CHIMNEY PERFORMANCE PROBLEMS

11.1 INTRODUCTION

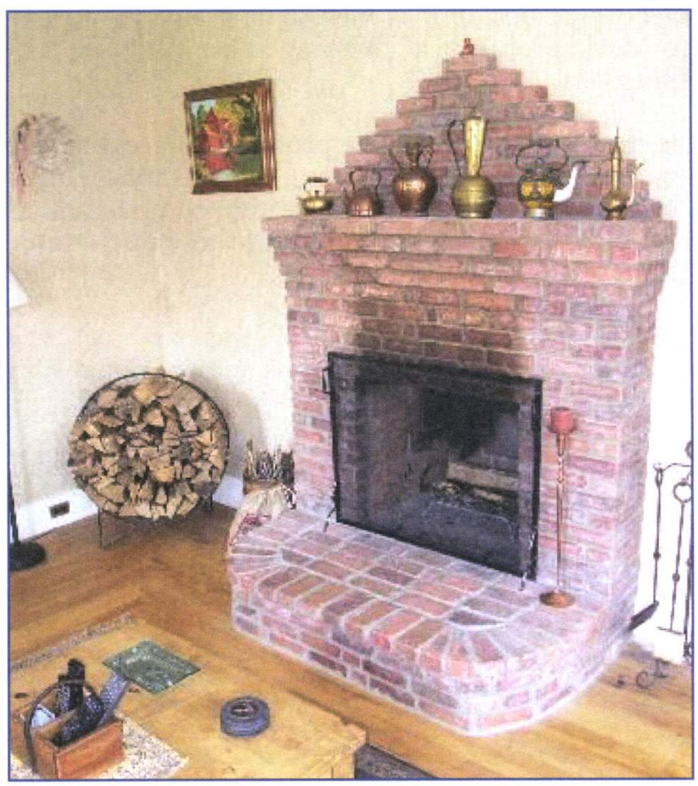
Aside from sweeping chimneys, solving chimney performance problems is a common service chimney sweeps provide. As chimney specialists, sweeps should understand how a chimney works. They should be able to use that knowledge to diagnose specific chimney performance problems and to advise homeowners concerning the best solutions. Sweeps usually get involved with problem solving when a consumer complains that an appliance smokes or burns sluggishly. However, the appliance can suffer from other performance problems even before common symptoms like smoking become obvious to the homeowner.

Occasionally these problems are due to poor design, deterioration, or the type of fuel burned. More often, however, the chimney operational problems are caused by some characteristic of the chimney, or the house itself.

11.2 OBJECTIVE

The objective of this chapter is to define some specific chimney performance problems. After studying this chapter, the certification candidate should be able to:

1. Name and follow an orderly three-step procedure for diagnosing and solving chimney performance problems.
2. Explain the difference between draft and flow.
3. List two major factors that influence the amount of draft.
4. List three major factors that influence the amount of flow.
5. Explain different ways draft and flow balance out in fireplaces and closed heaters.



Fireplaces that smoke are among the most common complaints.

6. Define and explain the cause of wind induced downdraft, flow reversal, inadequate flow, and back puffing as related to stoves.

7. Name specific draft problems and suggest some solutions.

8. Name specific flow capacity problems and suggest some solutions.

9. Recognize the effect improper construction can have in regards to venting performance.

11.3 DIAGNOSING CHIMNEY PERFORMANCE PROBLEMS

Every appliance is dependent on a properly functioning chimney.

If the chimney does not work properly the appliance will never perform as well as it could. In order to work properly, a chimney must perform two functions.

It must safely exhaust the products of combustion to the outside atmosphere, and it must draw oxygen into the appliance to sustain combustion. If anything interferes with either of these operations, the appliance will malfunction.

These so-called "draft" problems are actually chimney performance problems and are not always due to inadequate draft.

Since chimney performance problems can result from a wide variety of chimney conditions, it is often difficult for homeowners and sweeps to pinpoint their exact cause. Following a basic, three-step procedure can help sweeps diagnose and solve chimney performance problems logically.

1. Step One: Gather information about the symptoms of the problem.

2. Step Two: Make a tentative diagnosis about the problem and test it.

3. Step Three: Specify an effective solution.

11.3.1 STEP ONE: GATHERING INFORMATION

Gather information about the problem through personal observations and a detailed interview with the homeowner. Some possible questions for the interview are:

1. Is the operational problem constant or intermittent?

2. Is the problem gradually getting worse?

3. Under what circumstances does the problem occur? Possible circumstances include: starting the appliance, windy days, cold weather, mild weather, only when the appliance operates, only when a door is open, etcetera.

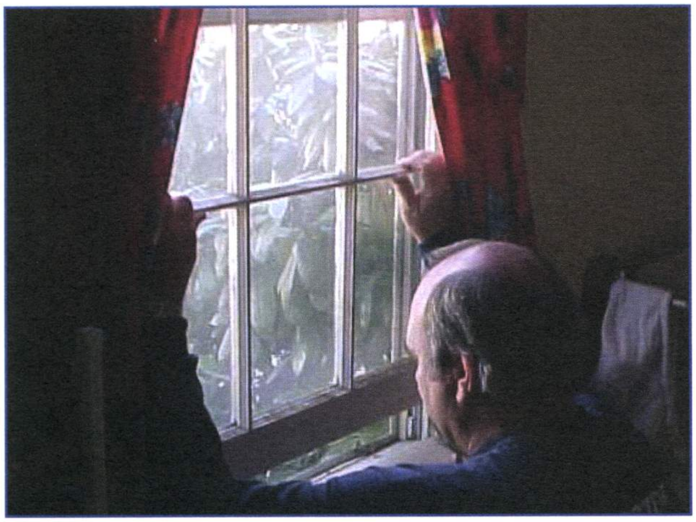
4. What solutions have already been attempted, and what results were observed?

If the performance problem can be staged without undue risk to personal safety or property, light the fireplace or appliance and observe the reported symptom. Then attempt a trial solution.

11.3.2 STEP TWO: MAKING A TENTATIVE DIAGNOSIS

Try to make a preliminary diagnosis of the chimney performance problem by using your knowledge

Sometimes the solution may be simple. In this case removing the debris should allow the appliance to operate normally.



If you suspect there is not enough combustion air available, you can test it by opening a window.

about how chimneys work, the information you gathered from the homeowner interview, your own on-site observations, and your experience in similar situations. Determine the general category of the problem (see Paragraph 11.5) even if you cannot pinpoint the exact cause.

Make sure your diagnosis is logical and consistent with all observed symptoms. Then try a temporary solution and note the results. Always keep some basic principles in mind when you are testing your preliminary diagnosis. Avoid a "shotgun" approach: attempt one solution at a time, and avoid permanent or expensive changes to the system until you are positive that your diagnosis is correct.

Often a temporary solution can be as simple as opening a window or turning off a fan. Sometimes it can be as complicated as temporarily extending the height of the chimney or reducing the size of the firebox opening.

If necessary, you can tell the homeowner to take specific corrective steps when the problem occurs during operation of the appliance or fireplace, and to observe and report the results to you.

You can arrive at a permanent solution once you have identified the cause of the problem with reasonable certainty, and have confirmed your diagnosis through testing.

11.3.3 STEP THREE: DEVISING A SOLUTION

Ethical chimney sweeps always prescribe the simplest and most cost-effective solutions to chimney performance problems. Since homeowners often assume that chimneys work automatically, they may not appreciate the importance of the problems you have detected. Therefore, rather than suggesting the most expensive solution, offer the homeowner a range of options and explain the results and advantages of each. Changing the way the homeowner operates the appliance or fireplace may control chimney performance problems. Often, the homeowner is willing to make these changes before committing to a permanent physical change in the system. Eventually, however, the consumer may find this approach bothersome and hire a sweep to make the necessary physical alterations to the heating/venting system. Regardless of the final solution, consumers always appreciate sweeps that give them the opportunity to try less expensive solutions.

11.4 DRAFT AND FLOW

Chimneys operate according to predictable laws of physics.

Sweeps can diagnose chimney performance problems more accurately if they understand these laws and the principles by which a chimney works.

The two major principles at work in a chimney are draft and flow. Draft is the force or pressure difference between the inside and the outside of the venting system that causes gases to flow up and out of the chimney and air to flow into the appliance. In other words, draft is a measure of the force that drives the venting system. Flow is the volume of gases that actually pass through the system as a

This chimney is not likely to work well. It is not tall enough and is much too close to the second story wall.

result of draft.

Comparing a chimney with a garden hose helps to clarify the difference between draft and flow. Draft in the chimney is similar to the pressure or force that pushes water through the hose. Flow is the volume of water that fits through the hose at a given pressure. In a chimney, flow is the volume of flue gases that move through the chimney at a given level of draft.

11.4.1 FACTORS INFLUENCING DRAFT

Two major factors influence the amount of draft: 1) the temperature difference between the average flue gas temperature and the temperature of the outside air and 2) height of the chimney. Both factors affect the pressure difference between the inside and the outside of the venting system. These factors often act together to enhance draft. At other times, they may act against each other to reduce draft.

