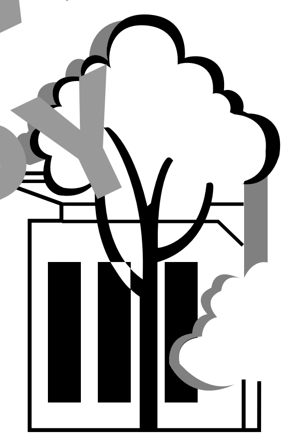
Heating System Equipment

Table of Contents

HEATING SYSTEM EQUIPMENT

Lesson One

Gas Heating Equipment



TPC Training Systems

44301

Lesson

1 Gas Heating Equipment

TOPICS

Gas Heating Basics
Gaseous Fuels
Combustion Air
Furnace Categories
Furnace Components for Heat Production
Furnace Ignition Systems
Furnace Components for Venting
Conditioned Air System
Heating System Controls
Service Procedures

OBJECTIVES

After studying this lesson, you should be able to…

- Describe the main parts of the furnace system, both those that produce the heat and those that distribute the heated air, and describe the four basic furnace configurations.
- Discuss the differences between natural gas and liquefied petroleum gas (LPG), the hazards associated with each fuel, and the heating rates of each fuel.
- Discuss the purposes of the primary and secondary air supplies to the combustion chamber and compare the characteristics of category I, III, and IV gas furnaces.
- Describe how the gas is introduced, mixed with the air, and burned in the heat-producing components of the furnace.
- Describe several burner ignition methods and safety shutdown measures in case of flame failure.
- Discuss the basic sequence of furnace operation and the safety and operating controls required.
- Describe common service procedures for gas heating systems and discuss safety concerns.

KEY TECHNICAL TERMS

Odorant 1.10 an unpleasant-smelling sulfur compound added to natural gas to make the gas readily identifiable

Primary air 1.18 air that is mixed with the gas just before the fuel enters the burner

Secondary air 1.19 air that mixes with the fuel during the combustion process

Condensing furnace 1.24 a category IV furnace, which includes a secondary heat exchanger to recover heat and provide greater efficiency

Spud 1.27 a small orifice fitting that controls the rate of gas flow in each passageway from the manifold to the burners

In this course, you will read about many different kinds of heating equipment. In particular, you will study the details of gas furnaces, oil furnaces, electric heating systems, hydronic systems, wood-burning furnaces, and some space heaters.

In this lesson, you will concentrate on gas furnaces, especially those that burn natural gas or liquefied petroleum gas (LPG). Although the furnace components for the two fuels are similar, you will find that their burners and gas control mechanisms must be different because of the different heating rates of the fuels.

The main focus of this lesson is on medium- and high-efficiency gas furnaces—those furnaces currently being manufactured. However, you will also read about the older, less-efficient furnaces that are still a common part of the technician's work. These older systems have a pilot light and rely on the chimney draft to vent the flue gas to the atmosphere.

Gas Heating Basics

1.01 Gas-fired hot air furnaces consist of two main parts—the heat-producing system and the heated-air distribution system. The heat-producing system is made up of the gas manifold and controls, the burners, the heat exchanger, and the flue venting system. The heated-air distribution system is made up of the blower that forces the return air through the system and the external portions of the heat exchanger that warm the air and direct it into the system ductwork.

1.02 The gas manifold and controls meter the quantity of air and gas into the burners. The hot burning gas products enter the inside of the heat exchangers and then pass into the flue venting system to be discharged to the atmosphere. The return air enters the furnace and is directed around the outside of the heat exchangers. The heat is transferred to the air, heating it sufficiently so that it can be ducted throughout the structure, supplying the required heating.

1.03 Gas furnaces are available in four common arrangements. These are as follows:

- upflow
- lowboy
- downflow
- horizontal.

1.04 The *upflow furnace* is designed for situations where the return air enters the furnace from the bottom or the sides near the bottom. The air flows up through the furnace and is discharged as warm air from the top. This furnace is suitable for basement installations where the ductwork is connected at the top of the furnace and directed underneath the floor of the building. Figure 1-1 shows an upflow furnace.

1.05 The *lowboy furnace* is so-named because it is only about 4 ft tall. In this furnace, both air intake and discharge of the conditioned air are at the top of the furnace. Return air then flows to an opening near the bottom of the furnace and flows upward, as in the upflow furnace. These furnaces are generally used in low-ceiling basements with ductwork under the first floor of the building. Figure 1-2 on the following page shows a typical lowboy furnace.

Fig. 1-1. Upflow furnace

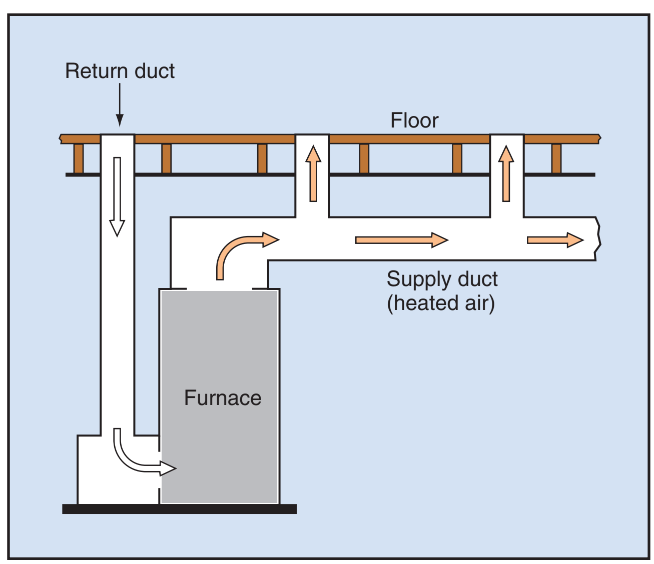
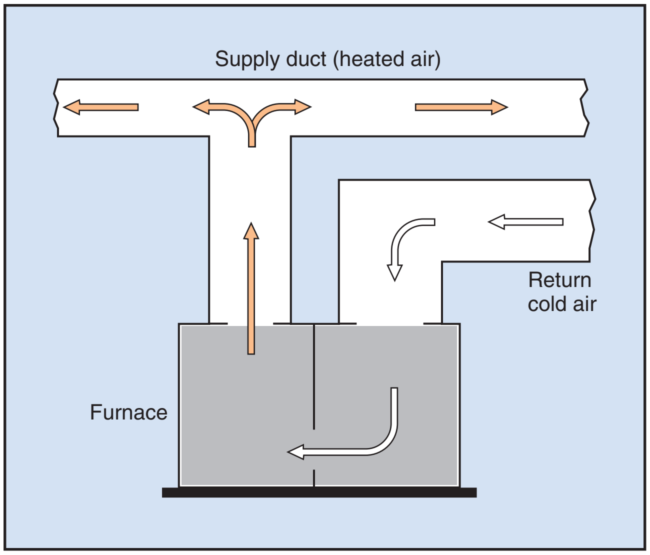


