Chapter 6

Draft & Venting

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Chapter 6

Draft and Venting

Introduction

A properly functioning venting system removes all the combustion gases from the appliance and safely directs them to a point outside the building. An improperly functioning venting system will prevent the heating system from operating efficiently and may be dangerous to the inhabitants.

What is draft?

Draft is the pressure difference that causes gases or air to flow through a chimney, vent, flue or appliance.

In practical terms, draft is a force that "pulls" or "sucks" the exhaust gases out of the heating unit and sends them up the chimney.

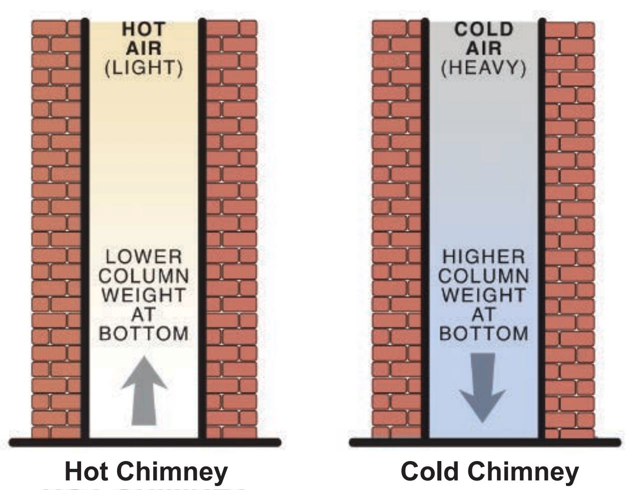
During the combustion process, hot gases rise through the heating appliance to the flue pipe then travel up the chimney creating negative pressure or suction, also known as "negative draft" at the bottom of the chimney.

This negative pressure is created because:

- When the burner is off and the chimney is cold, the air inside the combustion area, heat exchanger, flue pipe, and chimney is at atmospheric pressure.
- When the burner starts, the burner fan creates "static pressure" as it pushes air into the combustion area where it combines with the fuel.
- When the air and fuel burn, the temperature rises dramatically, and the combustion gases expand to more than double their volume. This expansive pressure adds to the pressure created by the burner fan and pushes the combustion gases through the heat exchanger.
- As the hot combustion gases travel up the chimney, they create a pressure drop behind them that sucks the combustion gases out of the heat exchanger, Figure 6-1.

Figure 6-1: Chimney draft

Hot Air Causes Lower Weight (Pressure) at Bottom of Chimney than Cold Air



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On a specific job site, draft is the total effect of the positive pressures of the burner fan, the expansive pressure of the flame and the negative pressure of the hot gases escaping the top of the chimney.

Burners need stable draft for proper operation. Variable draft can affect efficiency and cause operational problems. For example:

- Insufficient draft reduces the combustion air delivery to the burner and can cause noisy operation and smoke.
- Excessive draft increases combustion air delivery to the burner and decreases efficiency.

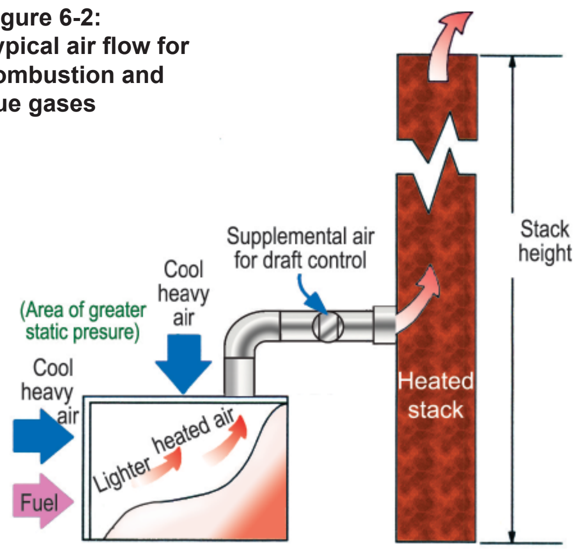
Chimney venting creates natural draft

There are two types of natural draft created in the chimney—thermal and currential.

Thermal draft is created when the air in the chimney is hotter and therefore lighter (less dense) than the air outside. As the lighter air moves up the chimney, air moves in from the surrounding room to replace it. Figure 6-2

Currential draft is caused by the suction created as wind rushes over the chimney top, creating a negative pressure in the chimney. Because wind is variable, currential draft is unpredictable and must be controlled. Occasionally wind will blow down the chimney causing a 'down draft.'

Figure 6-2: Typical air flow for combustion and flue gases



What affects draft?

The draft produced by a chimney is variable, not constant. The height of the chimney, temperature of the outside air, temperature of the flue gases, barometric pressure and humidity of the air all affect draft. Table 6-1 shows how draft is affected by outdoor temperature, chimney height and chimney temperature.

When the burner is first fired, the chimney is full of cool air and there is little or no thermal draft. As the chimney is warmed by the flue gases, the thermal draft increases.

When it is colder outside, the temperature difference is greater, and draft increases.

Other conditions that affect draft include wind velocity across or into the top of the chimney and flow restrictions in the chimney, flue pipe or heat exchanger. It is important that the chimney be properly constructed, clean and have no air leaks through cracks and gaps.

The placement of the chimney and its construction can also affect draft. A chimney operates best when it is warm and dry. Therefore, a chimney with one or more of its walls outside the building, does not work as well as an inside chimney.

Table 6-1
Theoretical Chimney Draft for Various Conditions

Case 1 OUTSIDE AIR = 60°F

AVG CHIMNEY TEMP. °F	CHIMNEY HEIGHT IN FEET 10	15	20	25	30
100	0.01	0.02	0.02	0.03	0.03
200	0.03	0.05	0.06	0.08	0.09
300	0.05	0.07	0.09	0.12	0.14
400	0.06	0.09	0.12	0.14	0.17
500	0.07	0.10	0.13	0.17	0.20
600	0.07	0.11	0.15	0.19	0.22
700	0.08	0.12	0.16	0.20	0.24
800	0.09	0.13	0.17	0.22	0.26
900	0.09	0.14	0.18	0.23	0.27

Case 2 OUTSIDE AIR = 0°F

AVG CHIMNEY TEMP. °F	CHIMNEY HEIGHT IN FEET 10	15	20	25	30
100	0.03	0.04	0.05	0.07	0.08
200	0.04	0.05	0.09	0.11	0.13
300	0.06	0.09	0.12	0.14	0.17
400	0.07	0.10	0.14	0.17	0.20
500	0.08	0.11	0.15	0.19	0.23
600	0.07	0.12	0.17	0.21	0.25
700	0.09	0.13	0.18	0.22	0.27
800	0.09	0.14	0.19	0.23	0.28
900	0.10	0.15	0.19	0.24	0.29

Draft = 0.01467 X Height X (1 - ([OAT + 460] / [TEMP + 460]))

Where:
Draft = Inches Water Column
OAT = Outdoor Air Temperature
TEMP = Average Chimney Temperature = (Tin - Tout)/2

Based on information in the North American Combustion Handbook, Second Edition, 1978.