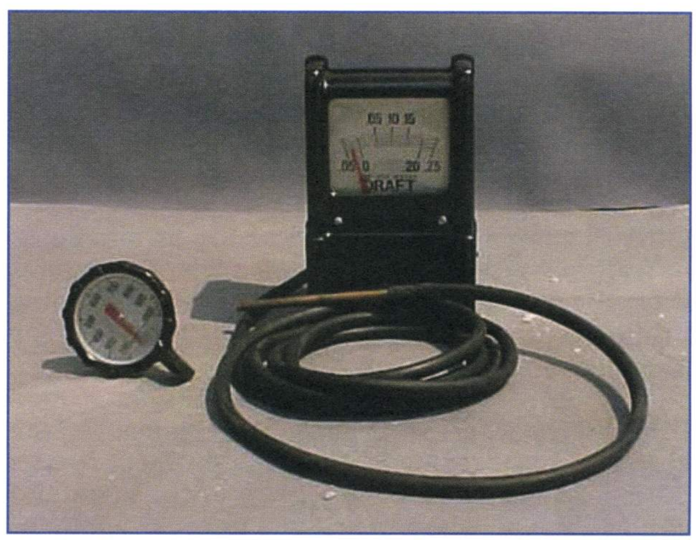
TEMPERATURE DIFFERENCE

Warmer flue gases have greater buoyancy and create a greater pressure difference at the bottom of a chimney. The principle of buoyancy states that warmer, less dense gases rise and are replaced by cooler, heavier gases. The rising gases create a

MEASURING CHIMNEY DRAFT

In the United States, chimney draft is measured in inches of water column (in. wc). The measurement is given as a negative number (-.06 in.wc.) to reflect the fact that pressure in the chimney is less than the surrounding atmosphere. Thus, lower numbers represent a greater draft: -.08 in.wc. is more draft than -.04 in.wc.

partial vacuum at the bottom of the chimney and in any appliance connected to the chimney. This vacuum or suction can be measured as a pressure difference between the inside and the outside of the venting system. If there are openings into the venting system - stove air inlets or a fireplace opening - room air starts to flow into the system to relieve the pressure difference. The greater the temperature difference, between the gases inside the flue and the air outside the chimney, the greater the draft or pressure difference and the more forcefully air is drawn into the system.



A draft gague is used to define the draft in the chimney.

CHIMNEY HEIGHT

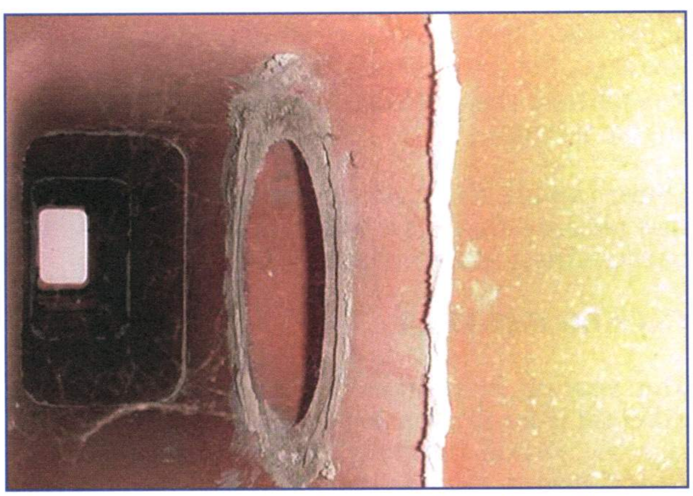
Taller chimneys contain a taller column of warm, rising gases.

The movement within the flue of this taller column of gases also increases the pressure difference (or draft) at the bottom of a chimney. The actual height of the chimney is the critical factor, not the volume of gases contained in it.

This is somewhat like the height of a water tower determining how much water pressure there will be: the taller the tower, the greater the water pressure. The amount of water in the tower is irrelevant.

11.4.2 FACTORS INFLUENCING FLOW CAPACITY

Three major factors influence the amount of flow or flow capacity: 1) draft, 2) amount of resistance to flow, and 3) size of the venting passageway (flue and connector). These factors work simultaneously in a functioning chimney and are interdependent. A change in one factor can affect the other two and change the overall performance of the chimney. The flow capacity of a venting system is determined by the way in which draft, amount of resistance to flow, and size of the venting passageway balance out in operation.



This is the way a thimble should be installed in a masonry flue.

NOTE
Flue tile dimensions may vary significantly in different areas and by manufacturer. It is important to make accurate measurements to determine flue area and flow capacity.

DRAFT

(See paragraph 11.4.1 for an explanation of this factor).

RESISTANCE TO FLOW

Friction always exists between moving gases and the passageways through which they flow. Some variables that affect the amount of friction - or resistance to flow - include: bends and turns in the venting system (connector elbows, offsets), changes in the size and shape of the flue or connector, and air inlet openings on an appliance. Even the straight walls of connectors and flues offer a certain amount of resistance to gas flow. It is a rule of thumb that the longer the total venting passageway, the greater the resistance will be. Since draft is necessary to overcome flow resistance and to initiate the flow of gases, systems with a large resistance to flow need greater draft to function properly.

SIZE OF THE VENTING PASSAGEWAYS

Of the three factors mentioned, the size of the flue and connector has the most critical influence on the amount of flow. The larger the flue, the larger the volume of gas that will be able to flow through the system in a given time period and at a given level of draft and system resistance.

The amount of flow or flow capacities of different flues can be compared by measuring the cross-sectional area of each flue. The formula for determining the cross-sectional area of a round flue or connector is: A = Pi x r2, where r is one-half the diameter of the flue. The formula for determining the cross-sectional area of a square or rectangular flue is: A = l x w, where l and w are the length and width. Using these formulas, an 8-inch interior dimension (i.d.) round flue has an area of approximately 50 square inches and, for example, an 8 x 12 inch (i.d.) rectangular flue has an area of 96 square inches. This example suggests that the 8 x 12-inch (i.d.) rectangular flue has almost twice the flow capacity of the 8-inch (i.d.) round flue.

11.4.3 RELATIONSHIPS BETWEEN DRAFT AND FLOW

Draft is necessary to move gases through a venting system, but the amount of flow actually determines a system's success. Theoretically, in a given heating/venting system, where all openings into the chimney have been closed off, draft still exists as long as the column of gases in the chimney is warmer than the surrounding air. However, the appliance does not operate because there is no flow. In practice, there are usually openings into the system that allow smoke to flow out of the appliance and air to enter. For the system to operate properly, there must be sufficient flow to remove smoke as fast as it is produced and to provide adequate air for combustion.

RELATIONSHIPS BETWEEN DRAFT AND FLOW

Keep the following interdependent draft and flow related principles in mind when diagnosing chimney performance problems.

11.4.4 HOW DRAFT AND FLOW VARY IN FIREPLACES AND CLOSED HEATERS

These principles of draft and flow apply both to fireplace chimneys and to chimneys serving stoves or other heaters. However, there are some differences in the way the effects of draft and flow balance out in various chimney systems.

FIREPLACE SYSTEMS

Fireplace systems need a large flow capacity. They exhaust a relatively large volume of smoke because of the speed at which combustion takes

Good draft is essential if you want a fire that is easy to start and burns well.

place. To sustain combustion - and to keep smoke from backing up into the house - they must also draw in plenty of room air. The mixing of exhaust (smoke) with room air lowers the average flue gas temperature and, therefore, lowers the draft. Because there is little resistance to gas flow through a fireplace system, strong draft generally is not needed. To compensate for low draft, a fireplace flue must be relatively large, so as to remove the air/smoke mixture.

Diluted smoke rises quickly through a large fireplace flue because there is a high volume of flow - not because there is a strong draft.

CLOSED HEATERS

The venting conditions for a closed heater are different from the venting conditions for a fireplace system. Wood normally burns more slowly in a closed heater, thus producing less exhaust in any given time period. Even though there is less exhaust at one time, wood stove smoke may appear denser than fireplace smoke because closed heaters draw in less room air to support combustion.

Unlike fireplace systems, closed heaters do not require a large flow capacity. Because the entry of air into the heater is restricted by relatively small air inlet openings, they do need a strong draft to draw air forcefully into the firebox and to overcome the resistance to flow.

Since draft is most dependent on higher average flue gas temperatures, cooling must be minimized as the gases rise up the chimney. Smaller flues encourage the quick rise of gases that results in higher average flue gas temperatures. By contrast, larger flues allow significant cooling -and therefore a decrease in flue gas temperatures - as the gases rise slowly up the flue. Large flues are necessary for open fireplaces; they are undesirable for closed heaters.

Closed heaters connected to a fireplace or fireplace flue will represent a conflict in venting system design goals. The large flow capacity built into fireplace venting systems is unnecessary for the low flow requirement of stoves. In fact, this excess capacity is detrimental to the development of the strong draft needed by a stove. Decreasing the size of the flue and thereby lowering the flow capacity can correct this performance problem.

