$15.00

The Reznor Gas-Fired

SPACE HEATING HANDBOOK

REZNOR®

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This text represents the combined efforts of several talented engineers, technical support personnel and others associated with Reznor®, HVAC Division of Thomas & Betts Corporation. This handbook has been prepared to provide an all-in-one-place source of information about natural-gas and propane space heating and space-heating equipment for industrial and commercial use. We have tried to make this manual useful to a broad range of people who deal with heating of industrial and commercial buildings. We believe architects and HVAC engineers will find the “Principles of Heater Operation”, “Practical Applications”, and “Technical Data” sections particularly helpful. We have included a “Basic Concepts” section which we hope will prove useful to engineering and technical students and which can also serve as a review of fundamentals for others.

As in most technical fields, terms in the heating trade have grown into use somewhat haphazardly, sometimes with ambiguous or multiple meanings. To ensure clarity and avoid possible misunderstanding, we have included a glossary of terms so that the reader may be sure of the meaning intended in this handbook.

We have aimed throughout the book to present, in a condensed and readable form, as much accurate and up-to-date information as possible. We welcome comments from readers and will appreciate suggestions for improvement in future reprints or editions of this handbook.

Natural gas is just one of the sources of heat energy available for space heating today; the others are fuel oil, manufactured gas, propane, butane, coal, electricity, and wood. Of all the available fuels, natural gas offers the best combination of convenience, availability, economy, cleanliness, non-pollution characteristics, and reliability of supply. As a result, it has become a most widely used fuel for commercial and industrial (and residential) space heating in the U.S. and other industrial nations.

The wide use of natural gas in the United States has come about in just a little over a century. Although it is possible to trace humankind's awareness of the existence of natural gas back about 2,500 years to the ancient Chinese (who piped it to the point of use through bamboo poles), modern natural-gas history in the United States did not begin until 1821. It was then that William Hart dug the first gas well (27 feet deep) outside Fredonia, New York. For the next 37 years, use of natural gas and the drilling of wells spread through western New York State and Pennsylvania, and northern Ohio and Indiana. The young natural gas industry grew quickly, and by 1900, there were natural gas wells in 17 states. Today, only a few states do no have any gas wells within their borders, but all have natural gas available because of the several million miles of gas transmission and distribution lines that now crisscross the entire country.

This vast underground network and the transportability of natural gas account for the convenience and reliability of natural gas as a fuel. Only electricity approaches the convenience and reliability of pipe delivered natural gas, but it is more costly and more subject to interruption due to weather. Coal, although less expensive, is awkward to transport and deliver to space heating equipment and more difficult to control to get the uniform heating expected of today's space heating equipment. Although fuel oil competes with natural gas in price and in controllability at the space heater, it must be transported and delivered by truck or rail and stored on site. Propane, although generally available, is used where natural-gas lines are not in place and is stored on site. All factors considered, natural gas offers the best combination of characteristics.

This handbook deals strictly with the heating of commercial and industrial buildings and facilities. It is also limited to space heating with natural gas and propane gas. For the most part, natural gas and propane gas are similar, and most of the technical text applies to both. Where major differences exist, propane will be mentioned; otherwise, the reader may assume that both are meant even if only natural gas is mentioned for convenience and brevity of expression.

Heat Physics

1-1 **The Nature of Heat.** In 1799 Sir Humphrey Davy melted two pieces of ice by rubbing them together in freezing weather, proving that heat is really a form of energy and not the weightless fluid scientists of the time believed it to be. Today, we know that heat is the energy of molecular motion. (Figure 1-1). How fast the molecules of matter in an object are moving determines our experience of the object as “hot” or “cold”. The faster the molecules are moving (that is, the more energy they have) the hotter the object seems to us.

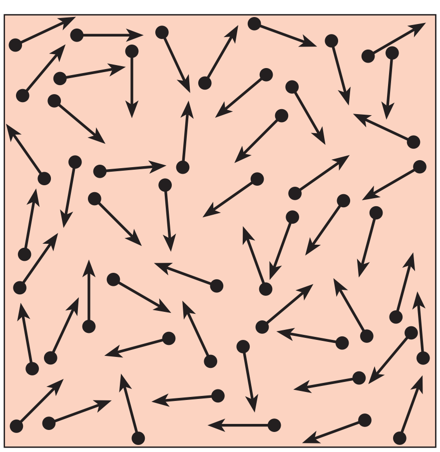
Temperature. The words “hot” and “cold” are common terms we use to describe the intensity of our feeling of heat. But they are not precise terms because our sensation of heat is not reliable. For example, a room that feels warm to an active person will seem cool to a person who has been sleeping or resting. For accurate measurement and for detection of small changes and differences in the intensity of heat, scientists long ago invented the concept of temperature and thermometer for measuring it.

Temperature Scales. Persons interested in heaters and space heating should be familiar with four temperature scales: Fahrenheit, Celsius (formerly called Centigrade), Kelvin, and Rankine (Figure 1-2). The Fahrenheit thermometer is in common use in the United States. On this scale the boiling temperature of water is 212 degrees and the freezing temperature of water is 32 degrees.

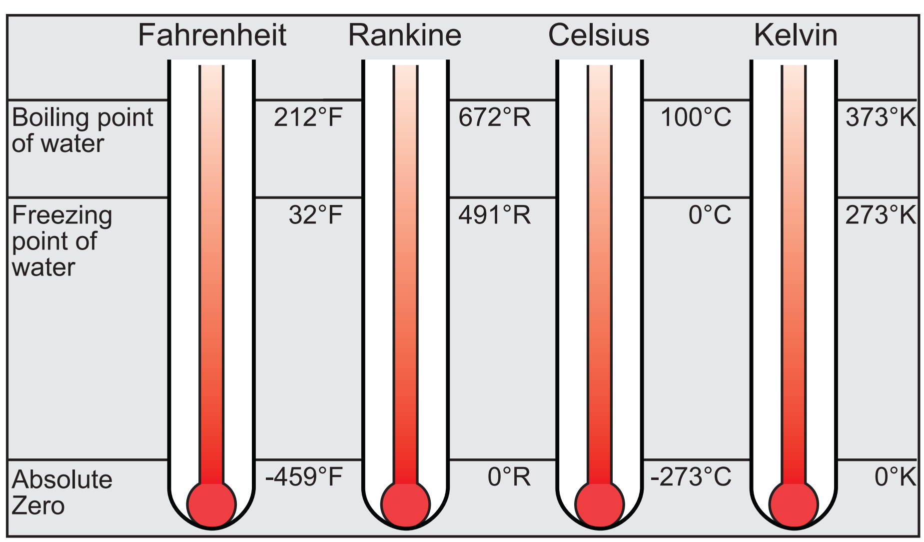
In scientific work and in most parts of the world, the Celsius scale is used. This scale was set up to have the convenient figures of 100 degrees for the boiling point of water and zero for the freezing point.

Kelvin and Rankine are absolute scales. The Fahrenheit and Celsius scales have a disadvantage: it does not have to get very cold to result in negative numbers. This means that at zero on either scale there is still some heat present (because it can get colder that zero, there is heat to be removed. Lord Kelvin in England took a Celsius scale and changed it so that zero represented the complete absence of heat.

The zero point on the kelvin scale is known as absolute zero--it is not possible to get any colder than zero degrees Kelvin. In practice, it is not even possible to actually cool anything down to absolute zero, but scientists have succeeded in cooling helium gas down to within several hundredths of a degree of absolute zero. Similarly, the Rankine scale is a Fahrenheit scale that start at absolute zero.



1-1 Molecules are in constant motion, in all directions



1-2 Four scales for measuring temperature: Fahrenheit, Rankine, Celcius, and Kelvin.

