



# Hearth Venting Manual

*For Fireplaces, Stoves, and BBQ's*



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**EXHAUSTO**  
VENTING DESIGN SOLUTIONS



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## Introduction

The primary purpose of this manual is to provide more detailed guidance on gravity venting and mechanical venting of decorative wood- or gas-fired heating appliances than can be found in the codes or in the appliance manufacturers' instructions. It is intended for the convenience and assistance of contractors, chimney sweeps, fireplace stores, building inspectors, architects, engineers and others concerned with the correct installation and configuration of gravity and mechanical venting systems.

The manual contains extensive information about chimney problems, how they can be solved, how to analyze and how to calculate venting systems for fireplaces and stoves. It also contains information about how to adapt mechanical venting for different applications.

Finally, for those who have an interest in a theoretical approach, the manual's appendix contains relevant theory regarding chimney systems for fireplaces and stoves.

Remember: A well-designed and well-functioning venting system is more important for successful wood and gas burning than a good stove or fireplace. In other words, concentrate on the venting design because it's always better to have a good chimney and a poor fireplace than a good fireplace and a poor chimney. This is reviewed throughout this manual.



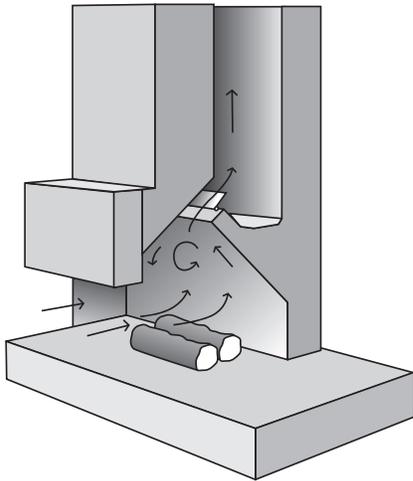
# 1. Venting in General

## 1.1 Designing Venting Systems

Open-fired heating appliances, like fireplaces, with natural draft chimneys follow the same gravity fluid flow laws as gas vents and thermal flow ventilation systems. All thermal or buoyant energy is converted into flow, and no draft exists over the fire or the appliance inlet.

Up to some limiting value, mass flow of hot flue gases through a vertical pipe is a function of rate of heat release and the chimney area, height and system pressure loss coefficient. An open-fired heating appliance may be considered as a gravity duct inlet fitting with a characteristic entrance-loss coefficient and an internal heat source. The heating appliance functions properly (does not smoke) when adequate intake or face velocity across those critical portions of the frontal opening nullifies external drafts and internal convection effects.

A mean flow velocity into a heating appliance's frontal opening is nearly constant from 300°F gas temperature rise up to any higher temperature. Local velocities vary within the opening, depending on its design, because the air enters horizontally along the hearth and then draws into the fire and upward, clinging to the back wall as shown below:



A recirculating eddy forms just inside the upper half of the opening, induced by the high velocity of flow along the back. Restrictions or poor construction in the throat area between the lintel and the damper also increases the eddy. Because the eddy moves smoke out of the zone of maximum velocity, the tendency of this smoke to escape must be counteracted by some minimum inward air movement over the entire front of the fireplace, particularly under the lintel.

## 1.2 Gravity vs. Mechanical Venting

Heating appliances can be vented by gravity or by mechanical means. "Gravity vented" is also called "naturally vented".

Gravity venting uses the difference in gravity of cold vs. warm air to create draft for the heating appliance. Gravity venting is very sensitive to the temperature of the products of combustion, the ambient/outdoor temperature, the barometric pressure and wind. It is difficult, if not impossible, to adjust the draft to changing conditions.

Mechanical venting uses a fan, blower or similar to create proper draft. It is not sensitive to the same issues as gravity venting, and it is possible to adjust the draft to meet changing conditions.

Gravity venting is by far the most popular method of venting a heating appliance. However, mechanical venting is becoming more popular, and for some heating appliances it has become an integrated part essential for maintaining proper draft and combustion and reduce emissions.

Many believe they know how gravity venting works, but very few can explain how a chimney works and why. Few really know how a mechanical venting system works, but many think they do. This leads to misconceptions and misapplications where gravity venting is expected to do something it can't do, and mechanical venting to create hazardous situations where it does not.

The definition of a Mechanical Draft System can be found in NFPA 97, Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances:

*"Equipment installed in and made part of a duct, chimney, or vent, that provides an induced draft"*

**Forced Draft:** *"Where a fan is located so as to push the flue gases through the chimney or vent"*

**Induced Draft:** *"Where a fan is located so as to pull the flue gases through the chimney or vent"*

Obviously, a mechanical draft system cannot be used in any stack or chimney exposed to habitable space if it pressurizes the chimney or vent. Products of combustion will be forced out through cracks in the chimney, and this will create a potentially hazardous or dangerous condition, due to the presence of carbon monoxide.

On the other hand, a mechanical draft system installed at the termination point can be used on any type of chimney because it maintains a negative pressure in the entire system.

## 2. Venting Problems and Possible Solutions

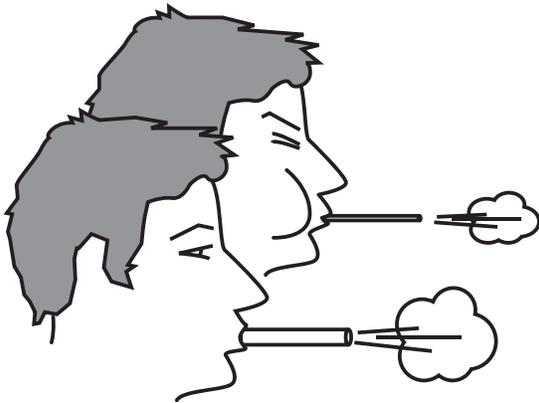
As mentioned earlier, a well-designed and well-functioning venting system is more important for successful wood and gas burning than a good stove or fireplace.

Chimneys operate on the simple principle that warm air rises because it has a lower density than cold air. Warmer flue gases in the chimney create buoyancy called “draft” and the rising gases create a partial vacuum at the bottom of the chimney and at the appliance outlet.

What’s known as “draft problems” are actually chimney performance problems and are seldom caused by inadequate draft. They are more often caused by poor design and caused by the chimney itself.

There are two major factors to consider when working with chimneys: “draft” and “flue gas volume” (or flow). “Draft” is the force, which causes the flue gas to be exhausted. The “flue gas volume” is the amount of products of combustion from the heating appliance passing through the system as a result of the draft.

The sizing of a chimney should be based on the flow requirements, as any chimney size has a certain capacity in regards to the amount of flue gases it is able to remove safely. An analogy here is drinking straws. Blowing in a small straw is much harder than in a large straw, and you can blow more air through the large one. A chimney works the same way: You can get a lot more air through a large flue than a small one.



Two major factors influence the chimney capacity: “draft” and “flow resistance”. “Flow resistance” is a result of friction and always exists between the moving gases and the chimney through which they flow. Bends and elbows represent flow resistance, but even straight pipe represents flow resistance in itself. The surface of the pipe is also important, and a corrugated or rough surface causes more flow resis-

tance than a smooth surface.

For a venting system to work properly, the draft **MUST** exceed the flow resistance. Otherwise there will be no movement of flue gases.

### 2.1 Chimney Performance Problems

The principles of flow and draft apply to all heating appliances.

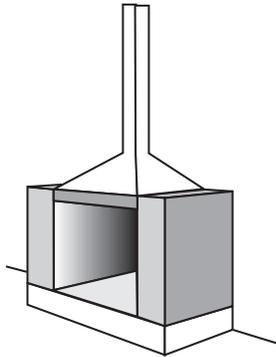
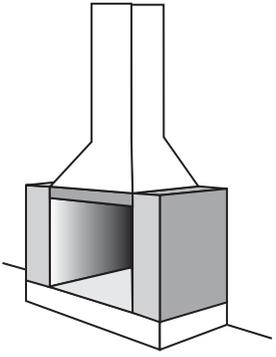
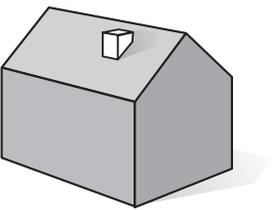
Open heaters (open fireplaces, BBQ’s etc.) require a large chimney capacity, as they exhaust a relatively large volume of flue gases. They allow for more dilution air, or excess air, to be introduced. As a result they draw more room air, which lowers the flue gas temperature. A lower flue gas temperature means less draft.

Closed heaters (stoves, fireplaces with doors, inserts, ovens etc.) burn more slowly and with much less dilution air. Thus there is less flue gas volume at a higher temperature, so this means more draft.

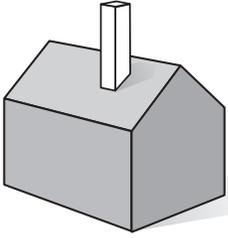
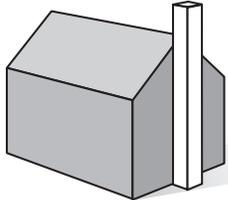
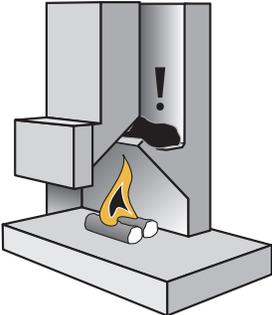
Open heaters are more susceptible to draft performance problems, but the following venting problem descriptions apply to all heating appliances:



### 2.1.1. Problems associated with the venting system

Problem	Description	Can Occur when..	Possible Solutions
<p>The chimney flue is too small.</p> 	<p>A chimney may be severely restricted if the inner diameter of the flue is too small. The velocity of the flue gases reaches a point where the flow resistance is so substantial that the flow resistance exceeds the draft.</p> <p>See also “Oversized Fireplace Opening”.</p>	<ul style="list-style-type: none"> <li>• A chimney is relined and the diameter thus reduced.</li> <li>• A one-sided fireplace is converted into a see-through fireplace.</li> <li>• The chimney is improperly designed (undersized) to begin with.</li> <li>• An existing chimney is used for a size heating appliance it was not designed for.</li> </ul>	<ul style="list-style-type: none"> <li>• Redesign and rebuild the chimney to meet the draft requirements.</li> <li>• Install a heating appliance that does not exceed the capacity of the existing chimney.</li> <li>• Close off one side of a see-through fireplace</li> <li>• Reduce the opening of the fireplace. (Installing glass doors will not help unless the glass doors are designed to be closed during fireplace operation)</li> <li>• Install a mechanical venting system</li> </ul>
<p>The chimney flue is too large.</p> 	<p>While increasing the flue size increases the capacity of a chimney, it can potentially reduce the available draft. Gases move more slowly in a large flue, and a large flue has more thermal mass (and more surface) than a small flue. More heat is transferred from the flue gas to the chimney, which affect the draft adversely.</p> <p>Extreme cooling of the chimney can offset gains in capacity (see also “The chimney is installed on an outside wall”)</p>	<ul style="list-style-type: none"> <li>• Stove or fireplace insert is connected into an existing chimney that used to serve a wood-burning fireplace.</li> <li>• A wood-burning fireplace is converted into a gas-fired fireplace and the existing chimney is used.</li> <li>• A set of gas logs is installed in a wood-burning fireplace.</li> <li>• The chimney is improperly designed to begin with.</li> </ul>	<ul style="list-style-type: none"> <li>• Reline the chimney to reduce the flue opening and match the requirements of the appliance it serves.</li> <li>• Convert the gas-fireplace back to its original wood-burning design.</li> <li>• Install a mechanical venting system</li> </ul>
<p>The chimney is too short</p> 	<p>A tall chimney creates more draft than a short chimney. Chimney height and the temperature difference between flue gas temperature and the temperature of the outside air are major factors influencing the amount of draft.</p> <p>A rule of thumb for minimum height is a total system height (from bottom of appliance to the top of the chimney) of not less than 15'. If it is too short, it could also be terminated improperly. The termination should generally be at least 3 feet above anything within 10 feet.</p>	<ul style="list-style-type: none"> <li>• The chimney is on a slanted roof</li> <li>• The chimney is improperly designed to begin with.</li> </ul>	<ul style="list-style-type: none"> <li>• Extend the chimney by adding chimney sections or tiles. If a system meets the recommended minimum height and draft problems are experienced, it may or may not have any effect to extend the chimney height. Try with a temporarily installed chimney pipe or steel pipe to verify this will in fact solve the problem.</li> <li>• Install a mechanical venting system</li> </ul>



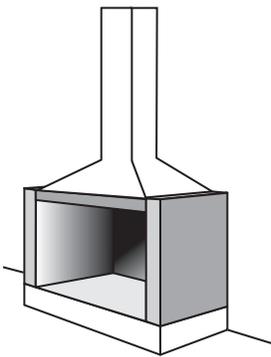
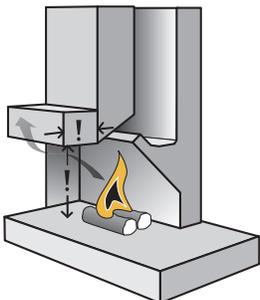
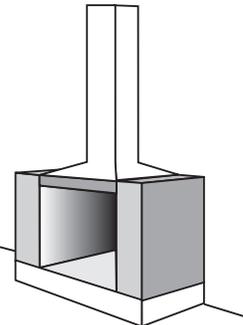
Problem	Description	Can Occur when..	Possible Solutions
<p>The chimney is too high.</p> 	<p>Increasing the height of a chimney increases the draft. Draft increases in proportion with chimney height but only to a certain point. At some point, additional height gives the flue gases more time to transfer heat to the flue walls and cool off. This will cause a reduction in the available draft.</p> <p>If a system meets the recommended minimum height and draft problems are experienced, it may or may not have any effect to extend the chimney height.</p>	<ul style="list-style-type: none"> <li>• The chimney is serving a fireplace in a multistory building (apartment complex)</li> <li>• A large part of the chimney is exposed to the outside.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce the height</li> <li>• Insulate the chimney</li> <li>• Install a mechanical venting system</li> </ul>
<p>The chimney is placed outside the building envelope</p> 	<p>If one or more sides of a chimney are exposed to the outside, the chimney can experience excess cooling, which will reduce the draft. The chilling effect can be so bad that the exhaust gas is not able to create any draft at all – at least not during start-up. The best location of a chimney is within the building so only a very small part of the chimney is exposed to the outside.</p>	<ul style="list-style-type: none"> <li>• The chimney is installed on an outside wall.</li> <li>• The chimney is not insulated</li> <li>• The chimney is installed in a location that meets code but is detrimental to proper draft.</li> </ul>	<ul style="list-style-type: none"> <li>• Reline the chimney and/or provide better insulation</li> <li>• Install a mechanical venting system</li> </ul>
<p>Obstructions or blockages in the venting system</p> 	<p>A chimney can be obstructed by debris, like leaves or by mortar left over during construction. Or it could be by an animal or bird building a nest. Creosote build-up could be blocking the flue or the chimney cap. Blockages might occur in deteriorating chimneys if parts of the interior collapses.</p>	<ul style="list-style-type: none"> <li>• The flue liner is deteriorating.</li> <li>• Birds nests have been built outside the heating season.</li> </ul>	<ul style="list-style-type: none"> <li>• Scan the inside of the chimney in search for obstructions blockages. Repair if deteriorations are found.</li> <li>• Remove animal's nests.</li> <li>• Clean the chimney for creosote or debris</li> </ul>