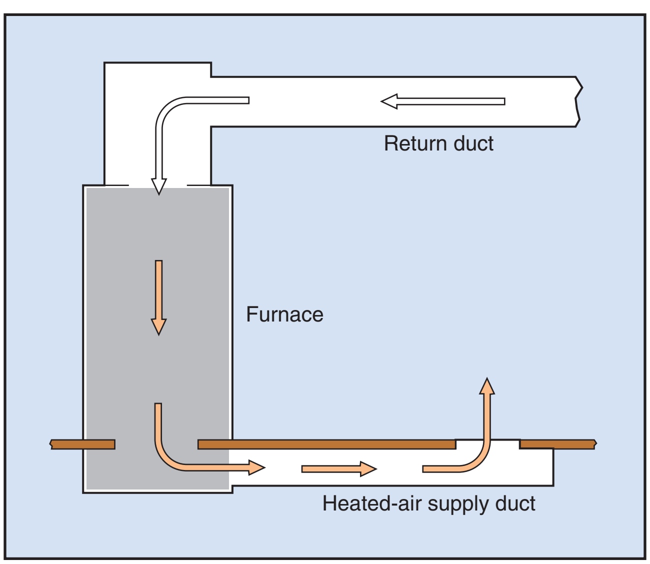
Fig. 1-2. Lowboy furnace



1.06 The *downflow furnace* is also referred to as a *counterflow furnace*. The direction of flow in this case is from the top of the furnace down, and the heated air discharges from the bottom. These furnaces are typically found in buildings that are built on a slab. The heated air discharges into ductwork that is built into the slab flooring. Figure 1-3 shows the typical arrangement for the counterflow furnace.

1.07 The *horizontal furnace* is positioned on its side. Air intake is at one end, with the air traveling horizontally and discharging at the other end. These furnaces are suitable for installation in crawl spaces and attics, or they can be suspended from the floor joists under a house. Figure 1-4 shows a horizontal furnace located beneath the floor joists.

Fig. 1-3. Downflow (counterflow) furnace



Gaseous Fuels

1.08 Natural gas is the fuel used most commonly in gas furnaces. A utility company distributes the natural gas as pressurized gas through an underground piping system. This is an economical method of distribution to highly populated areas. Liquefied petroleum gas (LPG) is distributed in rural areas beyond the reach of natural gas piping. LPG is supplied in tanks as a liquid and is expanded to a gas before being drawn from the tank.

1.09 Natural gas in the pipeline is 90 to 95% methane plus some other flammable hydrocarbon gases. This fuel burns efficiently and cleanly. Natural gas has a specific gravity of 0.65, which means that it weighs 65% as much as air. Because it is lighter than air, natural gas, when released, readily dissipates into the air. The chemical formula for methane is CH_4, which indicates that each methane molecule is composed of one carbon atom and four hydrogen atoms.

WARNING

When natural gas is released, it displaces oxygen in the air and can cause suffocation. In addition, the mixture of natural gas with air is highly explosive within a certain range of natural gas concentration.

1.10 Because of the hazards of natural gas and because natural gas from the wellhead does not have any identifying odor or color, the supplier adds an odorant before introducing the fuel into the utility pipeline. This *odorant* is a sulfur compound with an unpleasant smell, which makes the gas readily identifiable. It is what we smell when we say, "I smell a gas leak." The odor disappears as the gas is burned, and no harmful products result from the addition of the odorant.

1.11 When 1 ft^3 of natural gas is completely burned, it typically produces 1000 to 1050 British thermal units (Btu) of heat. In reality, however, natural gas can yield anywhere from 900 to 1200 Btu/ft^3. The actual heat yield depends on the specific well from which the gas is drawn and the percentage of methane. It is common for utilities to mix other hydrocarbons with the natural gas to maintain the rating of 1000 to 1050 Btu/ft^3.

1.12 To burn each cubic foot of natural gas completely, 10 ft^3 of air must be supplied. However, to ensure full combustion, furnace combustion is normally based on 15 ft^3 of air. The extra 5 ft^3 of air guarantees complete combustion. The products of complete combustion are the harmless products carbon dioxide (CO_2) and water vapor (H_2O). Incomplete combustion results in the creation of harmful products—for example, carbon monoxide (CO) and soot, in addition to the harmless products just named.

1.13 Liquefied petroleum gas (LPG) is composed of either butane, propane, or a mixture of the two. Butane and propane have different boiling points, chemical formulas, and heat-producing rates per cubic foot. The formula for butane is C_4H_{10}, and the formula for propane is C_3H_8. The numbers following the chemical symbols C and H indicate the number of atoms per molecule. The most significant difference is in the boiling or vaporization temperatures, which are as follows:

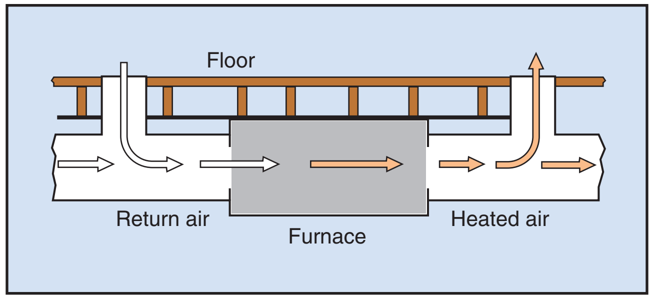
- At 40°F, butane has a vapor pressure of only 3 psig in the liquid storage tank.

