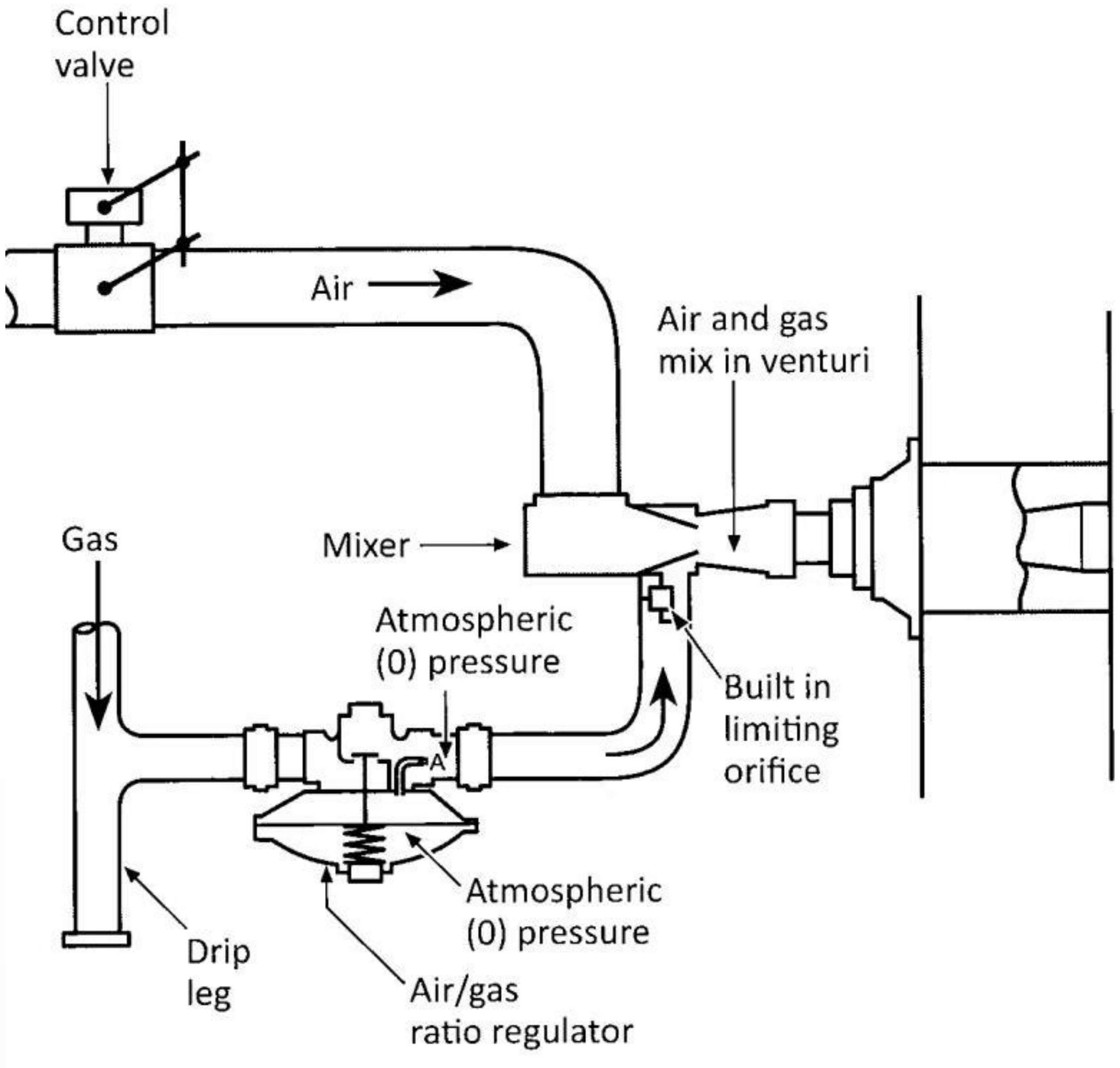


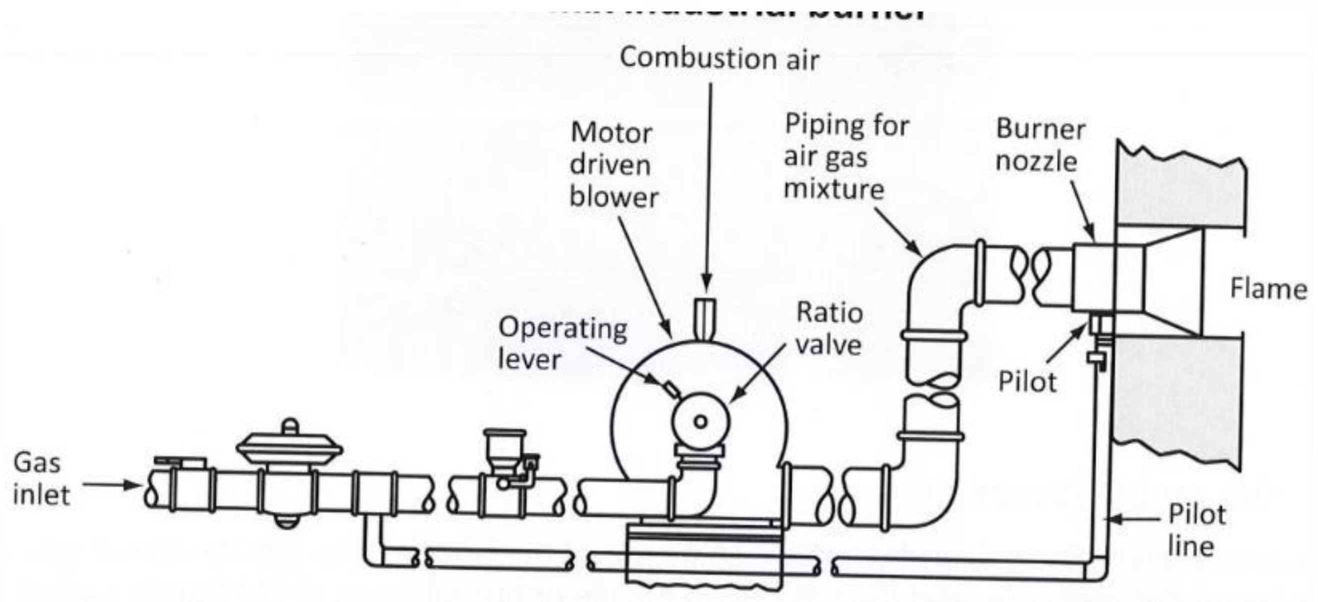

Figure 2-6 Aspirator premix burner with zero governor

# Blower (or Fan) Premix Burner

The blower-mix or fan-mix burner provides complete premixing with mechanical mixers. This burner produces and burns mixtures at any pressure:

- to overcome high combustion chamber pressures; or
- to give a wide range of operation to burner equipment.

Energy use is high because of the direct use of the mixture from the mixing machine without any further mixing losses.




Because ratio control is accurate and independent of the volume delivered, you may supply a number of burners independently.

# Zero Governor in Combination Gas Valve

The blower mixer draws in both air and gas at atmospheric pressure. The valve train has a zero governor as a separate component or as a part of the valve train.

This configuration allows for precise control of the air-to-gas ratio regardless of changes in input rate or combustion chamber pressure.

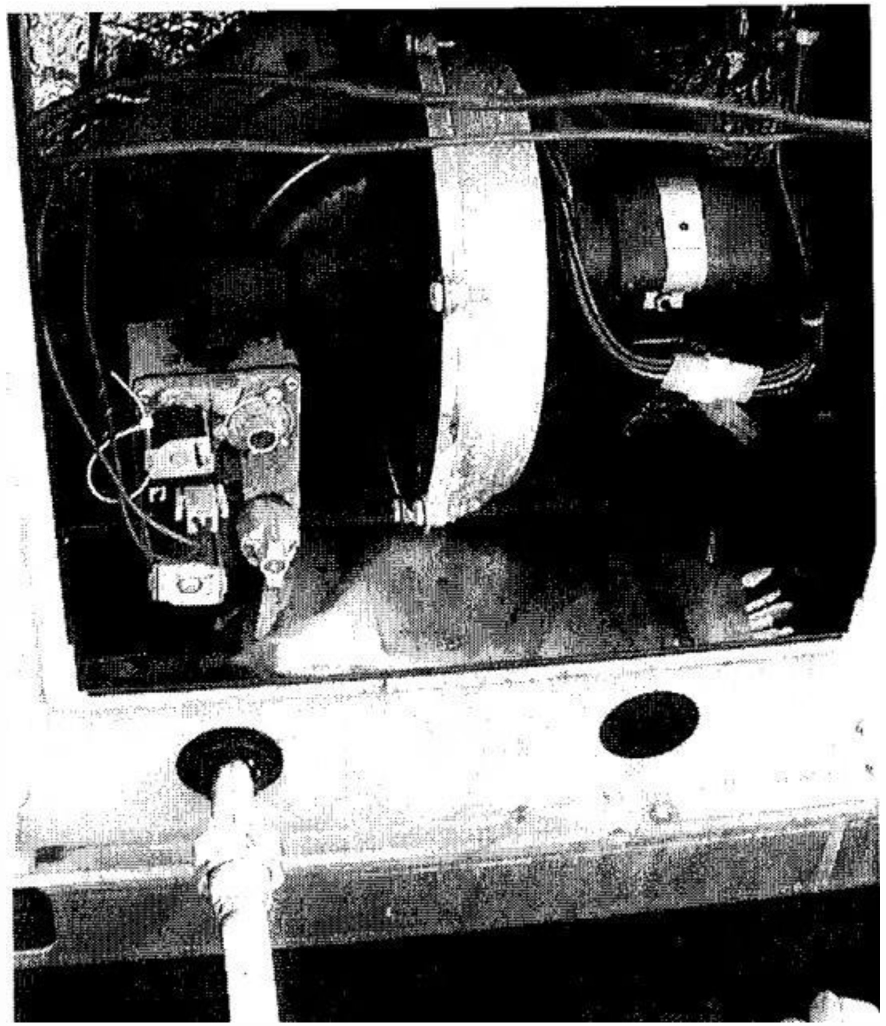


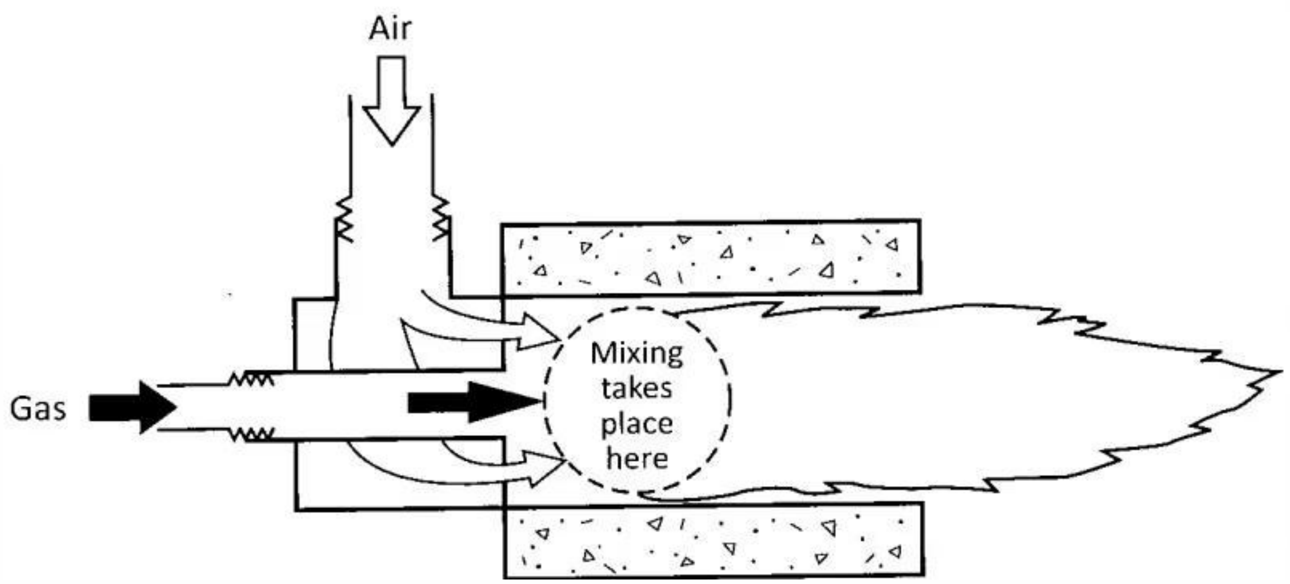
Figure 2-9 Zero governor in combination gas valve supplying gas to a blower premix burner

# Nozzle Mix Burners

As the name implies, the gas and combustion air mix at the nozzle. The supply of both gas and air have separate piping to the burner. Mixing in the tile or burner head of the burner occurs as they exit the fuel and air nozzles.

Firing of nozzle-mix burners can be on-ratio, on excess air, or on excess fuel. This fuel/air ratio range is much wider than that for premix burners, because nozzle-mix burners are not as limited since there is no premixed gas and air in the piping upstream of the burner nozzles.

**Figure 2-10**
**Nozzle mix burner**




These burners produce a characteristic "swirling" action to the flame. The flame shape varies with the number and arrangement of gas ports in relationship to the air turbulators.

# Nozzle Mix Burner Characteristics

## Very Long Flame

Requires space and time to complete combustion

## Colorful Flame

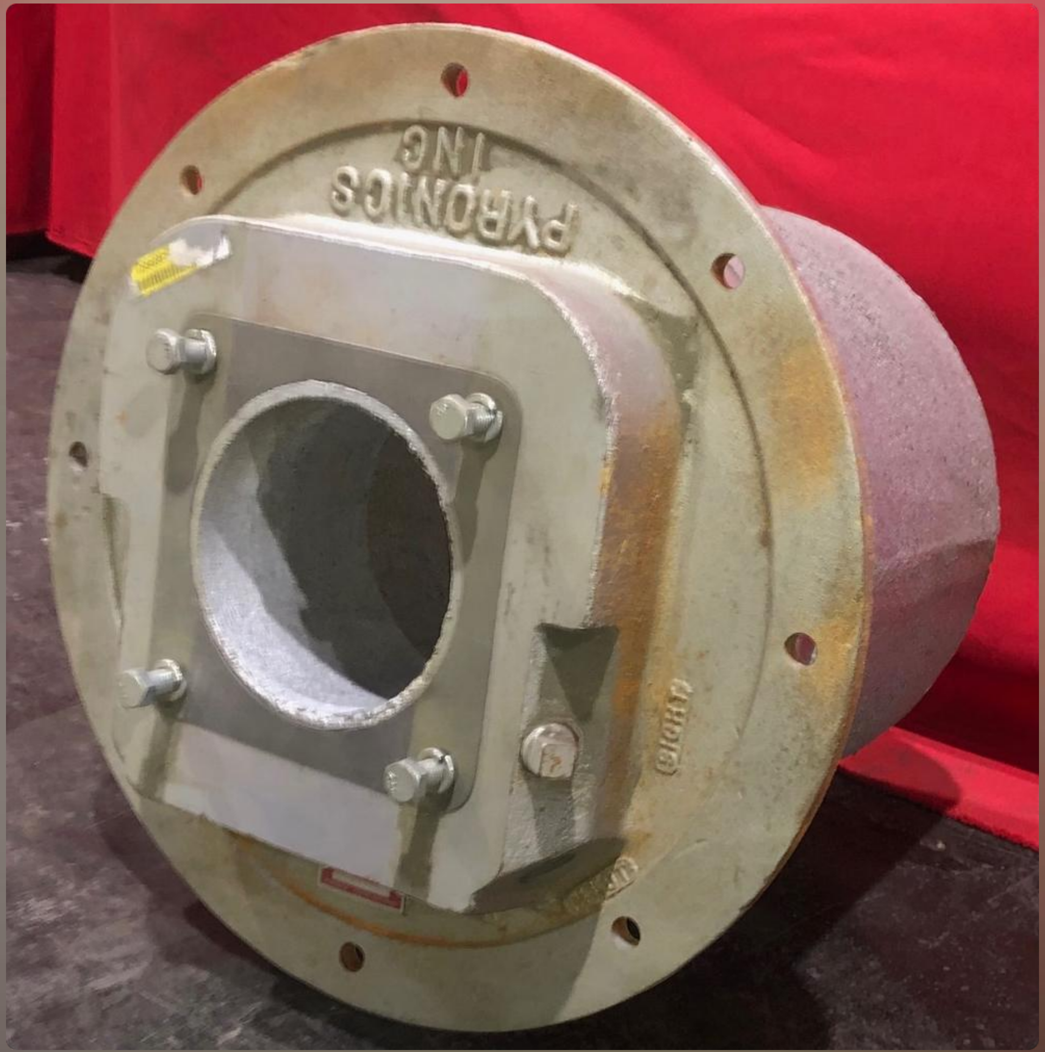
Usually blue and white with some yellow tips

## High Radiation Heat Energy

Provides excellent radiant heat transfer

## Lower Flame Temperature

Compared to premix burners



# Ring-Type Nozzle Mix Burner

Although you most commonly find nozzle mix burners on larger industrial burners, smaller input versions of the ring type are used in boilers, indirect-fired makeup air heaters, and conversion gas burners.

These smaller versions maintain the same operating principles as their larger industrial counterparts but are designed for lower input applications.

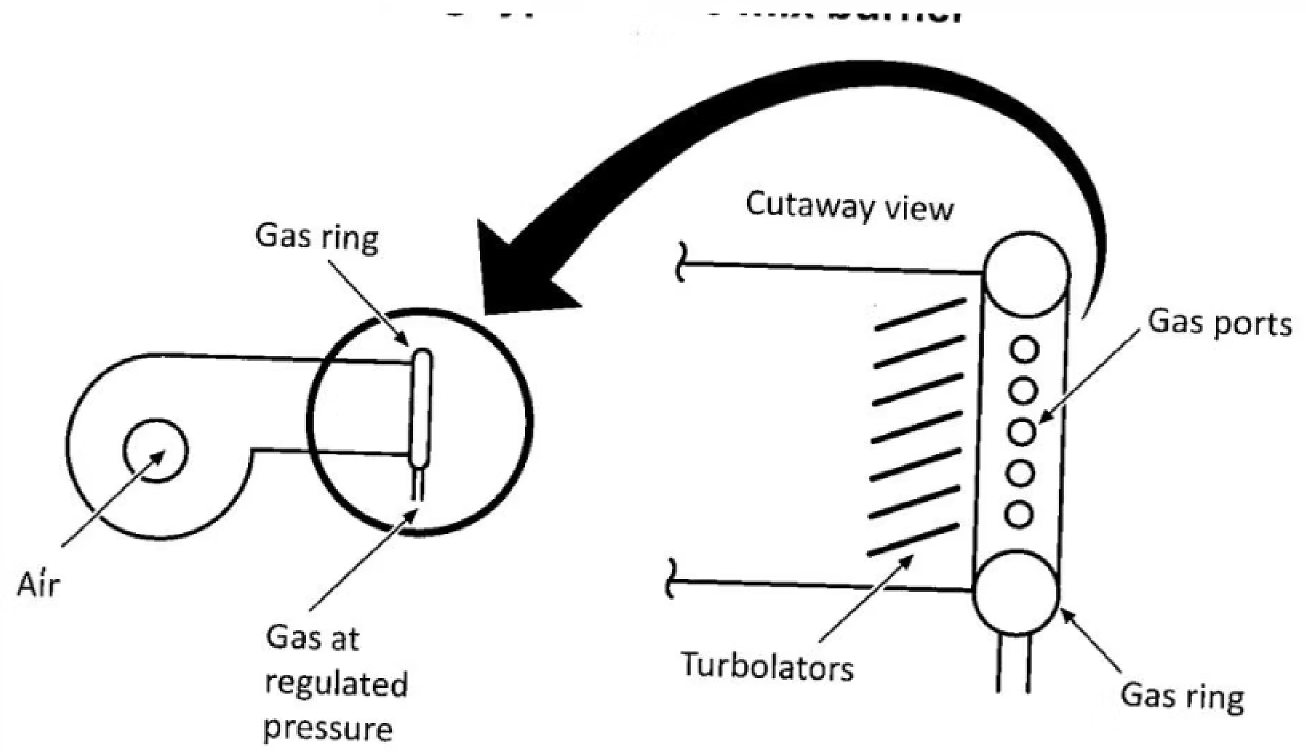



Figure 2-11 Ring-type nozzle mix burner

Courtesy of Honeywell Inc.

# Air/Gas Ratio Control Systems

You can provide the air/gas ratio to a nozzle mix burner in a wide variety of ways depending on the burner head design. The two most common proportioning systems are:

- modulating gas valve linking air and gas butterfly valves; and
- modulated air valve with an air/gas ratio regulator.

**Figure 2-12**
**Air to gas ratio to a nozzle mix burner controlled through a modulating motor cross-linked to gas and air butterfly valves**

These control systems ensure the proper air-to-gas ratio is maintained throughout the burner's operating range, which is essential for efficient and clean combustion.

# Air/Gas Ratio Regulator

Air to gas ratio to a nozzle mix burner can be controlled through an air/gas ratio regulator and the modulation of a modulated air line cross-linked through an impulse line.

This system provides precise control of the air-to-gas ratio regardless of changes in firing rate or combustion chamber conditions.

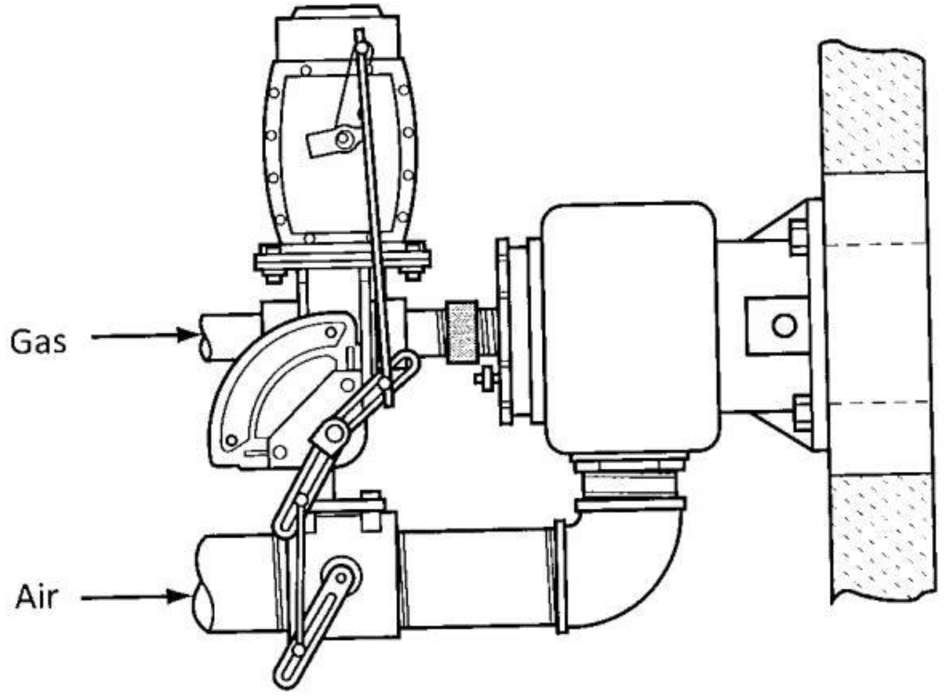



Figure 2-13 Air to gas ratio to a nozzle mix burner controlled through an air/gas ratio regulator

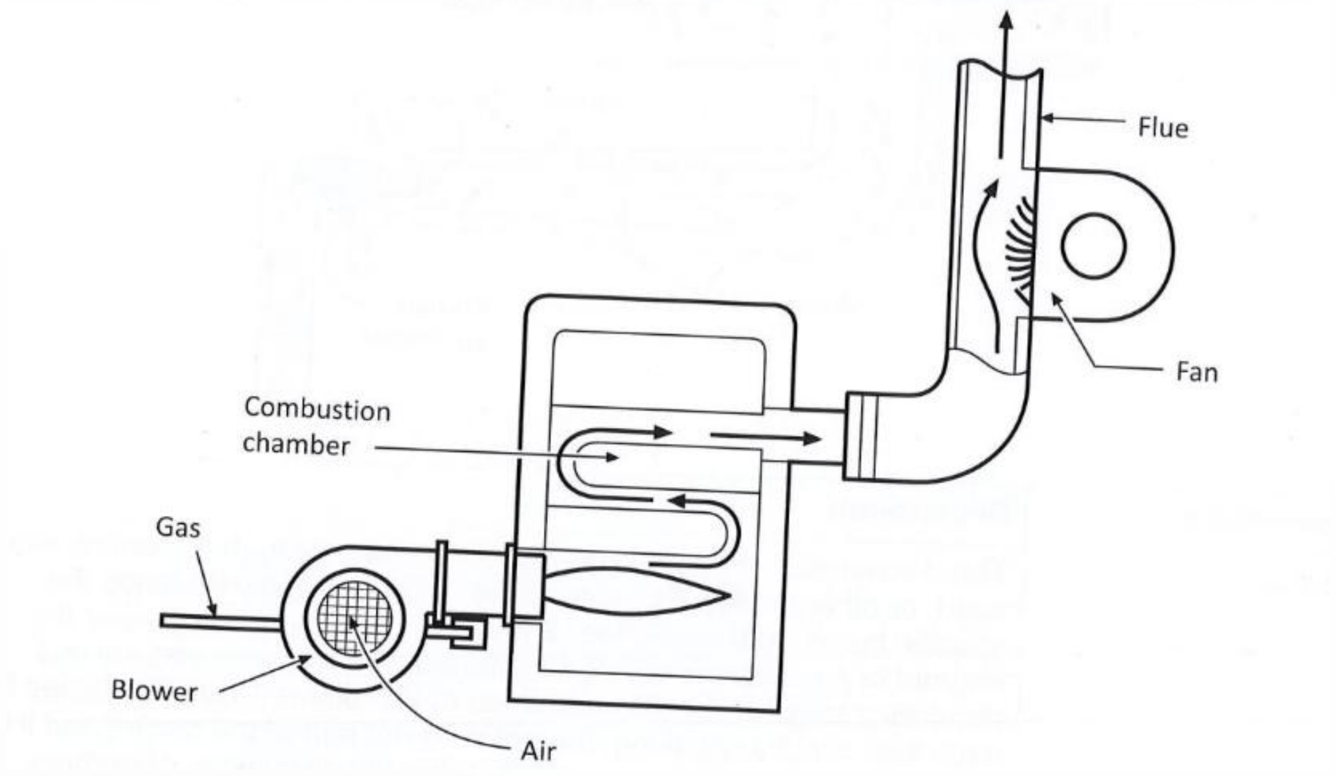
Courtesy of North American Mfg. (Canada) Inc.

# Power Burners

The industry generally uses the term power burner to refer to any gas burner equipped with a blower located upstream of the combustion chamber. As such, the term is interchangeable with the term forced draft burner.

Although it uses a blower to deliver all the combustion air to the combustion chamber, a power burner (like a forced-draft burner) does not necessarily force flue gases to the appliance outlet at zero pressure and may depend on a natural draft or fan-assist venting system to remove the flue gases to the outdoors.

**Figure 2-14**
**Power burner (or forced draft burner) with an induced draft venting system**

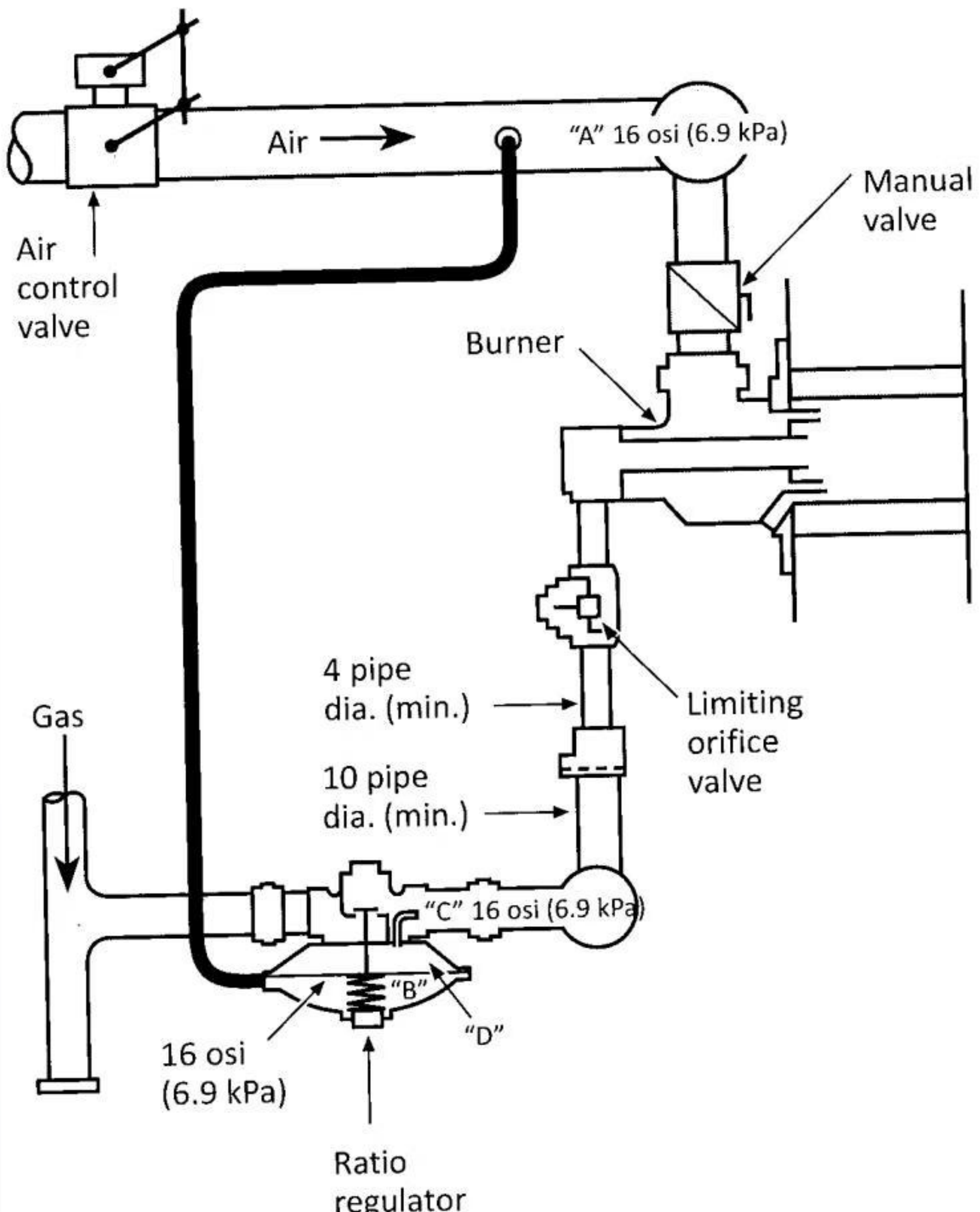



Power burners provide excellent control over the combustion process but require electrical power to operate, making them unsuitable for applications where electricity may not be available or reliable.

# Atmospheric Burners Overview

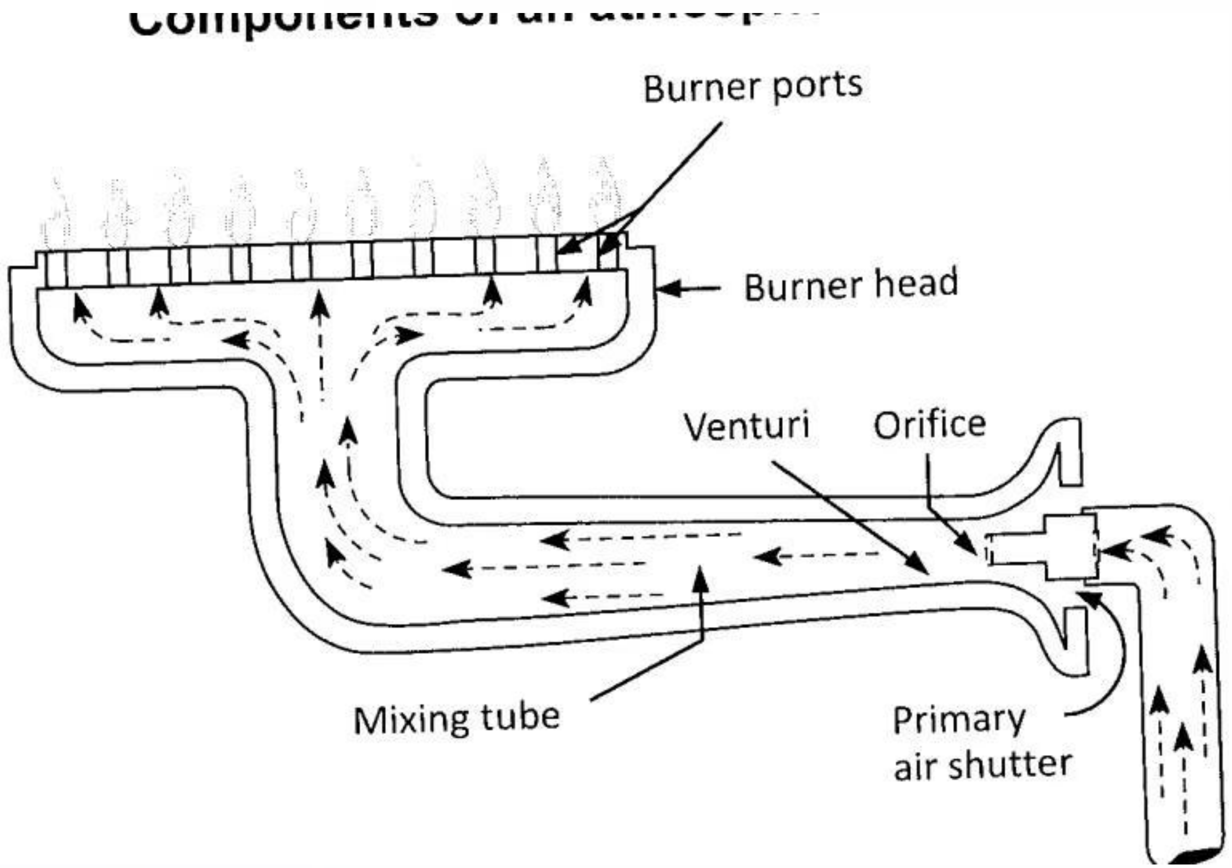
An atmospheric burner is the most common type of burner you can find in residential and commercial applications. Its function is to burn gaseous fuels efficiently and simply, while operating under normal atmospheric pressure with low gas pressures.

Atmospheric burners are a type of premix burner. However, their principle of operation only allows for the premixing of approximately 50% of the air needed for combustion. You must supply the remaining air required for complete combustion as secondary air after the point of ignition and around the flames of the burners. As such, the industry often calls them partial premix burners.



# Atmospheric Burner Components

Gas burners have many different shapes, sizes, and styles, but they all have the same basic components. Since you may need to adjust and service the burners after installing each appliance, you should know each component and how it operates.



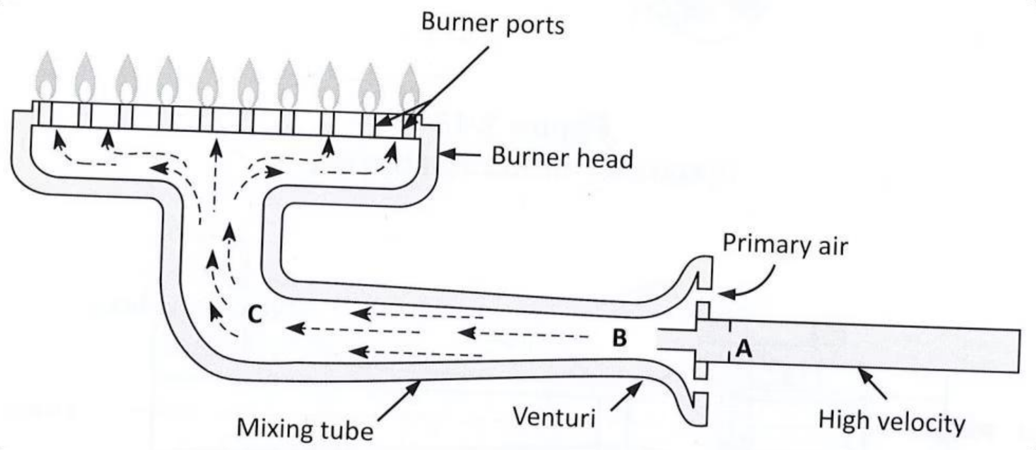

Understanding the function of each component is essential for proper installation, adjustment, and troubleshooting of atmospheric burners.

# Orifice and Primary Air Shutters

| Component | Description |
| --- | --- |
| Orifice | The discharge of the fuel to the burner passes through the orifice cap, spud, or other device. The size of the orifice precisely matches the specific burner and appliance. The larger the orifice, the greater the amount of gas flow through it. Compared with propane, natural gas requires a larger size orifice because of the different calorific values for each fuel. Strictly speaking, the orifice is not part of the burner, but it is such a vital part of the burner system that the discussion of burners includes it. |
| Primary air shutters | The air shutter adjusts the size of the primary air inlet(s). Some burners have a fixed primary air inlet and are designed for a particular gas at a specific gas pressure. Most burners, however, have an adjustable air shutter to adjust the primary air flow. |

# Venturi and Mixing Tube

| Component | Description |
| --- | --- |
| Venturi | The venturi is a short tube with a constricted, throat-like passage. This passage increases the velocity and lowers the pressure of a gas passing through it. Many atmospheric burners are necked down to a venturi throat. |
| Mixing tube | The mixing tube is the portion of the mixer that lies between the venturi and the burner head. The gas and primary air mix together as they move along this tube. |



# Burner Head and Ports

| Component | Description |
|---|---|
| Burner head | The burner head uniformly distributes the air/gas mixture to the burner ports. You can tailor its size and shape to fit an appliance combustion chamber and provide even heat release to heat transfer surfaces. |
| Burner ports | The burner port is an orifice, or opening, that does three things. It:<br>· discharges the air/gas mixture for ignition;<br>· distributes flames to provide an even heat transfer to the heat exchanger; and<br>· spreads the flames so they can be reached by secondary air. |

# Single Port (Monoport) Burners

The single port burner is an extremely simple design and is fairly inexpensive. To make a single port burner, simply extend the mixer tube and expect gas to exit at the end. In other words, there is no burner head.

This design produces a single large flame. To eliminate yellow tipping when burning natural gas, single port burners need about 50% (or more) primary air.

Single port burners usually are more susceptible to flashback and are noisier than most other types of burners. The flames on large single port burners also tend to lift. Oftentimes, you need to insert a flame retention device to prevent lifting.

The most common types of single port burners are the inshot and upshot burners.

# Inshot Burners

An inshot burner usually fires horizontally. Gas burns on the end of the straight extension of the mixer tube. A flame spreader is sometimes mounted in front of the port to spread the flame (not shown).

Inshot burners are commonly used in furnaces and other heating appliances where a horizontal flame pattern is desired.

**Figure 2-17**
**Inshot monoport burner**

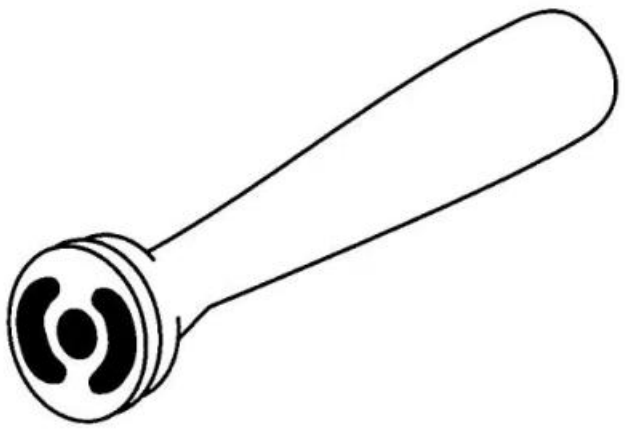
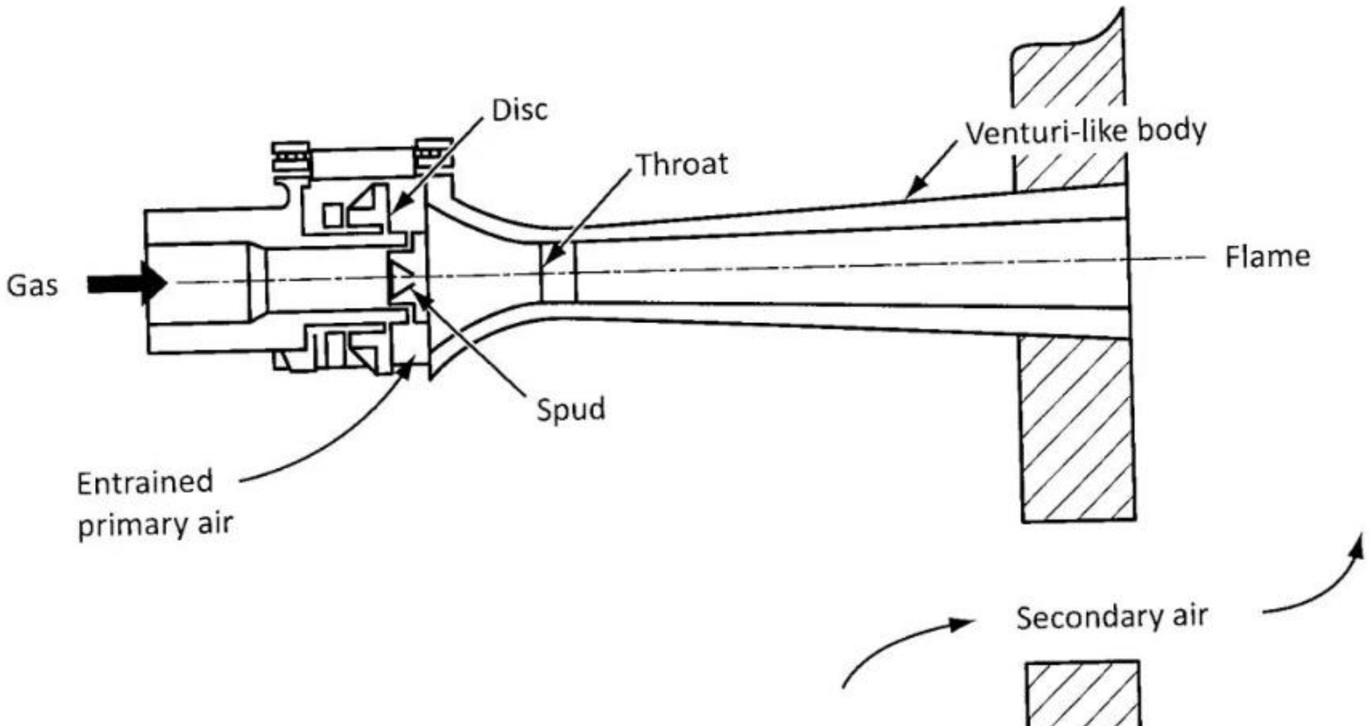


**Figure 2-18**
**Inspirator industrial burner**



# Upshot Burner

In an upshot burner, air/gas mixture flows through a bend and into a riser tube where it burns vertically. Again, a flame spreader is sometimes mounted above the port to spread the flame.

Upshot burners are commonly used in applications where a vertical flame pattern is desired, such as in certain types of water heaters and boilers.

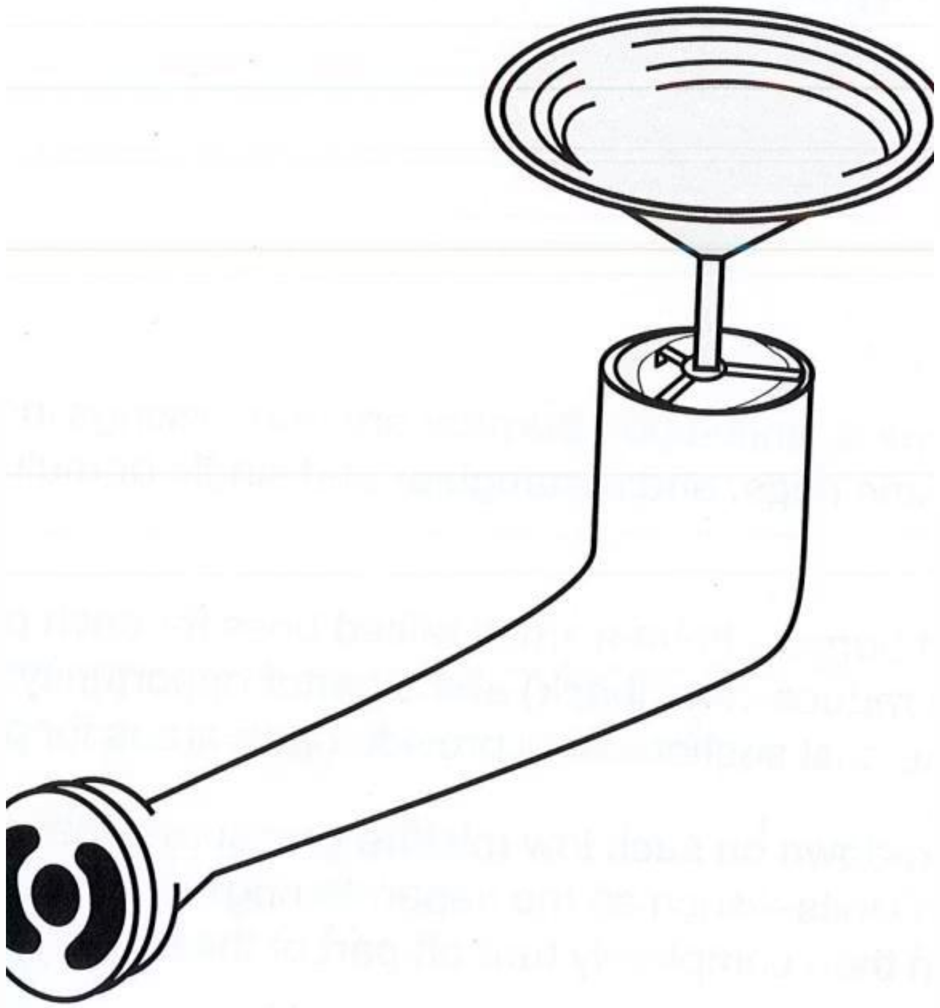


Figure 2-19 Upshot monoport burner

The vertical orientation of upshot burners can help improve heat transfer efficiency in certain appliance designs.

# Multiport Burners

The multiport burner is the most common atmospheric burner in appliances. The basic components are the same as a monoport upshot burner with the addition of a burner head with multiple ports.

The multiple burner ports serve several purposes:

- They distribute flames to provide good heat transfer to the heat exchanger.
- They spread the flames so they can be reached by secondary air.
- They provide stable blue flames.

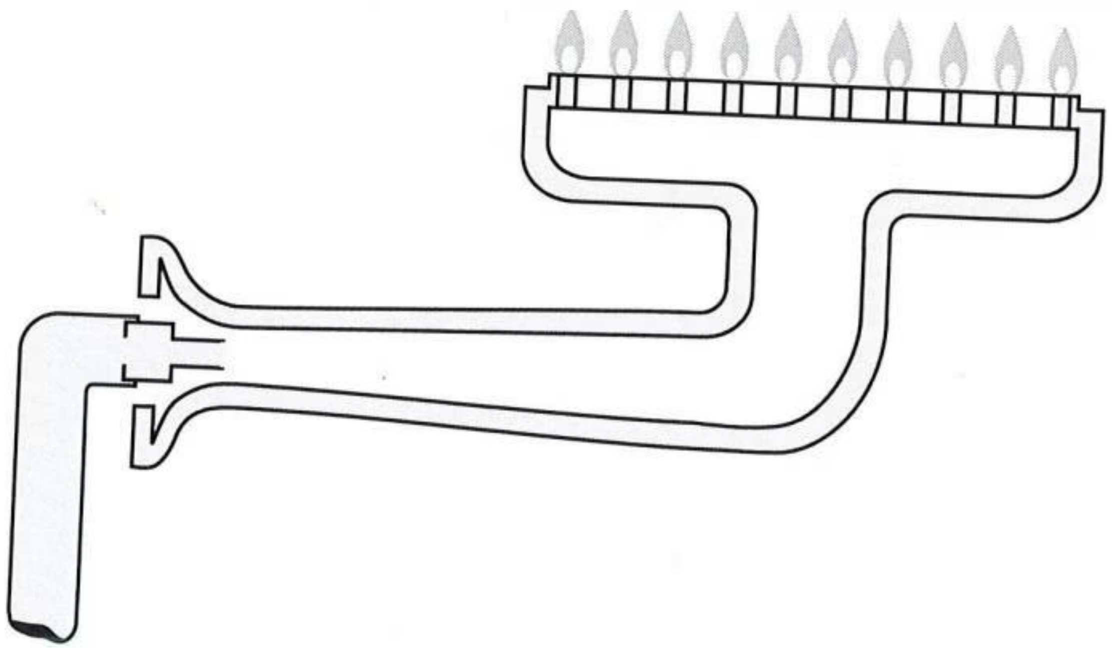


Figure 2-20 Upshot multiport burner

Multiport burners are susceptible to clogging from the inside with lint.


# Types of Multiport Burners

## Drilled Port

Iron castings in the form of stars, wheels, and rectangular or single or multiple bars.

## Drilled Pipe

Made from standard pipe with either one row of holes on top, or two rows at 30° each side of vertical.

## Slotted Port

Uses sawed slots instead of drilled holes in the pipe.

## Ribbon Port

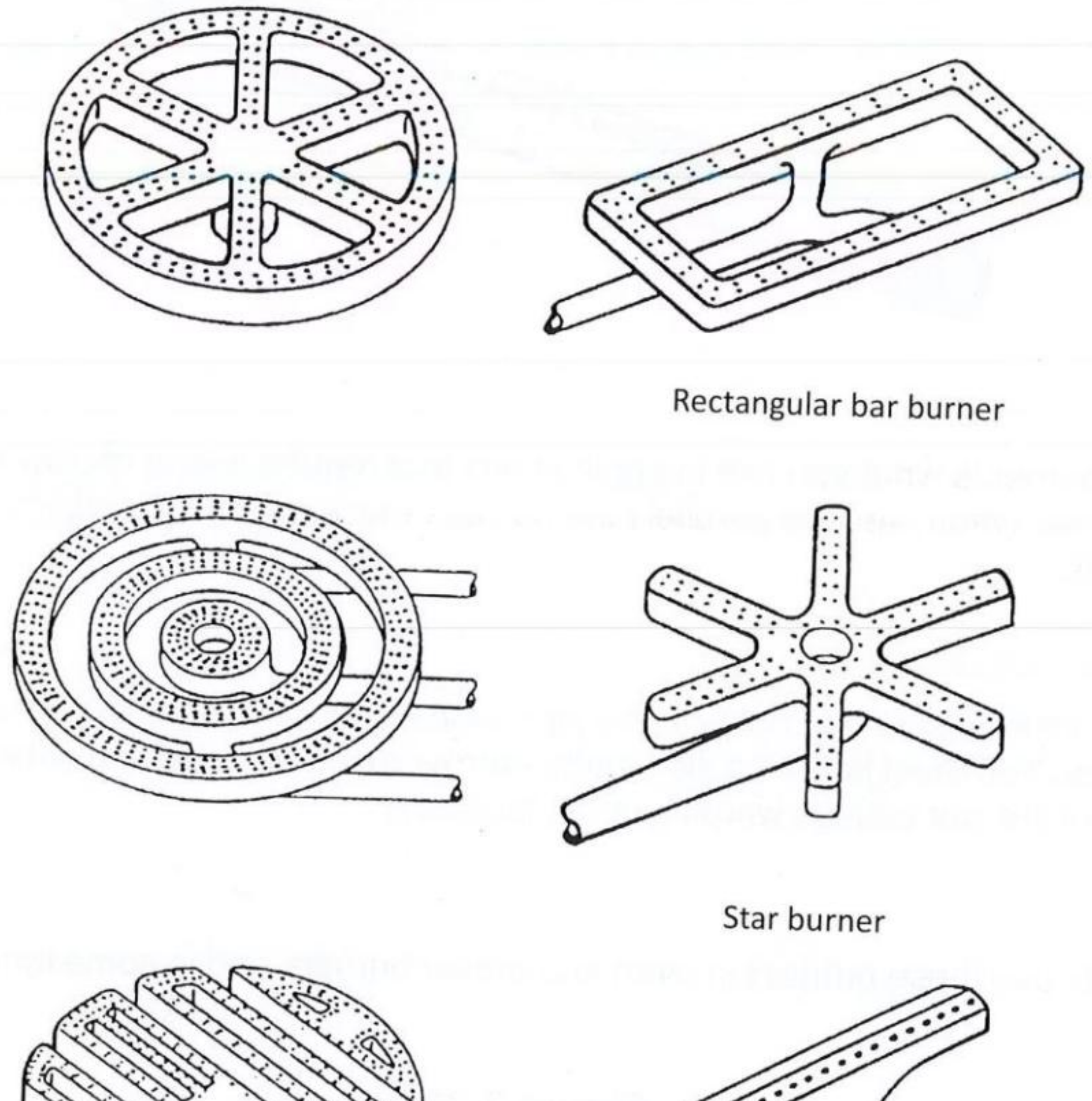
Similar to drilled pipe but with lengthwise slots that have an electrostrip pressed into them.

# Drilled Port Burner

Classified as multiport burners, drilled port burners are iron castings in the form of stars, wheels, and rectangular or single or multiple bars.

Some cast iron drilled port burners have a small raised boss for each port. These bosses give greater port length (which reduces flashback) and a better opportunity for secondary air to surround the flame jet. The cast sections also provide open areas for proper air distribution.

**Figure 2-21**
**Types of drilled port burners**
**Image courtesy of BC Gas.**



# Drilled Port Burner Uses

### Solution Tanks

These burners spread the heat at a low intensity over a relatively large area for low temperature operations such as heating small solution tanks.

### Cooking Applications

Commonly used in cooking kettles, candy furnaces, stove top ovens, and broiler burners.

### Industrial Processes

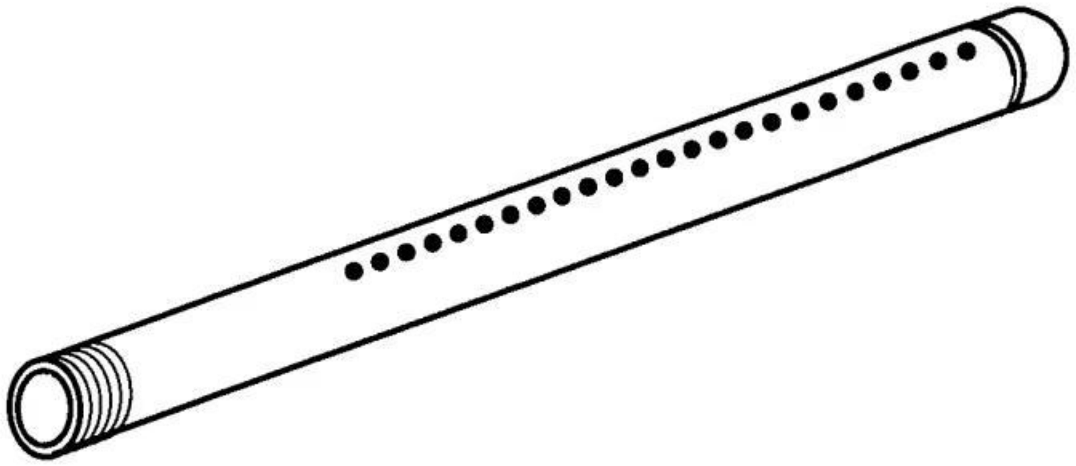
Suitable for various industrial heating applications requiring even heat distribution.

# Drilled Pipe Burner

Manufacturers make drilled pipe burners from standard pipe with either one row of holes on top, or two rows at 30° each side of vertical. The critical measurements are:

- port size;
- total port area;
- ratio of port area to cross-section;
- total length; and
- distance from mixer to first port.

Figure 2-22
Drilled pipe burner



The drilled pipe burner is used in applications that require a long narrow heat band, as in long ovens. They also make a simpler installation than several cast head burners.

# Slotted Port Burner

The sawed slots instead of drilled holes in the pipe are a modification of the drilled pipe burner. You must keep the slots quite narrow which makes them subject to clogging. Also, the length of the slot causes warping in hot locations.

People frequently use these burners in oven and broiler burners and in some industrial applications.

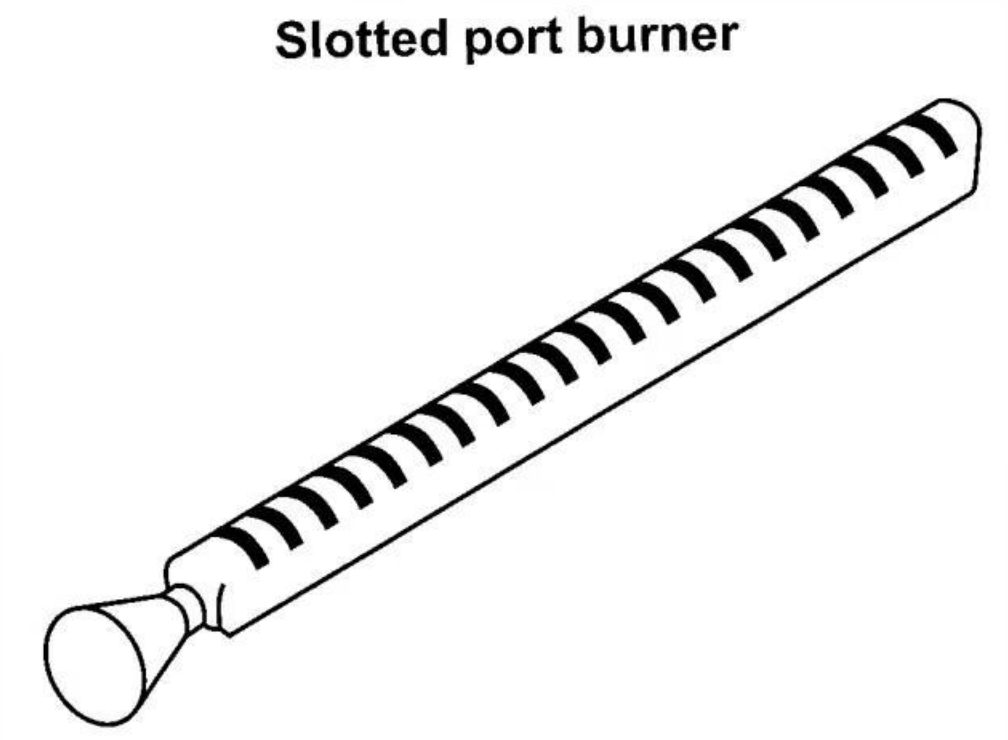



Figure 2-23 Slotted port burner

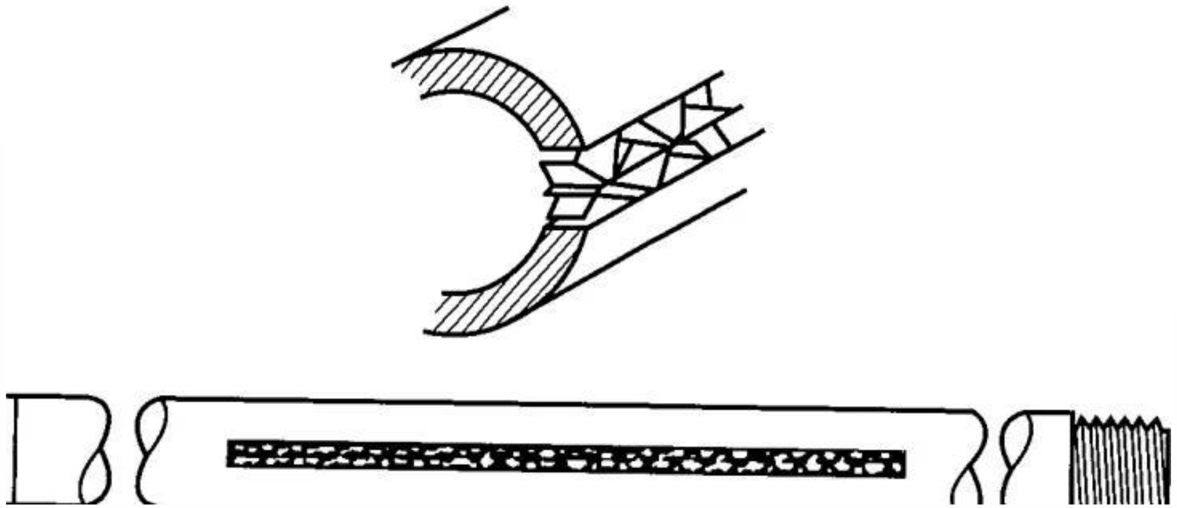
The slotted design allows for a more continuous flame pattern compared to drilled holes, which can be advantageous in certain heating applications.

# Ribbon Port Burner

Similar to the drilled pipe burner, the ribbon port burner is often made from standard pipe. However, instead of drilled holes, the pipes have lengthwise slots that have an electrostrip pressed into them.

The spaces that the crimped metal creates provide the individual ports. This results in a continuous flame, instead of individual jets. Because of the solid flame, the slot width must be narrow enough to allow secondary air to reach the centre of the flame.

**Figure 2-24**
**Ribbon burner**
**Image courtesy of BC Gas.**



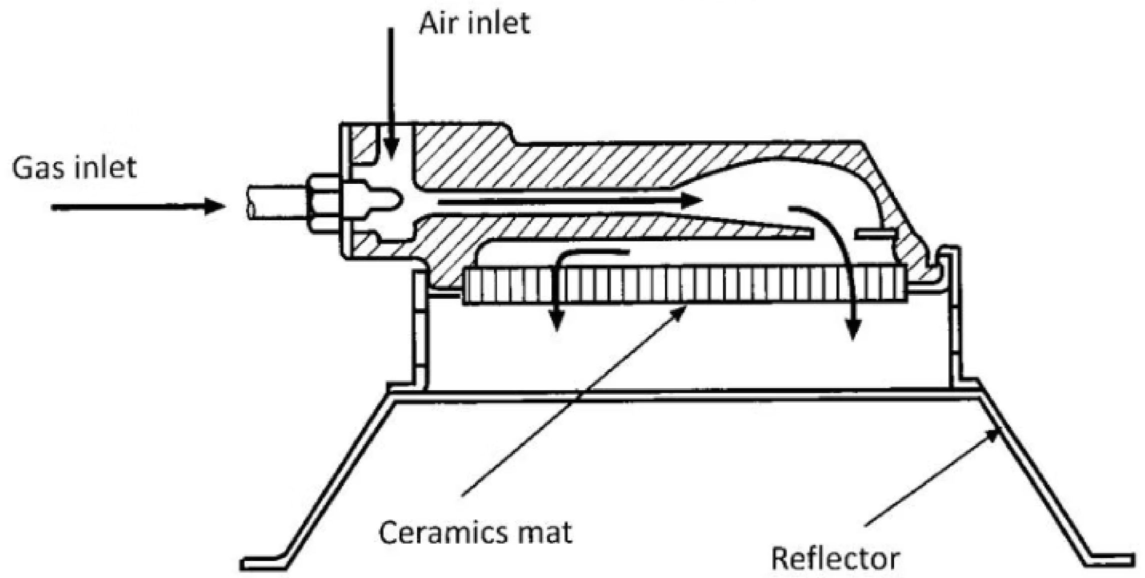
As a rule, the continuous flame is generally shorter for the same Btu release of heat in the ribbon port burner than the drilled pipe burner.

Large bakery ovens, solder pots on can machinery, and textile singeing and shrinking machines (tentering frames) widely employ ribbon burners.

# Radiant Head Atmospheric Burners

You can employ the basic atmospheric burner design to supply a partial premixture of air and gas to a catalytic burner head that creates a radiant heat surface. The catalytic burner head may be ceramic or metal in which a catalytic agent such as platinum is distributed.

**Ceramic radiant burner head on atmospheric burners**



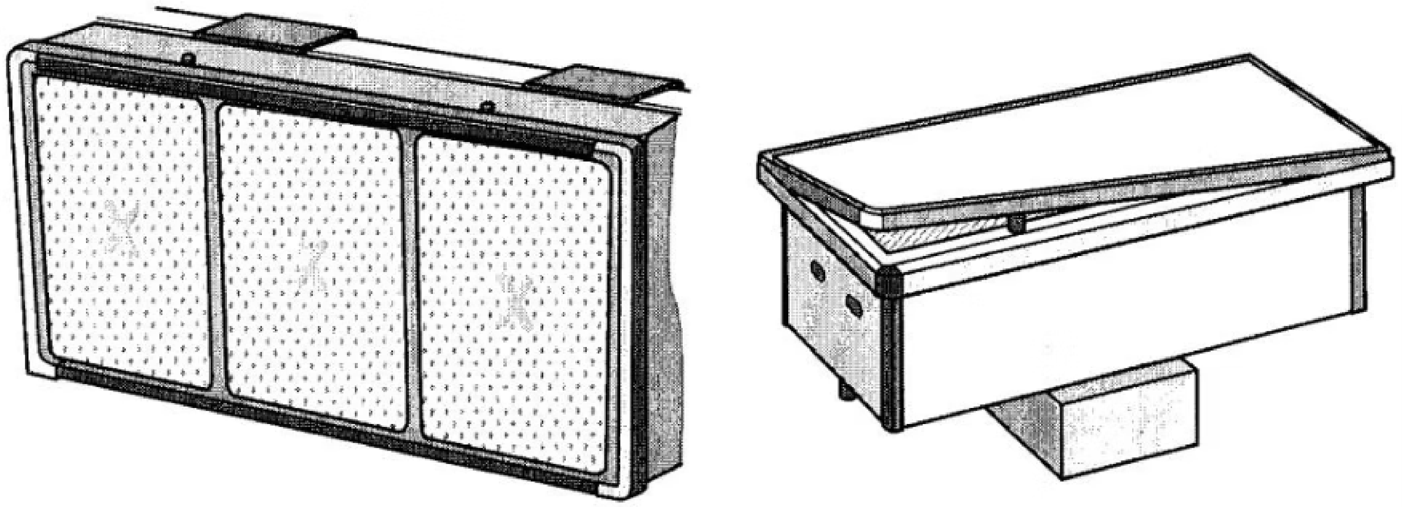



**Figure 2-26**
**Wire matrix radiant burner head**

# Ceramic Radiant Burner

Ceramic radiant burners use a ceramic material as the burner head, which becomes incandescent when heated by the combustion process.

The ceramic material provides a large surface area for the combustion reaction and radiates heat efficiently to the surrounding environment.

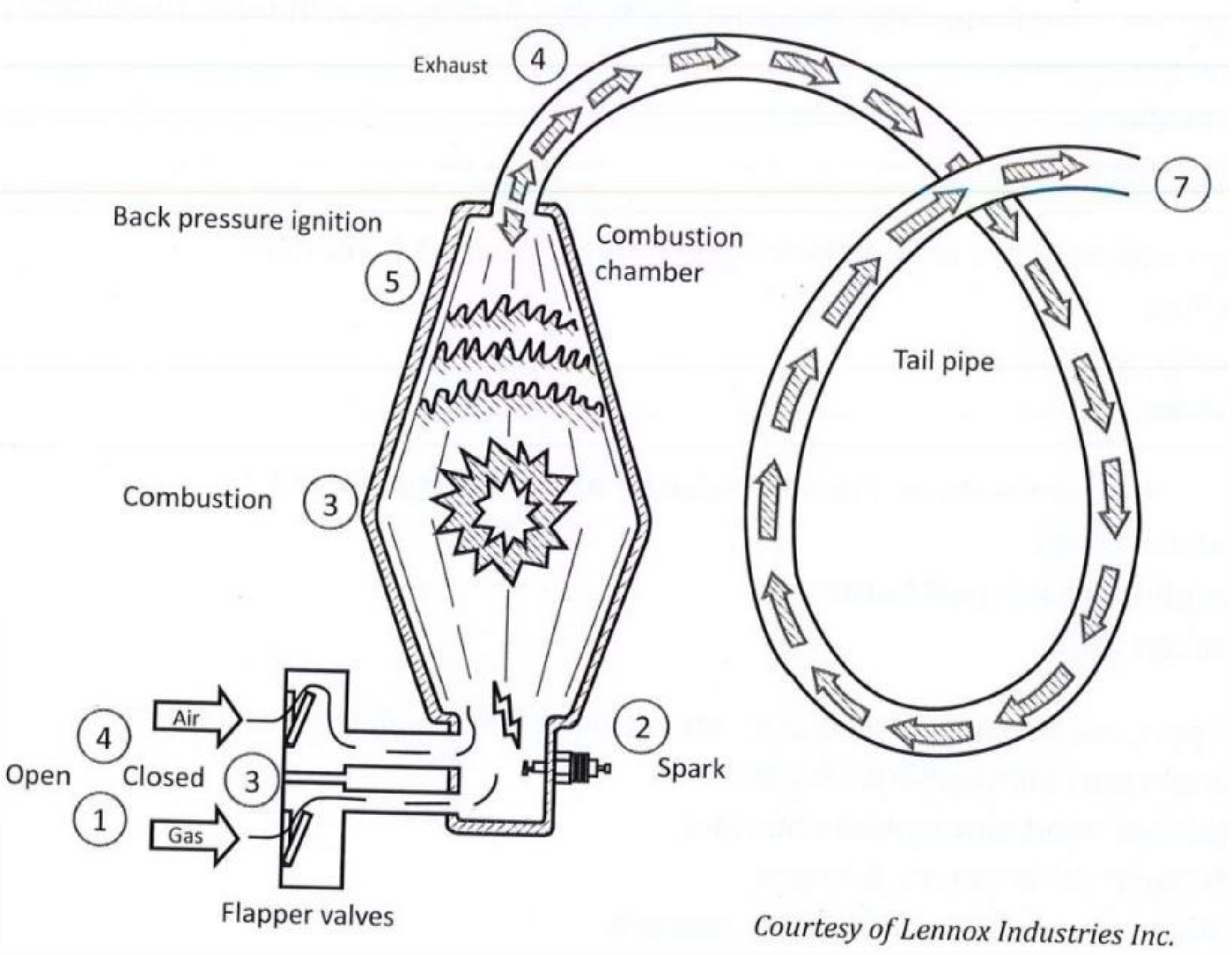
**Figure 2-25**
**Ceramic radiant burner head on atmospheric burners**

These burners are often used in applications where a high radiant component of heat transfer is desired, such as in certain types of space heaters and industrial process heating.