DIAGNOSING PROBLEMS IN FIREPLACES AND CLOSED HEATERS

Fireplace performance problems - like smoking - are commonly related to inadequate flow capacity while stoves are usually more sensitive to insufficient

RELATIONSHIPS BETWEEN DRAFT AND FLOW

Provided that everything else remains the same, an increase in draft always increases the amount of flow through the system.

Draft is determined by the temperature difference between the average flue gas temperature and the temperature of the outside air. If gases cool significantly before reaching the top of the flue, there will be a corresponding decrease in draft.

Anything that increases the amount of time gases spend in the venting,system causes cooler gases. The decreases in draft that results from cooler gases leads to a decrease in flow.

Increasing chimney height also increases draft. However, draft does not increase in direct proportion to the increased height, because flue gases have more time to cool on their way up a taller chimney.

Increasing flue size increases flow capacity; however, it will decrease draft, at least to some extent. Gases move more slowly through a larger flue, taking more time to reach the top. They will have a lower average temperature since they have more time to cool. If the cooling is extreme, the decrease in draft can offset the gain in capacity and can even lead to a net decrease in draft.

Anything that restricts the entry of air into the system immediately decreases flow and eventually decreases draft as the slow moving gases cool. This eventual decrease in draft will lower the flow even more. Conditions outside the chimney can also influence chimney performance.

For example, weather and the pressure and airflow conditions outside the home may affect draft and flow. Before blaming the chimney for performance problems, consider external factors.

draft. While there are exceptions, this general guideline may be helpful when you diagnose various performance problems in these systems.

11.5 CHARACTERISTICS OF EFFECTIVE VENTING

11.5.1 OVERVIEW

The performance of a wood burning system is largely dependent on the proper functioning of its venting system. We have covered many of the component selection criteria and design guidelines for effective venting. However, the house itself, the effect of the outside environment, and the way the system is operated can also influence effective venting.

Venting problems are the greatest source of customer complaints about wood burning systems. Since venting problems are so common, the technician must be able to identify causes and suggest ways to improve performance.

A large number of factors influence the venting process and this complicates the analysis of problems. This text explores the various factors that can influence successful venting and offers some suggestions as to how venting problems can be avoided by good planning and installation, and how they can be corrected in existing installations.

Gas temperature at the base of the chimney is affected by several factors:

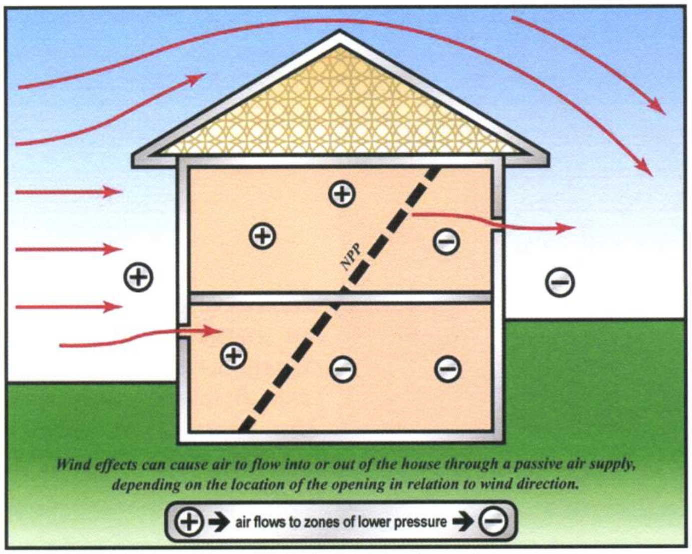
1. Flue pipe diameter.
2. Flue pipe length.
3. The number of flue pipe elbows.
4. Air leakage into flue pipe assembly.
5. Appliance firing rate.

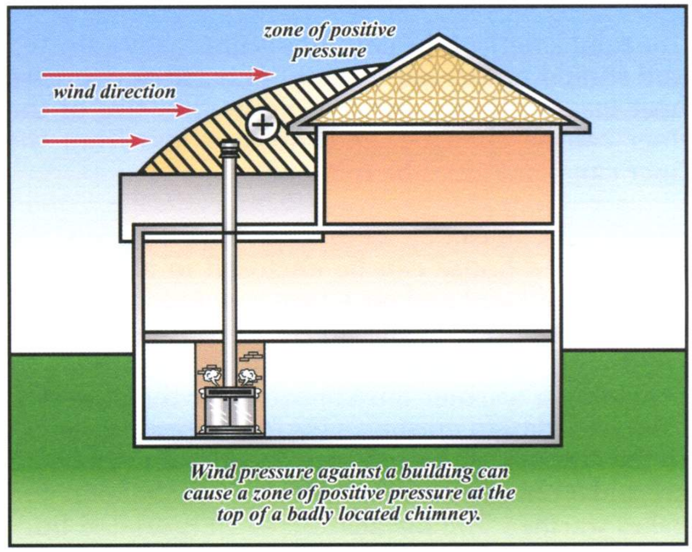
11.5.2 MAINTAIN TEMPERATURE DIFFERENTIAL

Draft is produced by the temperature difference between the gases in the vertical part of the chimney

An interior chimney works better than one exposed to the outside.

An exterior chimney will often make it more difficult to start a fire.





Wind can cause the development of high and low pressure zones around buildings.

All of these factors can be adjusted as necessary to raise or lower flue gas temperature at the base of the chimney. Even the firing rate of the appliance can be changed, but this requires some careful coaching of the operators. It is imperative to confirm an appropriate firing technique in an effort to promoting efficient wood burning. Most of the techniques offered here are intended to keep firebox temperatures high enough to sustain efficient combustion.

1. If there are no flames, something is wrong- when wood burns it should be flaming until only charcoal remains.
2. If there are firebricks in the appliance fire box, they should be tan in color, never black.
3. Steel parts of the firebox should be light to dark brown, never black and shiny.
4. When things are working properly, users should expect instant ignition of a new load of wood - the bottom pieces should be flaming by the time the door is closed.
5. If the stove has a glass door with air wash, it should be clear.
6. If the stove has a glass door without an air wash, it will be hazy, but should never be totally black.
7. The exhaust coming from the top of the chimney should be clear or white. A plume of blue or dark gray smoke indicates smoldering and probably low system operating temperatures.

These suggestions present the visual evidence of smoldering and are things that every user can understand. It may be easier to get users to change their firing procedures when they have visual guidelines to work with and particularly after you have told them that the way they use the appliance can have an effect on venting performance.

Gas temperature at the top of the chimney is affected by:

1. Gas velocity.
2. Total height of chimney.
3. Amount of insulation around liner.
4. Chimney inside or outside house.
5. Air leakage into the chimney.

The total length of the chimney is not easily adjusted and should not be adjusted to increase or decrease heat loss. However, in some cases, the size of the liner can be changed, and the heat loss from the liner can sometimes be reduced.

Metal and masonry chimneys that run up the outside of a house can be enclosed in a chase - a framed and insulated structure covered with siding to match the rest of the house. A chase eliminates wind-chill and reduces conductive heat losses by providing a warmer environment for the chimney. The chase design must provide for proper clearances to the chimney. However, the installation of a chase around a chimney is an expensive way to keep flue gases warmer. The installation of an insulated liner or a replacement inside chimney are more effective ways to reduce heat loss.

CHIMNEY CHASE: An insulated chimney chase reduces heat loss from a chimney. The insulation should be installed when it is built.

11.5.3 ELIMINATE FLOW RESTRICTIONS

Any restriction to the flow of flue gases has the effect of reducing draft. Flue pipe elbows and chimney offsets reduce draft to some degree. Flow restrictions are never desirable because they tend to cause increased creosote deposits and heat transfer from the flue gases.

Although draft is reduced by elbows and offsets, their effect on smoke spillage is most pronounced when the user opens the appliance loading door to add fuel. When the door is opened, the rate of gas flowing through the venting system increases abruptly. At this higher gas flow, there is far more turbulence created in the gas stream, more flow resistance and a greater chance of smoke spillage. If you encounter a system with one or more 90 degree flue pipe elbows and in which the appliance spills smoke when the loading door is opened, try eliminating the elbows or replacing them with 45 degree elbows. It has been demonstrated that systems with no flue pipe elbows are much less likely to spill when the loading door is opened.

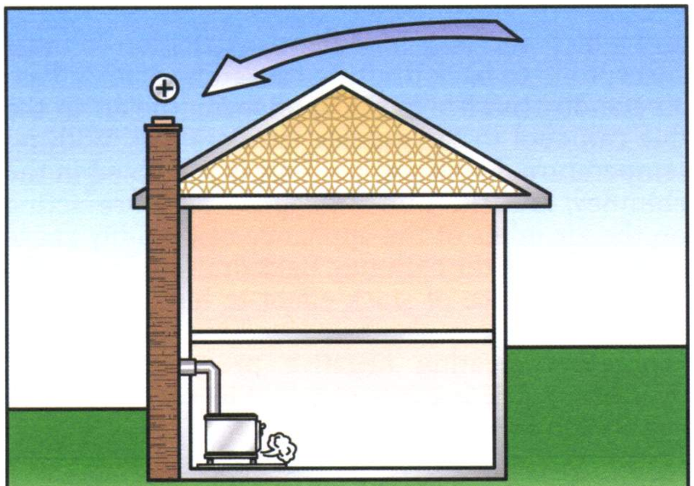
Venting systems with elbows and offsets can be more difficult to sweep and will likely need sweeping more often than straighter systems. When designing new systems or modifying existing ones, avoid elbows and offsets if you can.