- At 40°F, propane has a vapor pressure of 78 psig in the liquid storage tank.

1.14 In cold winter climates, butane vapor will not flow from the tank to the furnace because of insufficient vapor pressure. Propane, however, has sufficient pressure even at low temperatures. To compensate for temperature variations around the country, LPG contains a sufficient amount of propane so that the vapor pressure can provide the force to move the gas to the furnace regardless of temperature.

1.15 Both butane and propane have a specific gravity of about 2.0. This means that their vapors are twice as heavy as air. Therefore, released vapor will sink to low points in the area where it might collect and remain undetected.

Fig. 1-4. Horizontal furnace



WARNING

LPG vapor is dangerous because it replaces the oxygen in the air and can cause suffocation. Collection in low areas can result in pockets of highly explosive vapor. Proper ventilation is required.

1.16 Because LPG has more carbon and hydrogen atoms in each molecule of vapor than natural gas, it also has a higher heat rate per cubic foot than natural gas. The heat rate of butane is 3267 Btu/ft^3, and the heat rate of propane is 2521 Btu/ft^3.

1.17 LPG is generally a mixture of butane and propane, and the mixture may vary with climate conditions. The actual heat rate of the mixture can be obtained from the local LPG supplier. The value falls somewhere between the values for butane and propane and is always greater than the heat rate for natural gas. You should be aware that both natural gas and LPG can be burned in the same furnace, but only after the nozzles (or spuds) controlling the supply of fuel and airflow are adjusted for the specific fuel. The gas pressure must also be changed.

Combustion Air

1.18 The air supplied for complete combustion of gas in a furnace is introduced into the furnace from two distinct sources. One source supplies primary air, and the other supplies secondary air. The *primary air* is mixed with the gas before the fuel reaches the burner. As the gas is metered through the control orifice, or spud, it enters a venturi where the high velocity of the gas draws the primary air into the fuel. At this location, it mixes with the fuel just before entering the combustion burner. Primary airflow is designed to contain more air than necessary for complete combustion. Primary air also controls the rate at which the combustion takes place.

1.19 *Secondary air* is drawn into the combustion chamber, where it mixes with the fuel during the combustion process. This secondary air is required to ensure that the fuel is completely burned, thus avoiding the production of poisonous flue by-products of incomplete combustion.

Furnace Categories

1.20 Furnaces vent their combustion by-products to the atmosphere either by a natural draft or by a power venting system. In the natural draft system, the flue products are drawn into the vent or chimney because of the difference in density between the hot flue gases and the atmospheric pressure. Power venting systems use a fan or blower to ensure air intake to the burner. This force creates a positive flow of flue gases through the vent system.

1.21 Gas furnaces are classified into several categories, depending on the kind of vent system used in the furnace. Although four categories exist, no category II furnaces are currently being manufactured.

1.22 *Category I furnaces* use either natural draft or a power venting system, but the gas vented is at temperatures of 275°F or higher. These furnaces are generally in the low- to mid-efficiency range. This kind of furnace is an older style that produces higher-temperature flue gases that result in heat loss through the venting system.

1.23 *Category III* furnaces maintain the flue gases in the 275 to 360°F range and provide positive pressure within the vent. These furnaces are in the mid-efficiency range. However, condensation of the water vapor can occur in the vent. To counteract this condensation, the vent system must be made of materials that can withstand the corrosive products formed during condensation.

1.24 *Category IV* furnaces are high-efficiency equipment because they maintain the flue gas temperatures in the range of 100 to 275°F. This is accomplished by the use of a secondary heat exchanger in the furnace. The secondary heat exchanger recovers the heat normally lost in the category I and category III furnaces. Category IV furnaces are also known as *condensing furnaces*. The secondary heat exchanger is typically made of heat-resistant materials that can withstand the corrosive chemicals. The vent from the category IV furnace can be made of plastics, including PVC, CPVC, and ABS.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. The gas manifold and controls are ________ components, and the return-air blower is part of the ________ system.	1-1. HEAT-PRODUCING; HEATED-AIR DISTRIBUTION Ref: 1.01
1-2. The downflow furnace is also called a(n) ________ furnace.	1-2. COUNTERFLOW Ref: 1.06
1-3. Natural gas consists mainly of ________ and is ________ than air.	1-3. METHANE; LIGHTER Ref: 1.09
1-4. Natural gas leaks are readily detected because the ________ adds a(n) ________.	1-4. SUPPLIER; ODORANT Ref: 1.10
1-5. LPG is usually a mixture of ________ and ________ and is ________ than air.	1-5. BUTANE; PROPANE; HEAVIER Ref: 1.13, 1.15
1-6. For LPG to flow in cold climates, it must contain a higher percentage of ________.	1-6. PROPANE Ref: 1.14
1-7. ________ air is mixed with the fuel before combustion and ________ air is added after combustion.	1-7. PRIMARY; SECONDARY Ref: 1.18, 1.19
1-8. The condensing furnace is a ________-efficiency furnace with vent temperatures of ________.	1-8. HIGH; 100 TO 275°F Ref: 1.24

Furnace Components for Heat Production

1.25 The furnace components that are part of the heat-producing system are the following:

- gas pressure regulators (two)
- gas valve
- manifold
- spud
- burner
- heat exchanger(s).

The *gas regulator* is a device that reduces the pressure of the gas from the supply line to the furnace. Figure 1-5 shows a gas regulator. In a natural gas system, this valve is part of the gas company's meter system. In an LPG system, the liquid storage tank contains a pressure regulator that reduces the pressure of the vapor in the tank to the usage pressure. Both systems also have a *second pressure regulator*, typically located within the gas valve, to provide final control of the gas pressure to the burner. The natural gas regulator is set at a pressure of 3.5 in. W.C. (inches, water column). The vapor supply pressure setting for LPG systems is 11.0 in. W.C.