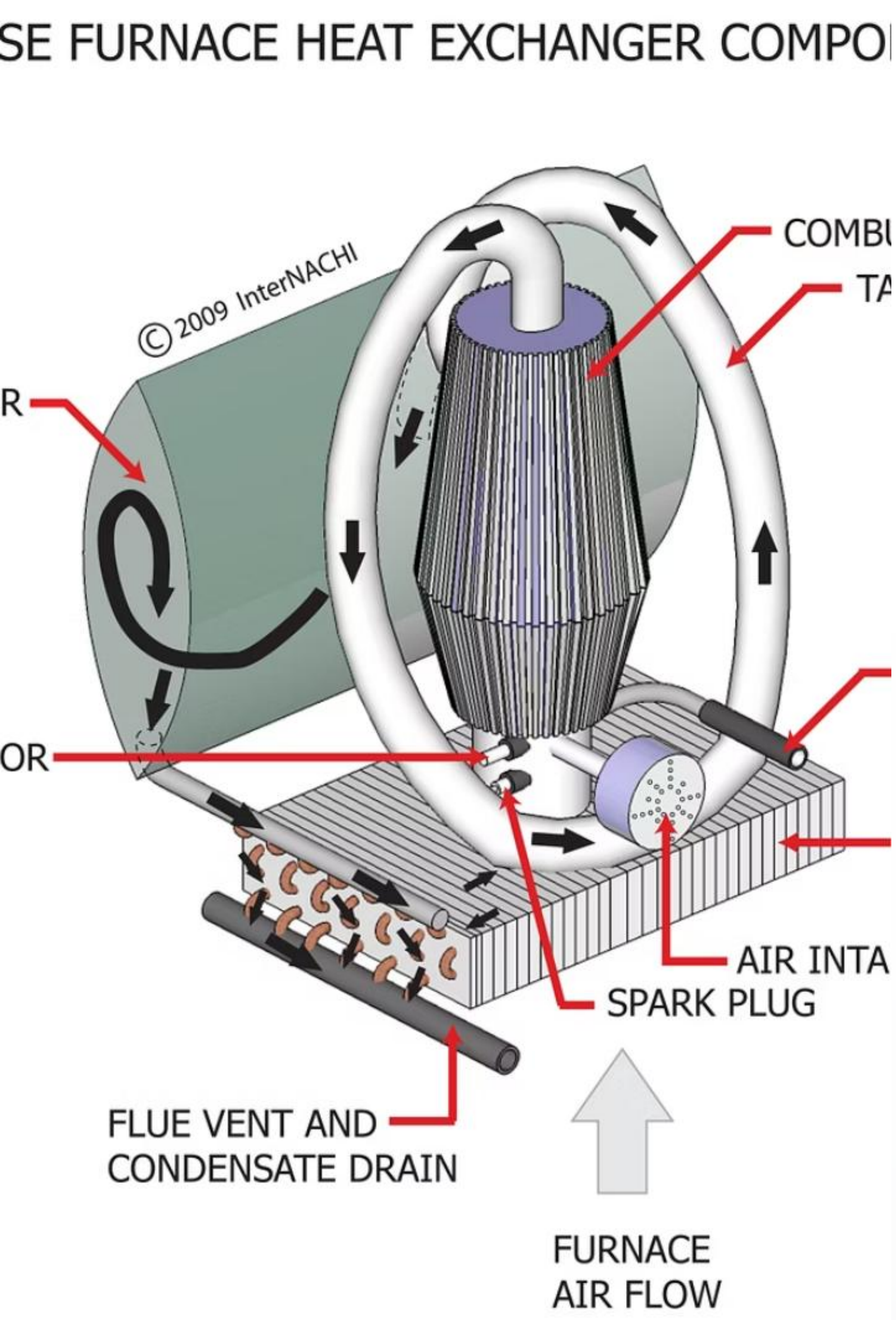
# Pulse Combustion Atmospheric Burner

A pulse combustion burner is a unique type of atmospheric burner that enables burning of the fuel air mixture in separate pulses (rather than continuously as in a standard gas burner). Since the supply of air does not require the use of a mechanical device, the pulse burner falls within the atmospheric burner category. Note that the use of a blower is for pre-purge and post-purge only.

Figure 2-27
Pulse combustion process
Image courtesy of Lennox Industries Inc.




Pulse combustion offers several advantages, including high




# Pulse Combustion Operation

### Gas and Air Mixing

Gas and air enter and mix in combustion chamber.

### Initial Ignition

To start the cycle, the burner uses a spark to ignite the gas and air mixture. (This is one "pulse".)

### Pressure Wave

Positive pressure from combustion closes flapper valves and forces exhaust gases down a tail pipe.

### Negative Pressure

Exhaust gases leaving the chamber create a negative pressure. This opens the flapper valve drawing in gas and air.

# Pulse Combustion Cycle Continuation

### Reflected Pulse

At the same instant, part of the pulse is reflected back from the tail pipe causing the new gas and air mixture to ignite. No spark is needed.

### Continuous Pulsing

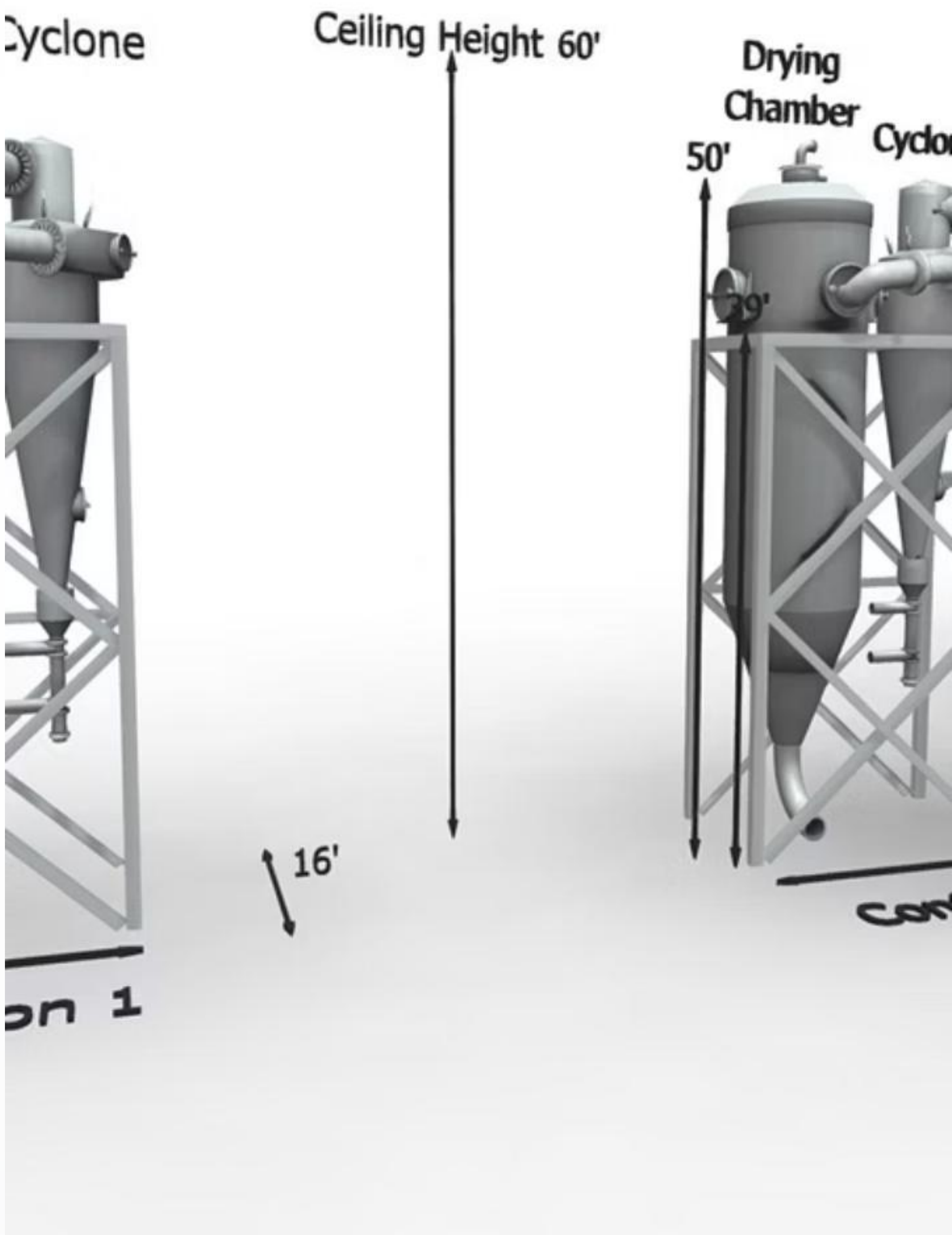
Steps 4 and 5 repeat 60 to 70 times per second forming consecutive "pulses" of 1/4 to 1/2 Btu/h each.

### Heat Extraction

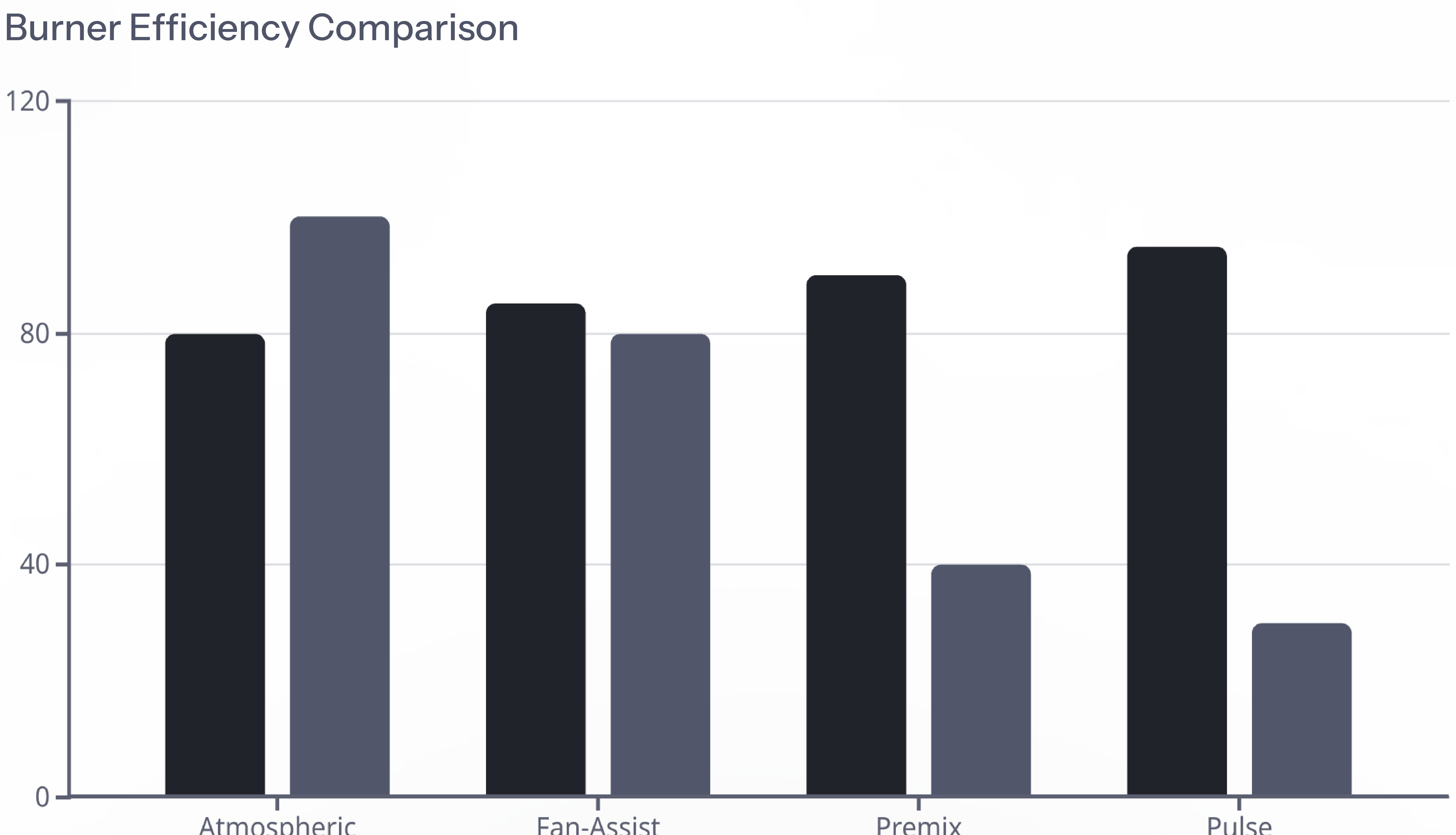
The process removes latent heat from combustion products.

### Condensation

Condensate (water) forms in the condensate coil.



# Burner Performance Analysis


Burner Efficiency Comparison
120
80
40
0
Atmospheric
Fan-Assist
Premix
Pulse

# Common Burner Applications


## Residential Heating

Furnaces, boilers, and water heaters commonly use atmospheric or fan-assist burners for reliable operation in home environments.

## Commercial Cooking

Restaurants and institutional kitchens rely on various burner types for cooking applications, from atmospheric burners in ranges to ribbon burners in ovens.

## Industrial Processing

Manufacturing facilities use specialized burners for process heating, often employing premix or nozzle mix designs for precise temperature control.

# Burner Maintenance Best Practices

## Regular Inspection

Visually inspect burners for signs of wear, corrosion, or damage

## Proper Cleaning

Clean burners according to manufacturer's instructions to remove lint, dust, and debris

## Combustion Testing

Perform combustion analysis to verify complete combustion and check for toxic gases

## Air Adjustment

Check and adjust primary air shutters to ensure proper air-to-gas ratio

# Burner Safety Considerations

## Proper Installation

Follow manufacturer specifications and local codes

## Flame Supervision

Ensure proper flame detection and safety shutdown systems

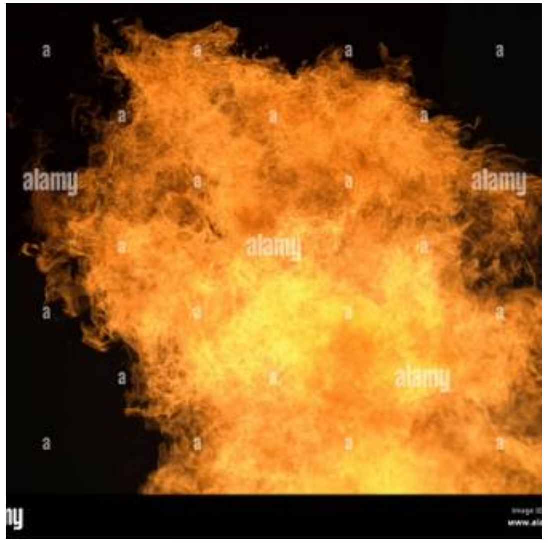
## Adequate Venting

Verify proper venting of combustion products

## CO Detection

Install carbon monoxide detectors in appropriate locations

# Troubleshooting Burner Issues




The images above show various flame conditions that can indicate burner problems. From left to right, top to bottom: yellow tipping (indicating incomplete combustion), flame lifting (often due to excess primary air), flashback (flame burning inside the mixing tube), floating flame (severe incomplete combustion), normal blue flame (proper combustion), and flame rollout (potentially dangerous condition requiring immediate attention).

# Burner Technology Advancements

## Early Atmospheric Burners

Simple designs with limited efficiency and control capabilities

## Fan-Assist Technology

Introduction of mechanical air supply for improved combustion control

## Full Premix Systems

Advanced mixing technologies for higher efficiency and lower emissions

## Pulse Combustion

Innovative design allowing for extremely high efficiency and condensing operation

## Smart Burner Systems

Integration of electronic controls and sensors for optimal performance

# Burner Selection Criteria

1

### Application Requirements

Consider the specific heating needs and operating conditions

2

### Efficiency Goals

Determine the desired energy efficiency level

3

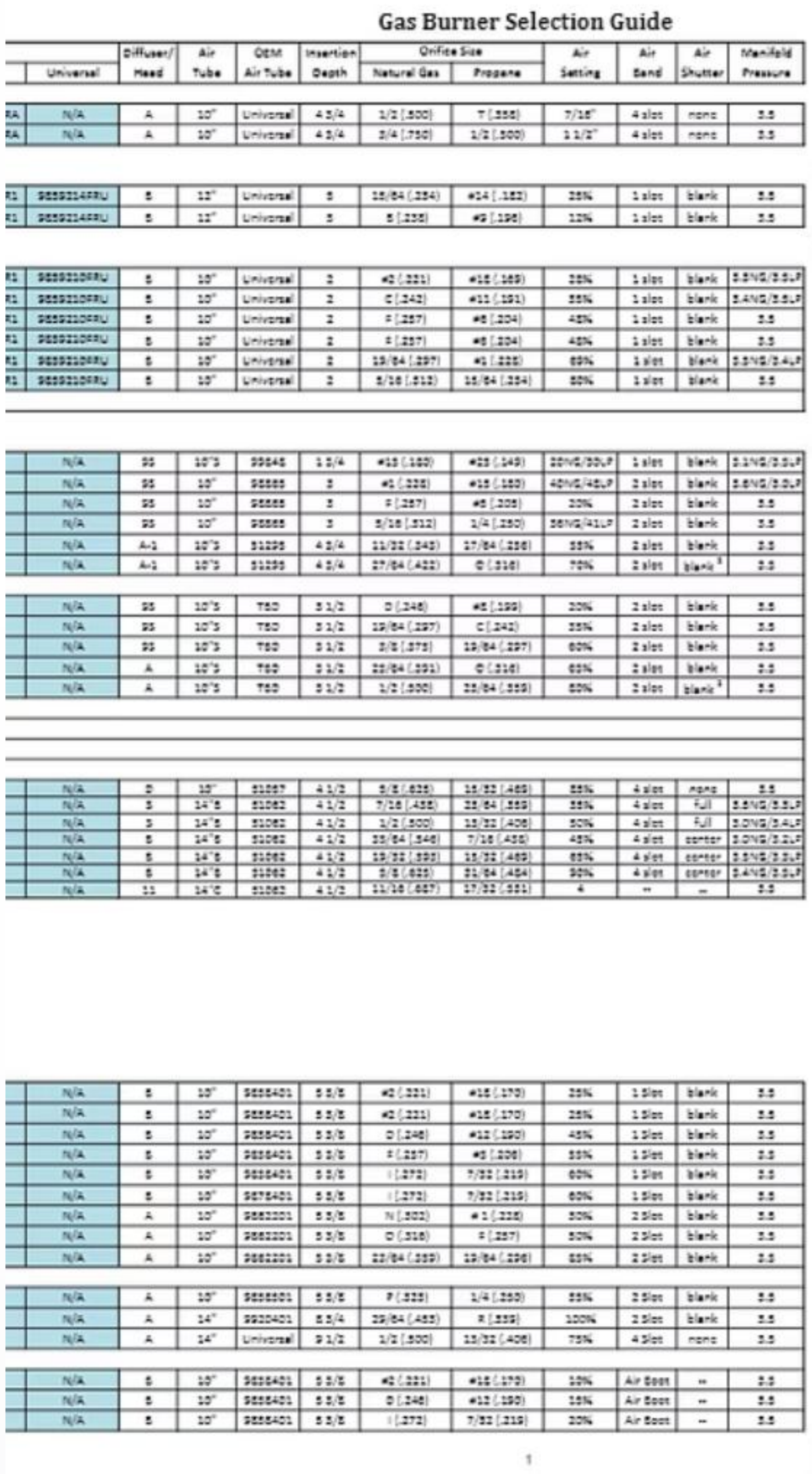
### Emission Standards

Ensure compliance with local air quality regulations

4

### Budget Constraints

Balance initial cost with long-term operational savings



Gas Burner Selection Guide

| | Universal | Diffuser/ Head | Air Tube | OEM Air Tube | Insertion Depth | Orifice Size Natural Gas | Orifice Size Propane | Air Setting | Air Band | Air Shutter | Manifold Pressure |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RA | N/A | A | 10" | Universal | 4 3/4 | 1/2 (.500) | T (.358) | 7/16" | 4 slot | none | 3.5 |
| RA | N/A | A | 10" | Universal | 4 3/4 | 3/4 (.750) | 1/2 (.500) | 1 1/2" | 4 slot | none | 3.5 |
| R1 | 9859214FRU | 5 | 12" | Universal | 3 | 15/64 (.234) | #14 (.182) | 25% | 1 slot | blank | 3.5 |
| R1 | 9859214FRU | 5 | 12" | Universal | 3 | B (.238) | #9 (.196) | 12% | 1 slot | blank | 3.5 |
| R1 | 9859210FRU | 5 | 10" | Universal | 2 | #2 (.221) | #18 (.169) | 25% | 1 slot | blank | 3.5NG/3.5LP |
| R1 | 9859210FRU | 5 | 10" | Universal | 2 | C (.242) | #11 (.191) | 35% | 1 slot | blank | 3.4NG/3.5LP |
| R1 | 9859210FRU | 5 | 10" | Universal | 2 | F (.257) | #6 (.204) | 45% | 1 slot | blank | 3.5 |
| R1 | 9859210FRU | 5 | 10" | Universal | 2 | F (.257) | #6 (.204) | 45% | 1 slot | blank | 3.5 |
| R1 | 9859210FRU | 5 | 10" | Universal | 2 | 19/64 (.297) | #1 (.228) | 65% | 1 slot | blank | 3.3NG/3.4LP |
| R1 | 9859210FRU | 5 | 10" | Universal | 2 | 5/16 (.312) | 15/64 (.234) | 80% | 1 slot | blank | 3.5 |
| | N/A | 33 | 10"3 | 99648 | 1 3/4 | #13 (.185) | #23 (.149) | 30NG/30LP | 1 slot | blank | 3.1NG/3.5LP |
| | N/A | 33 | 10" | 98665 | 3 | #1 (.228) | #15 (.180) | 40NG/45LP | 2 slot | blank | 3.6NG/3.5LP |
| | N/A | 33 | 10" | 98665 | 3 | F (.257) | #5 (.205) | 20% | 2 slot | blank | 3.5 |
| | N/A | 33 | 10" | 98665 | 3 | 5/16 (.312) | 1/4 (.250) | 38NG/41LP | 2 slot | blank | 3.5 |
| | N/A | A-1 | 10"3 | 51295 | 4 3/4 | 11/32 (.343) | 17/64 (.266) | 55% | 2 slot | blank | 3.5 |
| | N/A | A-1 | 10"3 | 51295 | 4 3/4 | 27/64 (.422) | O (.316) | 75% | 2 slot | blank [1] | 3.5 |
| | N/A | 33 | 10"3 | T60 | 3 1/2 | D (.246) | #8 (.199) | 20% | 2 slot | blank | 3.5 |
| | N/A | 33 | 10"3 | T60 | 3 1/2 | 19/64 (.297) | C (.242) | 35% | 2 slot | blank | 3.5 |
| | N/A | 33 | 10"3 | T60 | 3 1/2 | 3/8 (.375) | 19/64 (.297) | 60% | 2 slot | blank | 3.5 |
| | N/A | A | 10"3 | T60 | 3 1/2 | 25/64 (.391) | O (.316) | 65% | 2 slot | blank | 3.5 |
| | N/A | A | 10"3 | T60 | 3 1/2 | 1/2 (.500) | 23/64 (.359) | 80% | 2 slot | blank [1] | 3.5 |
| | N/A | D | 10" | 51067 | 4 1/2 | 5/8 (.625) | 15/32 (.469) | 85% | 4 slot | none | 3.5 |
| | N/A | 3 | 14"8 | 51062 | 4 1/2 | 7/16 (.438) | 23/64 (.359) | 35% | 4 slot | full | 3.5NG/3.5LP |
| | N/A | 3 | 14"8 | 51062 | 4 1/2 | 1/2 (.500) | 13/32 (.406) | 50% | 4 slot | full | 3.0NG/3.4LP |
| | N/A | 5 | 14"8 | 51062 | 4 1/2 | 35/64 (.546) | 7/16 (.438) | 45% | 4 slot | center | 3.0NG/3.2LP |
| | N/A | 5 | 14"8 | 51062 | 4 1/2 | 19/32 (.593) | 15/32 (.469) | 65% | 4 slot | center | 3.5NG/3.2LP |
| | N/A | 5 | 14"8 | 51062 | 4 1/2 | 5/8 (.625) | 31/64 (.484) | 90% | 4 slot | center | 3.4NG/3.5LP |
| | N/A | 11 | 14"C | 51062 | 4 1/2 | 11/16 (.687) | 17/32 (.531) | 4 | -- | -- | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | #2 (.221) | #18 (.170) | 25% | 1 Slot | blank | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | #2 (.221) | #18 (.170) | 25% | 1 Slot | blank | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | D (.246) | #12 (.190) | 45% | 1 Slot | blank | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | F (.257) | #5 (.206) | 55% | 1 Slot | blank | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | I (.272) | 7/32 (.219) | 60% | 1 Slot | blank | 3.5 |
| | N/A | 5 | 10" | 9878401 | 5 5/8 | I (.272) | 7/32 (.219) | 60% | 1 Slot | blank | 3.5 |
| | N/A | A | 10" | 9882201 | 5 5/8 | N (.302) | #1 (.228) | 50% | 2 Slot | blank | 3.5 |
| | N/A | A | 10" | 9882201 | 5 5/8 | O (.316) | F (.257) | 50% | 2 Slot | blank | 3.5 |
| | N/A | A | 10" | 9882201 | 5 5/8 | 22/64 (.339) | 19/64 (.296) | 85% | 2 Slot | blank | 3.5 |
| | N/A | A | 10" | 9858501 | 5 5/8 | P (.323) | 1/4 (.250) | 55% | 2 Slot | blank | 3.5 |
| | N/A | A | 14" | 9920401 | 8 3/4 | 29/64 (.453) | R (.339) | 100% | 2 Slot | blank | 3.5 |
| | N/A | A | 14" | Universal | 9 1/2 | 1/2 (.500) | 13/32 (.406) | 75% | 4 Slot | none | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | #2 (.221) | #18 (.170) | 10% | Air Boot | -- | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | D (.246) | #12 (.190) | 15% | Air Boot | -- | 3.5 |
| | N/A | 5 | 10" | 9858401 | 5 5/8 | I (.272) | 7/32 (.219) | 20% | Air Boot | -- | 3.5 |

1


# Future of Burner Technology

### Ultra-High Efficiency

Next-generation burners approaching 98%+ efficiency through advanced heat recovery

### Near-Zero Emissions

Advanced combustion control systems that minimize NOx, CO, and other pollutants

### Smart Integration

IoT-enabled burners with remote monitoring, predictive maintenance, and self-diagnostics

### Hybrid Systems

Integration with renewable energy sources for optimal energy utilization

# Summary: Burner Operations and Applications

### Performance Characteristics

Effective burners provide complete combustion, stable flames, quiet operation, immediate ignition, uniform heating, and appropriate turndown ratio.

### Classifications

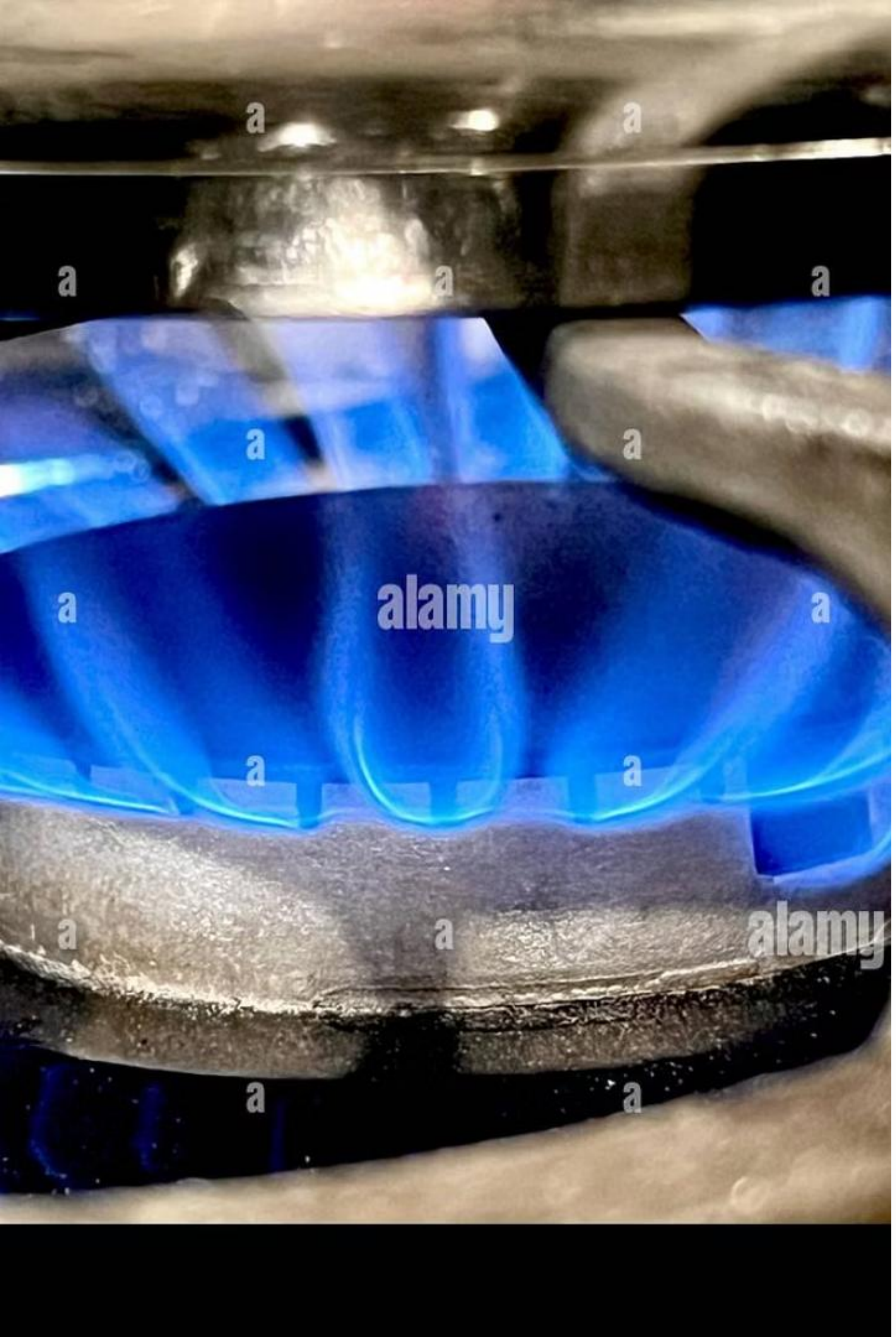
Burners are classified by air delivery method (natural draft, fan-assist, forced draft) and by mixing method (atmospheric/partial premix, premix, nozzle mix).

### Atmospheric Burners

The most common type in residential and commercial applications, atmospheric burners operate simply and reliably but have efficiency limitations due to their partial premix design.

### Proper Maintenance

Regular inspection, cleaning, and adjustment are essential for safe and efficient burner operation.



# CSA Unit 9

# Chapter 3
# Pilots and Ignition Systems

Initiating the combustion process requires the heating of a fuel-air mix to the point of ignition. This chapter examines various methods that the gas industry uses for this purpose, including pilot burners, ignition systems, and flame sensing devices.

# Chapter Objectives

## Explain Pilot Burners

Understand the different types of pilot burners and their functions in gas appliances

## Explain Ignition Systems

Learn about various manual and automatic ignition methods used in gas appliances

## Explain Flame Sensing Devices

Understand the different technologies used to detect and monitor flames in gas systems

# Key Terminology

| Term | Abbreviation (symbol) | Definition |
|---|---|---|
| Pilot burner | | Provide adequate ignition flame for a main burner |
| Thermistor | | Solid-state device whose electrical resistance decreases with temperature |
| Thermocouple | | Powers combustion safety circuits that have constant pilots |
| Thermopile (power pile) | | Consists of multiple thermocouples joined together at one end and connected in series to generate more voltage than a single thermocouple |

# Pilot Burner Functions

## 3

### Key Functions

Pilot burners serve three essential purposes in gas systems

1. **Create Proper Flame**

   To create a flame of the proper size and characteristics that can be proven by a flame detector to be a safe pilot flame

2. **Ignite Main Burner**

   To ignite the main burner flame safely and reliably

3. **Provide Mounting**

   To provide a mount for the igniter (if so equipped) and a flame detector

# Types of Pilot Burners

## Aerated Pilots

Premix air and gas before combustion

Develop a sharp, intense blue flame

Relatively stable flame not greatly affected by draft

Provide hot flame for good flame detector response

Tend to give shorter thermocouple life due to hotter flame

## Non-Aerated Pilots

No primary air intake

Give a softer blue flame

More affected by changes in draft than aerated pilots

Typically provide longer thermocouple life

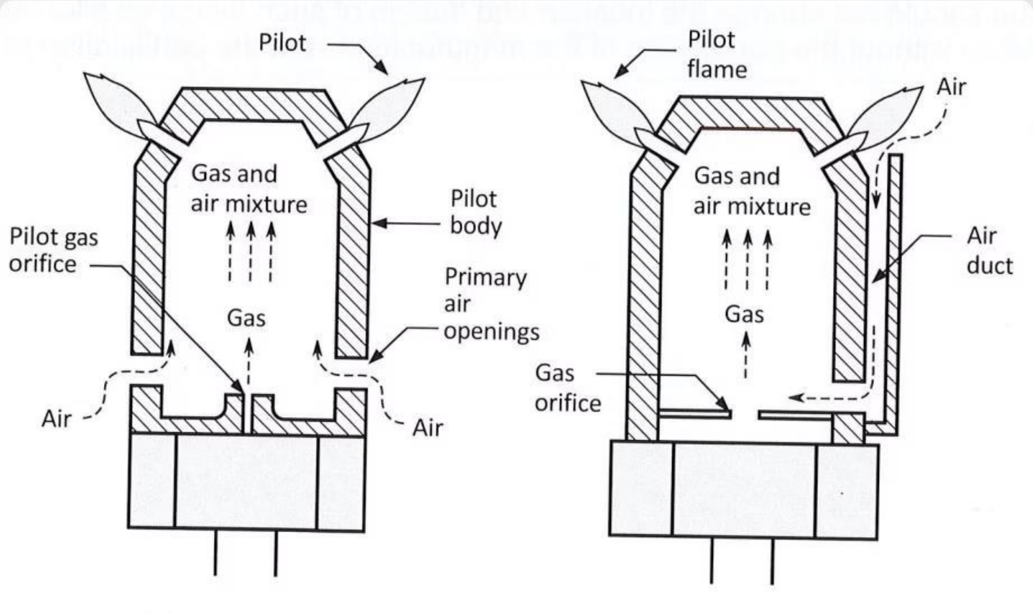
Less prone to dust and lint problems

# Aerated Pilot Burners

Aerated pilots premix air and gas and develop a sharp, intense blue flame. Draft and main flame variations do not greatly affect these pilots, which have a relatively stable flame.

Aerated pilots also provide a hot flame (due to primary air mixing) for good flame detector response. However, because of the hotter pilot flame, aerated pilots tend to give shorter thermocouple life.

The most common problem associated with aerated pilot burners is clogging due to dust and lint. This is especially true for burners that are near the floor, such as water heaters.



(a) Aerated pilot (b) Incinerating pilot

# Incinerating Pilot

## Design Features

The incinerating pilot solves the dust problem common to aerated pilots

This type of pilot draws the primary air through a tube or air duct

The tube passes around the pilot flame, incinerating any lint or dust that could be in the primary air

## Benefits

Reduces maintenance issues related to clogging

Maintains stable operation in dusty environments

Particularly useful for appliances located near floor level

Figure 3-1
Aerating pilot burners

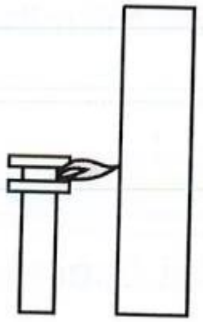
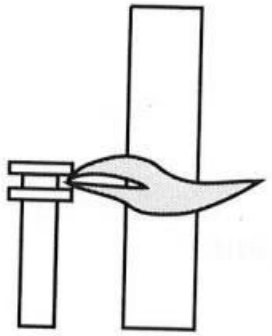
| | Causes | Remed |
|---|---|---|
| e | Dirty lint screen or primary air opening. | • cle as r ren scr |
| ne | Excessive draft at pilot location.<br>Recirculating products of combustion. | • relo<br>• inst baf |

# Troubleshooting Aerated Pilot Problems

Table 3-1 lists common aerated pilot problems, causes, and possible remedies. Use this guide when troubleshooting aerated pilot problems.

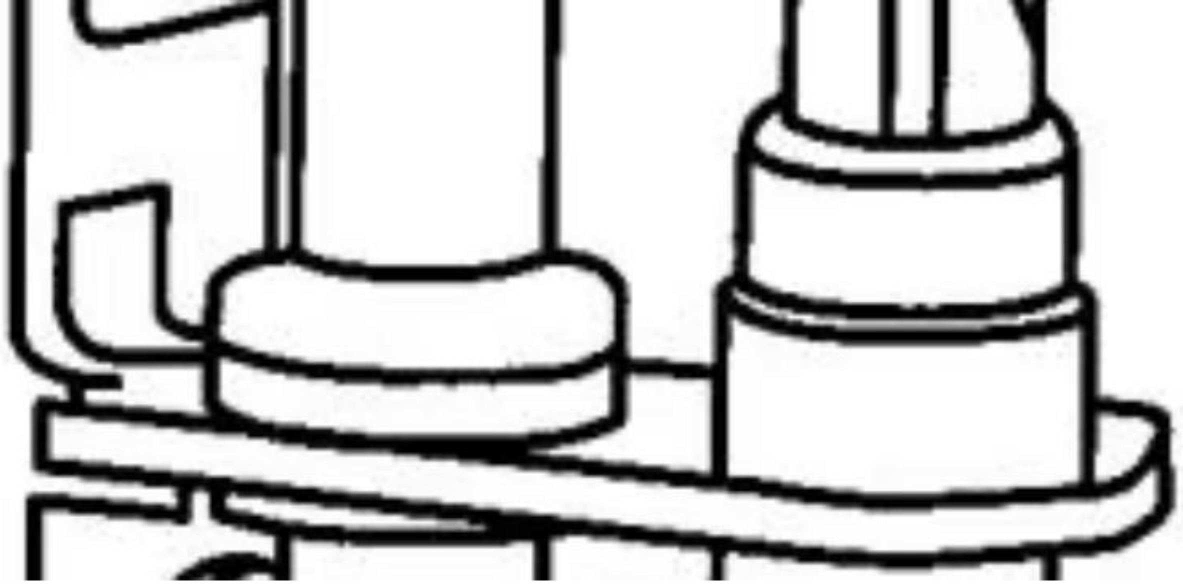
> Note that you should not change the location and design of such things as pilot burners and protecting baffles without the permission of the manufacturer and the certification organization.

# Non-Aerating and Target Pilot Burners

| Flame type | Causes | Remedy |
| --- | --- | --- |
| Small blue flame  | Low gas pressure<br>Clogged pilot burner orifice<br>Clogged pilot line filter<br>Improper orifice (too small) | • increase pressure to normal<br>• clean pilot burner orifice<br>• clean filter<br>• install correct orifice |
| Noisy lifting blowing flame  | High gas pressure | • reduce pressure to normal |
| Hard sharp flame  | Orifice too small | • install correct orifice inlet fitting |

# Effects of Supply Pressure on Non-Aerating Pilots

| If the supply pressure is | Then |
|---|---|
| Too high | The pilot flame will roar, giving a noisy pilot operation and lower thermocouple life. A lifting flame can also disrupt the operation of a flame rod flame detector. |
| Too low | There is insufficient heat, giving low thermocouple output voltage. A yellow, carbonizing flame may result, which can foul the flame rod or thermocouple and disrupt flame detection. |



# Typical Target Pilot Burner Application

1

2

3

4

### Pilot Gas Supply

Regulated gas enters the pilot assembly

### Igniter/Sensor

Provides spark for ignition and monitors flame

### Target Hood

Directs flame and provides stability

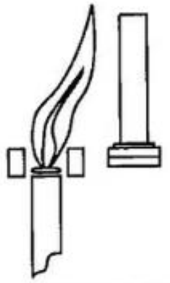
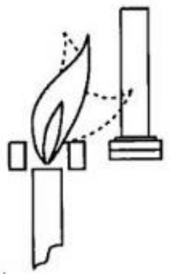
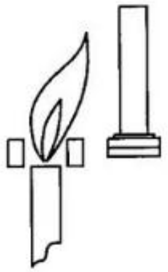
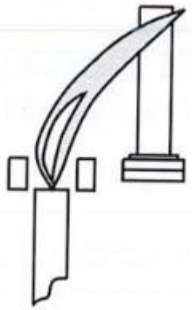
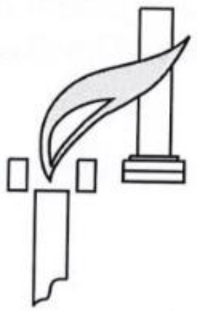
### Main Burner Ignition

Pilot flame positioned to ignite main burner

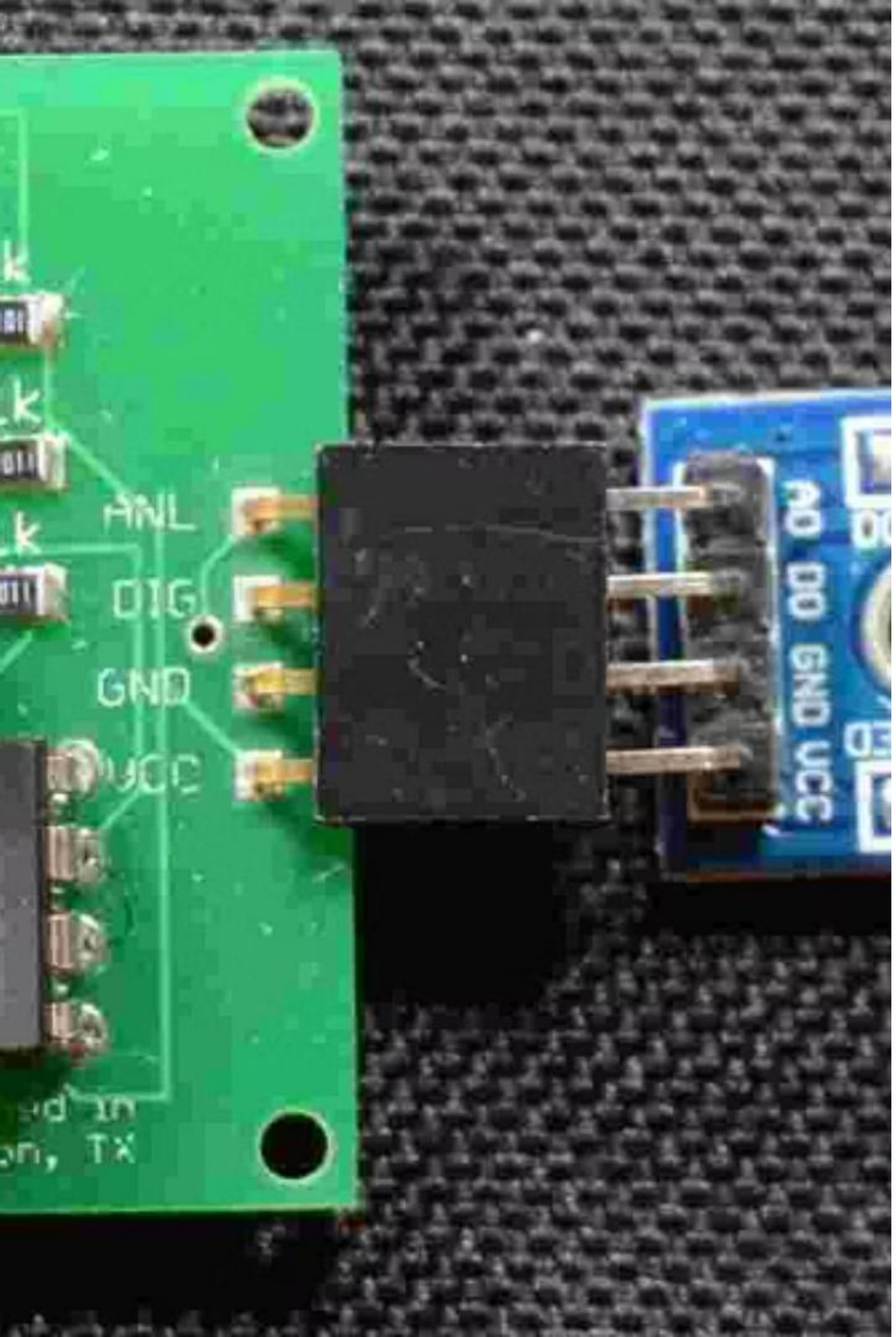
Figure 3-3 shows a typical application of a target pilot burner used in conjunction with an igniter/sensor.

# Troubleshooting Non-Aerating Pilot Burners

Table 3-2 lists common non-aerating pilot problems, causes, and possible remedies. Use this guide when troubleshooting non-aerated pilot problems.

| Flame type | Causes | Remedy |
| --- | --- | --- |
| Lazy yellow flame  | Orifice too large | • replace orifice spud |
| Waving blue flame  | Excessive draft at location<br>Recirculating products of combustion | • replace pilot, or<br>• install protecting baffle |
| Small blue flame  | Low gas pressure<br>Clogged pilot-burner orifice<br>Clogged pilot-line filter<br>Improper orifice | • increase pressure to normal<br>• clean pilot burner orifice<br>• clean filter<br>• install correct orifice |
| Noisy lifting blowing flame  | High gas pressure | • reduce pressure |
| Hard sharp flame  | Orifice too small | • install larger orifice |
| Normal flame  | Mostly blue, steady<br>Envelops 3/8 in to 1/2 in of thermocouple | • none needed |

at you should not change the location and design of such things as pilot burn
g baffles without the permission of the manufacturer and the certification org




# Proved Pilots

## Definition

When a flame detector that acts to prevent gas from flowing to the main burner, unless a proper pilot flame is proven, monitors a pilot flame, you call this flame a proved pilot.

## Operation

The flame detector may act upon a primary gas valve upstream of all burners—as in the case of a thermocouple flame detection system

Alternatively, it may send an electric signal to a flame safeguard control that in turn acts upon the gas valve(s)

# Manual Ignition Systems

## Two General Methods

1. Manually lighting the pilot, which, in turn, lights the main burner automatically as required
2. Manually lighting the main burner for every use

## Applications

Simple gas appliances

Older gas equipment

Appliances without electrical connections

Emergency backup systems

# Types of Manual Ignition Systems

## Continuous Pilot (Standing Pilot)

Burns throughout the entire time the burner assembly is in service, whether the main burner is firing or not

Manually lit using a match

## Expanding Pilot

Similar to the continuous pilot, burns whether the main burner is firing or not

Upon a call for heat, the pilot flame automatically increases in size to reliably ignite the main burner

May turn down automatically at the end of the main burner flame-establishing period

## Piezoelectric Pilot

Helps ignite pilot burners or main burners such as main burners on gas barbecues or refrigerators, or pilot burners on gas fireplaces

Generates a high voltage to supply a spark after the application of a mechanical force

# Automatic Ignition Systems

## Benefits

- Avoids problems associated with manual ignition systems
- Eliminates gas waste during off-cycles
- Does not require venting (unlike constant pilot systems)
- Improves overall efficiency
- Enhances safety with electronic monitoring

## Applications

High efficiency appliances use one of two automatic ignition systems:

- Intermittent ignition
- Interrupted ignition

Especially common in appliances that employ a mechanical venting device

# Intermittent vs. Interrupted Ignition

## Intermittent Ignition

Activation of an intermittent igniter or pilot at each call for heat in accordance with the sequence of operation of the burner control

The igniter or pilot continues to function during the entire period that the main flame is present

## Interrupted Ignition

Activation of an interrupted igniter or pilot at each call for heat in accordance with the sequence of operation of the burner control

Ceases to function after the establishment of the main flame

Energization of both automatic systems happens upon each call for heat, and monitoring of the flame occurs with the help of an electronic sensing device. The flame monitoring systems must provide a much faster response to flame failure than a thermal device such as a thermocouple.

# Types of Initial Ignition Sources

## Spark Ignition

Automatic ignition system that uses an ignition spark to light a pilot burner

## Direct Spark Ignition

Automatic ignition system that uses an ignition spark to light the main burner

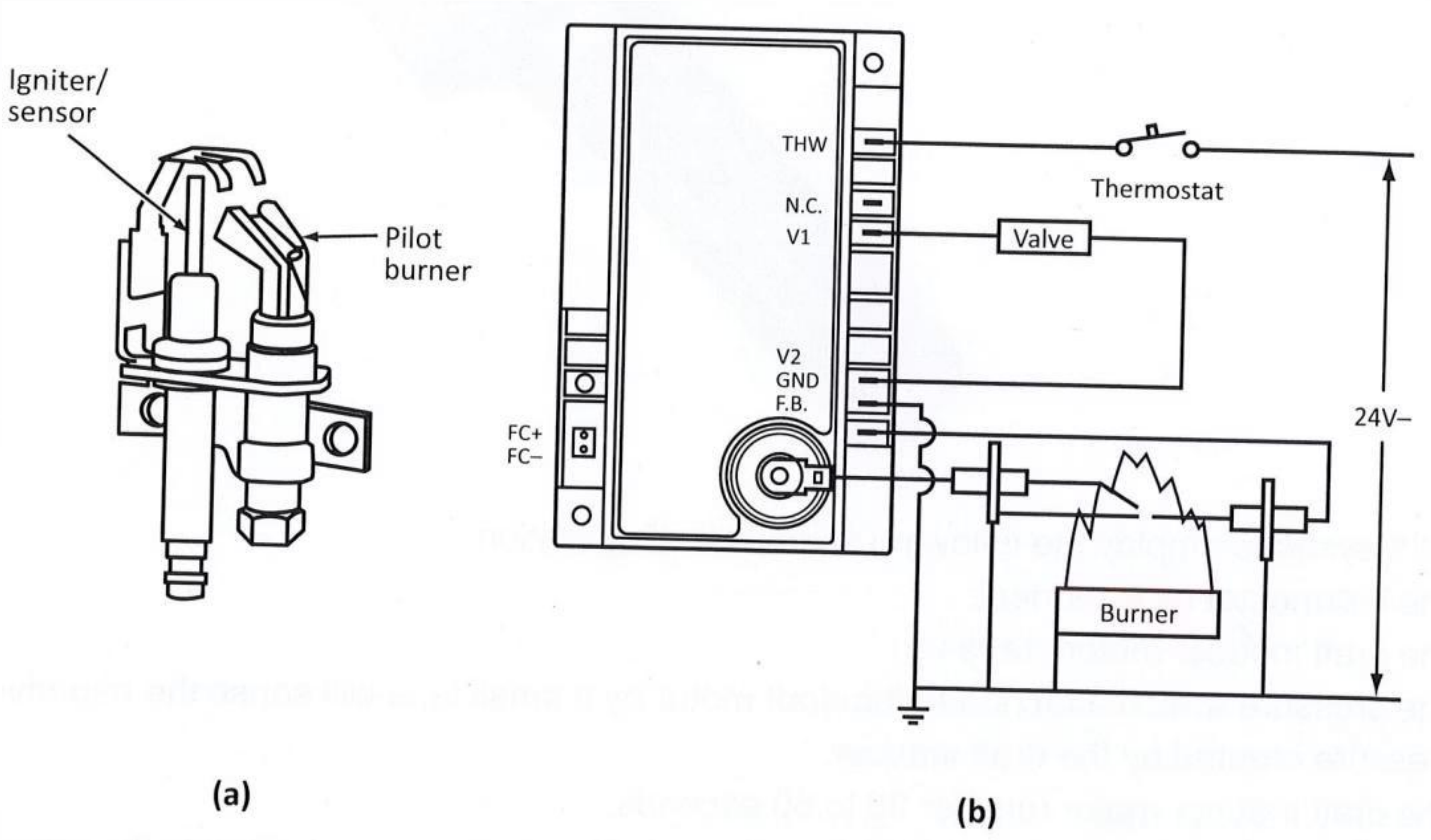
Applies to burners not using a pilot

## Hot Surface Ignition

Ignition system in which a hot surface (such as a glow bar) automatically ignites the pilot or main burner flame upon each call for heat

Older systems were designed to provide a relight function for continuous pilots

# Spark Ignition Systems




## Pilot Burner Spark Ignition (a)

Spark ignites a pilot flame

Pilot flame then ignites main burner

Provides reliable ignition sequence

Often used with flame rod sensing

## Direct Spark Ignition (b)

Spark directly ignites main burner

No pilot flame required

More energy efficient

Requires precise timing and positioning


# Hot Surface Ignition Systems

## Most Common Electronic Ignition

The hot surface igniter is arguably the most commonly used electronic ignition system today

They are reliable and inexpensive

## How It Works

Works like a light bulb filament

Usually made from a material like silicon carbide or nitride

When electricity passes through it, it glows white hot

## Applications

Modern furnaces

Water heaters

Boilers

Other gas appliances

# Hot Surface Igniter Sequence of Operation

### Thermostat Call

The thermostat calls for heat

### Draft Inducer Start

The draft inducer motor starts up

### Pressure Switch

The pressure switch attached to the draft motor by a small tube will sense the negative pressure created by the draft inducer

### Purge Cycle

The draft inducer motor runs for 30 to 60 seconds

### Ignition

The hot surface igniter or the intermittent pilot ignites the gas burner

### Flame Sensing

The flame sensor senses heat from the pilot or HSI and allows gas to flow to the burners

# Flame Sensing Devices

Flame detectors respond to the establishment of a flame during the trial for ignition of a pilot flame or main flame and to loss of an established flame—this is what you call flame failure. The standards to which the appliance received certification and the type of flame detection establish the maximum allowable time for this flame response.

The flame detector responds by shutting off the flow of gas of all burners—as in the case of a thermocouple flame detection system—or by sending an electric signal to a control that in turn acts upon the gas valve(s).

# Common Flame Sensing Methods

### Constant Supervision

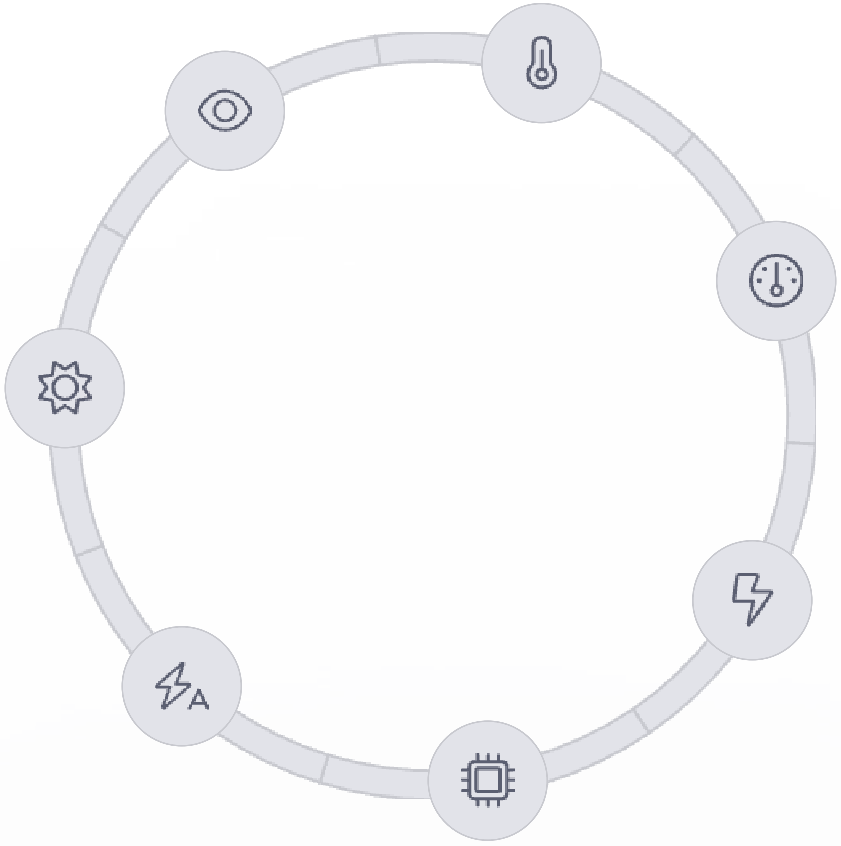
Visual monitoring by operator

### Optical Sensors

Detects light from flame

### Flame Rod

Uses flame rectification



### Bimetal Heat Sensors

Uses thermal expansion of metals

### Bulb and Bellows

Uses liquid expansion with heat

### Thermocouple/Thermopile

Generates voltage from heat

### Thermistor

Changes resistance with temperature


# Constant Supervision

## Definition

The simplest and least reliable means of detecting the presence or absence of a flame is to have a person constantly watching for ignition and flame failure

## Applications

This is the flame detection method for portable torches and barbecues

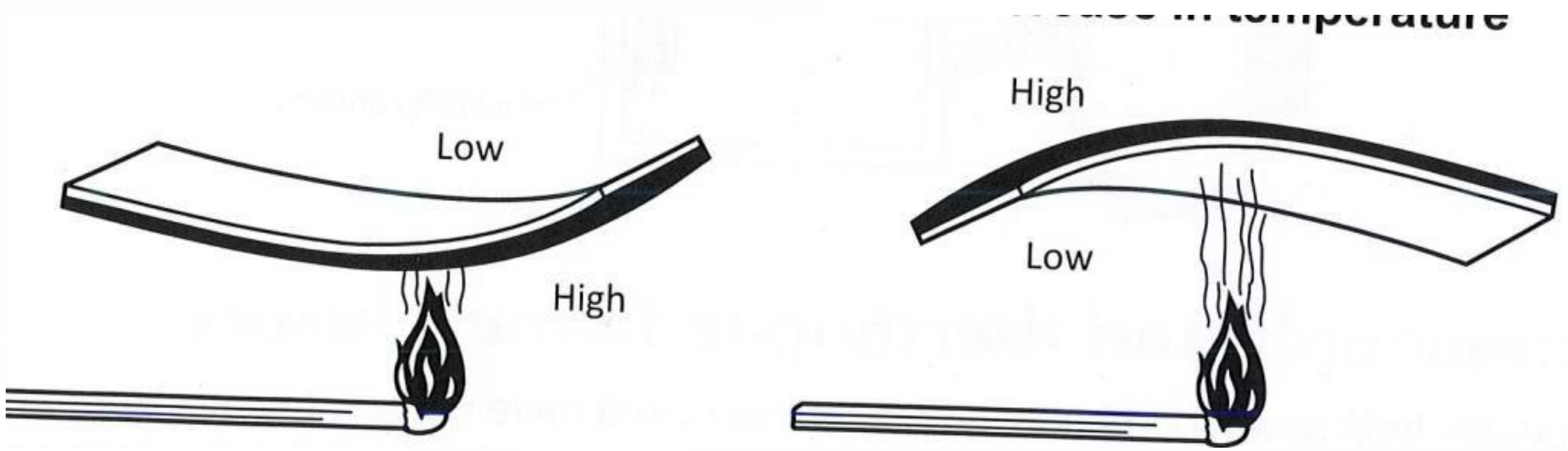
The most common example of this system is an outdoor barbecue

## Safety Requirements

Manufacturer's instructions state requirements and warn the person to remain in constant attendance during operation

Requirements for outdoor location and distances from building openings are provided

# Bimetal Flame Sensor




## How It Works

Two dissimilar metals welded together form the bimetal strip

Different temperature coefficients of expansion of the metals cause the strip to bevel or curve with changes in temperature

This principle can be used to sense the heat radiation of a flame and act upon a switch

## Applications

Some modern appliances such as clothes dryers employ highly sensitive bimetal flame sensors

Simple and reliable for certain applications

No electrical power required for operation

# Bimetal Flame Sensor in Clothes Dryer

1

### Sensor Placement

Positioned to detect flame presence

2

### Thermal Response

Bends when heated by flame

3

### Switch Activation

Movement closes or opens electrical circuit

4

### Safety Control

Controls gas valve based on flame presence

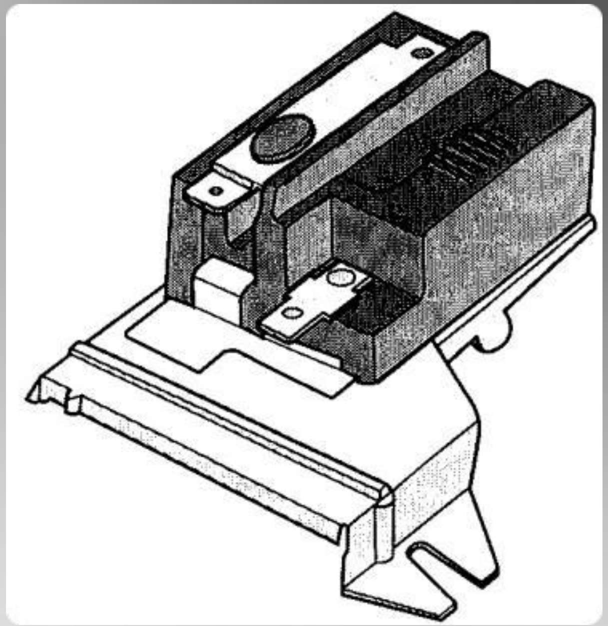


Figure 3-7 shows a bimetal flame sensor used on a gas-fired clothes dryer

# Bulb and Bellows Flame Sensors

## Components

This type of flame sensor consists of a bulb, capillary tube, and bellows

Contains a temperature expansive liquid, commonly toluene, silicone, or alkazine

## Operation

When exposed to heat, the liquid expands causing a hydraulic action on the bellows

This acts upon a switch to complete an electrical circuit to allow current flow to the gas valve(s)

If the flame fails, the liquid contracts and opens the circuit thereby closing the valve

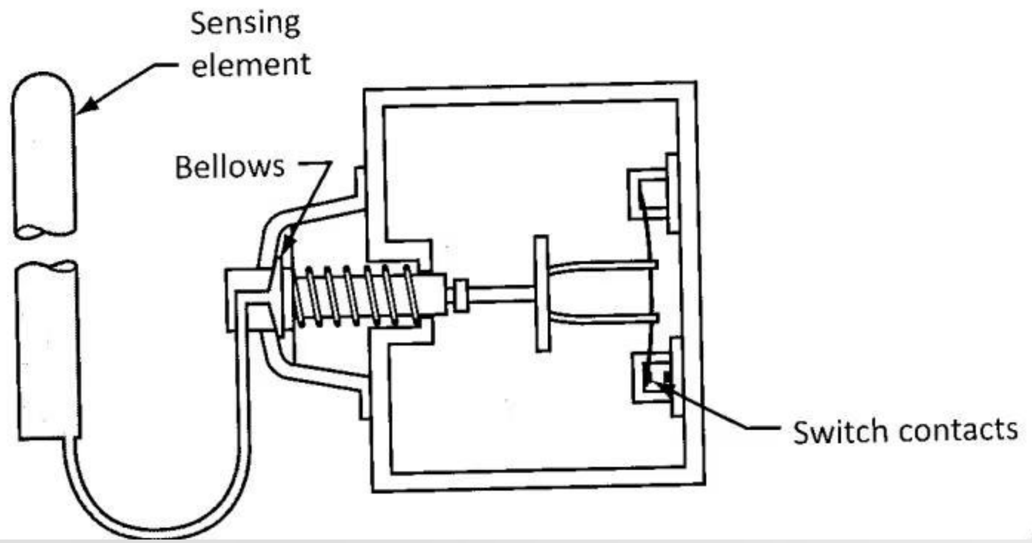
## Characteristics

Size and appearance similar to a thermocouple flame detector

Response time is much quicker (usually less than 15 seconds)

Commonly found on some residential gas fireplaces

Figure 3-8
Bulb and bellows flame sensor



# Thermocouple Flame Sensors

Figure 3-9
Combustion safety circuit thermocouple
Image courtesy of Terry Bell

## Function

Thermocouples help power combustion safety circuits that have constant pilots

The thermocouple is the power supply for the combustion safety circuit of a gas furnace

The thermocouple assembly is attached with a threaded male fitting

## Operation

When the pilot burner heats the hot junction, the thermocouple generates a voltage to power the electromagnet in the safety shutoff valve or safety switch

As long as the pilot remains lit, the shutoff valve will remain energized and open to allow the flow of gas to the main and pilot burners

If the pilot goes out, the resulting drop in voltage will trip the safety switch to shut off the flow of gas

# Thermocouple Components

1. ### Hot Junction
   Placed in pilot flame
2. ### Thermocouple Body
   Contains dissimilar metals
3. ### Lead Wire
   Carries generated voltage
4. ### Connection Terminal
   Attaches to gas valve

# Thermopile Flame Sensors

## Definition

A thermopile, which you may also know as a power pile, consists of multiple thermocouples joined together at one end and connected in series

## Advantage

Generates more voltage than a single thermocouple

The higher voltage allows the power pile to power an appliance's combustion safety circuit and its control circuit

## Applications

People use power piles on appliances with automatic-type gas valves

Common in gas fireplaces and some water heaters

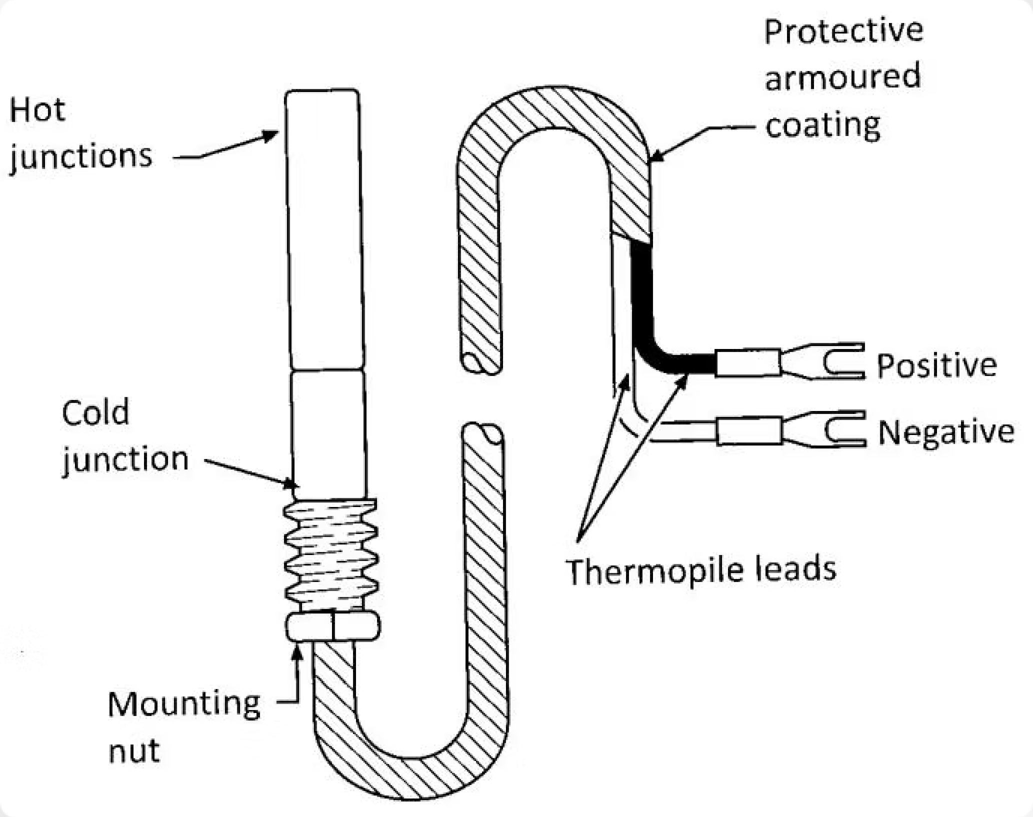


Figure 3-10
Power pile generator

# Thermopile Installation

1

## Pilot Assembly

Houses the thermopile

2

## Thermopile Position

Placed in hottest part of pilot flame

3

## Connection Wires

Carry generated voltage to control circuit

4

## Gas Valve Integration

Powers valve electromagnet

# Thermistor Flame Sensors

## Definition

A thermistor is a solid-state device whose electrical resistance decreases with temperature

## Operation

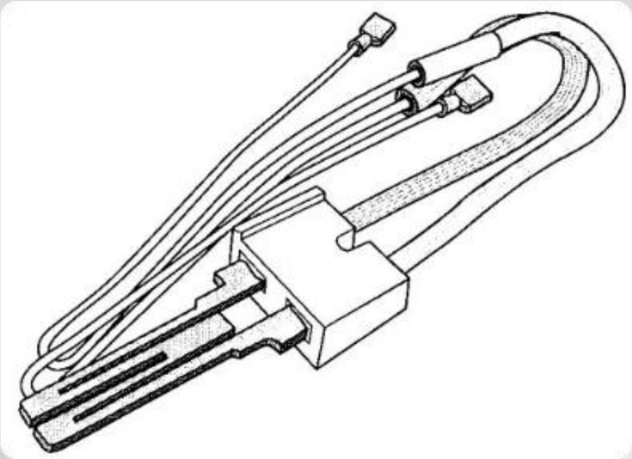
You can use this reaction to monitor the flame status by immersing the thermistor in the pilot and/or main flame

A flame safeguard control monitors the current flow through the thermistor

## Dual Function

A hot surface igniter used to light a pilot or main burner can also sense the presence or absence of the flame

After functioning as an igniter, the HSI remains hot and allows current to pass through the igniter



# Hot Surface Igniter as Flame Sensor

### Initial Function

Hot surface igniter heats up to ignite gas

### Transition

After ignition, the HSI transitions to sensing mode

### Sensing Operation

The HSI employs thermistor principles to detect flame presence

### Control Integration

Electronic control monitors HSI resistance to verify flame

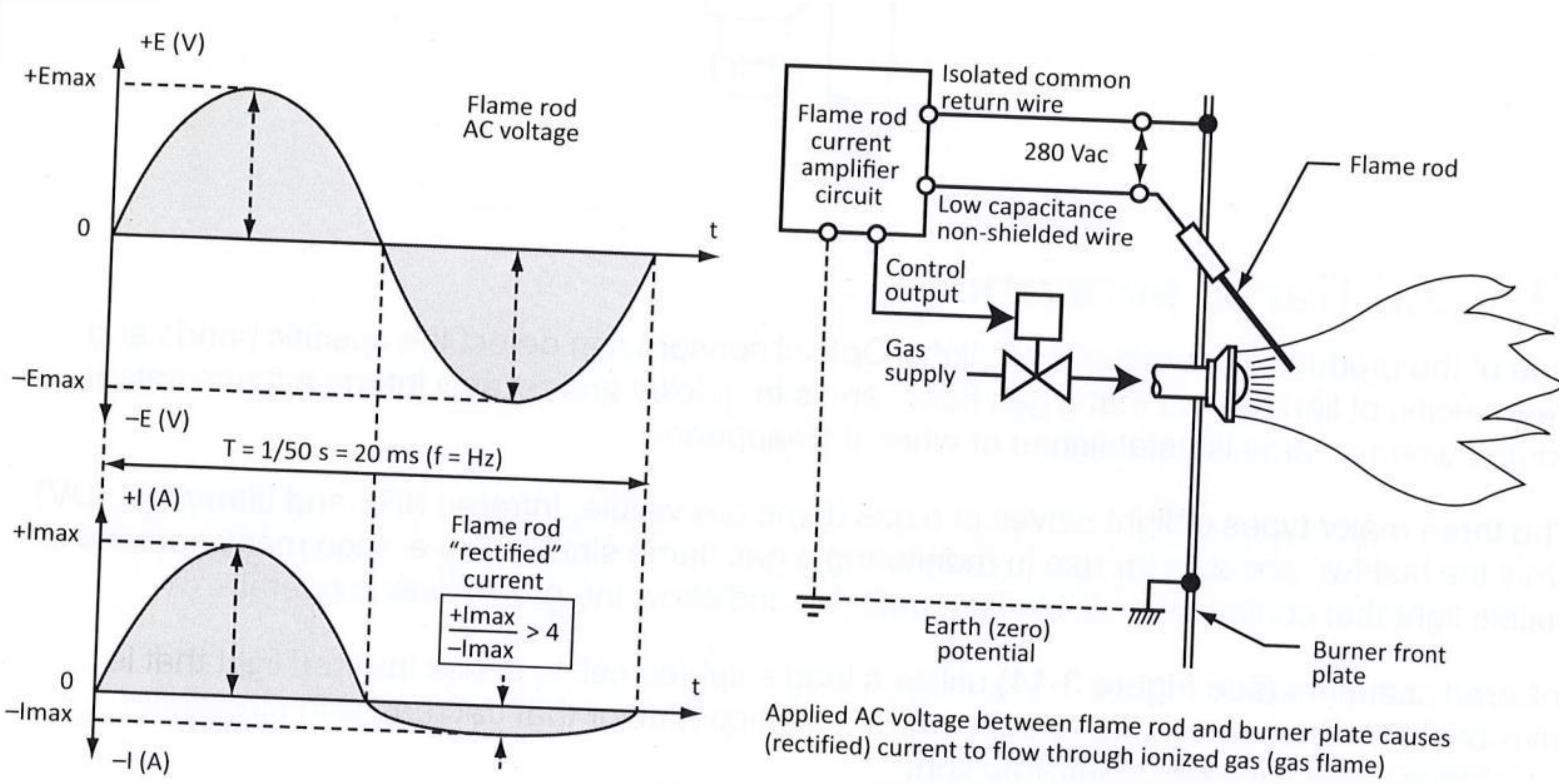
Figure 3-11 shows how some hot surface igniters serve double duty as an igniter and flame sensor

# Flame Rod Sensors

Flame rods are the most common type of flame sensor that people use on modern gas-fired appliances. Flame rod systems depend on the ability of the flame to conduct current when a voltage is applied across two electrodes in the flame. Heat from the flame causes molecules between the electrodes to collide with each other so forcibly as to knock some electrons out of the atoms, producing ions. This is called flame ionization.