Temperature Conversion Formulas. The following formulas can be used to convert from one temperature scale to another:

F = (9 ÷ 5 x C) +32

C = 5 ÷9 x (F - 32)

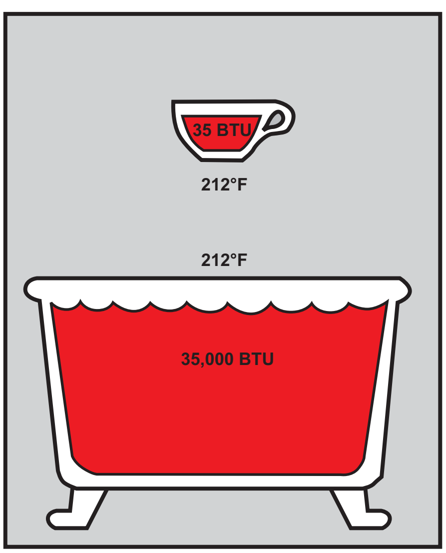
C = K - 273

K = C + 273

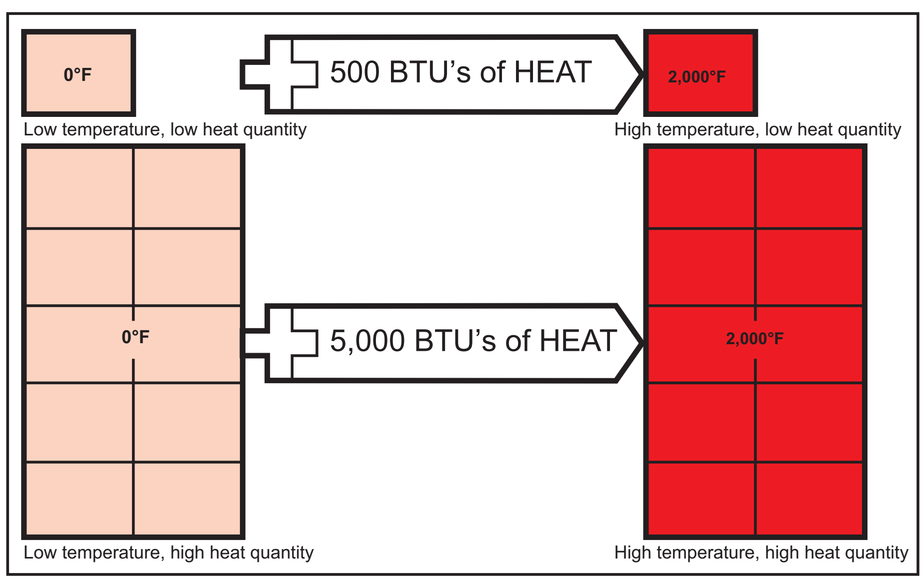
Heat Quantity. Temperature differs from heat quantity. The temperature of an object is no indication of the quantity of heat present. For example, the flame of a burning candle has a much higher temperature than a hot-water baseboard heater, but you couldn't heat a room with the candle. Here's another way of thinking about this: dip a cupful of boiling water from a bathtub full of boiling water and both will have the same temperature but not the same amount of heat. (Figure 1-3). The cupful of hot water might melt only an ice cube, but the tubful could melt several pounds of ice. It is possible for a body to have: 1. low temperature and little heat; 2. low temperature and a lot of heat; 3. high temperature and a small amount of heat; 4. high temperature and a large quantity of heat. Figure 1-4 shows a basic concept important for understanding and working with space heaters: the temperature of matter (gas, liquid or solid) can be increased by adding heat (energy) or lowered by removing heat (energy).

Measuring Heat Quantity. Heat quantity is usually measured in *calories* or in *British Thermal Units* (BTU). BTUs are the commonly used measurement in engineering in the United States. The calorie is the metric system unit used in the rest of the world for engineering purposes and it is used for scientific work universally, including in the United States.

The Calorie. The calorie used in engineering is defined as the quantity of heat needed to warm one gram of water one degree Celsius. That is, when one gram of water becomes one degree warmer, it picks up one calorie of heat energy and if it cools by one degree, it loses one calorie. Note: This "engineering" calorie is not the same as the one people count when dieting. The food Calorie is called the large Calorie and is equal to 1,000 "engineering" calories.



1-3 At the same temperature (degrees) the larger volume holds a greater heat quantity (BTU).



1-4 Temperature indicates intensity (not quantity) of heat.

Heat Physics

The British Thermal Unit (BTU). The heat quantity unit of the English system is defined as the amount of heat needed to warm one pound of water by one degree Fahrenheit. See Figure 1-5. One BTU equals 252 calories.

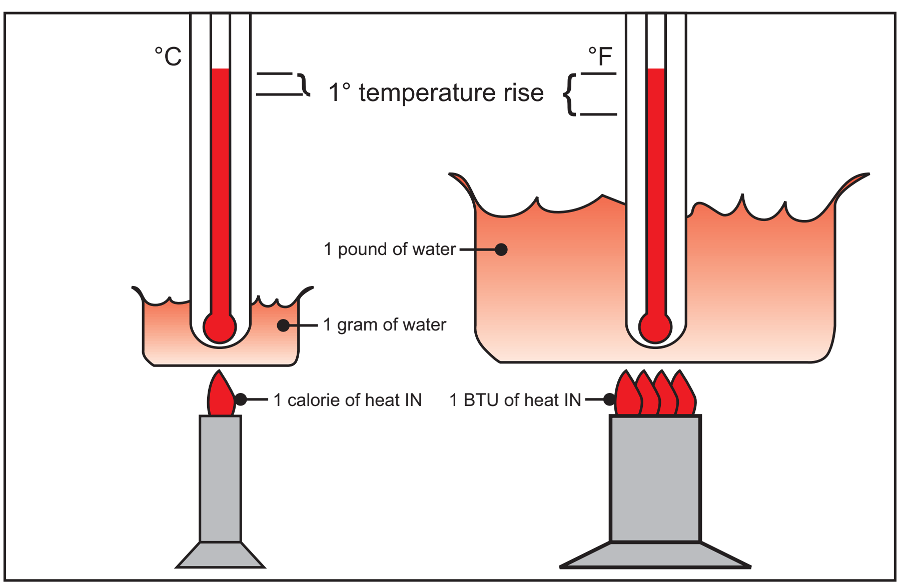
Heat Transfer. A property of heat that is important in space heating is that heat can move from one object or place to another. From personal experience since early in life, we know that when we bring two substances of different temperatures together, the warmer one cools and the cooler one warms up. This experience is stated in physics as the Law of Heat Exchange: in all cases of heat exchange between circulating currents as shown in substances the total number of BTUs or calories gained by the cooler substance equals the total number of BTUs or calories lost by the warmer substance.

Space heating engineers and technicians are usually interested in distributing heat throughout the space of a building or enclosure. This distribution can involve three methods of heat transfer: conduction, convection and radiation.

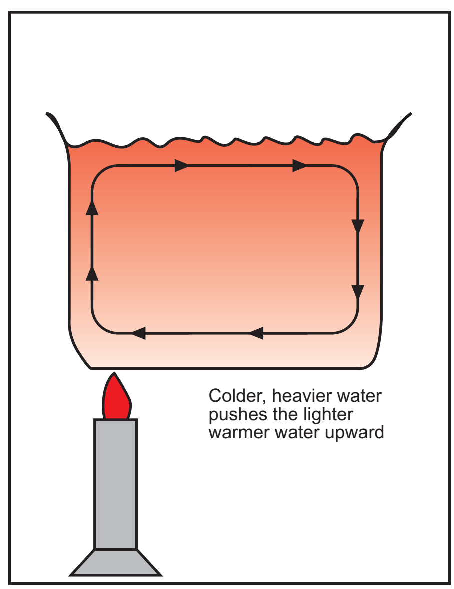
Convection. Convection takes place in liquids and gases because liquids and gases expand and become lighter when heated. When the heating is uneven, the lighter (hotter) gas or liquid rises, setting up Figure 1-6. This movement (convection) is an important factor in the distribution of heated air in buildings.

Conduction. In conduction, heat transfer takes place through a solid material (see Figure 1-7). For example, only the bottom of a pot is heated in cooking food, but the metal handle soon becomes hot. Generally, metals are excellent conductors of heat (some better than others), while wood, stone, cloth, liquids, and gases are poor conductors.

Radiation. Radiation is the transfer of heat energy by rays or waves. Radiant heat does not need matter on which to ride from one place to another (Figure 1-8). Heat rays can travel through a vacuum: that is how heat from the sun reaches the earth.



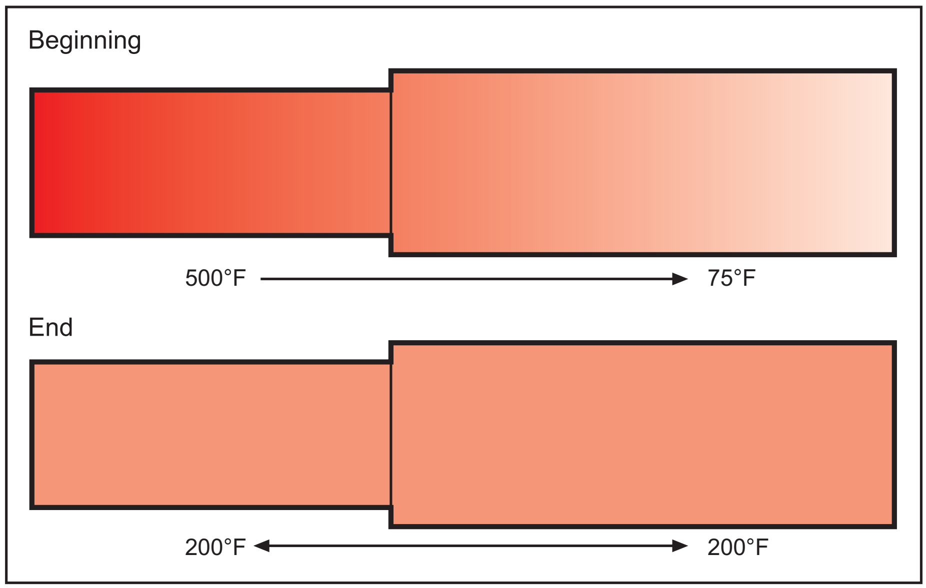
1-5 Calorie and British Thermal Unit (BTU) - two ways of measuring heat quantity.