1.26 The *gas valve* opens to supply gas to the furnace when required and closes to stop the combustion process. Several kinds of valves are commonly used to control the gas flow:

- diaphragm valves (magnetic and bimetal)
- solenoid valves
- redundant valves.

Figure 1-6 is a sketch of a redundant (dual solenoid) gas valve. Its main purpose is safety. If a gas valve solenoid should fail, another gas valve will close, thereby stopping the flow of gas within the furnace.

1.27 The *manifold* is the collector passageway that gathers the fuel vapor after the regulator and directs the gas toward the burners. The passageway from the manifold to each of the burners in the furnace is through a small orifice fitting called a *spud*, shown in Fig. 1-7. The small hole in the spud restricts, or controls, the rate of gas entering the burner from the fixed manifold pressure. The size of the orifice is very important. It is determined by the fuel gas (natural or LPG), by the size of the burner, and by the manifold pressure.

1.28 The *burner* is made of either cast iron or steel. Various shapes are available to optimize the efficiency of gas combustion for the specific furnace. In general, the burner is a long tube that has a number of slots or openings through which the mixture of gas and primary air flows. The fuel burns at the exit of each of these openings. Figure 1-8 shows two typical burner elements.

1.29 The fuel gas enters the burner through the spud, as mentioned previously. At the entrance to the burner, an opening permits the primary air to be drawn into the burner chamber. In some furnaces the air intake opening is fixed. Other furnaces are equipped with movable shutters that can be adjusted to control the primary air intake. Figure 1-9 on page 12 illustrates the burner arrangement and shows entry points for the fuel gas, primary air intake, and secondary air intake. Recall that primary air mixes with the fuel gas before the mixture enters the burner. Secondary air, however, enters the combustion chamber and mixes with the burning fuel and the flue gas. This ensures complete combustion in the furnace.

1.30 When the burner is properly adjusted, complete combustion of natural gas is indicated by a flame at the burner that has a light blue lower mantel about 3/4-in.

Fig. 1-5. Gas pressure regulator

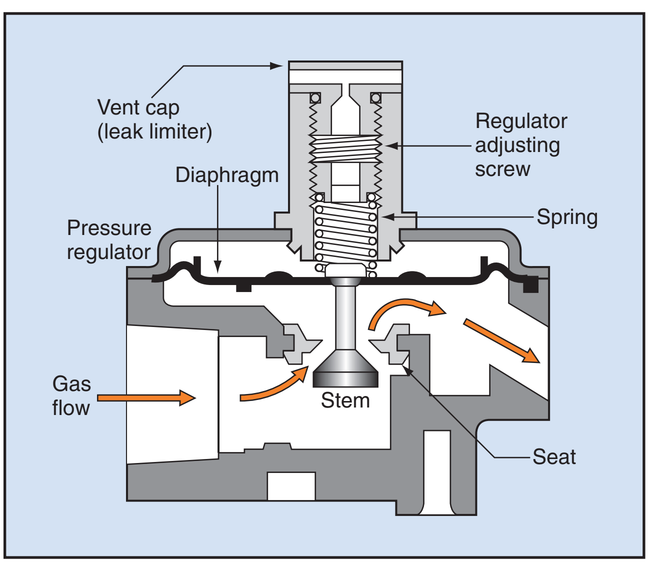
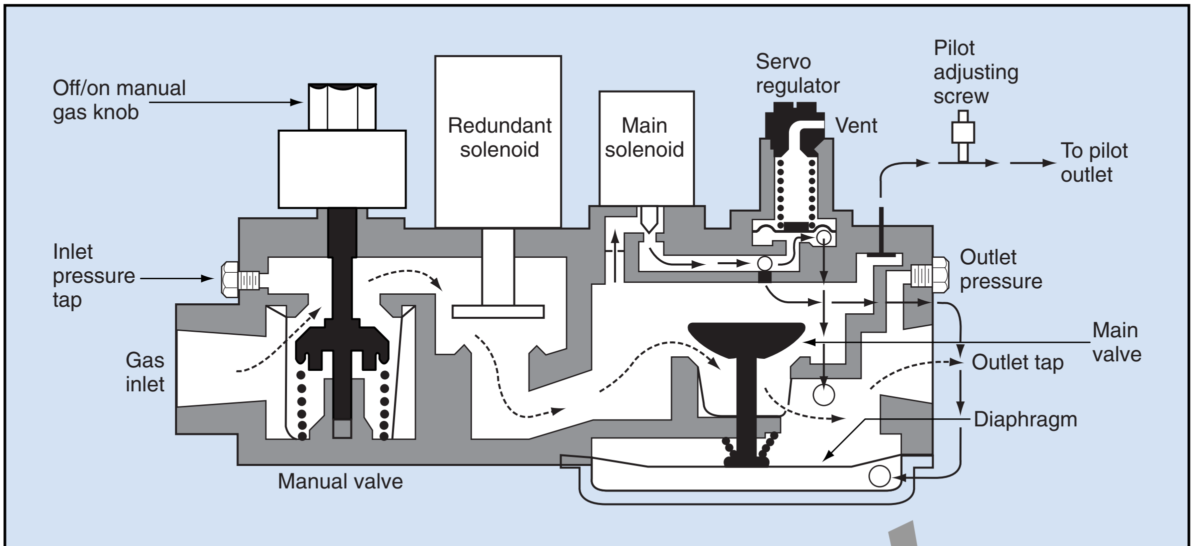


Fig. 1-6. Redundant (dual solenoid) gas valve



tall with a darker blue upper flame. There should be no yellow tipping on the flame. Complete combustion of LPG gas is indicated by a flame that is light blue and about $^1/_2$-in. tall. The upper flame of LPG should be darker blue with some slight yellow tipping. Incomplete combustion is indicated by a very lazy flame that shows a fair amount of yellow. Because incomplete combustion results in the production of poisonous carbon monoxide fumes, this situation must be corrected.