The electric control applies an AC voltage to the flame rod. However, a pulsating DC current passes through the flame, since the flame rod is at least four times smaller than the surface or electrode of the burner.

# Flame Rod Rectification Principles




## Flame Rectification

The flame acts as a rectifier, converting AC to DC

This occurs because electrons flow more easily from the small electrode (flame rod) to the large electrode (burner) than in the reverse direction

## Detection Circuit

The control module detects this DC current

Presence of DC current indicates flame is present

Absence of DC current indicates no flame

# Unirod Combination System

## Dual Function

In some cases, the flame rod also serves as the spark igniter rod until a flame is established and then acts as a flame sensor

This system is often called a "unirod"

## Operation Sequence

Initially functions as a spark igniter

After ignition, transitions to flame sensing mode

Control module manages the timing of these functions

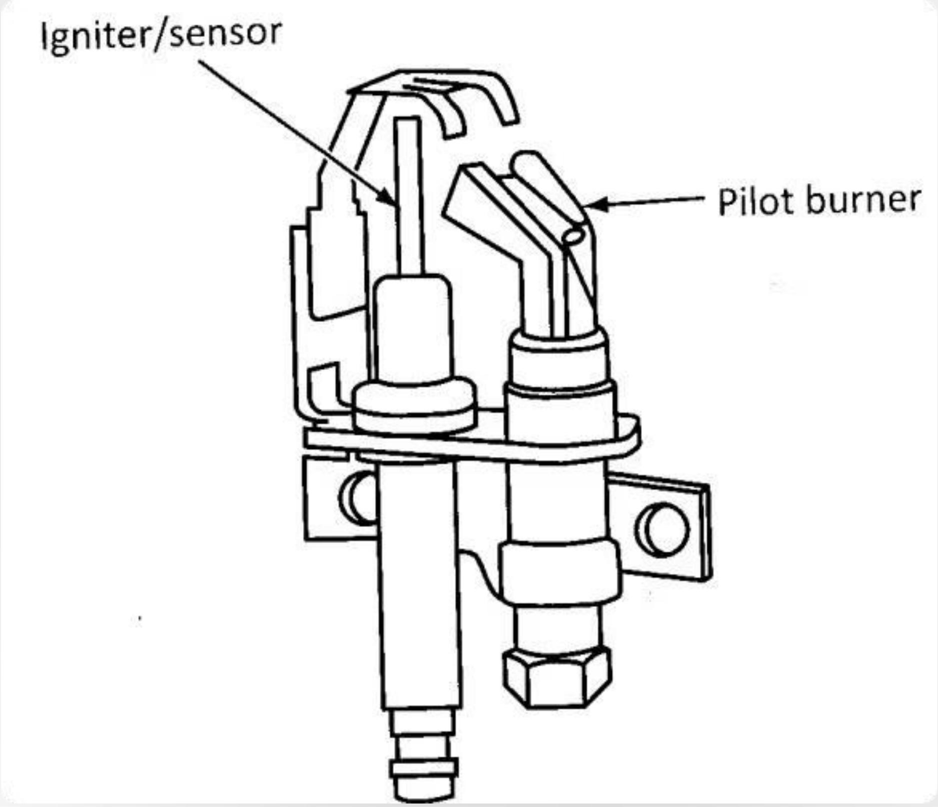
## Benefits

Simplifies design

Reduces components

Lowers manufacturing costs

Improves reliability

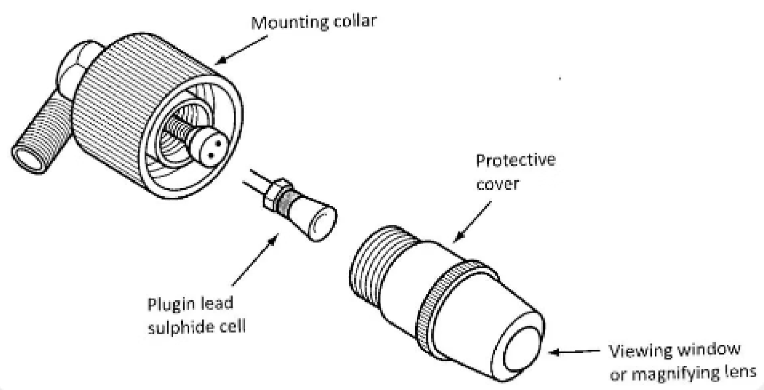


# Optical Flame Sensors

One of the products of combustion is light. Optical flame sensors use the specific frequencies of light waves that a gas flame emits to quickly and reliably inform a flame safeguard control of the presence or absence of a flame.

The three major types of light waves in a gas flame are visible, infrared (IR), and ultraviolet (UV). Only the last two are safe for use in monitoring a gas flame since there are too many sources of visible light that could fool a visible light detector and allow the gas valves to operate.

Figure 3-14
Infrared (IR) scanner




# Infrared Flame Scanners

## Technology

Infrared scanners utilize a lead sulphide cell to sense infrared light that is invisible to the human eye

## Operation

Lead sulphide is a semiconductor that decreases in electrical resistance when exposed to infrared light

This change in resistance is detected by the control circuit

## Applications

Used in commercial and industrial burner systems

Provides reliable flame detection in various environments

Less susceptible to false signals than visible light detectors

# Ultraviolet Flame Scanners

**Figure 3-15**
**Ultraviolet (UV) scanner**

## Construction

Ultraviolet scanners consist of two electrodes sealed in a gas-filled quartz glass tube filled with a special gas

## Operation

After the exposure of the special gas to a UV source, the cathode emits electrons which ionize the special gas sealed in the tube

When the gas is ionized, the tube becomes conductive and current flows through the tube

This current flow signals the presence of a flame

# UV Scanner Applications

## Industrial Applications

You can usually find optical flame sensors on higher input appliances

Common in industrial boilers and process heaters

## Safety Benefits

Highly reliable flame detection

Fast response to flame failure

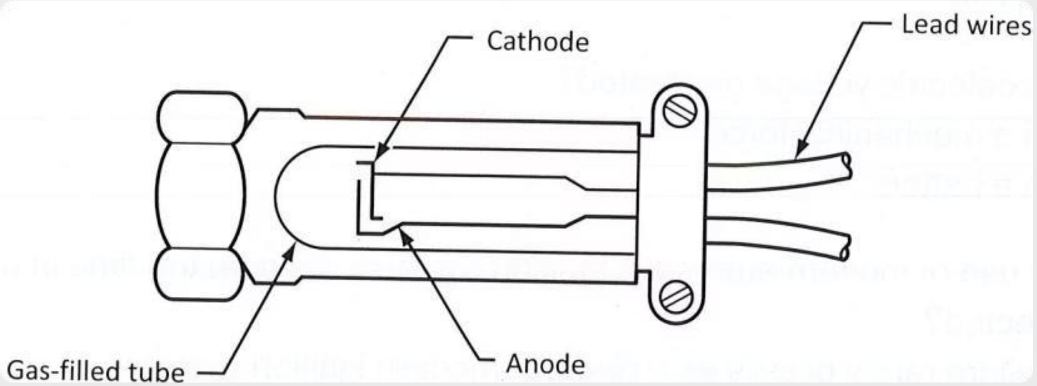
Immune to most false signals

## Maintenance Considerations

Requires periodic cleaning of viewing window

May need protection from excessive heat

Should be positioned for optimal flame viewing



# Burner Types and Air-Gas Mixing

## Premix Burners

Premix burners provide complete premixing with mechanical mixers

They mix controlled amounts of air and gas before ignition

## Blower-Mix Burner

The blower-mix burner uses air under pressure to entrain gas at atmospheric pressure

Provides consistent air-fuel ratio across varying conditions

## Atmospheric Burner

Relies on natural draft for combustion air

Simpler design with fewer moving parts

# Burner Draft Types

## Forced Draft Burner

Uses a fan located upstream of the combustion zone

Pushes air into the combustion chamber

Creates positive pressure in the combustion chamber

## Induced Draft Burner

Has a fan located downstream of the combustion zone

Pulls products of combustion through the heat exchanger

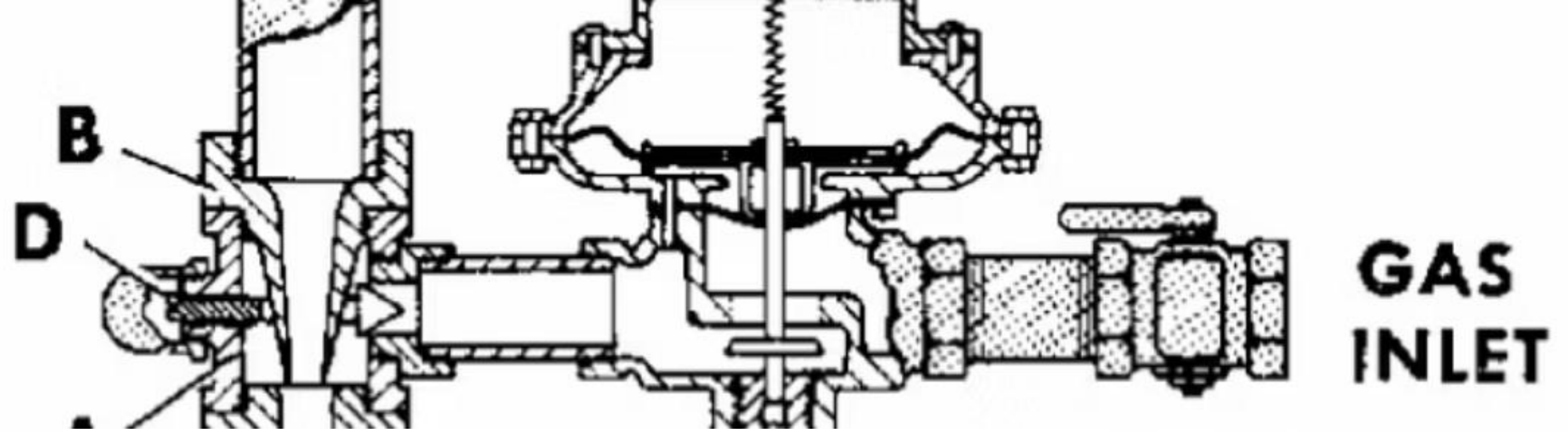
Creates negative pressure in the combustion chamber

## Atmospheric Burner

No fan

Relies on natural draft

Simplest design but less efficient




# Gas Supply Regulation

### Zero Governor

Regulates gas pressure to maintain consistent flow

Used in various burner applications

### Orifice

Used to regulate gas supply to an aspirator-type burner

Controls flow rate based on size of opening

### Blower Mixer

Combines air and gas in proper proportions

Used in power burner applications

# Atmospheric Burner Types

## Ribbon Burners

Most susceptible to flashback among atmospheric burners

Characterized by a ribbon-like flame pattern

Often used in applications requiring a linear flame distribution

## Ring Burners

Circular flame pattern

Less susceptible to flashback than ribbon burners

Common in appliances requiring circular heat distribution

## Mono-port Burners

Single port design

Less susceptible to flashback than ribbon burners

Often used in smaller appliances


# Mono-port Burner Flame Retention

### Crimped Ring

Helps to keep the flame retained at the burner port of a mono-port burner

Creates turbulence that stabilizes the flame

### Flame Spreader

Alternative method for flame retention

Distributes flame across desired area

### Gas Pressure

Proper gas pressure is essential for flame stability

Too high or too low pressure can cause flame issues

# Multiport Burner Challenges

## Clogging

Susceptible to clogging with lint from the inside

Requires regular maintenance

## Delayed Ignition

Can experience ignition delays

May cause startling pops during startup

## Flame Lifting

Can occur with improper gas pressure

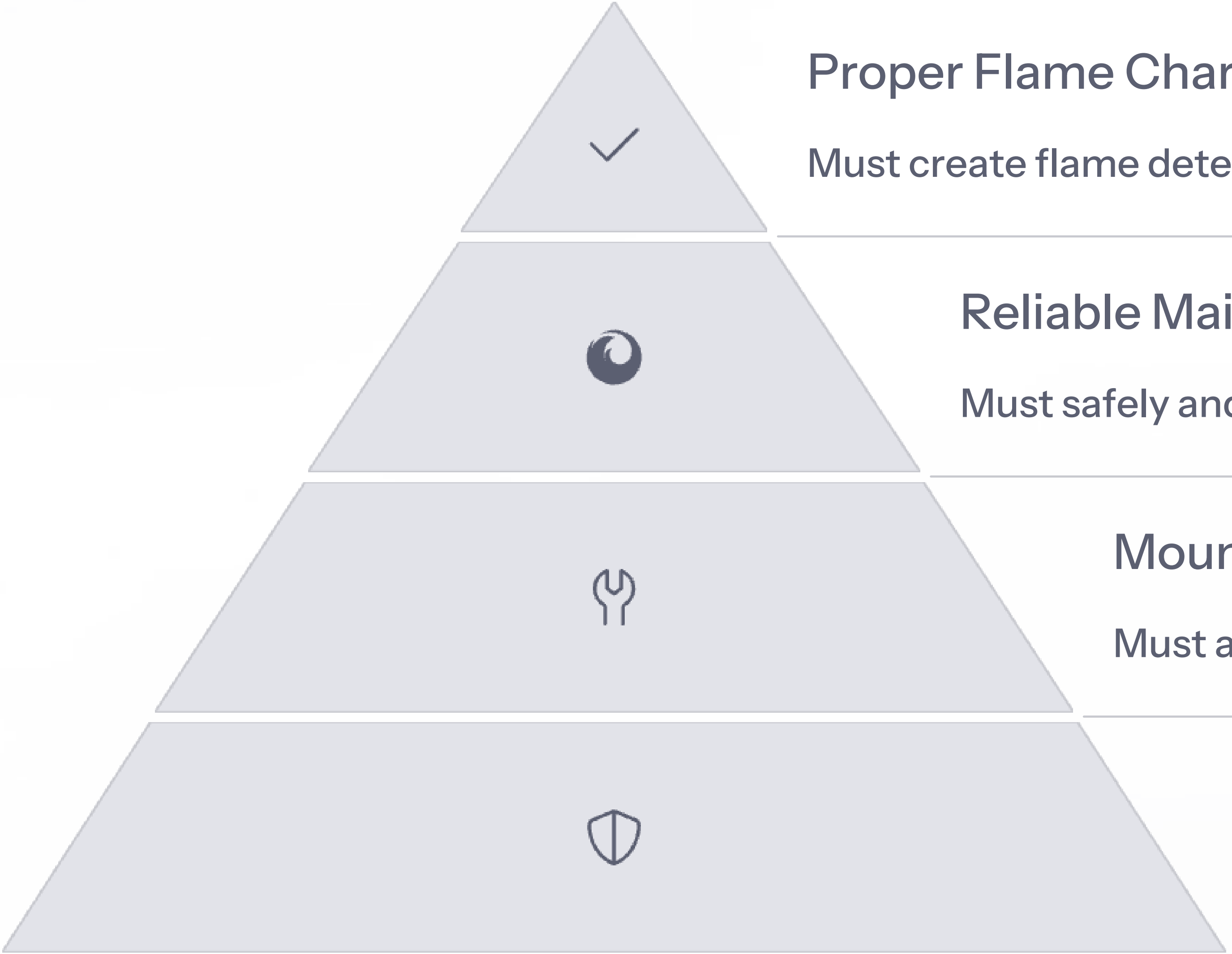
Reduces heating efficiency

## Sooting

Multiport burners are susceptible to sooting

Can reduce efficiency and create maintenance issues

# Pilot Burner Selection Considerations



### Proper Flame Characteristics

Must create flame detectable by flame sensor

### Reliable Main Burner Ignition

Must safely and consistently light main burner

### Mounting Compatibility

Must accommodate igniter and flame detector

### Environmental Suitability

Must withstand operating conditions

No one pilot burner can give adequate ignition flame for all types of main burners. Consequently, there are many different pilot burner designs with a wide selection of mounting styles and directional hoods.

# Aerated vs. Non-Aerated Pilots: Advantages

## Aerated Pilot Advantages

- Sharp, intense blue flame
- Stable flame less affected by draft
- Hot flame for good flame detector response
- Consistent performance in varying conditions

## Non-Aerated Pilot Advantages

- Softer blue flame
- Longer thermocouple life
- Less prone to dust and lint problems
- Simpler design with fewer components

# Aerated vs. Non-Aerated Pilots: Disadvantages

## Aerated Pilot Disadvantages

- Prone to clogging from dust and lint
- Shorter thermocouple life due to hotter flame
- May require more frequent maintenance
- More complex design

## Non-Aerated Pilot Disadvantages

- More affected by changes in draft
- More sensitive to supply pressure changes
- May produce yellow flame at low pressure
- Potential for flame rod fouling at low pressure

# Automatic Ignition System Benefits

## 30%

### Energy Savings

Typical reduction in gas consumption compared to standing pilot

## 100%

### Safety Compliance

Modern systems meet all current safety standards

## 15s

### Response Time

Typical flame failure detection speed

Automatic ignition of the pilot and/or main flame at the start of each call for heat avoids the problems associated with manual ignition systems. The off-cycle does not involve wasting of gas nor does it require venting (unlike with constant pilot systems).

# Hot Surface Igniter Materials

## Silicon Carbide

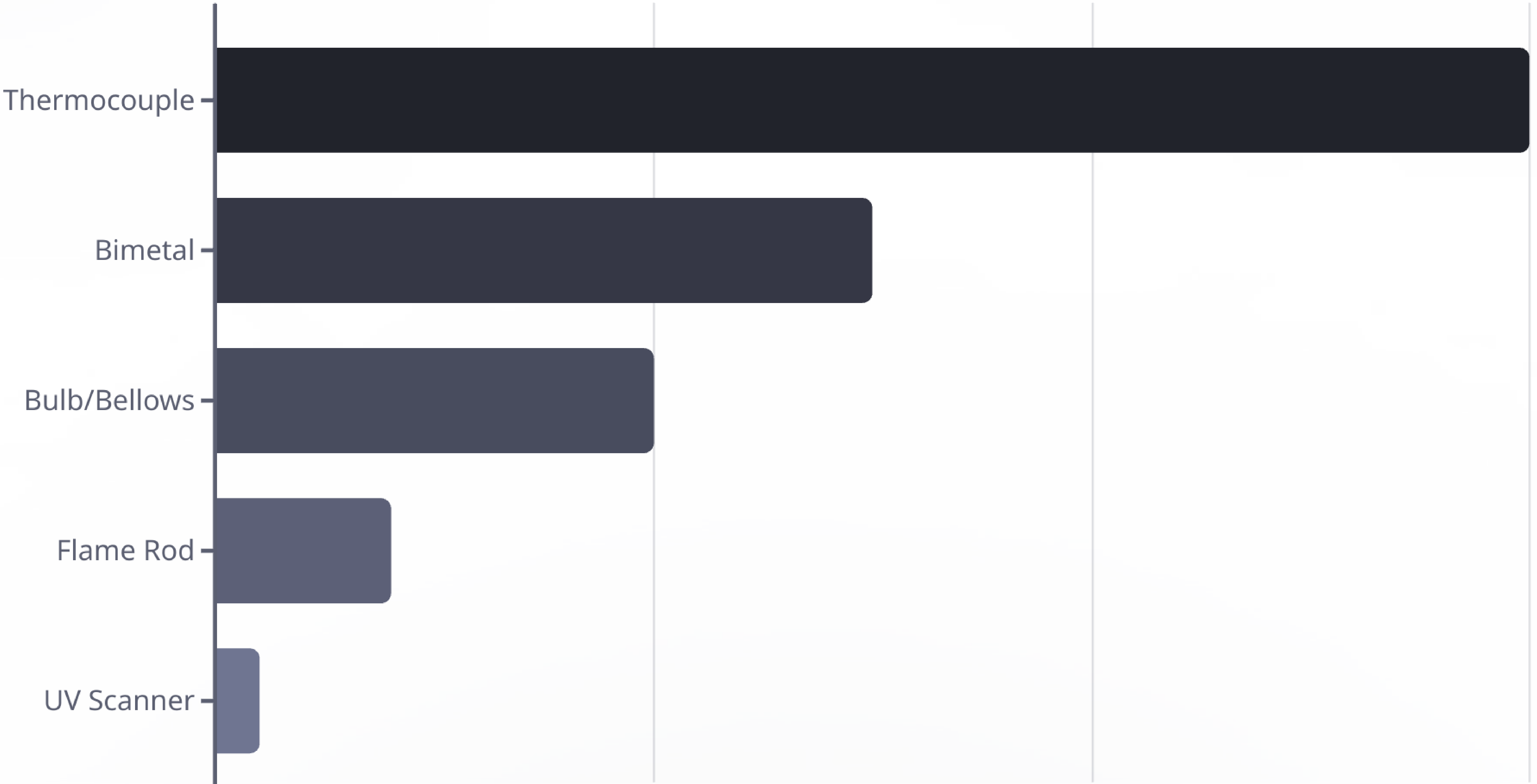
- Common HSI material
- Reaches temperatures of 1800-2500°F
- Glows white-hot when energized
- Relatively fragile - handle with care

## Silicon Nitride

- More durable than silicon carbide
- Better resistance to thermal shock
- Longer service life
- More expensive than silicon carbide

The hot surface igniter is usually made from a material like silicon carbide or nitride. When electricity passes through it, it glows white hot.

# Flame Sensing Response Time



# Thermocouple Voltage Output

## 25mV

### Typical Output

Average thermocouple voltage when properly heated

## 15mV

### Minimum Required

Threshold for most gas valve operation

## 750°F

### Operating Temperature

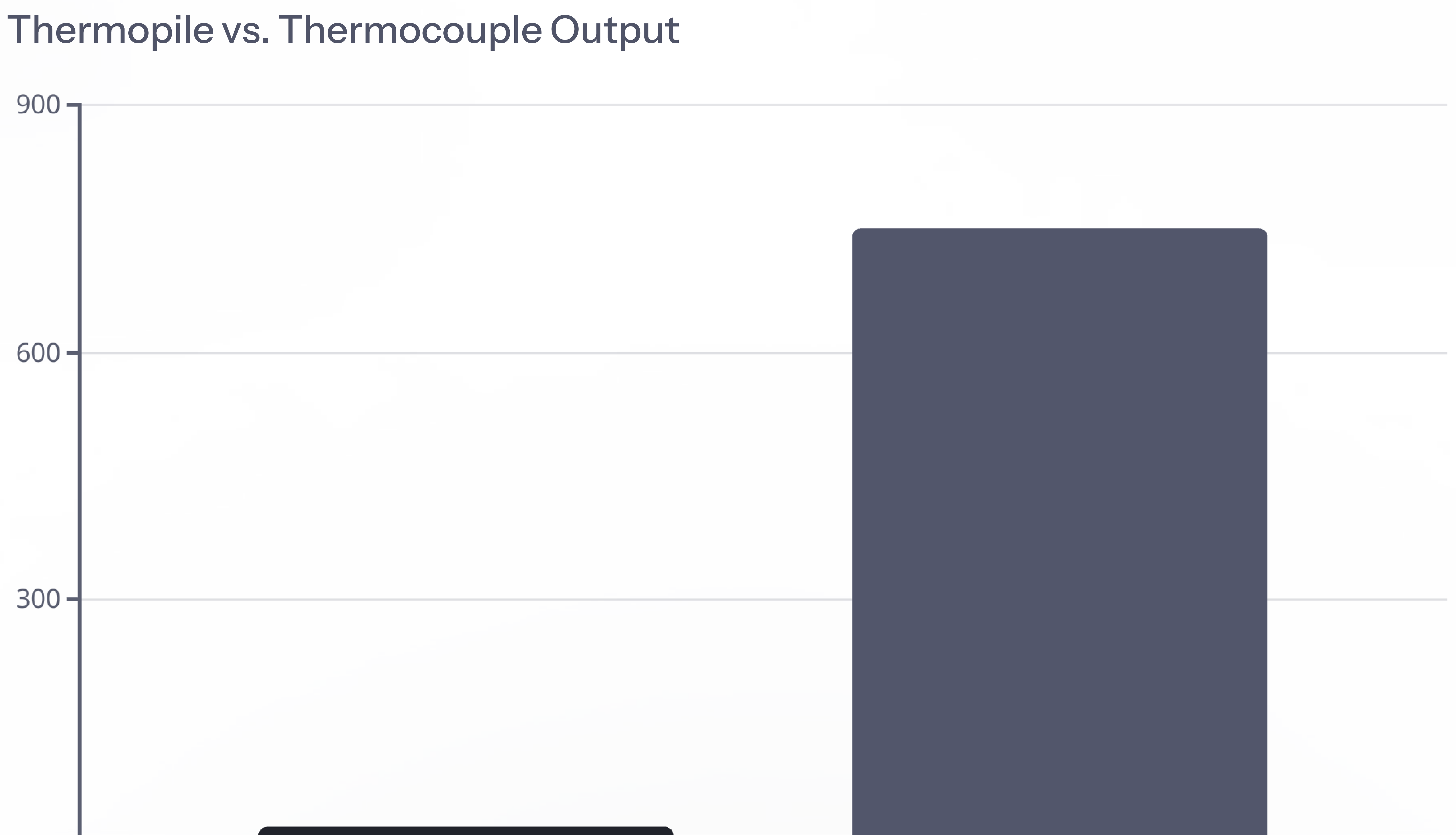
Typical temperature at hot junction

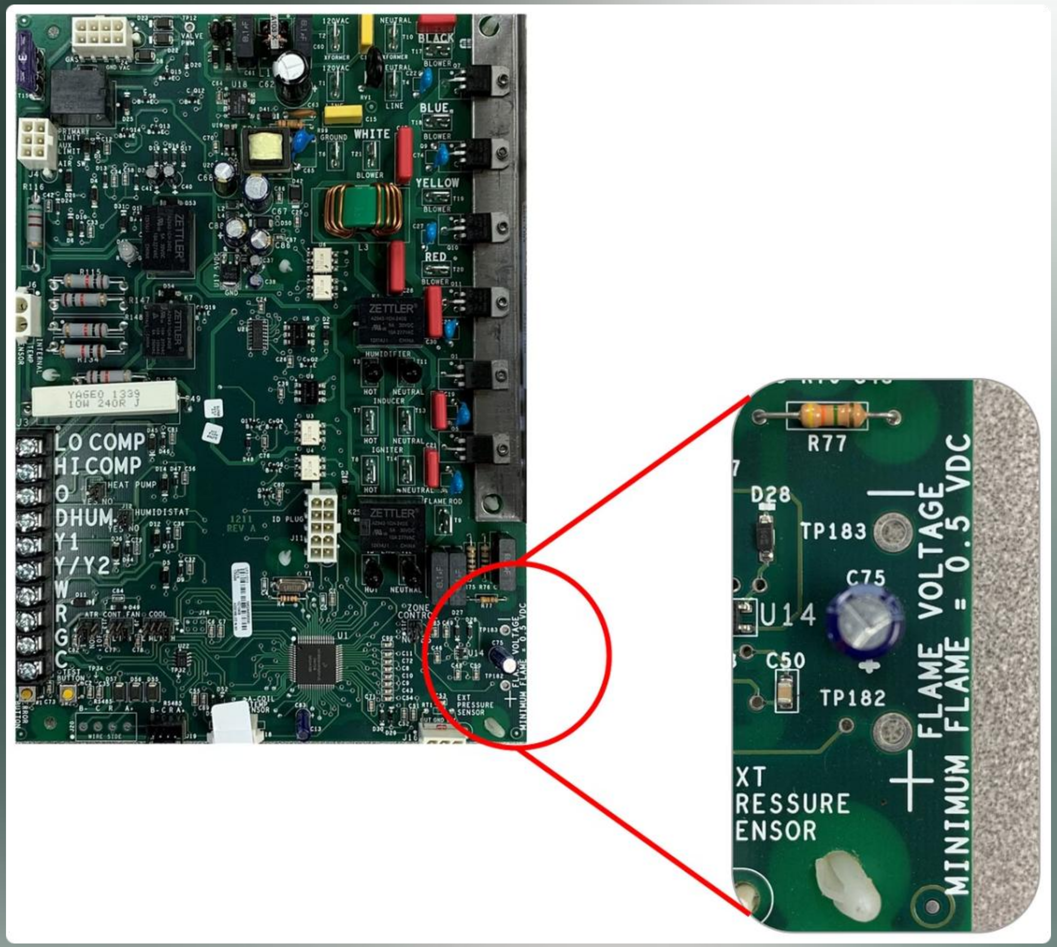
When the pilot burner heats the hot junction, the thermocouple generates a voltage to power the electromagnet in the safety shutoff valve or safety switch. This small but critical voltage is what keeps the gas flowing to the appliance.

**ITS-90 Table for Type K Thermocouple (Ref junction 0°C)**

Thermoelectric voltage in mV

| °C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.000 | 0.039 | 0.079 | 0.119 | 0.158 | 0.198 | 0.238 | 0.277 | 0.317 | 0.357 | 0.397 |
| 10 | 0.397 | 0.437 | 0.477 | 0.517 | 0.557 | 0.597 | 0.637 | 0.677 | 0.718 | 0.758 | 0.798 |
| 20 | 0.798 | 0.838 | 0.879 | 0.919 | 0.960 | 1.000 | 1.041 | 1.081 | 1.122 | 1.163 | 1.203 |
| 30 | 1.203 | 1.244 | 1.285 | 1.326 | 1.366 | 1.407 | 1.448 | 1.489 | 1.530 | 1.571 | 1.612 |
| 40 | 1.612 | 1.653 | 1.694 | 1.735 | 1.776 | 1.817 | 1.858 | 1.899 | 1.941 | 1.982 | 2.023 |
| 50 | 2.023 | 2.064 | 2.106 | 2.147 | 2.188 | 2.230 | 2.271 | 2.312 | 2.354 | 2.395 | 2.436 |
| 60 | 2.436 | 2.478 | 2.519 | 2.561 | 2.602 | 2.644 | 2.685 | 2.727 | 2.768 | 2.810 | 2.851 |
| 70 | 2.851 | 2.893 | 2.934 | 2.976 | 3.017 | 3.059 | 3.100 | 3.142 | 3.184 | 3.225 | 3.267 |
| 80 | 3.267 | 3.308 | 3.350 | 3.391 | 3.433 | 3.474 | 3.516 | 3.557 | 3.599 | 3.640 | 3.682 |
| 90 | 3.682 | 3.723 | 3.765 | 3.806 | 3.848 | 3.889 | 3.931 | 3.972 | 4.013 | 4.055 | 4.096 |


Thermopile vs. Thermocouple Output
900
600
300




# Flame Rod Rectification Process

## AC Voltage Application

The electric control applies an AC voltage to the flame rod

## Flame Ionization

Heat from the flame causes molecules between the electrodes to collide with each other so forcibly as to knock some electrons out of the atoms, producing ions

## Current Rectification

A pulsating DC current passes through the flame, since the flame rod is at least four times smaller than the surface or electrode of the burner

## Signal Processing

The control module detects this DC current as proof of flame presence

# Optical Flame Detection Spectrum

### Visible Light (400-700nm)

Not safe for flame detection

Too many potential false sources

Can be seen by human eye

### Infrared Light (700nm-1mm)

Safe for flame detection

Detected by lead sulphide cells

Invisible to human eye

### Ultraviolet Light (10-400nm)

Safe for flame detection

Detected by special gas-filled tubes

Invisible to human eye

Very few false sources

The three major types of light waves in a gas flame are visible, infrared (IR), and ultraviolet (UV). Only the last two are safe for use in monitoring a gas flame since there are too many sources of visible light that could fool a visible light detector.

# Flame Sensor Selection Criteria

## Response Time

How quickly the sensor detects flame failure

## Reliability

Performance in various conditions

## Power Requirements

Whether sensor needs external power

## Cost

Initial and replacement expenses

## Maintenance

Cleaning and replacement frequency

# Flame Sensor Maintenance

### Disconnect Power

Ensure appliance is off and cool

### Remove Sensor

Carefully extract from mounting

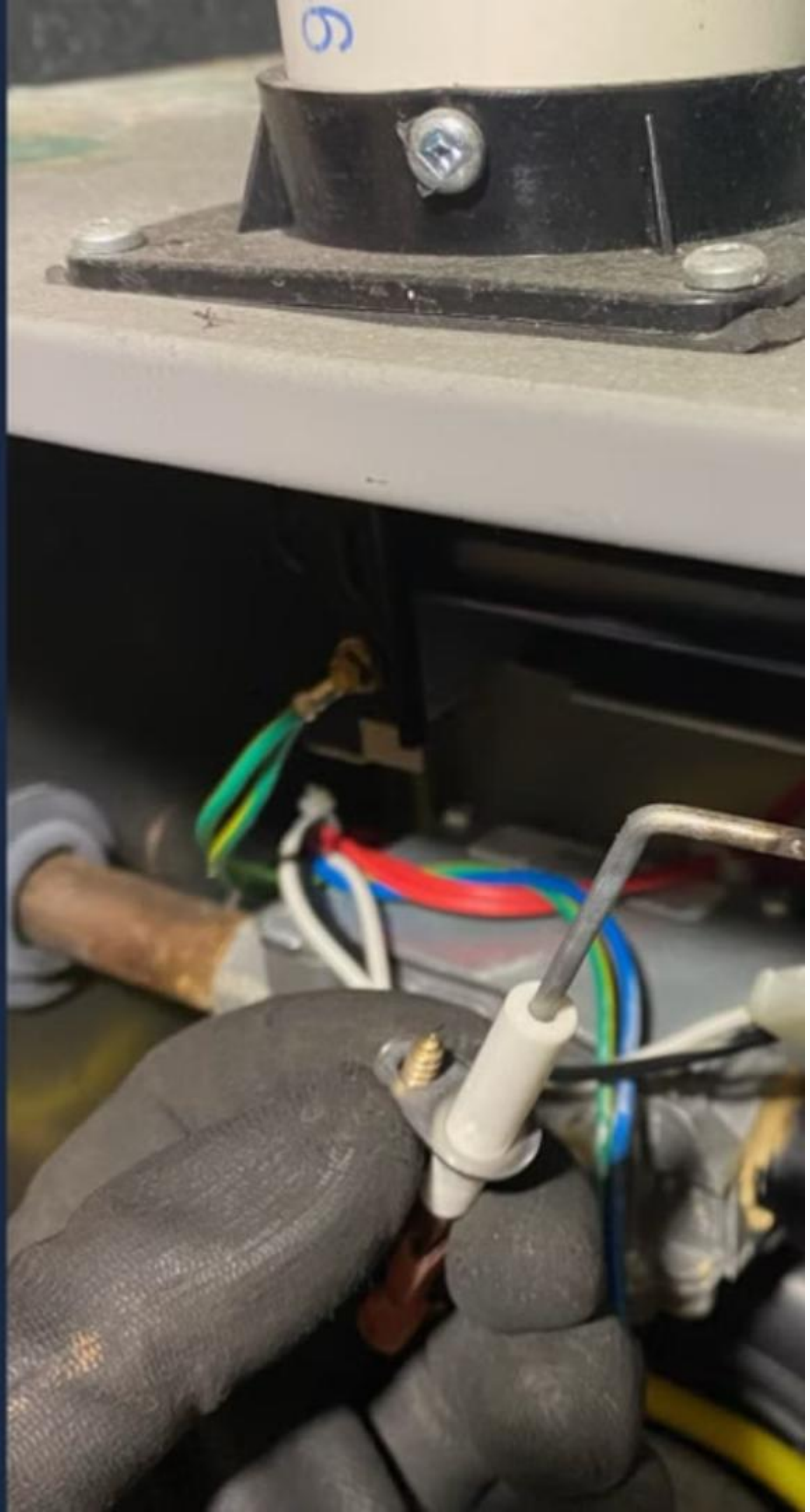
### Clean Sensing Element

Gently clean with fine abrasive pad

### Reinstall and Test

Secure sensor and verify operation

Regular maintenance of flame sensors, particularly flame rods, is essential for reliable operation. Carbon buildup on flame rods can prevent proper flame detection and cause system shutdowns.



# Troubleshooting Flame Sensing Issues

### No Flame Signal

- Dirty or damaged sensor
- Improper sensor positioning
- Faulty wiring connections
- Defective control module

### Weak Flame Signal

- Carbon buildup on sensor
- Poor ground connection
- Improper flame characteristics
- Sensor not properly in flame

### Intermittent Operation

- Loose connections
- Flame instability
- Deteriorating sensor
- Control module issues

# Safety Considerations for Ignition Systems

### Regular Inspection

All ignition and flame sensing components should be inspected annually by a qualified technician

### Never Bypass Safety Devices

Flame sensors and other safety components should never be bypassed or disabled

### Follow Manufacturer Guidelines

Always adhere to manufacturer specifications when servicing or replacing ignition components

### Certification Requirements

Do not change the location and design of pilot burners and protecting baffles without the permission of the manufacturer and the certification organization

# CSA Unit 9

# Chapter 4
# Controls and Safeties in Gas Burner Systems

All gas burners are under control in some way—either manually or automatically. This presentation identifies various controls that gas technicians/fitters use to either regulate the medium being heated or ensure maximum safe limits.

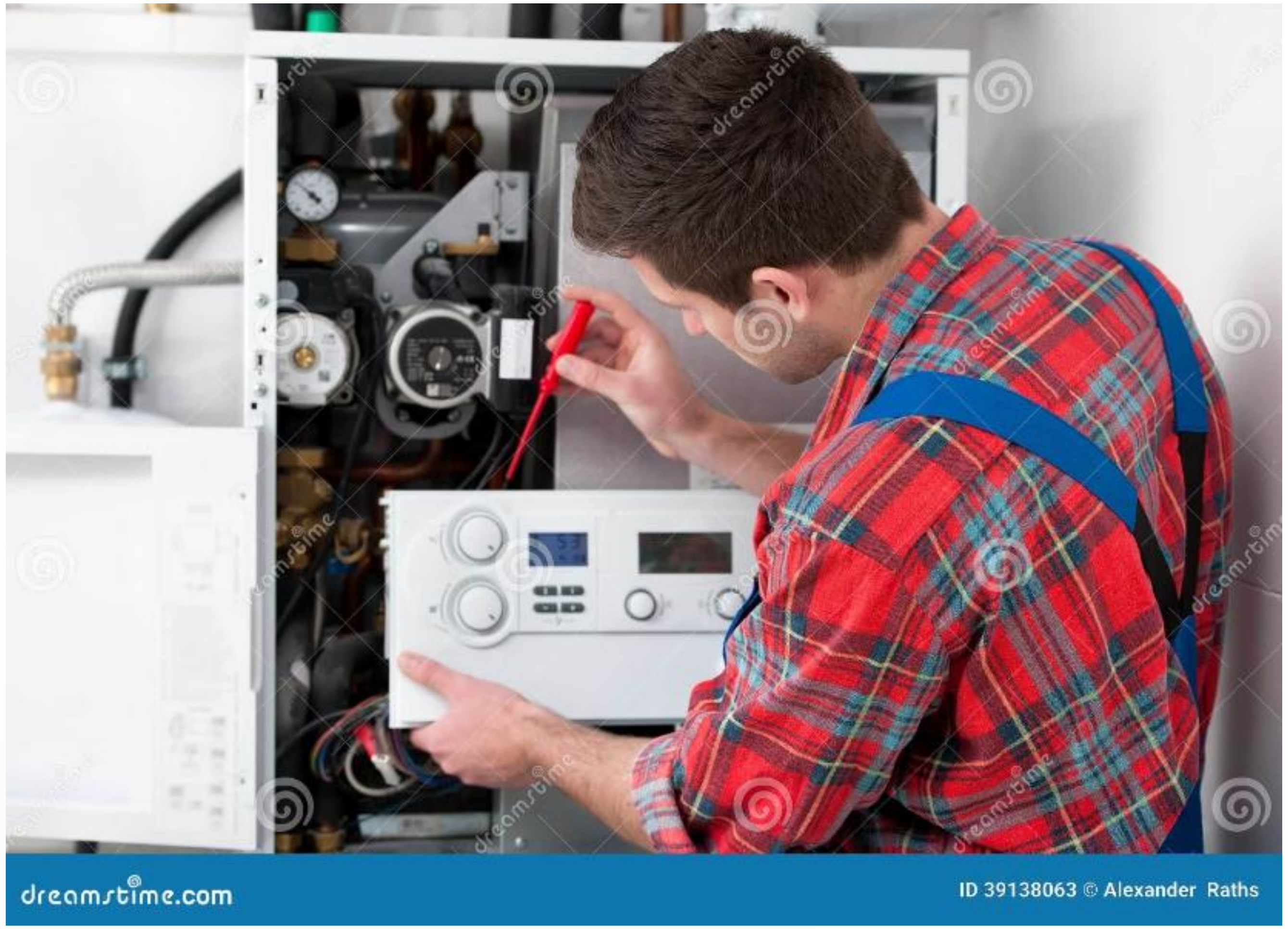
# Purpose and Objectives

## Purpose

All gas burners are under control in some way—either manually or automatically. This presentation identifies various controls that gas technicians/fitters use to either regulate the medium being heated or ensure maximum safe limits.

## Objectives

At the end of this presentation, you will be able to describe various controls and safeties used in gas burner systems.



# Key Terminology

| Term | Abbreviation (symbol) | Definition |
|---|---|---|
| Aquastat | | Device that controls water temperature in hydronic heating systems |
| Flame roll-out switch | | High temperature limit switch wired to the burner ignition control that de-energizes the gas valve if it sensed flame roll-out |
| Flow switch | | Ensures that the pumps are circulating water in the piping system and the boiler before the main burner can fire |
| Pressure relief valve | | Mechanical valve used on hot water boilers |
| Pressuretrol | | Operating steam pressure switch on a steam boiler |
| Unitrol | | Multipurpose valve typically installed in hot water heaters |

# Various Controls and Safeties

## Temperature Controls

Aquastats, high-limit switches, and combination controls that respond to changes in temperature

## Pressure Controls

Pressuretrols, pressure relief valves, and pressure switches that respond to changes in pressure

## Flow Controls

Flow switches and low water cut-off switches that respond to fluid movement or loss

## Safety Controls

Flame roll-out switches, blocked vent shut-off systems, and electronic control modules

The safety controls described are wired in the control circuits of various appliances. Changes in temperature, fluid movement, or pressure actuate them.

# Operating Aquastat

The operating aquastat acts in response to a change in water temperature. It is a normally closed switch (break on rise) that controls the temperature of the water inside a boiler.

For example, if you set the aquastat at 180°F (82°C), the contacts remain closed until the water reaches this temperature. At this point, the contacts open and cut off power to the main gas valve. The water cools several degrees before the contacts close again.

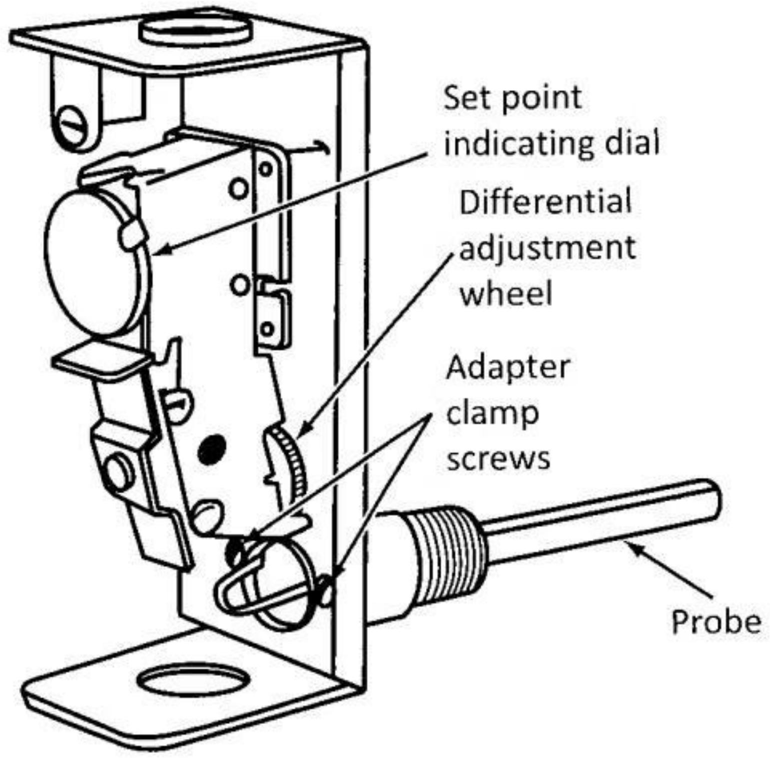



Figure 4-1 shows a direct-mounted operating aquastat with horizontal probe.

# High Limit Aquastat

## Function

The high limit aquastat is identical to the operating aquastat but is adjusted to a higher water temperature setting (commonly 20°F above the operator). It serves as a backup safety switch in case the operating aquastat fails.

## Mounting

You can mount the two aquastats side by side. In some cases, you consolidate them into one component and even make them share a single sensing element.

## Reset Feature

Some models come with a manual reset device. For example, if the water temperature reaches 200°F (93°C) and the contacts open, you must manually reset the switch for the contacts to close again.

Figure 4-2
Basic Electrical Control system for a small commercial hot water heating boiler

# Unitrol Multipurpose Valve

The Unitrol is a multipurpose valve that people typically install in hot water heaters. It contains in one compact unit:

- thermostat
- automatic gas shut-off valve
- over temperature energy cut-off (ECO) device
- main pressure regulator
- main and standby gas valve

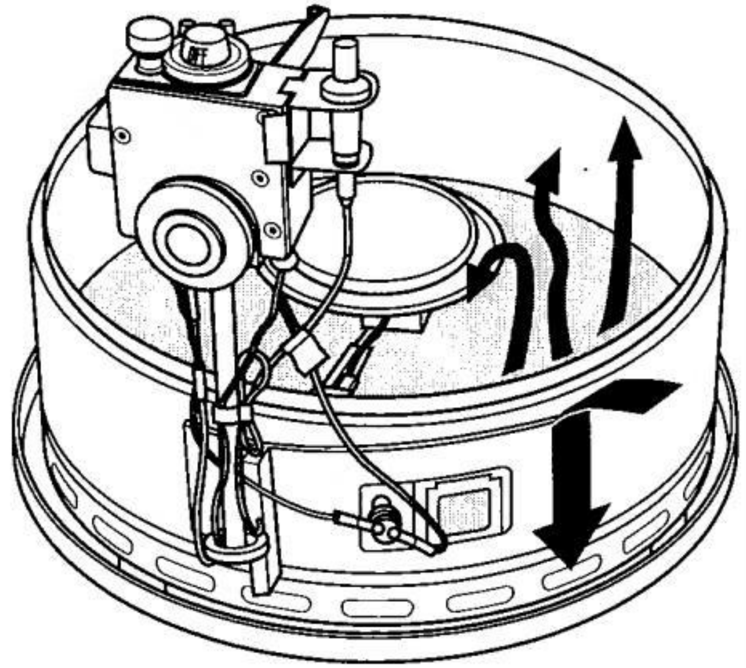


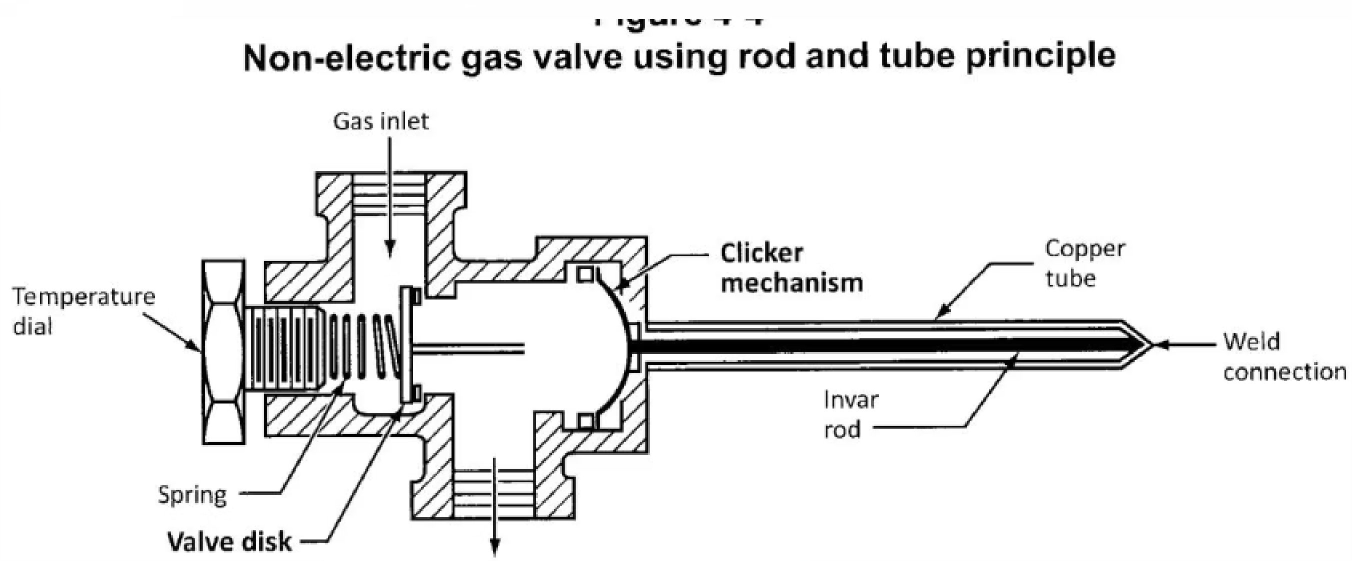
Figure 4-3 Unitrol multipurpose valve

# Unitrol Sensing Devices

## Rod and Tube Principle

When exposed to temperature change, different metals have different rates of expansion or contraction. The rod and tube thermostat use the expansion differential of a metal rod and a dissimilar metal tube to operate an electrical switch (or mechanism) controlling a gas port.

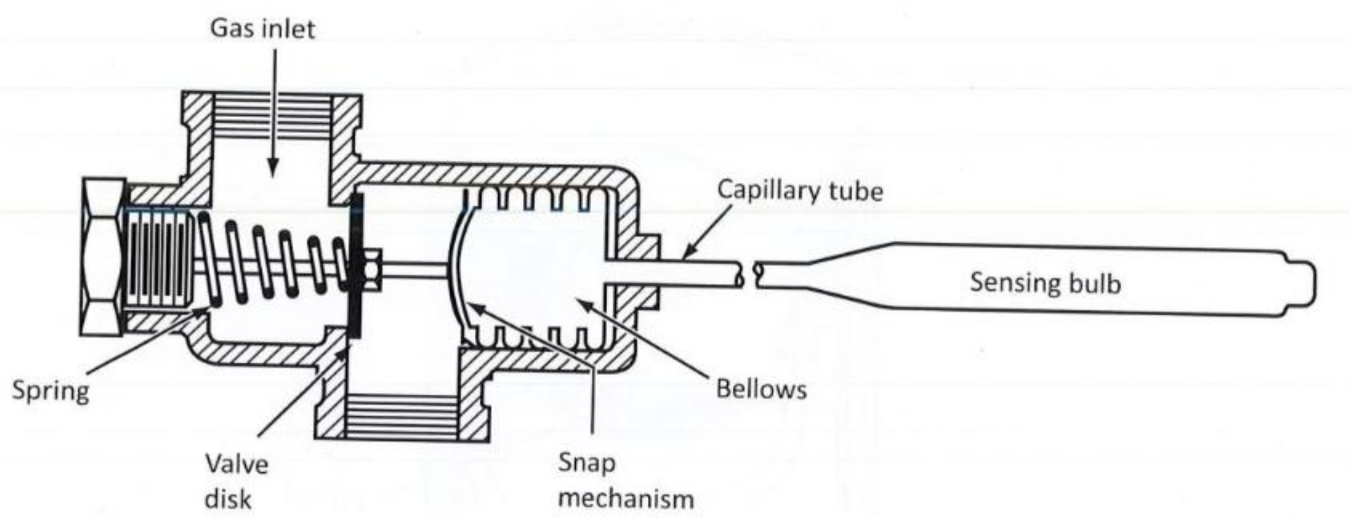
The rod is inside a tube and the two bond together at one end. Since the tube is made of a metal having a greater expansion rate than the rod, it expands or contracts more when both are exposed to the same temperature changes.




## Bulb and Bellows Principle

The force that results from the expansion of liquids or gases within a sealed capillary helps operate an electrical switch or a mechanism to open or close a gas port.

A bulb at one end of the capillary senses the temperature of the surrounding water or air. At the other end of the capillary, an attached bellows reacts to the pressure within the capillary by expanding or contracting.



# Combination High-Limit/Fan Control Switch

A combination high-limit/fan control switch is what you use on air heating systems to sense air temperature. The combination high-limit/fan control contains a normally open fan switch on the left side and a normally closed high limit switch on the right side. A jumper connects the same power source to the two switches.

As the temperature rises, the bimetal strip first closes the fan switch and start the blower. If an overheating condition occurs, the bimetal strip continues to warp until the limit cut-out temperature is reached (around 200°F) and then opens the limit.

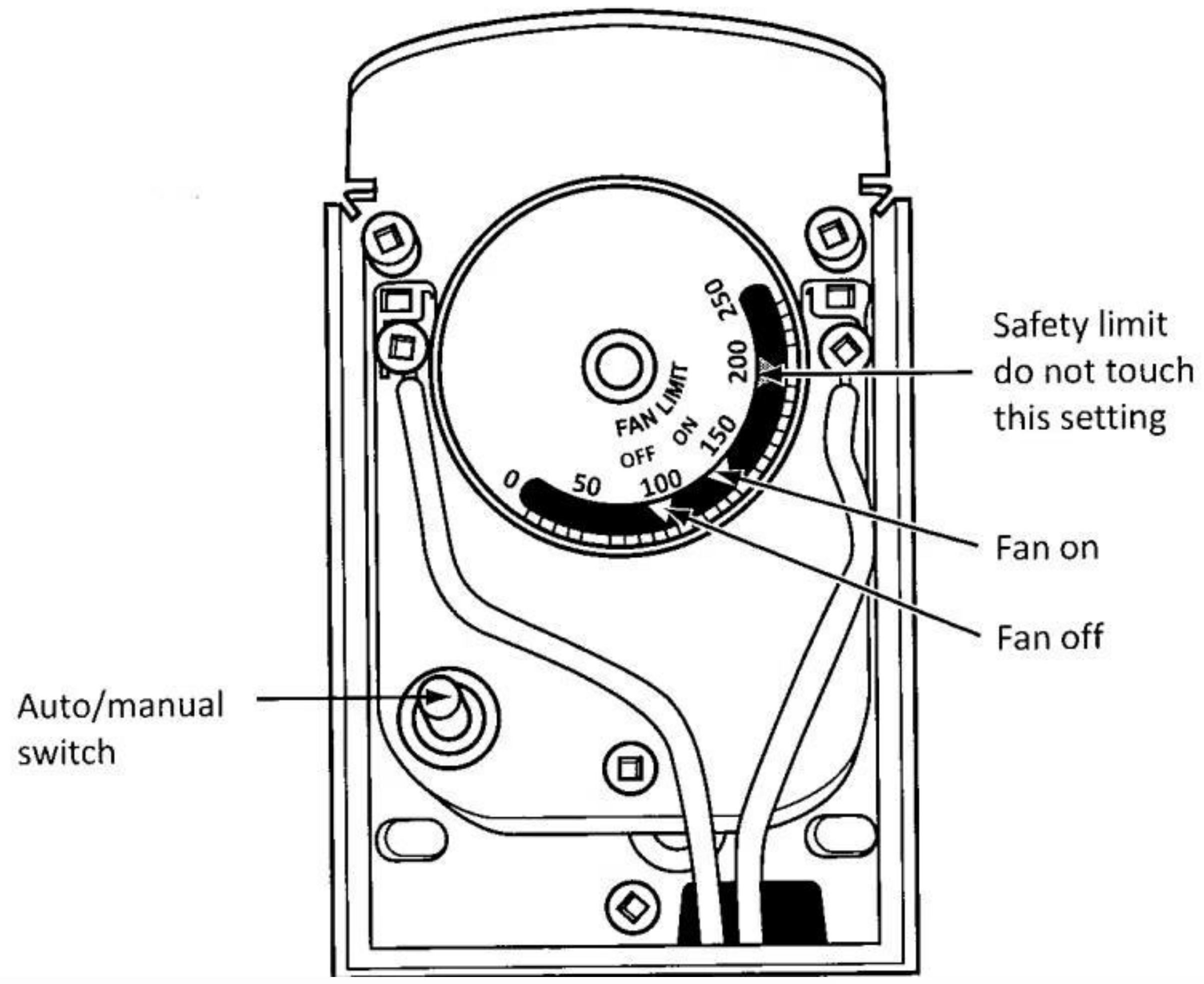



Figure 4-6 Combination high-limit/fan control

# Control Circuits for Residential Warm Air Furnace

When the limit switch is open, the transformer circuit is interrupted. This de-energizes the control circuit, causing the main gas valve to close. The blower continues to run until the fan switch cools and opens.

Many fan operations on new equipment are under the control of the electronic control board and operate on a time delay function. Rather than sensing for temperature in the furnace, the control board energizes the circulation blower after a predetermined time delay.

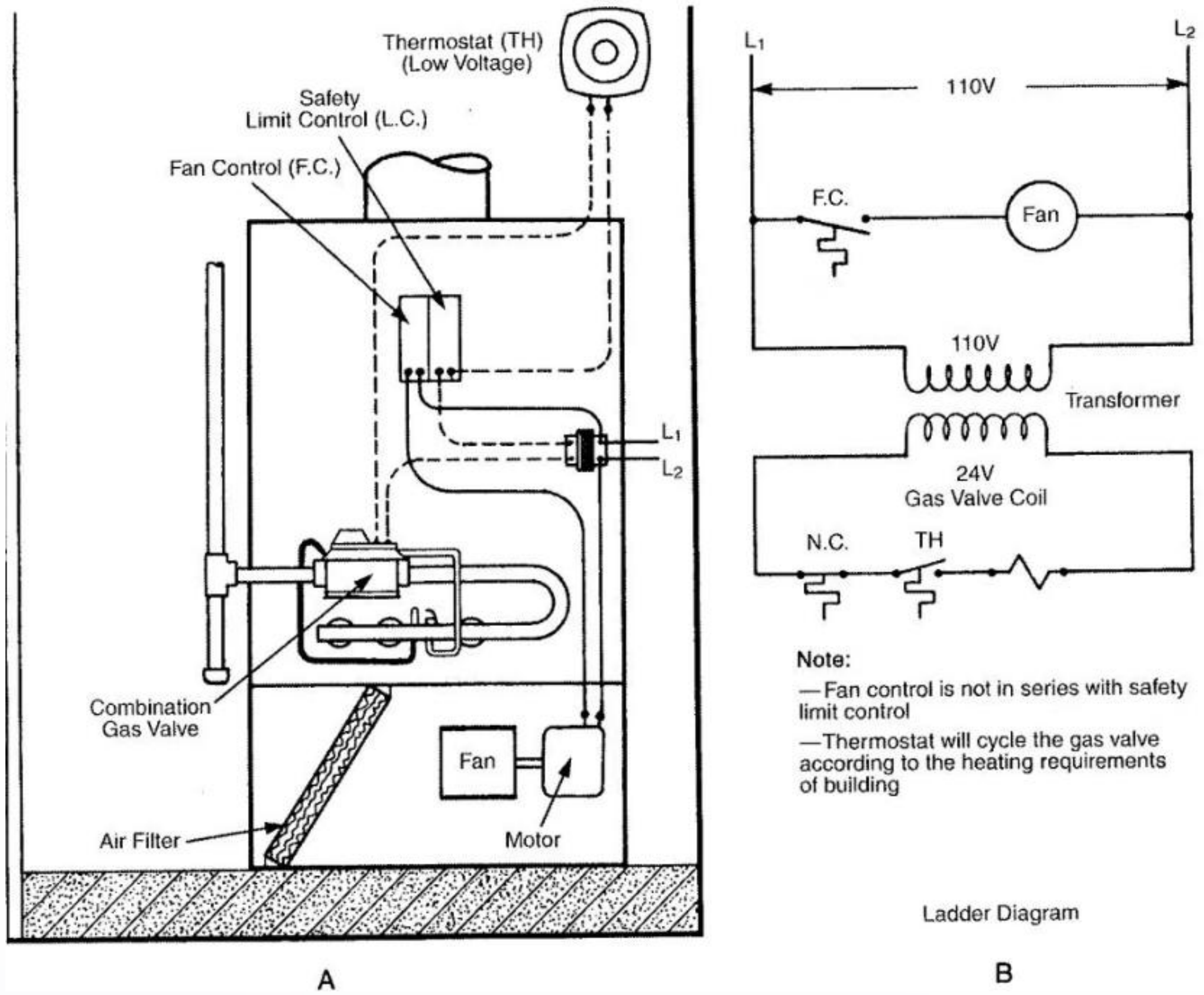



Figure 4-7 Control Circuits for a residential warm air furnace

# Operating Pressure Switch

A pressure switch acts in response to changes in water, steam, air, or gas pressure. You can find it on steam boilers, water boilers, as well as on combustion blowers for gas burners.

Operating steam pressure switches on steam boilers are what you call pressuretrols. As steam pressure in the boiler rises and reaches the set point of the pressuretrol, the switch contacts open and de-energize the power to the main gas valve.

For example, if you set the pressuretrol to 3 psig (21 kPa), the contacts stay closed until the steam pressure reaches 3 psig (21 kPa). Once it has reached this pressure, the contacts open and cut off power to the main gas valve. The contacts remain open until the steam pressure drops and reaches the low point setting.