Flue pipe dampers are another common flow restriction. Even when such dampers are fully open, they offer resistance to gas flow. The other problem with a key damper is that it does not offer precise control and the user will tend to close it too much and cause smoldering. Key dampers should always be avoided except with antique appliances that do not provide effective control of firing rate. If the firing rate of the appliance can be controlled adequately using its combustion air controls, a key damper serves no useful purpose and should not be installed.

11.5.4 EFFECTIVE CHIMNEY HEIGHT

Chimneys must be at least three feet higher than the highest point at which they exit the roof, and two feet higher than any point within ten feet of horizontal distance from the chimney. These are minimum chimney heights and may be increased if necessary.

The minimum chimney heights specified by building codes must be followed. Often, however, the chimney should extend higher above the roof than the minimum permitted so that reliable draft is assured.



wind flowing down towards a chimney over a nearby obsticle can be one cause of venting problems.

A rule of thumb for chimney height says that the distance between the floor that the appliance sits on and the top of the chimney should be at least 15 feet to produce adequate draft. This is a good rule to follow. If an appliance is installed on the main floor of a bungalow with a shallow pitch roof, the chimney height may be less than the suggested minimum. In such a case, you may wish to consider adding slightly to the minimum chimney height above the roof to ensure adequate draft under all conditions.

Any obstacles to smooth airflow over and around the top of the chimney can negatively affect chimney performance. Trees, buildings, or adjacent rooflines are common obstacles to airflow. If it appears that nearby obstacles may affect chimney draft, an extra foot or more of chimney height can help to prevent downdrafts.

Chimney cap design can affect the amount of draft produced by air flowing over the chimney. Specialized chimney caps can help to prevent down drafting due to airflow turbulence or air flowing down towards the top of the chimney. For factory-built chimneys, use only caps which are approved for use with the chimney. Check with the chimney manufacturer before installing a specialized chimney cap.

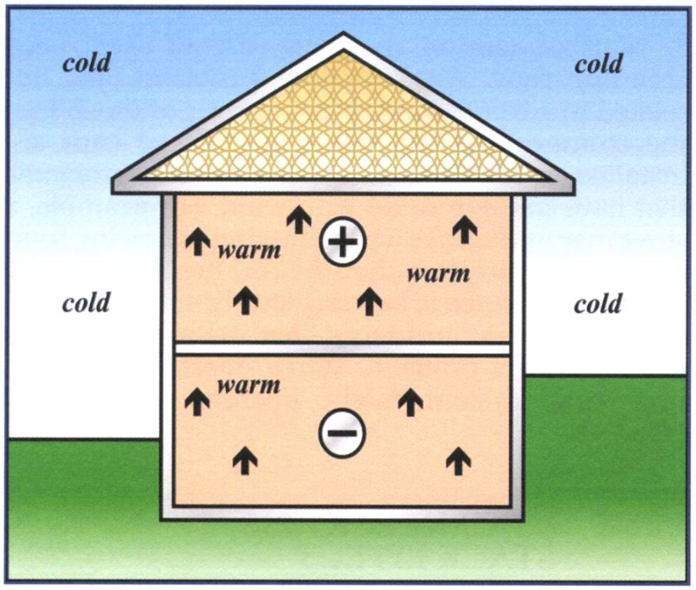
A word of caution about the use of specialized chimney caps: Most venting problems are not related to adverse winds blowing over or down into the chimney. All too often, specialized caps are installed in the hope of solving venting problems that have nothing to do with wind. For example, a stove may puff smoke when the wind is blowing from a particular direction, but the real problem may be that the appliance is burning slowly and there is so little draft being produced that the slightest wind effect causes a problem. When operated properly, that same system might operate reliably and effectively.

11.5.5 MINIMIZE HOUSE STACK EFFECT

Just as draft is created in chimneys by the buoyancy of the hot gases, a form of draft is created in houses because of the difference in temperature between air inside the house and the outdoor air. The warm air inside the house tends to rise because it is less dense and lighter than the outside air.

The tendency of the warm house air to rise results in pressure differences at various levels in the house. The pressure in the basement and lower levels of the house will be less than atmospheric pressure; the effect is similar to the low pressure at the base of a chimney. In upper levels of the house, the pressure will be higher than atmospheric pressure as the rising air pushes against the ceiling. At some point between the high and low pressure zones, the pressure will be neutral. This point is called the neutral pressure plane.

The taller the house is, the greater the stack effect. Stack effect can have a considerable effect on venting performance. Basement appliance installations are the most susceptible to problems caused by stack effect. Since they are located at the lowest point in the building, appliances installed in basements commonly operate in a negative pressure environment. In general, appliances and chimney openings located below the neutral pressure plane of the house must work against negative pressure induced by stack effect. Conversely, appliances



STACK EFFECT IN HOUSES: The warm air in a house tends to rise, producing a stack effect similar to draft in chimneys. The resulting negative pressure in a basement can cause venting problems in appliances located there.

and chimney openings located above the neutral pressure plane are assisted by positive pressure induced by stack effect.

The neutral pressure plane is often, but not always, located at the vertical mid-point of the house. A house with similar leakage rates at all levels will have a neutral pressure plane at approximately its mid-point. A house with a well sealed basement but a leakier upstairs will tend to have a neutral pressure plane higher than the mid-point, and a house with a leaky basement and sealed upstairs will have a lower neutral pressure plane. The neutral pressure plane tends to move towards the leakiest level of the house. This movement of the neutral pressure plane explains why opening a basement window can improve chimney flow in a basement installation. The open basement window represents a large enough leak to bring the neutral pressure plane down to basement level, reducing or eliminating the negative pressure the chimney was working against.

A chimney installed on the outside wall of a house and which serves a basement installation is most susceptible to back drafting caused by stack effect. At standby (no fire in the appliance), the air in the flue can cool to the outside temperature. With no temperature difference, no draft is produced in the chimney, and the minor negative pressure acting on the air inlets of the appliance can readily cause reverse flow in the chimney. Back drafting at standby is clear evidence of stack effect in buildings. Such back drafting may also be caused by other exhaust ventilators creating negative pressure, but this possible source is easily checked by carrying out a ventilation inventory.

It is often suggested that reverse flow in a chimney can be cured by holding a burning piece of paper or a hair drier at the base of the chimney to heat the flue. But heating the flue only treats the symptom of the problem, not the problem itself. Remember: A chimney that back drafts at standby can also back draft during a receding fire, especially in cold weather when an exterior chimney is being severely chilled. Back drafting during a receding fire could spill poisonous carbon monoxide into the house.

You cannot eliminate house stack effect, but you can reduce or eliminate the effects that it has on the venting of a wood burning appliance. The surest

AN EXAMPLE OF A PROBLEM SYSTEM: Operational problems caused by poor system designs like this are very difficult or impossible to correct once installed.

way to overcome stack effect is to avoid locating appliances in basements and to install chimneys inside buildings. Inside chimneys are always warmed by the house and produce some draft - usually enough to overcome house stack effect.

If the outside chimney is already installed, or if there is no alternative but to install it outside, there may be no reliable way to prevent back drafting at standby of an appliance located in a basement.

When diagnosing a draft-related problem in a basement installation, always keep in mind that negative pressure induced by stack effect can be a contributing factor.

The following symptoms can be caused by stack effect:

1. Chimney flow reversal when the system is not in use, making lighting a fire impossible and weak, unreliable draft.

2. Excessive smoking when loading door is opened.

3. Chimney flow reversal or back drafting, especially during a receding fire.

Here is an example of an actual installation that had serious problems due to excessive house stack effect. The wood stove was installed in a single story section of a two story house. It had severe cold back drafts so powerful that the homeowner found it almost impossible to light a fire without filling the house with smoke.

Possible contributors were thoroughly checked, but no solution was found. It was discovered that the top of the chimney was lower than the second floor ceiling in the main part of the house. This meant that the house was a higher "stack" than the chimney and could produce more "draft" or negative pressure in the basement than the chimney. In this case, raising the chimney height to be at least equal to the second floor ceiling height helped to resolve the problem.

This chimney was also built outside the house envelope, and so was being cooled. Ideally, this chimney should have been built at the other end of the addition and extended through the second floor eave to the top of the roof. Had this been done at the time of construction, there probably would not have been a draft problem.

Careful diagnosis is important in cases like this one. The problem might have been diagnosed incorrectly as being caused by wind flowing over the higher roof down onto the chimney. A specialized chimney cap might have been installed in an attempt to prevent downdrafts. But the cap would have had no effect on the problem and the homeowner would not have been happy with the person who recommended it.

COMPETITION FOR AIR: Appliances operating on natural draft cannot usually compete with mechanically-powered ventilators. The chimney may back draft when the negative pressure produced by mechanical ventilators overcomes chimney draft.

