Venting

Mechanical Systems - Multifamily

Key Terminology

Atmospheric combustion

Atmospheric pressure

Backdrafting

Barometric damper

British Thermal Unit (BTU)

Category I appliance

Category II appliance

Category III appliance

Category IV appliance

Combustion Appliance Zone (CAZ)

Condensation

Dew point

Direct vent appliance

Double-wall vents

Draft diverter

Fan-assisted combustion

Flame rollout

Forced draft

Induced draft

International Mechanical Code (IMC)

Latent heat

Mechanical draft

National Fire Protection Association (NFPA)

National Fuel Gas Code

Natural draft

Net free area

NFPA 31, Standard for the Installation of Oil-Burning Equipment

NFPA 54, National Fuel Gas Code

NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

Non-direct-vent appliance

Oxygen (O_2)

Power burner combustion

Sealed combustion

Second law of thermodynamics

Sensible heat

Single-wall vents

Spillage

Type B vents

Type L vents

Vent connector

Venting

Venting system

Section Transition

Learning Objectives (Slide #2)

By attending this session, participants will:

- Understand the functions of a ***venting*** system and the factors that affect its operation.
- Be able to recognize different types of venting systems, including those for Category I, II, III, and IV appliances.
- Learn the different types of combustion and draft, and the pros and cons of each one.

Venting (Slide #3)

- After combustion occurs, it is necessary to remove the byproducts from the building. Proper ***venting*** is essential for safe and efficient operation of combustion appliances.
- The term "venting" includes appliance flues, chimneys, and every connection in between. It encompasses the entire pathway for removing combustion byproducts from the building.
- A number of codes and standards provide guidance on proper venting:
    - ***National Fire Protection Association (NFPA) 31*** is the ***Standard for the Installation of Oil-Burning Equipment***.
    - ***NFPA 54*** is also known as the ***National Fuel Gas Code***.
    - ***NFPA 211*** is the ***Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances***.
    - Another good source for venting information is the ***International Mechanical Code (IMC)***.
    - Check any relevant state or local codes that may apply.

Venting for Gas Appliances (Slide #4)

- Gas-fired combustion appliances can be divided into four categories based on whether there is negative or positive pressure in the venting and whether ***condensation*** occurs in the venting by design. These four categories are designated in the table by Roman numerals.
- ***Category I*** and ***Category II appliances*** operate with negative pressure in the venting. In these appliances, ***natural draft*** or ***induced draft*** removes the combustion products from the building.
- ***Category III*** and ***Category IV appliances*** operate with positive static pressure in the venting. They rely on ***forced draft*** to remove their combustion products from the building.
- Tall chimneys are necessary for natural draft to be effective in Category I and Category II appliances.
- Appliances in Category III and Category IV can exhaust their products horizontally since they use a fan to create draft.
- One byproduct of combustion is water vapor. If the exhaust temperature gets low enough, the vapor will condense into water.
    - Category I and Category III appliances (in the top row) have exhaust temperatures high enough to avoid condensation. These appliances typically have combustion efficiencies of 83% or less.

- Category II and Category IV appliances have exhaust temperatures low enough for condensation to occur, which increases their efficiency. These condensing appliances have combustion efficiencies over 83%.

*Q: Why do more efficient appliances have condensation in the **venting system**?*

*A: Because more energy is extracted from the air, bringing it to a lower temperature, which makes it more likely that **dew point** will be reached and water will condense out of the air.*

What is condensing? (Slide #5)

What is condensing and why are condensing appliances more efficient than non-condensing ones?

To understand that, you need to understand the difference between ***sensible heat*** and ***latent heat***.

Sensible vs. Latent Heat (Slide #6)

This graph shows what happens to water as heat is added or released.

- Sensible heat can be measured by a thermometer or felt by a change in temperature. Add 1 ***British thermal unit (BTU)*** to a pound of water and, by definition, its temperature will increase by 1°F. Add 150 BTUs to a pound of 50°F water and its temperature will increase to 200°F (a 150° increase).
- This sensible relationship ends at 212°F when water hits its boiling point. At this point, liquid water goes through a phase change and becomes a gas, water vapor, or steam. As more heat is added, the pound of water remains at 212°F until it absorbs 970 BTUs to complete its evaporation into steam—six times the heat it absorbed going from 50°F to 212°F.
- The heat that is absorbed or released when a material changes phase between a solid and a liquid or between a liquid and a gas is called latent heat.
- If enough heat is extracted from the exhaust gases, the water vapor in them will actually go through a phase change and condense into liquid water. This condensation releases water's latent heat, those 970 BTUs per pound. This extra energy from water's phase change can give a big boost to combustion efficiency.