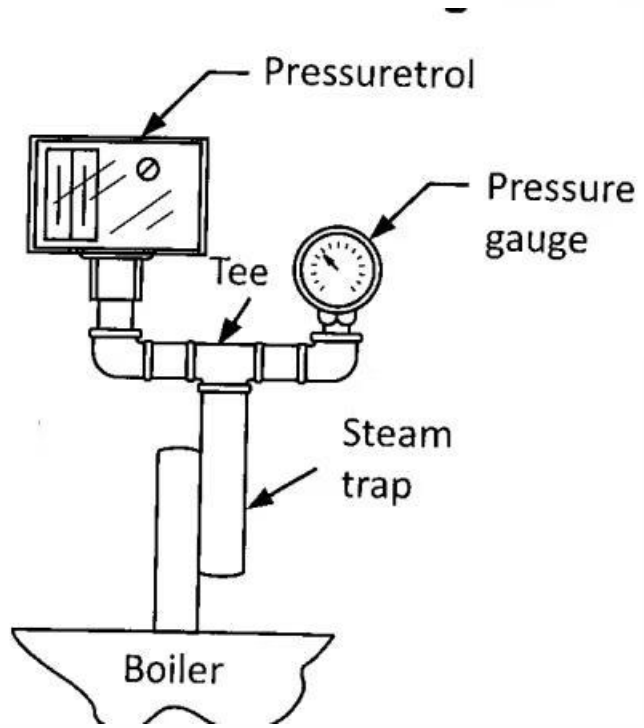



Figure 4-8 Pressure switch senses change in steam pressure

The high and low set points on the operating pressuretrols are adjustable, as are the differentials.

# High-Limit Pressure Switch

A high-limit pressuretrol works exactly like an operating pressuretrol, except that you adjust it to a higher-pressure setting. Some models come with a manual reset device.

This serves as a backup safety device in case the operating pressuretrol fails to function properly, providing an additional layer of protection against dangerous overpressure conditions.

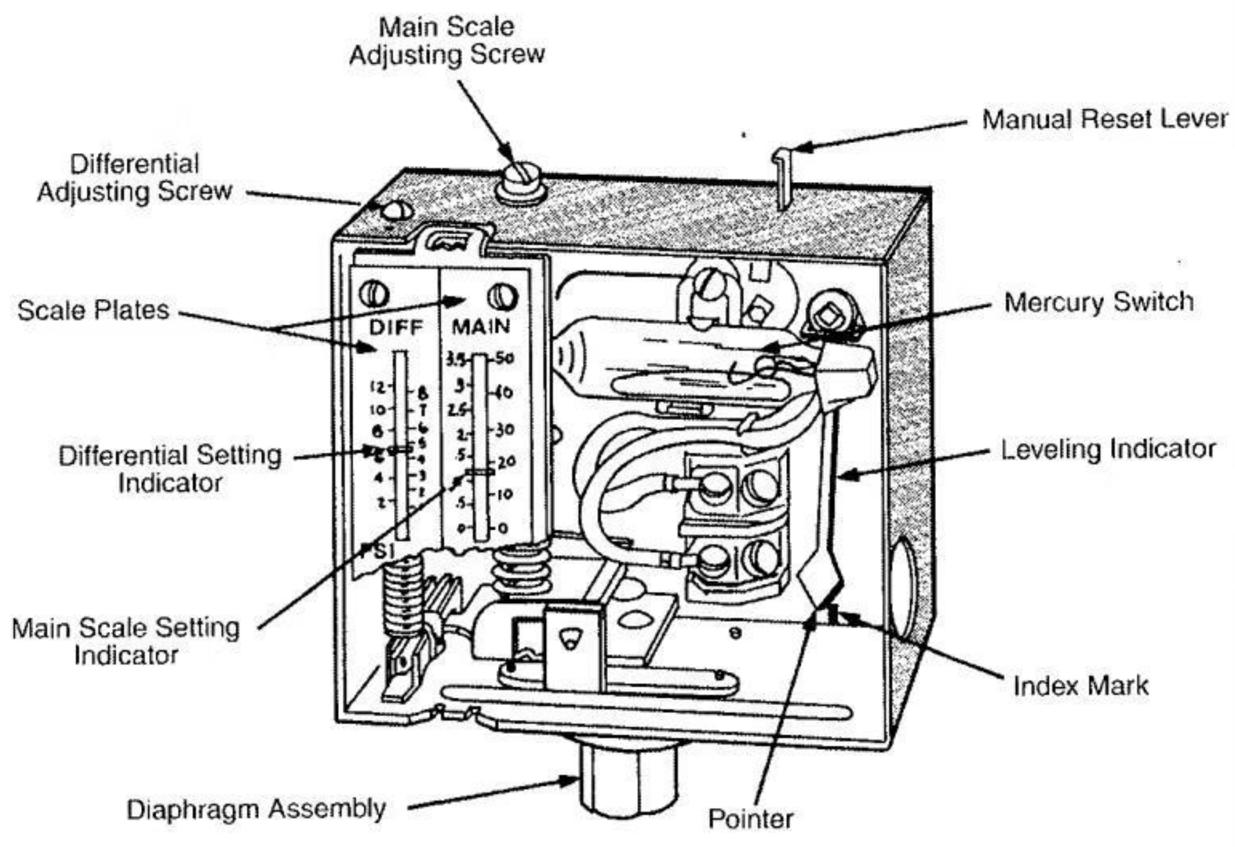



Figure 4-9 High-Limit Pressure Control with manual reset lever

# Pressure Relief Valve

The pressure relief valve is a mechanical valve that controls pressure on hot water boilers. If pressure in the system rises above the set point, the valve opens and dumps water until the pressure drops to an acceptable level.

This is a critical safety component that prevents dangerous overpressure conditions that could lead to equipment damage or even catastrophic failure.

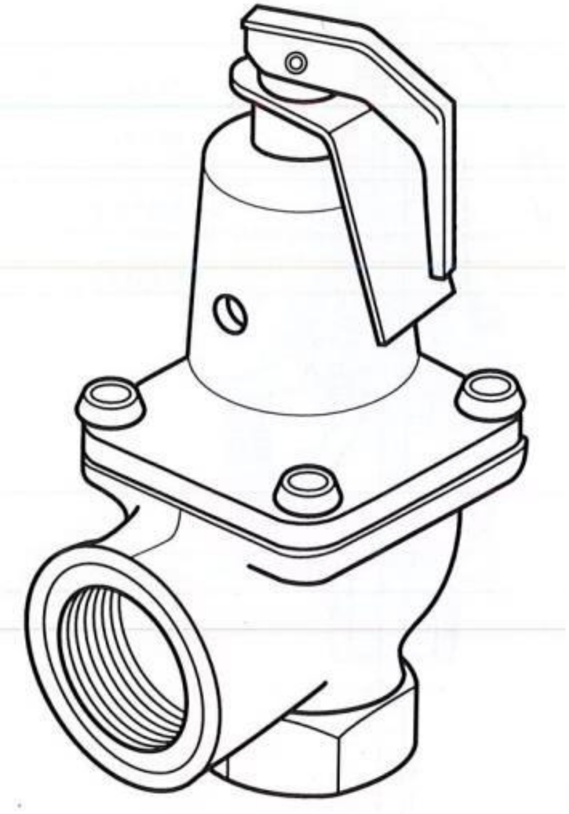


Figure 4-10 Pressure relief valve

# Combination Pressure-Temperature Relief Valve

Some local and national codes require the installation of storage water heaters with a combination pressure-temperature relief valve. The sensing stem of this valve extends into the water within the top six inches of the tank.

It opens to dump water if the tank pressure or water temperature is excessively high. Whenever a water heater is replaced, you should install a new valve and discard the old valve.

Note that you must pipe the discharge of relief valves without restrictions or reductions in diameter to an air gap as per local Building Codes. It must also be of a material suitable of withstanding the potential discharge temperatures.

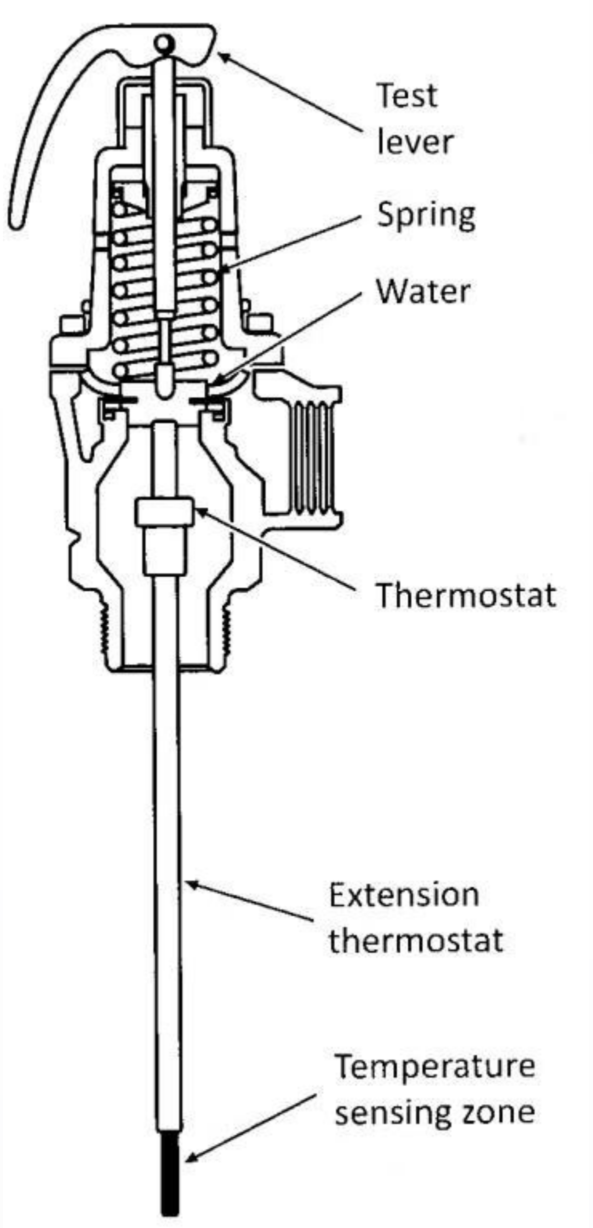



Figure 4-11 Combination pressure-temperature relief valve

# Low Water Cut-Off Switch

The low water cut-off switch is what you use on all steam boilers and hot water boilers over 400,000 Btu/h or where any part of the heating system is below the boiler and it acts in response to fluid loss. If the water level in the boiler falls below the minimum level, the low water cut-off switch opens its contacts and cuts off power to the main gas valve.

## Float Type

This is a normally open switch that the float on top of the water holds close. If the water level falls below a predetermined point, the float mechanism lowers and breaks the electrical contact.

## Probe Type

This is a normally open switch. It has an electronic circuitry that uses boiler water to conduct current between the terminals on the end of the probe. If the water falls below the level of the probe, the electronic circuit between the terminals is broken. In response to no circuit, the low water cut-off switch opens, cutting off power to the main gas valve.

# Flow Switch

Flow switches act in response to water movement. They ensure that the pumps are circulating water in the piping system and the boiler before the main burner can fire.

Boilers that require flow switches have small water capacities and their water may turn to steam if the flow of water is inadequate.

This safety device prevents potential damage to the system by ensuring proper water circulation before allowing the burner to operate.

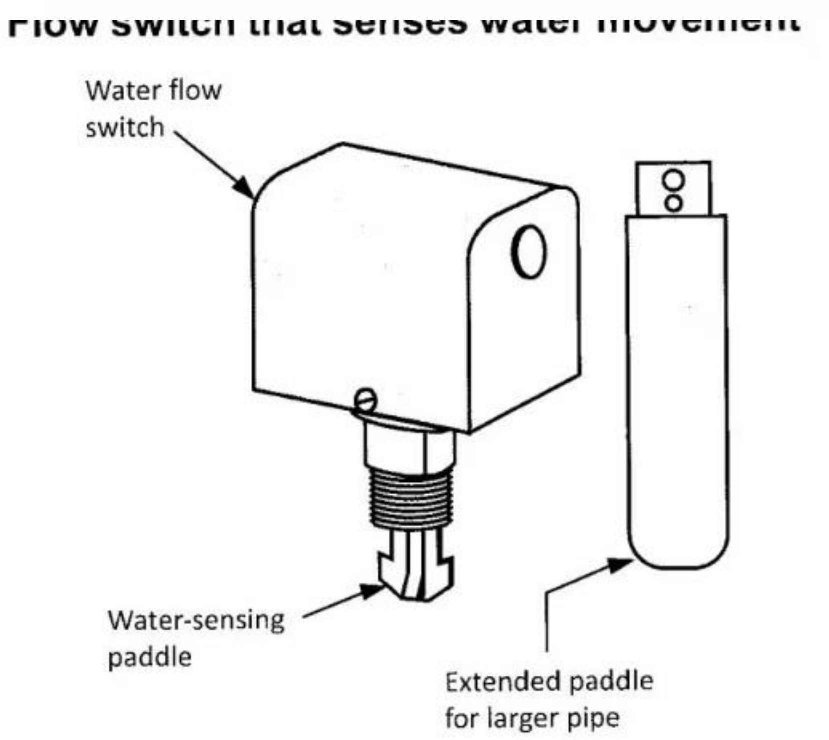
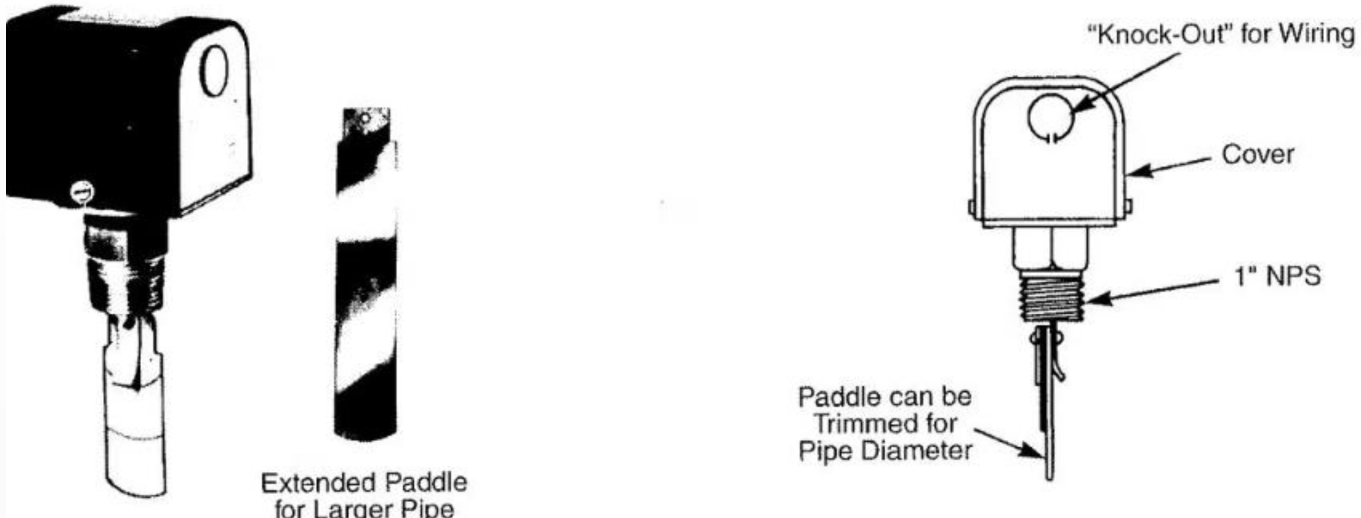



**Figure 4-15**
**Flow switch**



# Air Flow Switch Types

## Sail Switch

Works similarly to a flow switch, except that it acts in response to the movement of air rather than water.

## Pressure Differential Switch

Senses air flow by the differential of pressure across its sensing mechanism.

You use these switches in applications that require proving of air flow, e.g., for sensing combustion air or flue gas flow, or proving air flow in the case of a high-efficiency furnace.

A blocked vent, faulty heat exchanger or even a blocked drain tube could cause the pressure switch to activate and shut furnace operation down.

# Flame Roll-Out Switch

The flame roll-out switch is a high temperature limit switch wired to the burner ignition control. If it senses flame roll-out, it opens and de-energizes the gas valve. This is a manually reset switch.

A failure to vent the flue products from the combustion chambers or a heat exchanger failure usually causes flame roll-out. If the burner flame is trapped or disturbed in the heat exchanger, the flame may flash back or roll outside of the combustion chamber area, potentially causing a CO or fire hazard.

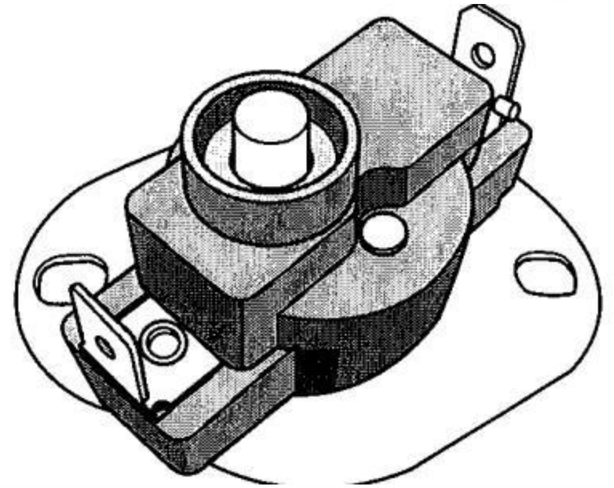


Figure 4-17 Bimetal roll-out switch

# Blocked Vent Shut-Off System

### Function

When furnaces have draft hoods, you may equip them with a shut-off system that automatically cuts out the main burner when the vent is totally blocked.

### Common Misconception

These shut-off systems are commonly—and incorrectly—referred to as spill switches.

### Operation

Similar to the flame roll-out switch, they are temperature sensing, manual reset switches wired in series to the gas valve function.

### Standards

Furnace certification standards specify test methods for these systems.

# Electronic Control Module

The brain of most modern furnace electronic ignition systems uses an integrated circuit board to control many sophisticated processes. These integrated controllers can also perform self-diagnostics providing various failure codes.

The integrated circuits continuously monitor the furnace's operation and the operation of the integrated control module itself. If a failure occurs, LEDs can indicate a failure code. The Owner's Manual and the furnace door provide the codes.

You always find these integrated controllers on higher efficiency furnaces that rely on many sophisticated design features to reach their high AFUE ratings of over 90%.

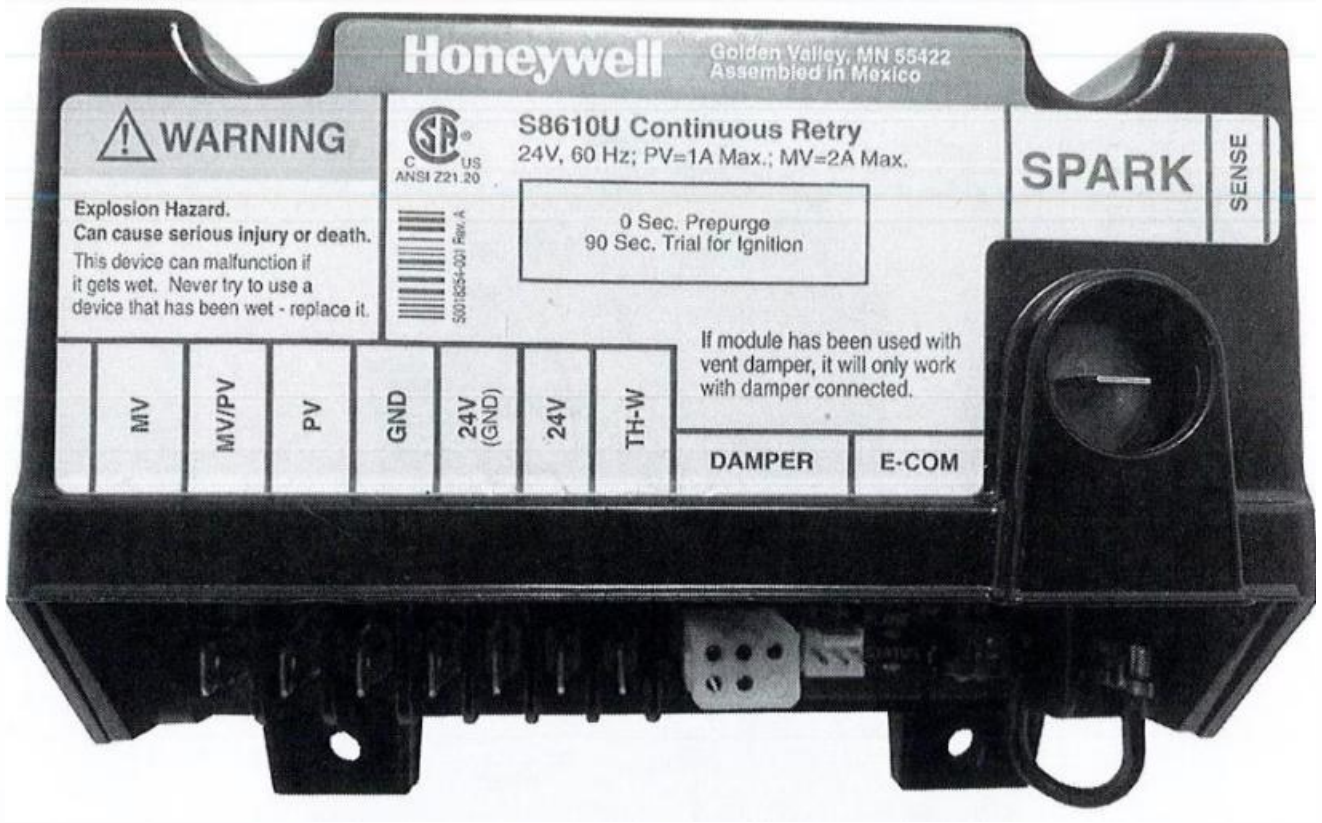



Figure 4-18 Control module


# Electronic Control Module Operation

### Continuous Monitoring

The control module monitors furnace operation and safety circuits continuously.

### Fault Detection

If safety circuits are open, the gas furnace control board detects this and locks the system out for a specific amount of time.

### Retry Sequence

After this time delay, the control board tries again for ignition unless the safety circuit is open.

### Lock-Out Mode

The board stays in lock-out mode until a gas technician/fitter resolves the problem.

# Gas Control Valve

Gas control valves come in many different models for many differing applications. Constant pilot, intermittent pilot, and direct ignition models provide the control of pilot and main burner gas to appliances to allow for safe ignition and controlled delivery of gas to burners.

The gas control valve consists of:

- a regulator or zero governor to reduce gas pressure or control gas flow
- one or two automatic gas shut-off valves
- a manual shut-off valve that may direct gas flow only to the pilot line (if so equipped)
- a means of controlling the flow rate to the pilot line (if so equipped)—usually by means of a needle valve
- tests ports to measure inlet and outlet pressure

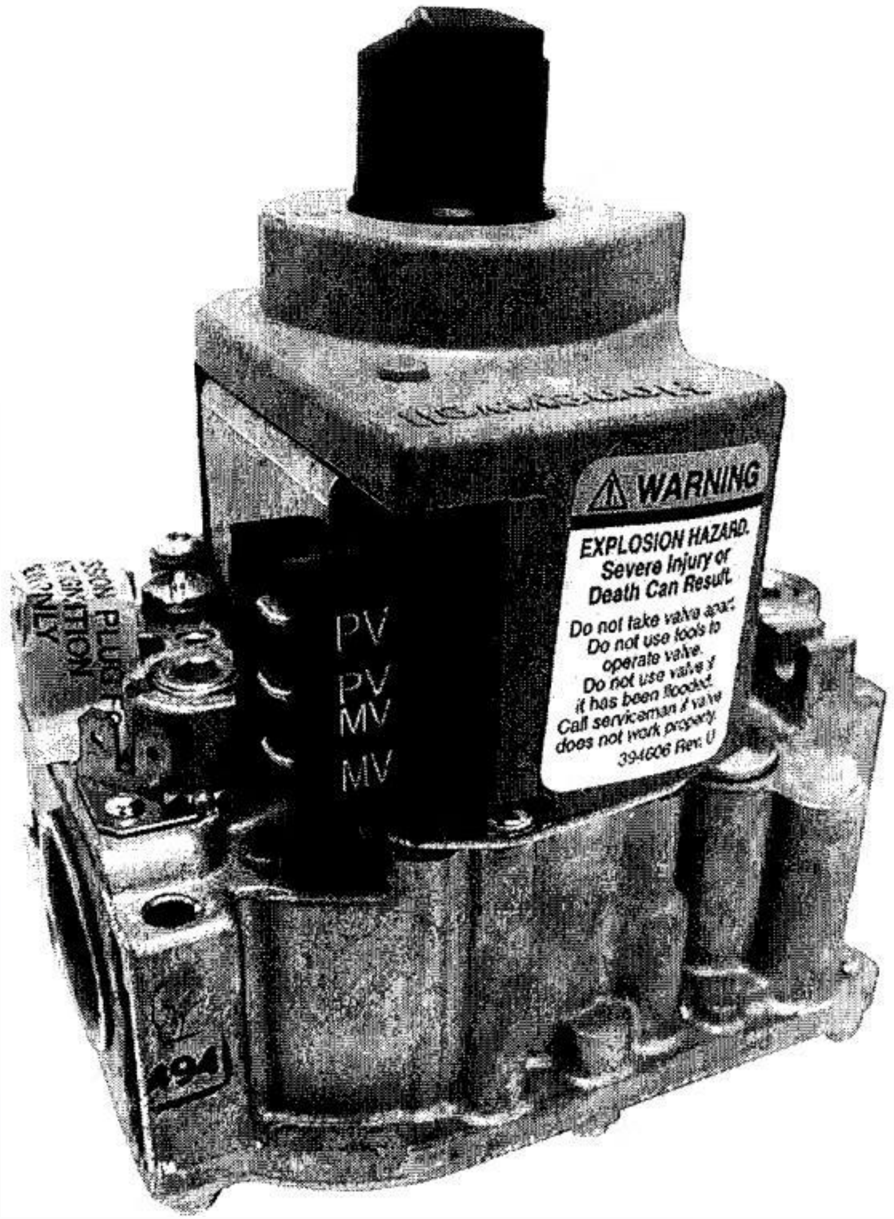



Figure 4-19 Gas control valve


# Wireless Controls

## Advantages

Hard-wired connections between thermostats and furnaces have many limitations that you can overcome with the application of wireless technology.

## Applications

Wireless thermostats allow for temperature control in one or more locations during retrofits or new construction projects.

## Components

Most wireless systems include a remote sensor thermostat and sensor along with the option of multiple remote controllers.

# Operating Aquastat: Detailed Operation

## Temperature Sensing

The aquastat continuously monitors water temperature in the boiler

## Set Point Reached

When water temperature reaches the set point (e.g., 180°F), contacts open

## Burner Shutdown

Open contacts cut power to the main gas valve, stopping the burner

## Temperature Drop

Water cools several degrees below set point

## Cycle Restart

Contacts close again, allowing burner to reignite


# Rod and Tube Thermostat: Working Principle

### Temperature Change

Water temperature around the thermostat changes

### Differential Expansion

The tube expands or contracts more than the rod due to different metals

### Mechanical Movement

This creates a relative movement between the rod and tube

### Switch Operation

Movement operates an electrical switch or mechanism controlling gas flow

# Bulb and Bellows Thermostat: Working Principle

### Temperature Sensing

Bulb senses temperature of surrounding water or air

### Fluid Expansion

Liquid or gas in the sealed capillary expands or contracts

### Pressure Change

Pressure changes within the capillary system

### Bellows Movement

Bellows expands or contracts in response to pressure

### Control Actuation

Bellows movement operates switch or mechanism

# Combination High-Limit/Fan Control: Operation Sequence

### Initial State

Fan switch is normally open, high limit switch is normally closed

### Temperature Rise

As furnace heats up, bimetal strip begins to warp

### Fan Activation

At fan-on temperature, bimetal closes fan switch, starting blower

4

### Overheat Condition

If temperature continues rising to around 200°F, bimetal warps further

5

### Limit Activation

High limit switch opens, interrupting transformer circuit

### Burner Shutdown

Control circuit de-energizes, closing main gas valve

### Cooling Phase

Blower continues running until temperature drops below fan-off setting

# Modern Fan Control Operations

### Electronic Control

Many fan operations on new equipment are under the control of the electronic control board and operate on a time delay function.

### Time Delay vs. Temperature

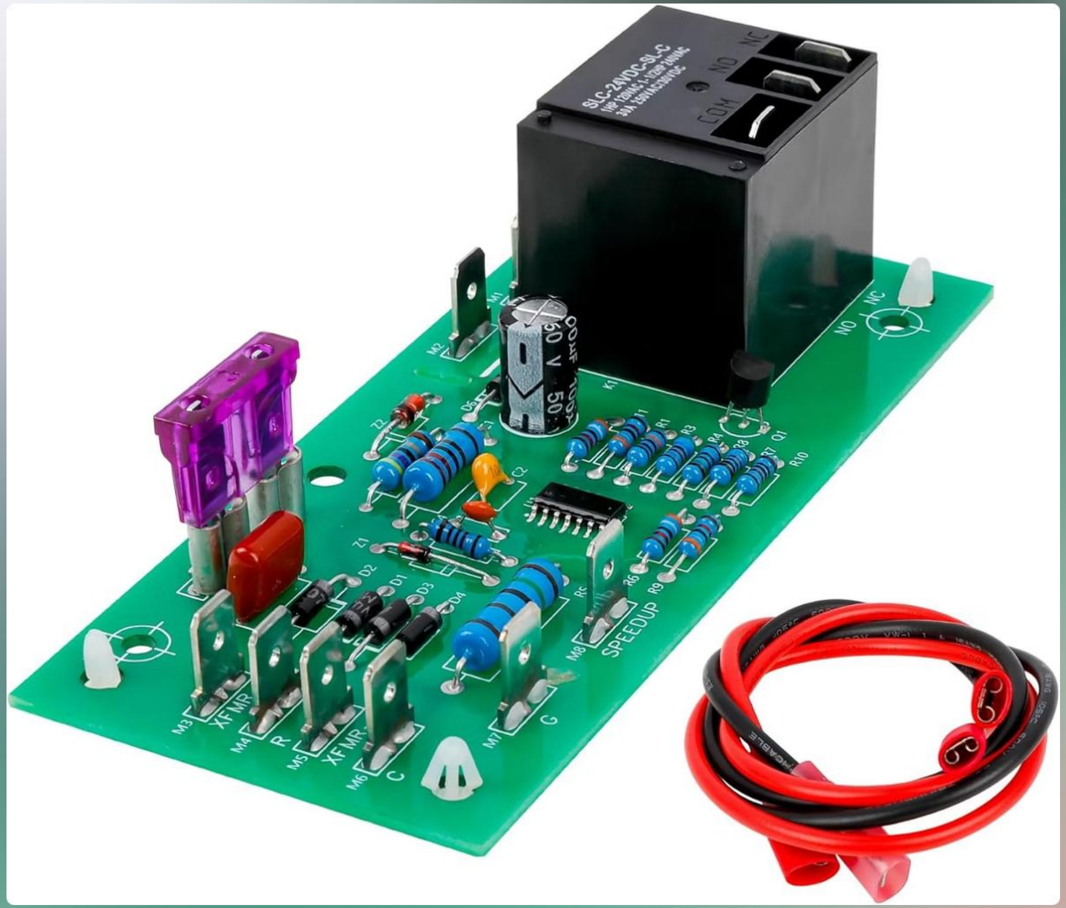
Rather than sensing for temperature in the furnace, the control board energizes the circulation blower after a predetermined time delay.

### Advantages

This approach provides more consistent operation, prevents cold air delivery at startup, and can be programmed for optimal efficiency.

### Programmable Settings

Modern control boards often allow for adjustable fan-on and fan-off delay times to maximize comfort and efficiency.




# Pressuretrol Operation

## 3 psig

Set Point

Example operating pressure setting

## 21 kPa

Metric Equivalent

Same pressure in kilopascals

## 2.5 psig

Low Point

Example restart pressure

## 0.5 psig

Differential

Difference between on/off points

Operating steam pressure switches on steam boilers are what you call pressuretrols. As steam pressure in the boiler rises and reaches the set point of the pressuretrol, the switch contacts open and de-energize the power to the main gas valve. The contacts remain open until the steam pressure drops and reaches the low point setting. The high and low set points on the operating pressuretrols are adjustable, as are the differentials.

# Pressure Relief Valve: Safety Function

## Pressure Monitoring

Continuously monitors system pressure

## Overpressure Detection

Activates when pressure exceeds set point

3

## Valve Opening

Opens to release water from the system

4

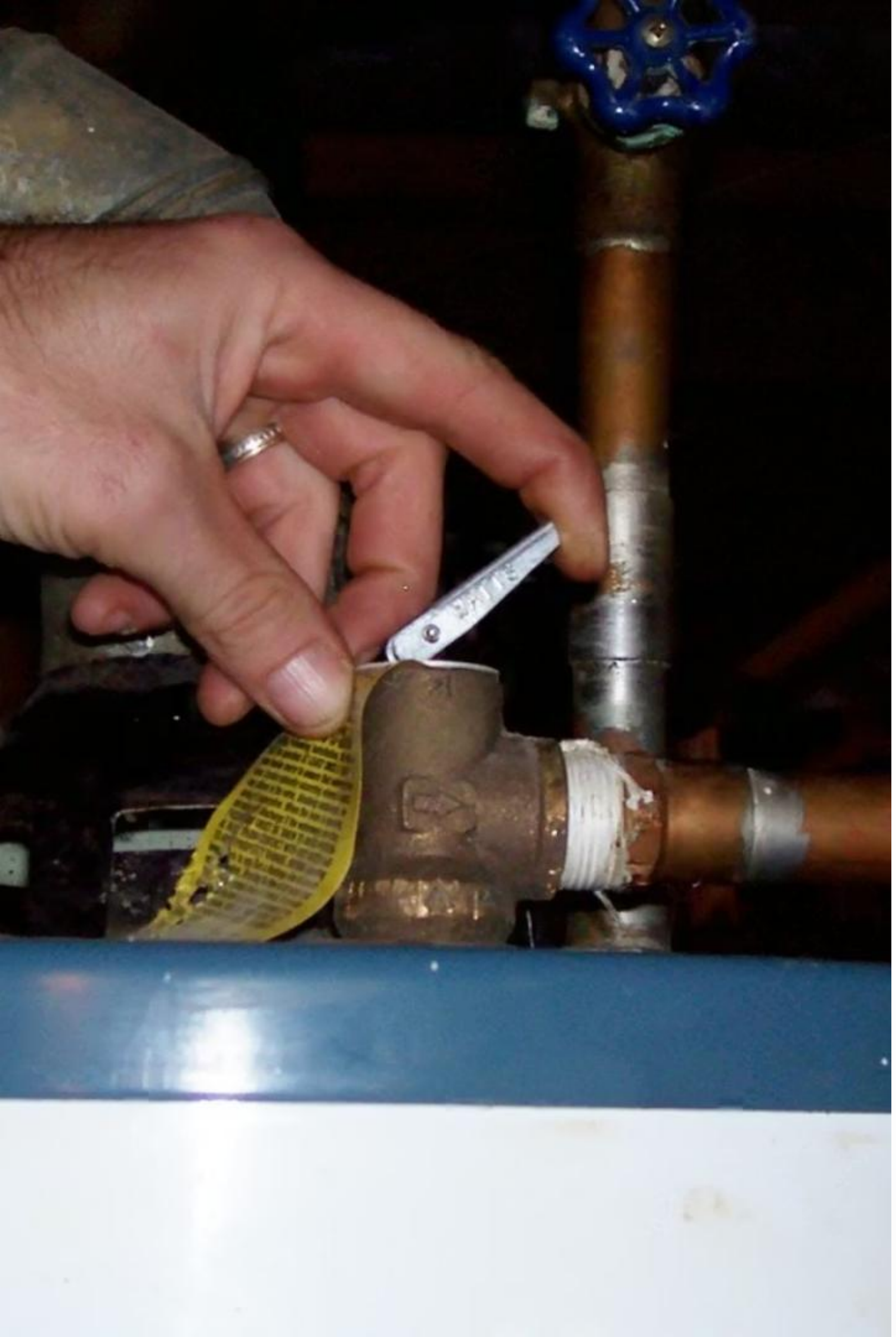
## Pressure Reduction

Continues releasing water until pressure normalizes

5

## Valve Closing

Automatically reseats when pressure returns to safe level



# Combination Pressure-Temperature Relief Valve: Installation Requirements

### Proper Positioning

The sensing stem must extend into the water within the top six inches of the tank

### Discharge Piping

Must be piped without restrictions or reductions in diameter to an air gap as per local Building Codes

### Material Selection

Discharge pipe must be of a material suitable of withstanding the potential discharge temperatures

### Replacement

Whenever a water heater is replaced, you should install a new valve and discard the old valve

# Low Water Cut-Off Switch: Float Type

The float type low water cut-off switch is a normally open switch that the float on top of the water holds close. If the water level falls below a predetermined point, the float mechanism lowers and breaks the electrical contact.

This type of low water cut-off is commonly used in larger boiler systems and provides a mechanical means of detecting low water conditions without relying on electronic sensors.

The float mechanism must be regularly maintained and inspected to ensure proper operation, as sediment or scale can affect its movement.

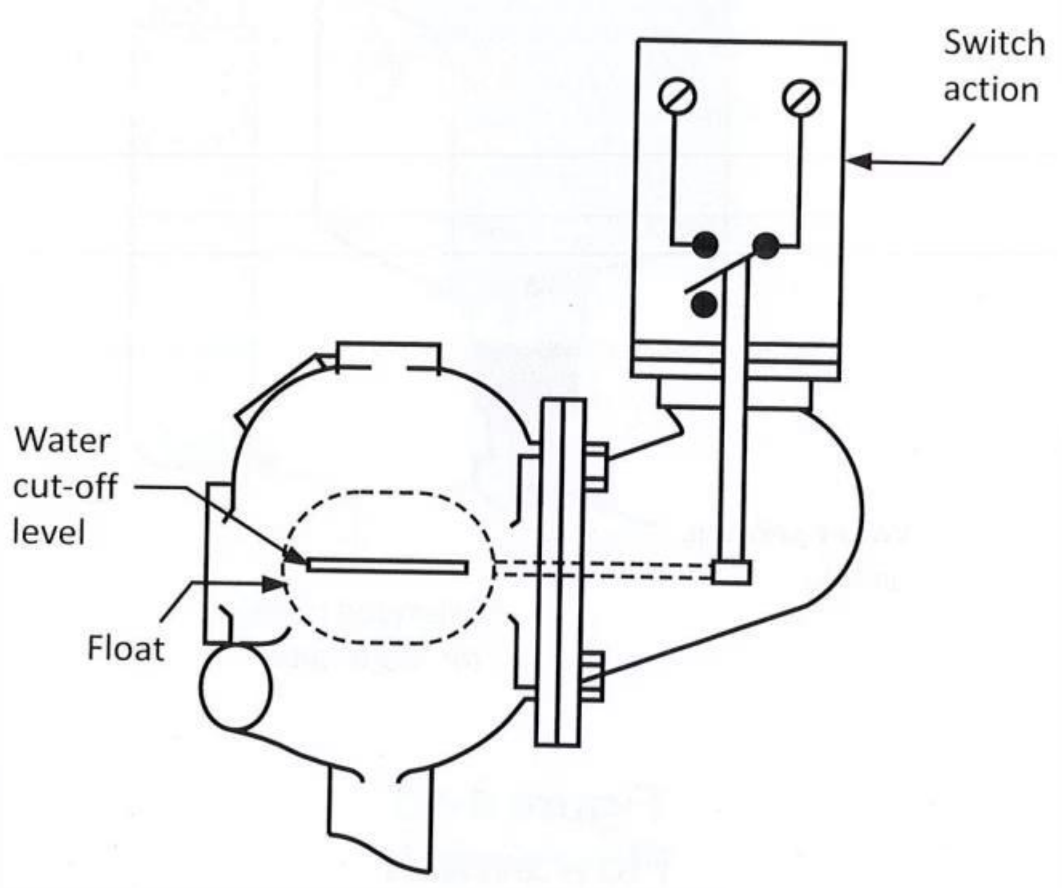



Figure 4-12 Float-type low water cut-off switch

# Low Water Cut-Off Switch: Probe Type

The probe type low water cut-off switch is a normally open switch. It has an electronic circuitry that uses boiler water to conduct current between the terminals on the end of the probe.

If the water falls below the level of the probe, the electronic circuit between the terminals is broken. In response to no circuit, the low water cut-off switch opens, cutting off power to the main gas valve.

Probe-type systems are often preferred in modern installations due to their reliability and lack of moving parts that can fail due to scale or sediment buildup.

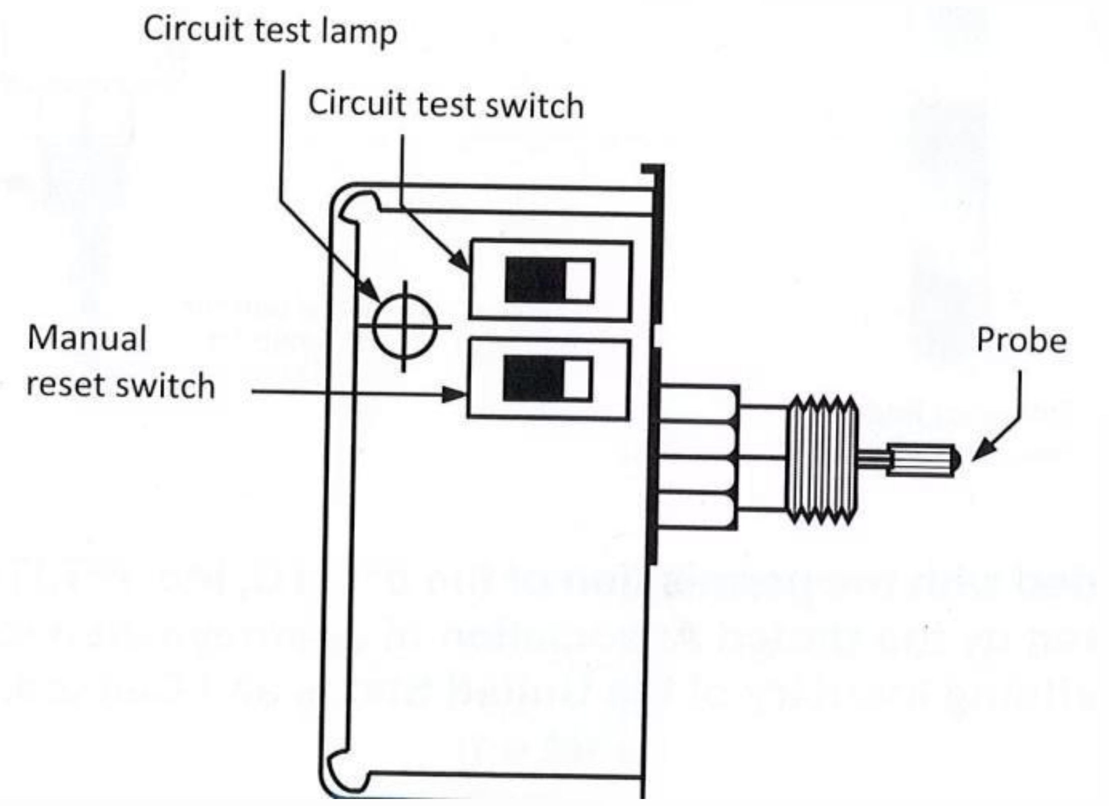
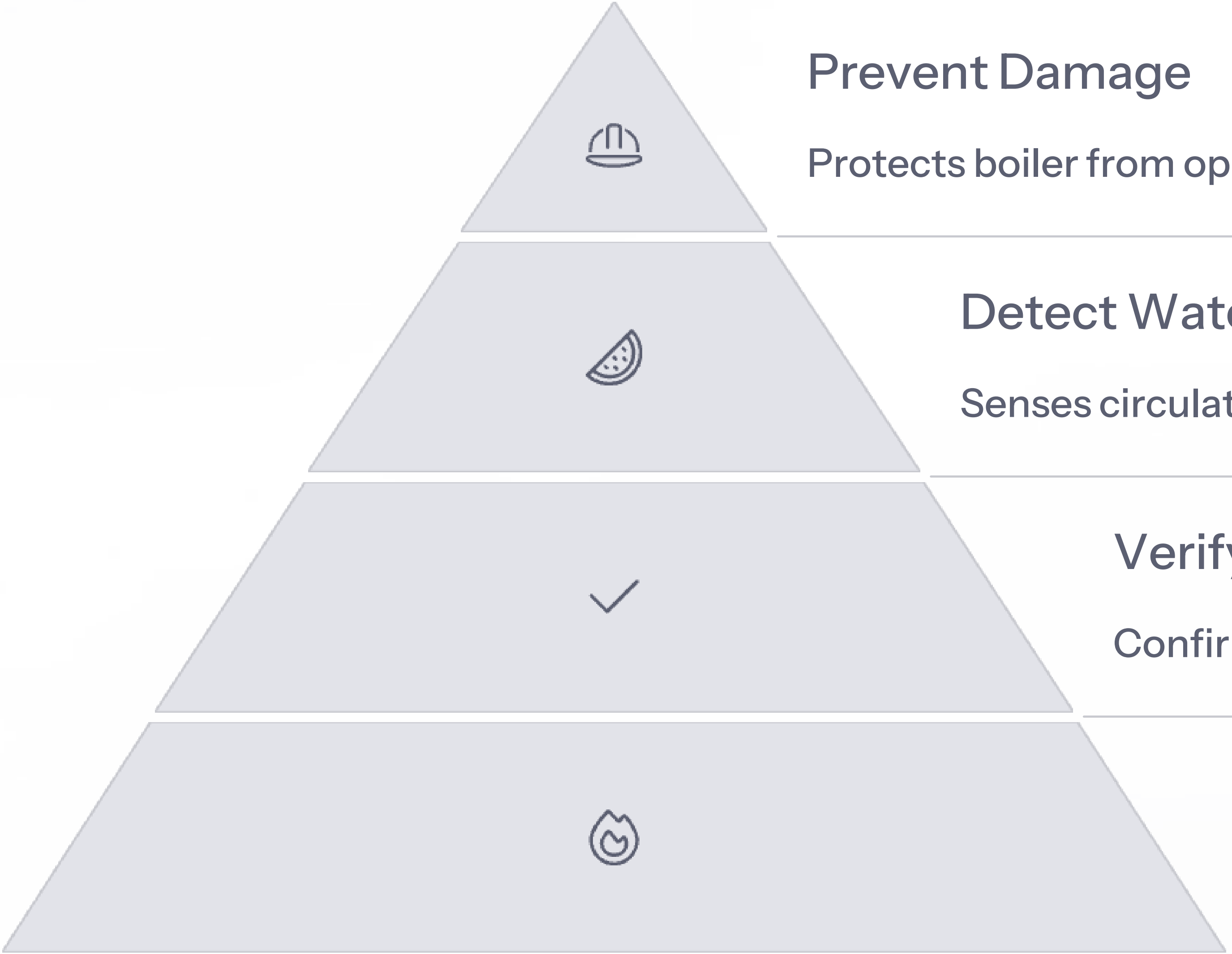



Figure 4-13 Probe-type low water cut-off switch (top view)

# Flow Switch: Critical Safety Function



### Prevent Damage

Protects boiler from operating without adequate water flow

### Detect Water Movement

Senses circulation in the piping system

### Verify Pump Operation

Confirms pumps are functioning properly

### Control Burner

Prevents firing without proper circulation

Flow switches are especially important for boilers with small water capacities, as their water may turn to steam if the flow of water is inadequate, potentially causing damage to the system.

# Air Flow Switch Applications

### Sail Switch

Used to detect the physical movement of air in ducts and ventilation systems. The "sail" portion moves when air flows past it, activating the switch mechanism.


### Pressure Differential Switch

Used in high-efficiency furnaces to verify proper combustion air flow and venting. It measures the pressure difference created by the draft inducer motor.


### Blocked Vent Safety

Air flow switches can detect blocked vents, faulty heat exchangers, or blocked drain tubes, shutting down furnace operation to prevent dangerous conditions.


# Flame Roll-Out: Causes and Hazards

## Definition

Flame roll-out occurs when the burner flame escapes from the combustion chamber, potentially causing fire or carbon monoxide hazards.

## Common Causes

- Failure to vent flue products properly
- Heat exchanger cracks or failures
- Blocked or restricted heat exchangers
- Excessive gas pressure
- Improper burner alignment

## Safety Response

The flame roll-out switch is a high temperature limit switch that opens and de-energizes the gas valve if it senses flame roll-out. This is a manually reset switch to ensure the issue is addressed before operation resumes.

# Blocked Vent Shut-Off System: Importance

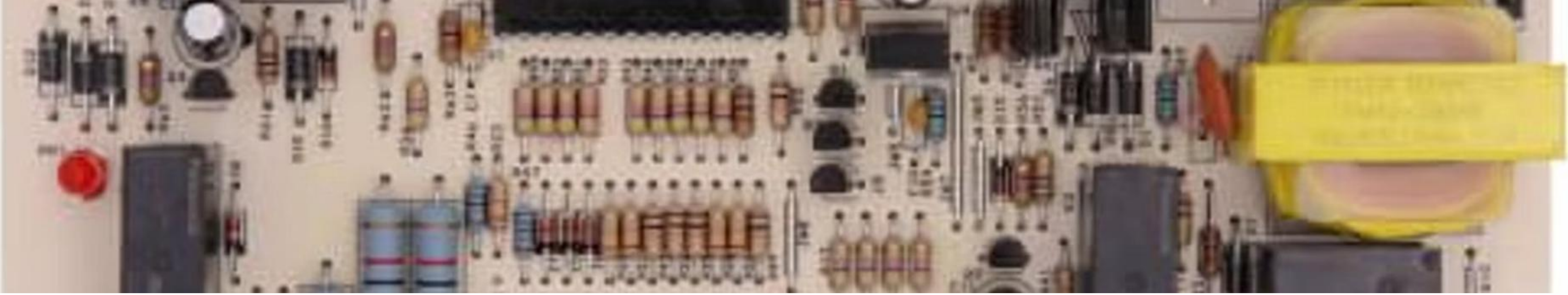
## Critical Safety Function

When furnaces have draft hoods, you may equip them with a shut-off system that automatically cuts out the main burner when the vent is totally blocked.

These systems are temperature sensing, manual reset switches wired in series to the gas valve function. They detect when flue gases are not properly venting and shut down the system to prevent carbon monoxide from entering the living space.

Furnace certification standards specify test methods for these systems to ensure they function properly in emergency situations.

These shut-off systems are commonly—and incorrectly—referred to as spill switches.



# Electronic Control Module: Diagnostic Capabilities

### Continuous Monitoring

The integrated circuits continuously monitor the furnace's operation and the operation of the integrated control module itself.

### Failure Codes

If a failure occurs, LEDs can indicate a failure code. The Owner's Manual and the furnace door provide the codes.

### Self-Diagnostics

These integrated controllers can perform self-diagnostics to identify specific system issues.

### Troubleshooting Aid

Diagnostic capabilities help technicians quickly identify and resolve problems.

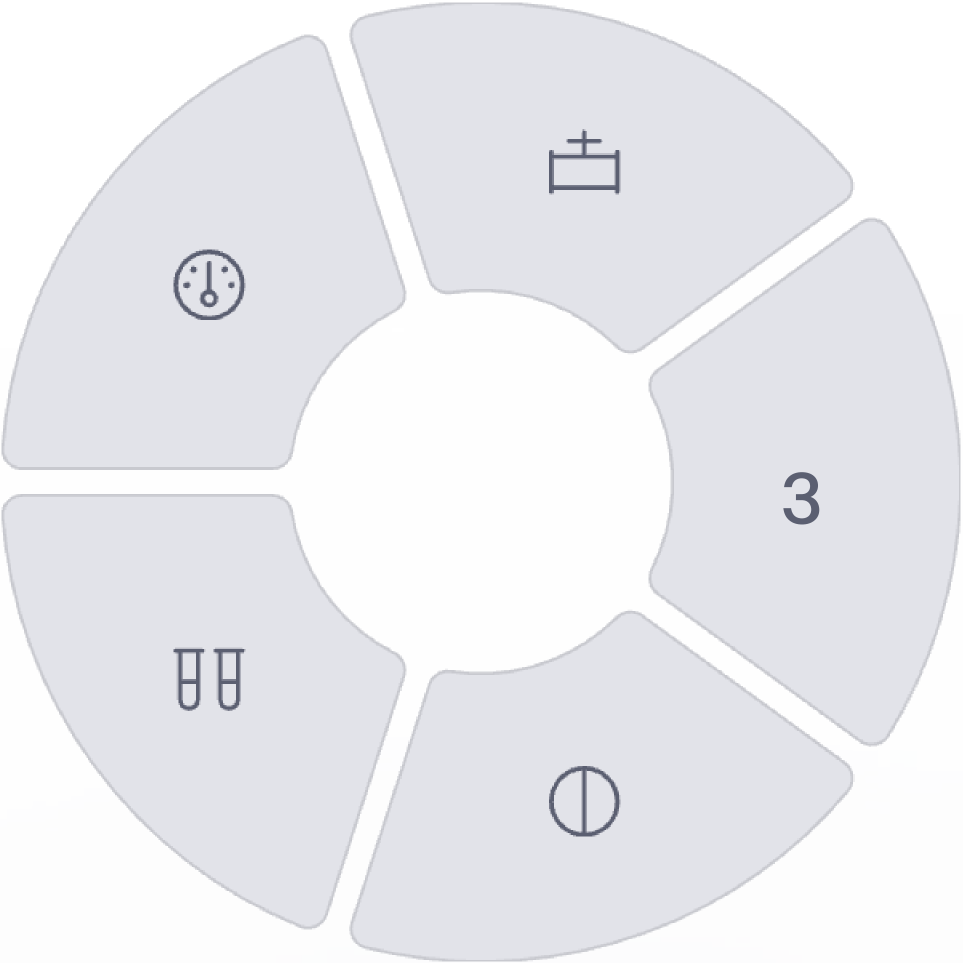
# High Efficiency Furnaces and Control Modules

You always find integrated electronic controllers on higher efficiency furnaces that rely on many sophisticated design features to reach their high AFUE ratings of over 90%.

These advanced control systems manage complex operations including:

- Variable-speed blower motor control
- Multi-stage or modulating gas valve operation
- Precise timing of ignition sequences
- Monitoring of multiple safety circuits
- Communication with smart thermostats
- Self-diagnostic functions

# Gas Control Valve Components




### Regulator

Reduces gas pressure or controls gas flow

### Test Ports

Allows measurement of inlet and outlet pressure

### Automatic Shut-Off Valves

One or two valves that automatically control gas flow

### Manual Shut-Off

Allows manual control of gas flow, may direct flow only to pilot line

### Pilot Flow Control

Controls flow rate to pilot line, usually by means of a needle valve

# Gas Control Valve Applications

### Constant Pilot Models

Used in older appliances where a small flame burns continuously to ignite the main burner when needed. These are becoming less common due to energy efficiency concerns.

### Intermittent Pilot Models

The pilot only ignites when the appliance calls for heat, then ignites the main burner. This improves efficiency by eliminating the constant pilot flame.

### Direct Ignition Models

No pilot flame is used. Instead, the main burner is ignited directly by a spark or hot surface igniter when heat is called for, maximizing efficiency.

### Modulating Valves

Advanced valves that can vary the gas flow rate to provide precise temperature control and improved efficiency in high-performance systems.

# Wireless Control Advantages

## Installation Flexibility

Hard-wired connections between thermostats and furnaces have many limitations that you can overcome with the application of wireless technology.

Wireless thermostats allow for temperature control in one or more locations during retrofits or new construction projects without the need to run new wiring through walls.

Most wireless systems include a remote sensor thermostat and sensor along with the option of multiple remote controllers, providing unprecedented flexibility in system design and operation.


Advanced Features

# Safety Control Circuit Integration

### Thermostat

Initiates call for heat based on room temperature

### Control Circuit

Processes signals and checks safety devices

### Safety Verification

Confirms all safety switches are in proper position

### Draft Inducer

Starts and air flow is verified by pressure switch

### Ignition Sequence

Begins only after all safety conditions are met

### Flame Proving

System verifies flame is established properly

### Main Blower

Starts after heat exchanger reaches proper temperature

# Aquastat Applications in Hydronic Systems

## Residential Boilers

Controls water temperature in home heating systems, typically maintaining temperatures between 160-180°F for optimal comfort and efficiency.

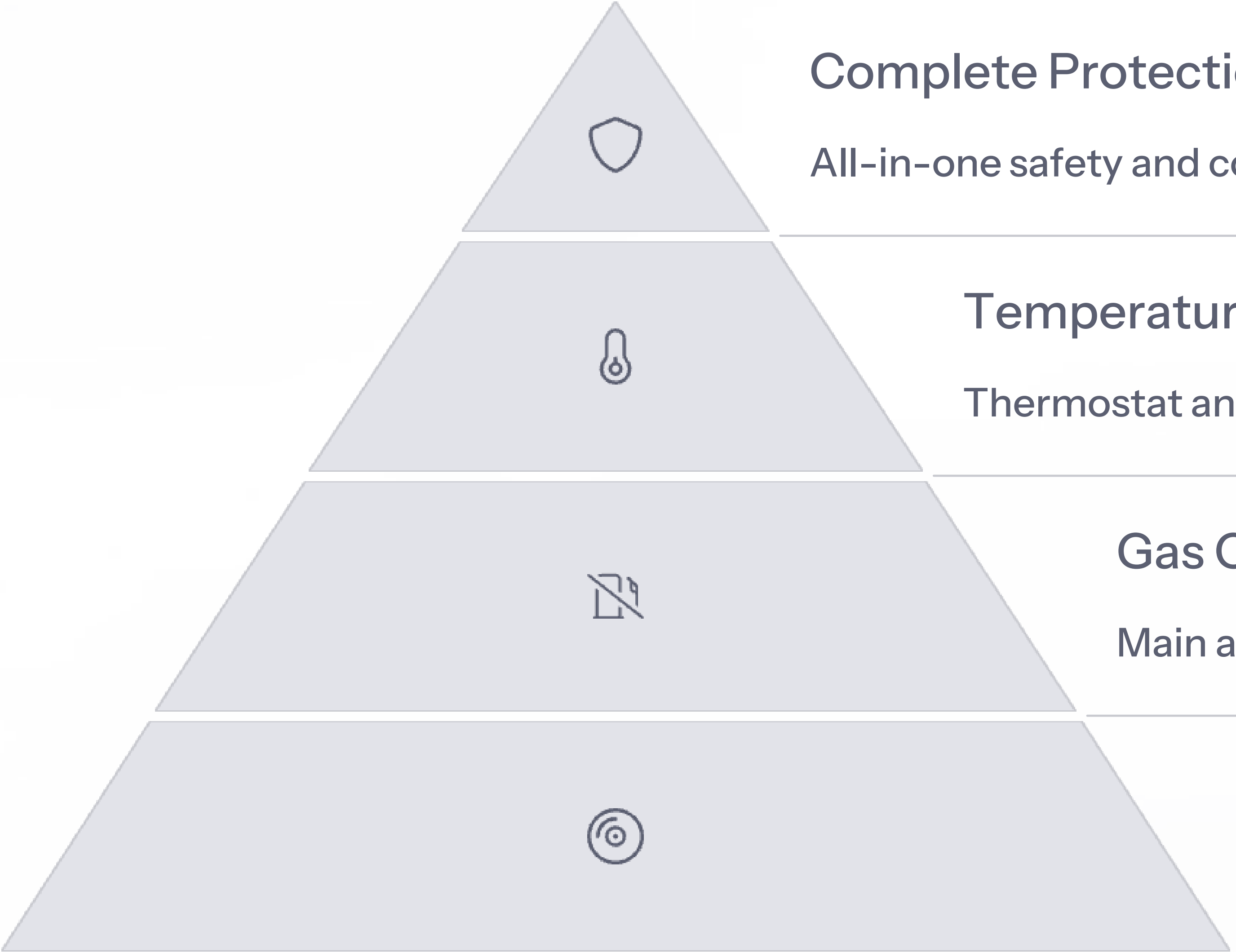
## Commercial Systems

Manages water temperature in larger commercial heating applications, often with more sophisticated control strategies and multiple zones.

## Radiant Floor Heating

Controls lower temperature water (typically 90-120°F) for radiant floor applications, requiring precise temperature management for comfort and efficiency.

# Unitrol Valve: Comprehensive Safety



### Complete Protection

All-in-one safety and control solution

### Temperature Management

Thermostat and ECO device

### Gas Control

Main and standby valves with pressure regulation

### Space Efficiency

Compact design integrates multiple functions

The Unitrol is a multipurpose valve that people typically install in hot water heaters. It contains in one compact unit: thermostat, automatic gas shut-off valve, over temperature energy cut-off (ECO) device, main pressure regulator, and main and standby gas valve.

# Pressuretrol Applications in Steam Systems

## Commercial Steam Boilers

Controls operating pressure in larger commercial steam heating systems, maintaining precise pressure levels for optimal distribution.

## Industrial Process Steam

Manages steam pressure for manufacturing processes where specific pressure levels are critical for production operations.

## Residential Steam Heating

Controls lower pressure steam in home heating systems, typically maintaining pressures below 2 psig for safe and efficient operation.

# Pressure Relief Valve Sizing and Selection

## Capacity Rating

Must be sized to discharge the full BTU/h capacity of the boiler if needed. Undersized valves cannot provide adequate protection.

## Pressure Setting

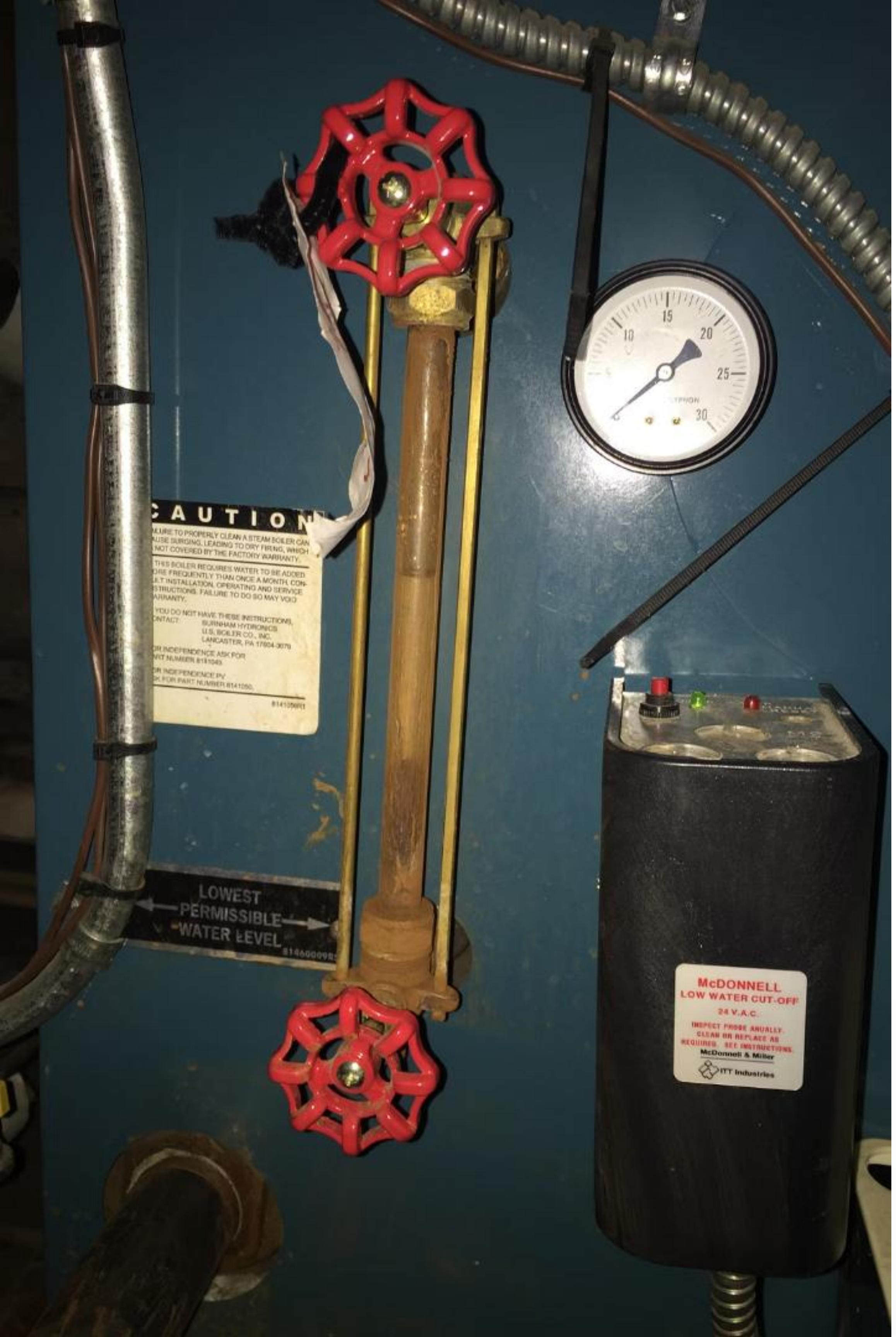
Must be set at or below the maximum allowable working pressure (MAWP) of the boiler, typically with a margin of safety.

## Code Compliance

Must meet ASME Boiler and Pressure Vessel Code requirements and be properly certified and stamped.

## Installation Requirements

Must be installed directly to the boiler without intervening valves that could isolate it. Discharge piping must be properly sized and supported.




# Low Water Cut-Off Maintenance

## Regular Testing

Low water cut-offs should be tested regularly according to manufacturer recommendations and local codes, typically weekly for commercial systems.

## Cleaning and Inspection

Float-type devices should be disassembled and cleaned periodically to remove sediment and scale that could affect operation.

## Probe Maintenance

Probe-type devices should have their probes inspected and cleaned to ensure proper electrical conductivity through the water.

## Documentation

All testing and maintenance should be documented in the boiler maintenance log for compliance and safety records.

# Flow Switch Installation Considerations

### Proper Location

Must be installed in a straight section of pipe with adequate upstream and downstream straight runs

### Flow Direction

Must be oriented correctly with respect to the direction of water flow

### Pipe Size Matching

Must be sized appropriately for the pipe diameter and expected flow rates

### Accessibility

Should be installed where it can be accessed for testing and maintenance

### 5 Electrical Connection

Must be properly wired into the safety circuit to prevent burner operation without flow

# Air Flow Switch Troubleshooting

| Problem | Possible Causes | Solutions |
|---|---|---|
| Switch won't close | Blocked air intake, Faulty inducer motor, Blocked vent pipe | Clear blockages, Replace motor, Clean vent system |
| Switch won't open | Switch stuck closed, Improper wiring, Damaged switch | Replace switch, Correct wiring, Verify proper operation |
| Intermittent operation | Partial blockage, Loose connections, Borderline pressure | Thorough cleaning, Secure connections, Adjust or replace |
| Nuisance tripping | Undersized venting, Wind effects, Condensation issues | Resize venting, Install wind guard, Address condensate |

# Flame Roll-Out Switch Testing

## Visual Inspection

Check for signs of overheating, discoloration, or damage to the switch and surrounding area.

## Continuity Testing

With power off, test for continuity across the switch terminals to verify the switch is closed at normal temperatures.

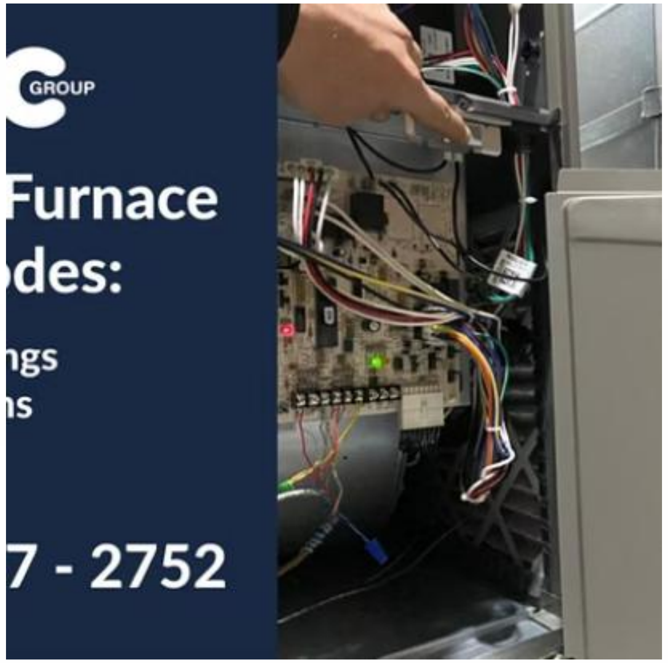
## Reset Verification

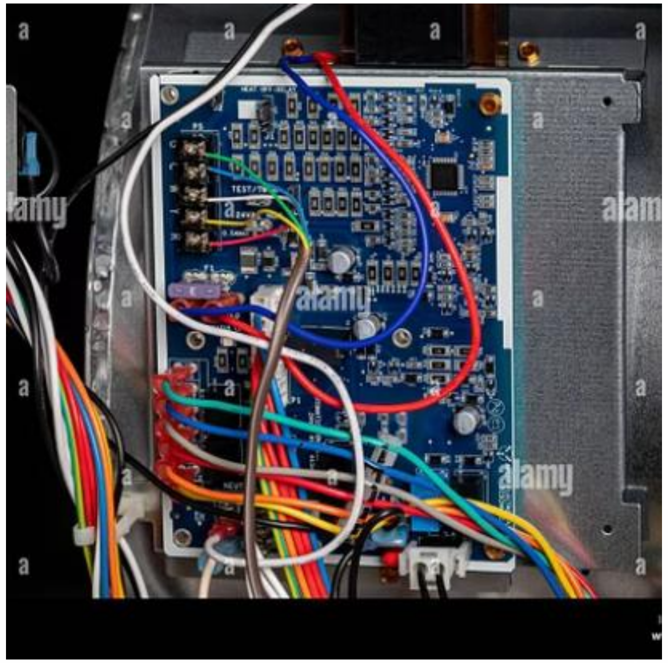
If the switch has tripped, press the reset button and verify it resets properly. If it won't reset, the switch may need replacement.