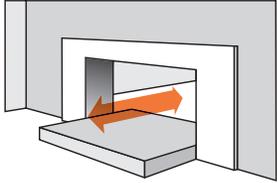
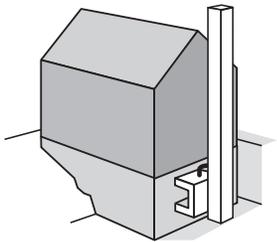
## 2.1.2 Problems associated with the heating appliance

The chimney is not the only culprit. The heating appliance itself can be the problem and cause spillage or improper combustion. Heating appliance problems

depend on the appliance type. Fireplaces and stoves experience different problems:

Problem	Description	Can Occur when..	Possible Solutions
<p>Oversized fireplace opening</p> 	<p>Generally speaking, there should be a 1:10 relationship in the cross-sectional area between flue size and fireplace opening. A 24"x 36" fireplace opening equals 864 sq.in., so the cross-sectional area of the flue should be at least 86 sq.in. This is equivalent to a 10" ID flue.</p>	<ul style="list-style-type: none"> <li>• The fire has been redesigned to add more front area.</li> <li>• The fireplace is not designed properly to begin with.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce the opening by installing a steel shield at the top of the fireplace opening. The height can be determined by using the 1:10 rule. Example: the fireplace opening is 40"x25" or 1,000 sq.in and the flue size is 10" ID – or 86 sq.in. Reduce the fireplace opening to 860 sq.in. by blocking off 140 sq.in. on top. 140 divided by 40 equals 3.5" which should be the height of the shield.</li> <li>• Reduce the opening by rebuilding it.</li> <li>• If the lintel is less than 6" below the damper assembly, it should be extended. Or, add a shield as described above.</li> <li>• Install a mechanical draft system.</li> </ul>
<p>The lintel may be too small or too deep</p> 	<p>The lintel prevents the smoke from rolling out by capturing and containing it – it serves the same purpose as the front edge of a kitchen hood. If it is too deep or too small, it may not be able to capture and contain the smoke.</p>	<ul style="list-style-type: none"> <li>•The fireplace is not designed properly to begin with.</li> </ul>	<ul style="list-style-type: none"> <li>• Increase the height of the lintel.</li> <li>• Decrease the depth of the lintel.</li> <li>• Install a mechanical draft system.</li> </ul>
<p>The smoke chamber is improperly designed</p> 	<p>The smoke chamber guides the smoke towards the chimney flue. If there is no smoke chamber, or it's too low, the smoke stays in the throat or the firebox and becomes turbulent after which it will start spilling. The smoke chamber should be centered with the sides angled at not less than 45°. It could also be that the inside construction is irregular with protrusions.</p>	<ul style="list-style-type: none"> <li>• The fireplace is not designed properly to begin with.</li> </ul>	<ul style="list-style-type: none"> <li>• Increase the height of the smoke chamber.</li> <li>• Parge the smoke chamber walls or otherwise smooth the sides.</li> <li>• Install a mechanical draft system.</li> </ul>



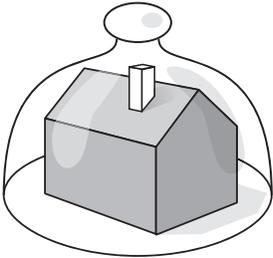
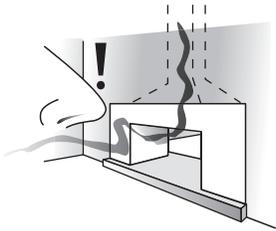
Problem	Description	Can Occur when..	Possible Solutions
<p>The appliance is a see-through fireplace</p> 	<p>Among critical fireplaces is the so-called “see-through” fireplace – a fireplace that is open into two rooms. The fireplaces must capture the air in the same way as an exhaust hood, which requires good draft in order to maintain a high velocity over the fireplace opening. Very often turbulence can be experienced inside the smoke chamber, and smoke problem can occur.</p>	<ul style="list-style-type: none"> <li>• Fireplace was converted from a one-sided fireplace into a see-through</li> <li>• No smoke chamber</li> <li>• Opening up into rooms with different pressures (one room has stairs, vaulted ceiling etc., the other one has not)</li> </ul>	<ul style="list-style-type: none"> <li>• Close one side of the see-through fireplace.</li> <li>• Redesign the smoke chamber to provide a better flow.</li> <li>• Redesign and rebuild the chimney to provide the proper draft.</li> <li>• Install a mechanical draft system</li> </ul>
<p>The appliance is in the wrong place.</p> 	<p>Performance problems can also be experienced if the appliance is in the wrong place. The chimney is put in an impossible situation where it is not given a chance to work.</p>	<ul style="list-style-type: none"> <li>• A fireplace or stove located in the basement of a building.</li> <li>• The chimney makes too many changes of directions (too many elbows) to get flue gases from the appliance to the outside.</li> </ul>	<ul style="list-style-type: none"> <li>• Redesign the venting system – if possible</li> <li>• Install a mechanical draft system</li> <li>• Remedies to increase frontal velocity include the following: (1) increase chimney height (using the same flue area) and extend the last tile 6 inches or more upward; (2) decrease frontal opening by lowering the lintel or raising the hearth (glass doors may help); and (3) increase the free area through the damper (ensure that it opens fully and without interference).</li> </ul>

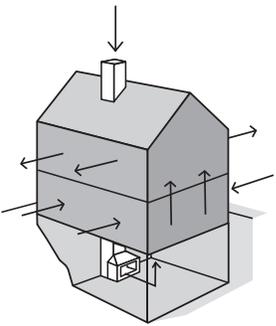


### 2.1.3 Problems associated with the building/house

In the past heating engineers often used high indoor pressure to keep cold air from infiltrating. When houses were leaky (before energy awareness), it was thought better to force warm air out through cracks to prevent cold air from infiltrating. In current homes and buildings pressurization is bad because pressurized

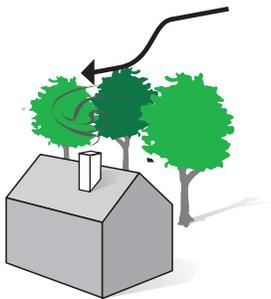
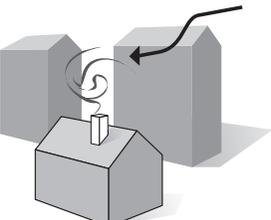
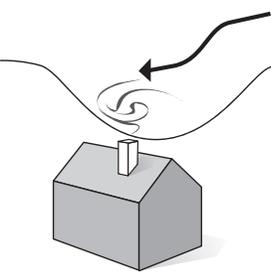
conditioned air is being pushed through walls and ceilings. If the pressurized air is moist – which it often is – water is being pushed into the walls where it will soak the insulation. This can lead to mold, mildew or rot.

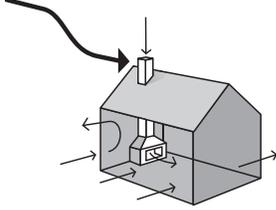
Problem	Description	Can Occur when..	Possible Solutions
<p>The building is too tight</p> 	<p>A heating appliance needs air for the combustion process. If the building is tight and the proper amount of combustion air can not be supplied, a smoking fireplace or stove may be the result. If opening a window or door close to the fireplace solves the problem an outside air supply should be installed.</p>	<ul style="list-style-type: none"> <li>• The house is build too tight to begin with.</li> <li>• New and better insulated windows have been installed.</li> <li>• The building has been properly insulated.</li> </ul>	<ul style="list-style-type: none"> <li>• Install a properly sized outside air intake ducted to the bottom of the fireplace. This must be relatively large and should in most cases exceed a 6 inch ID. Actual size depends on the fireplace opening. It could be powered by a fan or blower.</li> <li>• Provide supply air to the room in which the fireplace is located.</li> <li>• Install a mechanical venting system, but make sure air can be drawn into the room in which the fireplace is located, and it does not adversely affect the operation of other heating appliances.</li> </ul>
<p>There are odors from the heating appliance when not used</p> 	<p>Draft is highly dependant on barometric pressure and temperature. On a hot, humid and rainy day there is not much natural draft in a chimney and the flow may reverse causing it to produce the odor. This is more of an indoor air quality problem than a draft problem. The chimney may work fine once a fire is built in the heating appliance.</p>		<ul style="list-style-type: none"> <li>• Have the chimney cleaned thoroughly and make sure all creosote has been removed.</li> <li>• Install a chimney cap</li> <li>• Install a tight fitting chimney top mounted damper</li> <li>• Install a tight fitting set of glass door</li> <li>• Install a mechanical draft system</li> </ul>

Problem	Description	Can Occur when..	Possible Solutions
<p>Stack effect created inside the building</p> 	<p>Stack effect is a symptom primarily experienced in multistory buildings. The stack effect in itself is not a problem. It is a very common phenomenon in high-rise buildings where it is 'enhanced' by the existence of elevators that constantly changes the pressure when ascending and descending. Efforts to 'control' the stack effect often lead to a pressurized building, so by 'solving' one problem another – worse – problem could be created.</p> <p>In some literature expressions like “high-pressure plane”, “low-pressure plane” and “neutral-pressure plane” can be found. These expressions are used in conjunction with fire-rating of doors, and have no scientific meaning within the building science. “Stack-effect” is a word used in the science of IAQ or Indoor Air Quality as an explanation of how pollutants are transported within a building.</p> <p>Open-fired heating appliances often experience draft problems when exposed to the stack effect. The chimney draft is eliminated due to negative pressure at the inlet of the heating appliance, so spillage occurs immediately during start-up.</p>		<ul style="list-style-type: none"> <li>• Install a mechanical air supply fan to provide air into the building close to where the heating appliance is located.</li> <li>• “Isolate” the heating appliance from the negative pressure by building a room for it where combustion air can be supplied.</li> <li>• Install a mechanical venting system. Installing a mechanical venting system is often the simplest, most effective and least expensive solution to stack effect problems. Other solutions can interfere dramatically with the building operation and lead to dismal energy efficiency.</li> </ul>



## 2.1.4 Problems associated with the building's environment

Problem	Description	Can Occur when..	Possible Solutions
<p>Tall trees surrounding the building</p> 	<p>Being a very weak force it doesn't take much to affect the draft. A tall tree in the vicinity of the chimney can create turbulence that at times may cause spillage in the heating appliance served by the chimney.</p> <p>A problem like this could literally have been growing over the years. It is not uncommon that a fireplace that has been working well for years suddenly experience draft problems due to trees growing up around the building.</p>	<ul style="list-style-type: none"> <li>• Trees are growing during the years.</li> </ul>	<ul style="list-style-type: none"> <li>• Raise the chimney</li> <li>• Cut down trees</li> <li>• Install a mechanical draft system</li> </ul>
<p>There is a taller building next door</p> 	<p>Just like a tree the neighboring building can cause similar problems. It may be a taller building that affect the wind flow patterns and cause flow reversal in the chimney.</p>	<ul style="list-style-type: none"> <li>• New building is constructed on the neighboring lot.</li> </ul>	<ul style="list-style-type: none"> <li>• Raise the chimney</li> <li>• Install a mechanical draft system</li> </ul>
<p>The building is located in a valley or surrounded by taller buildings</p> 	<p>A building in a valley can find itself in a low pressure area (inversion) which can adversely affect the draft. Inversions are common in hilly or mountainous areas. A building surrounded by taller buildings can experience similar problems.</p>		<ul style="list-style-type: none"> <li>• Install a mechanical draft system</li> </ul>

Problem	Description	Can Occur when..	Possible Solutions
<p>The wind is creating a downdraft</p> 	<p>Wind induced downdraft is a common type of draft problem – and often it’s only occasional. As the name says it may only occur on a windy day when the wind is blowing from a certain direction. Wind induced downdraft is caused by “eddies” – or flow patterns around the building and the chimney.</p>	<ul style="list-style-type: none"> <li>• The downdraft can be caused by windloading. This is a scenario where eddies, or flow patterns, create an unfavorable draft condition. When the wind hits one side of the building it tends to create a positive pressure on this side (windward side). This is balanced out by a negative pressure on the opposite side (leeward side). This phenomenon can create pressure changes inside the building which can adversely affect fireplace operation.</li> <li>• This is often experienced at oceanfront or lakefront properties and when located in mountaineous areas.</li> </ul>	<ul style="list-style-type: none"> <li>• Install a chimney cap</li> <li>• Extend the chimney beyond the eddy</li> <li>• Install a mechanical draft system</li> </ul>



### 3. Venting Standards and Codes

All types of venting of a heating appliance, whether this is wood or gas fired, is governed by a national or local code.

The standards can be made by an independent organization, like National Fire Protection Association (NFPA) or by industry-related organizations. These standards can, by choice, be adopted by a state, a county, a city or another local jurisdiction.

In the venting area, the applicable code depends on the fuel used. Pay special attention to the code version in effect. Local jurisdictions don't always follow the latest version of a standard. Some may still use a 1992 version while others have adopted the 2002 version.