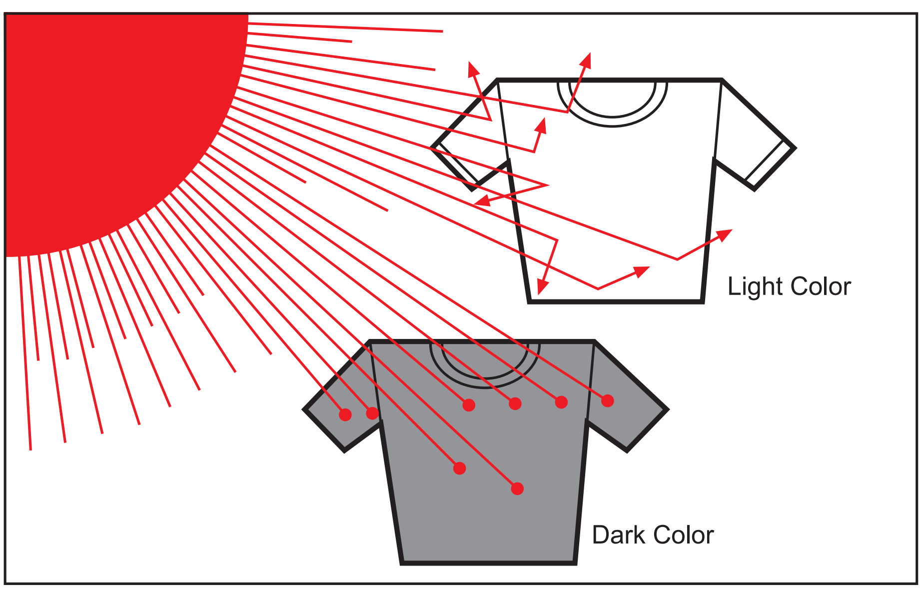
1-6 Convection: gas or liquid rises when heated and sinks when cooled.

Heat rays that strike matter can be transmitted, reflected or absorbed, or some combination of the three depending upon the nature of the material and the condition of its surface. Just as light passes through glass, radiant heat can pass through air. Heat rays are reflected when they meet bright smooth surfaces like highly polished metals. Rough dark surfaces absorb heat and become warmer in doing so (objects with black surfaces absorb heat rays better than objects having white surfaces because white surfaces reflect heat).

Building Heat Loss. Heat loss from a building can occur through conduction, convection and radiation. It can also occur through infiltration--the leakage of air into a building through cracks, poorly fitted windows and doors, chimneys and other breaks in the continuity of the enclosure. To minimize heat loss, buildings are provided with insulation which may consist of nonconductive materials like spun fiberglass, reflective materials like aluminum foil. Pliable compounds are used for sealing joints and cracks.



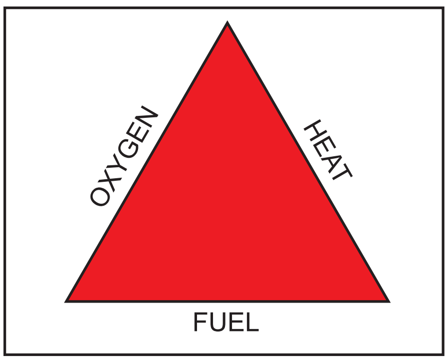
1-7 Heat travels “downhill” - from the hotter object to the cooler one.



1-8 All radiant energy, like heat from the sun, travels through empty space, needs no conducting material. Light colors reflect heat; dark colors absorb heat.

Combustion

The Process of Combustion. The burning of wood, paper or gas in the kitchen stove is a common everyday experience, so common we give little thought to the process taking place that produces heat. Actually, what takes place in this burning process - combustion - is a chemical reaction. The hydrogen and carbon atoms of the wood, paper or gas combine with oxygen atoms from the air and form carbon dioxide gas and water vapor. Chemists and chemical engineers call this an oxidation reaction.

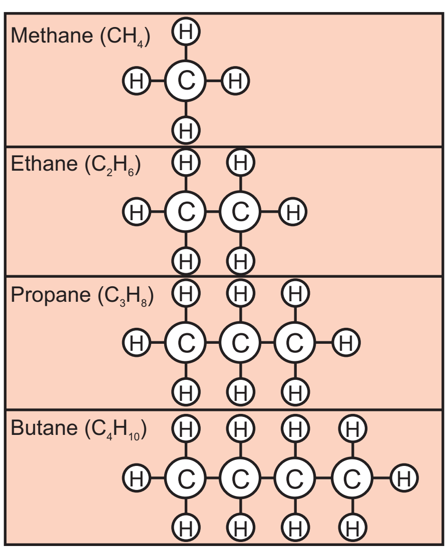


1-9 Three factors are needed for combustion.

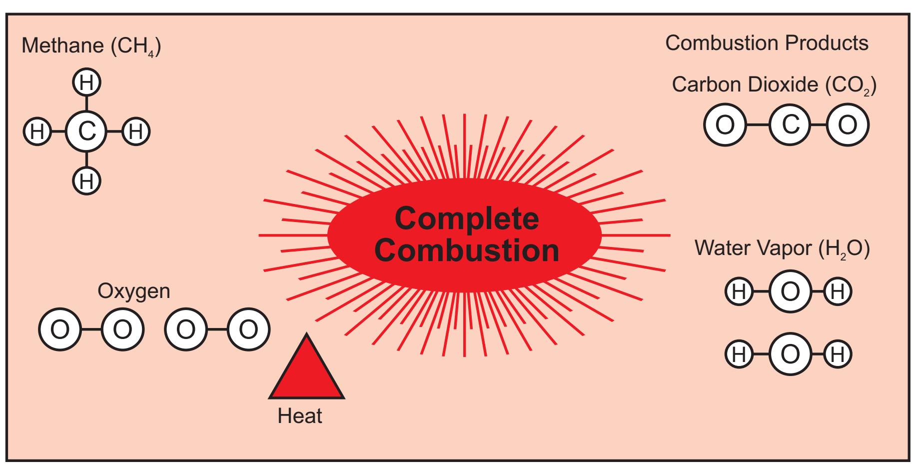
Requirements for Combustion. Three things are required to support combustion: fuel, air (for oxygen), and heat (to raise the fuel to its ignition temperature). All three elements must be present to start combustion and to keep it going (in most cases heat produced by the combustion process, once started, keeps the combustion process going). See Figure 1-9.

Composition and Combustion of Natural Gas. Natural gas consists chiefly of a gas called methane whose chemical formula is CH_4. This formula shows that each molecule of methane is made up of one atom of carbon and 4 atoms of hydrogen. Natural gas also contains small amounts of related gases like ethane (C_2H_6) and propane (C_3H_8). Notice that all three gases contain only carbon and hydrogen in their molecules. Figure 1-10 gives a visual idea of the molecules of these gases. Using the chief component of natural gas, methane, Figure 1 -11 illustrates the rearrangement of atoms and molecules that takes place in the chemical reaction we call combustion.

Complete and Incomplete Combustion. Figure 1-11 illustrates complete combustion which takes place when there are enough oxygen atoms to match up with all the carbon and hydrogen atoms present. This illustration of complete combustion points out three important facts: 1. burning fuel gas *completely* produces only harmless carbon dioxide and water vapor; 2. a definite amount of fuel requires a definite amount of oxygen for complete combustion; 3. definite amounts of combustion products are formed in burning a fuel gas completely.



1-10 Fuel gases consist of carbon and hydrogen atoms.



1-11 Complete combustion - forms only water and carbon dioxide.

When there is not enough oxygen for all the fuel present, the result is dangerous and costly incomplete combustion. Figure 1-12 shows what happens during incomplete combustion. Some atoms of carbon get to combine with only one atom of oxygen forming carbon monoxide--a poisonous gas that can cause death when breathed.

Carbon monoxide can be particularly dangerous because it has no odor, color or taste and has increasingly serious effects at increasing concentrations and exposure times.