11.5.6 MINIMIZE COMPETITION FOR AIR

Energy conservation measures are making houses more and more airtight. Sealed vapor barriers, caulking, and carefully installed and weather-stripped doors and windows all reduce the leakage of air into and out of houses (infiltration and exfiltration, respectively). The shell, or envelope, of such houses resists airflows created by exhaust ventilators. Fuel-burning appliances are exhaust ventilators, as are kitchen and bathroom fans, clothes dryers, and central vacuum systems. All draw air from the house and exhaust it outside. When an exhaust ventilator operates in a well-sealed house, it may not get all the air it needs to function properly. When two or more exhaust ventilators operate at once, they may compete with each other for available air.

In a competition for air, mechanical systems usually win out over natural draft systems. The operation of a clothes dryer or high-volume kitchen exhaust can cause back drafting of a fireplace or other wood burning system. In theory, all exhaust ventilators should be supplied with ducted sources of outdoor air. However, the many complications involved make the complete isolation of all ventilators very rare.

By allowing dilution air to enter the venting system downstream of the appliance, a barometric draft regulator reduces draft.

Further study of the issue of house pressure and air supply has led to some new strategies for diagnosing and managing air supplies and house pressures. Appendix G contains a procedure for predicting house depressurization levels and determining the need for make-up air.

11.5.7 AVOID USING ACCESSORIES

A number of accessories intended to control draft levels are available. In general, these should be avoided in wood burning systems because they are often used to solve problems which could be prevented more effectively with good system design and component selection.

BAROMETRIC DRAFT REGULATORS

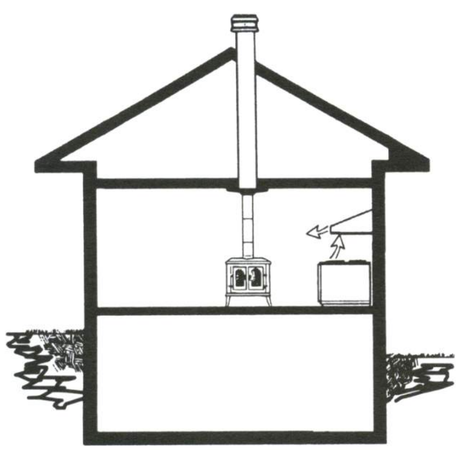
Barometric draft regulators reduce draft to a level suited to the appliance. Installed in the connector, these controls use an adjustable balance damper to admit air into the venting system. As the draft increases with flue gas heat or wind over the chimney, the damper opens further. The negative pressure at the appliance flue collar is reduced and the cooler dilution air reduces the chimney temperature and lowers the draft.

Most oil-fired central heating appliances must have barometric controls installed in their connectors to prevent high draft levels which lead to overheating. Central systems use automatic combustion controls allowing very high firing rates for short periods. The high temperatures can overheat internal components. Also, some central wood burning systems can be operated during electrical power failures during which the automatic safety limit control cannot function to reduce the firing rate.

The barometric control keeps the draft at a low level, thereby reducing the possibility of overheating in these systems.

Manually-controlled appliances do not normally need barometric controls. The appliance user adjusts the combustion air inlets to compensate for draft conditions as well as to produce the right amount of heat. If draft is high, the operator will use a slightly lower air setting, and if draft is low the user will set the control slightly more open. As a result, there is rarely a need to automatically control the draft level on manually controlled appliances.

The main drawback of barometric controls is that they consume large volumes of room air and can compete with the appliance's need for combustion air.



GOOD SYSTEM DESIGN: Well designed systems are less likely to spill smoke into the home, as well as being easier to maintain and convenient to use. Note that:

- *the appliance is located at or above the house neutral pressure plane,*
- *the chimney penetrates the roof near the peak,*
- *there are no elbows in the venting system, and*
- *the exhaust of air by mechanical ventilators is minimized.*

Although you might assume that the flow of relatively cool air into a chimney through a barometric control would chill the chimney liner and increase the rate of creosote build-up, this has not proven to be the case. Tests have shown that creosote build-up is no greater, and in some cases is much lower. There are two reasons for this:

1. The gas velocity increases with the greater volume of gas and air moving through the chimney.
2. The gases are diluted by the extra air, and this inhibits the condensation of creosote thats on the liner.

However, if a chimney fire occurs, the barometric control will open fully, admitting a large amount of air which feeds the chimney fire.

As a general rule, only install a barometric draft regulator if the manufacturer's instructions call for one. If there is no requirement to use one, don't - you may create more problems than you solve.

FORCED DRAFT AND INDUCED DRAFT

Forced draft refers to installations in which a fan is used to push combustion air into an appliance. An induced draft fan induces draft in the appliance by forcing exhaust gases out of the top of the chimney. Most pellet burning appliances use a draft inducing fan to push the exhaust into the pellet vent. There are important differences between forced draft and induced draft.

Combustion air fans are used to improve the performance of an appliance and are located upstream of the combustion chamber. They are sometimes used on central furnaces to accelerate the development of a full fire in the firebox. When the chimney is producing little or no draft at the beginning of a firing cycle, the fan may slightly pressurize the appliance, flue pipe, and chimney.

The other form of mechanical draft is provided by a fan downstream of the combustion chamber which forces the flue gases into the base of the chimney. Induced draft fans do not force air into the pipe, but use motor-driven paddles or propellers to move the gases towards the chimney. Another type of draft inducing fan is located at the top of the chimney to draw the exhaust gases out.

Connector-mounted draft fans are used to overcome serious venting problems. They should never be needed in residential applications unless something is wrong with the chimney, connector, or some other part of the installation. It is always better to find the source of the venting problem and correct it than to install a fan, which only treats the symptom of a problem.

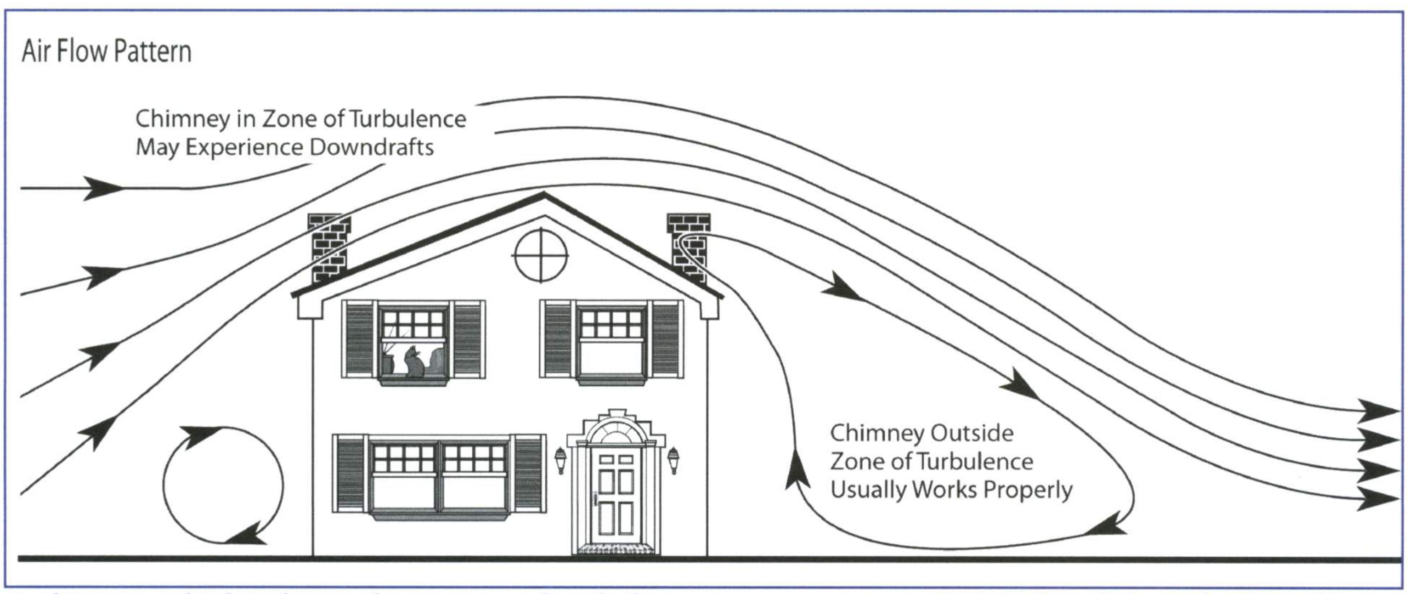
11.6 TYPES OF PERFORMANCE PROBLEMS

Chimney performance problems are usually marked by smoke that escapes from an appliance into the home or by an appliance that burns sluggishly and does not heat well. Chimney sweeps should be able to diagnose the exact type of chimney performance problem by studying the actual symptoms.