For solid-fuel fired applications the following standards and codes usually apply:

- NFPA211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances
- IMC, International Mechanical Code

For gas-fired applications these apply:

- NFPA54 / ANSI Z223.1 National Fuel Gas Code
- IFGC, International Fuel Gas Code

In very general terms there are no major differences in the way the different codes govern gravity venting. This is not the case when it comes to mechanical venting, so this section will concentrate on the codes and standards surrounding mechanical venting of heating appliance.

The concerns surrounding mechanical venting are about how to handle the "flow of fuel" in case the mechanical draft system experiences an electrical or mechanical failure.

#### 3.1 Solid-fuel standards and codes

The most important part of the venting code deals with the minimum performance. It says:

**1-7.1 Minimum Performance.** A chimney or vent shall be so designed and constructed to develop a flow sufficient to remove completely all flue or vent gases to the outside atmosphere. Chimneys or vents shall be evaluated to ensure proper performance with respect to draft, creosote buildup, and condensation. The venting system shall satisfy the draft requirements of the connected appliance(s) in accordance with the manufacturers' instructions or approved methods.

(NFPA211, 2000 Edition, pg. 211-10)

It's worth mentioning that according to the code,

a smoking fireplace is in fact a code violation that requires a correction.

#### NFPA211:

The NFPA211 standard allows the use of mechanical venting under certain conditions depending on the version adopted.

Up until and including the 1996 edition, the mechanical draft system had to meet these requirements:

**1-7.2 Mechanical Draft Systems.** A listed mechanical draft system of either forced or induced draft design shall be permitted to be used to increase draft or capacity. Where a mechanical draft system is installed, provision shall be made to prevent the flow of fuel to an automatically fired appliance(s) when that system is not operating.

(NFPA211, 1996 Edition, pg. 211-10)

Since the 2000 edition, a mechanical draft system must meet these requirements:

**1-7.2 Mechanical Draft Systems.** A listed mechanical draft system of either forced or induced draft design shall be permitted to be used to increase draft or capacity. Where a mechanical draft system is installed, provision shall be made to prevent the flow of fuel to an automatically fired appliance(s) when that system is not operating.

**1-7.2.1 Effect on Other Equipment.** The operation of a mechanical draft system shall not adversely affect the performance or safety of, or cause spillage of combustion products from, other combustion equipment operating within the same building. Proper performance and safety of other combustion equipment shall be verified by testing prior to putting the mechanical draft system into service. Such testing shall include operation of the mechanical draft system together with other exhaust equipment likely to operate simultaneously.

**1-7.2.2 Manually Fired Appliances.** Mechanical draft systems of either forced or induced draft shall not serve manually fired appliances.

Exception No. 1: Where the mechanical draft system is an integral part of a listed appliance.

Exception No. 2: Solid fuel cooking appliances as addressed in NFPA96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.

Exception No. 3: Engineered mechanical draft systems that include the following provisions:

(a) The following detection and warning devices shall be installed and line voltage devices when installed, shall be provided with a battery backup system:

- (1) A device that produces an audible and visible warning upon failure of the mechanical draft system shall be installed. The device

shall be activated by both loss of electrical power supply or by operational failure of the mechanical draft system, at any time while the mechanical draft system is switched on.

(2) A smoke detector and alarm shall be installed and maintained in accordance with NFPA72, National Fire Alarm Code®. The detector shall be installed in the same room as the appliance served by the mechanical draft system.

(3) A listed carbon monoxide warning device shall be installed in accordance with the manufacturers' instructions.

(b) The mechanical draft system shall be listed in accordance with UL378, Draft Equipment, for use with the type of appliance and range of chimney service appropriate for the application. The mechanical draft system shall not cause or permit blockage of the flue or electrical hazard after exposure to a chimney fire or over fire conditions. The mechanical draft system shall be installed in accordance with the terms of the listing and the manufacturers' instructions.

(c) The mechanical draft system shall be sized to maintain draft within the range specified by the appliance manufacturer.

(NFPA211, 2000 Edition, pg. 211-10)

The termination of a venting system including a mechanical draft system follows other requirements as described in the following:

7-4 Termination (Height).

7-4.1 All vents shall terminate above the roof surface.  
Exception: Pellet vents and other vents as provided in 7-4.5 and Section 7-7.

7-4.1.1 Vents installed with mechanical exhausters shall terminate not less than 12 in. (305 mm) above the highest point where they pass through the roof surface.

7-4.1.2 Vents installed with a listed cap shall terminate in accordance with the terms of the cap's listing.

7-4.1.3 Vents installed without listed caps or mechanical exhausters shall extend 2 ft (0.61 m) above the highest point where they pass through the roof surface of a building and at least 2 ft (0.61 m) higher than any portion of a building within 10 ft (3.1 m). [See Figures 1-8(a) and (b).]

7-4.2 Natural draft vents for gas appliances shall terminate at an elevation not less than 5 ft (1.53 m) above the highest connected appliance outlet.  
Exception: As provided in 7-4.3 and 7-7.2.

7-4.3 Natural draft gas vents serving vented wall furnaces shall terminate at an elevation not less than 12 ft (3.7 m) above the bottom of the furnace.

7-4.4 Vents passing through roofs shall extend through the roof flashing.

7-4.5 Mechanical draft systems shall not be required to comply with 7-4.1 and 7-4.3, provided they comply with the following:

(1) The exit terminal of a mechanical draft system other than a direct vent appliance (sealed combustion system appliance) shall be located in accordance with the following:

a. Not less than 3 ft (0.91 m) above any forced air inlet located within 10 ft (3 m)

b. Not less than 4 ft (1.2 m) below, 4 ft (1.2 m) horizontally from, or 1 ft (305 mm) above any door, window, or gravity air inlet into any building

c. Not less than 2 ft (0.61 m) from an adjacent building and not less than 7 ft (2.1 m) above grade where located adjacent to public walkways

(2) The exit terminal shall be so arranged that flue gases are not directed so that they jeopardize people, overheat combustible structures, or enter buildings. (3) Forced draft systems and all portions of induced draft systems under positive pressure during operation shall be designed and installed to be gastight or to prevent leakage of combustion products into a building.

(4) Through-the-wall vents for gas appliances shall not terminate over public walkways or over an area where condensate or vapor could create a nuisance or hazard or could be detrimental to the operation of regulators, relief valves, or other equipment.

(NFPA211, 2000 Edition, pg. 211-29)

## IMC

The International Mechanical Code is virtually in full agreement with NFPA211:

804.3.7 Exhauster sizing. Mechanical flue exhausters and the vent system served shall be sized and installed in accordance with the manufacturer's installation instructions.

804.3.8 Mechanical draft systems for manually fired appliances and fireplaces. A mechanical draft system shall be permitted to be used with manually fired appliances and fireplaces where such system complies with all of the following requirements:

1. The mechanical draft device shall be listed and installed in accordance with the manufacturer's installation instructions.
2. A device shall be installed that produces visible and audible warning upon failure of the mechanical draft device or loss of electrical power, at any time that the mechanical draft device is turned on. This device shall be equipped with a battery backup if it receives power from the building wiring.
3. A smoke detector shall be installed in the room with the appliance or fireplace. This device shall be equipped with a battery backup if it receives power from the building wiring.

(IMC, 2003 Edition, pg. 69)



Just as the NFPA211 describes termination requirements almost identical requirements can be found in the IMC:

804.3 Mechanical draft systems. Mechanical draft systems of either forced or induced draft design shall comply with Sections 804.3.1 through 804.3.7.

804.3.1 Forced draft systems. Forced draft systems and all portions of induced draft systems under positive pressure during operation shall be designed and installed so as to be gas tight to prevent leakage of combustion products into a building.

804.3.2 Automatic shutoff. Power exhausters serving automatically-fired appliances shall be electrically connected to each appliance to prevent operation of the appliance when the power exhauster is not in operation.

804.3.3 Termination. The termination of chimneys or vents equipped with power exhausters shall be located a minimum of 10 feet (3048 mm) from the lot line or from adjacent buildings. The exhaust shall be directed away from the building.

804.3.4 Horizontal terminations. Horizontal terminations shall comply with the following requirements:

1. Where located adjacent to walkways, the termination of mechanical draft systems shall be not less than 7 feet (2134 mm) above the level of the walkway.
2. Vents shall terminate at least 3 feet (914 mm) above any forced air inlet located within 10 feet (3048 mm).
3. The vent system shall terminate at least 4 feet (1219 mm) below, 4 feet (1219 mm) horizontally from or 1 foot (305 mm) above any door, window or gravity air inlet into the building.
4. The vent termination point shall not be located closer than 3 feet (914 mm) to an interior corner formed by two walls perpendicular to each other.
5. The vent termination shall not be mounted directly above or within 3 feet (914 mm) horizontally from an oil tank vent or gas meter.
6. The bottom of the vent termination shall be located at least 12 inches (305 mm) above finished grade.

804.3.5 Vertical terminations. Vertical terminations shall comply with the following requirements:

1. Where located adjacent to walkways, the termination of mechanical draft systems shall be not less than 7 feet (2134 mm) above the level of the walkway.
2. Vents shall terminate at least 3 feet (914 mm) above any forced air inlet located within 10 feet (3048 mm).
3. Where the vent termination is located below an adjacent roof structure, the termination point shall be located at least 3 feet (914 mm) from such structure.
4. The vent shall terminate at least 4 feet (1219

mm) below, 4 feet (1219mm) horizontally from, or 1 foot (305 mm) above any door, window or gravity air inlet for the building.

5. A vent cap shall be installed to prevent rain from entering the vent system.
6. The vent termination shall be located at least 3 feet (914 mm) horizontally from any portion of the roof structure.

804.3.6 Exhauster connections. An appliance vented by natural draft shall not be connected into a vent, chimney or vent connector on the discharge side of a mechanical flue exhauster.

(IMC, 2003 Edition, pg. 69)

### 3.2 Gas Standards and Codes

Mechanical venting of gas-fired appliances has become an accepted standard. Many of today's heating appliances rely on mechanical venting to perform and meet efficiency and emission standards.

Despite the growing popularity some appliance manufacturers are still reluctant to allow the use of mechanical venting to vent their appliances. However, they don't have any support from the standards and the codes and their reluctance is usually an indication of lack of knowledge rather than a lack of adaptability.

If an appliance's installation manual says that it must be installed according to NFPA54/ANSI Z223.1 or similar this means a mechanical draft system can be used. Only if the installation manual specifically limits its use by a statement like: "Mechanical venting is not acceptable" should the use of a mechanical draft system be avoided.

A manufacturer can not deny warranty coverage if the conditions above are met.

10.3.1 Minimum Safe Performance. A venting system shall be designed and constructed so as to develop a positive flow adequate to remove flue or vent gases to the outside atmosphere.

10.3.2 Equipment Draft Requirements. A venting system shall satisfy the draft requirements of the equipment in accordance with the manufacturer's instructions.

(NFPA54/ANSI Z223.1, 2002 Edition, pg. 54-47)

Just like for solid fuel-burning equipment, gas equipment must meet minimum performance requirements:



503.3 Design and construction. A venting system shall be designed and constructed so as to develop a positive flow adequate to remove flue or vent gases to the outside atmosphere.

503.3.1 Equipment Draft Requirements. A venting system shall satisfy the draft requirements of the equipment in accordance with the manufacturer's instructions.

(IFGC, 2003 Edition, pg. 75)

#### NFPA54 / ANSI Z223.1:

In this code the installation of a mechanical draft system must meet the following requirements:

##### 10.3.4 Mechanical Draft Systems.

10.3.4.1 Mechanical draft systems shall be listed and shall be installed in accordance with the terms of their listing and both the appliance and the mechanical draft system manufacturers' instructions.

10.3.4.2 Gas utilization equipment requiring venting shall be permitted to be vented by means of mechanical draft systems of either forced or induced draft design.

Exception: Incinerators.

10.3.4.3 Forced draft systems and all portions of induced draft systems under positive pressure during operation shall be designed and installed so as to prevent leakage of flue or vent gases into a building.

10.3.4.4 Vent connectors serving equipment vented by natural draft shall not be connected into any portion of mechanical draft systems operating under positive pressure.

10.3.4.5 Where a mechanical draft system is employed, provision shall be made to prevent the flow of gas to the main burners when the draft system is not performing so as to satisfy the operating requirements of the equipment for safe performance.

10.3.4.6 The exit terminals of mechanical draft systems shall be not less than 7 ft (2.1 m) above grade where located adjacent to public walkways and shall be located as specified in 10.8.1 and 10.8.2.

(NFPA54/ANSI Z223.1, 2002 Edition, pg. 54-47)

From this it is clear that any type of gas utilization equipment, except for incinerators, can be vented by means of a mechanical draft system. As the code notes one exception only, this means that any type fireplace, stove, gas heater, furnace etc. that is gas fired can be vented mechanically.

10.6.2 Gas Vent Termination. The termination of gas vents shall comply with the following requirements:

- (1) A gas vent shall terminate in accordance with one of the following:
  - (a) Above the roof surface with a listed cap or listed roof assembly. Gas vents 12 in. (300 mm)

in size or smaller with listed caps shall be permitted to be terminated in accordance with Figure 10.6.2 and Table 10.6.2, provided they are at least 8 ft (2.4 m) from a vertical wall or similar obstruction. All other gas vents shall terminate not less than 2 ft (0.6 m) above the highest point where they pass through the roof and at least 2 ft (0.6 m) higher than any portion of a building within 10 ft (3 m).

(b) Industrial gas utilization equipment as provided in 10.2.4.

(c) Direct-vent systems as provided in 10.2.5.

(d) Equipment with integral vents as provided in 10.2.6.

(e) Mechanical draft systems as provided in 10.3.4.

(f) Ventilating hoods and exhaust systems as provided in 10.3.5.

(NFPA54/ANSI Z223.1, 2002 Edition, pg. 54-50)

#### IFGC:

The International Fuel Gas Code is almost identical to the National Fuel Gas Code, which is clear when reviewing the following and comparing it to NFPA54 Par. 10.3.4.:

503.3.3 Mechanical Draft Systems. Mechanical draft systems shall comply with the following

1. Mechanical draft systems shall be listed and shall be installed in accordance with the terms of their listing and both the appliance and the mechanical draft system manufacturers' instructions.
2. Equipment, except incinerators, requiring venting shall be permitted to be vented by means of mechanical draft systems of either forced or induced draft design.
3. Forced draft systems and all portions of induced draft systems under positive pressure during operation shall be designed and installed so as to prevent leakage of flue or vent gases into a building.
4. Vent connectors serving equipment vented by natural draft shall not be connected into any portion of mechanical draft systems operating under positive pressure.
5. When a mechanical draft system is employed, provision shall be made to prevent the flow of gas to the main burners when the draft system is not performing so as to satisfy the operating requirements of the equipment for safe performance.