## Root Cause Analysis

If the switch has tripped, thoroughly investigate the cause of flame roll-out before returning the system to service.

# Electronic Control Module Diagnostic Codes



Modern electronic control modules use LED flash patterns or digital displays to indicate specific fault conditions. These diagnostic codes help technicians quickly identify issues such as flame failures, pressure switch problems, limit switch trips, or communication errors. The specific codes vary by manufacturer but are typically documented on the furnace door or in the service manual.

# Gas Control Valve Testing

## 24V

### Control Voltage

Typical operating voltage

## 3.5

### Inlet Pressure

Typical natural gas pressure

## 10-13 sec

### Opening Time

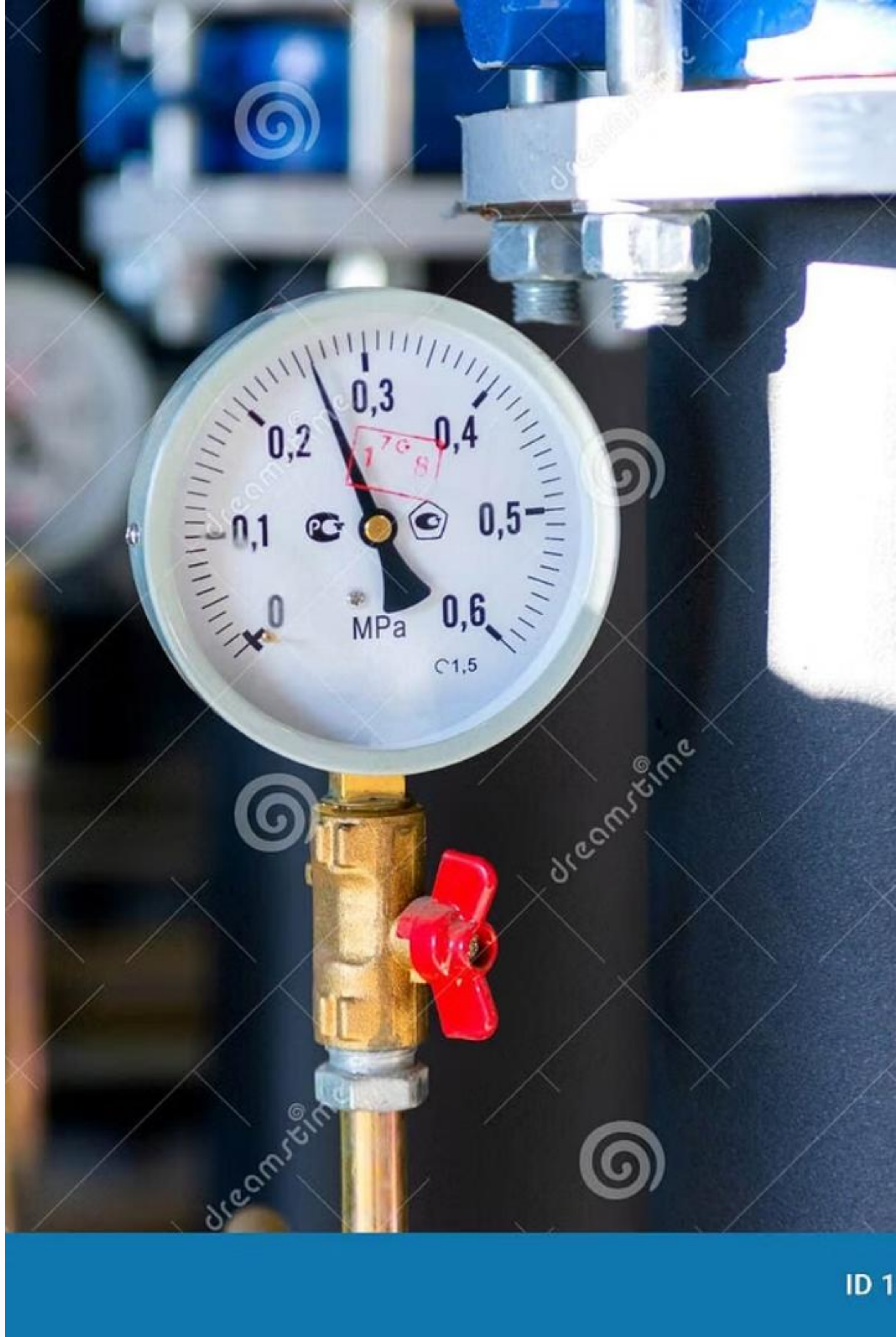
Typical valve response time

## 1-3 sec

### Closing Time

Maximum safe closing time

Gas control valves require regular testing to ensure proper operation. This includes verifying proper inlet and outlet pressures using the test ports, checking for gas leaks, confirming proper voltage to the valve, and testing the response time for opening and closing. All measurements should be within manufacturer specifications for safe and efficient operation.



# Wireless Control System Components


## Base Unit

Connects to the HVAC equipment and communicates wirelessly with remote sensors and controllers. Contains the primary control logic and relay connections.


## Remote Sensors

Placed in different rooms or zones to monitor temperature and sometimes humidity. Transmit data wirelessly to the base unit for more balanced comfort control.


## Control Interface

Wall-mounted or portable display that allows users to adjust settings, view system status, and program schedules. May also include smartphone app integration.

# Integrated Safety System Summary

### Temperature Controls

Aquastats, high-limit switches, and combination controls

### Pressure Controls

Pressuretrols, relief valves, and pressure switches


### Flow Controls

Flow switches and low water cut-off switches

### Electronic Controls

Control modules with diagnostic capabilities

### Combustion Safeties

Flame sensors, roll-out switches, and vent safeties

All gas burners incorporate multiple layers of safety controls that work together to ensure safe and efficient operation. These systems monitor temperature, pressure, flow, and combustion conditions, automatically shutting down the equipment if unsafe conditions are detected. Modern systems integrate these controls with sophisticated electronic modules that provide enhanced functionality and diagnostic capabilities.


# CSA Unit 9

# Chapter 5 Non-vented and Vented Gas Appliances

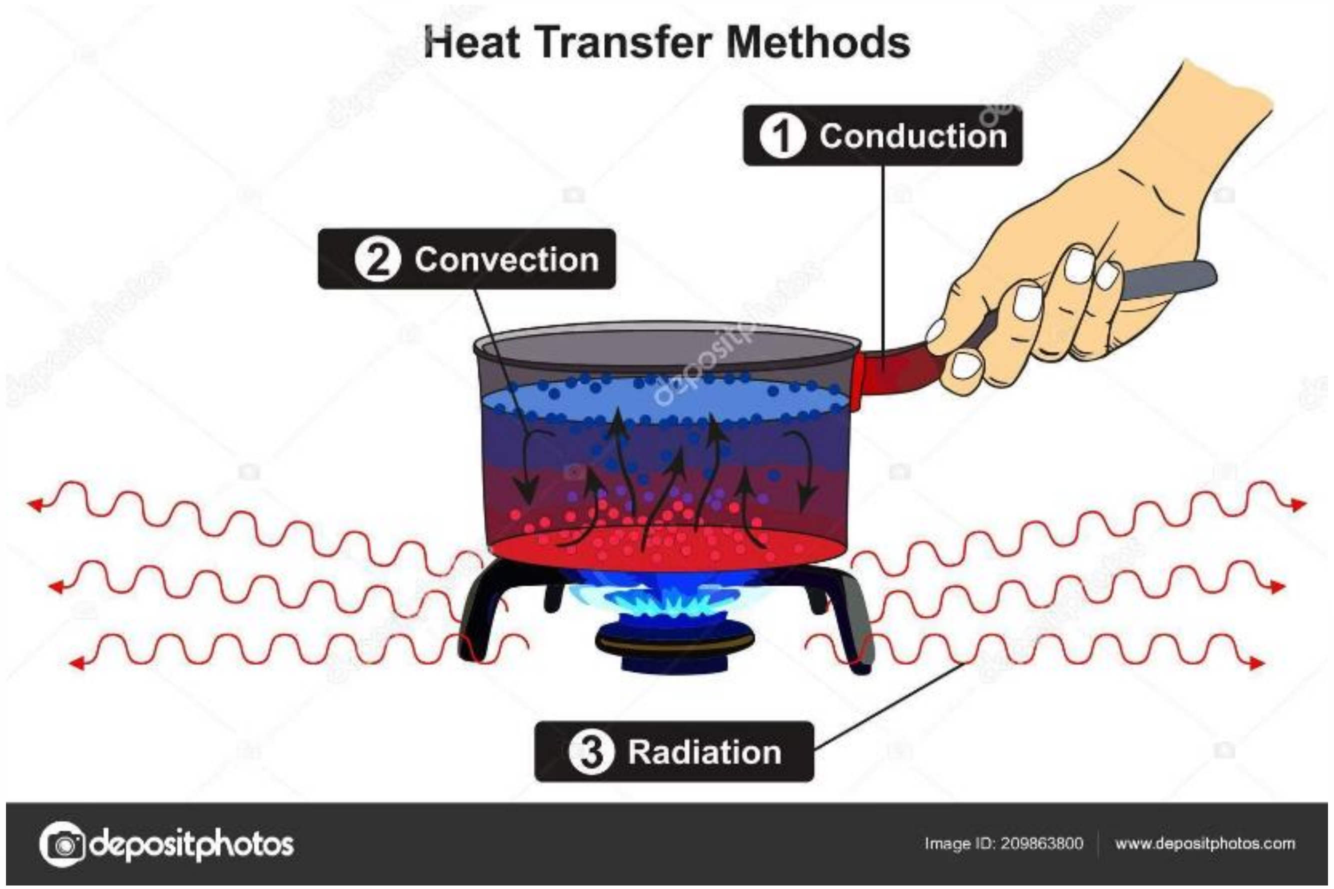
A gas technician/fitter encounters many different gas appliances: some simple, some complex, some vented, and others non-vented. The purpose of each is to transfer heat to his unliculpur purpose. This presentation gives an overview of gas appliances commonly found in the industry.

# Heat Transfer Methods

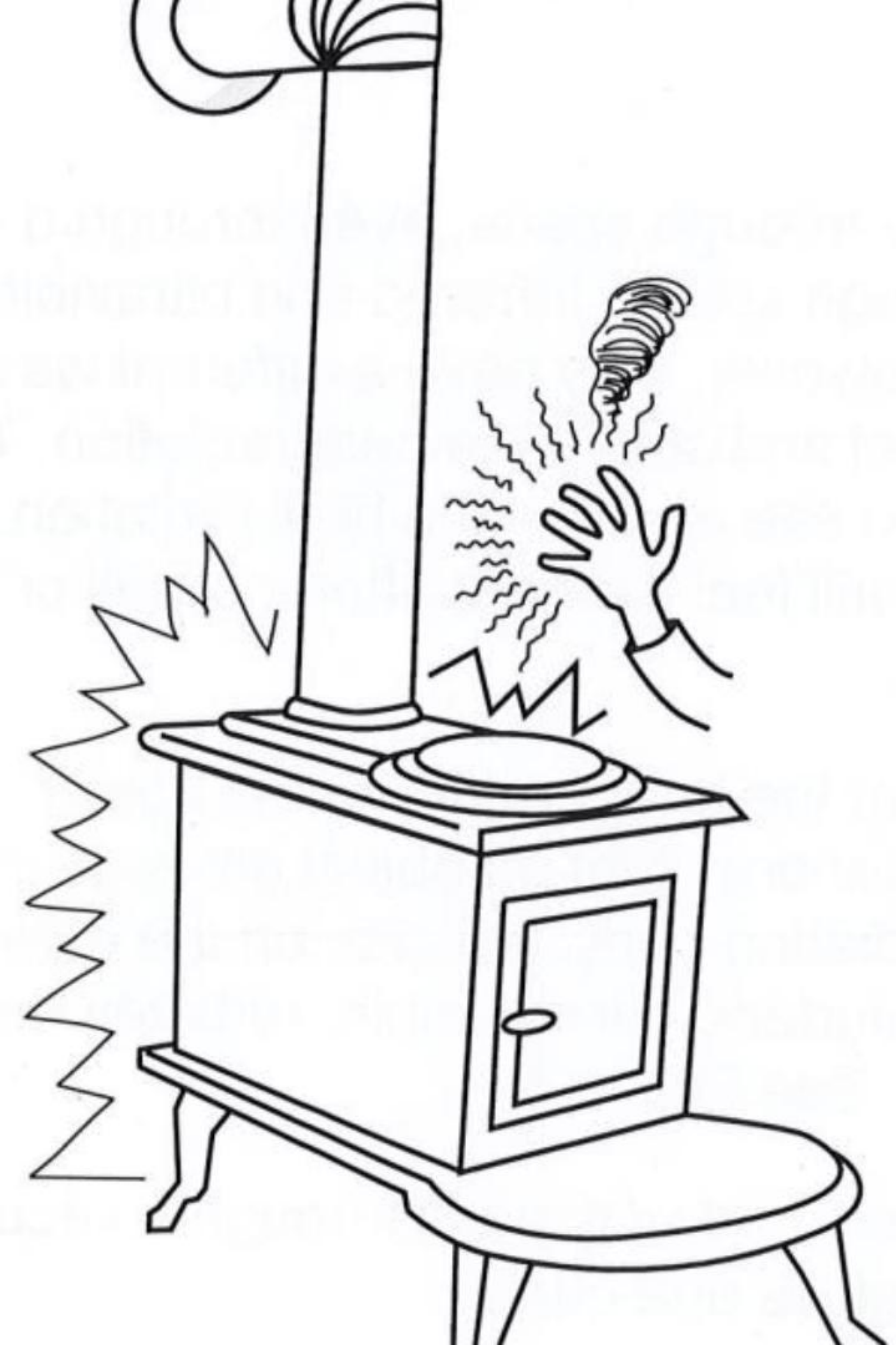
## Energy Transfer Principles

Energy is neither creatable nor destroyable. However, you can move or transport it from one place to another in various ways. To understand how a heating or cooling system works, you must first understand the ways in which heat transfer (energy movement) occurs.

Heat always flows in one direction, from hot to cold. When water flows downhill, the steeper the hill, the faster the water travels. Likewise, in the transfer of heat, the greater the temperature difference, the faster the heat flows.




Understanding heat transfer methods is essential for gas technicians to properly install, maintain, and troubleshoot various gas appliances. Each appliance utilizes one or more of these methods to deliver heat efficiently.



# Conduction Heat Transfer

## Definition

Conduction is the flow of heat through a substance by the transfer of heat energy from particle to particle.

## Process

As the particles with greater motion pass some of their energy to slower particles, heat energy flows from the warmer region to the colder region.

## Example

When a rod is heated over an open flame, heat travels by conduction from the hot end to the cooler end.

## Contact Transfer

Conduction heat transfer occurs not only within an object or substance, but between different substances that are in contact with one another.

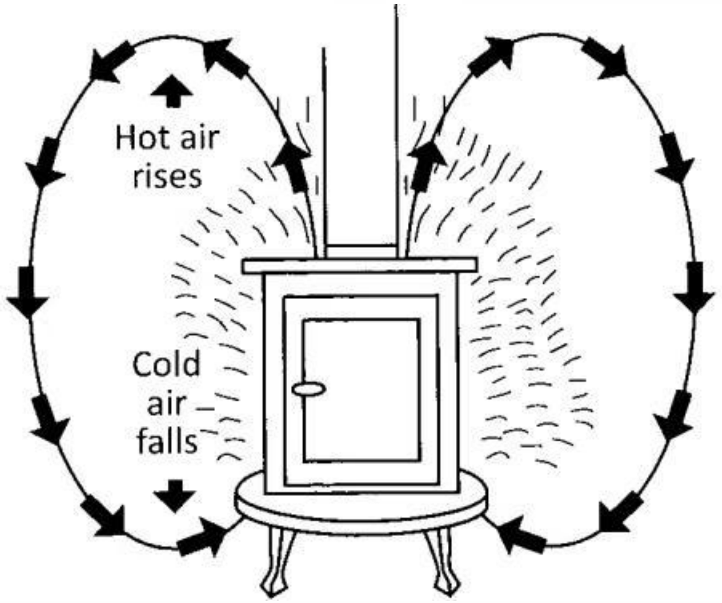
# Convection Heat Transfer

## Definition

Convection is the movement of heat due to the movement of the heated body. In a convection heating system, something undergoes heating, then moves to the location to be heated, where the system gives off the heat.

## Fluid Movement

You can most easily do this with fluids (gases and liquids), because you can easily make them flow from one place to another to carry the heat. Air is a mixture of several gases and is therefore considered a fluid. As the air flows or moves, it carries heat from one place to another.




## Natural Convection

When a fluid undergoes heating, it expands and becomes lighter. If part of a fluid is cooler than another part, gravity pulls the cooler part earthward, displacing the lighter part of the fluid so that it rises. Convection movements or currents are said to move the heat.

# Radiation Heat Transfer

### Definition

Radiation is the transfer of energy through space, even through a vacuum. Light is a visible form of wave energy that radiates through space.

### Invisible Radiation

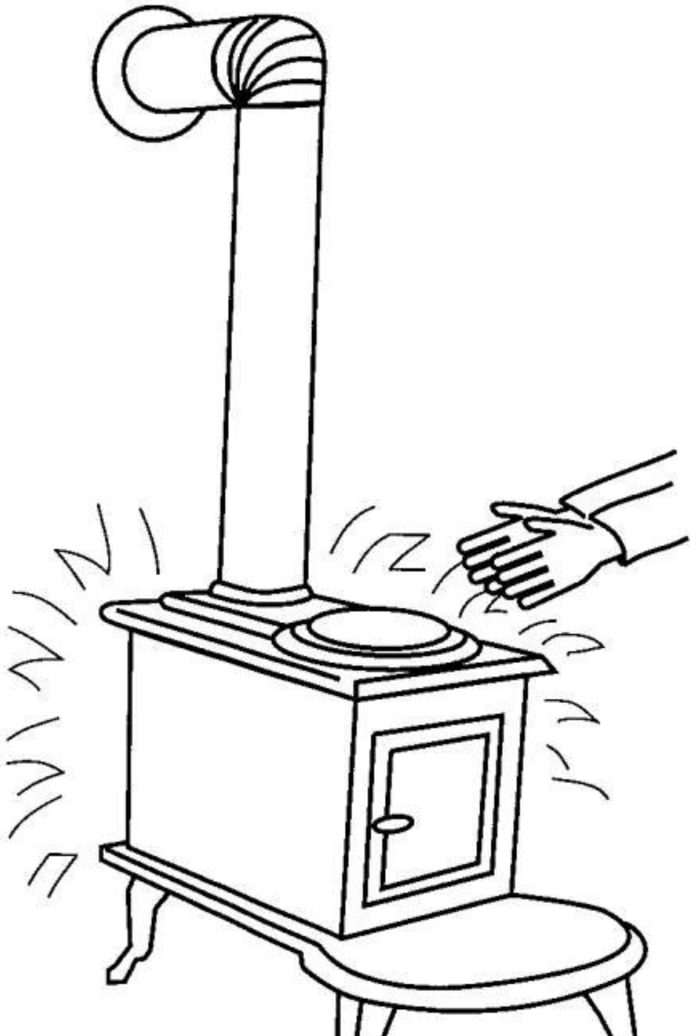
Infrared and ultraviolet rays are next to visible light waves on the colour spectrum. However, they have a different wavelength. You can feel, but not see, their effects.

### Visible Radiation

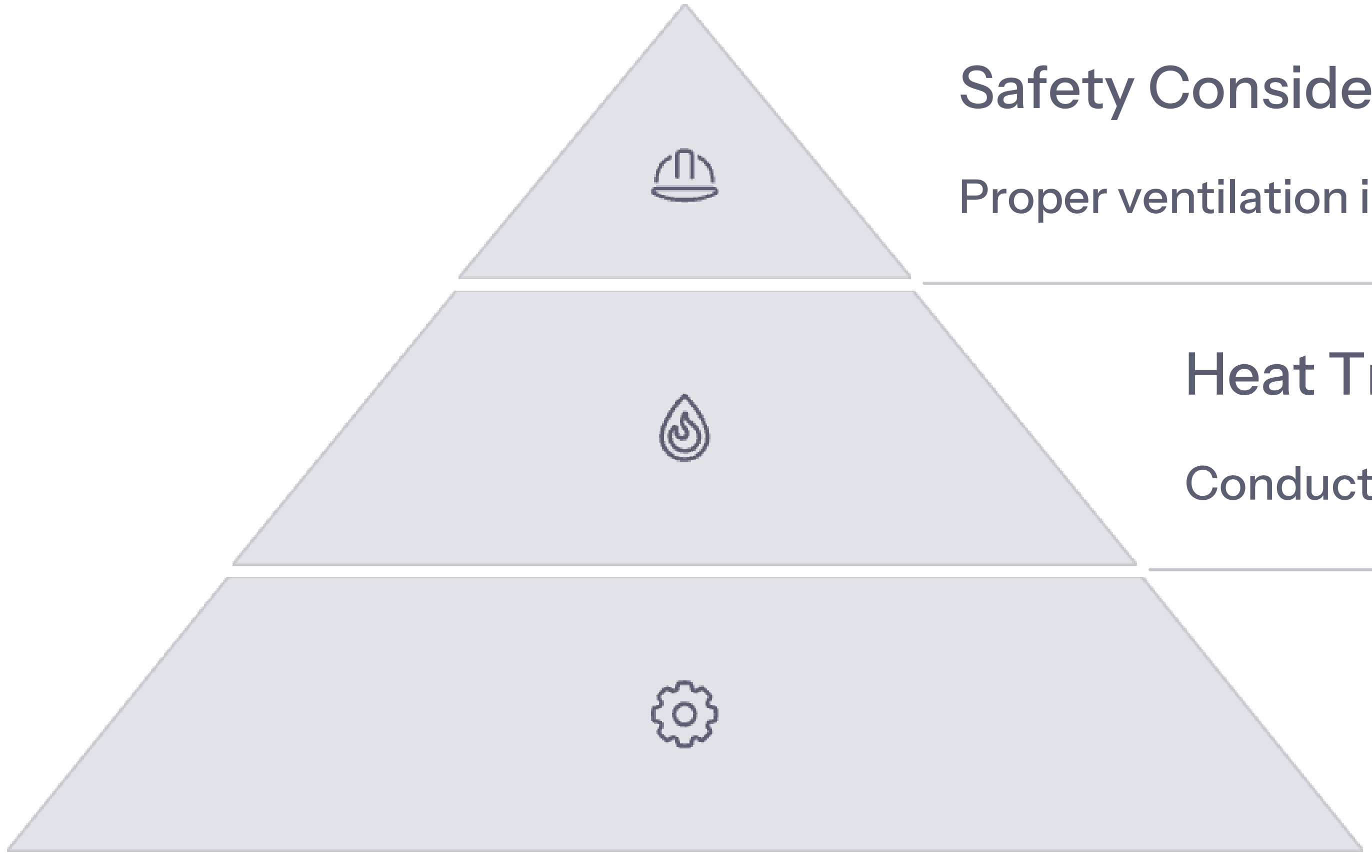
You can also feel and see some heat radiation. The light from the sun is a good example. Another is when you can see and feel the heat radiation from a red-hot furnace wall or a white-hot piece of metal.

### Surface Effects

At the same temperature, a rough dark surface, for example, radiates much more heat than another surface that is smooth and bright.



# Non-vented Gas Appliances Overview



### Safety Considerations

Proper ventilation is critical

### Heat Transfer Methods

Conduction, convection, radiation

### Installation Requirements

Follow CSA B149.1 standards

Gas technicians/fitters commonly install and service various non-vented gas appliances. These appliances don't require venting to the outside but must be installed in well-ventilated areas. For more detailed information on each of the characteristics, refer to other chapters covering venting, operation and applications of various burners, pilots and ignition systems, and controls and safeties.

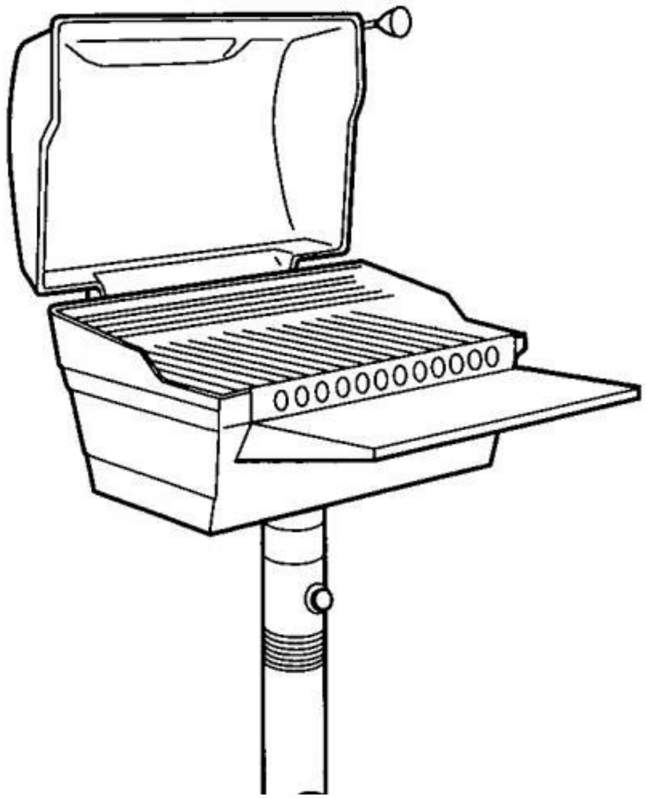
# Barbecue

## Heat Transfer

Although construction differs from one to another, gas barbecues cook mostly by infrared radiation and by convection.

The supply of heat occurs in one of two ways:

- From below the food by briquettes heated by a gas burner
- From above the food by a gas burner of radiant material



## Controls and Safety

Ignition: You can light barbecues by hand or with piezo igniters (push-button quartz igniters).

Burner control: Burner control is typically through a manual control dial.

Safeties: Barbecues do not have safeties included; however, you must place them in a well-ventilated area as a safety measure.

# Range: Cook Top

### Heat Transfer

Predominantly conduction

### Ignition

You light older models with a match. Newer models, on the other hand, have automatic ignition (spark ignition).

### Burner Control

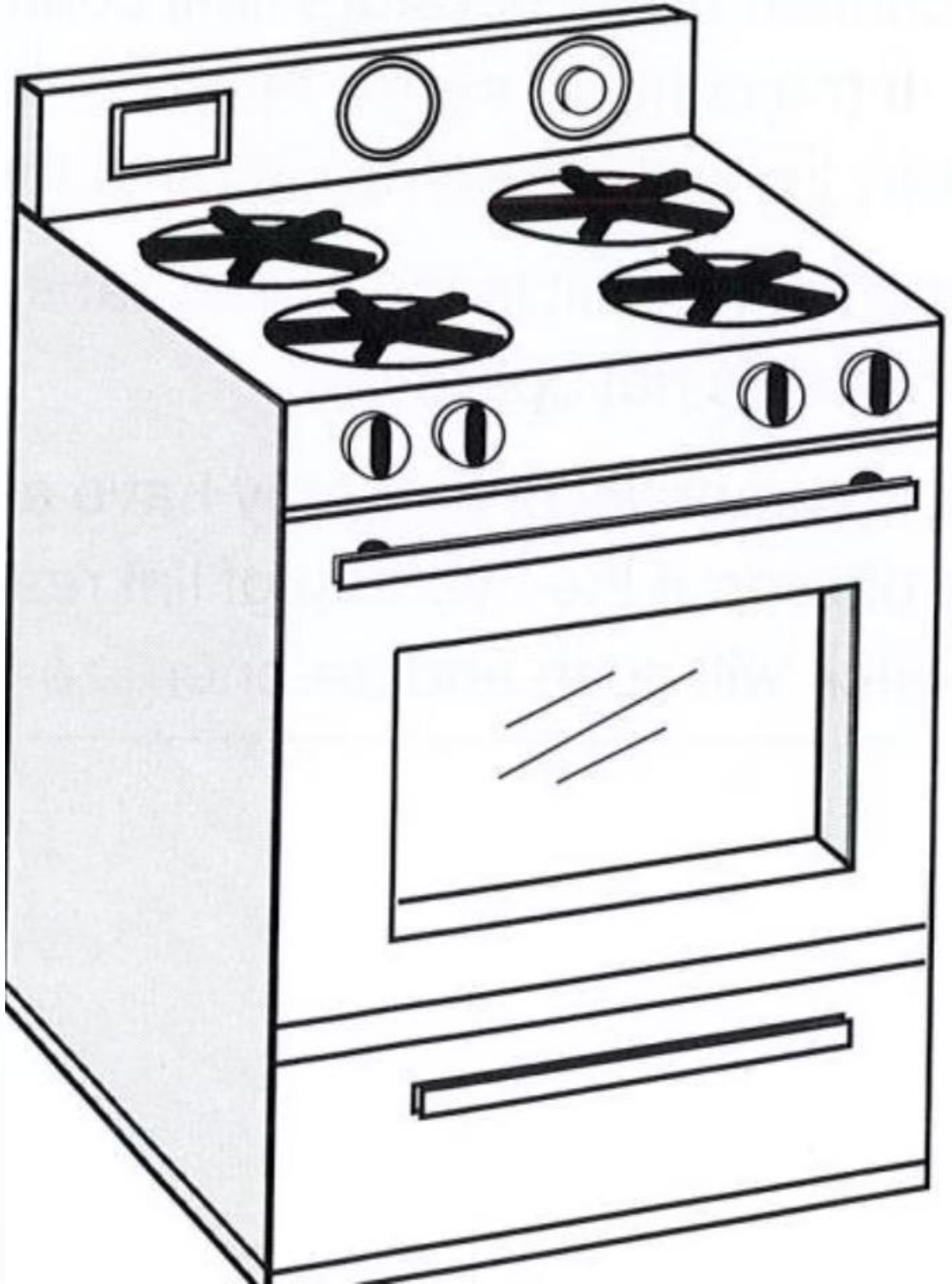
On most units, gas flow through a manual valve controls the heat. Some units have a thermostatically controlled burner whereby a device that contacts the bottom of the utensil being used senses the heat.

### Safeties

There are no safeties.

Refer to Clauses 7.32 and 7.33 of CSA B149.1 for the general installation requirements for residential and commercial ranges.

Figure 5-5
Residential range



# Range: Oven

## Heat Transfer

Natural or forced convection

## Ignition

You manually light older models with a match. Newer models have a standing pilot or hot surface ignition.

## Burner Control

You turn the burner on and off manually. Controlling the gas flow to the burner involves the use of a temperature sensor and gas valve as thermostat.

## Safeties

The safeties depend on the type of burner control.

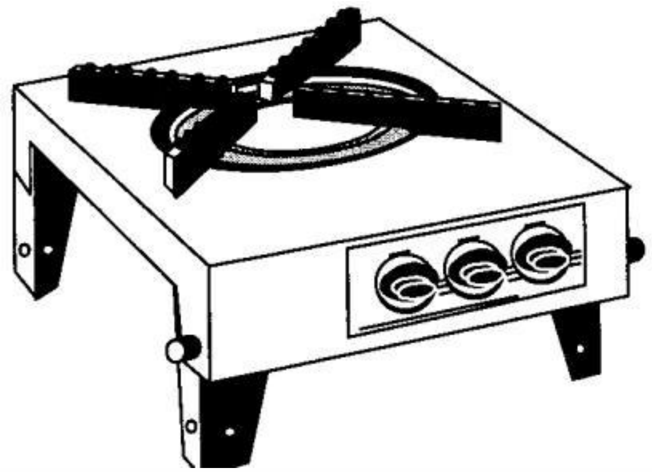
# Portable Cook Top and Hot Plate

## Installation Requirements

Refer to Clause 7.29 of CSA B149.1 for the general installation requirements for portable cook tops and hot plates.

## Specifications

- Heat transfer: Predominantly conduction
- Ignition: Manual
- Safeties: There are no safeties



Portable cook tops provide flexibility for cooking in various locations. They are simple devices with manual controls and no built-in safety features, making proper installation and usage critical for safe operation.

# Clothes Dryer

## Heat Transfer

Forced convection

## Ignition

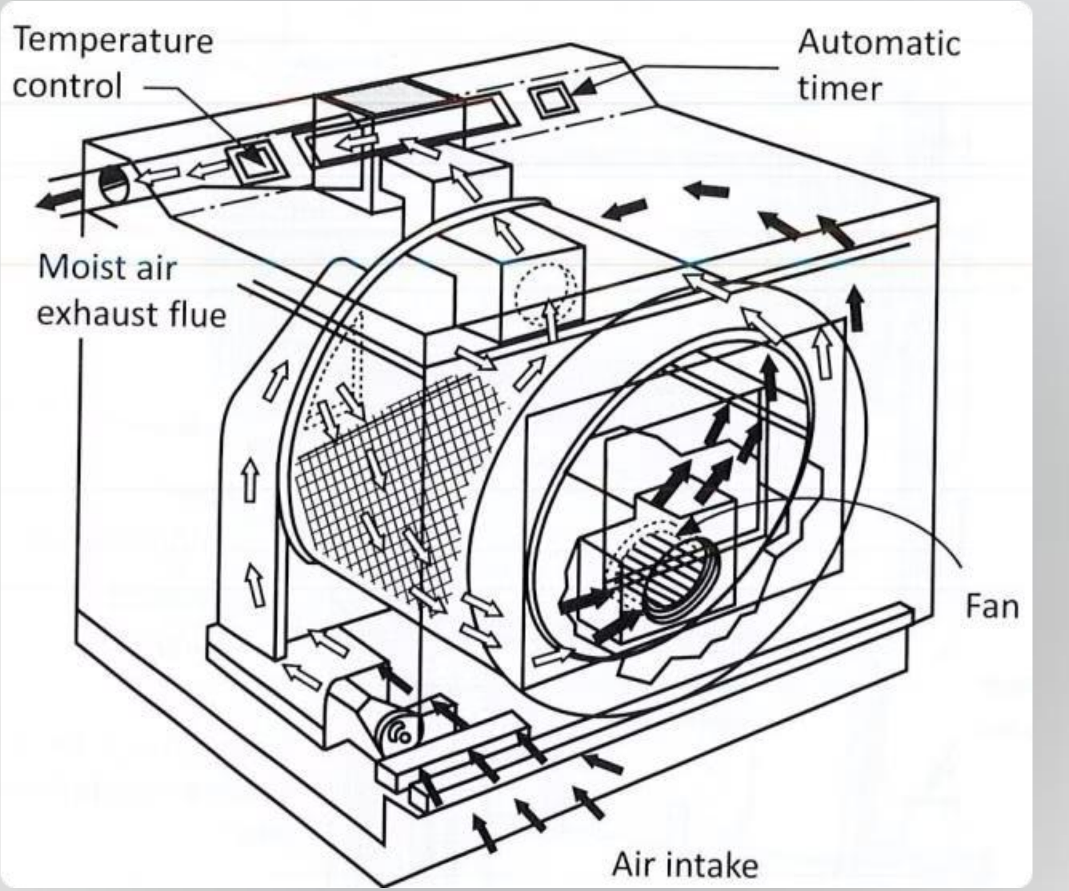
Standing pilot, spark igniter, glow coil, or glow bar

## Burner Control

Thermostat sensing element senses exhaust temperatures. This cycles the burner on and off. Moisture sensor or timer controls the drying period.

## Installation

Refer to Clauses 7.4 and 7.5 of CSA B149.1 for the general installation requirements for residential and commercial clothes dryers.



# Clothes Dryer Safety Features

### Temperature Limit Controls

The location of temperature limit controls is at strategic points in a dryer. If the controls sense the main burner compartment getting too hot, they open the electric circuit to the main gas valve.

### Motor Safety Circuit

A centrifugal circuit in the motor causes the main gas valve to close if the motor is not operating.

### Airflow Monitoring

Large commercial dryers may have a sail switch located at the outlet of the blower. If the build-up of lint results in the reduction of air flow, the switch will open and de-energize the main gas valve.

Gas dryers use a moisture exhaust duct that meets a separate set of code requirements from gas venting and as such is not considered a vented appliance.

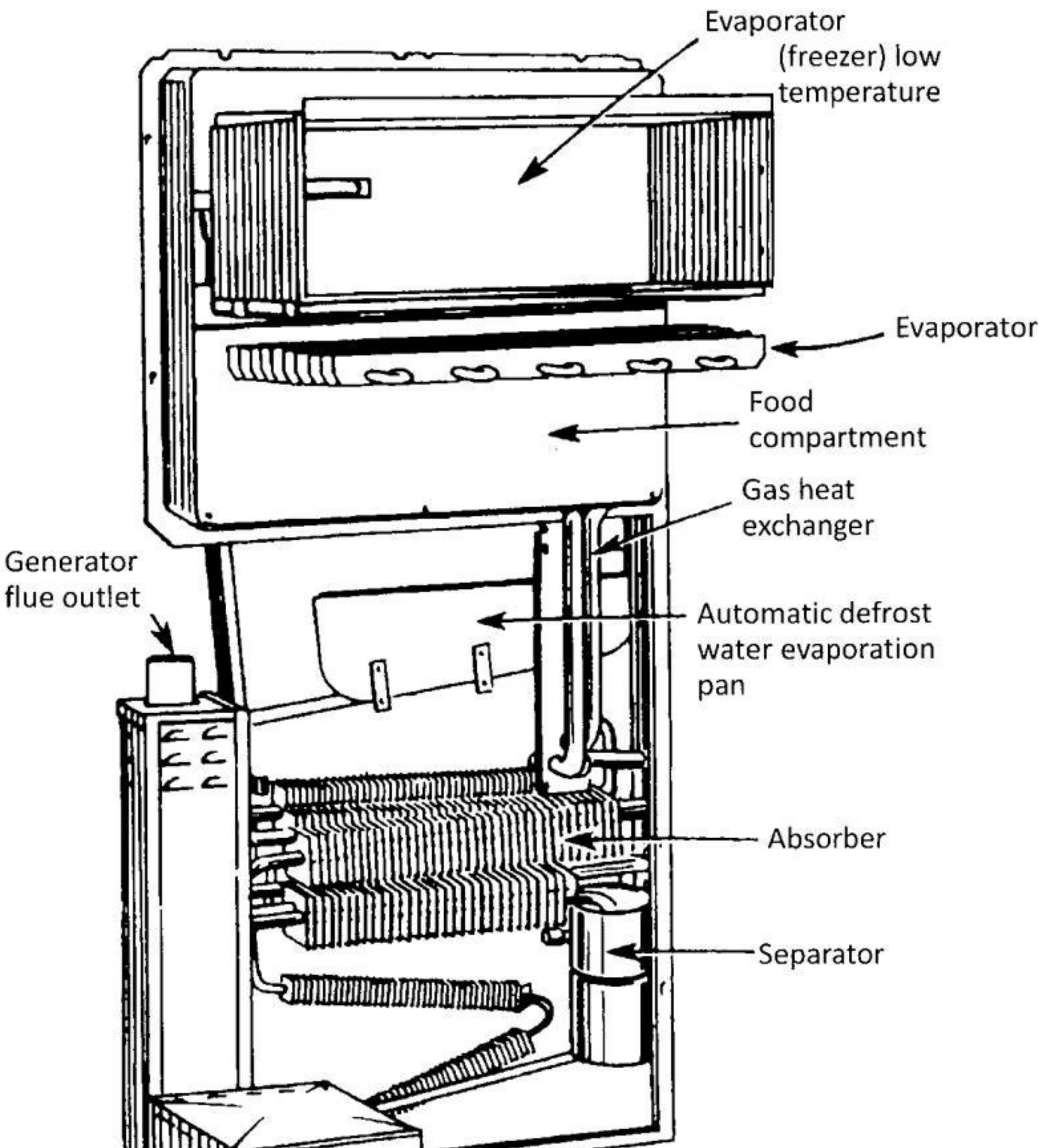
# Refrigerator

## Installation Requirements

Clause 7.34 of CSA B149.1 contains general installation requirements for refrigerators.

Unvented gas refrigerators have been responsible for numerous CO exposures to occupants. These units are older unvented models that regulators have subsequently banned for resale. Certified new units both unvented and direct vented are available once again incorporating CO detectors interlocked to the pilot safety.

**Figure 5-8**
**Refrigerator**



# Vented Gas Appliances Overview

### Forced Air Systems

Furnaces, unit heaters, duct heaters

### Water Heating

Water heaters, boilers, pool heaters

### Venting Systems

B-vent, direct vent, chimney

### Decorative & Space Heating

Fireplaces, infrared heaters, wall furnaces

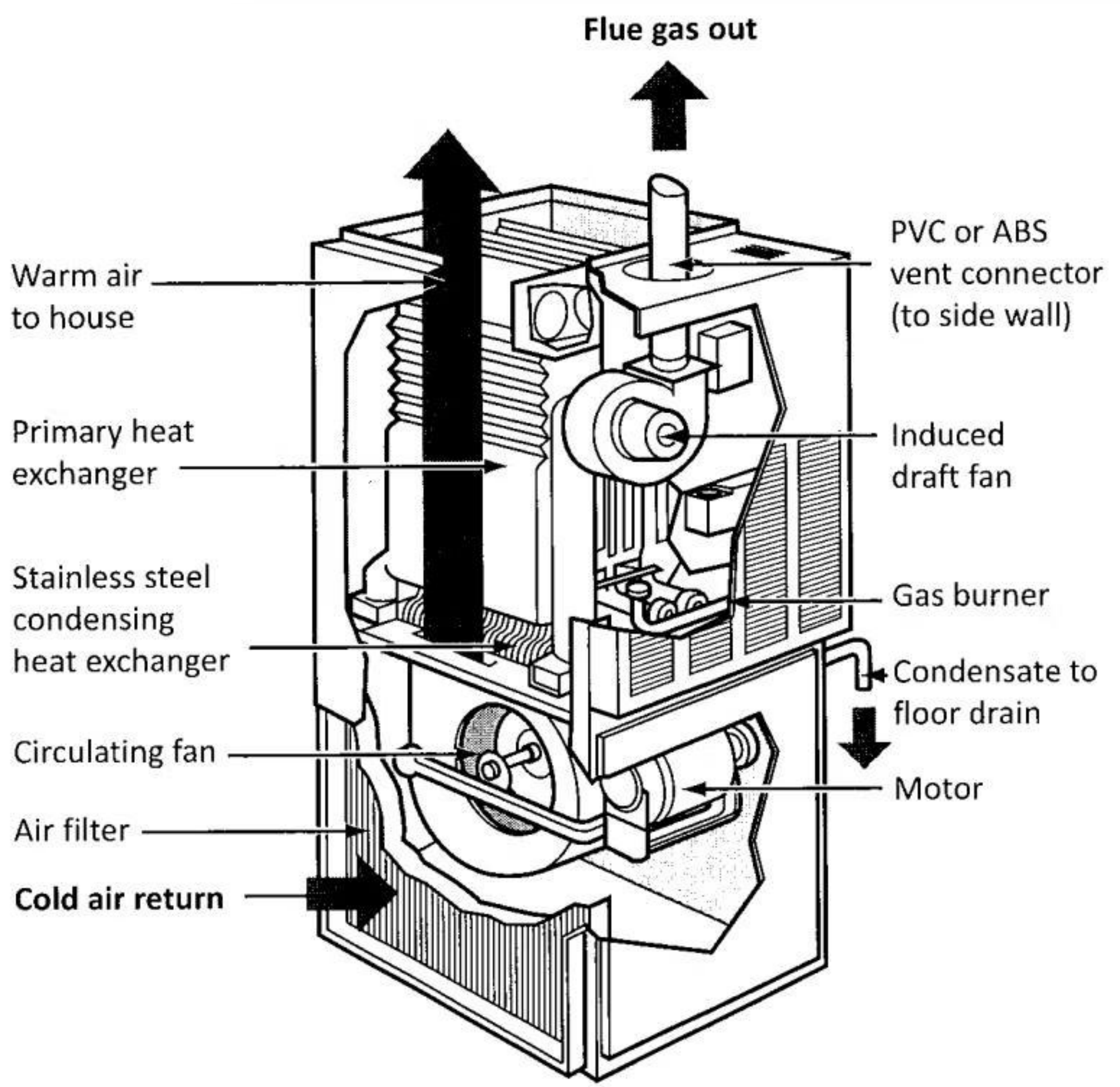
Vented gas appliances require proper venting systems to safely remove combustion products to the outdoors. These appliances come in various types and configurations to meet different heating needs.

# Forced Warm-Air Furnace

## Overview

Most furnaces in houses and small commercial buildings have a blower that circulates the conditioned air from a central area of the house, around the heat exchanger, and through the duct work to the rooms.

New gas furnaces in Canada are high-efficiency (89-96%) condensing furnaces. The high-efficiency furnaces use a plastic vent and are most often vented out the side wall.




## Specifications

- Venting: Natural draft, induced draft, or fan assist, depending on furnace design
- Venting material: B vent, BH vent, or direct vent
- Heat transfer: Forced convection

# Furnace Safety Features

### High Temperature Limit

Shuts down the furnace if temperature exceeds safe levels

### Flame Roll-Out Switch

Detects flames escaping the heat exchanger

### Combustion Air-Proving Switch

Ensures proper air for combustion

### Door Switch

Prevents operation when access panels are removed

### Blocked Vent Shutoff System

Detects improper venting conditions

### Burner Management System

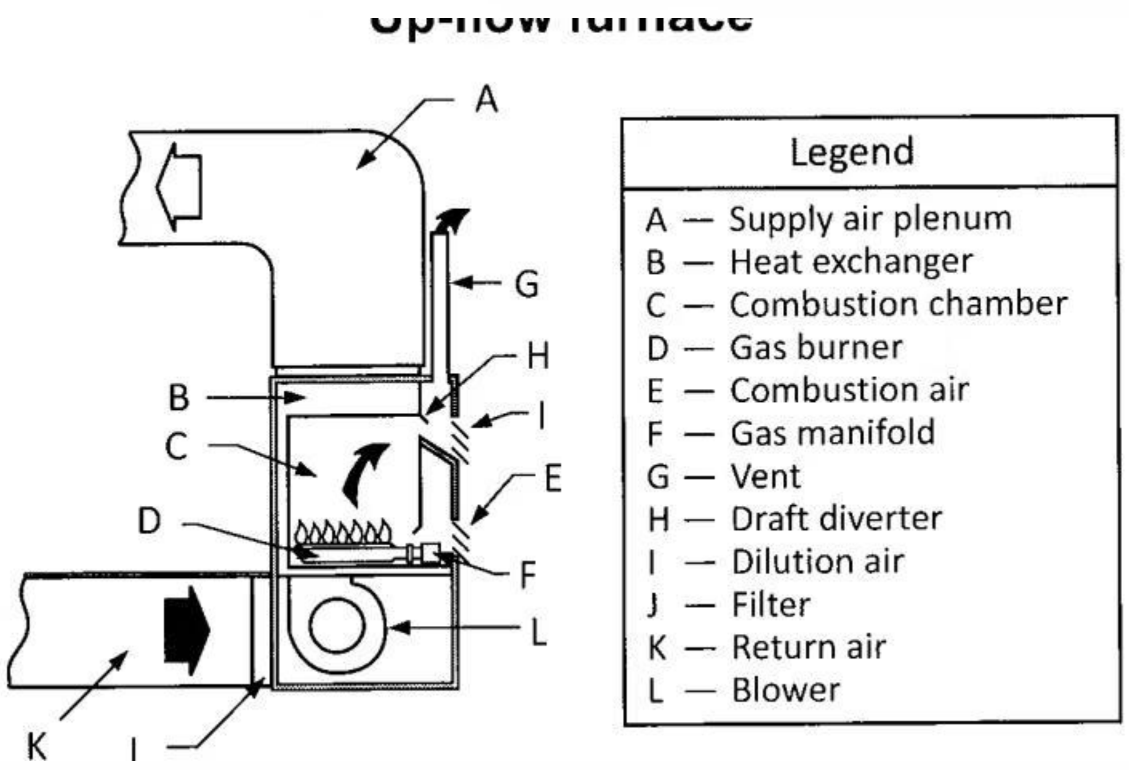
Controls ignition sequence and monitors operation

# Up-flow Furnace (High-boy)

## Design Characteristics

Up-flow units or high-boy units have the blower under the heat exchanger with the air flow going upward. You may install this type of furnace in closets or utility rooms.

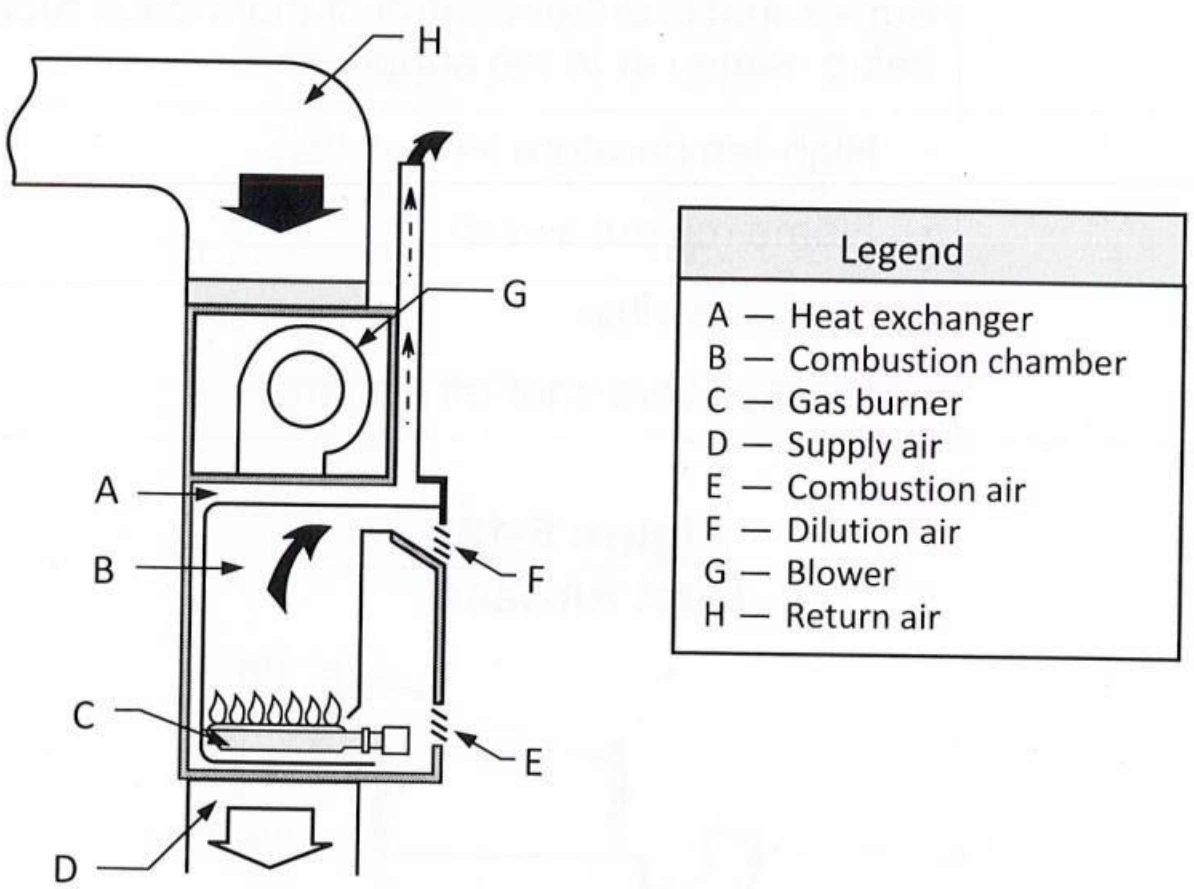
There are several types of blower designs to accommodate different installation requirements. You can find both direct drive and belt driven blower assemblies in the field today.




The up-flow design is one of the most common furnace configurations in residential applications. It's particularly well-suited for installations where the ductwork runs through the attic or upper floors of the building.

# Down-flow Furnace

Figure 5-11
Down-flow furnace




Down-flow furnaces are specifically designed for applications where the heating ducts are located beneath the furnace, such as in crawl spaces or basements.

## Design Characteristics

Down-flow units have the blower above the heat exchanger with the air flow going downward. You can find down-flow units usually in trailers and mobile homes, as well as in single-storey buildings where the heating supply duct is installed beneath the floor.

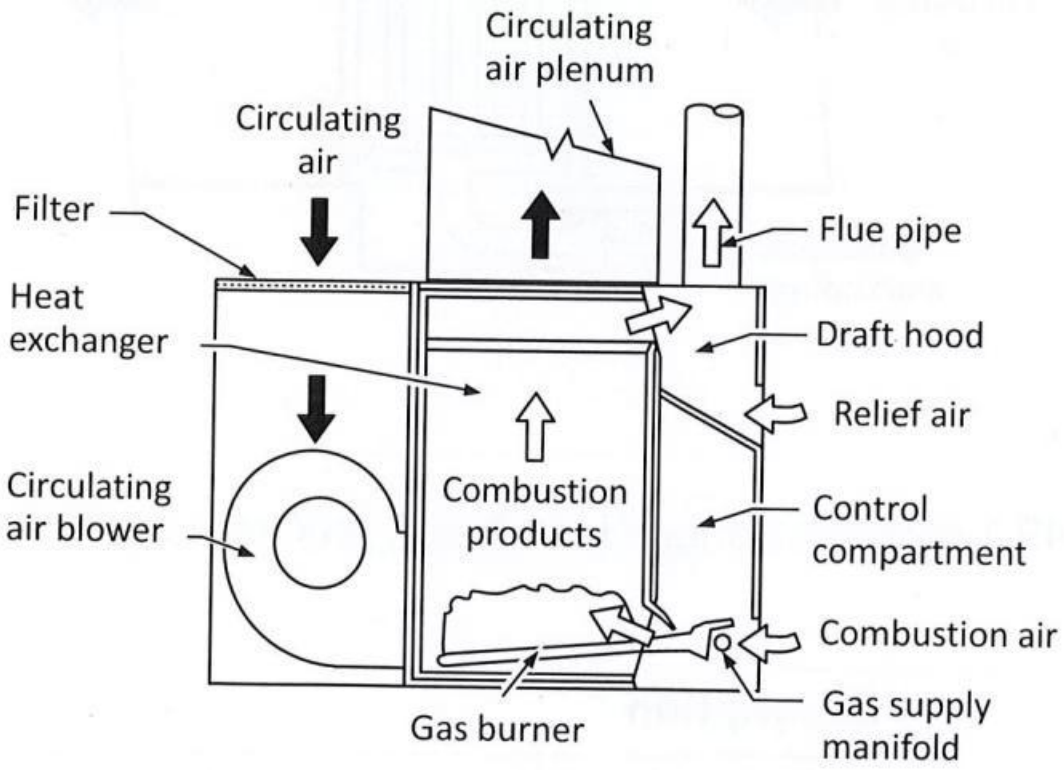
This configuration is ideal when space constraints require the furnace to be installed on the main floor with ductwork running below.

# Low-boy Furnace

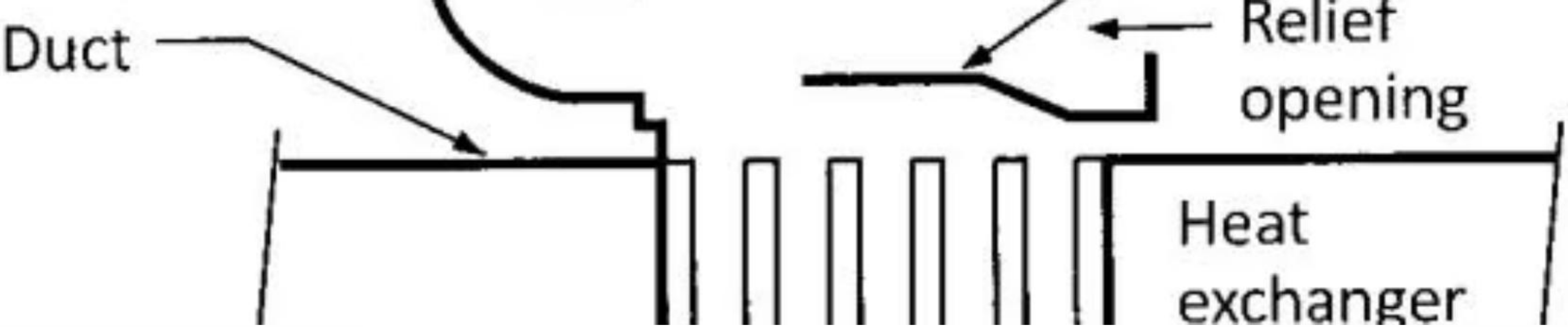
## Design Characteristics

The low-boy furnace is designed for installations with height restrictions, such as crawl spaces or areas with low ceilings.

This configuration features a more horizontal layout compared to traditional up-flow or down-flow designs, allowing it to fit in spaces where vertical clearance is limited.




Low-boy furnaces provide the same heating capacity and efficiency as their taller counterparts but in a more compact package that can fit in tight spaces.




# Duct Furnace

## Application

You use duct furnaces in duct distribution systems where air moving equipment is supplied separately. In some applications, they function as indirect-fired make-up air heaters.

## Heat Transfer

Forced convection

## Ignition

Standing pilot, spark-ignited pilot, direct spark ignition, hot surface ignition

## Burner Control

Burner that is under control of thermostat mounted in space being heated or in the supply duct

# Duct Furnace Safety Features

### High-Temperature Limit Switch

Prevents overheating by shutting down the burner if temperatures exceed safe limits

### Flame Roll-Out Switch

Detects flames escaping from the combustion chamber and shuts down the system

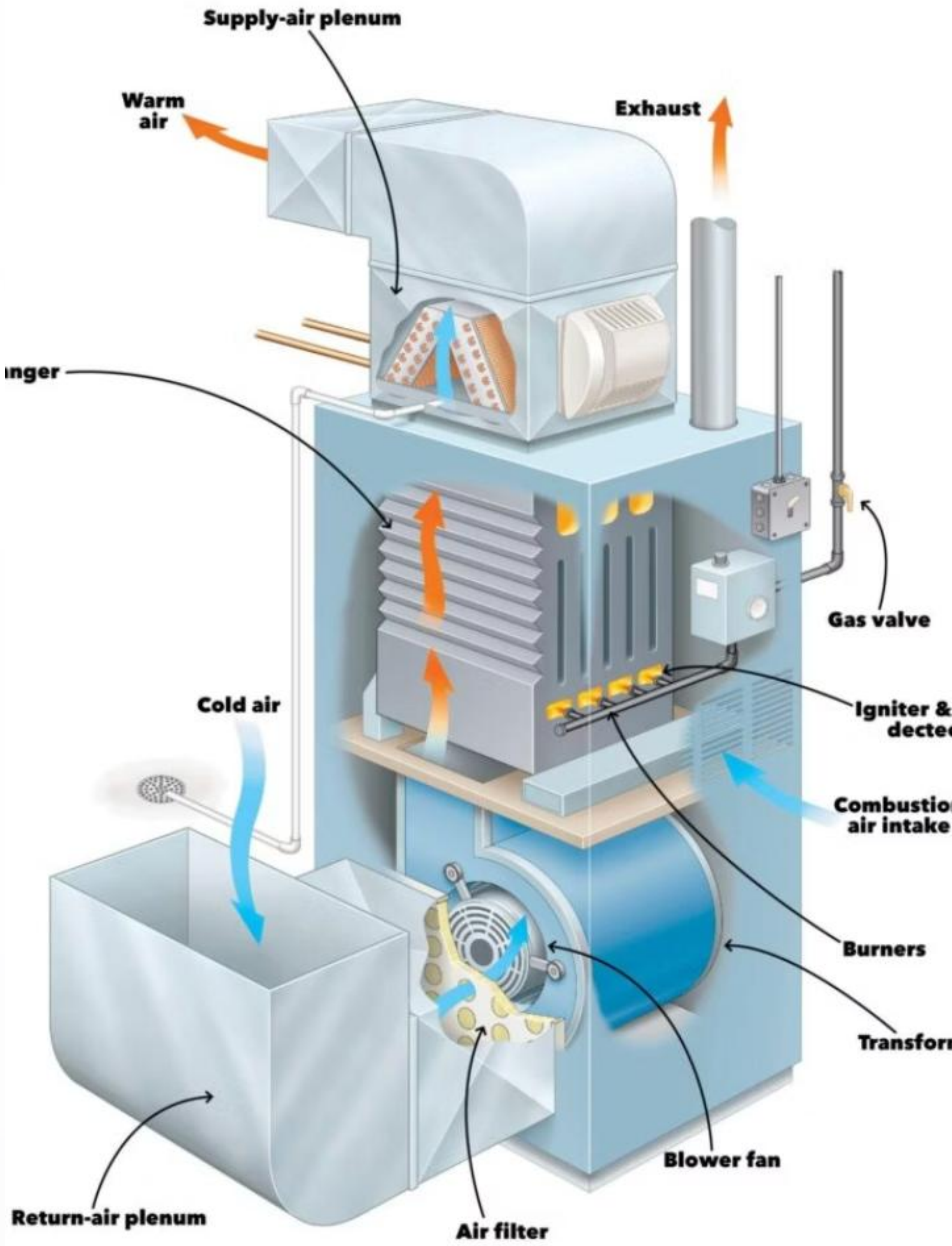
### Air-Flow Switch

Ensures adequate airflow is present before allowing the burner to operate

### Blocked Vent Shut-Off System

Detects improper venting conditions and shuts down the system to prevent hazardous operation

Clause 7.45 of CSA B149.1 contains general installation requirements for duct furnaces.

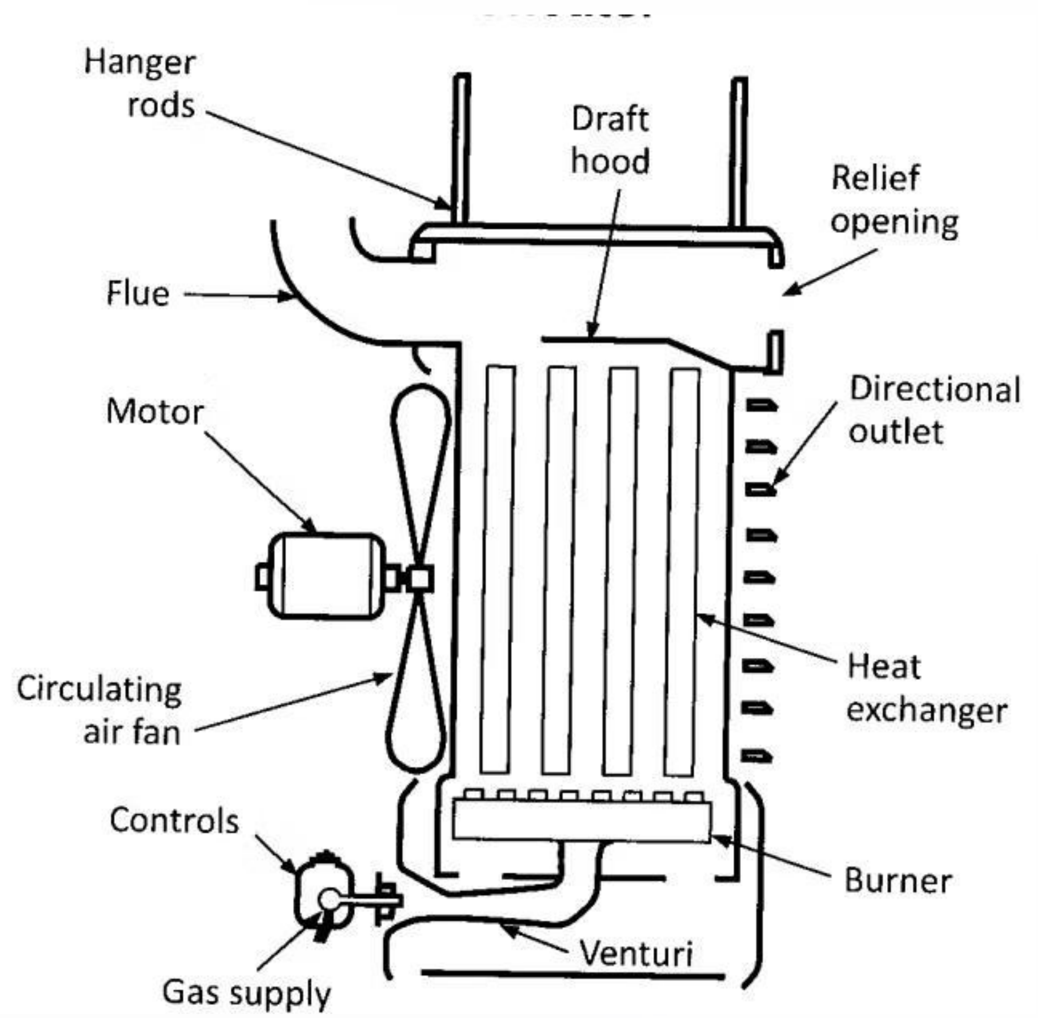


# Unit Heater

## Specifications

- Heat transfer: Forced convection
- Ignition: Standing pilot, spark ignited pilot, direct spark ignition, hot surface ignition
- Burner control: Manual switch or wall-mounted thermostat
- Safeties: High-temperature limit switch, blocked vent shutoff system

Clause 7.28 of CSA B149.1 contains general installation requirements for unit heaters.




Unit heaters are compact, self-contained heating appliances that are typically suspended from the ceiling or mounted on walls in commercial and industrial spaces. They provide efficient spot heating and are commonly used in warehouses, workshops, and other large open areas.

# Swimming Pool Heater

### Installation Considerations

Most pool heaters include all necessary controls, including a pool temperature control and water that reduces condensation in the heater. You can find water heating appliances installed in the water circulation system of the pool at a point between the treatment stage and the pool.

### Special Challenges

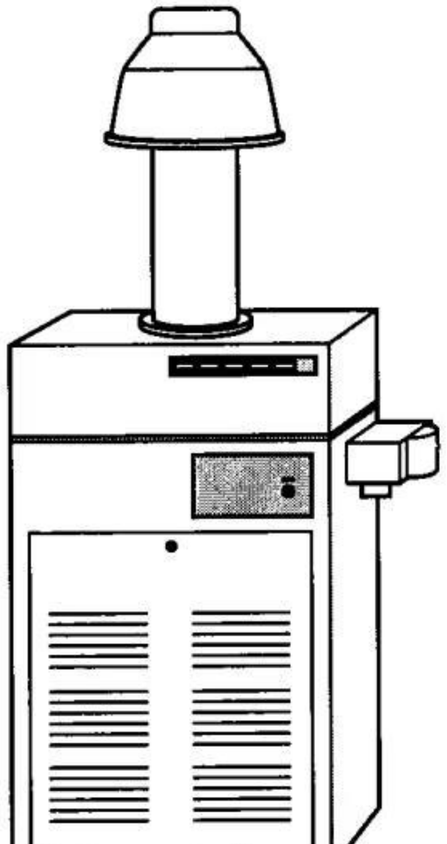
Swimming pool heaters may have problems not encountered with other water heaters and boilers because of the low water temperature at which they operate. In view of the condensation, which can be a problem, you should take extra care with respect to sizing, water flow, combustion air, and regular maintenance.

### Installation Restrictions

As a result of these ongoing maintenance issues and harsh operating environments, the installation of swimming pool heaters of the finned-tube type within a building that houses occupants is not allowed.

### Code Requirements

Clause 7.26 of CSA B149.1 contains general installation requirements for Pool Heaters.