Chimney performance problems can be broken down into three broad categories: 1) wind-induced downdrafts, 2) flow reversals, and 3) inadequate flow. Wind-induced downdrafts and flow reversals cause smoke to flow backwards down the chimney. Inadequate flow indicates that the flow is insufficient to handle the amount of flue gases even though the direction of the flow is correct. Back puffing stoves constitute a rare fourth category of problems. When back puffing, the stove emits intermittent puffs of smoke due to small explosions in the stove or venting system. Back puffing is not a true chimney performance problem, but is usually mistaken for one and will be discussed shortly.

11.6.1 WIND-INDUCED DOWNDRAFT PROBLEMS

Chimney performance problems caused by wind-induced downdrafts are characterized by smoke that is forced down the chimney because of unusually



A chimney which is located in a zone of turbulence can experience wind-induced downdraft problems.

TABLE 1: ASSESSMENT OF SYSTEM DESIGN FEATURES

Promotes Spillage	Resists Spillage
Appliance	
Too large for space heat loss	Properly sized for space heat loss
Unlined combustion chamber	Lined or insulated combustion chamber
No combustion system	Low emission combustion system
Large door opening area vs. flue collar	Moderate to small door opening
Leaky construction	Sealed construction
Large heat exchanger	Moderate to small heat exchanger
Firebox exhaust lower than door opening	Firebox exhaust higher than door opening
Solid doors	Glass doors with air wash system
Connector	
Sized different than appliance flue collar	Size matched to appliance flue collar
Assembly includes elbows	Assembly straight to chimney
More than six feet in length	Less than six feet in length
Assembly has key damper	No restriction to flow
Assembly loose and leaky	Assembly reasonably well sealed
Chimney	
Chimney flue is not insulated	Chimney flue is insulated
Located up outside wall	installed inside house envelope
Flue size different than flue collar size	Flue matched to appliance flue collar
Flue has offsets	Flue is straight
Total System height less than 15 feet	Total system height more than 15 feet
Chimney height less than code requires	Chimney height exceeds code requirements
Chimney not clear of roof	Chimney clears top of roof
Leakage causes cooling and dilution	Chimney is well-sealed
House/Setting	
Has high volume exhaust ventilators	No high volume exhaust ventilators
Appliance is located below neutral plane	Appliance is located above neutral plane
House set low compared to nearby features	House is clear of wind obstructions
Appliance Operator	
Tolerant to wood smoke smell	Intolerant to wood smoke
Routinely operates appliance at low output	Knows how to avoid smoldering
Misuses flue pipe key damper	Takes care in use of flue pipe key damper
Inexperienced wood burner	Experienced wood burner

TABLE 2: SUMMARY OF CORRECTIVE MEASURES	
Chimney Top Temperature	
Problems Diagnosis	Corrective Action
Outside chimney being chilled	1. Enclose in chase 2. Reline and insulate 3. Install inside chimney
Chimney flue oversized or undersized	1. Reline to correct size 2. Replace with chimney of correct size
Excessive connector heat loss	1. Replace with sealed double wall connector 2. Re-locate appliance or chimney to reduce connector length 3. Replace 90° elbows with 45° elbows
Low flue gas temperature from appliance	1. Instruct user to build hotter fires – avoid appliance smoldering 2 . Instruct user on influence of bi-metallic controls 3. Split wood smaller, use drier wood 4. Replace oversized appliance with one of correct size 5. Replace conventional appliance with on of advanced technology
Flow Restrictions	
Problems Diagnosis	Corrective Action
Elbows in connectors	1. Replace 90° elbows with 45° elbows
Connector key damper	1. If possible, remove key damper 2. Instruct user in proper use of damper
Creosote build-up or blocked thimble	1. Clean chimney or reconstruct thimble
Appliance by-pass damper	1. Instruct user on proper us of by-pass
External Influences	
Problems Diagnosis	Corrective Action
Chimney top affected by wind nd nearby obstacles	1. Increase chimney height 2. Remove obstacles 3. Specialized chimney cap may help
Adverse pressures	1. Eliminate competing exhaust ventilator 2. Install make-up air supply 3. Instruct user to avoid operating exhaust-only ventilators when wood burner is operating

high pressure at the top of the flue. If smoking occurs only when the wind blows or if smoking is inconsistent and marked by puffing, wind-induced downdrafts are often the cause of the problem.

Wind-induced downdrafts are always related to wind. They are usually caused by the airflow relationship between the house and the chimney termination. Most commonly, the top of the chimney is exposed to air turbulence caused by wind rushing over or around some nearby object or barrier, like a taller building. Air movements hit the top of the chimney in a downward direction, and force smoke down the chimney. This problem is very common when the chimney is located downwind of a barrier (the side situated away from the wind), and it normally occurs when the wind blows from a particular direction at a particular speed.

Similar wind-induced downdraft problems can occur when a chimney is located on the windward side of a barrier (the side situated toward the direction from which the wind is blowing). Wind blowing against a barrier can create a high-pressure zone on the windward side as the air piles up waiting to get around the barrier. When the chimney top is situated in this high-pressure zone and the pressure in the zone is greater than the pressure in the house, draft in the chimney is overcome, and smoke flows downward.

The surest solution to chimney performance problems caused by wind-induced downdrafts is to extend the chimney above the turbulence or the high-pressure zone. NFPA 211 provides chimney termination guidelines that serve well in the majority of cases. It states that the chimney should end three feet above the point where it penetrates the roof or roof overhang and extend at least two feet above any structure within ten feet. However, there are frequent cases where this guideline is inadequate, particularly when a large structure more than ten feet away is significantly taller than the chimney (for example, the second story of a neighboring house). Extending the height of the chimney often helps to overcome these effects of wind.

Chimney caps can also be used to correct wind induced downdraft problems. If the wind-induced downdraft problem is caused by turbulence, a chimney cap may deflect the wind enough for the chimney to function normally.

In fact, some caps are actually designed to take advantage of the wind. They use wind velocity to help draw smoke from the chimney regardless of the wind direction. The effect of using chimney caps when the chimney is located on the windward side of the house is less clear-cut since the cap must overcome a higher air pressure.

In some cases, chimney caps may not be an effective solution to wind-induced downdraft problems. They can make the problem worse by restricting the flow of gasses out of the top of the flue. Nevertheless, the high cost of extending a chimney justifies using chimney caps as a trial solution.

11.6.2 FLOW REVERSAL PROBLEMS

Flow reversal problems differ from wind-induced downdraft problems in that gases are drawn down the chimney by low pressure at the bottom; they are not forced down the chimney by high pressure or turbulence at the top.

While flow reversals can be caused by several conditions, most of them occur when there is a depressurization of the house. In other words, the pressure in the room becomes lower than the pressure in the chimney. When this happens, chimney draft which depends on room pressure being greater than pressure inside the lower part of the flue is overcome, and the flow is reversed. Smoke then moves down the chimney, and out of the appliance or fireplace and into the room.

FLOW REVERSALS CAUSED BY THE HOUSE ACTING LIKE A CHIMNEY

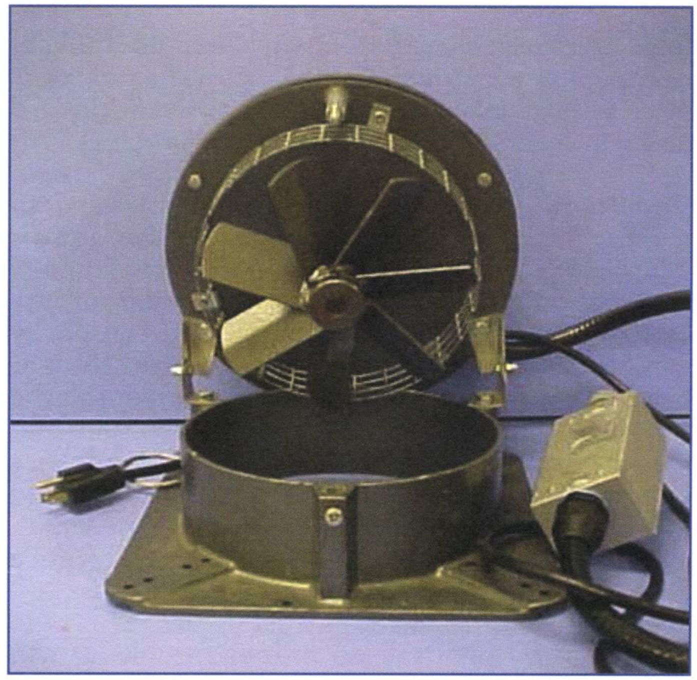
Sometimes the house itself acts like a chimney. For example, warm air inside the house is buoyant and tends to rise, just as warm gases rise within a chimney. Small openings at the top of the house, like leaks in windows, allow warm house air to escape. This creates draft and a slightly decreased pressure in the lower areas of the house (similar to the low pressure inside the lower part of the flue that is necessary for chimney draft).

Usually, there are openings into the lower areas of the house as well; so cooler outdoor air is drawn in to relieve the negative house pressure, and chimney draft is not affected. If an insufficient amount of cooler air is drawn in, the negative pressure tends to: 1) offset the low pressure at the base of the chimney, 2) counteract chimney draft, and 3) create a stack effect (see Glossary). If you have confirmed that a house stack effect is causing the flow reversal, leaving a window open is not a viable permanent solution. Isolate the air supply from the house atmosphere by adding a source of outside air directly to the combustion chamber or near the appliance. Locating and sealing openings at the top of the house also help minimize house stack effect.