Venting Safely (Slide #7)

It's important to know how each combustion appliance must be vented and what category it falls into.

- You cannot combine different venting categories in the same chimney.
- Appliances with positive pressure in the vent cannot mix with appliances with negative pressure in the vent.
  - The reason is safety. If they were to be combined, combustion products could be pushed from the positive pressure toward the other appliance instead of out the building. This could cause ***backdrafting*** and ***spillage***.

- Since natural draft appliances work with negative pressure in the vents, they may be able to share a common chimney, but only if they are installed per NFPA 54 guidelines. When multiple appliances are involved, the chimney must be sized to work properly with all combinations of operating appliances.
- Mechanically vented appliances can only share a common chimney when installed per manufacturer instructions.
- The length and pitch of the venting must be per manufacturer instructions. Some appliances have a maximum venting length over which they will not function properly. It is important to read the instructions to ensure appliances are installed and operating correctly.

Definitions (Slide #8)

Before we dive into discussions on the various types of draft and combustion in appliances, let's get the definitions straight. The following definitions are based on language in NFPA 54.

Natural draft – A venting system that relies on hot, buoyant air to move combustion gases to the outdoors. Appliances with natural draft are usually Category I with ***atmospheric combustion***, ***fan-assisted combustion***, or ***power burner combustion***. They may be direct vent or vented through the wall.

***Mechanical draft*:**

> **Forced draft –** A venting system in which a fan installed at the combustion appliance moves combustion gases to the outdoors with positive static pressure in the vent pipe. Because of this positive pressure, the ***vent connector*** must be airtight. Systems with forced draft are usually found in Category III and IV appliances; they do not usually have ***draft diverters*** or ***barometric dampers***. They generally have fans for venting combustion gases at or near the appliance, and usually vent through the wall. They may be condensing units.
>
> **Induced draft** – A venting system for which a fan—installed at or very near the termination point of the vent pipe—moves the combustion gases to the outdoors with negative static pressure in the vent pipe. Appliances with induced draft are usually Category I, have fans for venting combustion gases at the point of exit to the outdoors, and vent through the wall.

Direct vent appliance* –** A combustion appliance for which all combustion gases are vented to the outdoors through an exhaust pipe. Combustion supply air is vented to the combustion chamber from the outdoors through a separate, dedicated supply-air vent. Most direct vent gas appliances are Categories III and IV, but some are Category I. Some direct vent appliances use a concentrically constructed direct vent. This is sometimes referred to as ***sealed combustion.

Atmospheric combustion – Combustion that takes place under ***atmospheric pressure***.

Note that many terms used in the field have different meanings. For example, most people think atmospheric combustion is somewhat synonymous with natural draft. In fact, according to NFPA 54, atmospheric combustion means only that there is no fan bringing combustion air to the combustion chamber. It is possible to have a fan-assisted, natural draft appliance.

> *Refer to Combustion Basics Definitions for further definitions; all are based on language in the relevant codes.*

Natural Draft (Slide #9)

- In natural draft appliances, exhaust gases are removed from the building by the pressure difference between the hot combustion air and the cool outdoors. The ***second law of thermodynamics*** tells us that hot moves to cold and pressure moves from high to low, so the hot gases naturally rise through the chimney to the outdoors where the temperature and pressure are lower.
- This system requires a tall chimney to create natural draft.
- This picture shows seven atmospheric, naturally drafting boilers tied together.
- These boilers are all too common despite their problems.

Natural Draft Problems (Slide #10)

- Natural draft is inherently inefficient.
  - The combustion appliance is open to the outside, so conditioned air can leave the building through this venting any time, whether or not the appliance is firing.
- There is no way to control the amount of draft.
  - Draft can increase on cold winter days and pull too much conditioned air out of the building, which wastes energy.
  - In the hot summer months, there may not be enough draft to remove the combustion products from the building effectively.
  - This makes natural draft very susceptible to backdrafting and spillage.

Natural Draft and Outdoor Temperature (Slide #11)

- Natural draft relies in part on the temperature difference between the combustion chamber and the outside.
  - As the outdoor temperature drops, this temperature difference, along with draft strength, increases.
  - As the outdoor temperature rises, the temperature difference, along with draft strength, decreases.

Chimney Height (Slide #12)

Chimney height also affects natural draft strength. All other factors being equal, there will be a greater chimney effect and a stronger draft in a taller chimney than in a shorter one.