6. The exit terminals of mechanical draft systems shall be not less than 7 ft (2134 mm) above grade where located adjacent to public walkways and shall be located as specified in 503.8, Items 1 and 2.

*(IFGC, 2003 Edition, pg. 78)*

The International Fuel Gas Code is also virtually identical to NFPA54 when it comes to the venting termination:

503.6.6 Gas vent terminations. A gas vent shall terminate in accordance with one of the following:

1. Above the roof surface with a listed cap or listed roof assembly. Gas vents 12 inches (305 mm) in size or smaller with listed caps shall be permitted to be terminated in accordance with Figure 503.6.6, provided that such vents are at least 8 feet (2438 mm) from a vertical wall or similar obstruction. All other gas vents shall terminate not less than 2 feet (610mm) above the highest point where they pass through the roof and at least 2 feet (610 mm) higher than any portion of a building within 10 feet (3048 mm).
2. As provided for industrial equipment in Section 503.2.2.
3. As provided for direct-vent systems in Section 503.2.3.
4. As provided for equipment with integral vents in Section 503.2.4.
5. As provided for mechanical draft systems in Section 503.3.3.
6. As provided for ventilating hoods and exhaust systems in Section 503.3.4.

*(IFGC, 2003 Edition, pg. 78)*

## 4. Venting System Design

### 4.1. Gravity Systems

#### 4.1.1 The chimney

Chimneys come in different types, shapes and sizes. The two main types of chimneys are: metal and masonry.

Metal chimneys are available in different types of metal, like 430, 304, 316 or AL29-4C stainless steel, or it could be in aluminum. Metal chimneys are also called “pre-fabricated”, “Class A”, “Type B” as well as “single-wall”, “double-wall”, “triple-wall” or “zero-clearance”. Although they all serve the same purpose – removing products of combustion and maintain proper draft – each type has its limitation in the application in which it can be applied.

A “pre-fabricated” chimney is a chimney that is made as a standard product using a standardized manufacturing method and is made with a joint-system that makes it easy to install in the field. Virtually all metal chimneys are “pre-fabricated”. One exception, however, is the welded single-wall steel pipe which is typically designed and assembled via welding in the field.

The table below shows each chimneys application and listing:

Metal chimneys are available in many sizes, some

from 4 inch ID all the way up to 60 inch ID. Sizes up to 12 inch ID are often considered “residential” sizes while sizes larger than 12 inch are considered “commercial”. The size of a chimney affects its capacity and how much product of combustion it can remove. Each size has a specific usable area, which is called the “cross-sectional area”, and this area – along with the chimney height – determines the chimney’s capacity.

It’s important to understand that the cross-sectional area grows exponentially with the increase in ID. For example, a 6 inch ID chimney has a cross-sectional area of approx. 28 sq.in, while an 8 inch ID chimney has a cross-sectional area of approx. 50 sq.in. Increasing the ID by 33%, the cross-sectional area increased by almost 80% - and so did the chimney’s capacity. Increasing the ID from 6” to 12” (100% increase) increases the cross-sectional area by 400%!

Masonry chimneys are normally built using brick and mortar. The products of combustion are conveyed through a flue or liner in the center of the chimney. This flue or liner can be square, rectangular, oval or round.

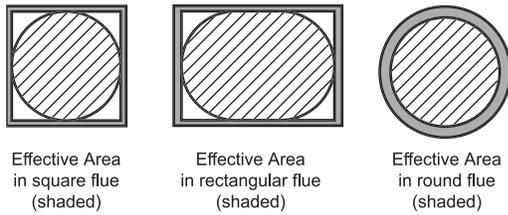
Just as steel chimneys, a masonry chimney has an effective area. Only a certain area of a flue is used due to general airflow patterns or characteristics.

Uses	Gas Appliance Vent	Chimney Liner		Building Heating Appliance Chimney		Pellet Vent	Special Gas Vent
Fuel	Nat. Gas, Propane and LP only	Nat. Gas, Propane and LP only	Nat. Gas, Propane, LP, Oil, Solid Fuel	Nat. Gas, Propane, LP, Oil, Solid Fuel	Nat. Gas, Propane, LP, Oil, Solid Fuel	Pellets, Nat. Gas, Propane, LP and Oil	Nat. Gas, Propane, LP and Oil
Test Standard	UL441	UL1777	UL103	UL103	UL103	UL641	UL1738
Max. Operating Temperature	400°F above ambient	400°F above ambient	1000°F 1400°F 1 Hour 2100°F 10 Min.	1000°F 1400°F 1 Hour 2100°F 10 Min. *)	1000°F 1400°F 1 Hour 2100°F 10 Min.	500°F above ambient	Single Wall: 480°F Double Wall: 550°F
Operating Conditions	Gravity or induced flow, neutral and negative pressure	Gravity or induced flow, neutral and negative pressure	Gravity or induced flow, neutral and negative pressure	Gravity or induced flow, neutral and negative pressure	Gravity or induced flow, neutral, negative and positive pressure	Gravity or induced flow, neutral and negative pressure	Gravity or induced flow, neutral and negative pressure
Appliances	Listed gas appliances and other appliances listed for venting with Type B gas vent	Listed gas appliances and other appliances listed for venting with Type B gas vent	Listed building heating appliances including fireplaces and stoves	Listed building heating appliances including fireplaces and stoves	Listed building heating appliances including fireplaces and stoves	Pellet fueled and certain gas, or oil appliances	Listed gas or oil fired building heating appliances and other
Material: - inner - outer	Aluminium Aluminium/galv. steel	Aluminum N/A	Stainless steel	304/430 SS 430 or Galv. Steel	304/316 SS Alumnized steel	430 SS Alumnized steel	AL29-4C Alumnized steel
Codes & Standards	NFPA54, NFPA211	NFPA54, NFPA211	NFPA37, NFPA54, NFPA211	NFPA37, NFPA54, NFPA211	NFPA37, NFPA54, NFPA211	NFPA211	NFPA37, NFPA54,
Mechanical Draft System Location	Termination only	Termination only	Termination only	Termination only	Termination or in-line	Termination only	Termination or in-line





The figure below shows the effective area of different flue shapes:



The effective area can be calculated by first determining the hydraulic diameter. More on this subject can be found in Section 5.1.1.

#### 4.1.2 The heating appliance

Designing a gravity venting system is relatively simple, but depends on the appliance in use.

##### 4.1.2.1 Pre-fabricated fireplace for wood or gas with integrated chimney.

This has become a very popular type of fireplace in new construction and it can be gas or wood fired. The chimney has already been sized for the fireplace and all that can vary is the chimney height – at least within some mandated minimum and maximum heights. One 30° offset is typically allowed.

The chimney size selection is often based on the volume of the firebox, and there is no scientific selection method behind it. The method used is often like “a 2 cu.ft. firebox requires a 6 in chimney, a 3 cu.ft. firebox requires an 8 in chimney” and so forth.

If an installation does fall within the recommendations given by the manufacturer then there is not much assistance available. The manufacturers may not be ‘experts’ in venting issues and may state that using a mechanical draft system will void their warranty or the product listing.

If the appliance’s installation manual demands that the installer follows NFPA211 and/or NFPA54 then that entire standard text must be followed. If the standard allows mechanical venting, and the installation manual does not clearly prohibit this, then the manufacturer cannot deny such installation neither can he reject warranty coverage.

##### 4.1.2.2 Pre-fabricated fireplace for wood or gas

This type does not include an integrated chimney. The chimney must be supplied by the installer. However, the fireplace manufacturer must provide sizing and type recommendations for the installer and the recommendations are very much like what you find for the fireplaces that integrate the chimney.

Again, if the appliance’s installation manual demands

that the installer follows NFPA211 and/or NFPA54 that entire standard text must be followed. If the standard allows mechanical venting, and the installation manual does not clearly prohibit this, then the manufacturer cannot deny such installation neither can he reject warranty coverage.

##### 4.1.2.3 Pre-fabricated wood or coal stoves

Stoves are supplied without a chimney. Again the chimney must be supplied by the installer, unless an existing chimney is used for the venting.

The manufacturers’ recommendations are limited to type of chimney, diameter, maximum number of elbows and height restrictions.

##### 4.1.2.4 Custom-made heating appliances

Custom-made heating appliances, such as masonry fireplaces that are wood or gas fired, are more challenging as there is no manufacturer to provide any sizing recommendations. The sizing must be determined by the designer or the installer.

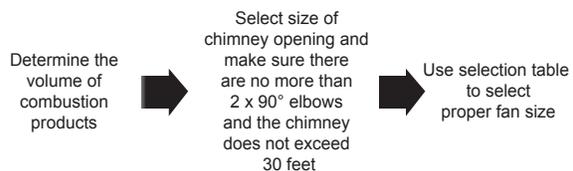
The sizing can be performed in a number of ways depending on the application.

In all open-fired heating appliances a minimum frontal inlet velocity of 0.8 feet per second in conjunction with a chimney gas temperature of at least 300-500°F above ambient, should control smoking in a well-constructed conventional masonry fireplace. The chart on page 24 shows fireplace and chimney dimensions for the specific conditions of circular flues at 0.8 feet per second frontal velocity. This chart readily accounts for maximum frontal opening for a given chimney, as well as for chimney size and height with a predetermined opening. The figure assumes no wind or air supply difficulties.

It may also be adequate to use the 1:10 rule where the cross-sectional area of the chimney flue must be min. 10% of the fireplace opening area.

Other applications may include fireplaces with more than one side or opening, horizontal runs or a number of different elbows, tee’s and more. For these an ‘approved engineering method’ must be used such as prescribed in the ASHRAE Handbook in the Equipment Volume, Chapter 30 for “Chimneys, Gas Vent, and Fireplace Systems”.

The design should follow these steps:



Indoor-outdoor pressure differences caused by winds, building stack effect, and operation of forced-air heating systems or mechanical ventilation affect the operation of a fireplace. Thus, smoking during start up can be caused by many factors unrelated to the chimney. Often, in new homes (especially in high-rise multiple-family construction), fireplaces of normal design cannot cope with mechanically induced reverse flow or shortages of combustion air. In such circumstances, a fireplace should include a mechanical draft system of sufficient capacity to overcome other mechanized air-consuming systems.

## 4.2 Mechanical Venting Systems

Designing and sizing of a mechanical draft system must be performed using an “approved engineering method” such as prescribed in the ASHRAE Handbook in the Equipment Volume, Chapter 30 for “Chimneys, Gas Vent, and Fireplace Systems”.

### 4.2.1 Location of a Mechanical Draft System

A mechanical draft system can be installed at the termination point or in-line between the appliance and the termination point.

In-line mechanical draft systems can only be used when the flue or chimney is airtight downstream from its location. The table on page 18 shows which chimney types can use mechanical draft systems and where they should be located.

### 4.2.2 Installation at Termination Point

When used with a pre-fabricated chimney system, the mechanical draft system should be installed on a special chimney adapter that gives proper support of the additional weight. It is usually not necessary to provide special support for the system as long as the chimney is terminated within 1-5 feet from the roof support.

If the chimney is of a type that requires ventilation between the chimney walls outside the flue, special precaution must be taken not to block the passageways. This can be accomplished by using an adapter that provides an opening of 1 inch between the termination of the chimney and the bottom of the fan (adapter).

### 4.2.3 Installation on Masonry Chimneys

In most cases, a mechanical draft system can be installed directly on the chimney where the flue terminates. The system is placed directly over the flue in lieu of a chimney cap.

### Aesthetics:

From an aesthetical point of view, the installation of a mechanical draft system is no different from the installation of a chimney cap.

However, sometimes a building design does not allow a visible chimney cap or fan. In those situations it may be possible to recess the fan into the cavity of the chimney. The fan must have adequate ventilation available, so it cannot be completely enclosed. A 1-2 inch space or clearance around the sides of the fan is usually acceptable and the discharge can be through weep-holes on the side of the chimney or straight up. There should not be any restrictions.

### 4.2.4 Chimney and Flue Sizing

Sizing of chimney and flue is as important as for gravity venting.

Measures should be taken to assure that the flue size is adequate to allow for a velocity that does not exceed 1,500-1,800 feet per minute. A higher velocity will lead to flow noise - especially in steel chimneys.

On the other hand, the velocity should never fall below 300 feet per minute as this may lead to excessive build-up of creosote or condensate.

“Oversized flues” can also make it more difficult to install the mechanical draft system. Special adapters may be needed to prevent the mechanical draft system from falling into the flue.



## 5. Mechanical System Design

### 5.1 Design Guidelines for Mechanical Venting of Manually Fired Appliances

There are two ways to determine the chimney fan type and size for the specific application.

One alternative is to calculate the flue gas volume and the flow resistance and then select the chimney fan that meets the calculated requirements. This is normally referred to as an “approved engineered method”. For directions on how to do a manual calculation please refer to Appendix A.

The sizings and the selection charts in the following are based on these assumptions:

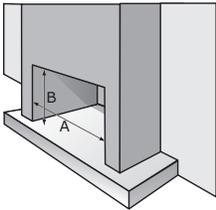
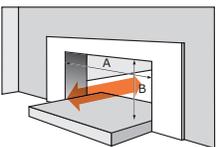
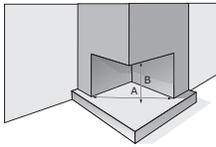
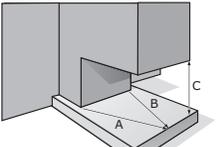
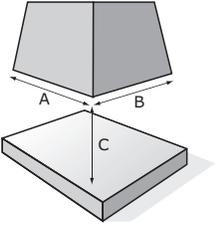
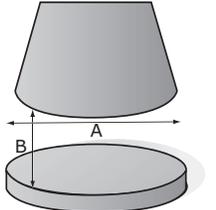
#### 5.1.1 Fireplaces – wood or gas

Height of chimney: feet	18-25
Flue gas temperature:	
Wood	300°F
Gas	200°F
Frontal inlet velocity:	
Fireplace (wood-fired)	48 fpm
Fireplace (gas-fired)	36 fpm
See-through (wood-fired)	72 fpm
See-through (gas-fired)	54 fpm
Freestanding (wood-fired)	88 fpm
Freestanding (gas-fired)	96 fpm
Stoves (wood-fired)	84 fpm

Most applications are relatively simple, and following these four steps makes it easy to size a proper chimney fan for an application.