# Swimming Pool Heater Specifications

### Heat Transfer

Predominantly convection

### Ignition

Standing pilot, spark-ignited pilot, direct spark ignition, hot surface ignition

### Burner Control

Aquastat

### Safeties

High-temperature limit aquastat, pool temperature control, flow switch

### Venting

Must comply with rating plate requirements

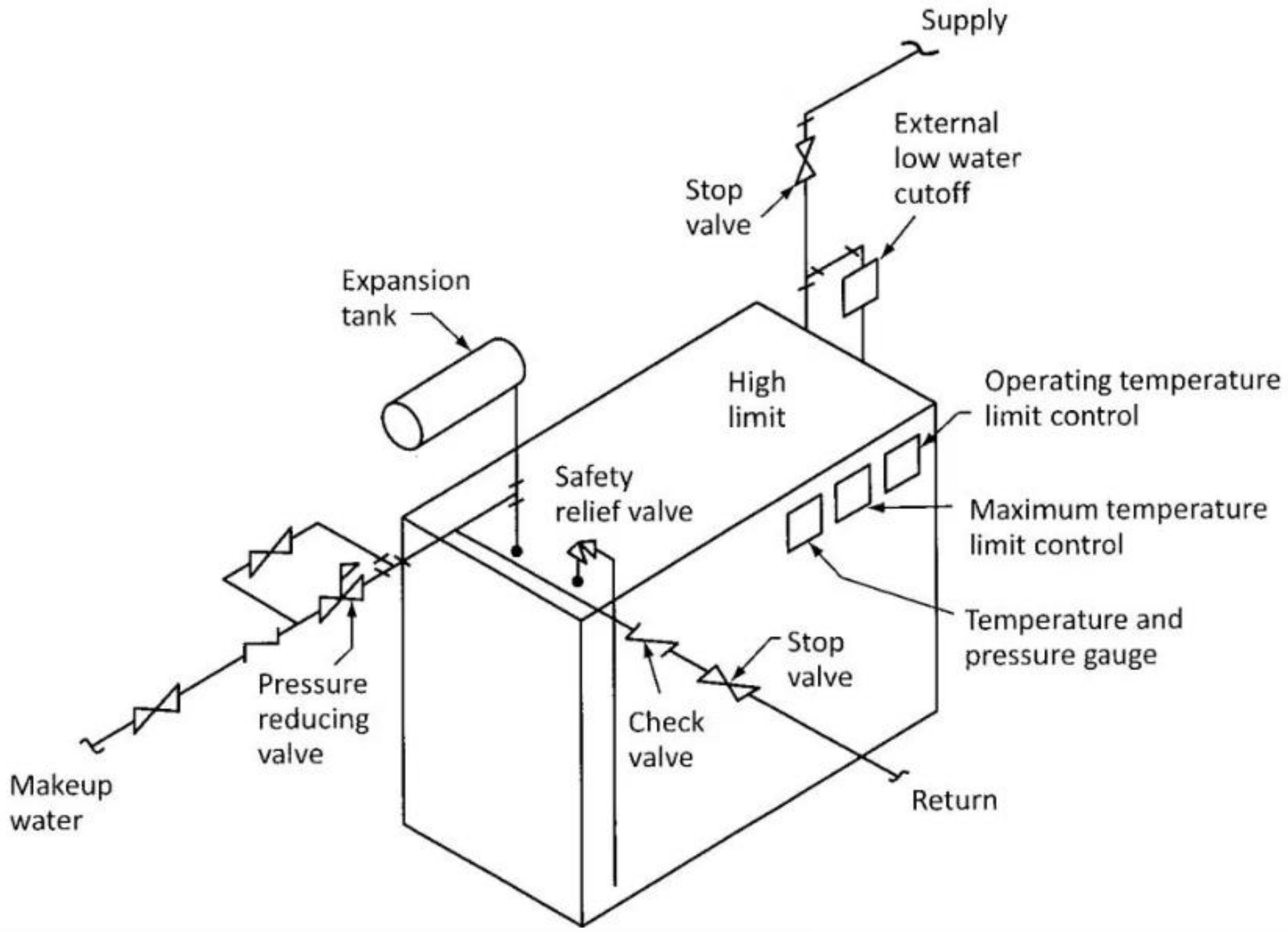
# Hot Water Boiler

## Overview

Domestic and commercial space heating commonly employ hot water boiler contains water, and a control system keeps the water at a preset temperature. A pump helps circulate the hot water through the heating system.

Clause 7.1 of CSA B149.1 contains general installation requirements for hot water boilers.

**Figure 5-16**
**Hot water boiler**




## Specifications

- Heat transfer: Convection and radiation
- Ignition system: Standing pilot, spark-ignited pilot, direct spark ignition, hot surface ignition

# Hot Water Boiler Controls and Safeties

## Make-up Water Supply

Whenever boiler water pressure drops below a set point, you must supply make-up water.

## Pressure Reducing Valve

The pressure reducing valve is set at a point below which boiler pressure must not drop. The valve allows the make-up water to enter and bring the boiler pressure back to the proper level.

## Expansion Tank

As the temperature of the water increases, the water expands. The expansion tank partially contains air, which compresses as the water expands and enters the expansion tank, allowing the system pressure to remain stable.

## Stop Valves

Stop valves help isolate the boiler from the system piping.

## Operating Temperature Limit Control

The operating temperature limit control monitors the water temperature and interlocks with the burner.

# More Hot Water Boiler Safety Features

## High Temperature Limit Control

If the operating limit control fails, the high-limit control will shut the burner down. You must set the high-limit control at a higher temperature than the operating limit control.

## Low Water Cut-off

A low water cut-off is required on hot water boilers when the input is in excess of 400,000 Btu/h (117 kW) or when the boiler is above the hot water circulating system. It interlocks with the burner to cause a shutdown if the water level drops below the set point.

## Flow Switch

Codes may require a flow switch on any copper fin tube type and/or low mass boiler, especially when the firing rate exceeds 400,000 Btu/h (117 kW).

## Safety Relief Valve

If the pressure in the boiler rises above the set point, the safety relief valve will open and remain open until the pressure drops to a safe level.

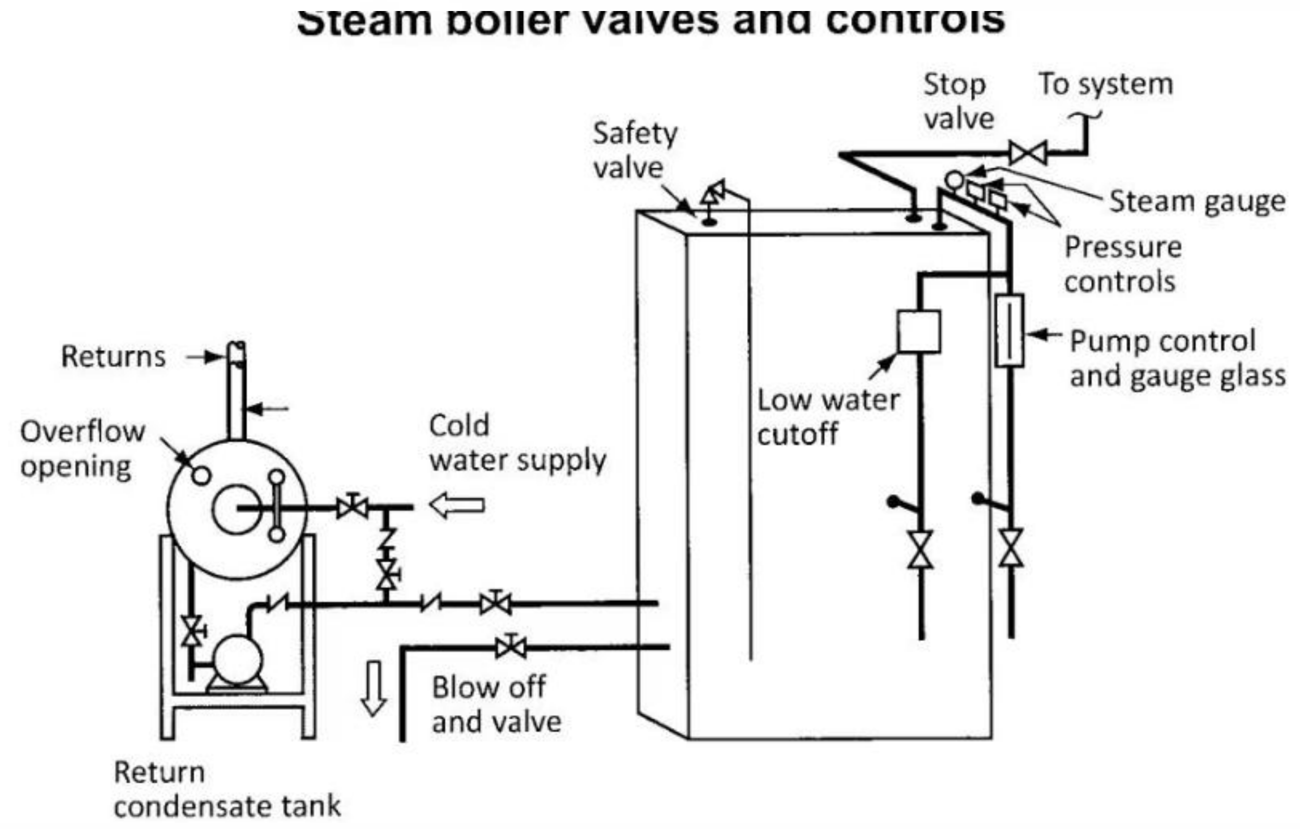
# Steam Boiler

## Overview

It is uncommon to use steam boilers for domestic purposes. Generally, people use it to heat large spaces or for industrial processing.

Steam boilers partially contain water and the space at the top of boiler allows steam to accumulate (steam drum). The combustion control system monitors steam pressure.

Clause 7.1 of CSA B149.1 contains general installation requirements for steam boilers.




## Specifications

- Heat transfer: Convection and radiation
- Ignition system: Standing pilot, spark-ignited pilot, direct spark ignition, hot surface ignition

# Steam Boiler Controls and Safeties

### Stop Valve

Helps isolate components

### Steam Gauge

Registers steam pressure in the boiler

### Operating Pressuretrol

Controls steam pressure in the boiler, interlocks with the burner

### High-Limit Pressuretrol

Set higher than the operating pressuretrol, interlocks with the burner to cause shutdown if the operating pressuretrol should fail

### Pump Control

Maintains proper water level in the boiler, which is visible through the gauge glass

# More Steam Boiler Safety Features

### Low Water Cut-off/Hartford Loop

Required on all steam boilers, interlocks with the burner, and causes shutdown if the water in the boiler drops below the required level

### Safety Valve

Opens and remains open until the pressure drops to a safe level if the pressure in the boiler rises above the set point

### Check Valve

Allows flow in only one direction, required on the condensate return line to the boiler

### Return Tank

Condensate from the piping system returns to the tank and is fed to the boiler via the pump

### Feedwater Pump

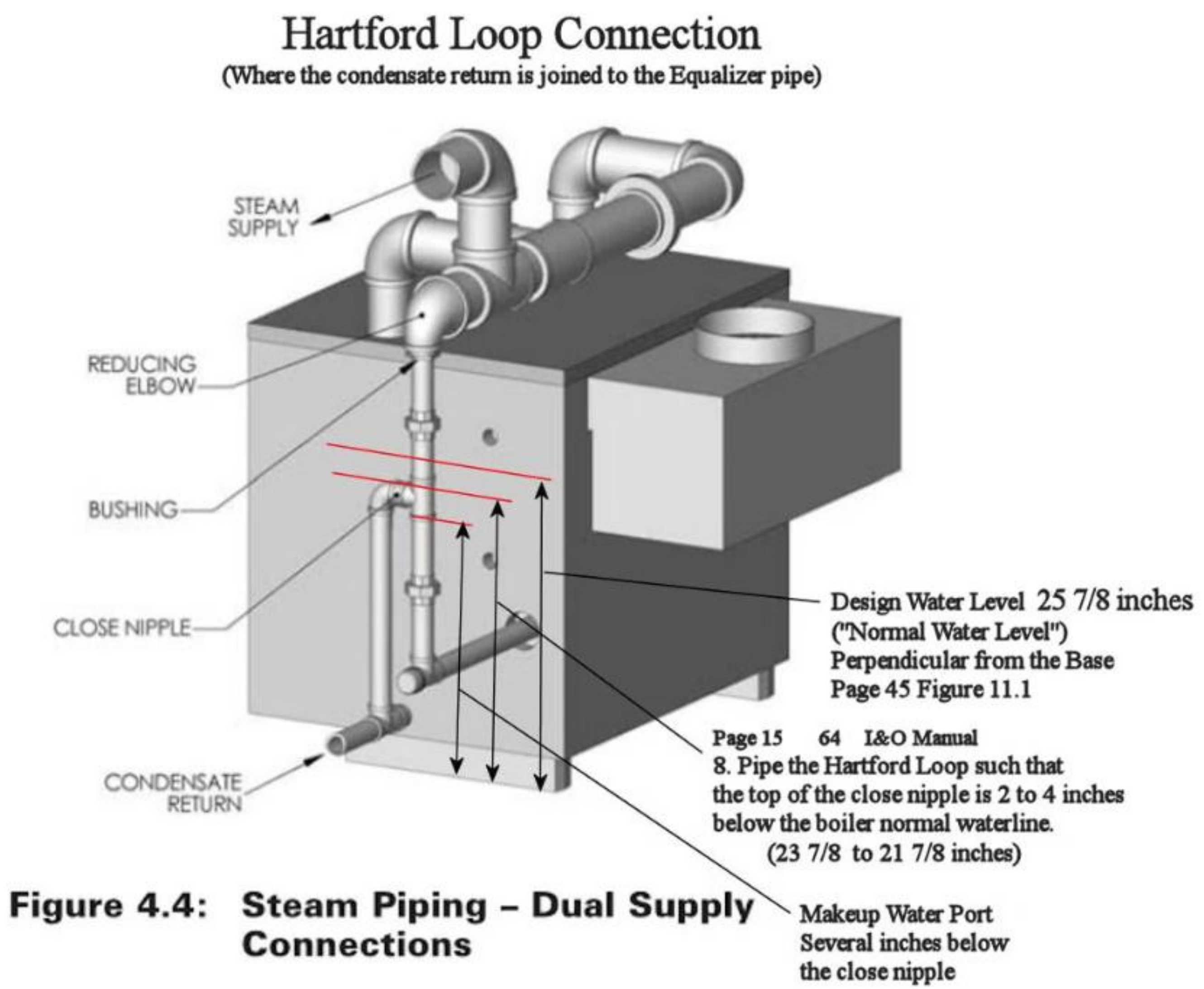
Supplies water to the boiler as required

# Hartford Loop in Steam Boilers

## Definition and Purpose

A Hartford Loop is an arrangement of piping between a steam boiler's header and its gravity-return piping. The end of the header drops vertically below the boiler's waterline and connects into the bottom of the boiler.

The pipe is termed the "equalizer" because it balances the pressure between the boiler's steam outlet and condensate-return inlet.




## Function and Benefits

The "wet" gravity return line, which returns the condensate from the system, rises from the floor to join the equalizer at a point about 2 inches below the boiler's lowest operating water line.

The piping arrangement is not fail-safe, but it is an improvement over the old way of returning condensate directly into the bottom of the boiler. A low water cut-off should protect the boiler against a sudden loss of water, but with

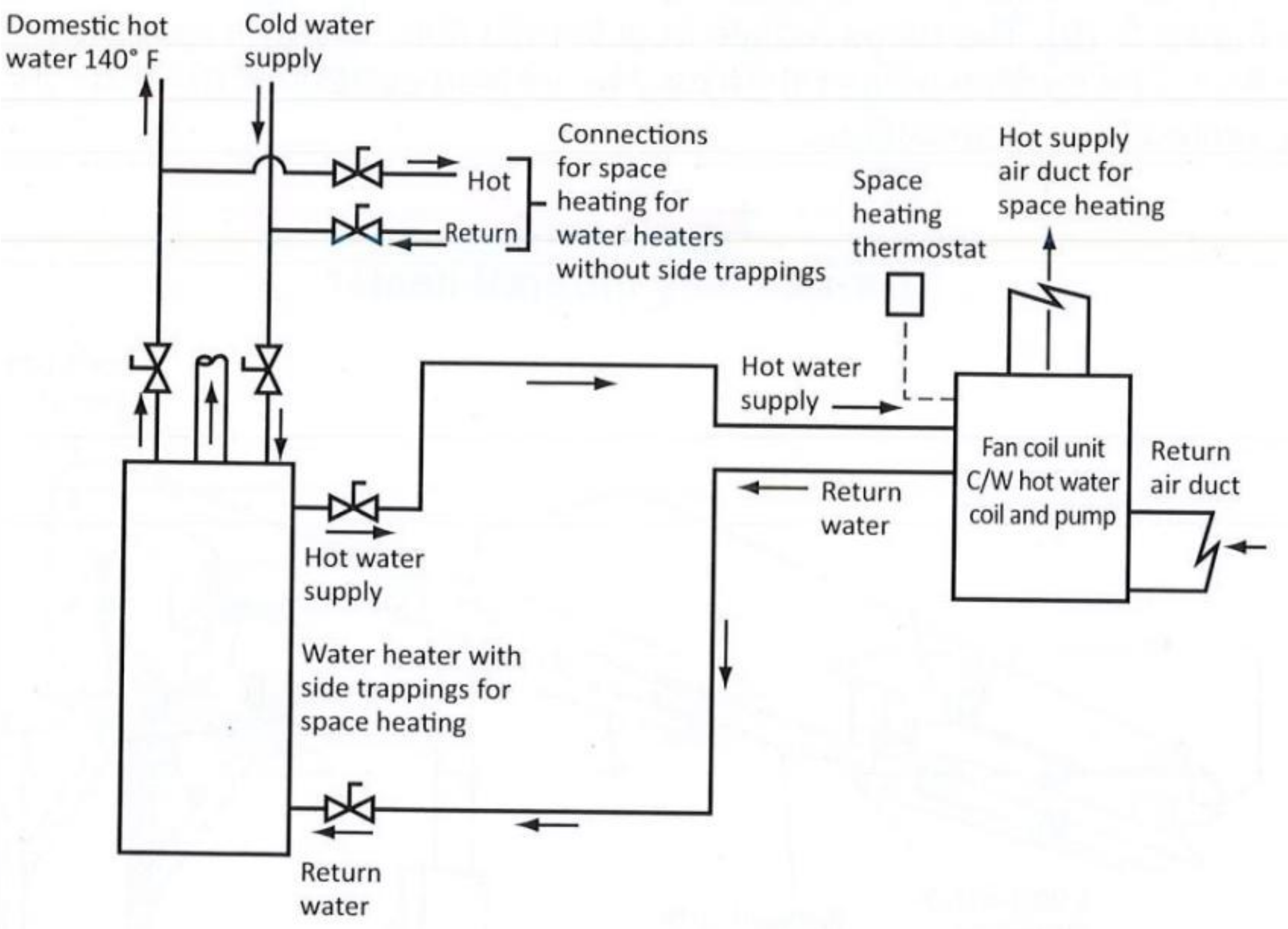
# Combination Unit

## Overview

A combination unit is a hot water that supplies water for domestic use, as well as a fan coil unit that heats air for space heating. More elaborate systems can also supply hot water for in-floor radiant space heating.

## Specifications

- Heat transfer: Conduction, convection, or radiation
- Ignition system: Standing pilot, spark-ignited pilot, direct spark ignition, hot surface ignition
- Burner control: Aquastat thermostat
- Safeties: High limit aquastat, temperature pressure relief valves
- Note: All components must have approval for potable water




This illustration shows a combination fan coil unit with storage-type water heater. All piping and safety requirements may not be shown. This illustration is for education purposes only. Adherence to local code requirements, as well as manufacturer's certified instructions is essential to efficient and safe operation of any combustion appliance.

# Infrared Heater

## Overview

An open flame can produce infrared energy. However, modern infrared systems use burning gas to heat a radiating surface. (These heated surfaces are better radiators than naked flames.) The radiating surfaces undergo heating by direct flame contact or with the products of combustion.

Clause 7.23 of CSA B149.1 contains general installation requirements for infrared heaters, which people primarily use for commercial or industrial purposes.

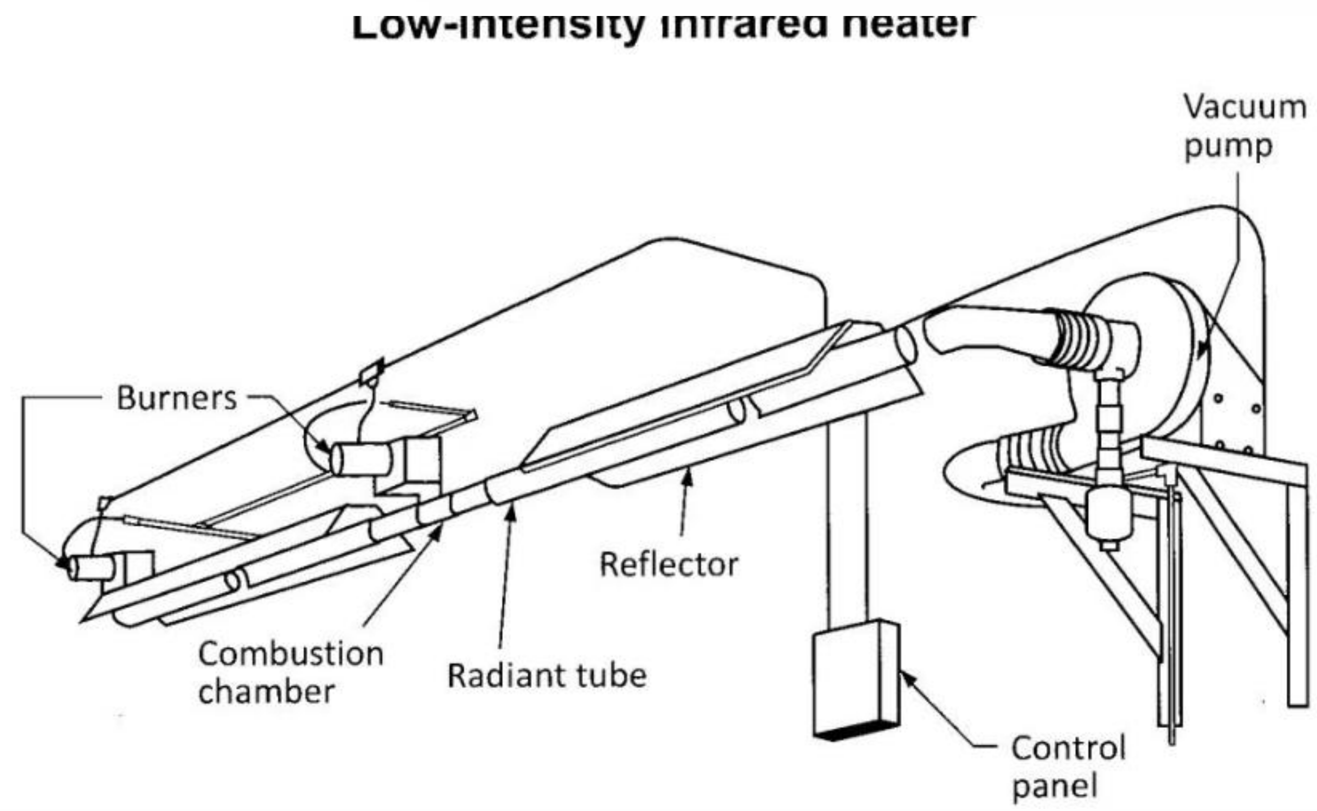
## Specifications

# Low-Intensity Infrared Heater

## Design and Operation

In low-intensity infrared heaters, combustion occurs in tubes or panels that are made of metal or ceramic. The tubes radiate heat to reflectors, which in turn direct the heat source to the floor.

The surface temperature may be as high as 1200°F (648°C) and the units are generally vented to the atmosphere.




Low-intensity infrared heaters are commonly used in large spaces like warehouses, aircraft hangars, and manufacturing facilities where zone heating is more efficient than heating the entire space. They provide comfortable radiant heat that warms objects and people directly rather than heating the air.

# High-Intensity Infrared Heater

Figure 5-20
High-intensity infrared heater

High-intensity infrared heaters are often used in outdoor or semi-outdoor applications such as restaurant patios, loading docks, and sports venues where direct, intense heat is needed.

## Design and Operation

High-intensity infrared heaters (often called "surface combustion infrared heaters") are made of porous ceramics, drilled port ceramics, stainless steel, or a metallic screen.

A combustible mixture of gas and air enters the enclosure and flows through the refractory material, at which point the gas ignites. Since the gas evenly spreads on the exposed surface, the flame is quite steady.

The surface temperature may rise as high as 1800°F (982°C). To reach these high temperatures, you may use an atmospheric burner if the porosity is suitable; if not, you must use a power burner.

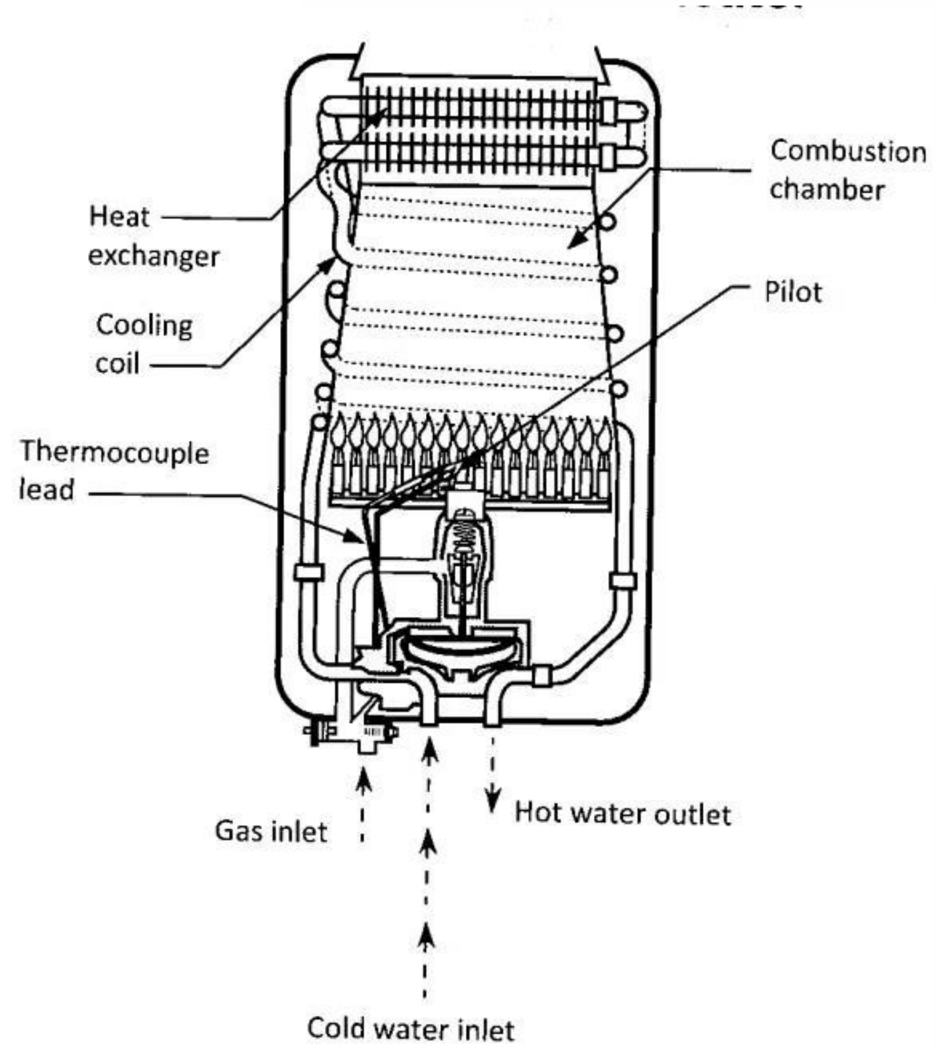
You must not connect high-intensity infrared heaters to a vent. They must, however, be in a well-ventilated area.

# Water Heaters

## Overview

A gas water heater heats water for cooking, dishwashing, clothes washing, lavatories, baths, and showers. It does not heat water for space or central heating.

There are two common ways to heat the water: instantaneously, as water is needed, and stored in a tank at constant temperature.




## Instantaneous Water Heater

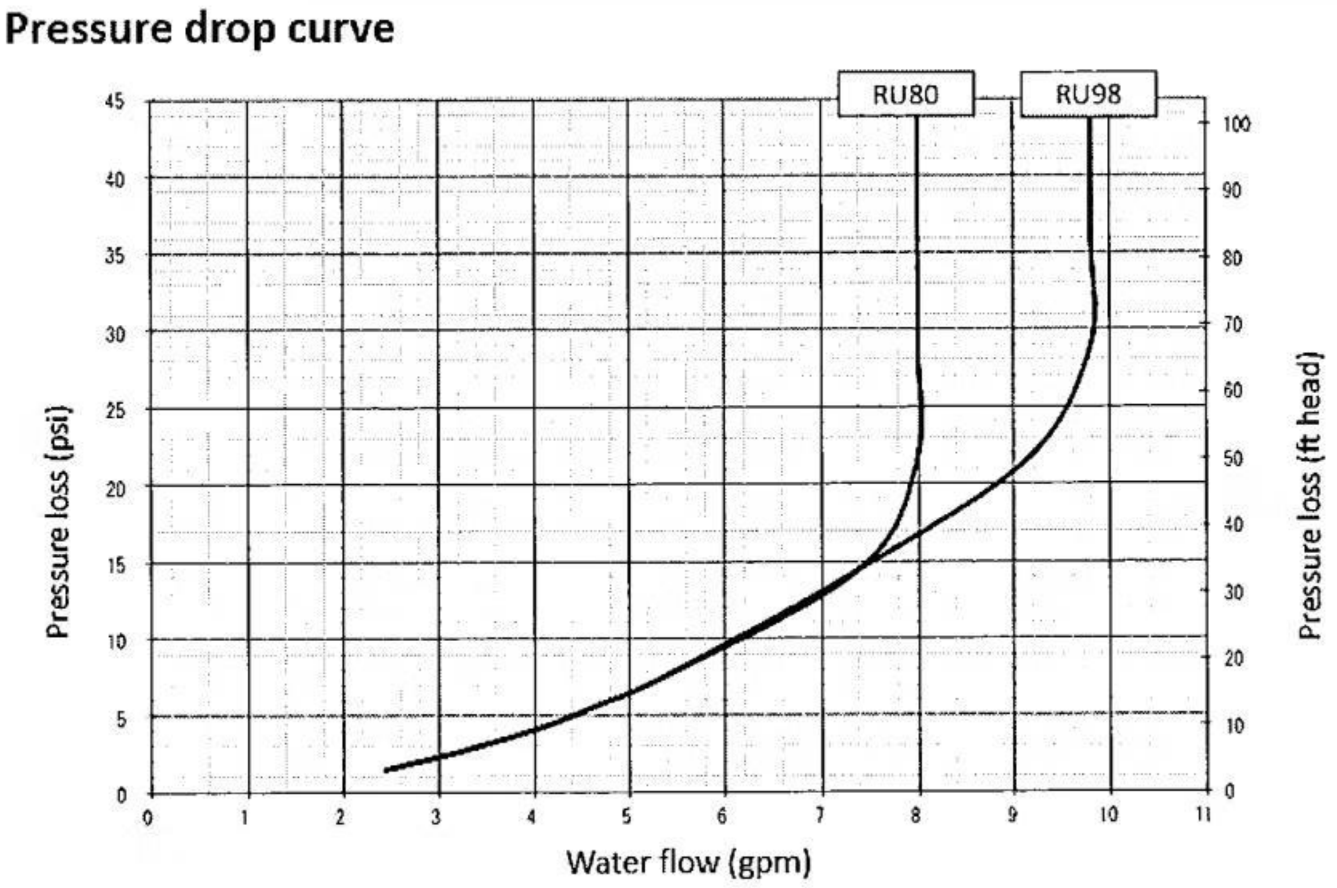
Tankless water heaters can provide an instant, endless supply of hot water within their net capacity and operating conditions. Though these units modulate, their net output firing rate capabilities and the temperature differential between the incoming water temperature and their set output temperature determine their minimum and maximum GPM yield.

# Tankless Water Heater Performance

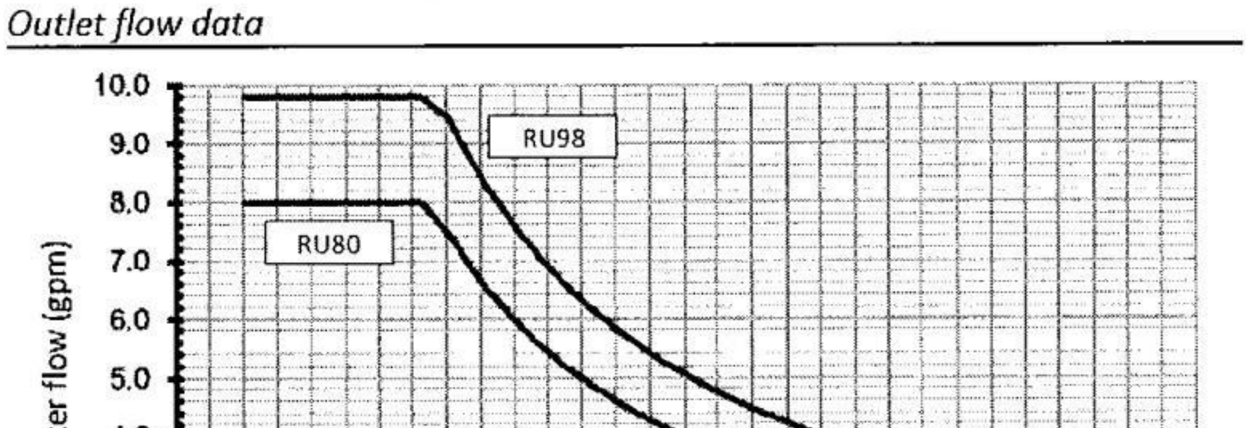
## Flow Rate Considerations

Pressure drop through tankless units increases with flow rate. They typically have substantially higher firing rates than tank-type hot water heaters; therefore, they have far better recovery rates.

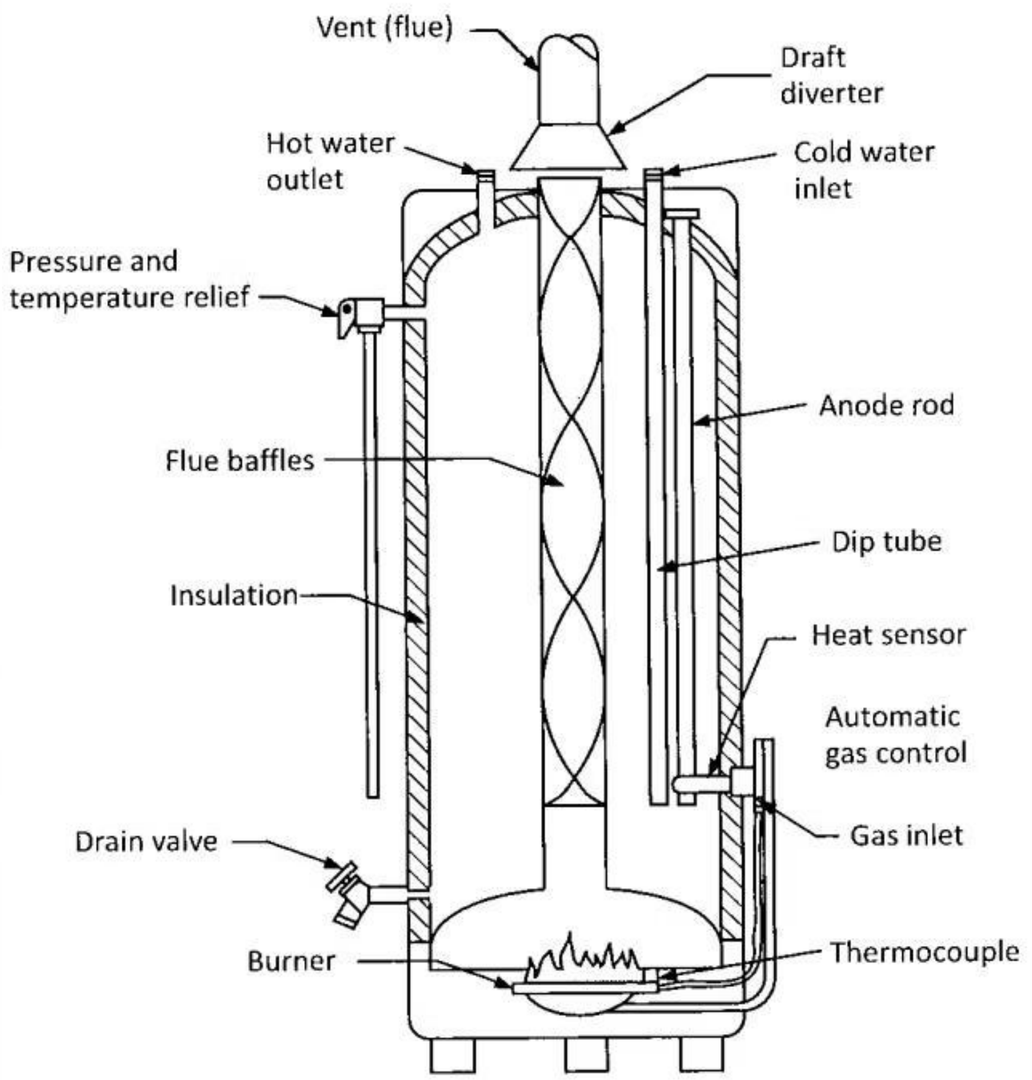
Since these systems function on an on-demand basis, they don't require a holding tank to store pre-warmed water. Having no storage or holding reserve means that tankless water heaters have a life span that's potentially twice as long as traditional systems, because the risk of rust and corrosion may significantly drop with proper maintenance.




| NOTICE | The chart below only applies to incoming water temperatures of 70°F (21 °C) or less. For incoming water temperatures greater than 70°F (21 °C) please contact Rinnai. |
|---|---|



# Storage-Type Water Heater




This unit is typical, however, limited in its recovery due to significantly lower firing rates. Its advantage over tankless type water heaters is its initial capacity and negligible pressure drop at high flow rates.

## Comparing Tank vs. Tankless

Gas technicians/fitters often get questions on their opinion regarding comparisons of tankless versus tank-type water heaters; however, there may not always be a clear "best choice".

Through an analysis of the potential system variables, such as potential GPM requirements, water hardness, and outputing and receives, potential Grill requirements, supply water procesure halp a lines, potential changes to gas/potable pipe sizing and supply water pressure help advise a customer of the advantages/disadvantages/disadvantages/disadvantages/of both.

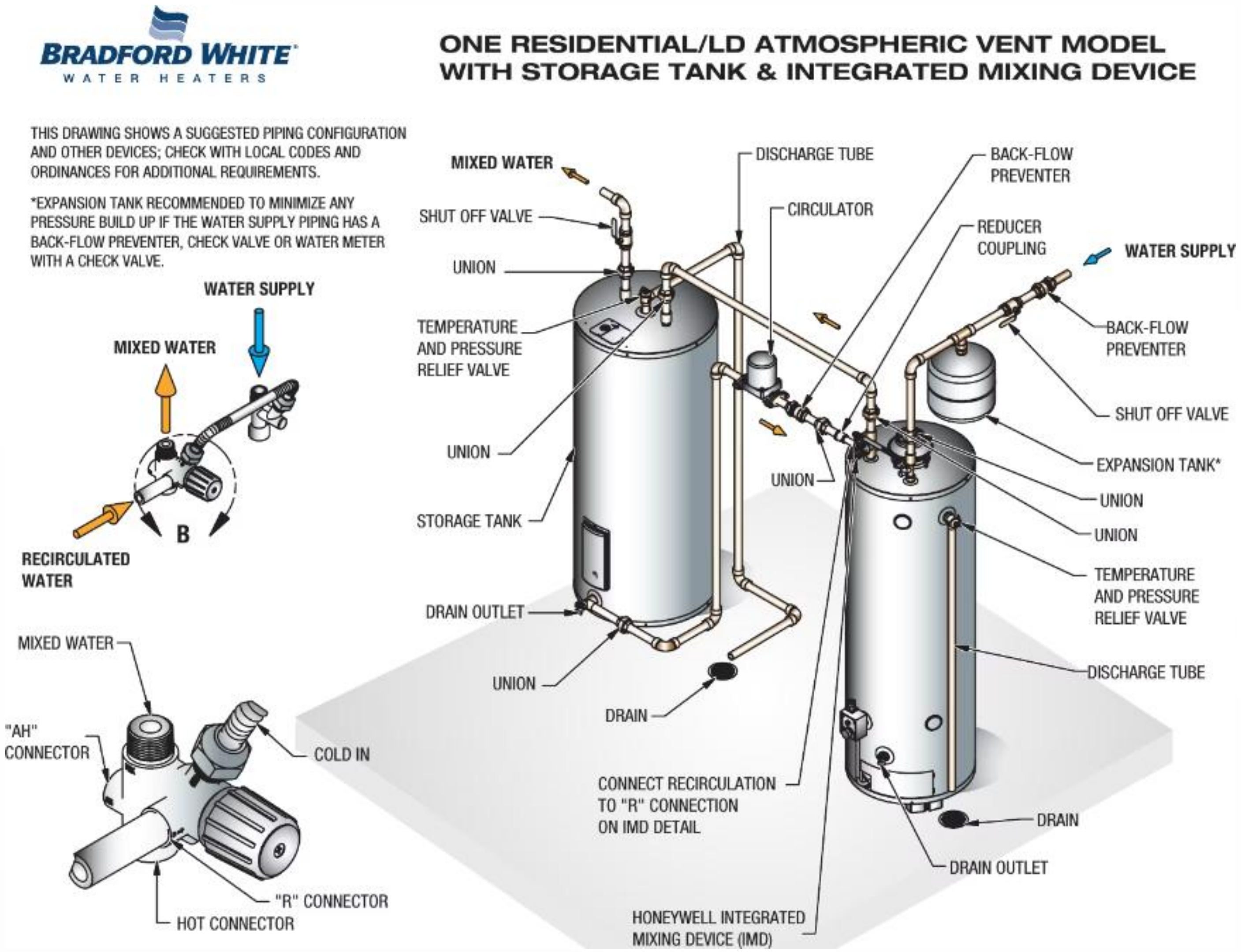
You must take application and site conditions into consideration.

# Dual-Tank Water Heating System

## Design and Operation

Figure 5-23 shows another version of a storage water heater where one tank houses water heating and a larger tank stores the water. Gravity or a circulating pump helps circulate the water is circulated through the heater.

This system allows storage of large amounts of water for intermittent draw and uses a smaller heating tank. Additionally, the heating tank can supply water that is of a different temperature from that in the large storage tank.




## Specifications

- Heat transfer: Conduction
- Ignition: Standing pilot, spark-ignited pilot, direct spark ignition, hot surface ignition
- Burner control: Aquastat, non-electric valves
- Safeties: Temperature and pressure relief valves, high-limit aquastat, FVIR design

Clause 7.27 of CSA B149.1 contains general installation requirements for water heaters.

# FVIR Water Heater Design

## Safety Innovation

Flammable Vapor Ignition Resistance (FVIR) is a technology developed for gas-fired water heaters that resists ignition of flammable vapours that may occur outside and near a water heater as a result of the mishandling of flammable products.

This helps guard against such an incident and reduce the risk of the water heater becoming a source of ignition.

**Figure 5-23**
**Circulating water heating system (a bypass should be shown)**

FVIR technology typically includes flame arrestors and sealed combustion chambers that prevent external vapors from being ignited by the water heater's burner. This safety feature has become standard on residential gas water heaters to prevent accidents involving flammable vapors from products like gasoline, paint thinners, or solvents.

# Decorative Gas Appliances

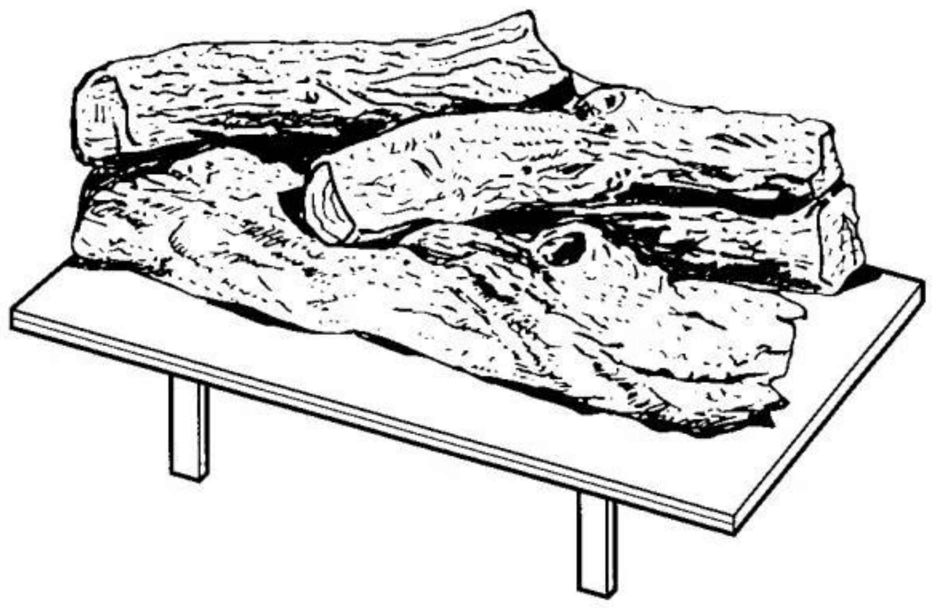
## Overview

Clause 7.25 of CSA B149.1 contains general installation requirements for decorative gas appliances such as gas logs.

## Specifications

- Heat transfer: Predominantly radiation
- Ignition: Standing pilot
- Burner control: None
- Safeties: None
- Venting: Chimney, chimney liner, and type B vent

**Figure 5-24**
**Gas logs**



Decorative gas appliances are designed primarily for aesthetic purposes rather than as a primary heat source. They create a realistic flame appearance while providing some radiant heat to the surrounding area.

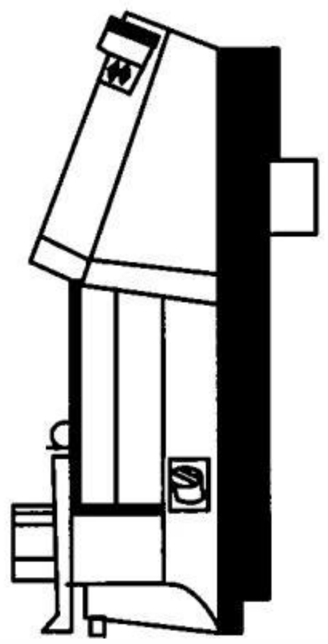
# Vented Gas Fireplace

## Types and Installation

Vented gas fireplaces (previously called decorative gas appliances) include fireplace inserts, free-standing stoves, and zero-clearance units. Clause 7.25 of CSA B149.1 contains general installation requirements for decorative gas appliances, including vented gas fireplaces.

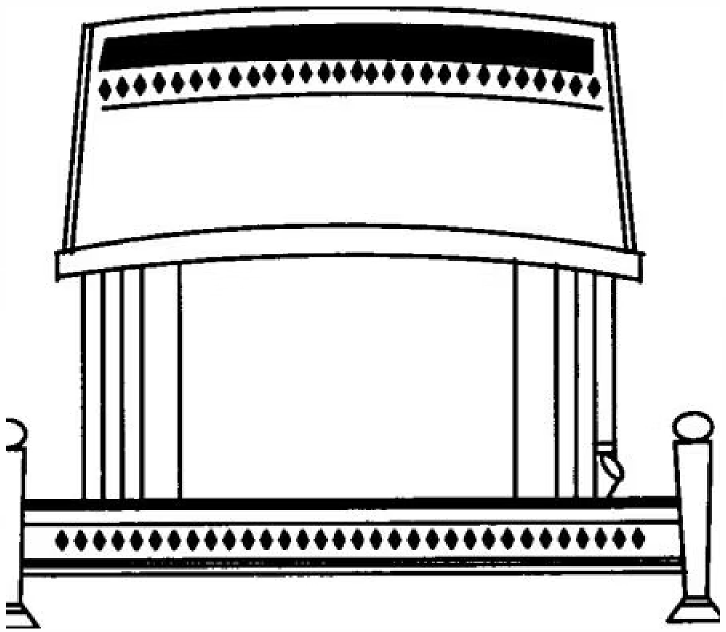
## Specifications

- Heat transfer: Convection, radiation
- Ignition: Standing pilot, piezo igniter, hot surface ignition
- Burner control: Thermostat or manual switch
- Safeties: Blocked vent safety shut-off switch
- Venting: Direct vent, Type B vent, flexible liners



Fireplace inserts are designed to fit into existing masonry fireplaces, converting them from wood-burning to gas. They provide efficient heating while maintaining the aesthetic appeal of a traditional fireplace.

# Free-Standing Gas Stove



Free-standing gas stoves offer flexibility in placement as they don't require an existing fireplace structure. They can be positioned in various locations within a room, provided proper venting and clearances are maintained.

## Design and Features

Free-standing gas stoves are self-contained heating appliances that simulate the appearance of traditional wood stoves while offering the convenience of gas fuel.

These units typically feature viewing windows on multiple sides, allowing the flame to be visible from different angles in the room.

Modern free-standing gas stoves often include features such as remote controls, programmable thermostats, and battery backup systems for operation during power outages.

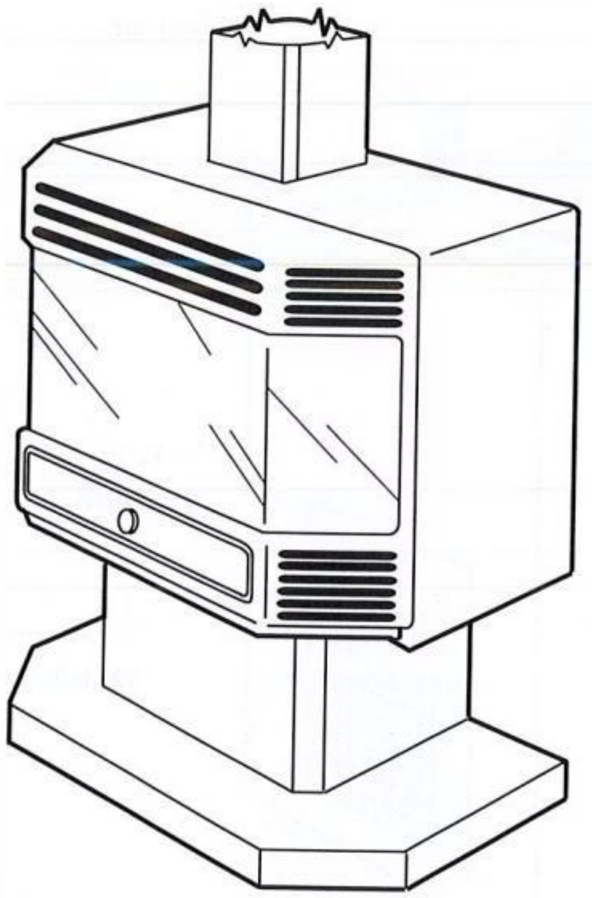
# Zero-Clearance Gas Fireplace

## Design and Installation

Zero-clearance gas fireplaces are factory-built units designed to be installed with minimal clearance to combustible materials.

These units are ideal for new construction or renovations where a traditional masonry fireplace isn't practical. They can be framed directly into walls using standard building materials.

Most zero-clearance fireplaces use direct venting, which draws combustion air from outside and exhausts combustion products to the exterior through a dual-channel vent system.



Zero-clearance fireplaces offer significant installation flexibility, as they can be placed in locations where traditional fireplaces would be impractical. Their sealed combustion systems also provide improved energy efficiency compared to traditional open fireplaces.

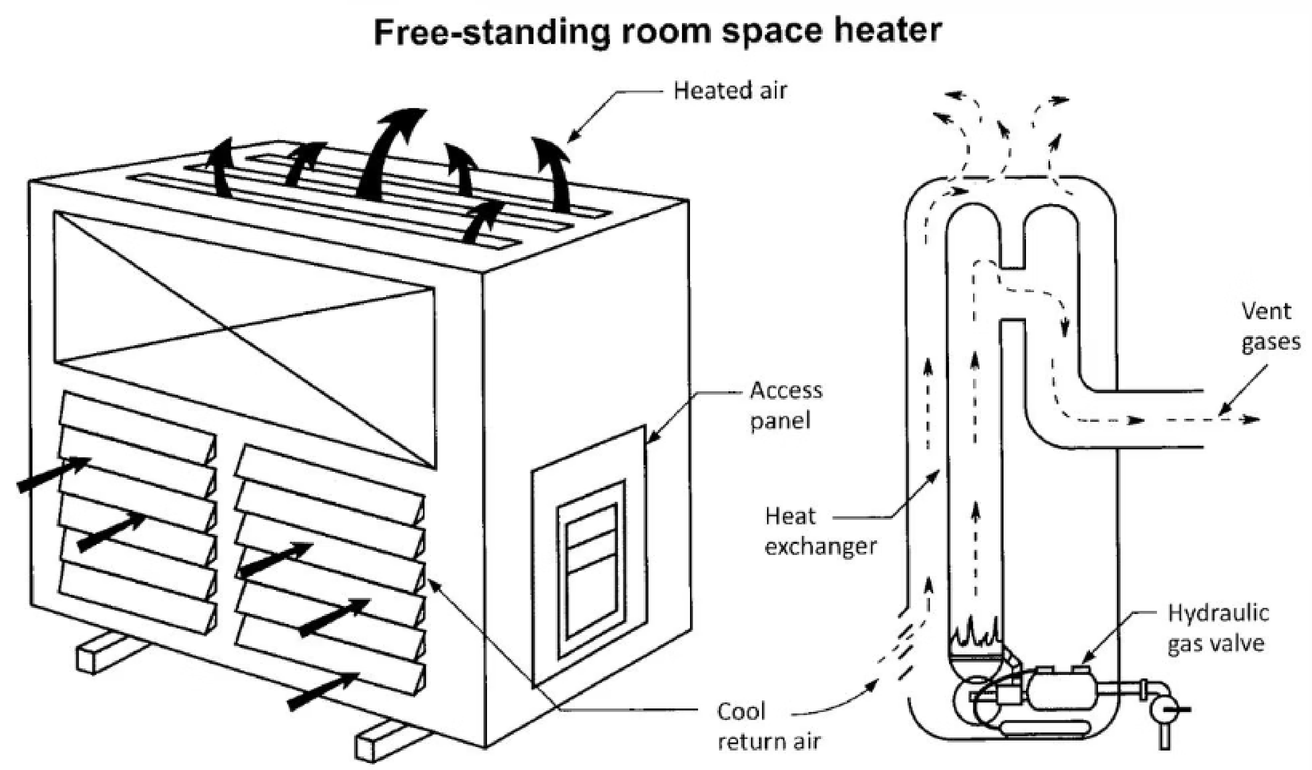
# Room Space-Heater

## Design and Application

The room space-heater is a free-standing, self-contained unit that is installed in the room where heat is necessary. Room heaters must be under thermostatic control. The venting system can be either gravity or forced-air (fan assisted).

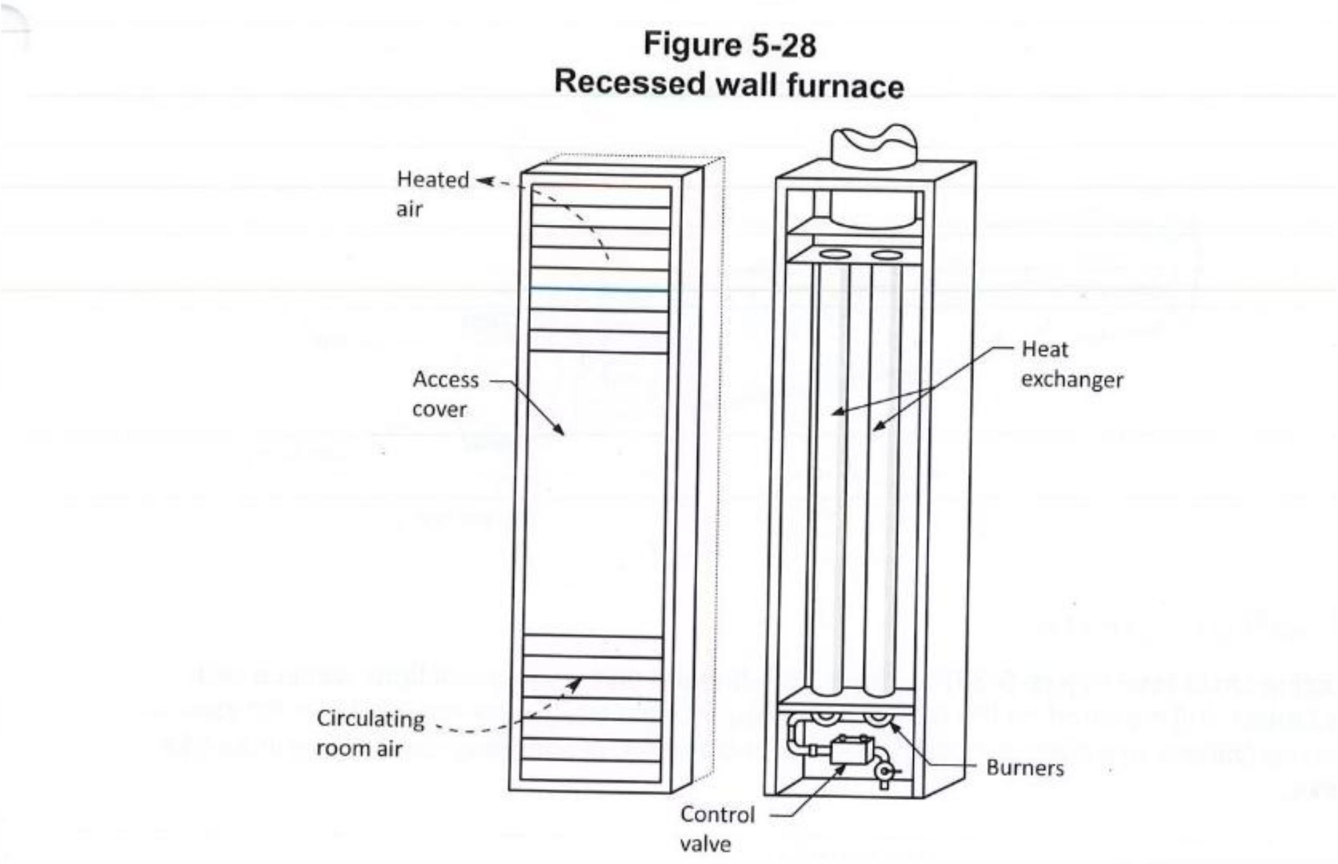
## Specifications

- Heat transfer: Convection, radiation
- Ignition: Standing pilot and spark igniter
- Burner control: Thermostat or manual switch
- Safeties: High-temperature limit switch
- Venting: Direct vent, Type B vent




Room space-heaters are commonly used for supplemental heating in individual rooms or in spaces where central heating is impractical. They provide localized comfort without the need to heat an entire building.

# Recessed Wall Furnace




Wall furnaces are an excellent solution for heating small spaces efficiently. Their compact design makes them ideal for applications where floor space is limited.

## Design and Application

The recessed wall furnace takes up less space and is easier to install than other room heaters. (Wall furnaces were once recessed into the wall between the wall studs, but now they mount directly on the wall.) They are self-contained and available with or without a fan.

You can find these appliances in small houses, room additions, garages, cabins, or motel rooms.

## Specifications

- Heat transfer: Conduction
- Ignition: Standing pilot, spark-ignited pilot, direct spark ignition and hot surface ignition
- Burner control: Thermostat
- Safeties: High-temperature limit switch
- Venting: Type BW vent

# Baseboard Heater

## Design and Application

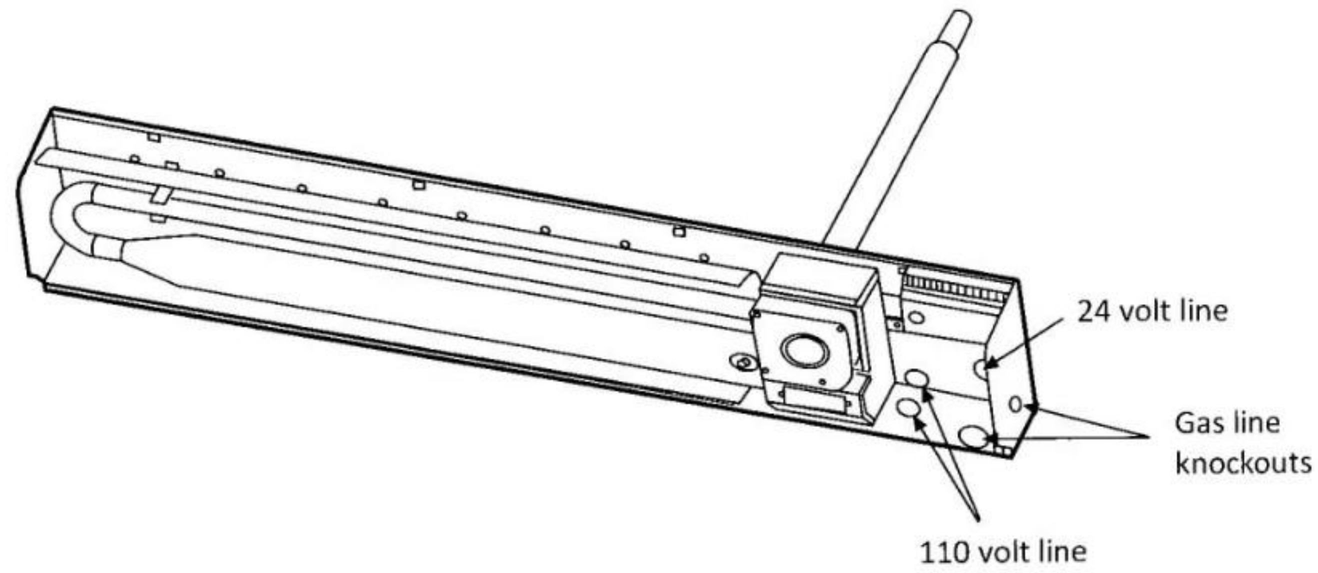
Baseboard heaters operate independently from other sources of heat. They can therefore be installed as required throughout a building. They are usually vented through an outside wall, rather than through the ceiling.

This is a low input heating appliance that heats an area within a room.

## Specifications

- Heat transfer: Conduction, convection
- Ignition: Standing pilot, spark igniter pilot, direct spark ignition, hot surface ignition
- Burner control: Manual switch or thermostat
- Safeties: High temperature limit switch
- Venting: Direct vent

**Figure 5-29**
**Baseboard heater**




Gas baseboard heaters provide an alternative to electric baseboard heating, offering the efficiency of gas with the distributed heating approach of baseboard units. They're particularly useful in rooms with large windows or exterior walls where heat loss is a concern.

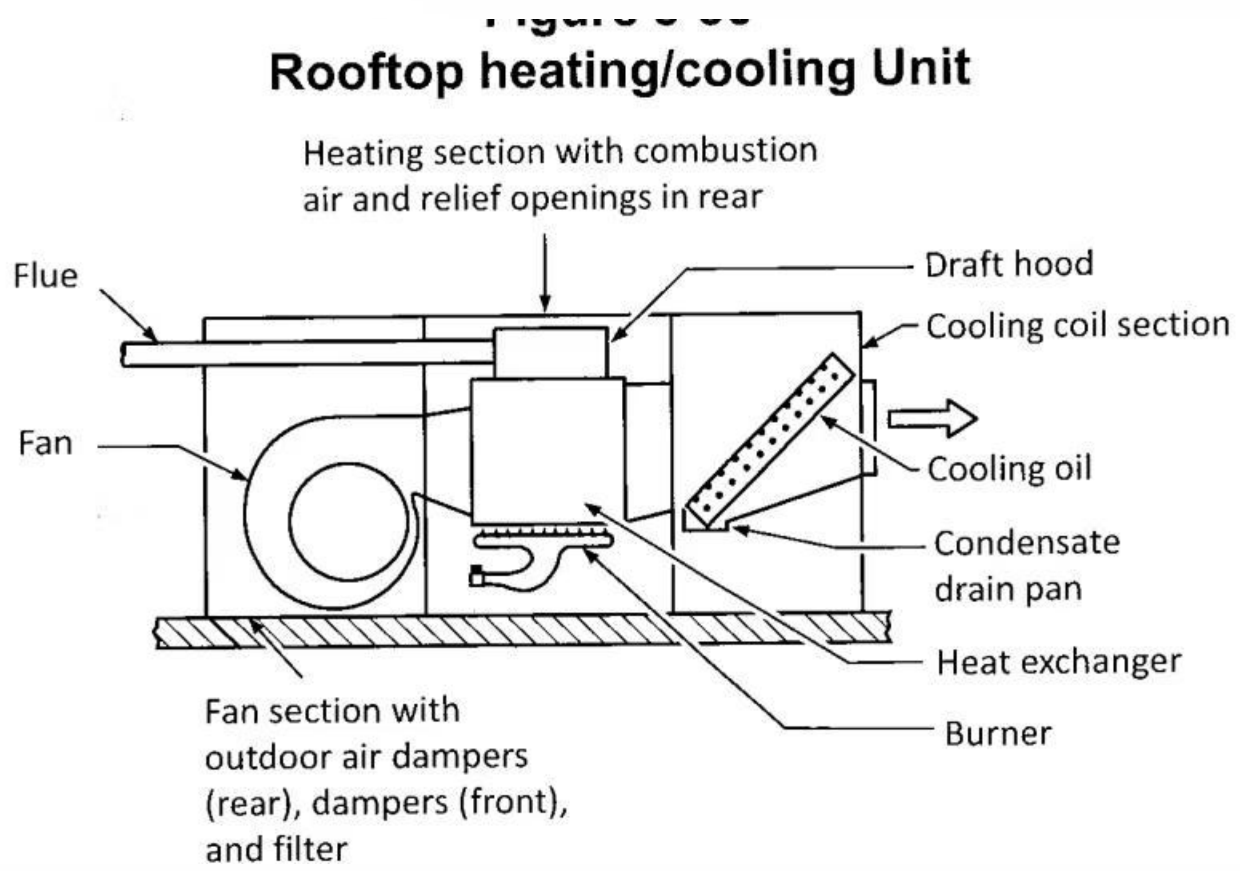
# Rooftop Units

## Design and Application

Rooftop units combine both heating and cooling functions within a self-contained unit mounted on the roof of a building. People mainly use rooftop units for low-rise commercial and industrial applications such as commercial shopping centers and industrial parks.

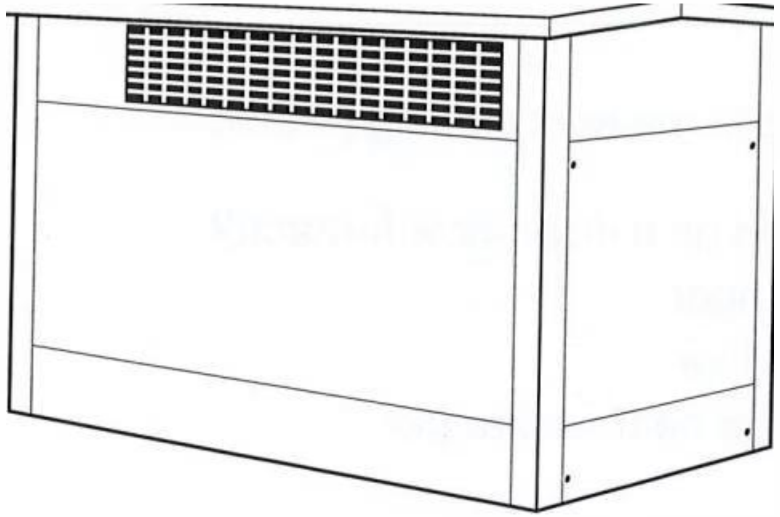
## Specifications

- Heat transfer: Conduction
- Ignition: Spark-ignited pilot, direct spark ignition, hot surface ignition
- Burner control: Thermostat
- Safeties: High-temperature limit switch, gas pressure, and mercury pilot proving switches




Rooftop units offer several advantages for commercial applications, including freeing up valuable interior space, simplified maintenance access, and reduced noise inside the building. Their all-in-one design combines heating, cooling, and ventilation functions in a single package.

# Gas-Fired Residential Generators



Residential gas generators provide reliable backup power during outages, automatically starting when utility power fails and shutting down when it's restored.

## Function and Benefits

You can also install home generator systems to run on your home's natural gas line or propane supply. When a power failure occurs, the electric load automatically transfers to the generator set.

Upon restoration of the commercial power service, the electric load transfers back to the utility line. Because this process is completely automatic, there is the assurance of a ready supply of electric power for lighting, heating, air conditioning, and other various applications.

## Installation Considerations

Gas generators require proper ventilation, clearances from buildings, and connection to the home's electrical system through a transfer switch. Professional installation by qualified technicians is essential for safe operation.

# Professional Development for Gas Technicians

## Manufacturer Training

Most appliance manufacturers offer training on their products or appliances. In some cases, validation of warranties may not be possible for equipment that a licensed, factory trained gas technician/fitter has not installed and/or initiated.

## Continuous Learning

It is in every gas technician's best interest to continuously update their skills with training made available, as this will provide further employability and added value to your customers.

## Code Compliance

It is the responsibility of the gas technician/fitter to comply with all codes as well as their local trade regulations.

## Scope of Practice

Connections made to gas appliances, including potable, hydronic, refrigerant, duct work, and electrical connections that exceed the essential components affecting the safe operation of the appliance must meet local provincial and municipal code requirements and may fall outside a gas technician's/fitter's scope of practice.