Various devices are available for detecting and measuring carbon monoxide. Figure 1-13 shows the effects of various carbon monoxide concentrations and exposure times. Levels of concentration are given in parts per million (PPM).

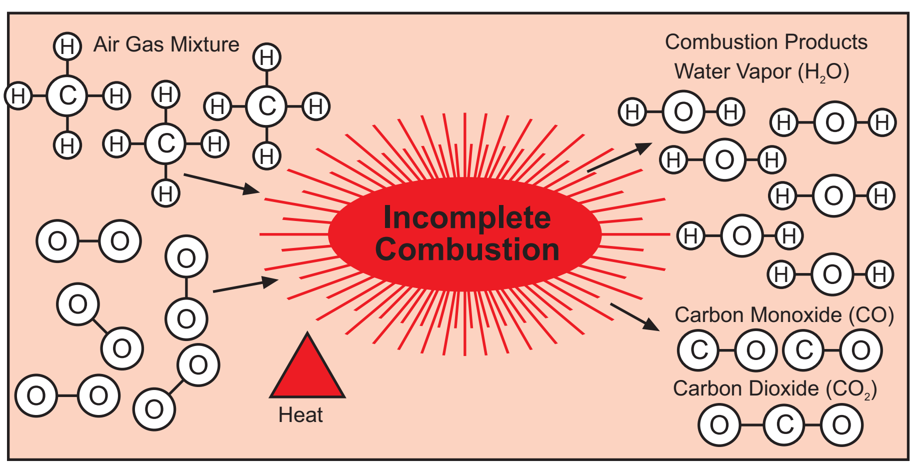
Incomplete combustion is also costly because not all the heat available in the fuel is released when carbon monoxide is formed, so there is a waste of fuel and consequent inefficiency.

Controlled and Explosive Combustion. Since complete combustion is necessary for both safety and economy in space heating, it is important to supply air and fuel gas to heating devices in the proper amounts and at proper rates to ensure complete burning of the gas in a steady controlled flame.

Explosive combustion can result when an air-gas mixture does not ignite the instant it leaves the burner. The air-gas mixture may then collect in the combustion chamber and burn almost instantaneously (explode).

The gas burners of heaters and furnaces are designed and equipped for safe and economical controlled combustion, when they are correctly adjusted and operated.

Odorants. For further protection against explosion, gas utilities add very small amounts of compounds that give natural gas a detectable odor. The "rotten-egg" or garlic-like smell of these odorants calls immediate attention to gas leaks so that corrective measures can be taken.



1-12 Incomplete combustion - causes some carbon monoxide to be formed.

Carbon Monoxide: (CO) - Product of Incomplete
100 PPM - Safe for continuous exposure
200 PPM - Slight effect after six (6) hours
400 PPM - Headache after three (3) hours
900 PPM - Headache and nausea after one (1) hour
1,000 PPM - Death on Long Exposure
1,500 PPM - Death after one (1) hour
Most codes specify that CO Concentrations shall not exceed 50 PPM

1-13 Effects of carbon monoxide.

Flammability Limits. The percentage of gas in a gas-air mixture determines whether a mixture will burn. Mixtures with less than 4% natural gas in air have too little gas to burn or explode. Mixtures containing 4% to 14% natural gas can burn with a controlled flame in a properly designed and adjusted burner or they can explode if they collect in an enclosed space before ignition. Mixtures containing more than 14% natural gas up to 100% cannot burn or explode. Figure 1-14 shows these ranges; 4% is known as the Lower Flammability Limit (LFL) and 14% is called the Upper Flammability Limit (UFL). These points are also known as the Lower Explosive Limit (LEL), and the Upper Explosive Limit (UEL) respectively. The flammability limits for propane are slightly different than for natural gas and are shown in Figure 1-15.

Gas Measurement

Use of natural gas as a fuel involves five factors that can be measured to describe the gas and put it to use.

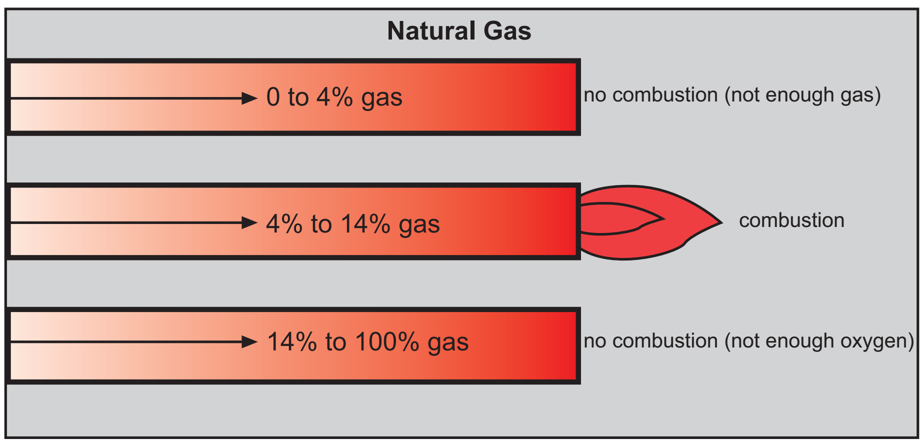
Volume. At the retail level utilities and pipelines deliver and sell gas by volume. The basic unit of measurement in the United States is the cubic foot--the volume of a space one foot high by one foot wide by one foot deep. For convenience in recordkeeping, most utilities have adopted a larger unit, the MCF, which equals 1,000 cubic feet; e.g., 96 MCF is the same as 96,000 cubic feet and 3,000,000 cubic feet is the same as 3,000 MCF.

Pressure. To be useful as a fuel, gas must be moved from its source at the wellhead through transmission and distribution pipes into the heater or furnace. The force for gas movement is the pressure imparted to gas by pumps and compressors.

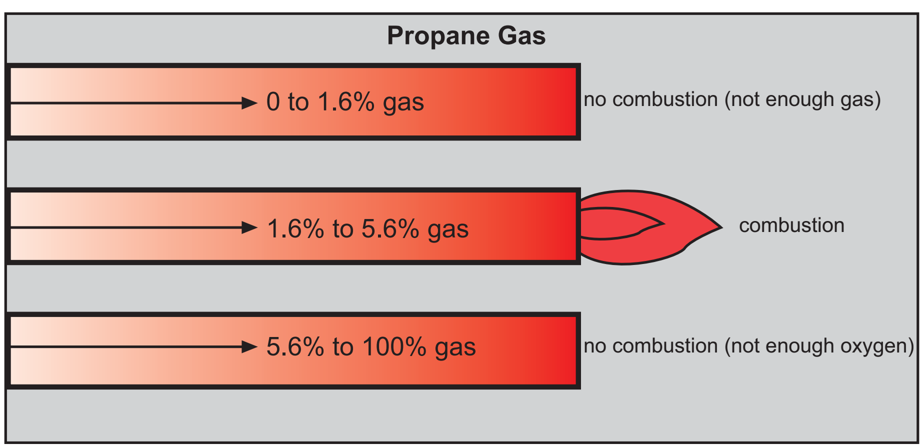
Three levels of pressure measurements apply to gas. In the high pressures of long-distance transmission pipelines, pressures are often several hundred pounds per square inch (PSI). For commercial and industrial use, natural gas is usually delivered at medium or low pressures. Medium pressure range is from 1/2 psi to 5 psi and is usually measured in inches of mercury (Hg). Pressure below 1/2 psi are considered low pressures and are commonly used for residential distribution. These low pressures are measured in inches of water (W.C.). In these cases the pressure of the gas is expressed as the height of a column of water or mercury (see Figure 1-16) balanced by the gas against gravity in a manometer. Two examples of measurements in this low-pressure range are inches of water (often abbreviated as W.C.) and inches of mercury (abbreviated as Hg).

Specific Gravity. Specific gravity is an important characteristic in the use of natural gas as a fuel. Knowing its specific gravity lets you know whether the gas will rise or fall when released into air, how well it will mix with air, and how it will flow through pipes and the orifices of the gas burners of heaters and furnaces. For example: because butane gas has a specific gravity of 2.0 (twice as heavy as air) it falls when released into the air and can drift into low areas and collect there, creating a possible fire or explosion hazard.

Specific gravity is the ratio of the weight of a gas compared to the same volume of dry air at the same temperature and pressure. For example, a cubic foot of natural gas that has a specific gravity of 0.5 will weigh just half as much as a cubic foot of



1-14 Flammability limits of natural gas.



1-15 Flammability limits of propane gas.

air. Actually, natural gas specific gravity ranges form 0.4 to 0.8, with most delivered in the U.S. having a specific gravity of 0.6. This range exists because natural gas contains varying amounts of methane, propane, etc., depending upon the source of the gas. Propane has a specific gravity of 1.52.