1.31 The combustion chamber vents the flue gas directly into the *heat exchanger(s)*, where the heat of combustion is transferred to the returning air from the structure. The air to be heated is totally separated from the flue gases by the heat exchanger. The design of the heat exchanger is critical to the efficiency of the furnace. The heat transfer characteristics must be relatively high. However, the heat exchanger must be strong enough to withstand high temperatures without corrosion and without leaking flue gases into the air being conditioned.

1.32 Recall that a high-efficiency condensing furnace is equipped with two heat exchangers. The pri-

Fig. 1-7. Spud

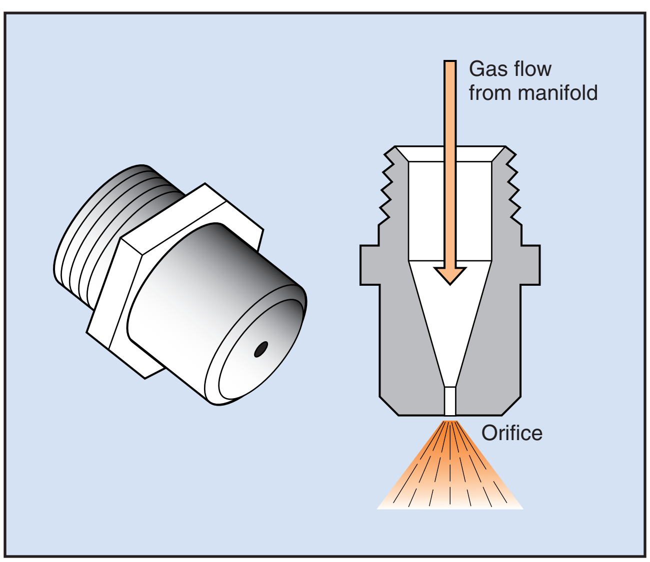


Fig. 1-8. Burners

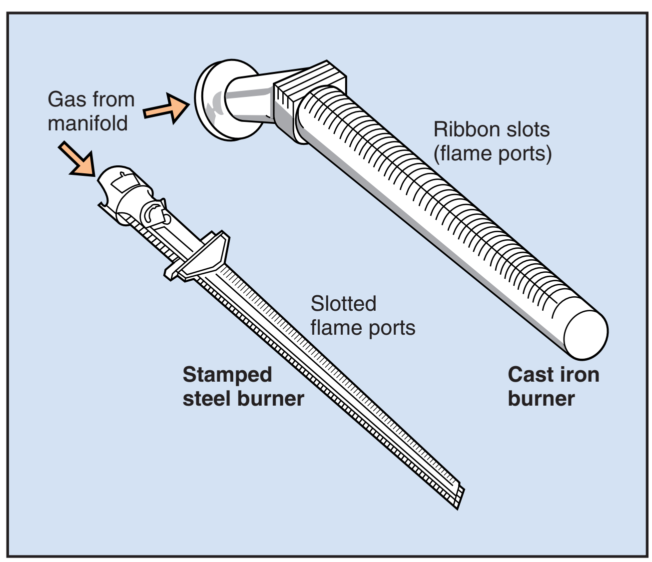
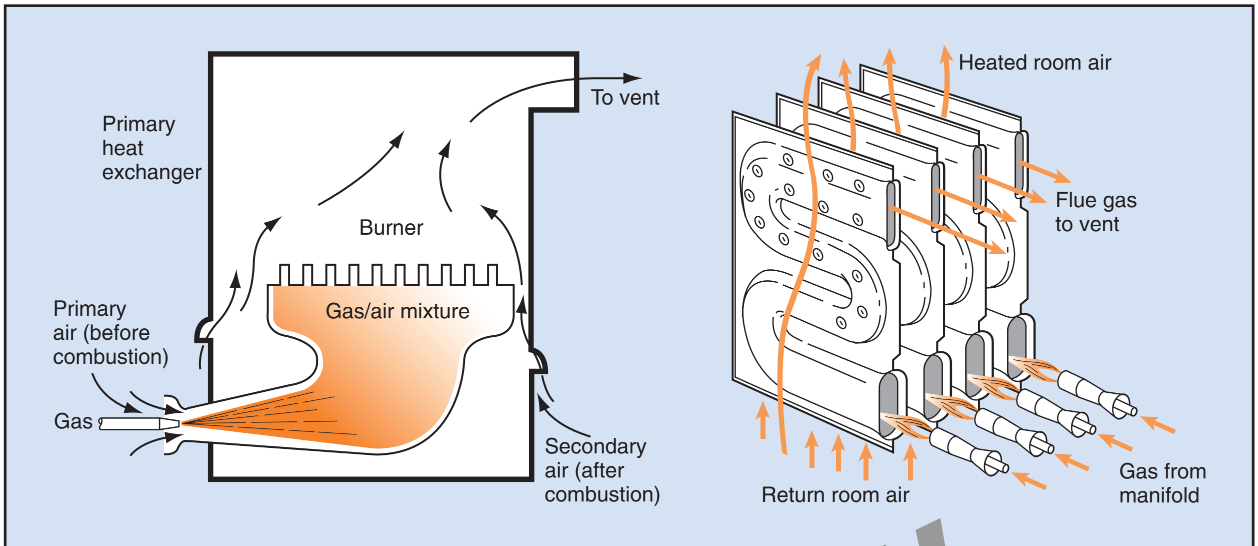