# Heat Transfer in Gas Appliances

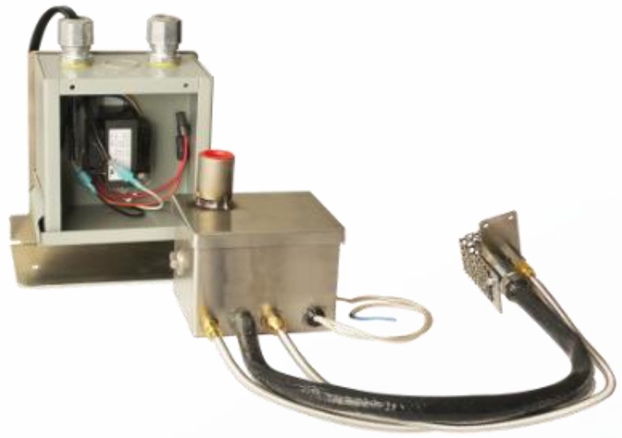
# Ignition Systems in Gas Appliances

## Standing Pilot

A small, continuously burning flame that ignites the main burner when needed. Common in older appliances and some modern decorative gas fireplaces. Advantages include operation without electricity, but they consume gas continuously even when the main burner is off.


## Spark Ignition

Uses an electric spark to ignite the gas when the appliance calls for heat. More energy efficient than standing pilots since no gas is consumed during standby periods. Common in modern ranges, furnaces, and water heaters.



## Hot Surface Ignition

Uses an electric heating element that glows red-hot to ignite the gas. Highly reliable and energy efficient. Commonly found in newer furnaces, water heaters, and boilers. Requires electricity to operate.

# Safety Features in Gas Appliances

1

## Flame Supervision

Ensures gas flow stops if flame is extinguished

2

## Temperature Limits

Prevents overheating of components

## Blocked Vent Protection

Detects improper venting conditions

## Pressure Relief

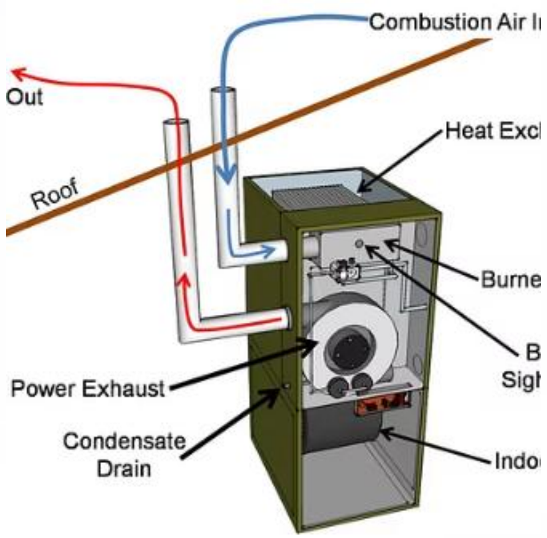
Prevents dangerous pressure buildup

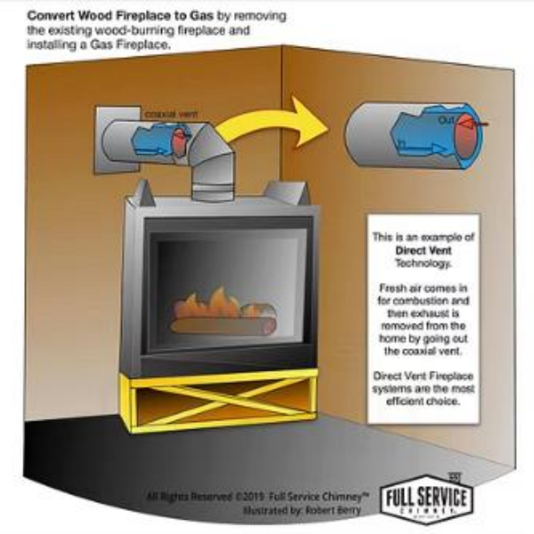
## CO Detection

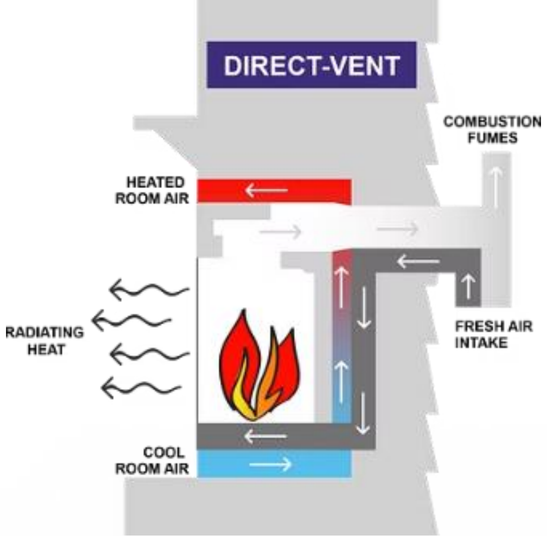
Monitors for dangerous carbon monoxide levels

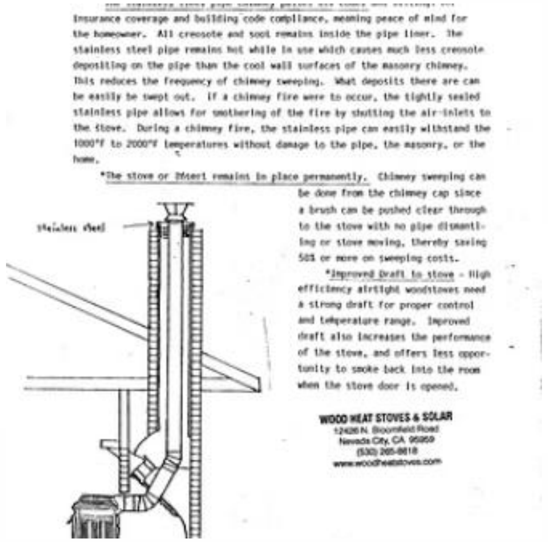
Modern gas appliances incorporate multiple layers of safety features to protect users from potential hazards. These systems work together to ensure safe operation under normal conditions and to shut down the appliance if unsafe conditions are detected.

# Venting Systems for Gas Appliances



insurance coverage and building code compliance, meaning peace of mind for the homeowner. All creosote and soot remains inside the pipe liner. The stainless steel pipe remains hot while in use which causes much less creosote depositing on the pipe than the cool wall surfaces of the masonry chimney. This reduces the frequency of chimney sweeping. What deposits there are can be easily be swept out. If a chimney fire were to occur, the tightly sealed stainless pipe allows for smothering of the fire by shutting the air-inlets to the stove. During a chimney fire, the stainless pipe can easily withstand the 1000°F to 2000°F temperatures without damage to the pipe, the masonry, or the home.

*The stove or insert remains in place permanently. Chimney sweeping can be done from the chimney cap since a brush can be pushed clear through to the stove with no pipe dismantling or stove moving, thereby saving 50% or more on sweeping costs.

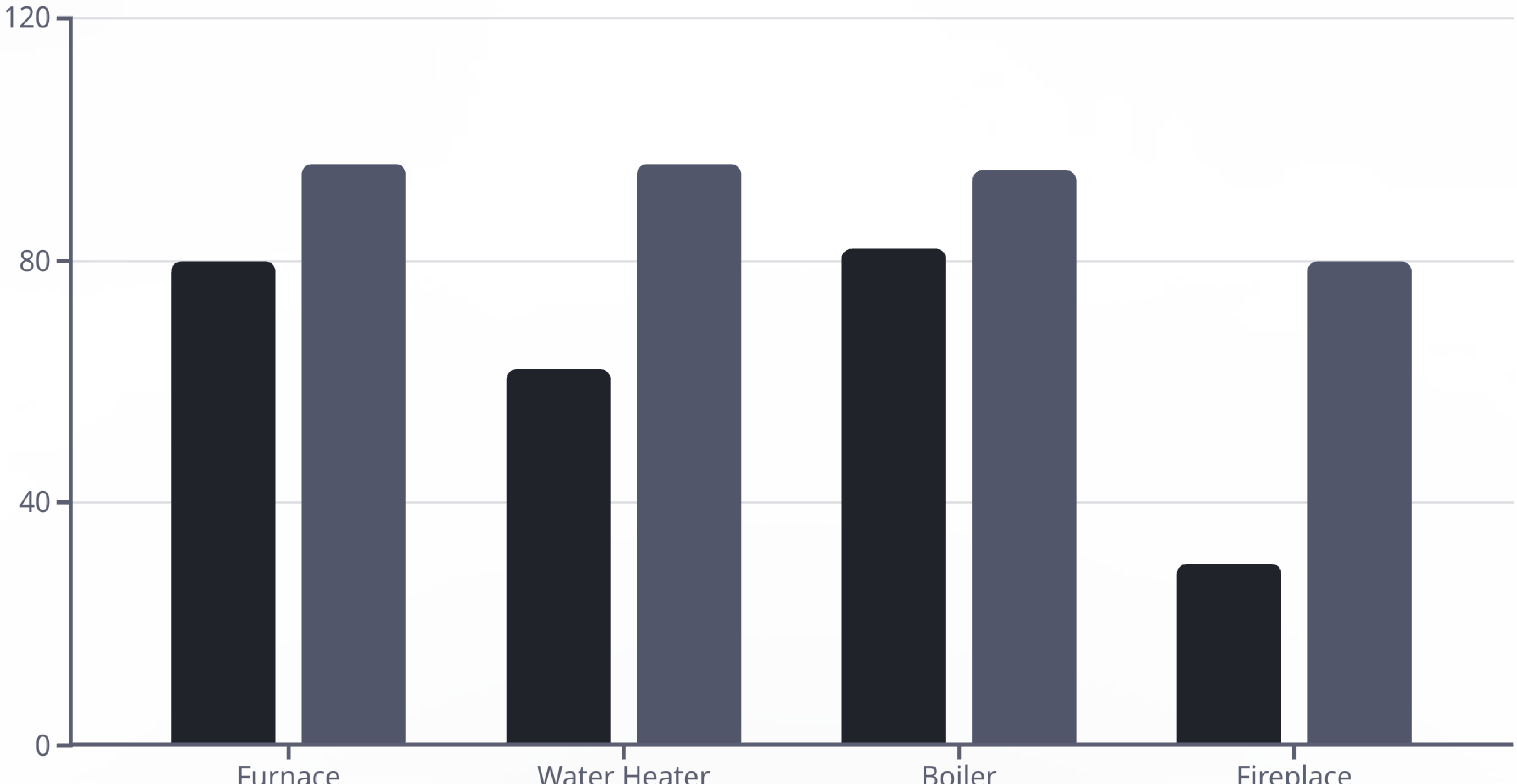
*Improved Draft to stove - High efficiency airtight woodstoves need a strong draft for proper control and temperature range. Improved draft also increases the performance of the stove, and offers less opportunity to smoke back into the room when the stove door is opened.



WOOD HEAT STOVES & SOLAR

Proper venting is critical for the safe operation of gas appliances. The type of venting system used depends on the appliance design, efficiency, and installation location. Common venting systems include B-vent, direct vent, power vent, and chimney systems. High-efficiency condensing appliances typically use PVC venting due to the lower temperature of exhaust gases.

# Efficiency Comparison of Gas Appliances



# Installation Requirements for Gas Appliances

## 7.5

CSA B149.1 Clause

For clothes dryer installation

## 7.26

CSA B149.1 Clause

For pool heater installation

## 7.27

CSA B149.1 Clause

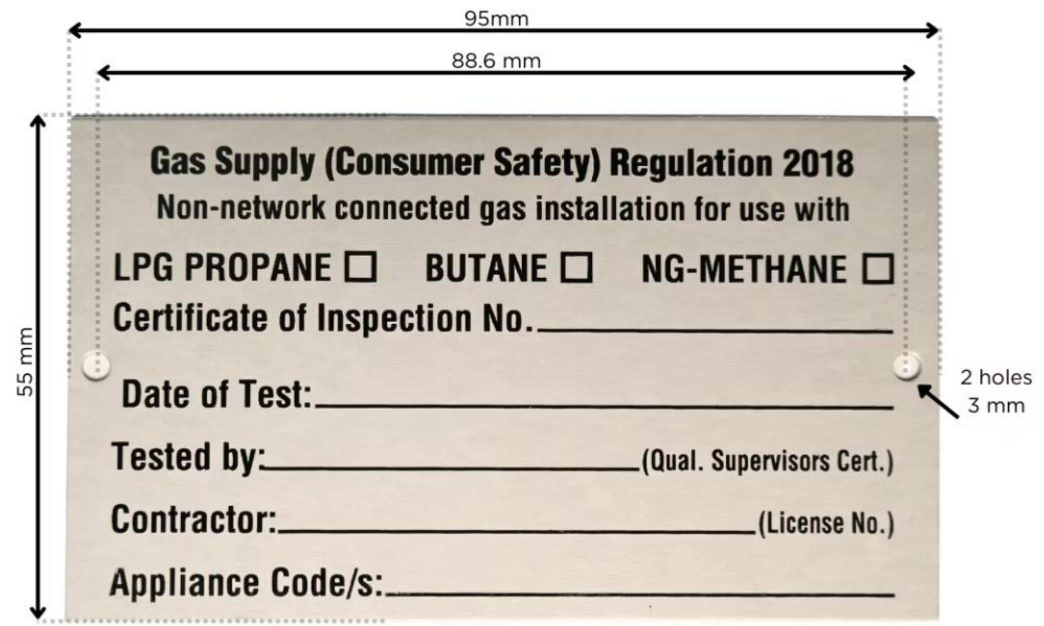
For water heater installation

## 7.28

CSA B149.1 Clause

For unit heater installation

The CSA B149.1 Natural Gas and Propane Installation Code provides specific requirements for the installation of various gas appliances. Each type of appliance has dedicated clauses that address clearances, venting, gas connections, and safety considerations. Gas technicians must be familiar with these requirements to ensure installations meet code compliance and operate safely.



# Troubleshooting Gas Appliances

### Identify the Problem

Gather information about symptoms and operation history

### Test Components

Check ignition, gas supply, controls, and venting

### Diagnose the Issue

Determine the root cause based on test results

### Repair or Replace

Fix the problem following manufacturer guidelines

### Verify Operation

Test the appliance to ensure proper function

# Maintenance Requirements for Gas Appliances

| Appliance Type | Recommended Maintenance Frequency | Key Maintenance Tasks |
|---|---|---|
| Furnace | Annual | Clean burners, check heat exchanger, test safety controls, inspect venting |
| Water Heater | Annual | Flush tank, check anode rod, test T&P valve, inspect burner |
| Boiler | Annual | Check pressure, inspect heat exchanger, test controls, analyze combustion |
| Fireplace | Annual | Clean glass, inspect logs/burner, check venting, test controls |
| Range/Cooktop | As needed | Clean burners, adjust flame, check ignition system |

# Future Trends in Gas Appliance Technology

### Higher Efficiency

Continued improvements in combustion and heat transfer technology

### Hydrogen Compatibility

Appliances designed for hydrogen or hydrogen-blend fuels

### Smart Integration

Connected appliances with remote monitoring and control

### Hybrid Systems

Combination of gas with renewable energy sources

### Lower Emissions

Cleaner combustion with reduced environmental impact

The gas appliance industry continues to evolve with technological advancements focused on improving efficiency, reducing emissions, and enhancing user experience. Future developments will likely include greater integration with smart home systems, compatibility with alternative fuels like hydrogen, and hybrid designs that combine gas with renewable energy sources.

# Summary: Non-vented and Vented Gas Appliances

### Professional Expertise

Continuous learning and certification

### Safety Considerations

Proper installation, venting, and maintenance

### Appliance Diversity

Understanding various types and applications

### Heat Transfer Fundamentals

Conduction, convection, and radiation principles

Gas technicians/fitters must have a comprehensive understanding of the various gas appliances they encounter in the field. This includes knowledge of heat transfer methods, appliance-specific features, installation requirements, and safety considerations. By mastering these fundamentals and staying current with evolving technologies and codes, technicians can ensure safe, efficient, and reliable operation of both non-vented and vented gas appliances.


# CSA Unit 9

# Chapter 6 Requirements for Converting Appliances Between Propane and Natural Gas

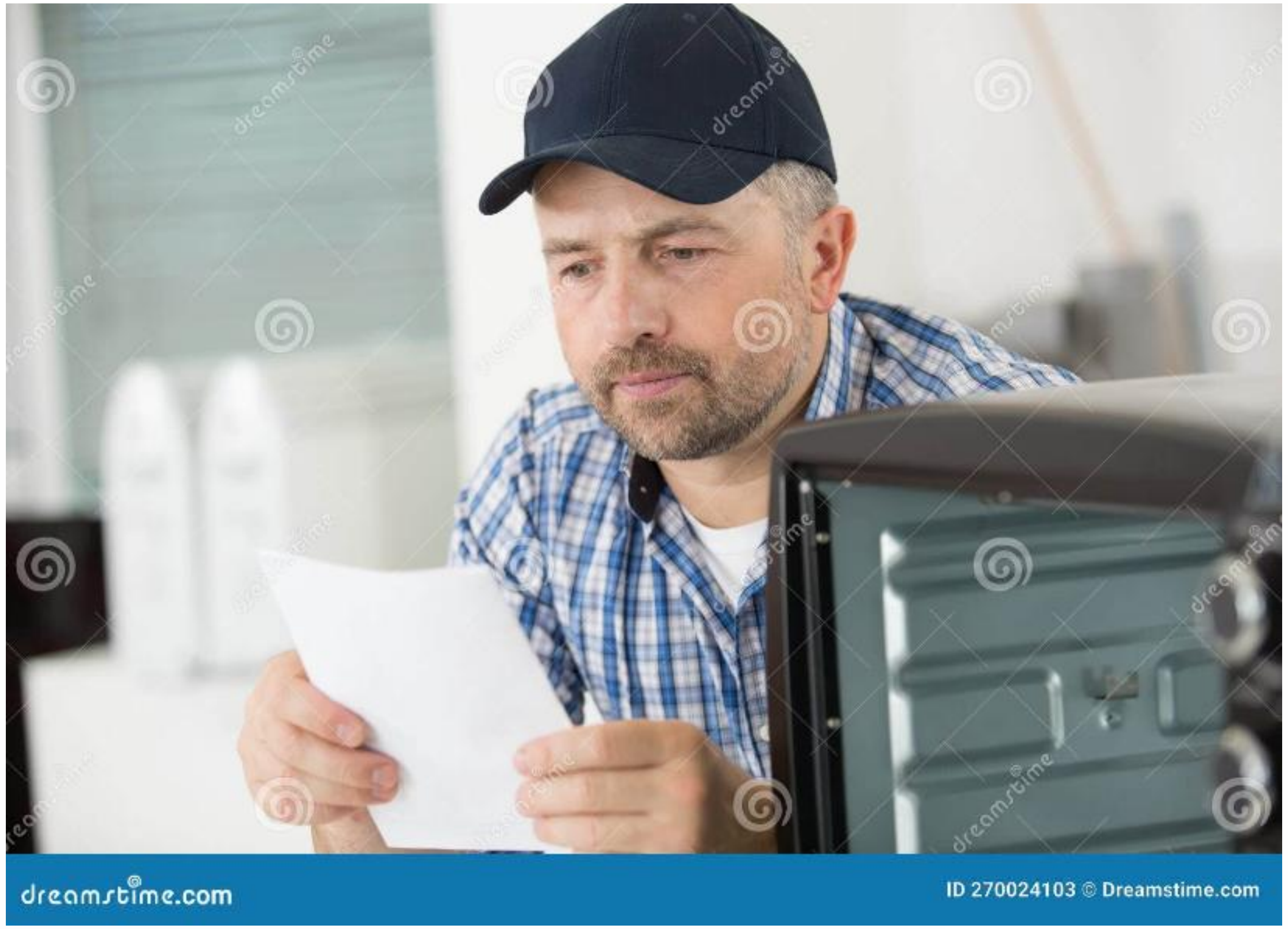
This presentation covers the essential requirements and responsibilities for safely converting appliances between propane and natural gas. Gas technicians must understand the critical differences between these fuel types and follow proper procedures to ensure safe and effective conversions.

# Purpose of Conversion Requirements

## Why Proper Conversion Matters

While natural gas and propane have similarities in appliance appearance and operation, their differences in specific gravity and calorific value must be considered when converting from one fuel to the other.

It is the responsibility of the gas technician/fitter making the conversion to ensure it is done safely, following all manufacturers' instructions and gas code requirements.



# Learning Objectives

## Describe installer's responsibilities

Understand the legal and technical obligations of gas technicians performing conversions

## Describe the requirements for conversion

Learn the technical specifications and procedures needed for safe and effective fuel conversions

# Key Terminology

### Gas Orifice

Hole or opening used to control the direction and amount of gas that is discharged into a burner


# Common Conversion Scenarios

### Natural Gas Availability

Conversion of propane appliances to natural gas when this fuel type becomes available to an area

### Barbecue Hookups

Propane barbecues that are hooked up to a natural gas supply

### Rural Installations

Post-purchase conversion of new natural gas appliances to propane when installed in areas where only propane is available

# Required Combustion Analysis

## Completeness of Combustion

Verify that fuel is burning efficiently and completely

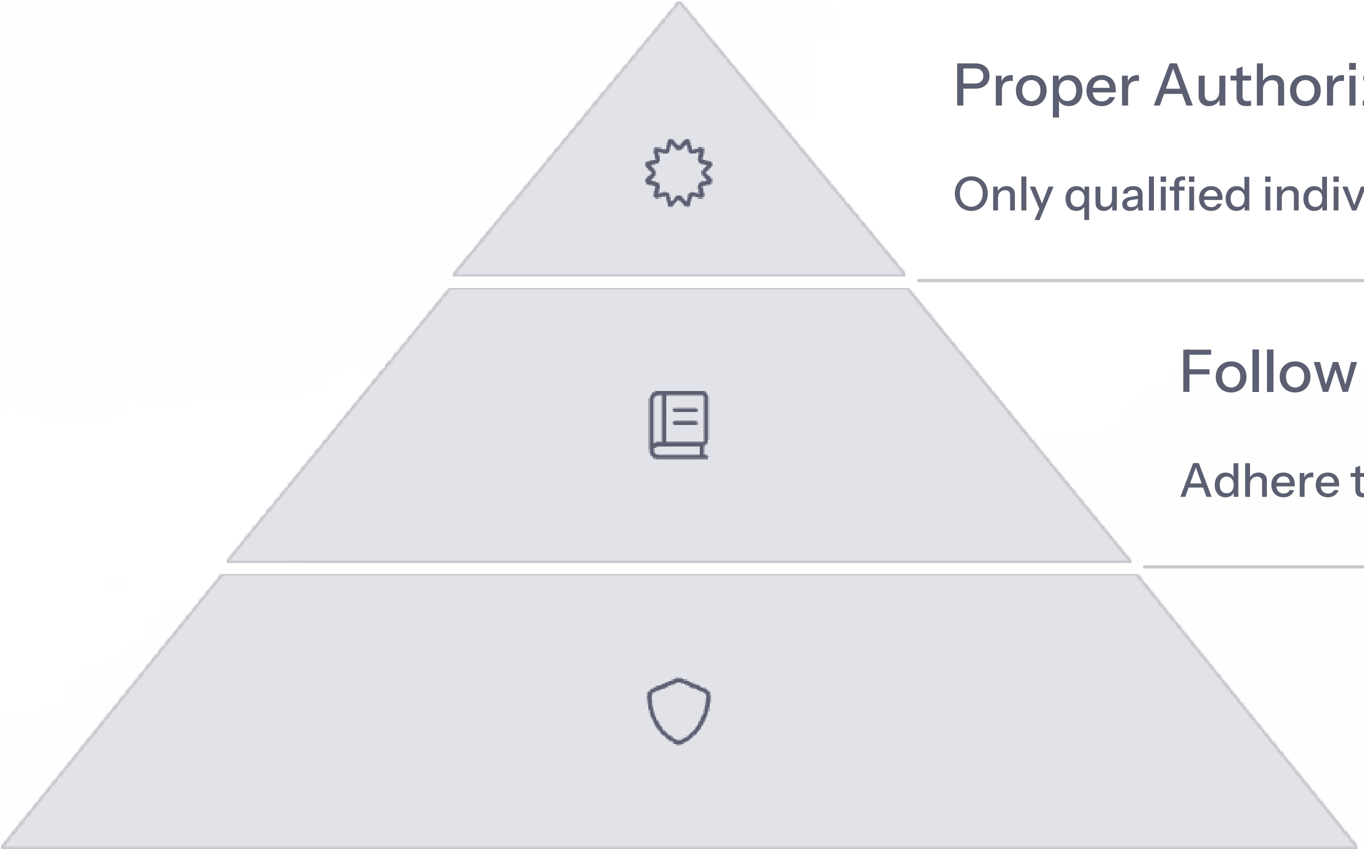
## Test for Toxic Gases

Ensure no dangerous byproducts like carbon monoxide are being produced

## Verify Proper Burner Operation

Confirm burners are functioning correctly with the new fuel type

# Installer's Responsibilities



### Proper Authorization

Only qualified individuals may perform conversions

### Follow Procedures

Adhere to manufacturer instructions and codes

### Safety First

Ensure all conversions are performed safely

The conversion of appliances from one fuel type to another requires special knowledge and procedures. If performed incorrectly, the appliance will not function properly and may prove potentially dangerous. The gas technician/fitter must therefore perform all procedures properly and, in some cases, arrange for inspection of the converted appliance by the inspection authority or an agency authorized by the inspection authority.


# Authorization Requirements

### Qualified Personnel

Only authorized individuals have permission to perform fuel type conversion on appliances with inputs of 400,000 Btu/h or less.

### Local Regulations

Check local regulations to determine the applicable qualifications.

### Permits

Some jurisdictions may require a permit prior to converting an appliance to an alternative fuel.

### Manufacturer Instructions

Always adhere to manufacturer's certified conversion instructions when these are available or obtain manufacturer's information.

# Pre-Conversion Inspection

### Inspect the appliance and heat exchanger

Ensure they are safe for continued use

### Remove components for inspection

Check burners, blowers, humidifiers, etc.

### Look for damage or wear

Identify scale, holes, cracks, water leaks, and seals

### Verify approval for conversion

Confirm existing appliance is approved for conversion

# Input Requirements

1

### Maintain Same Input

When converting an appliance, the input must remain the same, and the new gas must have a marking on the rating plate.

2

### Consider Orifice and Pressure

Based on the same orifice diameter and gas pressure, propane supplies a greater input than natural gas.

3

### Evaluate Supply Pipe Size

The supply pipe size may need a replacement during the conversion.

## GAS PIPE SIZING CHART

### NATURAL GAS

| PIPE LENGTH (feet) | 1/2" | 3/4" | 1" | 1 - 1/4" | 1 - 1/2" | 2" | 2 - 2 1/2" | 3" | 4" |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 108 | 230 | 387 | 793 | 1237 | 2259 | 3640 | 6434 | - |
| 20 | 75 | 160 | 280 | 569 | 877 | 1610 | 2613 | 5236 | 9521 |
| 30 | 61 | 129 | 224 | 471 | 719 | 1335 | 2165 | 4107 | 7859 |
| 40 | 52 | 110 | 196 | 401 | 635 | 1143 | 1867 | 3258 | 6795 |
| 50 | 46 | 98 | 177 | 364 | 560 | 1041 | 1680 | 2936 | 6142 |
| 60 | 42 | 89 | 159 | 336 | 513 | 957 | 1559 | 2684 | 5647 |
| 70 | 38 | 82 | 149 | 317 | 476 | 896 | 1447 | 2492 | 5250 |
| 80 | 36 | 76 | 140 | 239 | 443 | 840 | 1353 | 2315 | 4900 |
| 90 | 33 | 71 | 133 | 275 | 420 | 793 | 1288 | 2203 | 4667 |
| 100 | 32 | 68 | 126 | 266 | 411 | 775 | 1246 | 2128 | 4518 |
| 125 | 28 | 60 | 117 | 243 | 369 | 700 | 1143 | 1904 | 4065 |
| 150 | 25 | 54 | 105 | 215 | 327 | 625 | 1008 | 1689 | 3645 |
| 175 | 23 | 50 | 93 | 196 | 303 | 583 | 993 | 1554 | 3370 |
| 200 | 22 | 47 | 84 | 182 | 280 | 541 | 877 | 1437 | 3160 |
| 300 | 17 | 37 | 70 | 145 | 224 | 439 | 686 | 1139 | 2539 |

Natural Gas (NG) flow is given in thousands of BTU/hr. One cubic foot of NG gas - 1000 BTU.

Nominal pressure at the burner for Natural Gas is 3.5" of water column. (Typical machine supply 5" - 7").

Pipe length must include additional length for all fittings. Add approximately 5 feet of pipe per fitting.

Natural Gas Example: A machine with a burner that requires 440,000 BTU would need a 1 - 1/4" pipe for a 20' long run.

### LIQUID PROPANE

| PIPE LENGTH (feet) | 1/2" | 3/4" | 1" | 1 - 1/4" | 1 - 1/2" | 2" | 2 - 2 1/2" | 3" | 4" |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 275 | 567 | 1071 | 2205 | 3307 | 6221 | 10140 | 17990 | 35710 |
| 20 | 189 | 393 | 732 | 1496 | 2299 | 4331 | 7046 | 12510 | 25520 |
| 30 | 152 | 315 | 590 | 1212 | 1858 | 3465 | 5695 | 10110 | 20620 |
| 40 | 129 | 267 | 504 | 1039 | 1559 | 2992 | 4778 | 8481 | 17300 |
| 50 | 114 | 237 | 448 | 913 | 1417 | 2646 | 4343 | 7708 | 15730 |
| 60 | 103 | 217 | 409 | 834 | 1275 | 2394 | 3908 | 6936 | 14150 |
| 70 | 89 | 185 | 346 | 724 | 1086 | 2047 | 3329 | 5908 | 12050 |
| 80 | 78 | 162 | 307 | 630 | 976 | 1811 | 2991 | 5309 | 10830 |
| 90 | 69 | 146 | 275 | 567 | 866 | 1606 | 2654 | 4711 | 9613 |
| 100 | 63 | 132 | 252 | 511 | 787 | 1496 | 2412 | 4281 | 8736 |
| 125 | 54 | 112 | 209 | 439 | 665 | 1282 | 2083 | 3618 | 7382 |
| 150 | 48 | 100 | 185 | 390 | 590 | 1138 | 1808 | 3210 | 6549 |
| 175 | 43 | 90 | 168 | 353 | 534 | 1030 | 1637 | 2905 | 5927 |
| 200 | 40 | 83 | 155 | 325 | 491 | 947 | 1505 | 2671 | 5450 |
| 300 | 37 | 77 | 144 | 303 | 458 | 887 | 1404 | 2492 | 5084 |

Liquid Propane (LP) flow is given in thousands of BTU/hr. One cubic foot of NG gas - 2516 BTU.

This chart refers to low pressure LP, after regulation, standard nominal pressure at the burner for Liquid Propane Gas is 11" of water column

Pipe length must include additional length for all fittings. Add approximately 5 feet of pipe per fitting.

Liquid Propane Example: A machine with a burner that requires 440,000 BTU would need a 1" pipe for a 20' long run.

NOTE: The sizing charts above list the specific pipe sizes required for the amount of BTU's for a new gas line installations. If you are using an existing gas line you must take into consideration the existing gas line capacities to ensure you will have proper pressure. This chart is for reference only, we recommend you consult with a Licensed Plumber/Gas Fitter or NFPA54 (National Fuel Gas Code - current edition) for more details.

# Pipe Sizing Considerations

## Natural Gas to Propane

When converting from natural gas (7 in w.c.) to propane (11 in w.c.), unless the original piping or tubing was undersized, the requirement for new piping or tubing is not likely.

## Propane to Natural Gas

When converting from propane (11 in w.c.) to natural gas (7 in w.c.), new gas piping or tubing will likely need to satisfy sizing requirements.

## New Piping Requirements

When new piping is required, safe removal and abandonment of the old piping is a must.

# Propane Tank Decommissioning

Shut off all valves

Ensure all gas flow is stopped completely

Disconnect the pipe or tubing

Safely remove all connections to the tank

Plug the openings

Seal all openings to prevent gas leakage

# Venting and Air Requirements

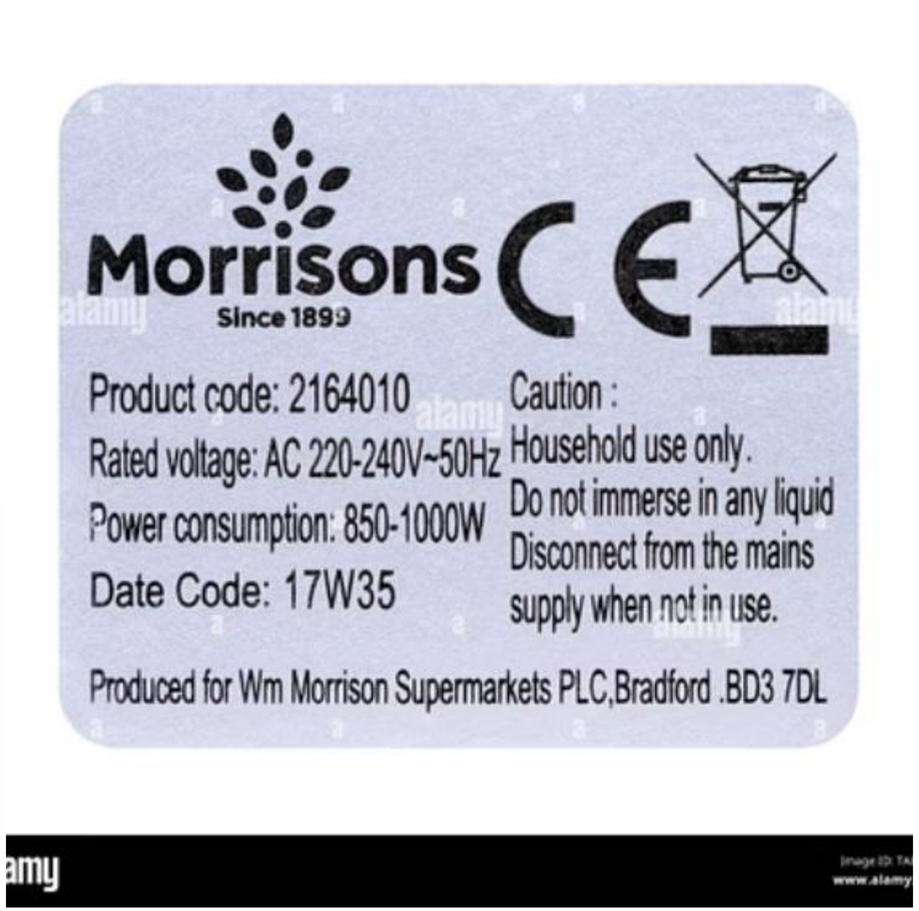
## Based on Input

The requirements for venting and combustion air are based on input and, therefore, do not normally undergo modification.

## Inspection Required

Checking the venting and air supply ducting to ensure their compliance with the Code requirements and their good physical condition is a must.

# CSA B149.1 Conversion Requirements




4.5.3 When an appliance is converted from the gas or fuel specified on the rating plate, the conversion shall be in accordance with the manufacturer's certified instructions. If there are no manufacturer's certified instructions for conversion of the appliance, the converted appliance shall be approved.

4.5.4 If an appliance is converted from one gas to another, the gas to which it is converted shall be marked on the appliance rating plate by the fitter making the conversion.

# Natural Gas to Propane Conversion Scenarios

### Certified conversion kit available

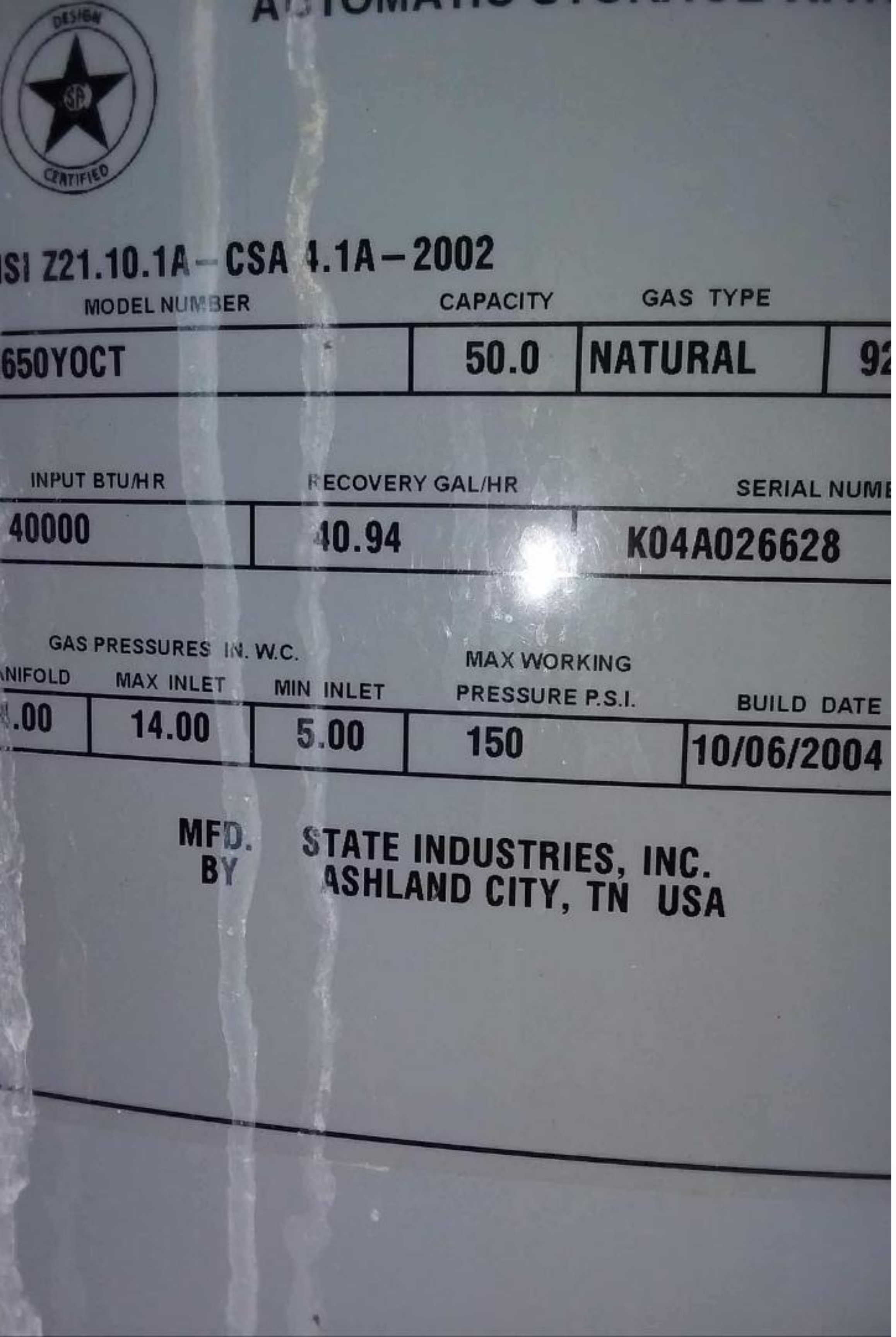
Follow manufacturer's instructions

### Similar model certified but no kit

Contact manufacturer for parts

### Natural gas only certification

Requires inspection authority approval




# Scenario 1: Certified Conversion Kit Available

1

## Follow Manufacturer's Instructions

The authorized gas technician/fitter may perform the conversion according to the manufacturer's certified conversion instructions—no additional approval is necessary.

2

## Update Rating Plate

The manufacturer should include a label or sticker for the rating plate indicating that the conversion has taken place and the appliance is now operating on propane gas.

# Scenario 2: Similar Model Certified for Propane

## Contact Manufacturer

Contact the appliance manufacturer and obtain the necessary parts to convert the appliance.

## Make the Conversion

Perform the conversion using the manufacturer-supplied parts.

## Request Inspection

Contact the agency certifying the appliance and request an inspection and a new rating plate.

# Scenario 3: Natural Gas Only Certification

## Field Approval Required

The inspection authority or an agency authorized by the inspection authority (field approved) must test and label the conversion.

## Cost Consideration

The gas technician/fitter should consider the costs of appliance recertification before deciding to proceed with the conversion.

# Propane to Natural Gas Conversion Scenarios

Certified conversion kit available

Follow manufacturer's instructions

Similar model certified but no kit

Contact manufacturer for parts

Propane only certification

Requires inspection authority approval

# Scenario 1: Certified Conversion Kit Available

## Follow Manufacturer's Instructions

Under these circumstances, the authorized gas technician/fitter may perform the conversion according to the manufacturer's certified conversion instructions—no additional approval is necessary.

## Update Rating Plate

In this case the manufacturer should include a label or sticker for the rating plate indicating that the conversion has taken place and the appliance is now rated for natural gas.

# Scenario 2: Similar Model Certified for Natural Gas

Contact the appliance manufacturer

Obtain the necessary parts to convert the appliance

Make the conversion

Install the parts according to manufacturer guidance

Request inspection and new rating plate

Contact the agency certifying the appliance

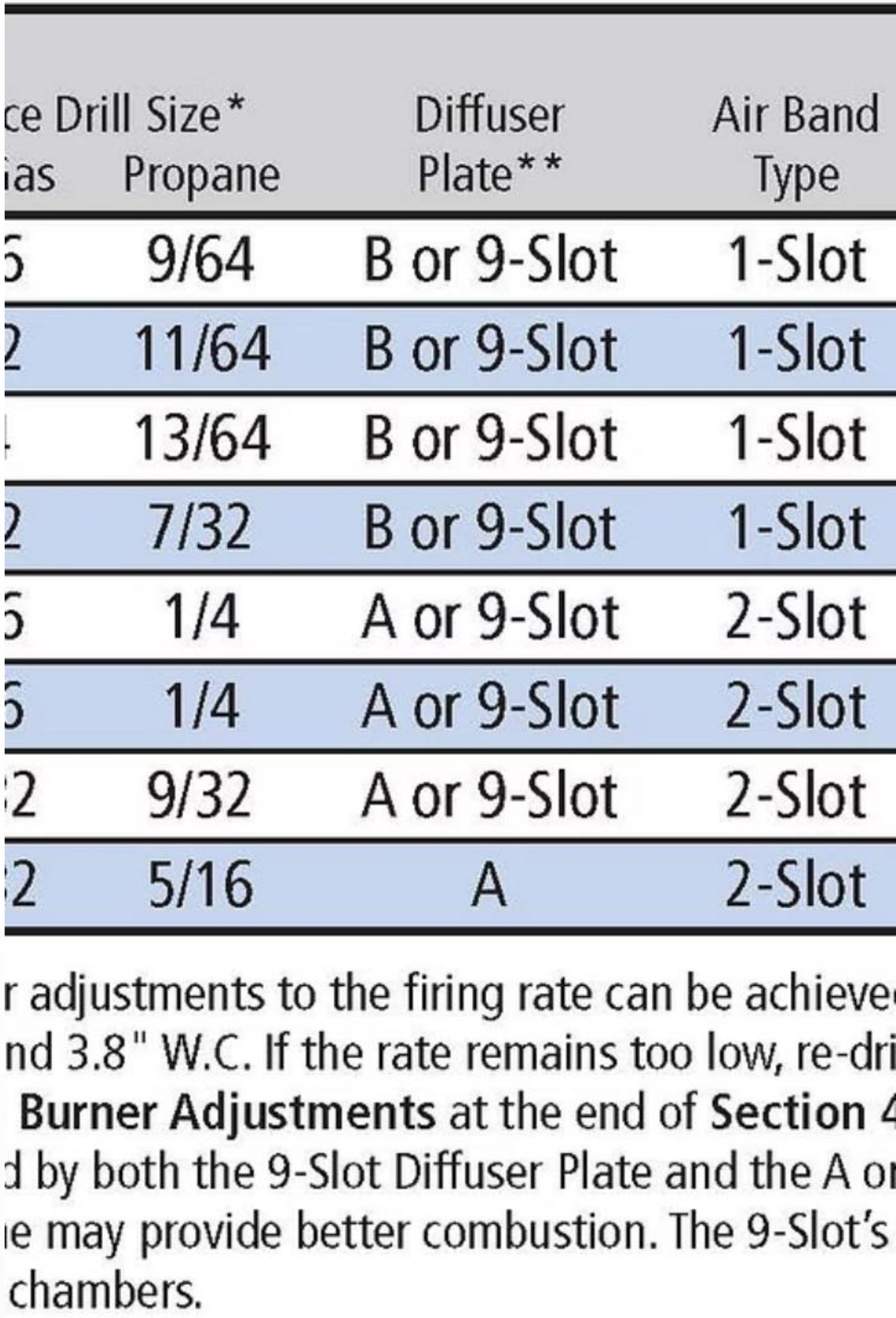
# Important Considerations for Scenario 2

## Burner Orifice Sizing

When performing these conversions, the most important factors to consider are burner orifice sizing and manifold pressure settings.

## Follow Instructions

It is also very important to follow the manufacturer's instructions.



| ce Drill Size* | | Diffuser | Air Band |
|---|---|---|---|
| ias | Propane | Plate** | Type |
| 5 | 9/64 | B or 9-Slot | 1-Slot |
| 2 | 11/64 | B or 9-Slot | 1-Slot |
| [illegible] | 13/64 | B or 9-Slot | 1-Slot |
| 2 | 7/32 | B or 9-Slot | 1-Slot |
| 5 | 1/4 | A or 9-Slot | 2-Slot |
| 5 | 1/4 | A or 9-Slot | 2-Slot |
| 2 | 9/32 | A or 9-Slot | 2-Slot |
| 2 | 5/16 | A | 2-Slot |

r adjustments to the firing rate can be achieve
nd 3.8" W.C. If the rate remains too low, re-dri
**Burner Adjustments** at the end of **Section 4**
d by both the 9-Slot Diffuser Plate and the A or
e may provide better combustion. The 9-Slot's
chambers.

# Scenario 3: Propane Only Certification

## Field Approval Required

In this case, the inspection authority or an agency authorized by the inspection authority (field approved) must test and label the conversion.

## Cost Consideration

Another factor to consider before deciding to proceed with the conversion is the costs of appliance recertification.

# Burner Orifice Sizing

Performing conversions entails the purchase and installation of a properly sized gas orifice.

A gas orifice is a hole or opening that controls the direction and amount of gas discharged into a burner. Burner orifices come in a variety of shapes and sizes, and the actual size and configuration of each orifice depends on several factors.

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**ORIFICE METERING SYSTEM**
Bulletin 8697

Ref: Sheets 8697-3 and -5, Bulletin 8736

April 2013

8697 Metering Orifices accurately measure gas flows to industrial burners. They are compact, inexpensive, and can be installed in individual burner gas lines to expedite adjustment of air/fuel ratio. They allow easy checking of operation while burners are firing.

Individual metering orifices are a great convenience on multi-burner furnaces, facilitating setting all burners the same or in desired gradients. Some installations add a larger 8697 Metering Orifice (upstream of the individual units) for continuous metering of total gas consumption in a zone or for the whole furnace.

Many plants also use 8697 Metering Orifices in burner air lines to enable precise matching flows of combustion air and gas.

**FEATURES**

8697 Sizes: ½" through 4" pipe size

Nominal flows: 90 scfh to 15,700 scfh natural gas

Flexibility: Each orifice holder offers a choice of seven or eight plates that can be exchanged without removing holder from pipe. This allows convenient on the job tailoring of the meter to fit its requirements.

**INSTALLATION**

10 Straight clean pipe diameters upstream, 4 diameters downstream, without valves or fittings.

For maximum accuracy, readings must be corrected for:
- gas (or air) line pressure
- gas (or air) temperature
- barometric pressure
- Sheets 8697-3 and 8697-5 deal with correction factors

Observe straight pipe run requirements.

Pressure taps should be on top or side of pipe to reduce problems with dirt or condensate collecting in taps or manometer hose.

When pressure is over 3 psi, remove hose barbs and install tube fittings to use metal tubing, rather than hose, between metering orifice and manometer.

When metering oxygen, use specially cleaned pipe and oxygen approved differential-pressure gauges and equipment.

**Models:**

**8697--A:** Standard meter for air and fuel gases up to 25 psi * pressure.

**8697--C:** Meter specially cleaned for oxygen service up to 25 psi pressure.

**SELECTING AN ORIFICE**

1. Determine high fire air flow rate at the burner.
2. Determine corresponding gas flow rate: (For typical natural gas, divide air flow by 11 to determine gas flow.) See table below for other air/gas volume ratios.
3. Select next smaller orifice plate capacity from Table B1 (realize that the plate capacity is offered in a number of different pipe size holders).

**8697 Orifice Holder with interchangeable orifice plates.**

| Fuel Gases | Air/gas volume ratios (10% XSAir and typical fuels) |
|---|---|
| natural | 11 |
| propane | 26.2 |
| butane | 33.6 |
| coke oven | 5.3 |

**Example:**

1. A 4422-7-A Burner passes 27,000 scfh air at 16 osi (assuming 16 osi represents "high fire" for this example).
2. Corresponding natural gas flow is 2455 scfh.
3. A #2000 plate is preferred because its higher required pressure drop--approximately 5.3"wc--means **low fire** readings will be easier and more accurate.

The 4422-7-A Burner has a 2½" gas connection; a #2000 plate is offered in the 8697-5 (2½") holder (as well as in the -3 [1½"] and -4 [2"] units), so an 8697-5-A2000 Metering Orifice may be the most convenient for this job.

* Maximum allowable prssure is 3 psig on all 8697A series orifice holders manufactured prior to October 2011.

# Factors Affecting Orifice Design

## Type of Gas

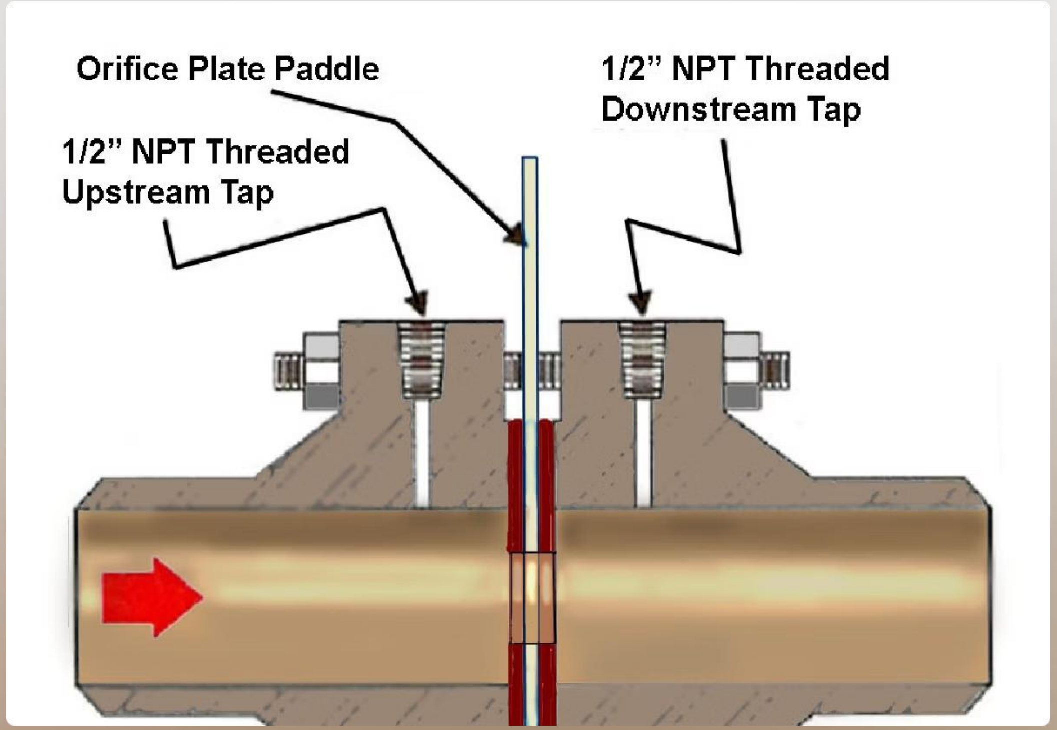
This is the most critical factor in orifice design. Although the specific gravity of propane is higher than natural gas (which will limit the flow through an orifice), the heat capacity of propane is higher than natural gas.

## Appliance Input

The orifice size directly affects the consumption rate of the appliance. The larger the appliance capacity, the larger the orifice size.

## Manifold Pressure

This influences the size of orifice required, since the greater the pressure, the greater the volumetric flow through the orifice.



# Propane vs. Natural Gas Orifice Size

## Heat Capacity Difference

Producing the same amount of heat requires a lesser volume of propane than when natural gas is used.

## Orifice Size Comparison

This means that a propane orifice will always be smaller than a natural gas orifice for the same heat output.

# Maintaining Proper Input Rate

## Follow Manufacturer Specifications

Always keep the appliance input rate the same as the one that the appliance manufacturer specified on the appliance rating plate or on the certified conversion kit instructions.

## Risks of Improper Adjustment

Improper input rate adjustment can result in poor burner flame characteristics and/or the production of carbon monoxide.

## Dangers of Overfiring

Overfiring can result in a potential fire hazard as well as overheating and destruction of the heat exchangers.

## Gas Pipe Size and BTU Supply Chart

**Natural Gas**
**Inlet Pressure:** Less than 2 psi
**Pressure Drop:** 0.5 in w.c.
**Specific Gravity:** 0.60

**Natural Gas** flow is given in thousands of BTU/hour. One cubic foot of NG gas = 1000 BTU's. Pipe length must include additional length for all fittings. Add approximately 5 feet of pipe per fitting. Natural Gas Example: A burner that requires 374,000 BTU would need a 1" pipe for a 30' long run.

| PIPE SIZE (inches) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nominal | ½" | ¾" | 1" | 1 ¼" | 1 ½" | 2" | 2 ½" | 3" | |
| Actual ID | 0.622 | 0.824 | 1.049 | 1.380 | 1.610 | 2.067 | 2.469 | 3.068 | 4. |
| Length (ft) | Capacity in Cubic Feet of Gas per Hour | | | | | | | | |
| 10 | 172 | 360 | 678 | 1,390 | 2,090 | 4,020 | 6,400 | 11,300 | 23 |
| 20 | 118 | 247 | 466 | 957 | 1,430 | 2,760 | 4,400 | 7,780 | 15 |
| 30 | 95 | 199 | 374 | 768 | 1,150 | 2,220 | 3,530 | 6,250 | 12 |
| 40 | 81 | 170 | 320 | 657 | 985 | 1,900 | 3,020 | 5,350 | 10 |
| 50 | 72 | 151 | 284 | 583 | 873 | 1,680 | 2,680 | 4,740 | 9, |
| 60 | 65 | 137 | 257 | 528 | 791 | 1,520 | 2,430 | 4,290 | 8, |
| 70 | 60 | 126 | 237 | 486 | 728 | 1,400 | 2,230 | 3,950 | 8, |
| 80 | 56 | 117 | 220 | 452 | 677 | 1,300 | 2,080 | 3,670 | 7, |
| 90 | 52 | 110 | 207 | 424 | 635 | 1,220 | 1,950 | 3,450 | 7, |
| 100 | 50 | 104 | 195 | 400 | 600 | 1,160 | 1,840 | 3,260 | 6, |
| 125 | 44 | 92 | 173 | 355 | 532 | 1,020 | 1,630 | 2,890 | 5, |
| 150 | 40 | 83 | 157 | 322 | 482 | 928 | 1,480 | 2,610 | 5, |
| 175 | 37 | 77 | 144 | 296 | 443 | 854 | 1,360 | 2,410 | 4, |
| 200 | 34 | 71 | 134 | 275 | 412 | 794 | 1,270 | 2,240 | 4, |
| 250 | 30 | 63 | 119 | 244 | 366 | 704 | 1,120 | 1,980 | 4, |
| 300 | 27 | 57 | 108 | 221 | 331 | 638 | 1,020 | 1,800 | 3, |
| 350 | 25 | 53 | 99 | 203 | 305 | 587 | 935 | 1,650 | 3, |
| 400 | 23 | 49 | 92 | 189 | 283 | 546 | 870 | 1,540 | 3, |

**Liquid Propane**
**Inlet Pressure:** 11.0 in w.c.
**Pressure Drop:** 0.5 in w.c.
**Specific Gravity:** 1.50

**Liquid Propane** gas flow is given in thousands of BTU/hour. One cubic foot of LP gas = 2516 BTU's. **This chart refers to low pressure Liquid Propane, after regulation.** Pipe length must include additional length for all fittings. Add approximately 5 feet of pipe per fitting. Liquid Propane Example: A burner that requires 787,000 BTU would need a 1" pipe for a 20' long run.

| PIPE SIZE (inches) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nominal | ½" | ¾" | 1" | 1 ¼" | 1 ½" | 2" | 2 ½" | 3" | |
| Actual ID | 0.622 | 0.824 | 1.049 | 1.380 | 1.610 | 2.067 | 2.469 | 3.068 | 4. |
| Length (ft) | Capacity in Cubic Feet of Gas per Hour | | | | | | | | |
| 10 | 291 | 608 | 1,150 | 2,350 | 3,520 | 6,790 | 10,800 | 19,100 | 39 |
| 20 | 200 | 418 | 787 | 1,620 | 2,420 | 4,660 | 7,430 | 13,100 | 26 |
| 30 | 160 | 336 | 632 | 1,300 | 1,940 | 3,750 | 5,970 | 10,600 | 21 |
| 40 | 137 | 287 | 541 | 1,110 | 1,660 | 3,210 | 5,110 | 9,030 | 18 |
| 50 | 122 | 255 | 480 | 985 | 1,480 | 2,840 | 4,530 | 8,000 | 16 |
| 60 | 110 | 231 | 434 | 892 | 1,340 | 2,570 | 4,100 | 7,250 | 14 |
| 80 | 101 | 212 | 400 | 821 | 1,230 | 2,370 | 3,770 | 6,670 | 13 |
| 100 | 94 | 197 | 372 | 763 | 1,140 | 2,200 | 3,510 | 6,210 | 12 |
| 125 | 89 | 185 | 349 | 716 | 1,070 | 2,070 | 3,290 | 5,820 | 11 |
| 150 | 84 | 175 | 330 | 677 | 1,010 | 1,950 | 3,110 | 5,500 | 11 |
| 175 | 74 | 155 | 292 | 600 | 899 | 1,730 | 2,760 | 4,880 | 9, |
| 200 | 67 | 140 | 265 | 543 | 814 | 1,570 | 2,500 | 4,420 | 9, |
| 250 | 62 | 129 | 243 | 500 | 749 | 1,440 | 2,300 | 4,060 | 8, |
| 300 | 58 | 120 | 227 | 465 | 697 | 1,340 | 2,140 | 3,780 | 7, |
| 350 | 51 | 107 | 201 | 412 | 618 | 1,190 | 1,900 | 3,350 | 6, |
| 400 | 46 | 97 | 182 | 373 | 560 | 1,080 | 1,720 | 3,040 | 6, |

**Disclaimers & Recommendations**
CONSULT WITH A LOCAL GAS PROFESSIONAL TO DETERMINE ACCURATE BTU AVAILABILITY. Use this chart as a guideline ONLY and does NOT account for vari the type of pipe (plastic or iron.) Chart does NOT account for other appliances, meter pressure, or fittings. Contact a gas professional to verify your gas pressure. V Trends is not a licensed gas professional and is NOT able to calculate accurate BTU availability. Numbers are in thousands of BTU's.
V2.R1

# Orifice Sizing Resources

## Manufacturer Data

Data about the size of orifice to input capacity for natural gas and propane is available from manufacturers.

## CSA B149.1 Annex I

Refer to Annex I General information of CSA B149.1 for orifice sizing information.

# Manifold Pressure Adjustment

In addition to changing the orifice size, the appliance manifold pressure requires adjustment. This procedure requires you to use pressure measuring equipment (a manometer) to confirm that the correct manifold pressure has been obtained.


# Manifold Pressure Adjustment Procedures

1

## Certified Conversion Kits

The appliance manufacturer will indicate whether or not any adjustments to the manifold pressure are required. In all cases, check that the gas supply pressure immediately upstream of the manifold falls within the recommended range for the appliance.

2

## No Certified Conversion Kits

When no certified conversion kits are available but the appliance has received certification for both fuels, obtain original testing data from the agency certifying the appliance. Adjust the manifold pressure accordingly.

# Manifold Pressure Specifications

## Stay Within Specifications

Always keep the manifold pressure within the range specified by the appliance manufacturer, since adjustments beyond this range can adversely affect the burner operation.

## Risks of Low Pressure

Pressures that are too low may not entrain enough air into the burner.

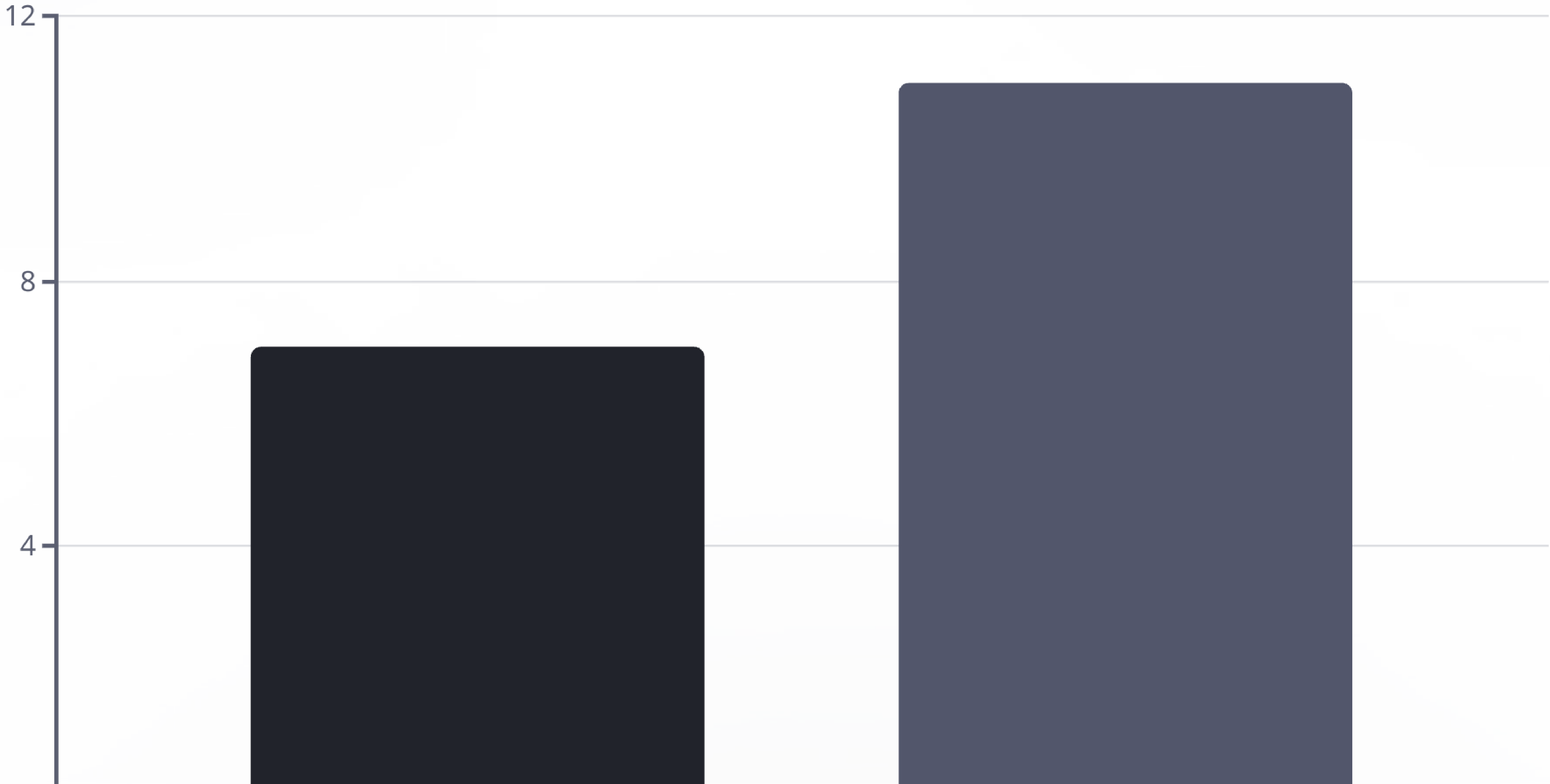
## Risks of High Pressure

Pressures that are too high may entrain too much air.

## Carbon Monoxide Risk

In either case, poor burner flame characteristics can occur, resulting in production of carbon monoxide.