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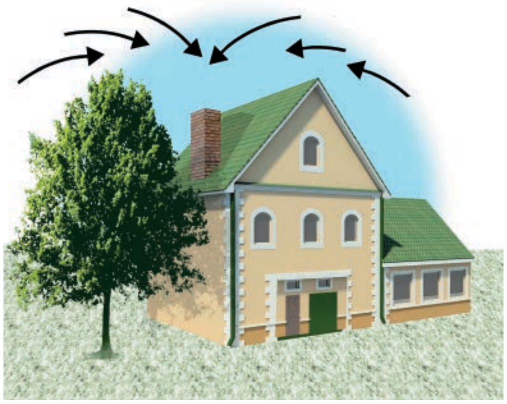
Figure 6-3: Down draft



The outside chimney heats up slowly and cools off rapidly. Additionally, the chimney must extend at least two feet above nearby objects, such as the roof peak, trees, and other buildings within 10 feet. Overhanging trees or high buildings can affect the draft and can cause wind currents to tumble, causing down draft. Figure 6-3.

Effects of draft on air leakage

Excessive draft will draw air into the appliance through air leaks. This air will cool the combustion products and reduce the efficiency of the heating system.

The most common locations for these air leaks are around the burner mounting flange, between the base and the heat exchanger, between the sections of a boiler and around clean-out and inspection doors and plates. Figure 6-4 shows outdoor air infiltration caused by the heating system and chimney.

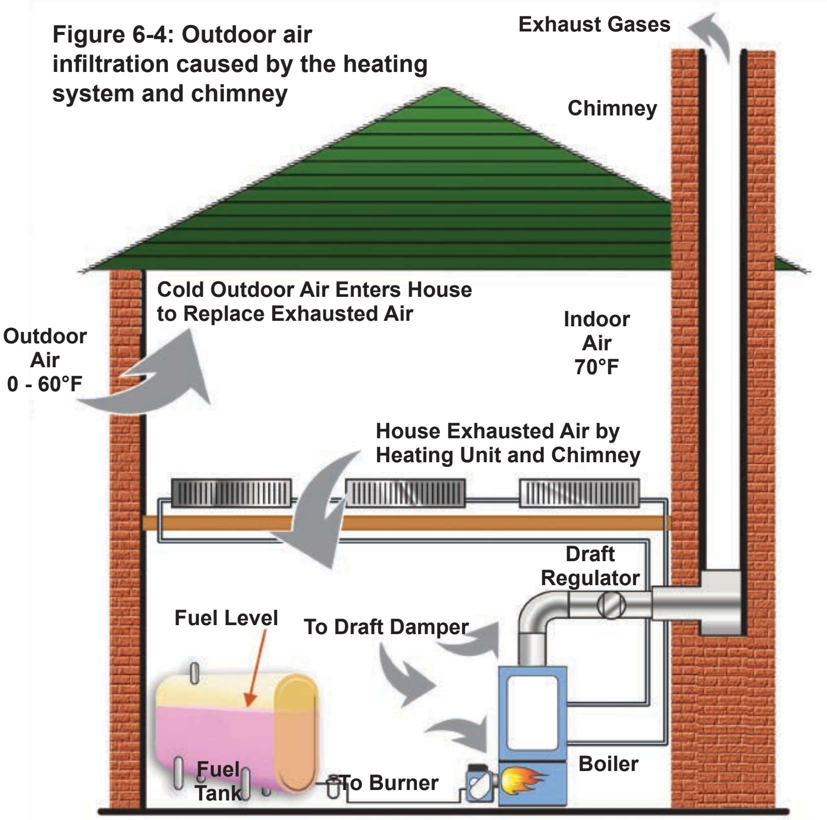
Effects of draft on stand-by losses

Whenever the air inside the chimney is warmer than the air outdoors, the chimney will create thermal draft. This is good when the burner is running, but not when the burner shuts off.

Air flowing up the chimney is replaced by air drawn into the building through windows, doors or other gaps in the building envelope.

It is very easy for the draft from the still warm chimney to draw warmed air from the building into the burner air intake and up through the heat exchanger. As it does so, it also takes heat from the heat exchanger as it goes up the chimney. This new hot air keeps the chimney warm, which, in turn, keeps producing draft that brings outside air into the building.

Figure 6-4: Outdoor air infiltration caused by the heating system and chimney



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Old equipment, especially boilers, have very high stand-by losses. New burner air intakes, air handling parts and combustion heads are not as wide open as the old ones, and new heat exchangers are much more restricted than the older types. The result is much higher efficiencies, less stand-by loss and much lower fuel consumption.

Draft regulators

It is necessary to regulate draft because natural draft is so variable. The most common draft regulator is the by-pass or air-bleed type. Since it responds to changes in barometric (atmospheric) pressure, it is also called a barometric draft regulator or damper, Figure 6-5.

The regulator consists of a counter weighted swinging door that opens to allow room air to flow into the flue and mix with the exhaust gases. This stabilizes over-the-fire draft, slows the flow of gases through the heat exchanger, lowers the stack temperature and increases efficiency When the draft drops below the draft regulator setting, the counterweight closes the draft regulator door.

It is important to understand that a draft regulator can't cause an increase in natural draft; it can only decrease draft at the breech and over-the-fire.

The draft regulator should be installed in the flue pipe, as close to the appliance as possible. If the appliance includes an obsolete stack mounted primary control, the regulator should be installed on the chimney side (at least 18 inches from) the primary control. If installed closer to the control, the cool air from the regulator can cause the unit to shut off on safety even when the system is operating properly. See Figure 6-6 for draft regulator locations.

Some heating appliances operate without a draft regulator. The burners create enough static pressure to move the combustion products up the chimney and the heat exchangers are designed to resist the effects of variable draft.

As with all appliances, always follow the manufacturers' instructions regarding draft.

Figure 6-6: Draft regulator locations: Correct and incorrect

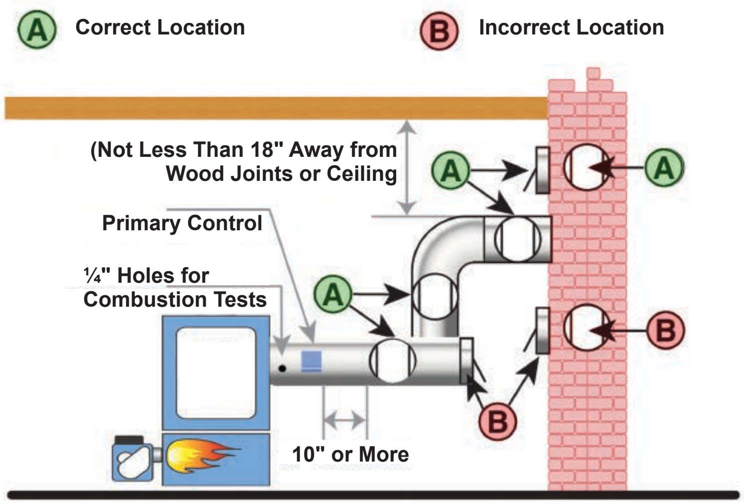

Figure 6-5: Draft regulators

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Measuring draft

Draft is measured in inches of water column. One inch of water column is the pressure difference required to lift a column of water one inch up a tube. (This is a pressure difference of 0.036 PSI)

Draft is checked at two places: over-the-fire (at the top of the combustion area) and in the flue pipe, as close to the breech as possible.