Specific gravity is one of the factors that the heater manufacturer must know to provide properly designed and factory-adjusted heating equipment. This characteristic affects flow of gas, particularly through orifices. See Basic System Components.

Heat Content. Another measure of interest to buyers and users of fuel gas is the energy or heat content.

Large-volume users, energy economists, and scientists who deal with large blocks of energy talk about therms, dekatherms and quads. These are very large units.

therm = 100,000 BTUs

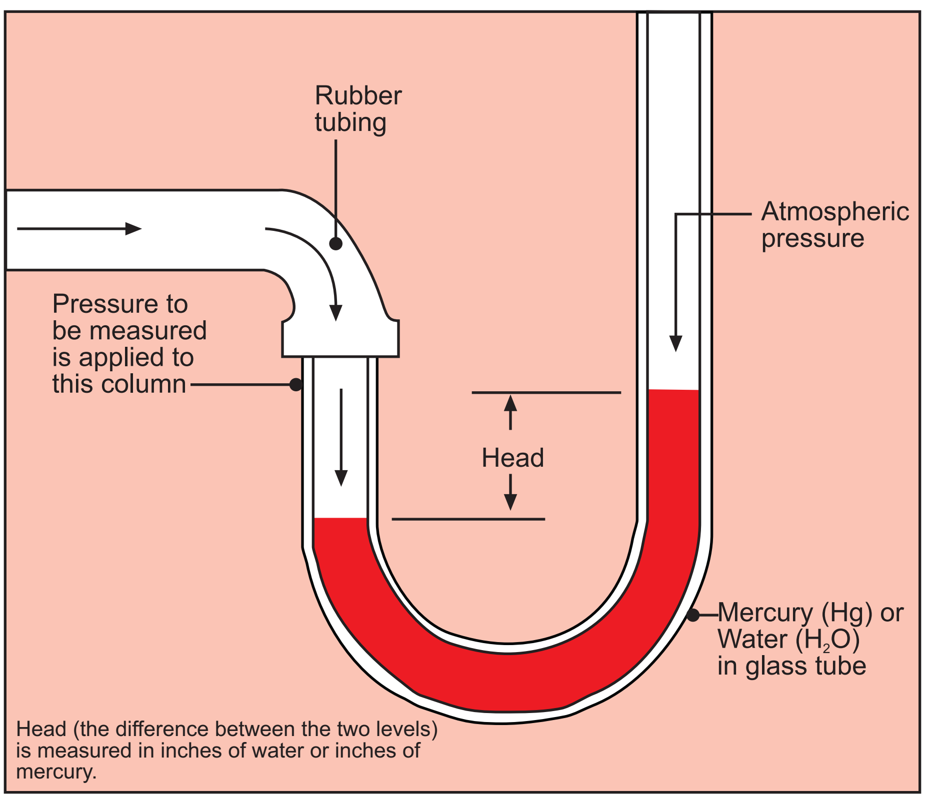
dekahterm = 1,000,000,000 BTUs

quad = 1,000,000,000,000,000 BTUs

A quad is one million dekatherms or one quadrillion BTUs, hence the name "quad".

Heating Value. The term "heating value" refers to the amount of heat generated by burning gas completely. Heating value is expressed in BTUs per cubic foot of gas measured at standard temperature and pressure.

Natural gas delivered for heating purposes typically has a heating value somewhere between 800 and 1150 BTUs per cubic foot. The exact heating value for a specific gas can be obtained from the supplying utility. The heating value for propane is approximately 2550 BTUs per cubic foot of gas.



1-16 Manometer for measuring gas pressure.

The heating value of natural gas shows considerable variation for several reasons. First, natural gas from different sources can contain different proportions of methane, ethane, propane, and butane. The more carbon and hydrogen atoms there are in a molecule of gas, the greater its heating value. This means that, as the percentage of ethane, propane, and butane increases, the heating value increases. Second, natural gas may contain varying amounts of nitrogen--an inert gas that does not burn at all. The greater the amount of nitrogen present, the lower the heating value will be.

The heating value for the natural gas to be used is a necessary piece of information for : 1. sizing a heater or furnace and the gas-supply piping for it; 2. estimating gas consumption and the cost of operation.

For heating equipment to do its job, it must receive the necessary number of BTUs per hour. This required BTU/Hour input rate usually appears on the nameplate of the device. It can be converted to gas flow rate for the particular gas available by using the heating value (obtainable form the supplying utility) and the following formula:

$$R = I \div H$$

where:

R = gas flow rate in cubic feet per hour;

I = input rate in BTUs per hour;

H = heating value of gas in BTUs per cubic foot.

Example calculation: A heater with an input rating of 125,000 BTUs per hour is to be supplied with gas having a heat value of 990 BTUs per cubic foot. The heater will use approximately 127 cubic feet of natural gas per hour (125,000÷990 = 126.263).

Three Basic Systems

2-1 A space heater does two basic things. It burns gas to generate heat and it transfers the heat to the room or other air-space to be heated. For most heaters, the heat is generated in the following way: a proper mixture of gas and air bursts into flame when heated to its ignition or combustion temperature and combustion continues as the gas-air mixture is steadily supplied to the flame.

Three Basic Types of Heaters

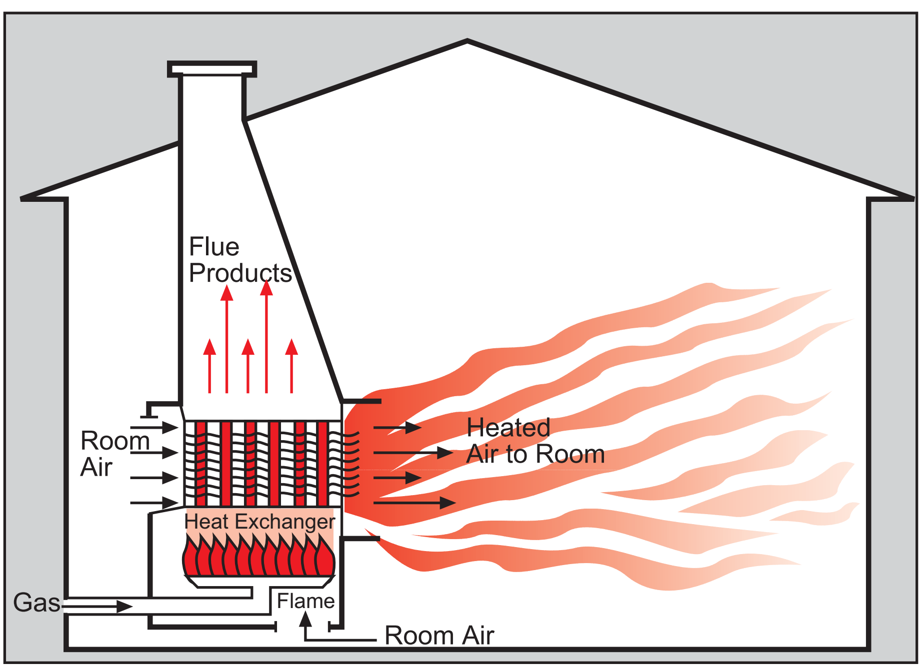
Once generated, the heat must be transferred to the space to be heated. There are three ways in which gas-fired heaters transfer their heat. Classified in this way, they are called indirect-fired heaters, direct-fired heaters, and radiant heaters.

Indirect-fired Heaters. The most commonly used type of gas-fired space heater is the indirect type. Figure 2-1 shows a schematic diagram of an indirect-fired heater. Combustion occurs at the burner located in a metal-walled chamber, called the combustion chamber, which may be a box or a tube (cylinder). The flame heats the chamber walls on the inside and the heat moves to the outside surface of the walls by conduction. The hot outside surfaces then heat the air of the space to be heated while the mixture of burned gases from the flame, called the combustion products, go their separate way to the outside of the building. This arrangement is called indirect because there is no direct contact between the flame and the heated inside room air. In most installations however, air for combustion comes from inside the room or building. NOTE: Air for combustion for indoor units is ultimately obtained from outside the building by infiltration through cracks at doors, windows, etc.

Direct-fired Heaters. In a direct fired heater, there is no separation between the air to be heated and the combustion chamber, as shown in Figure 2-2. The flame and its combustion gases mix with the air to be heated, that is, the space air is heated directly. Because the heated air contains the combustion gases, direct heating is limited to certain types of buildings and situations where large volumes of fresh outside air are admitted to the heated space as a normal part of the building's function. The uses of direct-fired heaters are discussed in the section on GENERAL APPLICATION AND SELECTION CRITERIA.