Fig. 1-9. Heat exchangers

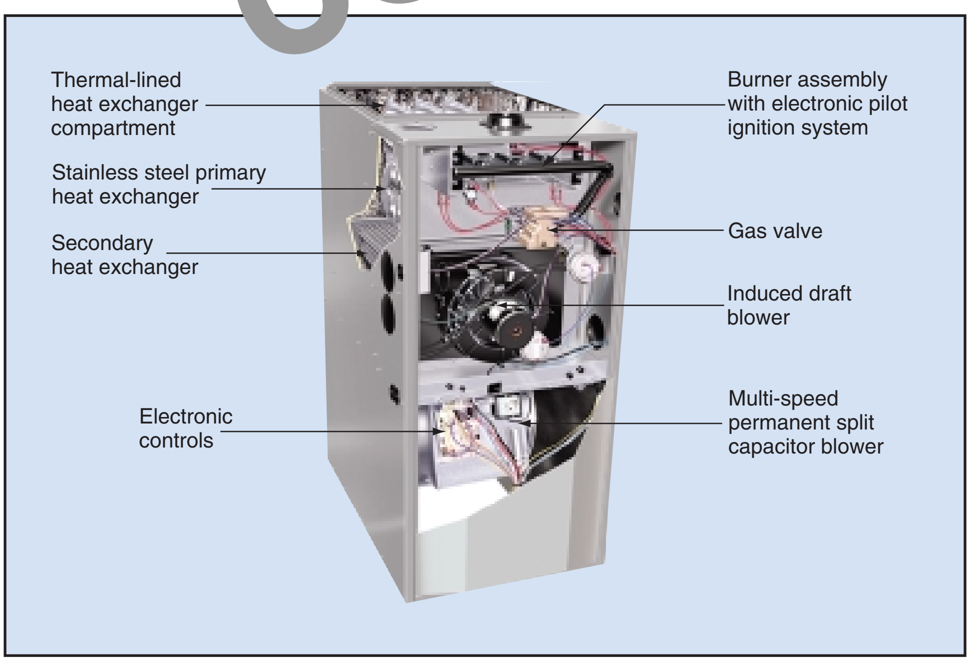


mary heat exchanger is similar to the one described in the previous paragraph. The secondary heat exchanger is much smaller and handles the flue gases after they have been discharged from the primary heat exchanger. In this secondary heat exchanger, the heat that would normally be sent up the chimney is transferred to the cooler return air. During this process, some of the water vapor in the flue gas condenses to a liquid and is drained from the system. The extra heat extracted in this heat exchanger increases the efficiency of currently manufactured furnaces. Figure 1-10 shows the arrangement of the primary and secondary heat exchangers.

Furnace Ignition Systems

1.33 The purpose of the ignition system is to provide the flame, spark, or heat source necessary to start

Fig. 1-10. Typical high-efficiency gas furnace arrangement



the gas burning when the furnace is turned on. The following three kinds of ignition systems are used with gas furnaces:

- continuous ignition
- intermittent (automatic) pilot
- direct ignition.

1.34 *Continuous ignition* was used mainly on older furnaces where a pilot flame ignited the supply of gas when the furnace was turned on. The pilot flame remained burning continuously, even when the furnace was not in use. Safety controls sensed whether or not the pilot was actually lit and shut off the gas supply to the furnace in the event of a pilot blowout. Restart was manual on these furnaces.

1.35 In order to overcome the need for manual relighting of the pilot, especially in remote areas, manufacturers introduced the *intermittent pilot*, also called *automatic pilot*. This arrangement also uses a pilot flame to ignite the burner. However, if the pilot flame is blown out, a sensor initiates a glow plug or a spark igniter to relight the pilot flame. These systems include sensors that signal when the pilot flame is out and initiate relighting of the pilot flame. If the flame is not re-established within a predetermined number of tries, the gas supply will be shut off. In this case, service is required to restart the system.

1.36 The intermittent ignition system uses an electronic ignition module to control the sequences of operation and safety. The module performs the following functions:

- checks that all systems are in order to start when there is a call for heating
- reacts to the flame sensor
- supplies power to the pilot igniter
- controls the gas valve
- monitors both the pilot and the burner during furnace operation
- shuts down the heating system in the event of a problem.

1.37 High-efficiency furnaces use the *direct ignition* system, which does not include a pilot light. The burner is lit either by direct spark ignition (DI) or by a hot surface igniter (HSI). In these cases, the burner is lit directly by the igniter each time the furnace starts. The absence of the pilot flame saves considerable fuel and contributes to the high efficiency of the furnace.

1.38 The direct spark ignition system uses a high voltage to produce a spark across a device that is similar to the spark plug in an automobile. The hot surface igniter uses an electric current in a high-temperature element. The element glows at a temperature high enough to cause the gas in the area to ignite.

1.39 In both of these arrangements, the system is controlled and monitored by an electronic ignition module similar to, but not quite the same as, the module for the intermittent ignition. The module fully controls the power to the igniter, the gas valve, and the burner flame sensor. The monitor safely shuts down the furnace in the event that the burner does not ignite.

1.40 A typical direct ignition furnace goes through the following sequence of operations. When the system thermostat calls for heat, the combustion air blower is energized. When the required amount of airflow is sensed, power is supplied to the ignition control. At this time, the gas valve opens and the igniter lights the burner. A sensor signals that the burner is actually lit. Then the igniter is de-energized and the fuel continues to burn. If the flame ceases at any time during this normal operation, the gas valve closes and the furnace shuts down. Automatic restart can be initiated for a predetermined number of tries.

1.41 When the system is operating normally and the heat exchanger reaches its temperature limit, the gas supply to the furnace shuts down temporarily while the supply air blower continues to withdraw heat from the furnace. This happens even though the thermostat is still calling for heat. When the heat exchanger temperature cools to a safe limit, the furnace re-ignites and continues the heating process. The furnace goes through a normal shutdown when the system thermostat is satisfied. In all cases, if there is no flame, the furnace is safely shut down.

Furnace Components for Venting

1.42 High-efficiency furnaces use a small fan called a *combustion blower* or power venting to control the primary air supply to the furnace. In a forced-air system, the fan is located before combustion. In an induced-air system, the fan is located after the combustion chamber, in the vent. The induced system fan must handle the flue gas products and the higher temperatures associated with the flue gas.