Exterior Chimneys (Slide #13)

- Exterior chimneys are more prone to failure than interior chimneys because they are exposed to the elements and experience greater thermal stress.
- In the winter, the hot exhaust gases can lose enough heat to the cold outdoors that they condense and rot out the chimney.
- The exterior chimney shown here has already started to corrode at its seams.

So why do people use natural draft equipment? (Slide #14)

- It's cheap…at first.

The first costs for naturally draft equipment are low, but those savings quickly disappear once operating costs kick in. The low efficiency and lack of draft control make these appliances expensive in the long run.

Combustion Air (Slide #15)

- In addition to the removal of combustion byproducts, combustion appliances require an ample supply of combustion air to operate safely and effectively. Fresh air provides the ***oxygen (O_2)*** that is essential to the chemical reaction.
- There are two ways this air can get into the combustion chamber:
    - From the ambient air – Many older appliances take their combustion air from within the building from the area known as the ***combustion appliance zone (CAZ)***. These are often referred to as atmospheric combustion appliances, but based strictly on NFPA language, this is not entirely accurate. They may also be referred to as ***non-direct-vent appliances***, but that is a little wordy. In this training, we will refer to appliances that take their combustion air from the CAZ as non-direct-vent appliances. Think of these appliances as suckers; they suck on the room they are in as the combustion process uses up the air, creating a negative pressure with reference to the outside.
    - Directly from outside – Direct vent appliances, sometimes called sealed combustion appliances, take their combustion air from outdoors and vent combustion byproducts directly outdoors.

Non-direct-vent Appliances (Slide #16)

- In non-direct-vent appliances, the combustion chamber is open to the room, just like an open campfire.
- There is no way to prevent conditioned building air from entering the combustion chamber and leaving through the chimney. The open combustion chamber is also susceptible to ***flame rollout***.
- The picture on the left shows three boilers connected together that take their combustion air from the room.
- The picture on the right shows a close-up of one of the burners. You can see that the combustion chamber is completely open to the room.
- Air is drawn into the combustion chamber of these appliances by the heat of the combustion process.

Fan-assisted Combustion (Slide #17)

- In fan-assisted combustion, a fan draws the needed supply air into the combustion chamber. Burners with integrated fans are also known as power burners.
- A power burner is a burner for which air is supplied at a pressure greater than atmospheric pressure. Most oil-fired burners are power burners. Gas burners used to replace oil burners are usually power burners.
    - Power burners can be more efficient than typical burners because power burners only draw air into the combustion chamber and the appliance room when they are firing.

Non-direct-vent Appliance Problems (Slide #18)

Non-direct-vent appliances have many problems.

- Air is consumed in the combustion process, and that air must come from outside.
    - To provide enough makeup air, there must be an opening between the CAZ and the outside. This is usually a fixed louver. This permanent opening to the outside lets cold air into the building 24 hours a day, 7 days a week, regardless of whether the appliance is firing.
    - This cold air increases the amount of infiltration into the building and forces the heating system to work harder.
- The size of the louver is based on code requirements for ***net free area***.
    - These requirements are usually specified on a per-BTU basis.
    - They can be found in either NFPA 54 or local codes.
- It may be possible to replace an open louver with a motorized damper that is tied to the combustion equipment so that the damper opens only when the burner is firing and stays closed during off cycles. The damper must fail in the open position for safety, so that in the case of damper malfunction, the combustion equipment will still have ample combustion air.
    - Check the local codes to see if this is an option to increase energy efficiency.

So why do people use non-direct-vent appliances? (Slide #19)

- It’s cheap… at first.

Non-direct-vent appliances are inexpensive to purchase, but their low efficiency and increased infiltration make them very expensive to operate.

Mechanical Draft (Slide #20)

- An alternative to natural draft is mechanical draft: this includes forced draft and induced draft appliances.
- In forced draft appliances, the fan is installed at the combustion appliance, so combustion byproducts are blown through the venting, creating a positive pressure. These vent connections must be airtight.

- In induced draft appliances, the fan is installed very near the outdoor termination point of the venting, and creates negative static pressure in the venting as it sucks combustion byproducts out of the building.
- Since mechanically drafted appliances do not require a tall chimney to create draft, they can vent horizontally through a wall. This can be a big cost savings in many applications.
- The two boilers shown here are forced draft boilers. The fans are built into the boilers.

Mechanical Draft Benefits (Slide #21)

Mechanically drafted combustion appliances have a few benefits over naturally drafted ones.