Terminology note on direct and indirect. Some publications and workers in the heating field use the terms "direct-fired" and "indirect-fired" in a different sense than defined in the preceding paragraphs. They apply the term "indirect-fired" to a heater that generates the heat away from the point of use (for example, a remotely located boiler generates steam which passes through piping to a radiator or other heater in the room to be heated); they use "direct-fired" to refer to all heaters that generate the heat *at the point of use*. Readers should be aware of this possibility for misunderstanding when using other sources of information. Throughout this handbook, the two terms are used only in the sense defined in the two paragraphs titled "indirect-fired heaters" and "direct-fired heaters."

Infrared Radiant Heaters. Radiant heaters operate on an entirely different principle from indirect- and direct-fired heaters. In a radiant gas-fired heater, the flame is used to heat a surface which in turn emits heat in the form of rays. (See Figure 2-3.) The materials used in this process can withstand extremely high temperatures. Radiant gas-fired heaters are fast and efficient and can be used conveniently in indus-



2-1 Indired-fired heating.

trial processes like the drying of paper, paint, and textiles as well as space heating.

High-intensity Infrared Heaters. In high-intensity heaters, the burner (see Figure 2-3) is cast from ceramic material and possesses a great number of ports of orifices in which the flame resides. The surface between these ports or orifices reaches about 1500-1950°F. At this temperature, the surface flows cherry red and becomes an infrared radiator. Then, like the sun, it heats objects in the room through radiation, without heating the air in between.

Low-intensity Radiant Heaters. Radiant heaters designed for low-intensity operation are based on the same principles as high-intensity heaters. The main difference is that the radiating plate is heated to a lower temperature (200-900°F). At this temperature, the plate does not glow but emits long-wave heat energy more like the heat from an electric iron or steam radiator.

Relative Efficiencies. Each type of heater has its own set of operating characteristics and applications, including efficiency characteristics. In *thermal* (combustion) *efficiency*, all three types of gas-fired heaters are about the same, that is, their burners extract about the same amount of heat from a cubic foot of gas. However, in overall system efficiency, there are differences, mostly due to installation and heat transmission methods.

Indirect-fired duct-furnace system efficiencies are lower due to duct heat losses (heat lost from warm-air ducts to the unheated spaces through which the ducts may be directed), casing losses (heat lost from the heater to the space surrounding the heater), flue loss (heat lost through walls and ceilings due to movement of heated air). Because non-duct indirect-fired systems (see unit heaters, page 3-2) eliminate duct and casing losses, their system efficiency is somewhat higher.

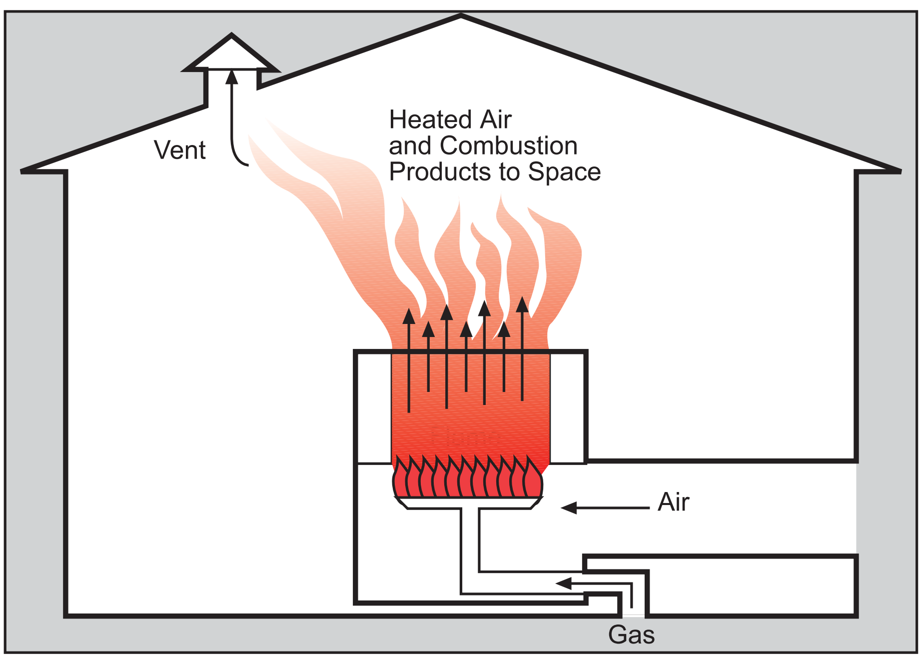
Direct-fired systems may not have duct loses and generally do not have casing losses. They also minimize flue losses (because they are not vented to the outdoors. The hot combustion gases directly warm the circulated air that is being heated), so their efficiency tends to be higher than for indirect-fired systems (theoretically 100%). However, efficiency is limited to about 90% because buildings heated in this manner must be ventilated at the rate of 3.5 to 4.5 CFM for each 1000 BTUH input.

Finally, radiant heaters have very good system efficiencies for the following reasons:

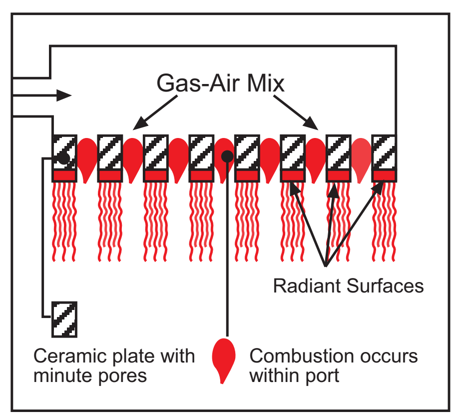
1. Radiant heaters do not heat the air; they heat the objects in the space by radiation. Occupants can be comfortable at a lower air temperature--and a lower air temperature means lower losses through the building's walls;

2. Radiant heaters require no forced air circulation, minimizing convection losses through the building's walls;

3. Radiant heaters normally are unvented but buildings must be ventilated at the rate of 3.5 to 4.5 CFM for each 1000 BTUH input. Such ventilation is usually accomplished with powered exhausters installed at the highest point of the roof.



2-2 Direct-fired heating.



2-3 Radiant Heating.

Basic System Components

A modern gas-fired space heater is more than a flame in a metal box. It's a system of components and subsystems working together automatically, efficiently, and safely. A generic forced-air heating system is shown in Figure 2-4 and its parts and subsystems are described in the following paragraphs.

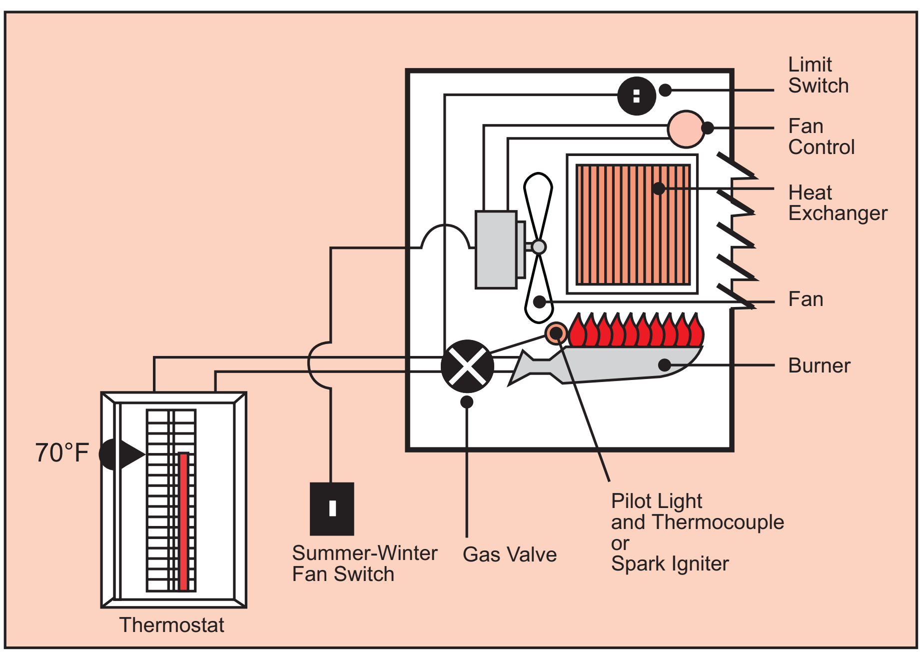
Gas Burners

The burner is a device for burning gas under control. It is made of cast iron or press-formed sheet steel. Space heaters employ burners designed on the principle of the blue-flame or Bunsen burner. Invented in 1842 by Robert Wilhelm von Bensen, this type of burner has many advantages over the yellow-flame burner that was in use at the time.