Before any measurements or adjustments are made, the condition of the draft regulator should be checked. The pivot shaft should be horizontal, not cocked and the door should swing freely. Draft should be measured when the appliance has been operating for several minutes and the chimney has warmed up.

Draft over-the-fire

Draft over-the-fire is the most important draft measurement. The over-the-fire draft must be constant so combustion air delivery will also be constant. The setting must be high enough to ensure that combustion products are drawn through the heat exchanger and do not leak into the building. Normally, an over-the-fire draft of -.01" to -.02" will be sufficient for most appliances.

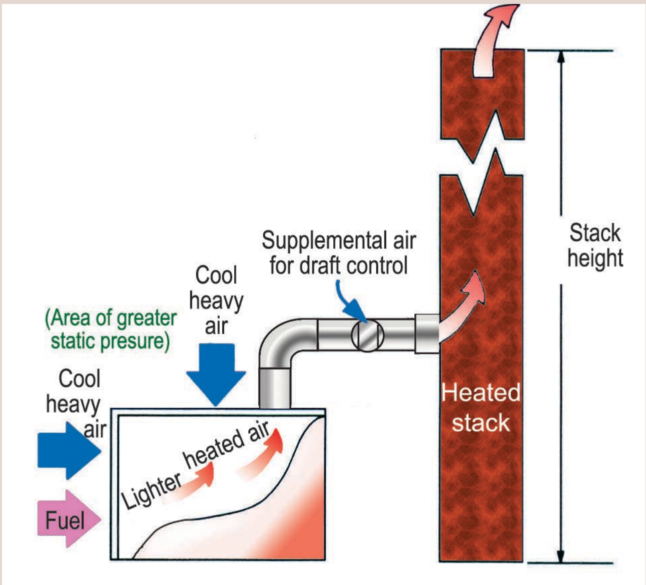
If the over-the-fire draft is higher than manufacturers recommendations (typically -.02"), the draft regulator weight should be adjusted to allow the door to open more. If the draft is below manufacturer's recommendations, the weight should be adjusted to close the regulator door.

Draft at the breech

The draft in the flue pipe will be slightly higher than the over-fire draft due to the restriction caused by the heat exchanger. This restriction, or the lack of it, is a clue to the design and condition of the heat exchanger. The difference between the breech draft and the over-the fire draft is called the 'draft drop' or 'draft loss" across the heat exchanger. If the breech draft is -.07" and the over-the-fire draft is -.02", the draft drop is .05". Manufacturer's typically

How draft controls work

Static pressure of the cool air exerts pressure on the outside of the furnace or boiler, the breeching, and flue. The pressure difference between the room air and heated gas (air) causes products of combustion to flow (draft) through the unit and rise through the breeching and chimney. Room temperature air enters through the barometric draft control in the precise amount needed to overcome the excess drafts caused by temperature variations, wind fluctuations and barometric pressure changes. Combustion of fuel is complete and the process is stabilized. The velocity of combustion gases through the heat exchanger is slowed so more heat is extracted.



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include recommendations regarding over the fire draft and draft drop.

Excessive draft drop may indicate heavy soot and scale deposits in the unit. It is important to understand that over-the-fire draft is indirectly controlled. It is a function, not only of the draft created by the chimney, but also of restrictions in the heat exchanger.

A burner operating at above zero smoke will result in soot deposits that restrict the flow of combustion gases through the heat exchanger. These deposits cause a larger draft drop which lowers over-the-fire draft, reduces combustion air and creates more smoke. The result is a quickly plugged heat exchanger.

Chimney sizing

Proper chimney sizing is important for the safe and efficient operation of all heating appliances. The requirements can vary depending upon the size and design of the appliance, the manufacturer's instructions must be followed.

Flue pipe

The condition of the flue pipe should be checked during each service call. If it looks questionable, replace it. The stack temperatures on new high efficiency units are much lower and are more likely to cause condensation and rusting of the flue pipe. This is extremely important because combustion gases can enter the building if the flue pipe is porous or disconnected.

The flue pipe must be at least 18 inches from a combustible wall or ceiling as a fire prevention measure. It should be as short as possible. It should have a minimum of ¼" per foot pitch from the appliance up to the chimney and be run with a minimum number of elbows. Use 45° elbows instead of 90°s, when possible.

The flue pipe should be firmly secured with a minimum of three sheet metal screws per joint and supported with straps or wire. It should be tightly fitted to the breeching and installed into a clay or metal

Draft Regulator Sizing

Diameter of Flue or Breeching	If Chimney Height Is	Use this Size Control	If Chimney Height Is	Use this Size Control	If Chimney Height Is	Use this Size Control
4 in.	15 ft. or less	4 in.	16 ft. or more	5 in.		
5 in.	15 ft. or less	5 in.	16 ft. or more	6 in.		
6 in.	15 ft. or less	6 in.	16 ft. or more	7 in.		
7 in.	15 ft. or less	7 in.	16 ft. or more	8 in.		
8 in.	15 ft. or less	8 in.	16 ft. or more	9 in.		
9 in.	15 ft. or less	9 in.	16-30 ft.	10 in.	31 ft. or more	12 in.
10 in.	20 ft. or less	10 in.	21-40 ft.	12 in.	41 ft. or more	14 in.
11 in.	20 ft. or less	12 in.	21-40 ft.	12 in.	41 ft. or more	14 in.
12 in.	20 ft. or less	12 in.	21-40 ft.	14 in.	41 ft. or more	16 in.

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13:07

thimble that is securely cemented into the chimney. Be sure the thimble and pipe do not protrude beyond the inside wall of the chimney tile.

Chimney & draft problems

Insufficient draft can occur with too many appliances connected to a chimney. Whenever connecting two or more fuel burning appliances to a single chimney, verify that there is sufficient draft for safe operation of all units. Insufficient draft also occurs when obstructions such as soot, loose bricks, animal nests or other foreign objects build up in the chimney and restrict flow. See Figure 6-7 (opposite page) for common chimney troubles and their corrections.

Lack of air in the combustion zone

Modern tightly constructed buildings and older buildings that have been updated with insulation, air sealing, efficient windows etc., can reduce the amount of outside air entering the building. As a result, the building may not be able to provide enough air to support proper combustion even if the combustion zone meets the definition of an unconfined space, (see Chapter 7). Burner combustion requires at least 1,500 cubic feet of air per gallon of fuel to operate properly. In most cases this air is supplied through normal infiltration. However, fireplaces, exhaust fans and clothes dryers also remove air from the building. If the house is energy efficient (aka tight) and has few air leaks, the burner may not have adequate combustion air when these other devices are in use.