#### Step 1 - Determine the size of the appliance opening

Use the following charts to determine the opening of the appliance:

Fireplace Type	Formula to determine opening size	
One-sided	$A \times B$	
Two-sided (See-through)	$1.5 \times A \times B$	
Corner	$A \times B$	
Three-sided	$(A + B) \times C$	
Free-standing	$1.5 \times A \times B$  (Dim. C should not exceed 40 inches)	
Free-standing round	$1.185 \times A^2$  (Dim. B should not exceed 40 inches)	

Example: A two-sided fireplace measures 24" x 36" on the largest size. The opening measures 864 sq.in. Multiply with 1.5 and the opening used for the selection table is 1,296 sq.in.

### Step 2 - Determine the size of the chimney opening

For this method a chimney or flue opening must be expressed as the inside diameter in inches. For a round chimney or flue this is not a problem as the size is expressed as f.inst. 9"ID, indicating the inside diameter is 9".

Oval, square or rectangular chimney must first be converted to an equivalent ID. If the flue is a clay tile, then the table below shows the typical standard flue tile size along with the equivalent ID:

Outside Dimensions (inch)	Effective Flue Area (sq.in.)	Equivalent Diameter (ID) (inch)
4 1/2 x 8 1/2	23	5
4 1/2 x 13	34	6
8 x 8	42	7
8 1/2 x 8 1/2	49	8
8 x 12	67	9
8 1/2 x 13	76	10
8 1/2 x 18	102	11
12 x 12	102	11
12 x 16	131	13
13 x 13	127	12
13 x 18	173	14
16 x 16	181	15
16 x 20	222	16
18 x 18	233	17
20 x 20	298	19
20 x 24	335	20
24 x 24	431	23

Example: A fireplace is served by a flue that is 8" x 12" or 9 in ID.

Flue sizes not shown in above table can be converted using the table in Appendix B.

### Step 3 - Check number of offsets and height

Check that there are no more than 2x90° elbows and no more than 30' of height. If there is more than 2x90° elbows, use a bigger fan.

### Step 4 - Select a fan from the sizing table

The following table is used for fireplaces that are wood fired:

	Fireplace Opening (sq.in.) - Wood							
	400	600	900	1,200	1,500	2,000	2,500	3,300
5	RS12	RS16	-	-	-	-	-	-
6	RS9	RS12	RS16	-	-	-	-	-
7	RS9	RS9	RS14	RS16	-	-	-	-
8	RS9	RS9	RS12	RS14	RS16	-	-	-
9	RS9	RS9	RS12	RS14	RS16	RS16	-	-
10	RS9	RS9	RS12	RS12	RS14	RS16	-	-
12	RS9	RS9	RS12	RS12	RS14	RS14	RS16	-
14	RS9	RS9	RS12	RS12	RS12	RS12	RS14	RS16
16	RS9	RS9	RS12	RS12	RS12	RS12	RS14	RS16
18	RS9	RS9	RS12	RS12	RS12	RS12	RS14	RS16
20	RS9	RS9	RS12	RS12	RS12	RS12	RS14	RS16
22	RS9	RS9	RS12	RS12	RS12	RS12	RS14	RS16
24	RS9	RS9	RS12	RS12	RS12	RS12	RS14	RS16

**Note:** The red (dark) background indicates that the fan will most likely create some air-flow noise due to a high air velocity in the chimney. The light grey background indicates the fan base will not cover the chimney opening and a special adapter must be used.

Examples: We have calculated a 24" x 36" (864 sq.in.) wood-fired fireplace and a chimney flue at 8" x 12" or 9 in ID. Using the table we need to use a model RS 12.

If the application involves a gas-fired appliance use this table:

	Fireplace Opening (sq.in.) - Gas							
	400	600	1,000	2,000	2,500	3,000	3,500	5,000
5	RS9	RS12	-	-	-	-	-	-
6	RS9	RS9	RS12	-	-	-	-	-
7	RS9	RS9	RS12	RS14	RS14	-	-	-
8	RS9	RS9	RS9	RS12	RS16	-	-	-
9	RS9	RS9	RS9	RS12	RS12	-	-	-
10	RS9	RS9	RS9	RS12	RS14	RS16	RS16	-
12	RS9	RS9	RS9	RS12	RS14	RS14	RS16	-
14	RS9	RS9	RS9	RS12	RS14	RS14	RS14	-
16	RS9	RS9	RS9	RS12	RS14	RS14	RS14	-
18	RS9	RS9	RS9	RS12	RS14	RS14	RS14	RS16
20	RS9	RS9	RS9	RS12	RS14	RS14	RS14	RS16
22	RS9	RS9	RS9	RS12	RS14	RS14	RS14	RS16
24	RS9	RS9	RS9	RS12	RS14	RS14	RS14	RS16

**Note:** The red (dark) background indicates that the fan will most likely create some air-flow noise due to a high air velocity in the chimney. The light grey background indicates the fan base will not cover the chimney opening and a special adapter must be used.

Examples: We have calculated a 24" x 36" (864 sq.in.) gas-fired fireplace and a chimney flue at 8" x 12" or 9 in ID. Using the table we need to use a model RS 9 - one size smaller than the above sample using a wood-fired fireplace.



### Special applications

#### Fireplaces with two flues:

When a fireplace is served by two flues with identical sizes, it is recommended using two fans – one for each flue. To size up such a system, take the total area of the appliance opening and divide by two. Then select fans as if there are two fireplaces with each one flue.

Example: A wood-fired fireplace with 2,400 sq.in. opening is served by two flues of each 8" x 12" or 9" ID each. Select fans by using 2,400 sq.in. opening divided by two or 1,200 sq.in. Using the sizing tables two RS 14's are needed.

In some situations, a single fan's capacity may be enough to handle a fireplace with two flue. If so, the fan should be installed so it can pull equally from the two flues. A good way to accomplish this is to install the fan on a plenum box where the two flues can vent into.

#### Fan used as a ventilator for odor control:

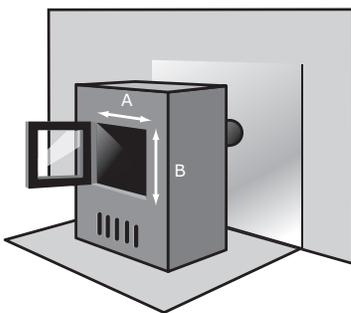
The fan can also be used for odor control. For sizing purposes it should be sized for the application following above guidelines.

### 5.1.2 Stoves & Fireplaces Inserts

Sizing of mechanical venting for stoves and fireplace inserts follow the same guidelines as above.

#### Step 1 - Determine the size of the stove or insert opening

Measure the opening dimensions as shown on the figure below:



#### Step 2 - Determine the size of the chimney opening

Follow the procedure and the table used for fireplaces.

#### Step 3 - Check number of offsets and height

Check that there are no more than 2x90° elbows and no more than 30' of height.

If there is more than 2x90° elbows, use a bigger fan.

#### Step 4 - Select a fan from the sizing table

Select fan from sizing table

Use this chart to select the fan size:

	Opening in sq.in.	
	Max. 300	Over 300
6	RS9	RS12
7	RS9	RS12
8	RS9	RS12
9	RS9	RS12
10	RS9	RS12

### 5.1.3 Other Applications

If you need a chimney fan for an application that is not covered by the charts or if you are not sure about what's needed for your applications, please contact your supplier or call EXHAUSTO for assistance.

## 6. Guide for Mechanical Draft Systems

There is a number of different ways of using mechanical venting systems. The following presents a variety of these applications.

### 6.1 Mechanical Draft System for Wood-fired Fireplace with a Single Flue

#### Application

This is the most common form of installation and is used in all jurisdictions where the 2000 or later edition of the NFPA211 has not yet been adopted.

#### Sequence of Operation

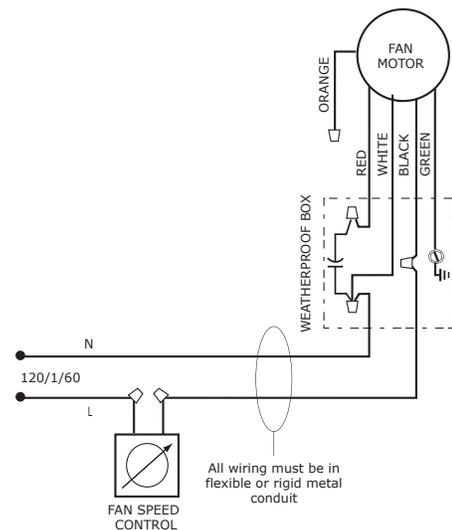
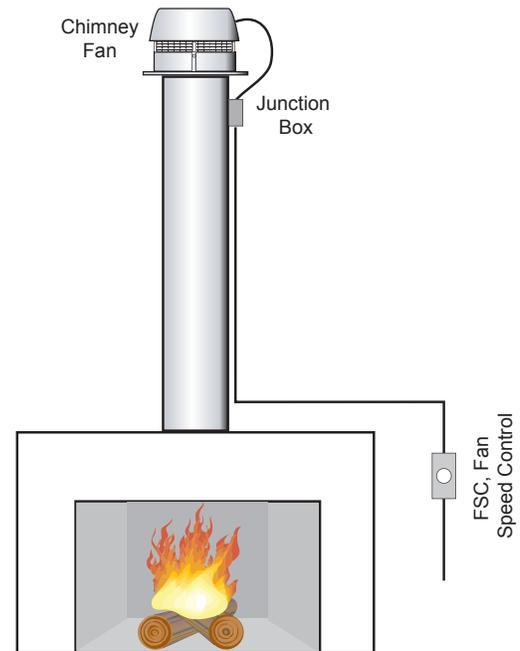
1. Prepare the wood logs in the fireplace.
2. Turn the control on by turning the knob clockwise. A “click” is heard when the dial is turned clockwise which indicates the control is turned on. Adjust the knob to the desired speed.
3. Start your fire by igniting the logs.
4. Once a good flame has been achieved, turn the dial clockwise (reduces speed) until you start to see spillage from the fireplace opening. Spillage can often be detected by holding a hand flat above the fireplace opening and feel the heat from spilling flue gases hitting it. From this point, increase the fan speed slightly by turning the dial counter-clockwise. The dial can be left in this position.
5. If adding logs to the fire, it may be necessary to increase the speed again.
6. When the fire is dying reduce the speed setting further to remove remaining products of combustion.

#### IMPORTANT NOTE:

**Never leave a fire unattended. When a fire is smoldering it is more likely to emit carbon monoxide.**

**It is always a good idea to have a smoke detector installed in the same room as where the solid-appliance is installed.**

#### System 1



#### NOTES:

- 1 THE DISCONNECT MEANS AND CIRCUIT PROTECTION ARE TO BE PROVIDED BY THE INSTALLER OF THIS DEVICE

#### LEGEND:

- 24 VAC
- 120 VAC



## 6.2 Mechanical Draft System for Wood-fired Fireplace with multiple Flues

### Application

This is used in the same situations as System 1, but where a single fan is unable to handle the heat load. It is a typical installation for fireplaces that are so large that a single flue can not handle the amount of products of combustion generated.

For one fan serving two flues please refer to section 6.1 as the wiring diagram is identical. A special plenum box may be required.

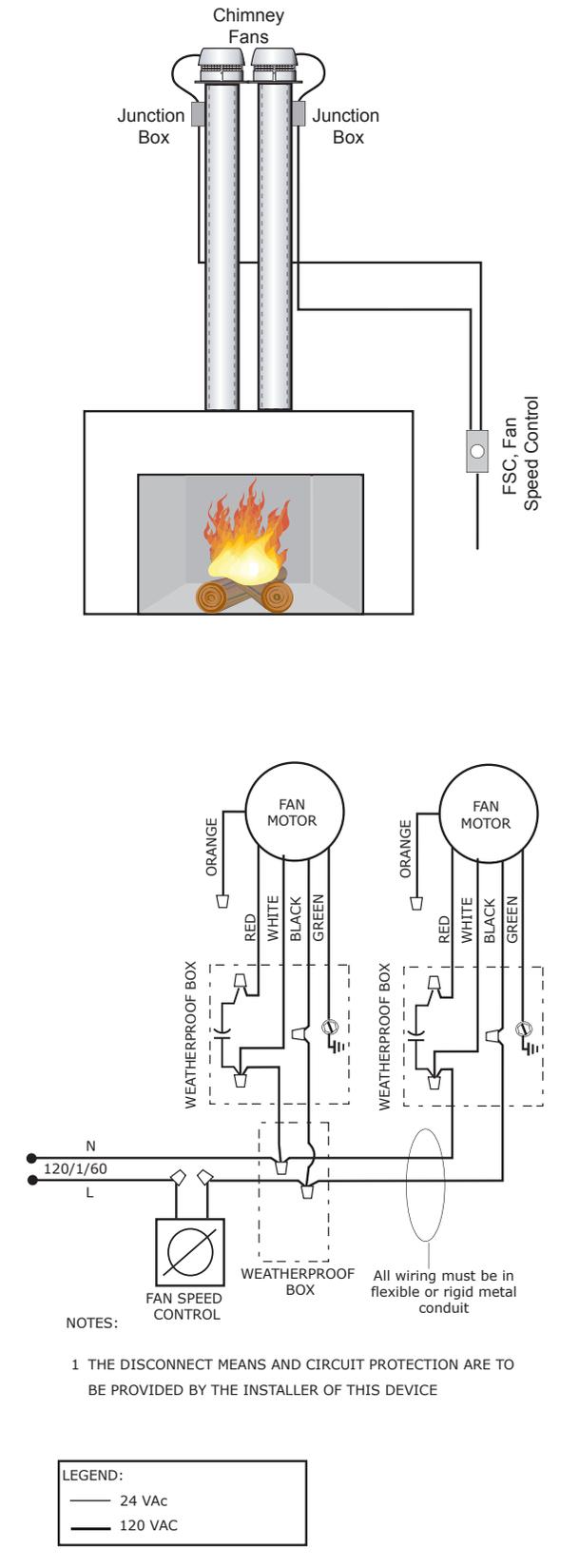
### Sequence of Operation

The sequence of operation is no different from System 1, but make sure a single fan speed control is simultaneously handling both fans.