# Typical Manifold Pressures



# Conversion Documentation

### Record all conversion details

Document all parts changed and adjustments made

### Update the rating plate

Mark the new gas type on the appliance rating plate

### Complete any required certification

Submit documentation to inspection authorities if required

# Flame Characteristics

## Proper Flame

A properly adjusted gas burner will have a steady blue flame with well-defined inner and outer cones

## Improper Flame - Too Much Air

Flames that lift off the burner indicate too much primary air or excessive gas pressure


## Improper Flame - Too Little Air

Yellow, lazy flames indicate insufficient primary air or low gas pressure

# Testing After Conversion

### Check operating temperature

Verify the appliance operates within normal temperature range

### Test for carbon monoxide

Ensure no dangerous CO is being produced

### Observe flame characteristics

Check for proper color, height, and stability

### 4 Verify all safety controls

Test that all safety devices function correctly

# Common Conversion Mistakes

## Incorrect Orifice Size

Using the wrong size orifice for the gas type and appliance input

## Improper Manifold Pressure

Failing to adjust or incorrectly setting the manifold pressure

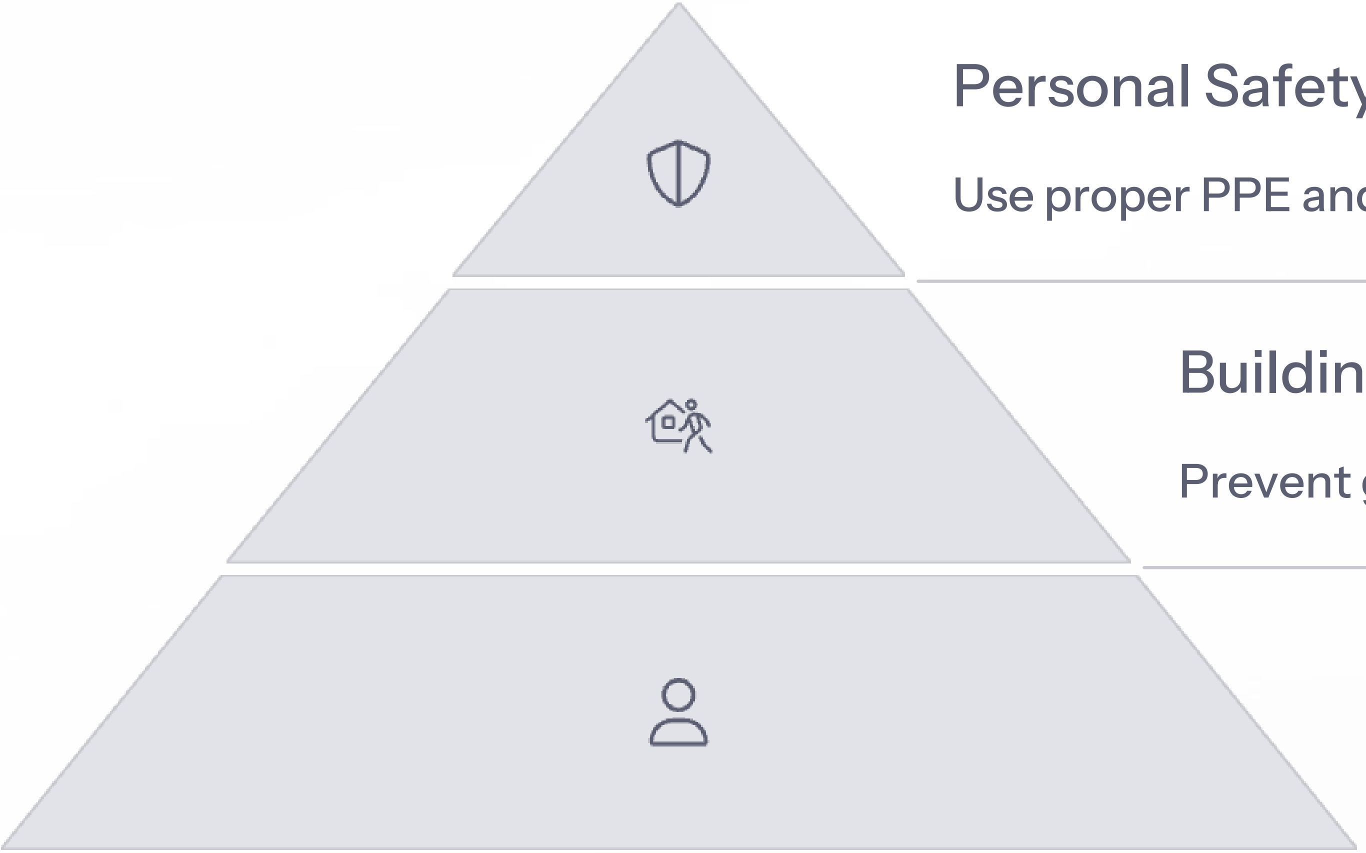
## Inadequate Testing

Not performing complete combustion analysis after conversion

## Missing Documentation

Failing to update the rating plate or document the conversion

# Safety Considerations



### Personal Safety

Use proper PPE and tools

### Building Safety

Prevent gas leaks and fire hazards

### Occupant Safety

Ensure safe operation for end users

# Leak Testing Requirements

### Prepare the test solution

Use approved leak detection solution or soap and water mixture

### Apply to all connections

Cover all joints, fittings, and potential leak points

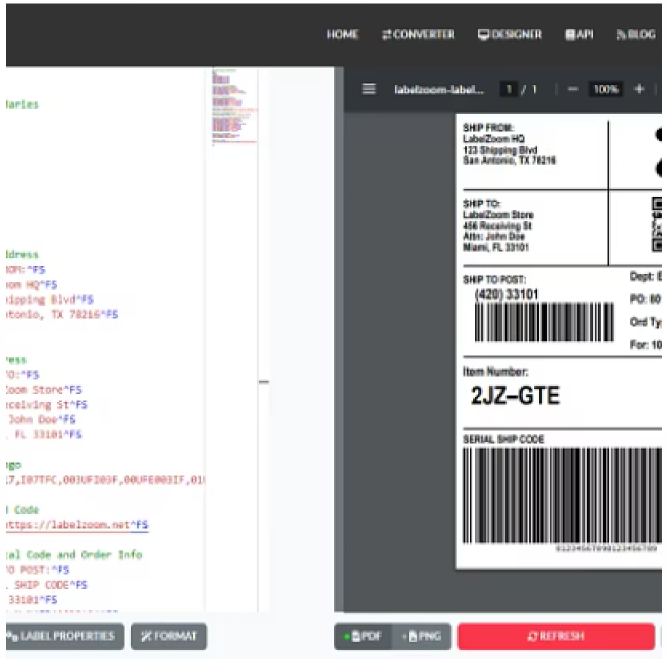
### Observe for bubbles

Watch carefully for any bubble formation indicating leaks

### Repair and retest

Fix any leaks found and test again until no leaks are detected

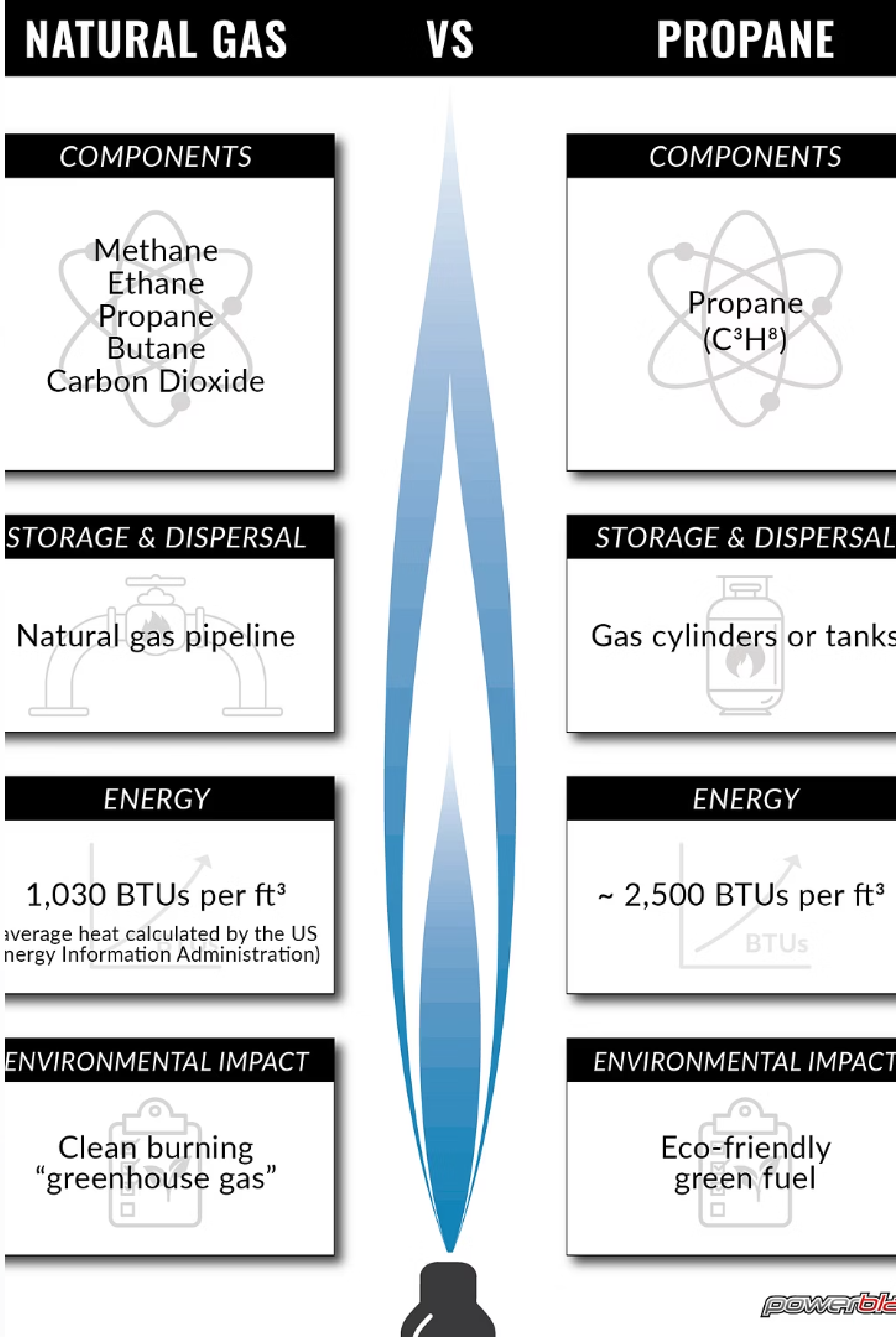
# Conversion Kit Components


Typical conversion kits include properly sized orifices, pressure regulator springs or conversion parts, and documentation including labels for the rating plate.

# Comparing Natural Gas and Propane Properties

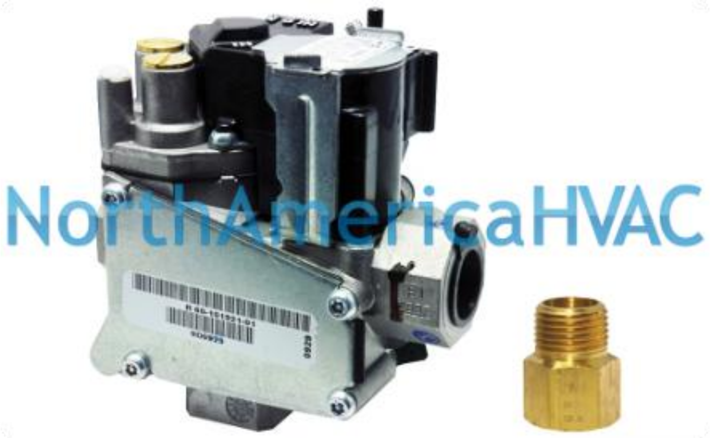
| Property | Natural Gas | Propane |
|---|---|---|
| Specific Gravity | 0.60 | 1.52 |
| BTU per cubic foot | 1,000 | 2,500 |
| Manifold Pressure | 7" w.c. | 11" w.c. |
| State at room temperature | Gas | Liquid under pressure |



# Appliance Types Requiring Special Consideration

### Cooking Appliances

Ranges and cooktops often have multiple burners with different orifice sizes that all need to be replaced during conversion

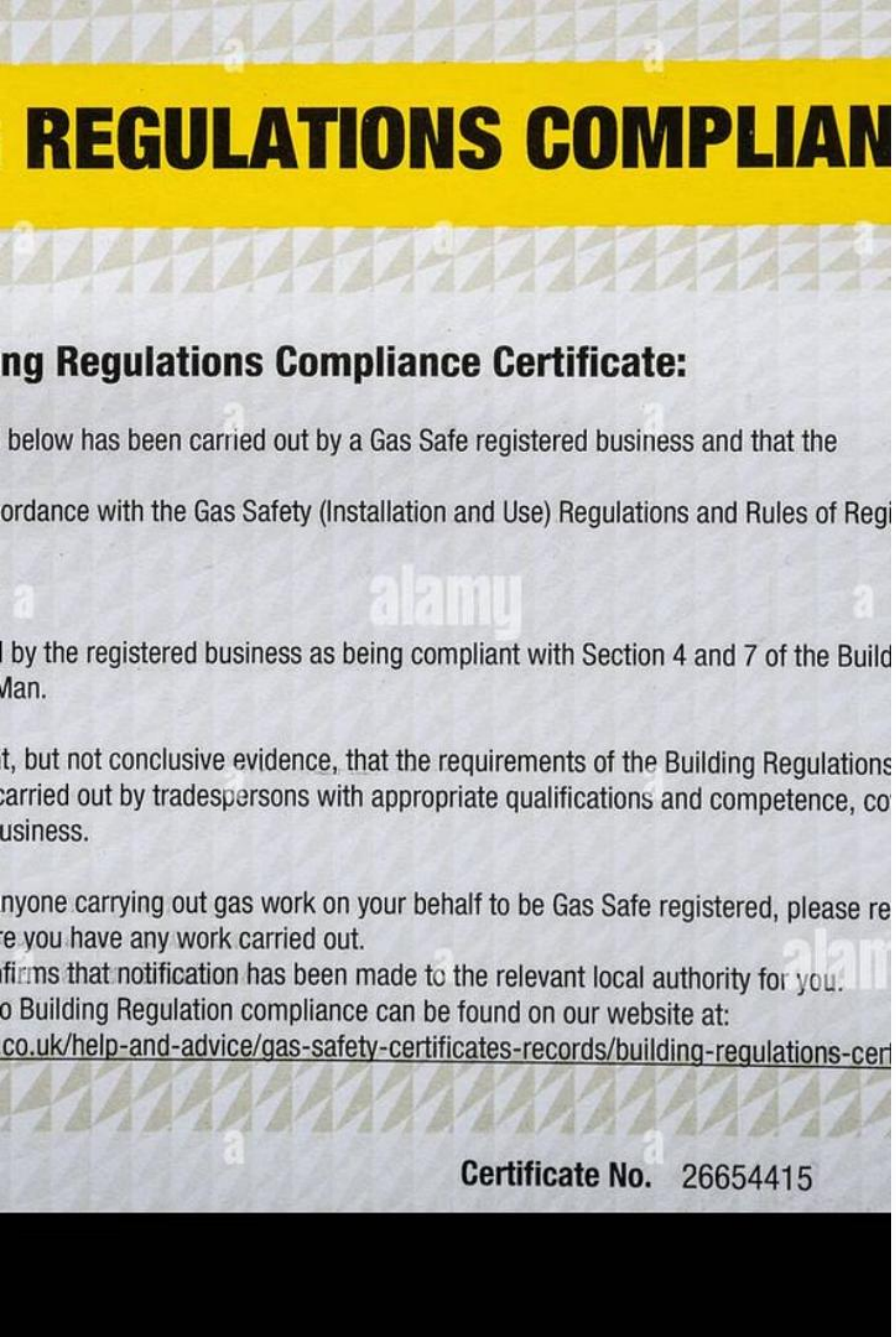



### Heating Equipment

Furnaces and boilers may have complex gas valve systems requiring careful adjustment


### Water Heaters

Water heaters may have special thermostat systems that need specific conversion procedures




# Regulatory Compliance

## National Codes

CSA B149.1 Natural Gas and Propane Installation Code

## Local Regulations

Municipal and provincial/territorial requirements

## Manufacturer Requirements

Specific instructions and limitations from appliance manufacturers

## Certification Bodies

Requirements from agencies like CSA, UL, ETL, etc.

# When Conversion Is Not Recommended

## Manufacturer Prohibition

When the manufacturer explicitly states the appliance cannot be converted

## Cost Prohibitive

When the cost of conversion and recertification exceeds the value of the appliance

## Unavailable Parts

When proper conversion parts cannot be obtained from the manufacturer

## End of Life Equipment

When the appliance is near the end of its useful life

# Technician Qualifications

## Education

Formal training in gas technology

## Certification

Proper licensing and credentials

## Continuing Education

Ongoing training on new technologies

## Experience

Practical field knowledge

# Summary of Key Points

## Installer Responsibility

Gas technicians must ensure safe conversions following all requirements

## Follow Procedures

Always use manufacturer's certified instructions when available

## Technical Requirements

Proper orifice sizing and manifold pressure adjustment are critical

4

## Documentation

Update rating plates and maintain proper records of all conversions

# CSA Unit 9

# Chapter 7
# Reactivation of Appliances

This presentation covers the essential procedures and checklists that gas technicians must follow before reactivating gas appliances. We'll explore pre-reactivation inspections, venting system checks, and proper reactivation techniques to ensure safe and efficient operation.

# Purpose of Proper Reactivation

## Safety First

Gas technicians must perform a series of checks before lighting up an appliance to ensure that the reactivation occurs safely.

## Efficiency Matters

Proper reactivation procedures help ensure that the appliance operates efficiently after being serviced or installed.


Always consult the appliance manufacturer before attempting any unusual conversions to avoid problems and save time.

# Learning Objectives

## Pre-reactivation Checklists

Describe the comprehensive pre-reactivation checklists that must be completed before an appliance can be safely reactivated

## Reactivation Procedures

Describe how to properly reactivate gas appliances following industry standards and safety protocols

# Key Terminology

## Flame Impingement

Touching the flame produced by the burners to the heating surfaces

Understanding key terminology is essential for gas technicians to communicate effectively and perform their duties safely.

2. RECOMMENDED MINIMUM INSIDE DIMENS
OF REFRACTORY-TYPE COMBUSTION CHAM

| 4 Dimension (C) | 5 Suggested Height (H) | 6 Minimum Dia. Vertical Cyl. |
|---|---|---|
| 3 | 8 | 7 |
| 3.5 | 9 | 7.5 |
| 3.5 | 9 | 8 |
| 3.5 | 9 | 8.5 |
| 4 | 10 | 9 |
| 4 | 10 | 9.5 |
| 4 | 10 | 10 |
| 4 | 10 | 11 |
| 4.5 | 11 | 12 |
| 4.5 | 11 | 13 |
| 4.5 | 11 | 14 |
| 4.5 | 11 | 15 |
| 5 | 12 | 16 |
| 5 | 12 | 17 |
| 5 | 12 | 18 |

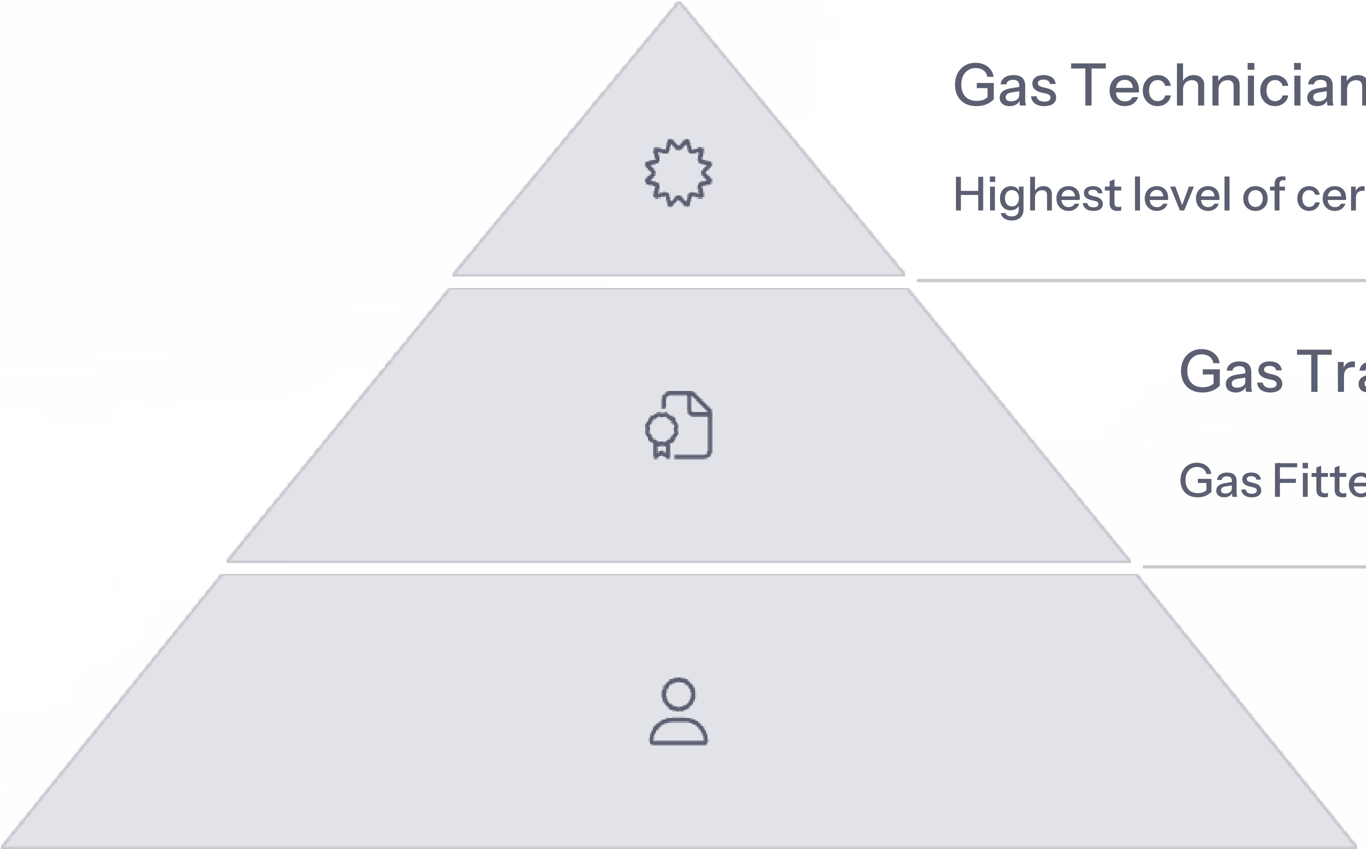
Fig. 5

shown in column (2). Often,
e well with chambers shorter
2).

dimensions can be exceeded

cylinders should be at least

# Licensing Requirements



### Gas Technician/Fitter

Highest level of certification

### Gas Trade 3

Gas Fitter B - level 1

### Supervised Work

Working under higher licensed technician

In most jurisdictions where a Gas Trade 3 (Gas Fitter B – level 1) is recognized, a Gas Technician 3 may perform the reactivation of a gas appliance under the supervision of a higher licensed gas technician/fitter. The gas technician/fitter needs to be familiar with local regulations to understand which qualifications are required to perform various activities associated with installation, servicing, and reactivation of natural gas and propane equipment.

# Pre-reactivation Overview

### Initial Checks

Verify venting system and appliance condition

### System Preparation

Clean components and prepare for gas introduction

### Testing

Perform pressure tests and leak checks

### Reactivation

Light appliance and verify operation

Before lighting up the appliance, the gas technician/fitter must perform a series of checks to ensure that the reactivation occurs safely and that the appliance operates efficiently and safely.

# Venting System Importance

### Safety Critical

Prevents carbon monoxide poisoning

### Code Compliance

Must meet regulatory requirements

### Regular Inspection

Requires thorough examination

The venting system is the first system to check before reactivating an appliance. The most common cause of carbon monoxide poisoning from gas equipment is due to venting system problems.


# Venting System Checklist - Step 1

1 Check Vent Area

Check that the area of the vent meets the Code requirements for the input of the appliance

2 Verify Venting Material

Check that the venting material meets the Code requirements for the type of appliance and the expected flue temperatures

# Venting System Checklist - Step 2

### Visual Inspection

Visually check the inside of the vent or chimney to ensure there are no obstructions, soot or creosote, or deterioration

### Exterior Condition

Check the exterior venting to ensure it is in acceptable condition

### Height Requirements

Check termination height and required distances from other vertical surfaces

### Termination Caps

Check for proper termination caps

# Exterior Venting Inspection

| Venting Type | What to Check For |
| --- | --- |
| Masonry chimneys | Eroded or cracked mortar |
| Metal chimneys | Corrosion |

If a masonry chimney has a metal liner, check to make sure the top seal plate is in place to prevent air flow through the chimney that can result in condensation and corrosion of the metal liner.

# Venting System Checklist - Step 3

## Interior Venting Inspection

| Venting Type | What to Check |
|---|---|
| Masonry chimneys | The type of lining tile and its condition |
| Metal chimneys | For corrosion |

Visually check the inside of the vent or chimney to ensure there are no blockages. Use a

# Interior Venting System Checks

## Clean Debris

Examine and empty any debris from the chimney cleanout opening and make sure the door is tight fitting

## Check for Unapproved Components

Check for unapproved dampers and other devices

## Inspect Draft Hood

Inspect the draft hood for any signs of carbon (black powder). Carbon deposits could be a sign of incomplete combustion, and burner adjustments may be required

## Plastic Venting Inspection

For plastic venting systems, inspect for leaks at joints and cracks or distortion along the vent length


# Additional Pre-reactivation Checks

### Verify Air Openings

Check that combustion and ventilation air openings meet the Code requirements

### Inspect Combustion Chamber

Check the appliance combustion chamber and surrounding area for issues

### Check Gas Supply

Check available gas pressure and pipe size

### Connect and Test

Connect the gas supply to the appliance and test according to Code requirements

# Combustion Chamber Inspection

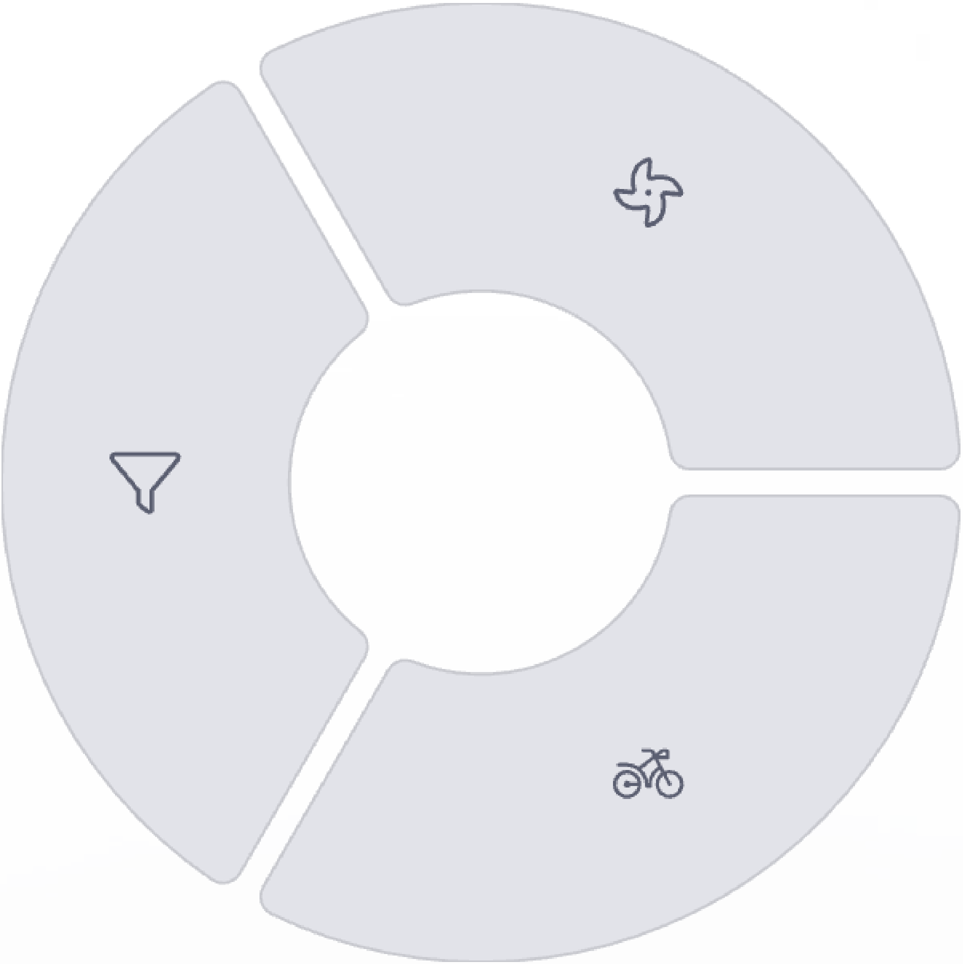
| Check for | Which indicates | Then |
| --- | --- | --- |
| Scorching | Overheating | Check appliance is not overfiring. Check for restrictions in flue and vent passages. |
| Sooting | Incomplete combustion | Check appliance input rate and burner operation, for adequate air supply and possible restrictions in flue or vent passages. |
| Scaling | Corrosion | If rust flakes build up inside the top section of a heat exchanger, incomplete combustion and carbon monoxide could result. If advanced, flame roll-out could also occur. |

# Additional Combustion Chamber Checks

| Check for | Which indicates | Then |
|---|---|---|
| Burnt wiring | Overheating condition | May result from flame roll-out |
| Heat exchanger cracks, etc., by visual inspection or other test method | Heat exchanger cracks | Note: There are many methods to test, but generally, you can perform a combination of suggested methods to confirm before proceeding. |

If any of these conditions exist, you must correct the problem, either before or after reactivation, depending on the nature of the problem.

# Furnace Cleaning Overview



## Blower

Clean blower assembly to prevent airflow restrictions

## Filter System

Replace or clean filters to ensure proper airflow

## Motor

Maintain motor according to manufacturer specifications

Always ensure that the power supply is turned off before beginning these furnace cleaning steps!


# Filter System Cleaning

## Filter Inspection

- Take it out and hold it up to the light
- If it looks clogged, replace it with a new filter of the same type and size regardless of the length of time it has been used

## Filter Replacement

- An electronic air cleaner should have cartridges cleaned in accordance with the manufacturer's instructions
- Permanent screen filters should be removed and cleaned

# Types of Furnace Filters

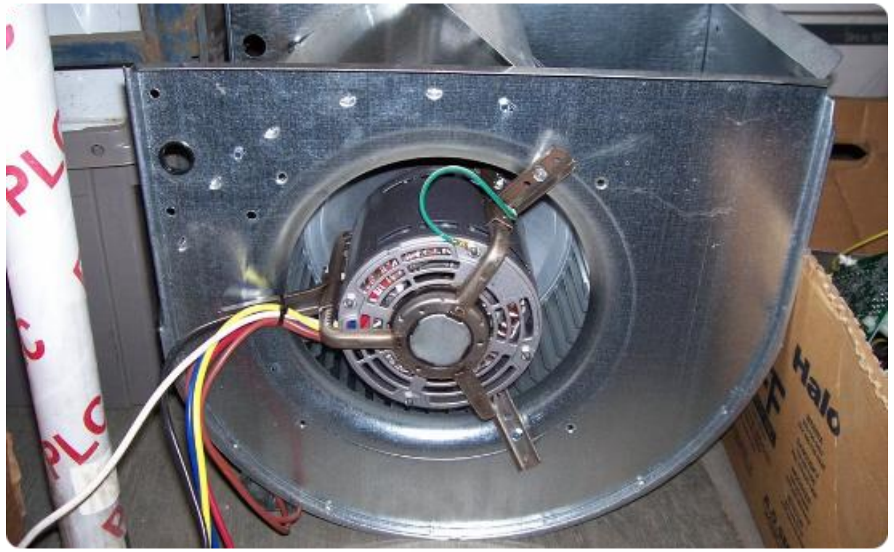
## Disposable Furnace Filter

- Consists of a fibre mesh in a cardboard frame
- The size of the filter is printed on the edge of the frame
- An arrow on the edge of the frame indicates the correct direction of air flow through the filter
- Air flows from the return-air duct toward the blower
- The arrow on the filter should point away from the return-air duct and toward the blower

## Permanent Filter

- Usually sprayed with a special filter-coating chemical, available at hardware stores and home centers
- Clean this type of filter according to the manufacturer's instructions, which are usually attached to furnace housing

# Blower Cleaning




## Blower Assembly

You must clean the blower assembly, belts and pulleys to the blower, and motor housing. Cleaning the blower is critical if the furnace has a squirrel-cage fan because openings in this type of blower often become clogged with dirt.

## Squirrel-Cage Fan

This type of blower can easily become clogged with dirt, restricting airflow and reducing efficiency.

## Accessing the Blower

Remove the panel that covers the filter to gain access to the blower or panel on the front of the furnace. This panel may be slip-fit on hooks or held by a series of retaining screws. Sliding out the fan Unit, which is held on track by screws, may help you gain access to inside of the blower.

# Motor Cleaning

### Access Electrical Panel

It may be necessary to swing out an electrical panel or module control on high-efficiency Units

### Check Fan Belt

Check the condition of fan belt if equipped

### Maintain Motor

Maintain the fan motor with oil, if the manufacturer advises

# Additional Cleaning Considerations

## Air-Conditioning A-Coils

Other items of concern are the underside of air-conditioning A-coils, as they can become clogged with dirt and act as a dirty filter would.


## Secondary Heat Exchanger

Additionally, on high-efficiency Units the secondary heat exchanger, which you can access while the blower assembly is removed, may require cleaning in order to remove dirt build up on the coil surface.

## Condensate Drain

You should clean the condensate drain tubing, specifically on high-efficiency Units, and confirm it to be free running all the way to the floor drain to ensure trouble-free drainage.

# Reactivation Process Overview

### Pre-checks

Complete all pre-reactivation checklists

### Gasification

Introduce gas to the system

### System Testing

Check for leaks and proper pressure

### Ignition

Light the appliance following manufacturer's instructions

### Analysis

Perform combustion analysis

When the appliance is ready for reactivation, you must re-check the system after its gasification and before you light up the appliance. In all cases, you must perform combustion analysis to determine the completeness of combustion and to test for toxic gases before leaving the appliance in operation.


# Natural Gas Regulator Activation

### Important Note

You should turn on the main valve to a natural gas regulator/meter set slowly when reactivating a system. If turned on too quickly, the regulator will not have time to react, which could cause overpressure damage to the meter diaphragm, regulator, and other downstream gas controls.


# Checking System Once Gasified

### Visual Inspection

Visually check the piping to ensure there are no openings in the system from which gas could escape

### Valve Check

Check for shut-off valve seepage

### Appliance Preparation

Shut off the appliance

### Pressure Gauge Installation

Install a manometer or pressure gauge at the gas meter outlet

# Introducing Gas to the System

### Open Gas Supply

Introduce gas into the system

### Listen for Flow

Listen for the gas flow to stop

### Monitor Meter

Monitor the gas meter test dial to ensure that no gas is escaping

### Pressure Test

Maintain the gas pressure indicated on the manometer or pressure test gauge for a minimum of 10 minutes

### Leak Test

Use a soap solution to perform a leak test of all control valves and appliance piping

# Pressure Testing Process

## Pressure Test Steps

1. Turn off the meter valve. The system contains the gas, under pressure
2. Maintain the gas pressure indicated on the manometer or pressure test gauge for a minimum of 10 minutes
3. If the manometer or pressure gauge decreases, indicating that there is a leak, refer to piping and tubing systems procedures


Upon successfully completing the test, use a soap solution to perform a leak test of all control valves and appliance piping not previously tested under normal operating pressure to ensure they are gas tight.

# Tank or Cylinder Reactivation

### Valve Seepage Test

Do a valve seepage test on each stage

### Pressure Gauge Placement

Place a pressure gauge on each stage

### Shut Off Appliance

Turn off the manual shut-off valve at the appliance

### Pressurize System

Pressurize the system with the gas

### Monitor Pressure

Monitor gauges for a decrease in pressure, which indicates external leakage


# Lighting the Appliance

### Follow Instructions

Upon completing all necessary checks, light up the appliance following manufacturer's instructions

### Check Pressure

Check the manifold gas pressure with a manometer. Adjust the regulator if necessary

### Observe Flame

Check for flame stability, impingement, lift-off, or roll-out

### Verify Venting

Check venting action for proper draft and no spillage

# Final Checks Before Departure

1

## Combustion Analysis

Always analyze the flue products to check for complete and efficient combustion

2

## Safety Control Verification

Check and confirm the proper operation of all safety controls on the Unit, such as high limits, flame safeguards, pressure switches, and auxiliary limits

3

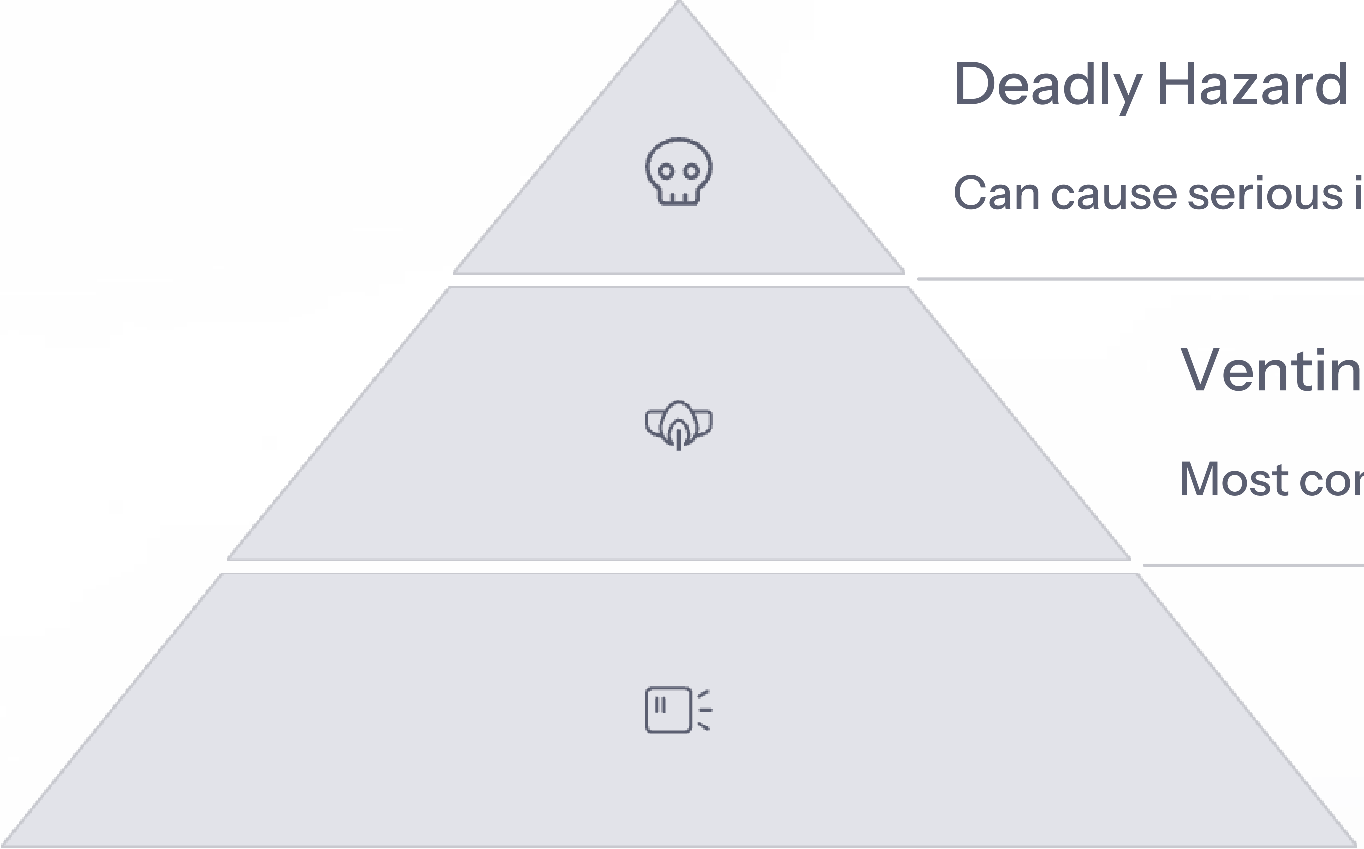
## Input Verification

Before leaving the appliance, check the input

# Input Verification Methods

| If a meter | Then |
| --- | --- |
| Is available | Check the input by measuring the flow rate through the meter by monitoring the test dial ("clocking the meter") |
| Is not available | Make sure that the installation of the proper orifice and the maintenance of the manifold pressure are in accordance with the manufacturer's specified rating |

# Carbon Monoxide Safety



### Deadly Hazard

Can cause serious illness or death

### Venting Issues

Most common cause is venting problems

### Detection

Proper testing is essential

The most common cause of carbon monoxide poisoning from gas equipment is due to venting system problems. This is why thorough inspection of the venting system is the first priority before reactivating any gas appliance.

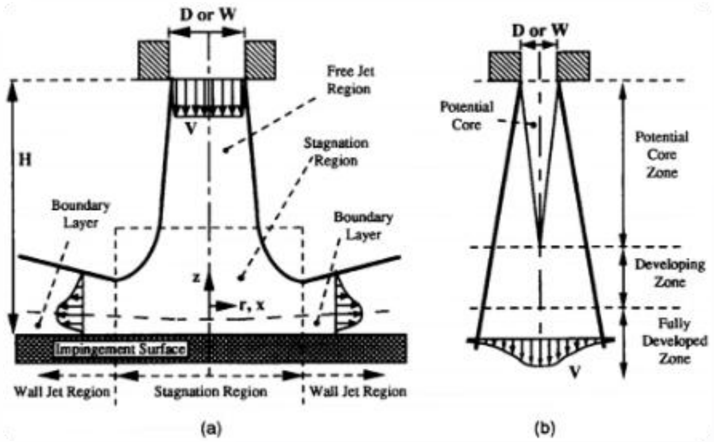
# Flame Characteristics

## Proper Flame

A proper gas flame should be blue with slight yellow tips. It should be stable and consistent across all burners.

## Improper Flame

Yellow flames indicate incomplete combustion, which can produce carbon monoxide. This requires immediate adjustment.



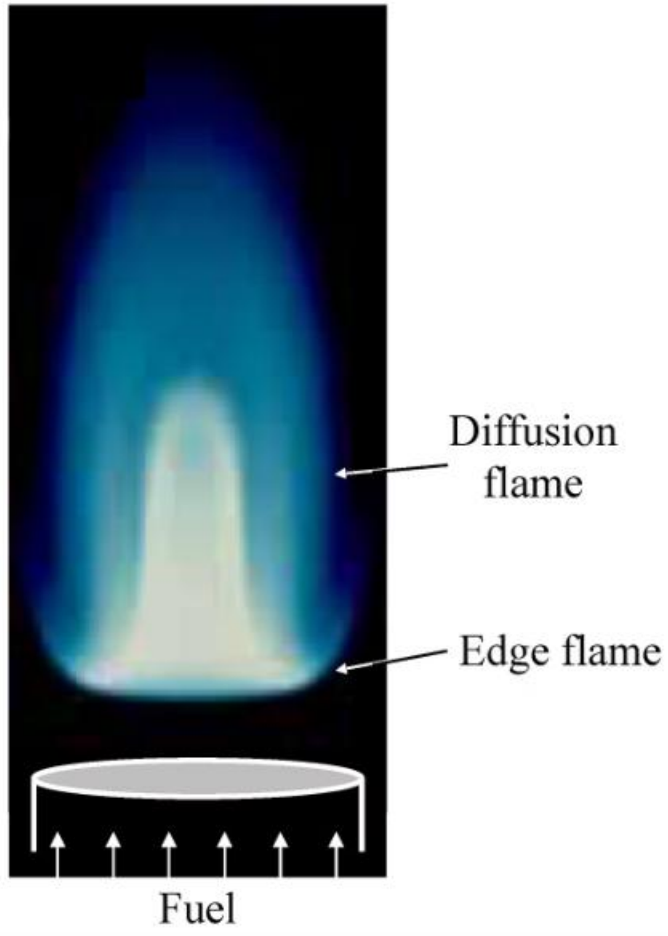

## Flame Impingement

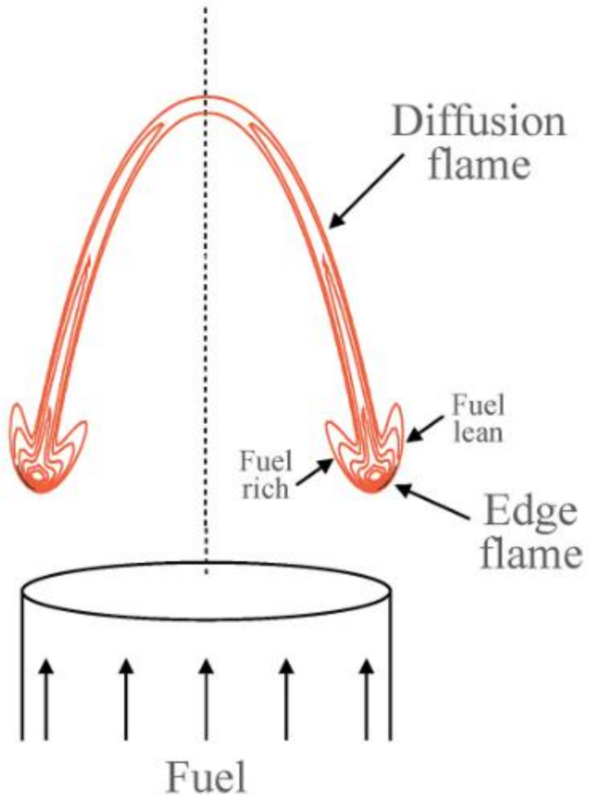
When flames touch heating surfaces directly, it can cause overheating, damage, and inefficient operation.

# Flame Problems to Watch For

### Flame Lift-off

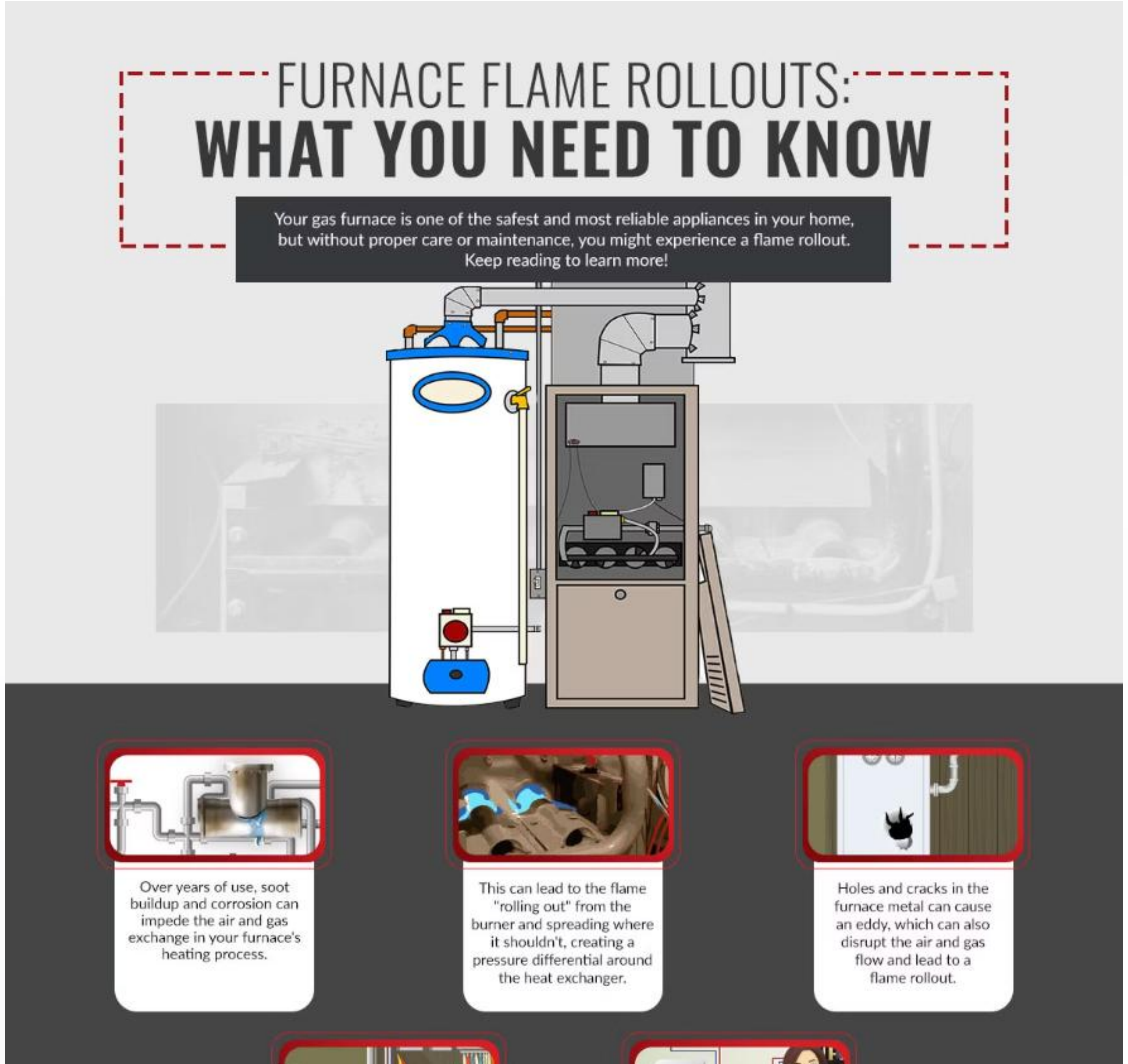
When flames lift away from the burner ports, it indicates improper gas pressure or air-to-fuel ratio. This can lead to flame outage and gas accumulation.




### Flame Roll-out

When flames extend outside the combustion chamber, it indicates a serious problem such as blocked heat exchanger or insufficient combustion air. This can cause overheating of components and is a fire hazard.



# Venting Action Verification

## Proper Draft

- Use a draft gauge to measure the draft in the vent connector
- Compare readings to manufacturer specifications
- Adjust barometric damper if necessary

## Spillage Test

- Hold a smoke pencil or match near the draft hood
- Smoke should be drawn into the draft hood
- No spillage should occur after 30 seconds of operation

# Safety Controls Verification

### High Limit Controls

Prevent overheating by shutting down the system when temperature exceeds safe levels

### Flame Safeguards

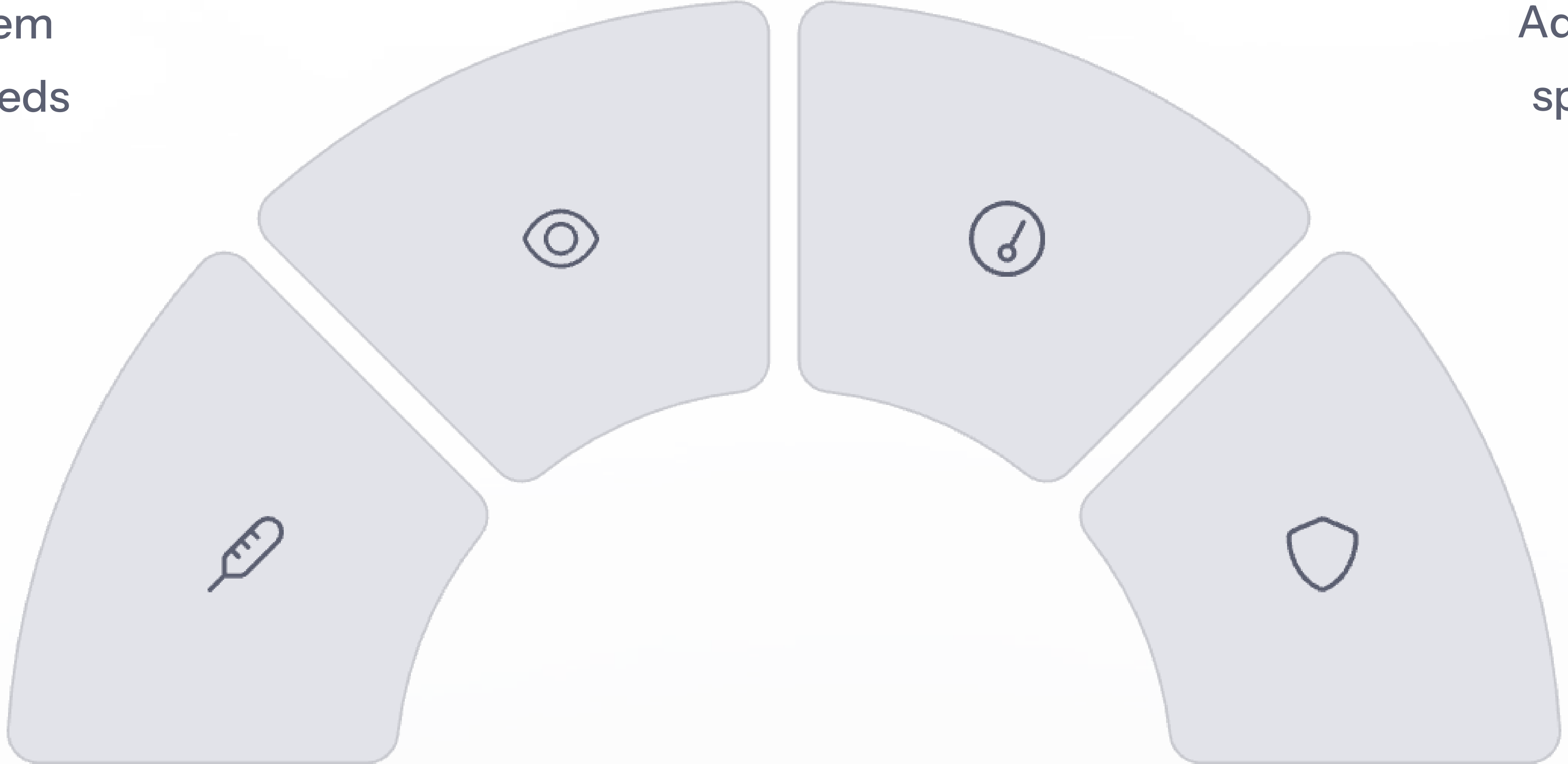
Monitor flame presence and shut off gas if flame is lost

### Pressure Switches

Ensure proper air flow and venting before allowing operation

### Auxiliary Limits

Additional safety controls specific to the appliance type



# Combustion Analysis

## Equipment Setup

Insert combustion analyzer probe into the flue pipe at the proper location

## Measurement

Measure oxygen, carbon monoxide, carbon dioxide, and stack temperature

## Analysis

Compare readings to manufacturer specifications and adjust as needed

## Documentation

Record all readings for future reference

# Combustion Analysis Parameters

| Parameter | Ideal Range | Indicates |
|---|---|---|
| Oxygen ($O_2$) | 4-9% | Air-to-fuel ratio |
| Carbon Dioxide ($CO_2$) | 9-10.5% | Combustion efficiency |
| Carbon Monoxide (CO) | 0-50 ppm | Combustion safety |
| Stack Temperature | 300-500°F | Heat transfer efficiency |

# Clocking the Meter

### Time Gas Flow

Time how long it takes for one cubic foot of gas to flow

### Calculate BTU Input

Convert flow rate to BTU input using gas heating value

### Compare to Rating

Compare calculated input to appliance rating plate

### Adjust if Needed

Adjust gas pressure if input is not within 5% of rating

# Clocking the Meter Formula

## Formula for Natural Gas

BTU Input = (3600 × Heating Value) ÷ Seconds per cubic foot

- 3600 = seconds in an hour
- Heating Value = BTU per cubic foot (typically 1000 for natural gas)
- Seconds per cubic foot = time measured during test

## Example Calculation

If it takes 40 seconds for the meter to complete one revolution of 1 cubic foot:

BTU Input = (3600 × 1000) ÷ 40 = 90,000 BTU/hr

# Manifold Pressure Adjustment

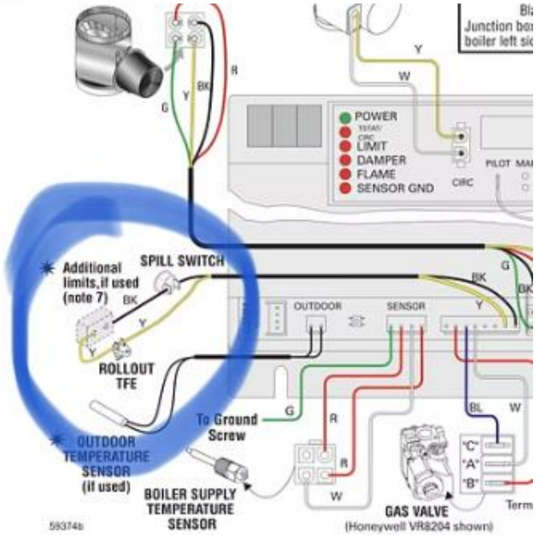
## When No Meter is Available

When a gas meter is not available for clocking, you must ensure:

1. The proper orifice is installed according to manufacturer specifications
2. The manifold pressure is set correctly using a manometer
3. All adjustments match the manufacturer's specified rating


Most gas valves have an adjustment screw for setting the manifold pressure. Always refer to the manufacturer's instructions for the correct procedure and specifications.

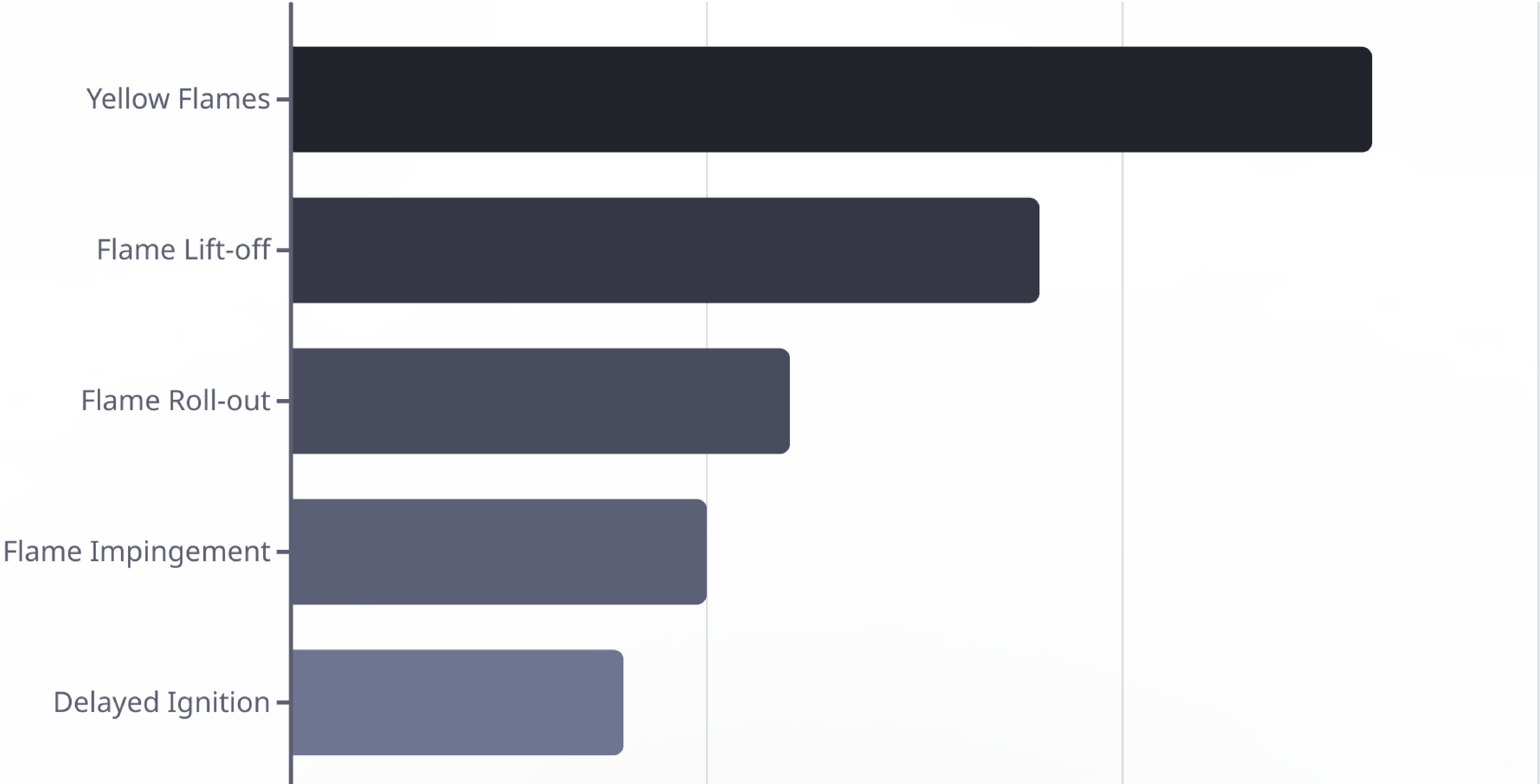
# Common Reactivation Issues






These are common issues that may be encountered during the reactivation process. Each requires proper diagnosis and correction before the appliance can be safely operated.

# Troubleshooting Flame Problems



# Reactivation Documentation

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Combustion Chamber | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A |
| Manual Shutoff | ☐ | | ☐ | | ☐ | | ☐ | |
| Sediment Trap | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A |
| Pilot Safety System | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A |
| Electronic Ignition System | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A |
| Venting System | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A |
| Combustion Air | ☐ | | ☐ | | ☐ | | ☐ | |
| Taken Out of Service | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A | ☐ | ☐ N/A |

| Installation Review | Yes | No |
|---|---|---|
| Safety information and materials provided to customer | ☐ | ☐ |
| Appliance(s) are suitable for continued service | ☐ | ☐ |
| Interior gas piping is suitable for continued service | ☐ | ☐ |

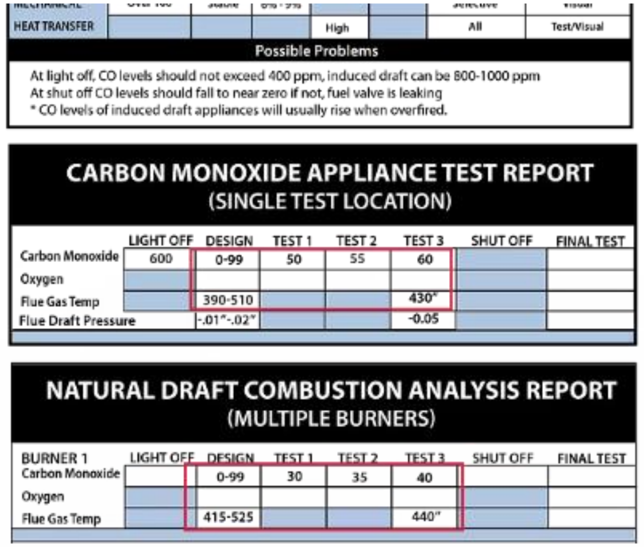
I, ______________ ______________ certify that I have completed the system check and installation review as described above.
Service Technician (Printed Name)

______________ ____/____/____
Service Technician (Signature) Date

**Customer Acknowledgement:** I understand a gas appliance and interior piping system check and installation review has been completed on my gas system as described above. I also acknowledge that the individual performing the Gas Appliance Check informed me of the procedure and the outcome of the inspection; what was covered by the inspection and what was not covered; what repairs and/or alterations, if any, were made to the gas system or appliances; and options available for making recommended changes to my gas system. I further acknowledge, by initialing each of the following items, that:

_____ I have informed the service technician of all gas-burning appliances and gas lines on my property.

_____ I have smelled the propane gas and can detect its odor.



| HEAT TRANSFER | | | | High | | All | Test/Visual |
|---|---|---|---|---|---|---|---|

**Possible Problems**

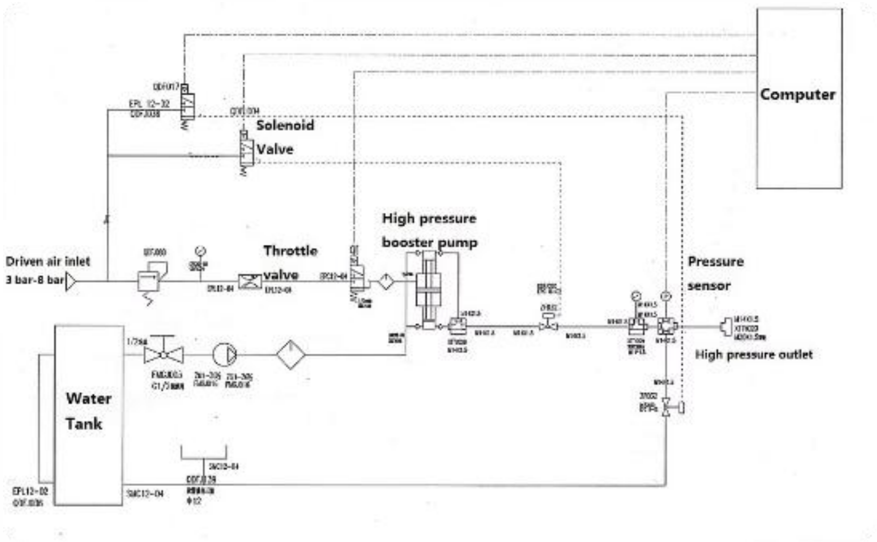
At light off, CO levels should not exceed 400 ppm, induced draft can be 800-1000 ppm
At shut off CO levels should fall to near zero if not, fuel valve is leaking
* CO levels of induced draft appliances will usually rise when overfired.

**CARBON MONOXIDE APPLIANCE TEST REPORT**
**(SINGLE TEST LOCATION)**

| | LIGHT OFF | DESIGN | TEST 1 | TEST 2 | TEST 3 | SHUT OFF | FINAL TEST |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 600 | 0-99 | 50 | 55 | 60 | | |
| Oxygen | | | | | | | |
| Flue Gas Temp | | 390-510 | | | 430" | | |
| Flue Draft Pressure | | -.01"-.02" | | | -0.05 | | |

**NATURAL DRAFT COMBUSTION ANALYSIS REPORT**
**(MULTIPLE BURNERS)**

| BURNER 1 | LIGHT OFF | DESIGN | TEST 1 | TEST 2 | TEST 3 | SHUT OFF | FINAL TEST |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | | 0-99 | 30 | 35 | 40 | | |
| Oxygen | | | | | | | |
| Flue Gas Temp | | 415-525 | | | 440" | | |




## Inspection Form

Document all checks performed and their results, including venting system condition, combustion chamber inspection, and filter replacement.

## Combustion Analysis Report

Record all combustion test readings including $O_2$, $CO_2$, CO levels, and stack temperature to verify proper combustion.

## Pressure Test Documentation

Document all pressure readings, including inlet pressure, manifold pressure, and results of leak tests to confirm system integrity.

# Safety Equipment for Technicians

### Respirator

For protection when working in dusty environments or with potential airborne contaminants

### Heat-Resistant Gloves

For handling hot components during inspection and reactivation

### Safety Glasses

For eye protection during all service procedures

### Gas Leak Detector

For identifying gas leaks during system testing

### Carbon Monoxide Monitor

For personal safety when working with combustion appliances

# Reactivation Timeline

## Initial Assessment

Perform visual inspection of appliance and venting system (15-30 minutes)

## Cleaning Procedures

Clean filters, blower, and motor components (30-45 minutes)

## System Preparation

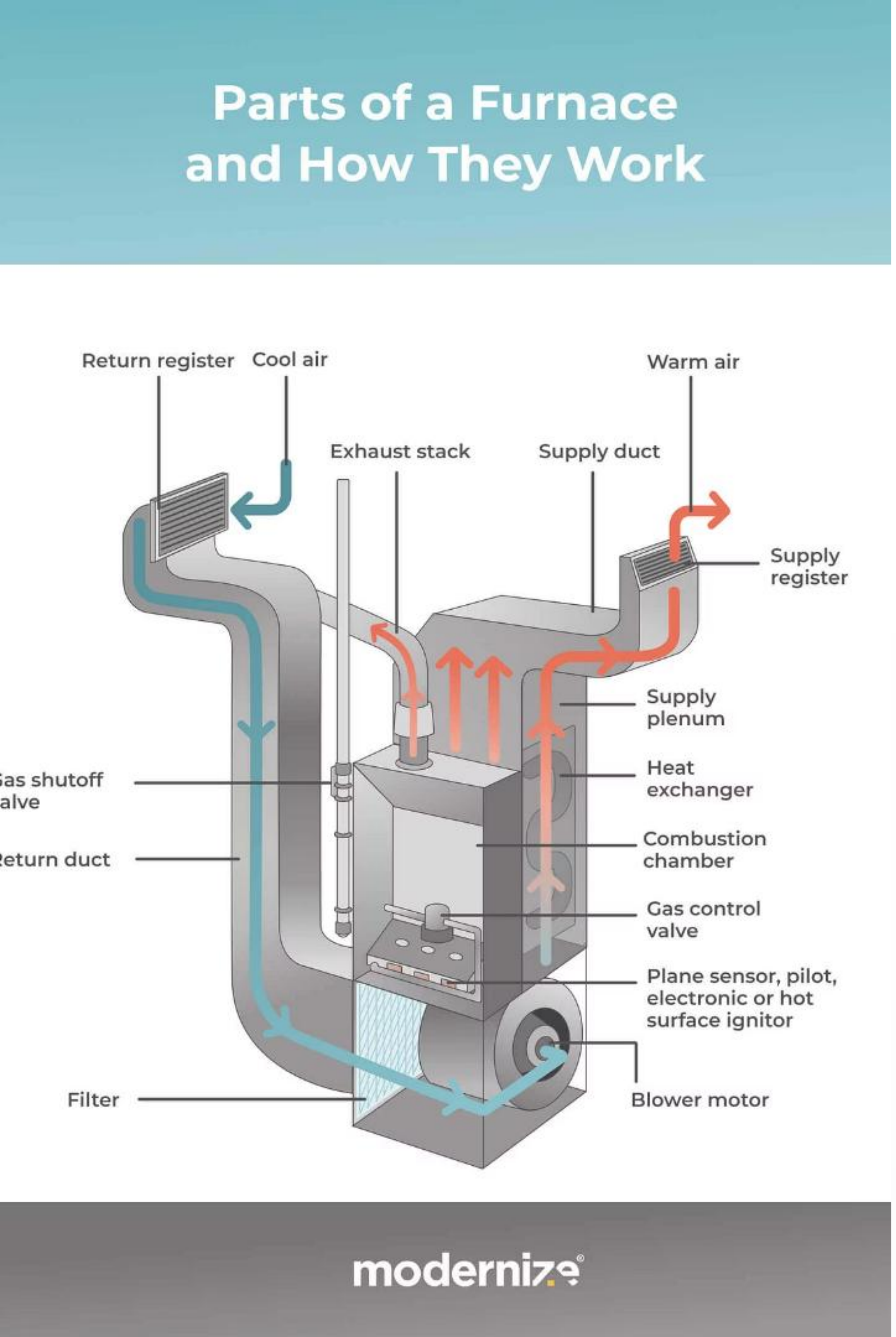
Connect gas supply and perform pressure tests (15-30 minutes)

## Reactivation

Light appliance and perform operational checks (15-30 minutes)

## Final Testing & Documentation

Conduct combustion analysis and complete paperwork (15-30 minutes)




# Reactivation Efficiency Factors

## 15%

### Energy Savings

Potential reduction in energy consumption after proper reactivation and adjustment

## 30%

### Performance Increase

Typical improvement in heating efficiency after thorough cleaning and adjustment

## 50%

### Risk Reduction

Decrease in carbon monoxide risk with proper venting system inspection

# Regulatory Compliance

### Local Codes

Jurisdiction-specific requirements

### Licensing Requirements

Proper certification for reactivation work

### Documentation

Required records of all work performed

The gas technician/fitter needs to be familiar with local regulations to understand which qualifications are required to perform various activities associated with installation, servicing, and reactivation of natural gas and propane equipment.

# Customer Communication

## Before Reactivation

- Explain the reactivation process
- Discuss potential issues that might be found
- Provide cost estimates for repairs if needed
- Set expectations for completion time

## After Reactivation

- Review work performed
- Explain any adjustments made
- Provide maintenance recommendations
- Answer questions about operation
- Schedule follow-up if necessary

# Maintenance Recommendations

### Annual Inspection

Schedule professional inspection before heating season

### Regular Filter Changes

Replace filters every 1-3 months during use

### CO Detector Testing

Test carbon monoxide detectors monthly

### Vent Checks

Visually inspect exterior vents periodically

# Key Takeaways

### Safety First

Always prioritize safety in all reactivation procedures

### Complete Checklists

Follow all pre-reactivation checklists thoroughly

### Venting is Critical

The venting system is the most important safety component to check

### Verify Combustion

Always perform combustion analysis before completing service

### Document Everything

Keep detailed records of all checks, tests, and adjustments