1.43 The combustion blowers provide the force for moving the flue gas through the vent to the outside atmosphere. High-efficiency furnaces have low flue temperatures and can use suitable plastic vent pipes. Older systems rely on the temperature difference between the flue gas and the outside air temperature together with the height of a chimney to vent the flue gas. However, these factors are not important in furnaces with combustion blowers.

1.44 High-efficiency condensing furnaces must be fitted with a drain to remove any liquid condensed during furnace operation. Because these liquids contain corrosive materials, the condensing heat exchanger and associated components are manufactured from materials that can withstand the harsh environment. The drain from these units must be provided in accordance with the manufacturer's specifications and in compliance with local codes. It is illegal to drain the condensate onto the ground.

Conditioned Air System

1.45 Return air from the building enters the furnace through a filter and then flows around the primary and secondary heat exchangers. The building air does not come in direct contact with the combustion process or with the flue products. Instead, the air picks up heat from the heat exchangers and then exits the furnace to return to the building as warm conditioned air. The flow of air is maintained by the blower that is located within the furnace. This blower is located in the furnace either before the combustion chamber (forced air) or after the air is reheated (induced air), depending on the furnace design.

1.46 In most cases, this blower (unlike the combustion blower) starts after the furnace is in operation and the plenum has reached a set temperature. The purpose of this arrangement is to ensure that the air being supplied is warm. If the blower started at the same time as the furnace, uncomfortably cool air would enter the rooms before the furnace heated sufficiently to send warm air. At furnace shutdown, the blower continues to operate until the furnace plenum has cooled to its set temperature.

Heating System Controls

1.47 The following controls help ensure safe and efficient heating system operation:

- thermostat
- high-temperature safety limit switch
- fan limit switch
- vent safety switch
- ignition and flame control sensors.

The *thermostat* controls the temperature within the structure. It turns the furnace on when heating is required and turns it off when the temperature is satisfied. The thermostat is installed at a location where the indicated temperature is typical of the entire area. Most thermostats used today are solid state designs that allow the programming of temperatures throughout the day and week.

1.48 A *high-temperature safety limit switch* located in the furnace shuts down the furnace in the event that it overheats for any reason. A *fan limit switch*, also located in the furnace, controls the room air blower. This switch provides the blower delay on furnace startup and shutdown to ensure that the air is comfortably warm, as discussed in the previous section.

1.49 A *vent safety switch* is located in the flue outlet. Its purpose is to sense any blockage in the vent system and safely stop the furnace. The switch can be either temperature sensitive or, in the case of power venting, pressure sensitive. In either case, the switch shuts the furnace down to prevent the possibility of fire or dangerous fumes entering the structure.

1.50 *Ignition* and *flame control sensors* are located within the combustion area and serve to monitor and shut off the furnace and gas supply, should the burner flame be extinguished while the furnace is in operation. The functions of these devices were discussed earlier in this lesson in conjunction with ignition, the ignition module, and the gas and regulator valves.

Service Procedures

1.51 In most furnaces, primary air can be adjusted to obtain the desired complete combustion flame by changing the shutter in the burner opening. When adjustment is required for natural gas, open the shutter fully on each burner. Observe the flame and close the shutter just enough for the flame to develop a yellow tip. Now open the shutter very slightly until the yellow tip disappears. Then lock the shutter in position. Repeat for all burners. Some furnaces have a fixed shutter. In these cases, consult the manufacturer's literature for instructions regarding air adjustment.

1.52 For LPG furnaces, open the shutter fully and observe the flame. Close the shutter until a strong yellow tip appears at the top of the flame. Then open the shutter to the point where a small or slight yellow tip remains. Lock the shutter in place and repeat for all burners. For both natural gas and LPG, cycle the furnace several times to ensure that the adjustment is correct.

1.53 You might need to check or adjust the manifold pressure at the regulator. For natural gas systems, the normal pressure is 3.5 in. W.C. For LPG systems, the normal pressure is 11.0 in. W.C. The pressure reading can be obtained with a U-tube manometer or a suitable pressure gauge.

1.54 An excellent method for checking furnace efficiency and checking for complete combustion is by means of measuring the exhaust gases for carbon dioxide, carbon monoxide, and oxygen. This procedure requires careful use of a flue gas analyzer according to the specific instructions supplied with the equipment. For natural gas, the carbon dioxide content should be in the range of 8.5 to 10%. For LPG, the carbon dioxide content should be in the range of 11 to 12%.

1.55 The content of carbon monoxide in the exhaust must be under 0.04% for the furnace to be operating normally and safely. If the value is above 0.04%, the unit must be shut down and the problem found and corrected. Carbon monoxide detectors should be installed in any home or facility that has equipment that burns fossil fuels. This equipment includes not only gas furnaces but also clothes dryers, gas stoves, and so on.

WARNING

A high level of carbon monoxide can be fatal.

1.56 The oxygen content should be 1% or less. An oxygen content of higher than 1% indicates excess air in the combustion chamber. This problem can be corrected by adjustment of the primary air source.

1.57 Furnaces operate with a highly flammable fuel and electricity, both of which can be extremely hazardous when handled improperly. Any service, adjustment, or work on the furnace should be done only by persons properly trained on the particular piece of equipment that is being serviced. Always observe all manufacturer's instructions and warnings and remember that gas plus a spark can mean an explosion.

1-9. The gas regulator located within the gas valve controls gas ________ to the ________.	1-9. PRESSURE; BURNER Ref: 1.25
1-10. Gas leaves the manifold through a small orifice fitting called a(n) ________.	1-10. SPUD Ref: 1.27
1-11. A properly adjusted burner produces a blue flame with ________ yellow tipping for natural gas and ________ yellow tipping for LPG.	1-11. NO; SLIGHT Ref: 1.30
1-12. A high-efficiency furnace recovers heat from flue gases by means of a secondary ________.	1-12. HEAT EXCHANGER Ref: 1.32
1-13. The direct ignition system ignites the burner by means of a(n) ________ or ________.	1-13. SPARK; HOT SURFACE Ref: 1.37
1-14. High-efficiency furnaces ensure sufficient primary air supply by means of a(n) ________ blower or ________ venting.	1-14. COMBUSTION; POWER Ref: 1.42
1-15. The ________ switch provides the blower delay on furnace startup and shutdown.	1-15. FAN LIMIT Ref: 1.48
1-16. Gas plus a spark can equal a(n) ________.	1-16. EXPLOSION Ref: 1.57

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. The ________ furnace is used in locations with low ceilings, and the ________ is used in crawl spaces.