FLOW REVERSALS CAUSED BY ANOTHER CHIMNEY IN THE HOUSE

A second chimney operating elsewhere in the home can also cause depressurization. This problem is common in homes that have two fireplaces - one upstairs and one in the basement. Air removed by the upstairs flue is replaced by air that was drawn into the home by the flue venting the basement appliance. Smoke exhausted by the first flue can be sucked into the top of the second flue, causing the appliance vented by the second flue to smoke, even if it is not operating. This effect can also cause appliance chimneys to reverse flow and spill the products of combustion into the home. If the top of the flues are in close proximity to each other and are of about equal height, extending the height of the flue serving the appliance installed in the higher location in the house, by about 12 inches, can stop smoke from being drawn into the home, but does not solve the flow reversal problem itself.

Installing a source of outside air to the combustion air zone of the lower appliance may be the solution to this problem.



An Exhausto draft inducing fan designed to be mounted to the top of the chimney.

OTHER CAUSES OF FLOW REVERSALS

Operating exhaust fans can also cause depressurization of the house. Air exhausted from relatively airtight homes by bathroom, kitchen, or attic fans, or by clothes dryers, may not be completely replaced by normal air infiltration. When this occurs, the fans actually work against the chimney and can create a flow reversal. Turning off the fans is an easy test for this cause of flow reversal. A permanent solution is to provide a source of outside air directly to the heating appliance.

Poorly sealed ducting systems can also cause depressurization of the home. This is particularly true of chimney-connected appliances that are located in basements. In theory, the air system pulls air from the living areas of the home and replaces it with an equal amount of heated air. During this process, pressures throughout the house stay balanced.

In practice, however, if the return system is poorly designed or unusually restricted, the appliance blower may pull too much air from the basement causing depressurization in this area. Such depressurization works against all chimneys with openings into the basement, including the one that serves an appliance. This type of flow reversal problem is common in some solid fuel add-on appliances that have an open blower rather than a return ducting system. The return ducting system should be repaired to maintain a balanced pressure in the home. Means can also be provided to allow an adequate amount of air to flow from the first floor to the basement. For example, a basement door could be left open.

Another flow reversal problem occurs only on windy days. When the wind blows, a low-pressure zone is usually created on the downwind side of a house. As long as there are no unusual openings into the home, this low-pressure zone is roughly equalized by the positive pressure on the windward side of the home. If there are large openings on the downwind side, like open doors or windows, house air can be drawn outward causing depressurization inside the home. To test for this problem, seal significant openings on the downwind side of the house or open a window on the windward side. The most effective permanent solution is to install an outside combustion air inlet directly to the appliance on the windward side or in a neutral sheltered area. Extending the height of the chimney will not solve this problem.

Most of the time, flow reversal problems are solved by repairing the cause of the problem or supplying the appliance with an alternative source of combustion air. When these solutions are ineffective, it is sometimes necessary to create an artificial draft by installing a mechanical draft inducer at the top of the chimney. (These devices should never be installed at the bottom of the chimney to push smoke out unless they have been listed for residential chimneys and manufacturer instructions are followed exactly. Draft inducers installed at the bottom create a positive pressure in the chimney and will tend to force smoke out of any small leaks in the chimney.)

The tight construction of today's homes can greatly assist in keeping energy costs down. But contractors sometimes overlook the need for fresh air introduction into the home- not only for the health of the occupants, air is also needed for combustion appliances such as wood and gas stoves, fireplaces, gas ranges, gas logs, furnaces, and hot water heaters. All of these appliances need air for combustion, with the furnace taking the most air from the home. The furnace may take the air needed from the place of least resistance, which is usually the fireplace flue (even with the damper closed). This can cause smoke to backup or reverse completely. The addition of a make-up air system can alleviate this problem.

11.6.3 INADEQUATE FLOW

In a large percentage of chimney performance problems, smoke flow is inhibited rather than reversed completely. This type of problem is caused by inadequate flow in the chimney and characterized by an appliance that smokes or burns fuel poorly.

Inadequate flow problems can be the result of insufficient draft or insufficient flow capacity. When the inadequate flow problem is draft-related, draft is insufficient to move all of the gases through the flue and to overcome the resistance to flow. When the problem is flow related, draft is sufficient for the appliance, but the system itself does not have the appropriate capacity to handle the volume of exhaust.

Sometimes, low draft can result from inadequate flow capacity. In this case, increasing draft can partially compensate for the capacity problem. The proper solution, however, is to identify and remedy the insufficient flow capacity.

INADEQUATE FLOW PROBLEMS CAUSED BY DRAFT

Inadequate flue gas temperatures cause most draft problems. Appliances that burn slowly typically have low flue gas temperatures. Since these fires do not produce a hot exhaust, smoke is already cool when it enters the venting system.

In addition, when the air inlets on the stove are restricted to achieve a low burn rate, this restriction of airflow can slow down the velocity of all gases moving through the flue. Anything that decreases the velocity of gases also increases their cooling. Smoke can cool excessively after entering the chimney for a variety of reasons. These include:

1. Oversized flues, particularly fireplace chimneys serving an insert or stove.

2. Chimneys exposed to extremely cold outside air that cool the gases inside.

3. Long lengths of connector that allow smoke to cool significantly before it reaches the chimney.

4. Heat exchangers on connectors that rob the smoke of heat, result in lower temperatures and ultimately lower draft that may be insufficient to overcome the extra flow resistance of the heat exchanger.

5. Large smoke chambers reduce flow due to the expansion and cooling of gases in the chamber itself; these chambers can also create more turbulence as the gases pass through the damper, resulting in even more cooling.

Newer, high efficiency stoves can be very sensitive to inadequate flow problems caused by draft. They often contain a heat exchanger that results in low flue gas temperatures even when the stove is burned properly.

In addition, these stoves may require more draft to overcome their complicated interior passageways. They demand ideal chimney conditions to operate at their potential.

These draft problems usually become more noticeable as the appliance is "dampened down" and smoke is cooled, lowering the flue gas temperatures before they even enter the chimney.

Slow-burning appliances will generate a lot of dense smoke.

These problems may not be evident when the fire is first started or when it is burning hot. As the system cools and draft decreases, less air for combustion is drawn into the stove allowing the fire to cool even more. Low flue gas temperature is the cause of this draft problem.

Since many factors can lower draft, sweeps must determine the most critical factor causing loss in flue gas temperature and the subsequent decrease in draft. Changing the way homeowners operate appliances is usually the most cost-effective solution to this problem.

Consumers should avoid burning conditions that lower the flue gas temperature. In other words, they need to burn the stove hotter. Sometimes changing homeowner habits may prove unsuccessful, since altering the burning technique may mean operating the stove at a rate that makes the room uncomfortably hot or that decreases the burn time to a level that the homeowner finds unacceptable. However, suggesting that the homeowner put in less wood and feed the fire more often while allowing plenty of combustion air (smaller hotter fire) may work better by not making the room uncomfortably hot.

It is possible to burn the stove hotter even if the room becomes too warm. For example, small fans in doorways or walls will circulate heated room air to other areas in the home. This improved distribution of the heat produced by the stove often overcomes the discomfort problem.

Altering the venting system to compensate for cooling gases is a better approach to solving draft problems. Some possible modifications include:

1. Removing a heat exchanger from the connector.
2. Shortening a run of connector, and reducing, or eliminating elbows.
3. Changing an oversized flue to a smaller, appropriately sized insulated liner.

INADEQUATE FLOW PROBLEMS CAUSED BY INSUFFICIENT FLOW CAPACITY

The size of the venting passageways in the system and the amount of resistance offered by obstacles or bends in the system are the factors that determine flow capacity. Flow capacity problems are defined as the inability of a chimney to handle the volume of smoke produced by an appliance, even when draft is adequate. Flues that are too small, too long, or partially obstructed with creosote, mortar, or other forms of debris cause most of these problems.
The specifications for proper flue size are different for fireplace and closed heater systems. Fireplaces and stoves with large door openings are more likely to suffer if vented by an undersized flue. By contrast, chimney flues venting closed heater systems are rarely too small since their flow requirements (when closed) are relatively low.

RATE OF REDUCTION OF FLOW CAPACITY

The reduction of flow capacity occurs more quickly in smaller flues. A 1/2" build-up on an 11" by 11" flue reduces the usable cross-sectional area (and the flow capacity) by approximately 17 percent. The same 1/2" build-up in an 8" round flue reduces capacity by approximately 30 percent.

For fireplaces and stoves that can operate with doors in the open position, the cross-sectional area of the flue should be approximately:

1. One-twelth the size of the fireplace opening for round flues.
2. One-tenth the size of the fireplace opening for square flues or rectangular flues with an aspect ratio of less than two to one.
3. One-eight the size of the fireplace opening for rectangular flues with an aspect ratio greater than two to one.

The requirements above are for straight flues at least eight feet tall. For other situations, consult the current edition of the ASHRAE Handbook, HVAC Systems, and Equipment.