In that case, the other appliances may create a negative pressure within the home, essentially getting the air they need by pulling it down through the burner's chimney. In that case, odors, soot, smoke and carbon monoxide will be drawn into the building.

'Isolated combustion' (ducting outside air directly to the burner) is the best solution to this problem and there are many effective isolated combustion air options available. See Figure 6-8.

Multiple appliance chimney connections

In some situations, two appliances are connected to the same chimney. This can be done in two ways:

1. The two flue pipes can be joined together with a Y connector, as shown in Figure 6-9, following page. ('T' connectors should NOT be used as they often cause venting problems for both appliances.) The exit, or chimney side of the Y should be at least one size larger than the largest flue pipe.
2. A second opening can be made into the chimney.

If two or more openings are provided into one chimney flue, they must be at

Figure 6-8: Typical installation of an outside air kit

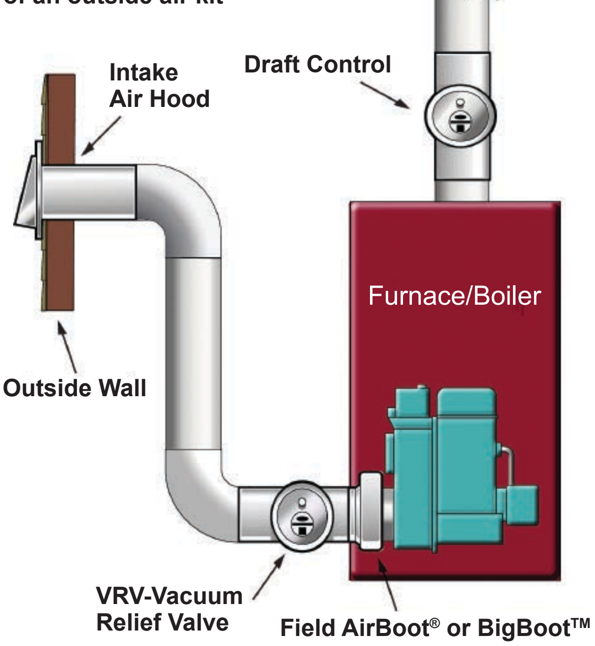