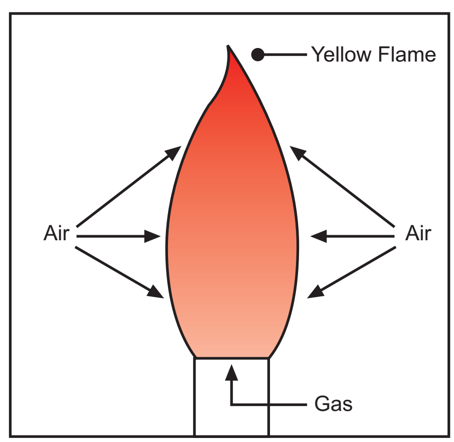
Yellow-flame Burners. As shown in Figure 2-5, the yellow-flame burner was simply a tube of port fed by gas. In this type of burner, the gas tends to burn inefficiently and forms soot (unburned carbon particles). Early in the heating industry, such burners were used and were called "luminous flame" burners because of the bright yellow appearance of the flame. Special tipped orifices were used to encourage air to unite with the gas, creating less likelihood of sooting. However, by today's standards, such flames are considered unsafe.

Blue-flame (Bunsen) Burners. The Bunsen burner was a considerable improvement over the yellow-flame burner. Figure 2-6 shows the basic design. It consists of a mixer tube equipped with an opening and shutter (for admitting a controlled amount of air to mix with the incoming gas) and an adjustable orifice for regulating the gas flow. Air that enters the burner to be mixed with raw gas is called primary air; air that enters the flame while combustion is in progress is called secondary air. The theoretically exact amount of primary air plus secondary air needed for complete combustion is called total air. In practice, some additional air is required to make sure combustion is complete. The air required over and above the ideal total is called excess air.

Air and gas mix in the body tube. The mixture burns at the end of the tube with a flame that has four zones. The most clear-cut zone is a thin bright blue cone, called the primary cone where the combustion process begins. The dark area inside the primary cone is the raw gas mixture still below the ignition temperature, having just left the mixing tube. Air around the flame enters the flame and completes the combustion, forming the darker outer cone. Finally, an almost-invisible outer glow of incandescent combustion products surrounds the flame.



2-4 Generic indirect-fired heating system.



2-5 Yellow-flame burner.

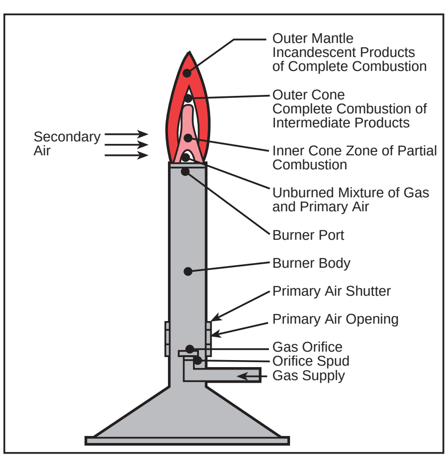
Temperatures are not the same at all points in the flame. The lowest temperature is in the unburned-gas dark zone and the highest temperature usually exists just above the primary cone tip.

Atmospheric Burners. Burners that take in primary combustion air at atmospheric pressure are known as atmospheric burners. Figure 2-7 shows the cross section of a typical atmospheric burner for gas-fired heating and identifies its 3 functional sections and their principal elements. The mixing head lets in gas through the small hole (orifice) in the orifice spud and admits primary air through large openings in the mixing-head face. Flow of air can be adjusted with shutters that slide over the air openings; in some burners the rate of gas flow can be adjusted by turning the orifice spud, in others the orifice size is fixed.

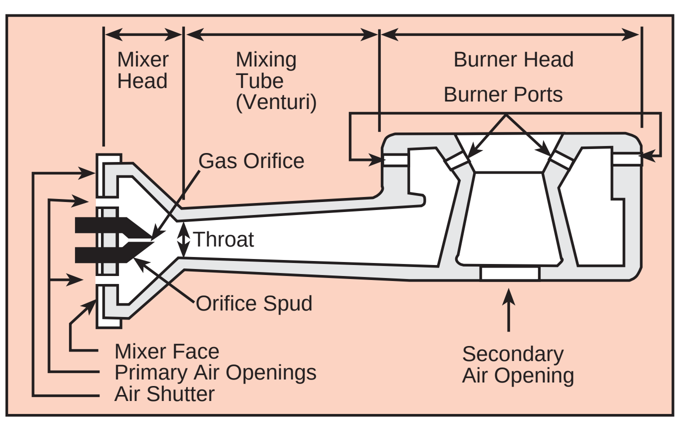
The mixing tube mixes the air and gas as it conveys them to the burning head. The mixer is tapered to create a venturi. The gas jet generates a suction that causes air to enter the burner at the primary opening, the venturi shape causes the air to flow into the mixing chamber at high velocity.

The burner head distributes the air gas mixture uniformly to many small holes called ports. These multiple ports spread the flames to provide good heat transfer and good access of secondary air to the flame; however, the primary function of the ports is to control the air-gas-mixture velocity so that the flame rests on the port.

Velocities that are too high will allow the flame to lift off the port. Conversely, velocities that are too low will often permit the flame to flash back through the port and end up in the mixing chamber.



2-6 Bunsen Burner.



2-7 Basic burner for gas-fired heaters.

Basic System Components

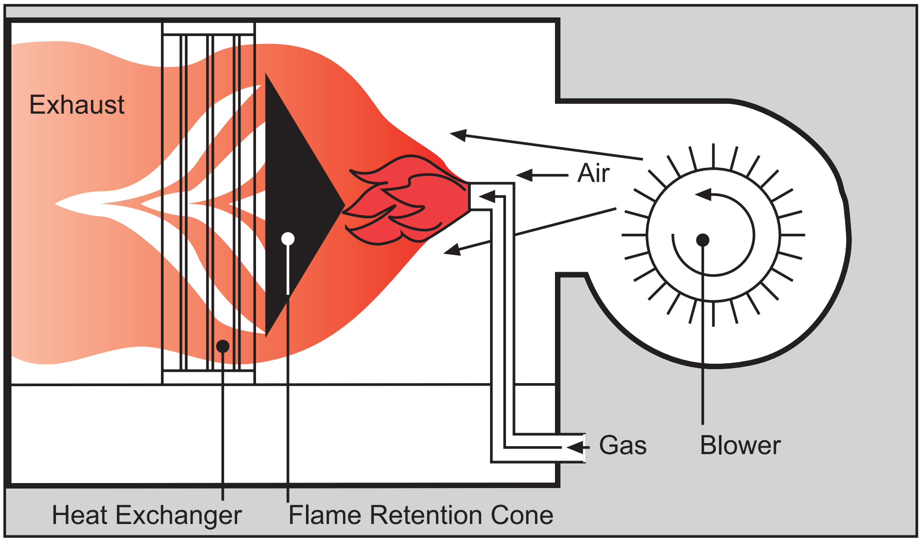
2-5 **Power Burners**. In most commercial and industrial applications, gas-fired space heating equipment employs atmospheric burners, but in some very large indirect-fired heaters (one million BTU/hour capacity and greater), burners receive their combustion air under pressure from a fan.

Forced-draft and induced-draft burners. *Forced-draft power burners* receive their combustion air at pressures above atmospheric pressure from a blower or other air source located in the burner primary air supply. (See Figure 2-8). *Induced-draft power burners* have combustion air pulled through them by a vacuum created by a fan located in the flue outlet. (See Figure 2-9.)

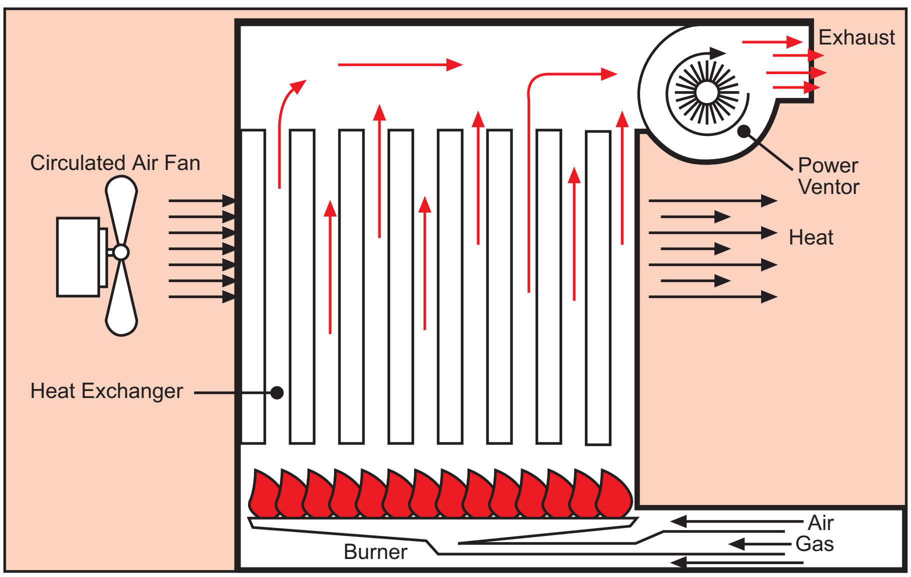
Burner Designs. Gas burners come in a great variety of shapes, sizes, and designs. There are several basic types: slotted-port, ribbon-port, single-port, impingement-target, and jet. Each type is subject to variation when designed for specific heating equipment.