1. Prepare the wood logs in the fireplace.
2. Turn the control on by turning the knob clockwise. A “click” is heard when the dial is turned clockwise which indicates the control is turned on. Adjust the knob to the desired speed.
3. Start your fire by igniting the logs.
4. Once a good flame has been achieved, turn the dial clockwise (reduces speed) until you start to see spillage from the fireplace opening. Spillage can often be detected by holding a hand flat above the fireplace opening and feel the heat from spilling flue gases hitting it. From this point, increase the fan speed slightly by turning the dial counter-clockwise. The dial can be left in this position.
5. If adding logs to the fire, it may be necessary to increase the speed again.
6. When the fire is dying reduce the speed setting further to remove remaining products of combustion.

**Please see important notice on page 24.**

### System 2



### 6.3 Mechanical Draft System for a Wood-fired Fireplace with Safety System per NFPA211/IMC

#### Application

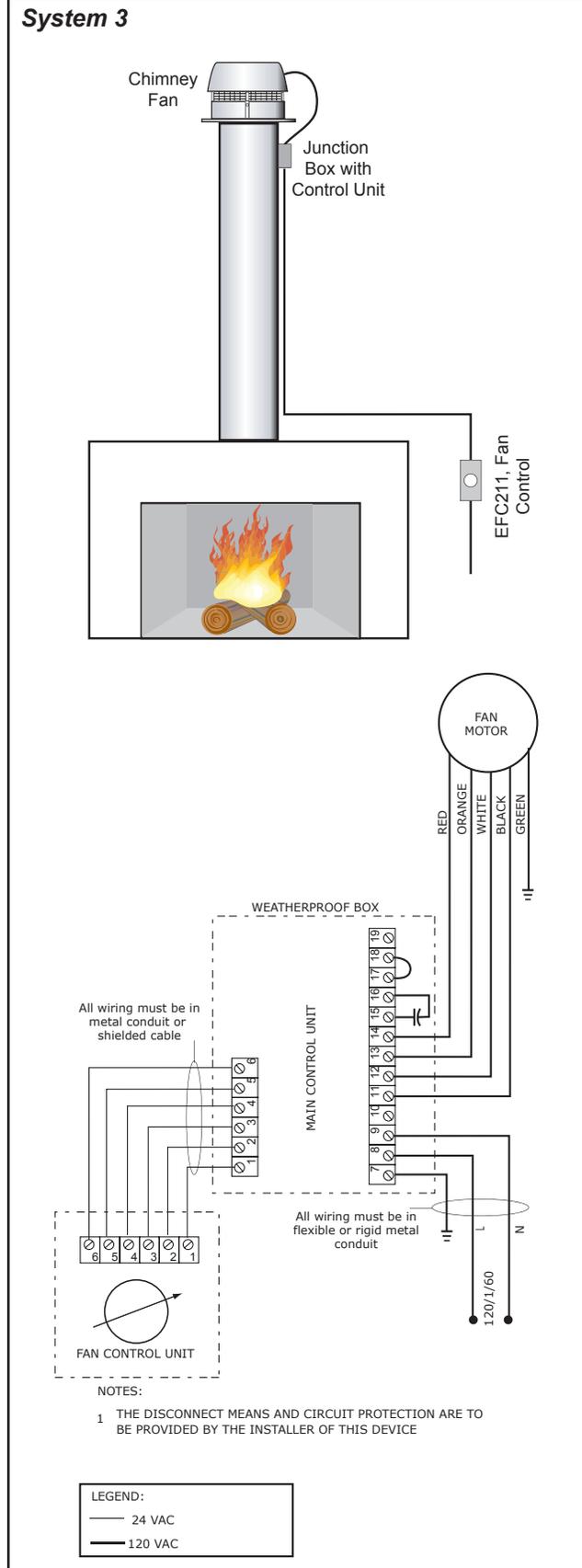
In jurisdictions where the 2000 or later edition of the NFPA211 has been adopted there are new requirements for the use of mechanical draft systems in conjunction with solid fuel. The installation requires a safety control such as the EFC211 Fan Control.

#### Sequence of Operation

1. Turn the control on by turning the knob clockwise. A “click” is heard when the knob is turned which indicates the control is turned on. Adjust the knob to the desired speed. The speed must be set so no smoke escapes the solid fuel heating appliances (fireplace, stove, wood-fired oven etc.) through the opening into a room. The smoke should safely be exhausted through the chimney.
2. The chimney fan will start with a 15 seconds boost to assure proper fan operation. The green LED on the speed control unit cover will flash. After 15 seconds the chimney fan will be reduced to the preset level and continue to operate at this speed.
3. During appliance operation the speed setting can be adjusted if needed. This is especially true if logs are added.
4. The control constantly monitors the chimney fan operation. It automatically measures the fan speed every minute and if necessary, it will increase the speed which can be heard as quiet “hick-up” from the fan. If necessary, the control will increase the speed to full speed for 15 seconds (green LED flashes), after which it will slow the fan speed down to the desired speed.
5. If the green LED flashes during operation (after the 15 seconds initiation) the fan speed is set too low or the fan wheel is somehow obstructed. If the red LED flashes and the buzzer sounds, it can be caused by:

- Blocked flue.
- Defect chimney fan
- Disconnected thermo-couple
- Disconnected power supply The control can be reset, and the alarm turned off, by pressing the RESET button for 1-2 seconds.

Please see important notice on page 24.





## 6.4 Mechanical Draft System for a Gas-fired Fireplace with a single flue with Safety System per NFPA54/IFGC

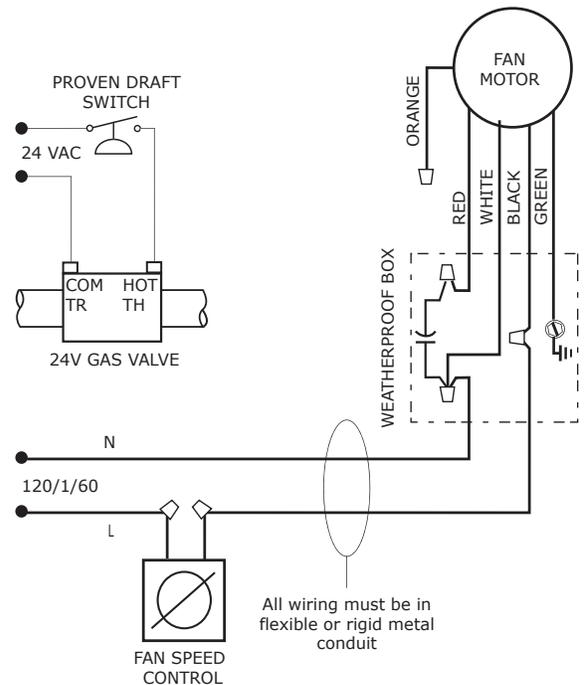
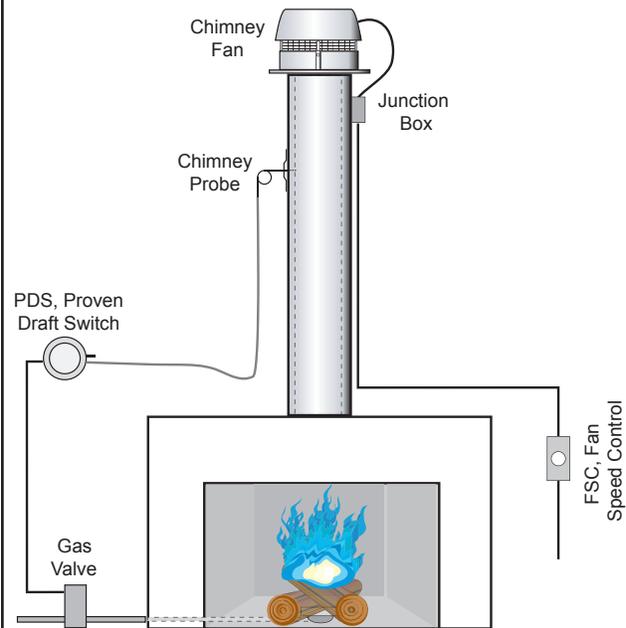
### Application

This is the simplest form of installation when used with a gas-fired fireplace. The set-up can be used with virtually any type of gas-fired heating appliance.

### Sequence of Operation

1. Turn the fan speed control on by turning the knob clockwise. A “click” is heard when the dial is turned clockwise which indicates the control is turned on. Adjust the knob to the desired speed.
3. Start your fire by pushing the igniter or other means used to start the fire.
4. Fine-tune the fan speed setting so spillage from the fireplace opening can not be detected. Spillage can be detected by holding a flat hand over the opening. Spillage feels like a moist heat. For even better detection, use a mirror instead of the hand.
5. In case of mechanical or electrical fan failure, the proven draft switch will disconnect the flow of fuel to the fireplace or the gas logs.
6. Once the proper draft has been established the proven draft switch will open to allow the flow of fuel.
7. When the fan is turned off this will automatically turn the flow of gas off.

### System 4



#### NOTES:

- 1 THE DISCONNECT MEANS AND CIRCUIT PROTECTION ARE TO BE PROVIDED BY THE INSTALLER OF THIS DEVICE

#### LEGEND:

- 24 VAC
- 120 VAC

## 6.5 Mechanical Draft System (automated) for a Gas-fired Fireplace with single flues with Safety System per NFPA54/IFGC

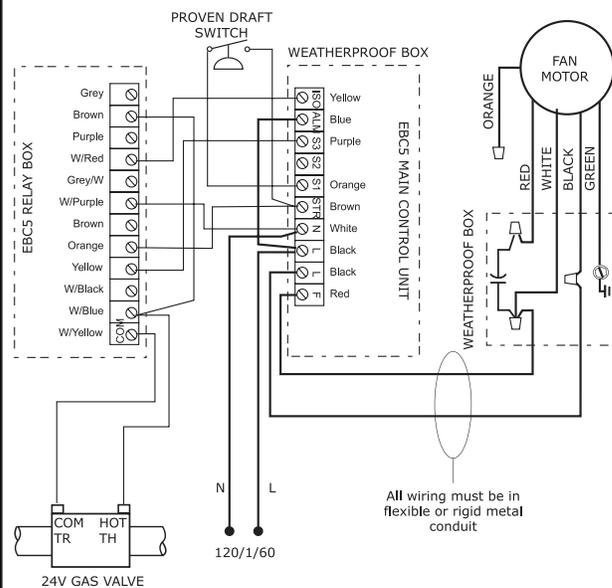
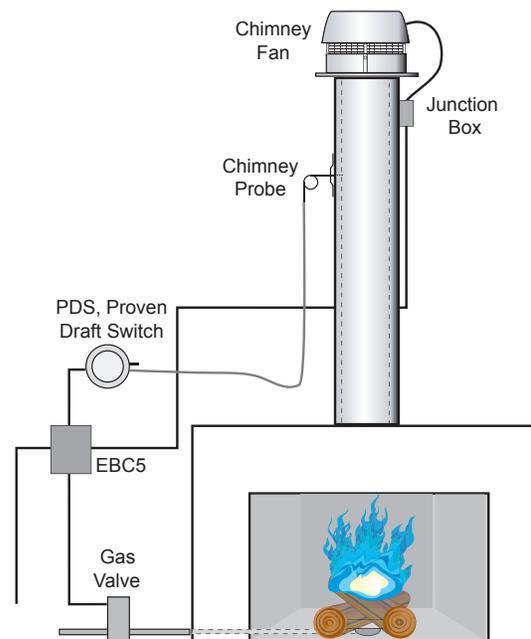
### Application

This is the most automated type of installation for a gas-fired application. The EBC5 control monitors both operation and safety system and no adjustments are necessary after the system is installed and commissioned. The EBC5 does not have to be visible and can be installed in the attic.

### Sequence of Operation

1. During commissioning, the fan speed is set using the dip-switches provided in the EBC5 control.
2. When the gas ignitor is activated, the fan will increase speed and after a preset time provided the proven draft switch is satisfied, the flow of gas will be allowed by the EBC5 .
3. If proper draft is not maintained, the EBC 5 will increase fan speed 3 times after which it will shut off the flow of fuel.
4. Once the fireplace is turned off, the fan will continue to operate for a set time to remove any remaining products of combustion after which it will shut down.
5. In case of a mechanical or electrical failure the EBC5 will shut off the flow of fuel.

### System 5



#### NOTES:

- 1 THE DISCONNECT MEANS AND CIRCUIT PROTECTION ARE TO BE PROVIDED BY THE INSTALLER OF THIS DEVICE

#### LEGEND:

- 24 VAC
- 120 VAC



## 6.6 Mechanical Draft System for a Gas-fired Fireplace with multiple flues with Safety System per NFPA54/IFGC

### Application

This is used in the same situations as System 4, but where a single fan is unable to handle the heat load. It is a typical installation for fireplaces that are so large that a single flue can not handle the amount of products of combustion generated

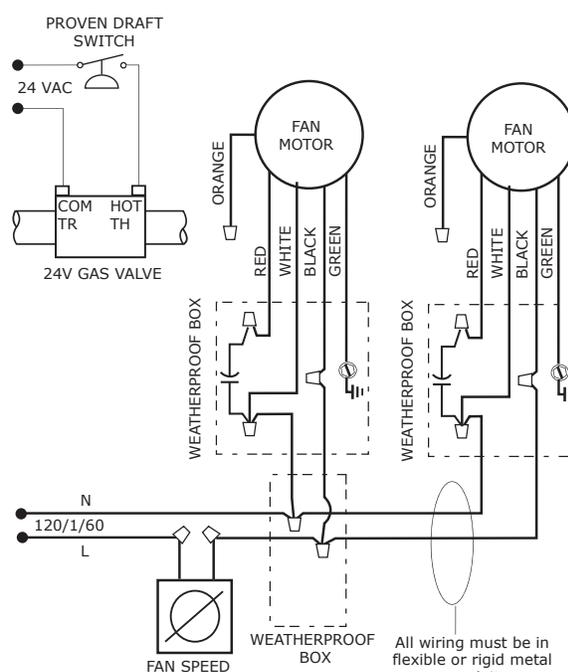
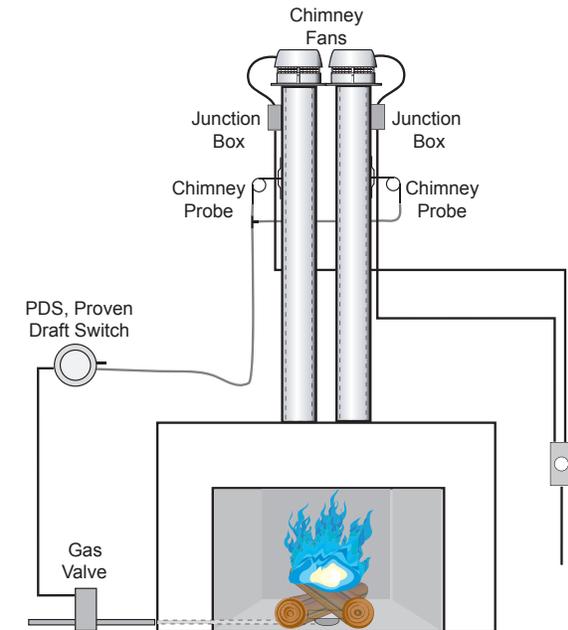
This is a simple form of installation when used with a gas-fired fireplace. The set-up can be used with virtually any type of gas-fired heating appliance.