Figure 6-7: Combustion chimney troubles

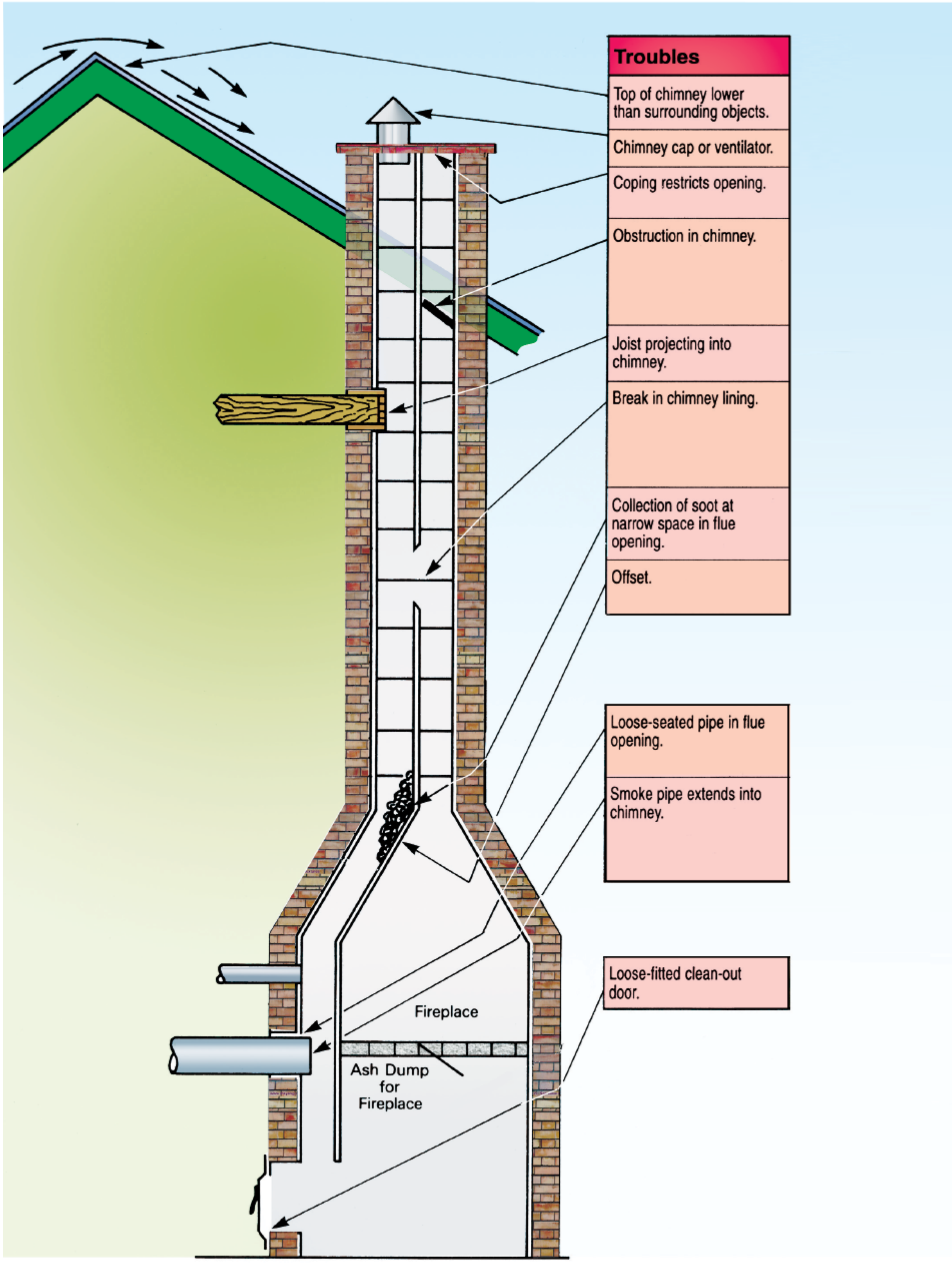

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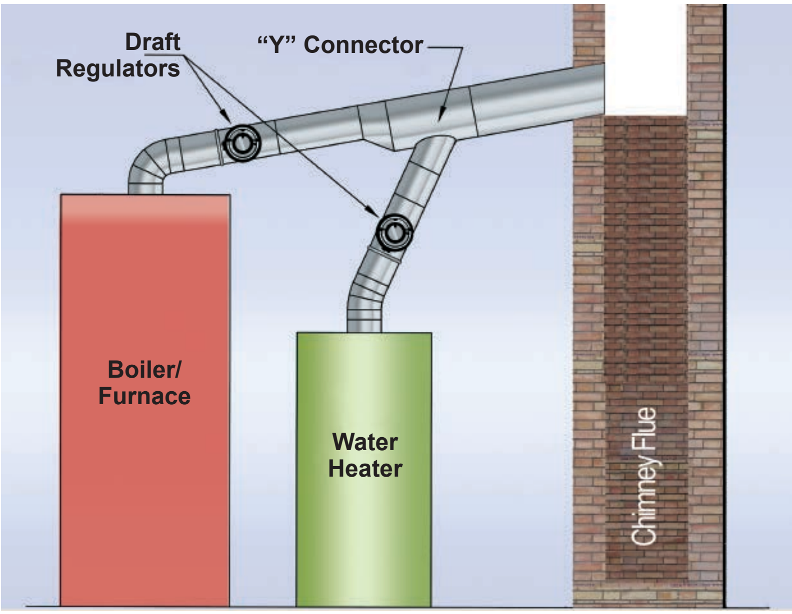
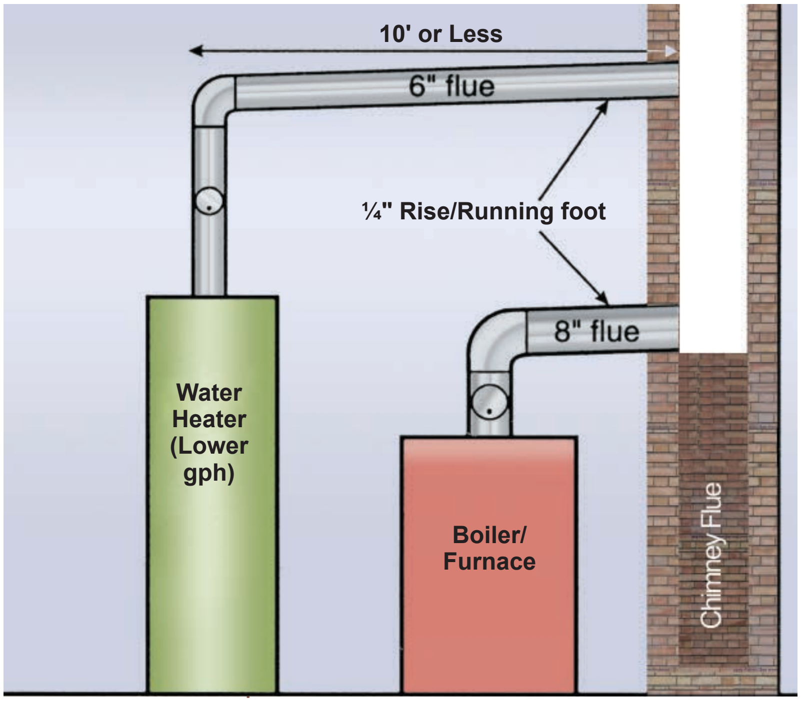
Figure 6-9: Water heater stack connections



Each section sized to handle combination of all appliances attached

Figure 6-10: Water heater stack connections



The larger appliance firing rate enters the chimney below the smaller appliance firing rate

different levels. The flue pipe from the unit with the lower firing rate should enter at the highest level consistent with available headroom and clearances to combustible material, see Figure 6-10. A separate draft regulator should be installed for each appliance.

The effects of high efficiency appliances on chimneys and exhaust

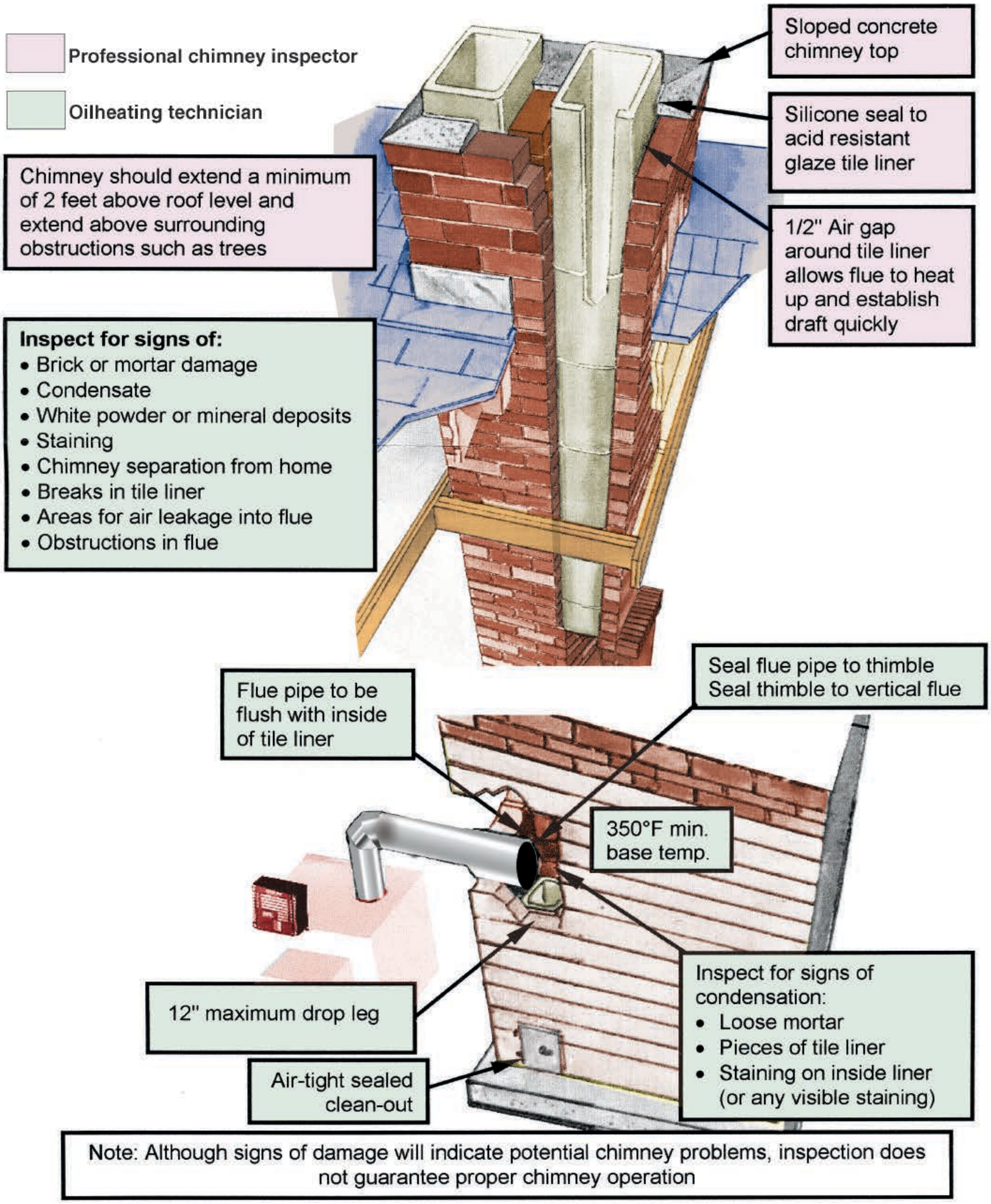
High efficiency equipment has brought about changes that can affect chimney draft. Some of these developments, such as lower flue gas temperatures, reduced firing rates and cold start boilers, will reduce the draft produced by chimneys and can cause operational problems.