- ☐ a. downflow; lowboy
- ☐ b. downflow; upflow
- ☐ c. horizontal; downflow
- ☐ d. lowboy; horizontal

1-2. Both natural gas and LPG

- ☐ a. are about twice as heavy as air
- ☐ b. are supplied by underground pipelines
- ☐ c. can cause suffocation and explosions
- ☐ d. produce about 1000 to 1050 Btu/ft^3 of fuel

1-3. In cold winter climates, LPG requires a higher percentage of

- ☐ a. air
- ☐ b. butane
- ☐ c. methane
- ☐ d. propane

1-4. Primary air is drawn into the furnace through the

- ☐ a. draft hood
- ☐ b. gas valve
- ☐ c. spud
- ☐ d. venturi

1-5. Condensing furnaces

- ☐ a. are classified as category III equipment
- ☐ b. are low-efficiency equipment found in older buildings
- ☐ c. maintain the flue gases at temperatures between 100 and 275°F
- ☐ d. require masonry chimneys

1-6. The gas regulator is set at ________ in a natural gas system and at ________ in an LPG system.

- ☐ a. 0.65 in. W.C.; 2 in. W.C.
- ☐ b. 3 psig; 78 psig
- ☐ c. 3.5 in. W.C.; 11.0 in. W.C.
- ☐ d. 11.0 in. W.C.; 3.5 in. W.C.

1-7. A lazy flame that is about one-quarter yellow indicates

- ☐ a. complete combustion of LPG
- ☐ b. complete combustion of natural gas
- ☐ c. incomplete combustion, which must be corrected
- ☐ d. use of excess air

1-8. Return air from the building is heated as it

- ☐ a. flows around the heat exchanger(s)
- ☐ b. is blown across the burner
- ☐ c. is induced across the burner
- ☐ d. passes through the heat exchanger(s)

1-9. If there is a blockage in the vent, a gas furnace with power venting will be shut down by the

- ☐ a. fan limit switch
- ☐ b. pressure-sensitive vent safety switch
- ☐ c. temperature-sensitive vent safety switch
- ☐ d. thermostat

1-10. The results from tests with a flue gas analyzer should include a reading that indicates a content of

- ☐ a. carbon dioxide between 8.5 and 10 for LPG systems
- ☐ b. carbon dioxide between 11 and 12% for natural gas systems
- ☐ c. carbon monoxide below 0.04%
- ☐ d. oxygen above 1%

SUMMARY

A gas heating system includes a heat-producing system and a heated-air distribution system. Furnaces are available as upflow, lowboy, downflow (counterflow), and horizontal models. Most gas furnaces burn piped-in natural gas. Liquefied petroleum gas (LPG) is provided in tanks for use in rural areas.

Natural gas is composed mainly of methane (CH_4) and is lighter than air. The supplier adds an odorant so that leaks can be detected. Natural gas generally produces 1000 to 1050 Btu/ft^3. About 15 ft^3 of supply air per 1 ft^3 of natural gas ensures complete combustion. LPG usually is a mixture of butane (C_4H_{10}) and propane (C_3H_8). Propane ensures flow from the tanks in cold climates. LPG always has a higher heat rate than natural gas.

Primary air is introduced before combustion. Secondary air mixes with the fuel during combustion. Furnaces are divided into four categories, depending on their venting systems and flue temperatures. Category IV furnaces (condensing furnaces) use a secondary heat exchanger and are the most efficient.

Heat-producing furnace components include the gas regulator, second pressure regulator, gas valve, spud, burner, and heat exchanger(s). Complete combustion is indicated by a flame that is blue with little (LPG) or no (natural gas) yellow tipping. Older furnaces used continuous ignition, in which a pilot flame was always lit and manual restart was needed if the flame blew out. The intermittent (automatic) pilot ignition uses a pilot flame but includes a sensor-operated glow plug or spark igniter for restart. High-efficiency furnaces use the direct ignition system, which does not require a pilot flame. The burner is lit by direct spark ignition or by a hot surface lighter.

Furnace venting in newer systems is by means of a combustion blower. Older systems generally relied on natural draft. Condensing furnaces must be fitted with a drain. The return (conditioned) air never comes in direct contact with the combustion process or flue products, but rather, flows around the outside of the heat exchanger(s). The thermostat, sensors, and various switches help ensure safe, efficient operation. Service procedures commonly include adjusting the primary air intake, checking or adjusting manifold pressures, and checking for furnace efficiency and complete combustion. Carbon dioxide, carbon monoxide, and oxygen all must be within the correct range of percentages. Work on a furnace must be performed only by those trained to do so. All safety measures *must* be observed at all times.

Answers to Self-Check Quiz

1-1. d. Lowboy; horizontal. Ref: 1.05, 1.07

1-2. c. Can cause suffocation and explosions. Ref: 1.09 and 1.15 WARNINGs

1-3. d. Propane. Ref: 1.14

1-4. d. Venturi. Ref: 1.18, Fig. 1-9

1-5. c. Maintain the flue gases at temperatures between 100 and 275°F. Ref: 1.24

1-6. c. 3.5 in. W.C.; 11.0 in. W.C. Ref: 1.25

1-7. c. Incomplete combustion, which must be corrected. Ref: 1.30

1-8. a. Flows around the heat exchanger(s). Ref: 1.45

1-9. b. Pressure-sensitive vent safety switch. Ref: 1.49

1-10. c. Carbon monoxide below 0.04%. Ref: 1.55

Contributions from the following sources are appreciated:

Figure 1-8. Carrier Corp.
Figure 1-10. Comfortmaker Heating and Air Conditioning