Thus a fireplace opening measuring 36 by 28 inches has an area of 1008 square inches and would require a square flue that measures at least 101 square inches.

When the cross-sectional area of a fireplace flue does not fall within the one-tenth range, the size of the fireplace opening should be decreased. Sweeps can perform this service for the consumer by placing sheet metal at the top of the fireplace opening and gradually lowering it until the size of the opening is reduced and the fireplace stops smoking.

Restrictions in the venting system can cause inadequate flow in closed heater systems. Since flow capacity is determined by the smallest part of a venting system, the wrong size connector can often cause a flow-related problem. Connectors that are too small can cause an appliance to smoke regardless of the flue size.

A connector which is sized properly for a given

Air will take the path of least resistance in or out of the chimney based on pressure differences.

heating/venting system should not be smaller or appreciably larger than the flue outlet on the stove. Ideally, this also applies to the chimney flue. Other problem areas include chimney caps that are too restrictive in design or clogged with creosote, mesh screens at the top of the flue that can easily plug, and thimbles that are too small.

Changes in shape or direction of the venting system will add extra resistance to gas flow. To prevent this resistance, heating/venting systems - whether fireplaces, open stoves or closed heaters - should adhere to these specifications:

1. The connector installed from the appliance to the flue should be kept as direct and short as possible.

2. Since connector elbows cause resistance to flow, an installation should not have more than two 90-degree bends in the chimney connector (not including the turn up into the chimney).

3. Chimney flues should be constructed as nearly vertical as possible. Offset flues can cause smoking problems in fireplace systems. In wood burning, there is usually increased creosote build-up at offsets.

All venting systems suffer a reduction in flow capacity when the system is partially blocked. Debris in the chimney, such as pieces of masonry, bird nests, or animals can all cause smoking. In addition, creosote build-up progressively blocks the flue, resulting in a gradual reduction of flow capacity. Creosote also inhibits smoke flow due to resistance since the surface of creosote is rougher than the surface of a flue. To solve this flow capacity problem, remove all blockages and take action to prevent their reoccurrence.

OTHER FLOW PROBLEMS

Other flow related problems could be caused by air leaks in a chimney. Air leaks allow air to flow through chimney system openings other than through the appliance. If there are excessive openings, the remaining flow may be insufficient to exhaust the system. Air leaks in the chimney can be caused by poorly sealed cleanout openings, missing bricks in the lower section of the chimney, and leaks between adjacent flue liners in the same chimney.

Using a single flue to vent more than one appliance can also cause inadequate flow. Since a second appliance has its own draft and flow requirements, many venting systems do not have the capacity to handle more than one appliance at the same time. In addition to open fireplaces, barometric dampers on oil appliances, and draft hoods on gas appliances function as air leaks when connected to the same flue as a wood burner. Unless a wood burner is specifically tested and listed for such use, a solid fuel appliance should not be vented through a flue venting a gas, or oil appliance. Airtight houses can cause performance problems for heating/venting systems. For example, chimneys in extremely airtight homes can have flow (and draft) problems. The air drawn into any appliance must be replaced by an equal amount of air entering the house from the outside. If the house is well sealed, there may not be enough outside air infiltration to support this flow. The appliance will not deplete the home oxygen supply, but it will smoke.

In airtight homes, fireplaces can have smoking problems that are related to their large flow requirement. Fireplaces consume between 100-500 cubic feet per minute of room air. Many new homes are designed with air infiltration rates substantially less than this requirement. If a fireplace smokes, try opening a window to increase the amount of air flowing into the house. If the open window relieves the smoking, you have confirmed a flow problem with the system due to the air-tightness of the house. Recommend 1) adding a direct source of combustion air for the fireplace, and 2) covering the firebox opening with glass doors.

11.6.4 BACKPUFFING STOVES: A SPECIAL CASE

When a stove back puffs, it emits smoke in short, sharp puffs. This problem can be easily mistaken for chimney performance problems caused by wind-induced downdrafts. Actually, back puffing is caused by a series of small explosions in the stove or venting system.

Back puffing may occur with closed heaters in the following manner. Burning fuel produces combustible gases that usually burn as the familiar flame of a wood fire. If a stove is operated at a high firing rate and the air supply is restricted, the gases can become too oxygen starved to continue burning, instead, they go up the chimney as smoke. Under some circumstances, the gases remain in the stove at temperatures high enough to burn but with an insufficient amount of oxygen to sustain combustion.

As small amounts of additional air become mixed with the hot gases, the gas/air mixture may approach the critical ratio of air to fuel at which it can burn. (Any combustible gas has a range of air to fuel ratios within which it can burn. This is called "the limits of flammability" in the fire prevention profession.)

When a cloud of gases suddenly reaches this critical point, it flashes, causing a small explosion. The ensuing explosion keeps air out temporarily and forces smoke and gases out of the stove and connector. As the explosion ends, it creates a vacuum in the system that draws in new air. When new air mixes with the cloud of gases, it reaches the critical point again, another explosion occurs, and the chain continues.

Back puffing can be distinguished from smoking problems caused by wind-induced downdrafts by the sharpness and force of the puffs of smoke.

Unlike smoking caused by wind-induced downdrafts, back puffing can occur any time rather than just on windy days. Back puffing happens most frequently after a stove is loaded with a large amount of unusually dry wood, burned hot for a short time, and then drastically dampened down. It can also occur midway through a burning cycle if the right combination of gases and temperature develops or when the flow of gases through the system becomes sluggish.

Fortunately, back puffing rarely occurs. When it does, increasing airflow into the appliance can immediately stop it. Preventing back puffing is entirely dependent on proper operation of the stove. The stove operator should never build a roaring fire and then close it down, but should keep gases flowing steadily through the system and avoid large fuel loads, especially if the wood is unusually dry.

The operator should gradually build the fire to a moderate flaming level, maintain that level, or only slightly reduce the air supply. Following these operating techniques can also minimize creosote deposits in the venting system and may improve the heating efficiency of the stove.

11.7 SUMMARY

Following a basic, three-step procedure can help sweeps diagnose and solve chimney performance problems logically. The three steps in this procedure are:

1. Gathering information about the symptoms of the problem.

2. Making a tentative diagnosis of the cause of

the problem and testing it.
3. Specifying an effective solution.

The two major principles at work in a chimney are draft and flow. Draft is the force or pressure that causes gases to flow up and out of the chimney and air to flow into the appliance. Draft is a measure of the force that drives the venting system. Flow is a measure of the volume of gases that actually pass through the system as a result of draft.

Several factors influence draft and flow. Two major factors which influence the amount of draft are: 1) the temperature difference between the average flue gas temperature and the temperature of the outside air, and 2) the height of the chimney.

Three major factors that influence the amount of flow are: draft, amount of flow resistance, and flue cross-sectional area. The flow capacity of a venting system is determined by the way in which draft, amount of flow resistance, and flue area balance out in operation. The size of the venting passageways is the most critical variable influencing the amount of flow: the larger the flue, the greater the volume of gases that will be able to flow through the system in a given time and at a given draft and flow resistance. Measuring the cross-sectional area of each flue can compare flow capacities of different flues.

The same principles of draft and flow apply to fireplace flues and flues serving stoves or other heaters. However, there are differences in the way the effects of draft and flow balance in various chimney systems. Connecting closed heaters to a fireplace or fireplace chimney represents a conflict of venting system design goals.
Chimney performance problems can be divided into three broad categories:

1) wind-induced downdrafts
2) flow reversals, and
3) inadequate flow. Wind-induced downdrafts and flow reversals cause smoke to flow backwards down the chimney. Inadequate flow indicates that the flow volume is insufficient to handle the amount of flue gases even though the direction of the flow is correct.

Wind-induced downdrafts are always related to wind. The surest solution is to extend the chimney above the turbulence or high-pressure zone causing the problem. Chimney caps, especially those designed to take advantage of the wind, are often a more economical solution to wind-induced downdraft problems.

There are several causes for flow reversal problems:

1) interaction between the chimney and the house
2) another chimney in the home
3) operating exhaust fans in airtight houses
4) improperly connected appliance ducting systems. Most of the time, flow reversal problems can be solved by repairing the cause of the problem or supplying the appliance with an alternative source of combustion air.

Inadequate flow problems can be the result of insufficient draft or of insufficient flow capacity. Inadequate flue gas temperatures cause most draft problems. Anything that decreases the velocity of gases also increases their cooling. The size of the flue and other passageways in the system and the amount of resistance offered by obstacles, bends or debris in the system determine flow capacity. Other flow related problems could be due to air leaks in a chimney, using a single flue to vent more than one appliance, and airtight houses.

Back puffing can be distinguished from smoking problems caused by wind-induced downdrafts by the sharpness and force of the puffs of smoke.

In back puffing, the stove emits intermittent puffs of smoke due to small explosions in the stove or venting system. Back puffing is not a true chimney performance problem, but is often mistaken for one when it occurs.

Allowing more air to enter the appliance will stop back puffing. Its prevention is entirely dependent on proper operation of the stove.