The most serious consequence of lowered flue gas temperatures is condensation in the chimney. The water vapor in the combustion products can drop below the dew point and condense into water. This water is acidic and will create scale in the heat exchanger, corrode the flue pipe and degrade the cement in the chimney. If flue gas is condensing in the chimney, a corrosion resistant chimney liner is recommended.

Chimney check

The objective of a chimney check is to identify obvious and serious chimney problems. It is not intended to be a detailed inspection. If any chimney damage or deterioration that would inhibit the safe operation of the heating appliance is found, the owner of the building should be notified immediately so a qualified chimney professional can be called in for a follow-up inspection, Figure 6-11.

Figure 6-11: Chimney check



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The chimney check should include the following:

- If there is one, visually inspect the clean-out at the base of the chimney for excessive or abnormal debris. Be sure the clean-out door is shut tight and sealed before leaving the job site.
- Remove the flue pipe from the chimney breech and inspect the inside of the chimney with a light and a flame mirror for signs of damage or deterioration. Debris, mortar, brick and pieces of liner material at the base of the chimney are signs of trouble.
- Go outside and observe the exterior of the chimney. If damage or deterioration is observed, or if the chimney is leaning, further inspection by a chimney professional is required.

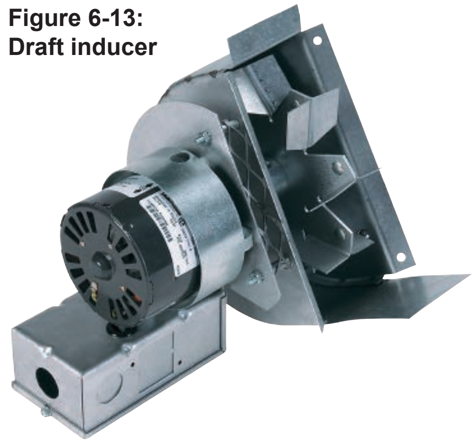
Chimney caps & draft inducers

Chimneys may suffer variable draft due to changes in wind or air turbulence. A simple and inexpensive solution is to install a cap, Figure 6-12, or hood over the top of the chimney. However, these caps can rust and discolor roofs, so ensure that a high-grade stainless steel is used.

Figure 6-12: Chimney cap

An alternative is to use a draft inducer, Figure 6-13. Draft inducers are electrically powered fans installed in the flue pipe. They help to pull the air from the unit and push it up the chimney. They can also be used to boost the draft if the natural chimney draft is too weak.

Figure 6-13: Draft inducer



Alternative venting systems

Alternative venting systems are available that do not use a chimney. The technology takes two different approaches: power-venting and direct-venting. They work as follows:

Power-venting: A fan is attached to the flue pipe at the exit terminal from the building to pull the products of combustion out of the heating unit. Power-venters do not need a chimney and are usually side-wall vented.

Direct-venting: The static pressure created by the burner fan pushes the combustion gases through the heat exchanger and out of the building. A direct-vented system is a positive pressure system and no chimney is needed.

The advantages of alternative venting systems are:

- More positive control of draft
- No chimney warm-up problems
- Lowered cost in new building construction and electric to fuel conversions (eliminates the chimney)
- A significant reduction in burner noise with direct-venting

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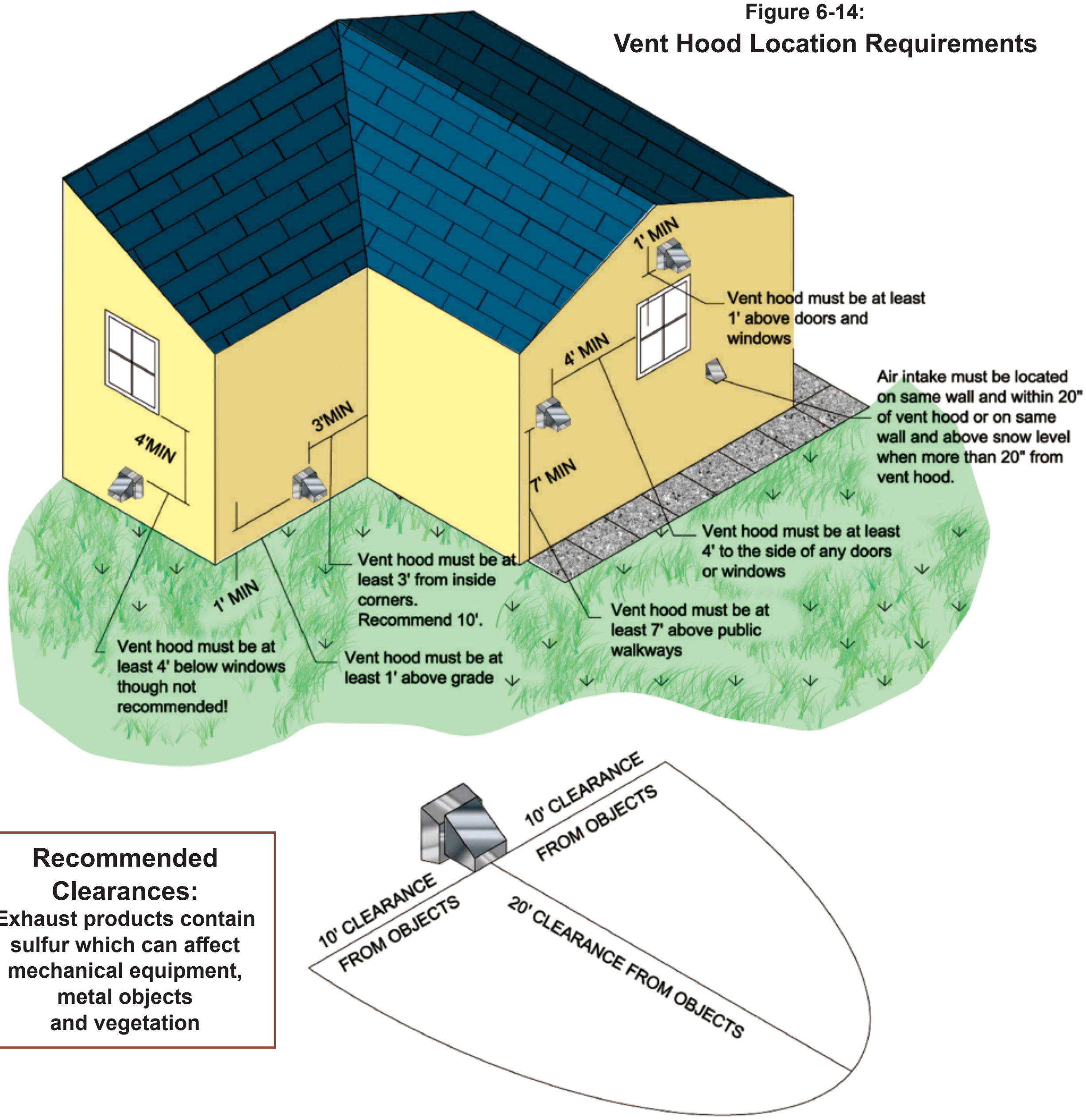
- Back drafts caused by a nearby structure that is above the top of the chimney are eliminated
- System standby losses are reduced because there is no off-cycle chimney draft

When installing or servicing alternative venting systems, it is very important to read and understand the manufacturer's instructions. A copy of the instructions should be left in an obvious place at the jobsite for future use.