For one fan serving two flues please refer to section 6.5 as the wiring diagram is identical. A special plenum box may be required.

### Sequence of Operation

1. Turn the fan speed control on by turning the knob clockwise. A “click” is heard when the dial is turned clockwise which indicates the control is turned on. Adjust the knob to the desired speed.
3. Start your fire by pushing the igniter or other means used to start the fire.
4. Fine-tune the fan speed setting so spillage from the fireplace opening can not be detected. Spillage can be detected by holding a flat hand over the opening. Spillage feels like a moist heat. For even better detection, use a mirror instead of the hand.
5. In case of mechanical or electrical fan failure, the proven draft switch will disconnect the flow of fuel to the fireplace or the gas logs.
6. Once the proper draft has been established the proven draft switch will open and allow the flow of fuel.
7. When the fan is turned off this will automatically turn the flow of gas off.

### System 6



NOTES:

1 THE DISCONNECT MEANS AND CIRCUIT PROTECTION ARE TO BE PROVIDED BY THE INSTALLER OF THIS DEVICE

LEGEND:	
—	24 VAc
—	120 VAc



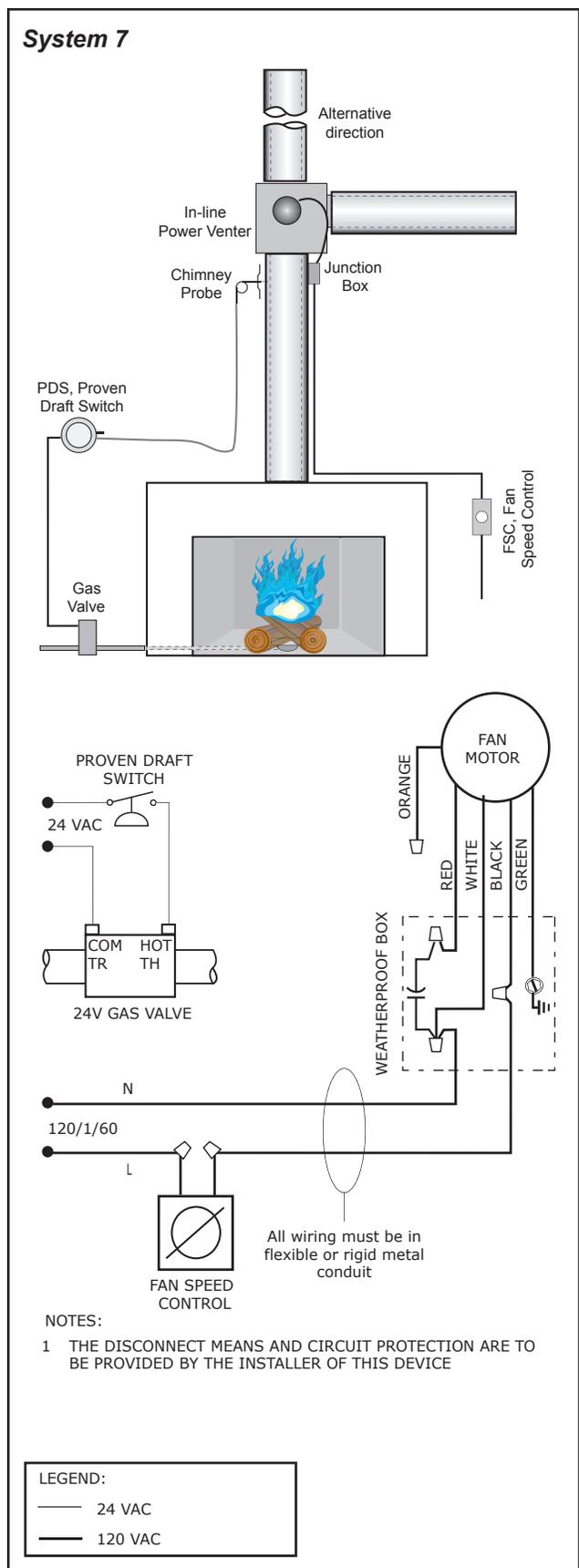
## 6.7 Mechanical Draft System (in-line) for a Gas-fired Fireplace with a single flue with Safety System per NFPA54/IFGC

### Application

This is a simple form of installation where a mechanical draft system is installed inline and indoors while used with a gas-fired fireplace. This can be used in situations where it is impossible or inconvenient to have the mechanical draft system terminate on the exterior. The set-up can be used with virtually any type of gas-fired heating appliance.

### Sequence of Operation

1. Turn the fan speed control on by turning the knob clockwise. A “click” is heard when the dial is turned clockwise which indicates the control is turned on. Adjust the knob to the desired speed.
3. Start your fire by pushing the igniter or other means used to start the fire.
4. Fine-tune the fan speed setting so spillage from the fireplace opening can not be detected. Spillage can be detected by holding a flat hand over the opening. Spillage feels like a moist heat. For even better detection, use a mirror instead of the hand.
5. In case of mechanical or electrical fan failure, the proven draft switch will disconnect the flow of fuel to the fireplace or the gas logs.
6. Once the proper draft has been established the proven draft switch will open and allow the flow of fuel.
7. When the fan is turned off this will automatically turn the flow of gas off.





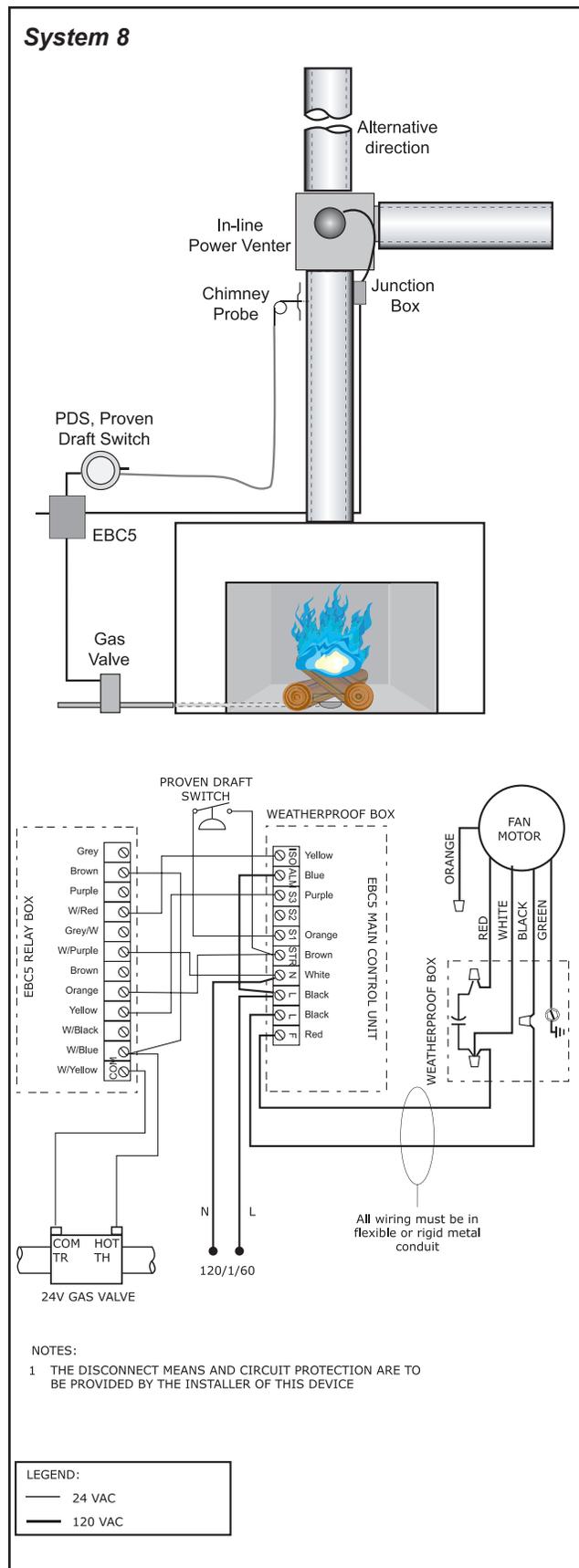
## 6.8 Mechanical Draft System (automated and in-line) for a Gas-fired Fireplace with a single flue with Safety System per NFPA54/IFGC

### Application

This is the most automated type of installation for a gas-fired application with the mechanical draft system installed inline and indoors. This can be used in situations where it is impossible or inconvenient to have the mechanical draft system terminate on the exterior. The EBC5 control monitors both operation and safety system and no adjustments are necessary after the system is installed and commissioned. The EBC5 does not have to be visible and can be installed in the attic.

### Sequence of Operation

1. Turn the fan speed control on by turning the knob clockwise. A “click” is heard when the dial is turned clockwise which indicates the control is turned on. Adjust the knob to the desired speed.
3. Start your fire by pushing the igniter or other means used to start the fire.
4. Fine-tune the fan speed setting so spillage from the fireplace opening cannot be detected. Spillage can be detected by holding a flat hand over the opening. Spillage feels like a moist heat. For even better detection, use a mirror instead of the hand.
5. In case of mechanical or electrical fan failure, the proven draft switch will disconnect the flow of fuel to the fireplace or the gas logs.
6. Once the proper draft has been established the proven draft switch will open and allow the flow of fuel.
7. When the fan is turned off this will automatically turn the flow of gas off.



## 7. Frequently Asked Questions

**Q. Does the fan always have to be on when I have a fire in the fireplace?**

A. The motor can only be cooled when the chimney fan is operating, thus the fan should always be on, when you have a fire in the fireplace. Otherwise, you may reduce the longevity of the fan. You may, however, run it at a very low speed.

**Q. The fireplace spills due to negative pressure in the house. Won't the chimney fan add to the problem?**

A. Any exhaust fan will pull air out. However, proper use of the fan speed control assures the chimney fan simply simulates the natural draft required for the fireplace to operate. Thus, the chimney fan will not exhaust more air than a well-functioning fireplace would have done.

\*It is important to emphasize that all furnaces, water heaters and other combustion equipment be checked for proper venting before regular use of a chimney fan.

**Q. Can the fan be recessed or hidden?**

A. Yes, the fan may be recessed or hidden, for example, with chimney pots, copper caps, or cupolas as long as the fan is allowed to vent properly. We recommend a minimum clearance of 1 1/2" on each side of the fan.

**Q. Does the chimney fan have to be removed every time I have my chimney cleaned?**

A. No, the fan is equipped with hinges, which allows the top of the fan to be tilted. This gives you full access to the chimney for cleaning purposes.

**Q. Does the fan require its own circuit?**

A. No, the fan only draws about 1 to 4 amps (about the same as a standard light bulb), depending on the size, and runs on 110 volts.

**Q. Can you run the wire inside the flue?**

A. No. However, you may run it inside a chase. Otherwise it will have to be run on the outside of the chimney.

**Q. What happens when you have a fire in the fireplace and a power failure occurs?**

A: Obviously, the fan will stop working, and you may experience the same problems with smoke or draft that caused you to put the fan on to begin with. However – a power failure will cause all other fans in the house to stop running as well, which may increase the natural draft in the chimney. The fan itself offers very little resistance to the flow.

**Q. What if the chimney has a constant down-draft and odor when not in use?**

A: Just leave the fan running continuously at a very low setting.

**Q. Is the fan noisy?**

A. The fan is equipped with a very quiet motor, and is installed outside and at the end of the chimney. Noise is usually not an issue unless the fan is installed incorrectly or if the flue is extremely narrow or short.

**Q. How involved is the installation?**

Installations vary from house to house, but typically a fan can be installed and wired in just a few hours. No major reconstruction is needed.

**Q. Can the fan be installed on a pre-fabricated chimney?**

A. Yes, the fan can be installed on a pre-fabricated metal chimney. An adapter is used to fit the fan onto whatever size and type of metal chimney being used.

**Q. What about the appearance of the fan?**

A. The fan is low-profile and a flat charcoal grey in color. In most cases, the fan is barely noticeable from the ground. As discussed in a previous FAQ, the fan can be disguised by a cap or chimney pot. The fan may be painted with a high-temperature paint to match the house if so desired.



## Appendix A: Design Theory

Fireplaces with natural draft chimneys follow the same gravity fluid law as gas vents and thermal flow ventilation systems.

To a certain degree, mass flow of hot flue gases through a vertical pipe is a function of the heat release, the chimney area, height, and the flow resistance (system pressure loss coefficient).

According to ASHRAE, standard sizing of chimneys must include an estimate of the flue gas volume and the available draft. Available draft is the difference between the natural draft and the system pressure loss. The available draft must be able to overcome the system pressure loss for the system to work.

There are limitations to this approach. A lot can be determined and explained via calculations, but some factors must be determined by using common sense and experience. The location of a building, the presence of cross winds, eddies etc. are examples of such factors. The factors can be expressed as pressure losses, but it is not easy to put a value to them.