- Mechanical draft is more efficient than natural draft because heat loss is reduced when the appliance is not firing.
- Mechanical draft appliances have some control over the amount of draft, which is usually constant when the vent fan is running. They are not affected by changing outdoor weather conditions.
- They ensure consistent removal of combustion byproducts at all times.

Direct Vent (Slide #22)

Q: What's the alternative to a non-direct-vent appliance?

A: A direct vent appliance. Direct vent appliances are also referred to as sealed combustion appliances.

In a direct vent appliance, the combustion chamber is sealed off from the room. The required combustion air is provided directly to the appliance from the outside.

Benefits of Direct Venting (Slide #23)

- Since the combustion chamber is sealed, there is less chance of combustion products entering the room or causing flame rollout.
- A sealed combustion appliance is more efficient than a non-direct-vent appliance.
  - The standby losses when the appliance is not firing are reduced.
  - Cold air is not pulled into the room, where it can displace conditioned air. Instead, it is provided directly to the combustion appliance.
  - You have more control over the fuel/air mixture in a sealed combustion appliance. Adjusting this ratio can help improve the appliance's combustion efficiency.

Venting Materials (Slide #24)

A few materials, including galvanized steel, stainless steel, and PVC, are commonly used for venting combustion equipment. These materials are typically marked to indicate which appliance categories they can be used with.

Galvanized steel:

- Galvanized steel is typically used for venting Category I appliances.
- It should not be used on condensing equipment since condensate is corrosive and will rot through venting components.

Stainless steel:

- Stainless steel is a more durable venting material that can be used in condensing equipment.
- Stainless steel can also be used in non-condensing equipment, but it costs a lot more than galvanized steel and typically isn't installed when less expensive materials will suffice.

PVC or CPVC:

- PVC or CPVC are other venting options for condensing combustion appliances.
- These plastic pipes can resist condensation, but are not permitted in all areas. Check the local codes to see if this type of venting is acceptable.

Venting Types (Slide #25)

- ***Single-wall vents*** consist of a single wall of metal. Single-wall vents are typically used for natural draft appliances, which vent under negative pressure.
- ***Double-wall vents*** are becoming the standard. They are usually required for forced draft appliances, which use a fan to blow combustion products out of a building under positive pressure. ***Type B vents*** and ***Type L vents*** are common double-wall vent types:
    - Type B vents have an aluminum inner wall and a galvanized steel outer wall. They can be used only for gas appliances.
    - Type L vents have a stainless steel inner wall and either a galvanized steel or black steel outer wall. They are typically used for oil-fired appliances but can also be used with gas.
- The air space between the double walls acts as an insulator and helps keep the flue gas temperature high enough to avoid unwanted condensation. The air space also helps keep the surface temperature of the venting lower so that it gives off less heat to the appliance room and can be installed closer to combustible materials.
- A subset of double-wall venting uses both the inner and outer spaces for gas movement.
    - In these types of vents, which are more common on smaller appliances, the exhaust gases leave the building through the inner pipe and exit at the top of the chimney.
    - The intake air needed for combustion is drawn in from the slots under the chimney cap and travels through the area between the inner and outer walls.
    - This is common in mobile home furnaces.

Summary (Slide #26)

- The purpose of venting is to safely remove combustion byproducts from the home. The term “venting” includes appliance flues, chimneys, and every connection in between. It encompasses the entire pathway for removing combustion products from the building.
- Appliance categories refer to the pressure in the flue right above an appliance. These categories indicate whether the appliance is condensing or non-condensing. Categories II and IV are condensing appliances, which typically have a combustion efficiency over 83%.
- Categories I and II have negative flue pressure, while III and IV have positive flue pressure. Leaks in the connections in Category III and Category IV appliances could let harmful combustion byproducts into the living space.
- Vent types are generally labeled to indicate which categories they can be safely used with.
- Non-direct-vent appliances take their combustion air from the surroundings, either from attached living space or through a louver in an exterior wall.
- Direct vent appliances have designated combustion air intake directly from the outside. They are generally more efficient than non-direct-vent appliances.
- Natural draft relies on the natural buoyancy of the heated air and lower outdoor pressure to safely evacuate combustion byproducts. Natural draft appliances require a tall chimney to ensure a consistent draft.
- Mechanical draft relies on a fan to either push or pull combustion byproducts safely out of the home. Appliances with mechanical draft can have horizontal chimneys, since they don’t rely on natural buoyancy.