As with all heating equipment, the installation and use of any alternative venting system must not only follow the manufacturer's instructions, but also comply with all local and state building codes. Most of the instructions and codes conform to the following guidelines for the location of the exit terminal of the system. See Figure 6-14.

Figure 6-14:
Vent Hood Location Requirements



Recommended Clearances:
Exhaust products contain sulfur which can affect mechanical equipment, metal objects and vegetation

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The following guidelines are often required by code and/or manufacturer instructions:

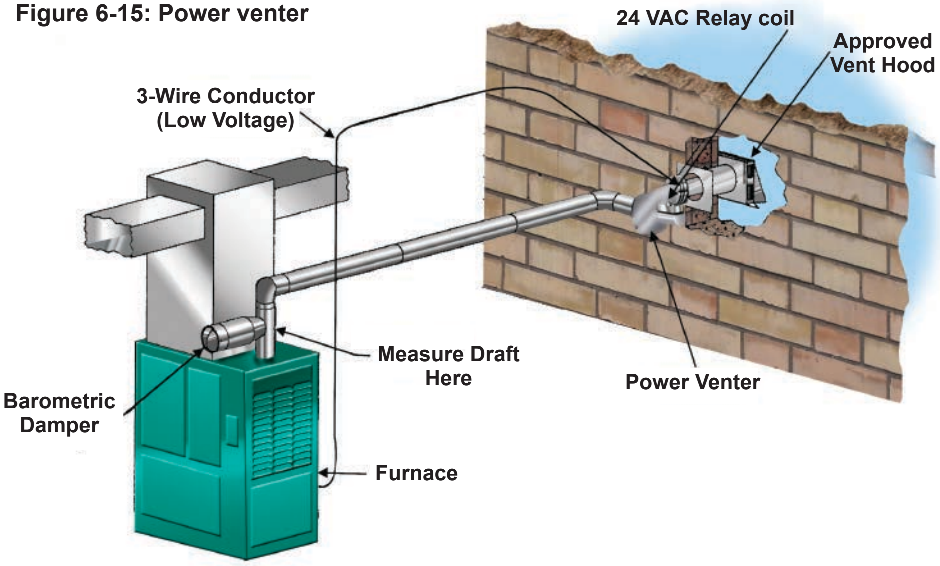
- The vent terminal must be at least one-foot above grade level, and three feet away from any inside corner. It may need to be higher in areas with snowfall.
- The vent terminal must not be less than three feet above any forced air inlet into the building that is located within 10 feet of the terminal .
- The vent terminal must not be less than four feet below, four feet horizontally, or one foot above any door, window, or gravity inlet into any building.
- The vent terminal must not be installed in a window well.
- The vent terminal must not be less than seven feet above grade when located adjacent to public walkways.
- The vent terminal must be located so that flue gases are not directed to jeopardize people, overheat combustible structures or materials, or enter buildings.
- All positive pressure joints in the vent system (all joints in direct-vent, all joints on the exhaust side of the power-venter) must be sealed with Permatex #81164 high temperature sealer or equivalent to prevent leakage of the products of combustion into the building. This includes both the joints between pieces of pipe and the slip joints on elbows.
- The minimum distance to combustible materials from any single wall vent system component is 18 inches.
- The vent termination must not be mounted directly above or within three feet horizontally from a gas meter, electric meter or air conditioning condenser.

Power-venting

Power-venting is an economical alternative to conventional chimney venting. Power-venters use a motor and fan to vent the products of combustion from the appliance to the outdoors.

Power-venters are designed with the

Figure 6-15: Power venter



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fan located either outdoors, or indoors just before the outside wall, as in Figure 6-15. This ensures that combustion gases in the flue pipe are always under negative pressure, so if there are any leaks, air will leak into the pipe and the combustion gases will not spill into the building.

The flue gases are discharged through a double wall vent termination piece and an outside vent hood, Figure 6-16. They should be fastened securely to the outside wall or hung from the floor joists to reduce noise.

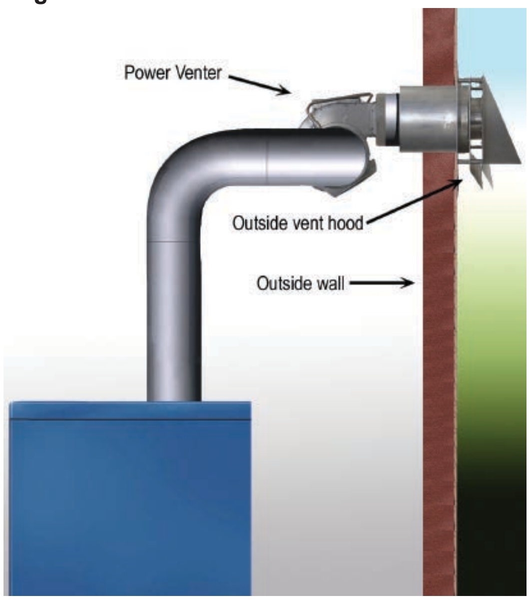
Some power-vented systems use a double wall exhaust connection that draws cooler outside air into the outer pipe and the hot exhaust gases are contained in the inner pipe (concentric venting). This provides a layer of safety between the hot exhaust gases and the combustible wall and floor joist materials and pre-heats the combustion air.

System operation: Power-venting requires that the burner primary control has delayed valve-on and burner motor-off delay feature, commonly referred to as pre-purge and post-purge. When there is a call for heat, the power-venter motor starts. After the motor has come up to speed the pressure switch closes (in one to two seconds) and closes the circuit to the burner primary control, allowing the burner to operate. After the heating requirement is satisfied, the burner motor off delay (post-purge) cycle begins. During this cycle, the oil valve closes shutting off the flame but the power-venter and the burner motor continue to run for a period of time venting the last of the combustion products and cooling the burner components.

Inspection and maintenance: The power-venter should be inspected once a year:

- Check to be sure the motor and fan rotate freely.
- Lubricate the motor as directed by the manufacturer.
- Inspect the power-venter wheel to clear out any soot, ash or coating that inhibits either rotation or air flow.
- Remove and clean the air sensing tube.
- Remove all foreign materials before operating. Inspect all vent connections for evidence of corrosion and flue gas leakage.
- Replace, seal or tighten all the pipe connections as necessary.
- Check the choke plate to insure it is secured in place.
- Check the barometric draft control to insure the gate swings freely.
- Check the safety system devices—start the heating system, and then disconnect the pressure sensing tube from the pressure switch. This should stop the burner. Reconnecting the tube should restart the burner.