The flue gas volume depends on the fuel burned and the amount of air used for the combustion. The general method used to determining the flue gas volume is to base the calculation on the air requirements of the combustion.

The air requirement is found by determining the area of the air inlet and multiplying it with the frontal inlet velocity. As the air expands when it is warmed up in the fire, the actual flow in the chimney depends on the temperature in the chimney.

A 300° F mean gas temperature rise above ambient (usually 60°F) is used as a guideline, and with this temperature rise, the air will expand by almost 60%. Airflow at 60°F is usually expressed as “standard cubic feet per minute” or SCFM. If the air is heated and expansion is accounted for it is usually expressed as “actual cubic feet per minute” or ACFM.

The following examples will show how the flue gas volume can be determined for different applications.

### Estimating Flow

The combustion air requirements can be determined using this formula:

$$Q_t = \frac{q \times A_{\text{inlet}} \times V_{\text{inlet}}}{144}$$

$Q_t$  = Flow at t °s (CFM, or cubic feet per minute)

$A_{\text{inlet}}$  = Area of opening (square inches)

$V_{\text{inlet}}$  = Frontal inlet velocity (FPM, or feet per minute)

q = density expansion factor

One-sided fireplaces for solid fuel.

In a one-sided fireplace a total front velocity of 36-48 FPM with a mean chimney temperature of min. 300°F should provide a good combustion and a well-working fireplace.

Example: Fireplace height is 24”, width is 36” and the frontal velocity is estimated at 48 FPM. The flow into the fireplace is:

$$Q_{60} = \frac{24 \times 36 \times 48 \text{ CFM}}{144} = 288 \text{ SCFM}$$

The density expansion factor is 1.6 at a 300°F temperature rise, so the flue gas volume is:

In other words, a wood-fired fireplace with a 2'x3'

$$Q_{300} = 288 \text{ SCFM} \times 1.6 = 460 \text{ ACFM}$$

opening produces 460 ACFM of flue gas at an average flue gas temperature of 300°F, while it only consumes 288 SCFM from the room.

One-sided fireplaces for gas.

In a one-sided fireplace a total front velocity of 18-36 FPM with a mean chimney temperature of min. 200°F should provide a good combustion and a well-working fireplace.

Example: Fireplace height is 24”, width is 36” and the frontal velocity is estimated at 36 FPM. The flow into the fireplace is:

$$Q_{60} = \frac{24 \times 36 \times 36 \text{ CFM}}{144} = 216 \text{ SCFM}$$

The density expansion factor is 1.4 at a 200°F temperature rise, so the flue gas volume is:

$$Q_{200} = 216 \text{ SCFM} \times 1.4 = 302 \text{ ACFM}$$

In other words, a gas-fired fireplace with a 2'x3' opening produces 302 ACFM of flue gas at an average flue gas temperature of 200°F, while it only consumes 216 SCFM from the room.

Open fireplaces without a smoke chamber

If the fireplace does not have a smoke chamber, or if the smoke chamber is very small, it is wise to use a higher frontal inlet velocity – preferably in the range of 48-84 FPM.

Freestanding fireplaces

This type of fireplace requires a high frontal inlet velocity in order to capture and contain the products of combustion. For design purposes it is recommended to use a velocity of 84-96 FPM. This is in line with the code requirements for commercial kitchen hoods.

## Stoves and fireplace inserts

Stoves are different from open fireplaces due to the fact that they just have a small inlet for the combustion air. However, the worst-case scenario is when the door is open, so this is the situation the sizing should be based on.

Again, use the airflow formula with a recommended frontal inlet velocity of 36-48 FPM.

$$Q_{300} = \frac{A_{\text{inlet}} \times V_{\text{inlet}} \times 1.6}{144}$$

This design method is also used for a fireplace insert. The flow is determined by using the fireplace opening with the doors opened.

## Residential wood-fired pizza ovens

This type of appliance is both an oven and a firebox. The door opening serves as an air inlet as well as the flue outlet.

Temperatures can reach 5-600°F, but the flue gas temperature is much lower due to the design of the smoke chamber. The smoke chamber is just a small hood that leads into the flue.

For design purposes it is recommended to use a frontal inlet velocity of 84-96 FPM. The formula for calculating the airflow is:

$$Q_{300} = \frac{A \times B \times V_{\text{inlet}} \times 1.6}{144}$$

A = height of door opening

B = width of door opening

## Estimating Flow Resistance

The total flow resistance in a vent system that moves air is normally referred to as “total static pressure loss”. The formula used to determine the static pressure loss in a system is:

$$P_s = .015 \times d_m \times V_{\text{pipe}}^2 \times Ek$$

$$= .015 \times d_m \times (Q_t / A_{\text{pipe}})^2 \times Ek$$

$D_m$  = gas density (lb/ft<sup>3</sup>)

$V_{\text{pipe}}$  = system gas velocity at mean condition (ft/s).  
Can also be expressed as flue gas volume / flue area)

$A_{\text{pipe}}$  = area of flue (square inches)

$Ek$  = sum of all resistance factors

There are several factors creating resistance in a fireplace chimney system:

- the flue
- flue components and fittings

- transition from firebox to flue

In addition there are “external” factors influencing the resistance:

- internal building pressure
- external building pressure
- wind patterns

When trying to determine the total resistance in a chimney system, resistance factors, or k-values, are used to ease calculations. K-values are dimensionless.

## Flue pipe resistance

As in any pipe material, the roughness of the surface influences the flow resistance - the rougher the more resistance. Roughness of a pipe surface is normally expressed as a Reynold’s number, but for all practical purposes these can be converted into k-values that are easier to work with.

ASHRAE have set a range of friction factors that chimney and stack manufacturers use for the calculation of k-values for different types of chimneys and vents:

Vent type	Friction factor, F
Class A chimney	0.22
Gas Vent (B-vent)	0.25
Single wall steel	0.32
Refractory liners	0.34
Clay tile liners	0.38-0.42
Corrugated liners	0.50

The k-value of a chimney can be determined with this formula:

$$K_L = F \times L / D_i$$

L = Length of entire chimney system (ft)

$D_i$  = Diameter of chimney (inches)

Example: An 8” single steel wall system with a total length of 25’ has a k-value of:

$$K_L = .32 \times 25 / 8 = 1.0$$

## Resistance inside firebox

Resistance can be found in the transition between the firebox and the chimney. The transition can be considered a converging tapered entry. Allow for a k-value of min. 2, if the inlet is smooth – more if it’s rough.

## Component resistance

ASHRAE has set up a range of k-values for different



types of components in a chimney system. Chimney and stack manufacturers have set specific values for their own products. A list of component k-values can be found in Appendix C.

#### Other resistance

Resistance from negative building pressure, external building pressures, eddies etc. must also be taken into consideration. This could actually be measured by using a pressure gauge in the fireplace chimney before starting a fire. It is not that unusual to see a negative pressure of 0.05-0.1"WC for problem fireplaces.

#### Estimating natural draft

The theoretical draft of a gravity chimney or vent is the difference in weight (mass) between a given column of warm flue gas and an equal column of colder ambient air. The theoretical can be derived from the following formula:

$$D_t = .2554 \times B \times H \times (1/T_o - 1/T_m)$$

$D_t$  = Theoretical draft ("WC)

B = Local barometric pressure (inHg)

H = Height of chimney (feet)

$T_o$  = Absolute ambient temperature – Ambient +460 (°R)

$T_m$  = Absolute mean flue gas temperature – Mean flue gas + 460 (°R)

The formula indicates that the draft increases with the height. However, as the height increases the mean flue gas temperature decreases, so adding height to create more draft only works up to a certain height.

Example: With a barometric pressure of 29.92 inHg, a 25' chimney, 70°F ambient temperature and a mean flue gas temperature of 250°F, the theoretical draft will be:

$$D_t = .2554 \times 29.92 \times 25 \times (1/530 - 1/710) = 0.115 \text{ "WC}$$

According to the formula a chimney without draft does not exist.

#### Estimating available draft

To derive the available draft ( $D_a$ ) for a chimney system, the static pressure loss is deducted from the theoretical draft:

$$D_a = -D_t + P_s$$

Notice that draft is always negative, while static pressure is always positive.

Example:

Theoretical draft, $D_t$	- 0.138 "WC
Static Pressure Loss, $P_s$	+ 0.100 "WC
Available draft, $D_a$	- 0.038 "WC

#### Analyzing a fireplace venting system

The following is an example on how to analyze and estimate fireplace systems. The data is as follows:

One-sided fireplace for wood: 24" x 36"

Ambient temperature = 60°F

Mean chimney temperature = 300°F

Chimney = single wall steel chimney

Flue size = 8"

Chimney height = 25'

Off-sets = one 30° off-set (= 2x30° elbows)

$D_m = 0.075 \text{ lbs/ft}^3 \text{ @ } 60^\circ\text{F}$

$= 0.047 \text{ lbs/ft}^3 \text{ @ } 300^\circ\text{F}$

#### 1. Determine flow

$$Q_t = q \times A_{\text{inlet}} \times V_{\text{inlet}} / 144$$

$$= 1.6 \times 24 \times 36 \times 48 \text{ ACFM} = 460 \text{ ACFM}$$

#### 2. Determine k-values

Pipe:

$$K_L = F \times L / D_i = 0.32 \times 25 / 8 = 1.0$$

Components:

$$2 \times 30^\circ \text{ elbows} = 2 \times 0.15 = 0.30$$

$$\text{Inlet from firebox} = 2.00$$

$$\text{Total k-value} = 2.30$$

$$E_k = 1.0 + 2.30 = 3.3$$

#### 3. Determine system pressure loss

$$P_s = 0.015 \times d_m \times (Q_t / A_{\text{pipe}})^2 \times E_k$$

$$= 0.015 \times 0.047 \times (460 / 50)^2 \times 3.3$$

$$= 0.197 \text{ "WC}$$

#### 4. Determine natural draft

$$D_t = 0.2554 \times B \times H \times (1 / T_o - 1 / T_m)$$

$$= 0.2554 \times 29.92 \times 25 \times (1/530 - 1/710)$$

$$= 0.115 \text{ "WC}$$

#### 5. Determine available draft

$$D_a = -D_t + P_s$$

$$= -0.115 + 0.197$$

$$= +0.082 \text{ "WC}$$

The available draft is positive, so the system should not work. There are two ways to solve this problem: increase the chimney height or increase the diameter, let's say from 8" to 10". A 10" flue would give these results:

$$Q_t = 460 \text{ ACFM (no change)}$$

$$K_L = 0.8$$

$$E_k = 3.1$$

$$P_s = 0.015 \times 0.047 \times (460/78.5)^2 \times 3.1 \\ = 0.075 \text{ WC}$$

$$D_t = 0.115 \text{ WC (no change)}$$

$$D_a = -0.115 + 0.075 = -0.04 \text{ WC}$$

Now there is draft in the system, so a 10" vent is the appropriate size for venting this 24"x36" fireplace.

Analyzing other factors

If the fireplace and chimney seems to be sized correctly, but there is a smoke problem, other information may be needed.

A depressurized building will negatively affect the draft situation. If the negative pressure is found to be 0.1"WC, the chimney would have to be able to overcome this as well and the draft calculation would look like this:

$$D_a = -0.04 \text{ WC} + 0.1 \text{ WC} = +0.06 \text{ WC}$$

In other words, the negative building pressure easily overcomes the draft and would make the system back draft.



## Appendix B: Conversion table from rectangular to round flues.

		Hydraulic Diameter																
A \ B	B	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4	4	4	4	5	5	5	6	6	6	6	6	6	6	6	6	7	7	7
5	4	4	5	5	6	6	6	7	7	7	7	7	8	8	8	8	8	8
6	5	5	5	6	6	7	7	8	8	8	8	8	9	9	9	9	9	9
7	5	6	6	6	7	7	8	8	9	9	9	9	10	10	10	10	10	10
8	5	6	7	7	7	8	8	9	9	10	10	10	10	11	11	11	11	11
9	6	6	7	7	8	8	9	9	10	10	11	11	11	12	12	12	12	12
10	6	7	8	8	9	9	10	10	10	11	11	12	12	12	13	13	13	13
11	6	7	8	9	9	10	10	10	11	11	12	12	13	13	13	14	14	14
12	6	7	8	9	10	10	11	11	11	12	12	13	13	14	14	14	15	15
13	6	7	8	9	10	11	11	12	12	13	13	14	14	15	15	15	15	16
14	6	7	8	9	10	11	12	12	13	13	14	14	15	15	16	16	16	16
15	6	8	9	10	10	11	12	13	13	14	14	15	15	16	16	17	17	17
16	6	8	9	10	11	12	12	13	14	14	15	15	16	16	17	17	17	18
17	6	8	9	10	11	12	13	13	14	15	15	16	16	17	17	18	18	18
18	7	8	9	10	11	12	13	14	14	15	16	16	17	17	18	18	18	19
19	7	8	9	10	11	12	13	14	15	15	16	17	17	18	18	19	19	19
20	7	8	9	10	11	12	13	14	15	16	16	17	18	18	19	19	19	20

## Appendix C: Resistance Factors

	Gas Vent	Pressure Stack	Clay Tile Liner	Poured/Cast Liner	Single Wall Steel	Corrugated Steel/Alum.
Pipe Coefficient	0.25	0.22	0.38	0.34	0.32	0.50
30° Elbow	0.15	0.12	0.18	0.18	0.15	0.30
45° Elbow	0.25	0.15	0.28	0.28	0.25	0.50
90° Elbow	0.75	0.30	0.90	0.90	0.75	1.5
Tee or 90° Connector	1.25	1.25	1.25	1.25	1.25	1.75
90° WYE	0.60	0.60	0.60	0.60	1.60	0.60
Barometric Damper	0.50	0.50	0.50	0.50	0.50	0.50
Round to Square Transition	0.50	0.50	0.50	0.50	0.50	0.50
Low Resistance Cap (listed)	0.50	0.50	0.50	0.50	0.50	0.50
Standard Cap (not listed)	1.00	1.00	1.00	1.00	1.00	1.00
Bird Screen	0.50	0.50	0.50	0.50	0.50	0.50
Tapered Reducer	From $d_1$ to $d_2$ : $1 - (d_2 / d_1)^4$					





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**Notes:**



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