Figure 6-16: Outside vent hood



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For proper system installation, set-up and testing, follow the manufacturer's instructions exactly. It is a good practice when installing a power-venter to also install a fresh air kit to bring combustion air to the burner from outdoors. Many power-venters integrate a fresh combustion air intake into their system. Fresh air should be brought in from the same wall as the power-venter exhaust to equalize air pressure within the vent and intake system.

Direct venting

Direct-vent systems use the power of the burner fan to push the products of combustion out of the building. Direct-vent provides sidewall venting without the use of a power-venter, extra motors, fans or wiring. Direct-vent systems utilize outside air for combustion. Figure 6-17 shows an example of a direct vent system.

Unlike chimney venting and power-venting, with direct-vent the air pressure inside the boiler or furnace and flue pipe is greater than the pressure in the building. If there is a leak in the heat exchanger or the flue pipe, products of combustion will leak into the building.

It is important to understand that direct-vent systems are sold as a complete package, including the appliance as well as the venting system. Mixing and matching or do-it-yourself engineering may void the manufacturer's warranty and may create a hazardous condition.

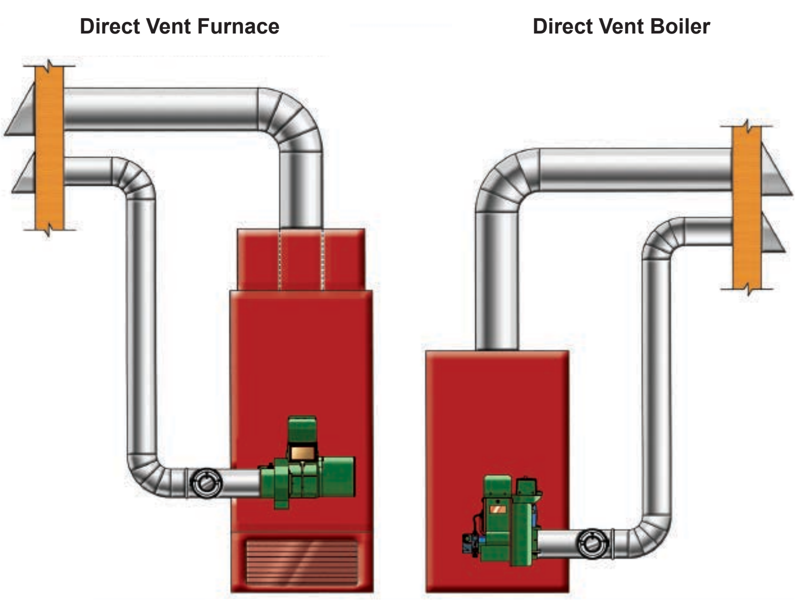
Drawbacks to a direct-vent system are:

- Surface discoloration of the building may occur due to improper burner and control adjustment.
- The residential units can only push the exhaust gases and pull combustion air from about 20 feet maximum. This means that you must locate the boiler, furnace, or water heater as close to an outside wall as possible.

Things to consider when installing direct-vent systems are:

- Seal all joints on the venting system with a high temperature sealant.
- Combustion efficiency tests should be taken at the port provided on the unit by the manufacturer. Do not puncture the stainless-steel vent tubing. Adjust the burner combustion with a 'window of tolerance'. Set the air to produce a trace of smoke. Take the CO_2 reading at a trace of smoke and reduce the CO_2 by 1.5% to 2%. For instance, if the CO_2 reading with a trace is 13%, reduce it to 11% to 11.5% CO_2. This will compensate for variations in fuel and outdoor temperatures, and other variables over the year. See Chapter 7 on combustion for more details.

Figure 6-17: Direct side-wall venting and outside combustion air



Audio
28:32

Advanced venting technology

As appliance manufacturers strive to increase efficiency, new developments continue to appear.

Research has shown that some of the major challenges to reaching higher efficiencies have been the venting of low temperature flue gases, the effects of condensate from condensing appliances and the effects of draft regulators on standby losses.

Dilution venting offers a solution to all three of these challenges, see Figure 6-18.

Adding dilution air (from outside the building) to flue gases as they leave the appliance lowers their temperature enough to allow the use of polypropylene venting materials, eliminate the draft regulator, and greatly reduce condensation in the venting system.

In addition, dilution venting enables manufacturers to develop new higher efficiency appliances that have such low flue gas temperatures that they can not operate with standard venting systems.

For more information about dilution venting see: *www.energykinetics.com*

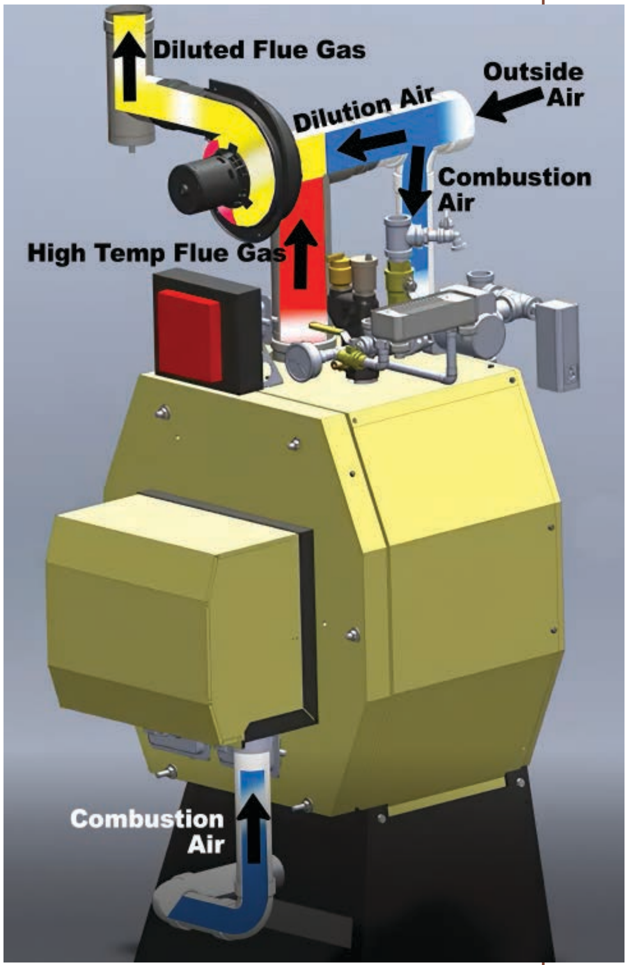


Figure 6-18: Dilution venting

Chapter 6: Additional Resources

NORA has compiled a library of additional technical resources for your continued education. Scan the QR code or go to the web address. Check back often, as NORA will continually add content as it becomes available.

You will find:
- Videos
- Technical Bulletins
- Instructions
- and More

https://Learning.NORAweb.org/draft_venting