Typical Gas Burners Found in Direct-fired Heaters are unique, in that they are equipped with aeration plates that are adjacent to the gas ports and they control the circulated air velocities over the burner to insure efficient burning of the gaseous fuels (Figure 2-10).

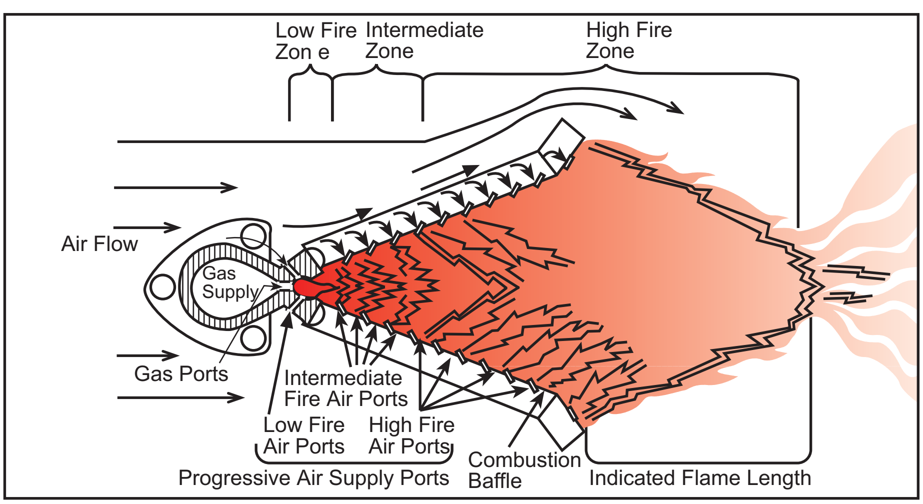
Unlike ribbon-type burners, these devices are so designed that they can burn a wide variety of gas fuels by adjusting gas pressure at the orifice.



2-8 Forced-draft burner principle.



2-9 Induced-draft burner principle.



2-10 Direct-fired burner.

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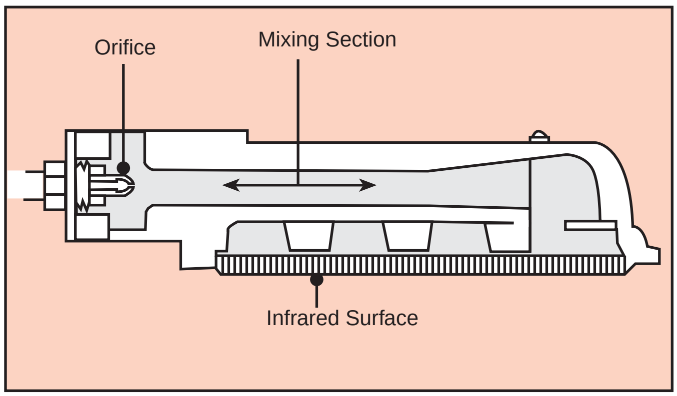
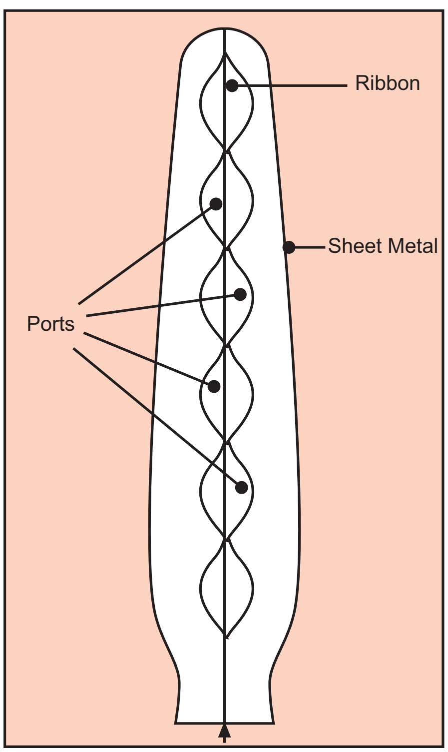
Typical Gas Burners Found in Indirect-fired Heaters are the ribbon-port type that vary in length and in port sizes, and may employ a single ribbon or many ribbons, depending on the volume of gas to be burned. Normally they are atmospherically aspirated. Usually, these burners require only primary air adjustments to operate efficiently on different gaseous fuels. (See Figure 2-11). Ribbon-type burners produce a stable flame, allowing use of a wide variety of gaseous fuels.

Typical Gas Burners Found in Infrared-radiant Heaters are:

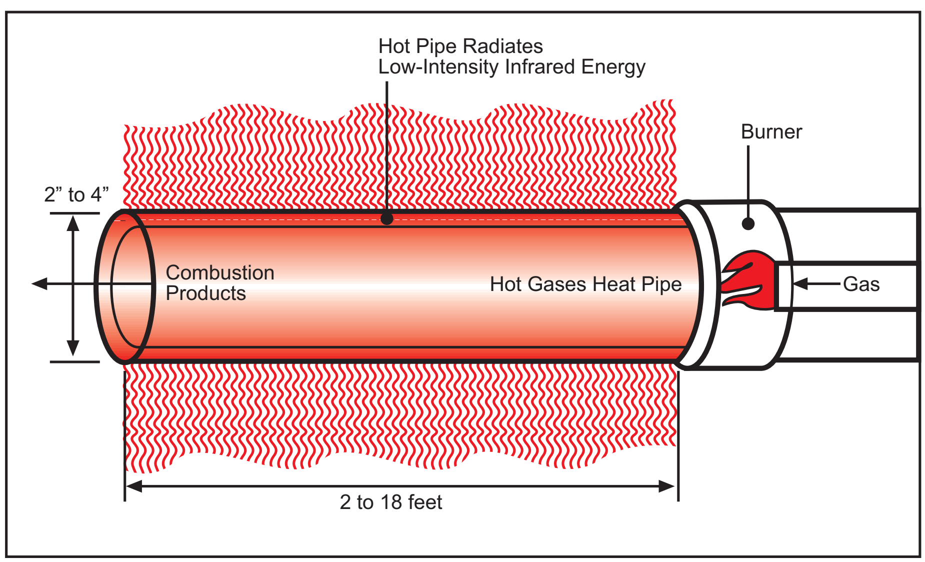
- High-intensity infrared units. These contain ceramic plates with multiple ports on very close centers. The ports are sized so that the flame is confined partially with the ports, creating extremely hot surface temperatures, usually between 1500°F and 1950°F. This surface emits infrared energy (see Figure 2-12).
- Low-intensity infrared units. These use a jet-type burner that receives its combustion air from a powered blower. The flame is contained within a tube which, when heated, emits infrared energy (see Figure 2-13).



2-12 High-intensity infrared burner



2-11 Ribbon-type burner.



2-13 Low-intensity infrared burner.

Basic System Components

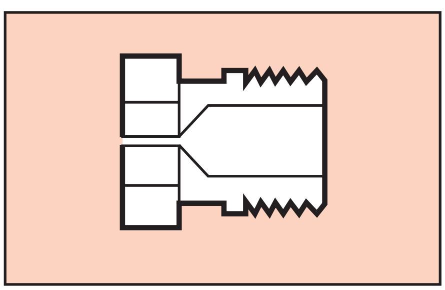
Orifices. Burner orifices (Figure 2-14) are required to meter gas to each burner or pilot at a rate determined by burner capacity, gas heating value, specific gravity of the gas, and the altitude at which the burner is installed. Orifices are machined from brass, aluminum or steel and are threaded into the gas train for easy installation and removal.

A Good Burner Flame. For most economical operation and best nonpolluting operation, the flame should be stable and have a blue center cone that is not sharply defined, with minimum yellowing in the outer cone. In any properly designed burner, this flame pattern is accomplished by a proper balance of primary air and secondary air provided in sufficient amounts to ensure complete combustion (Figure 2-15a).

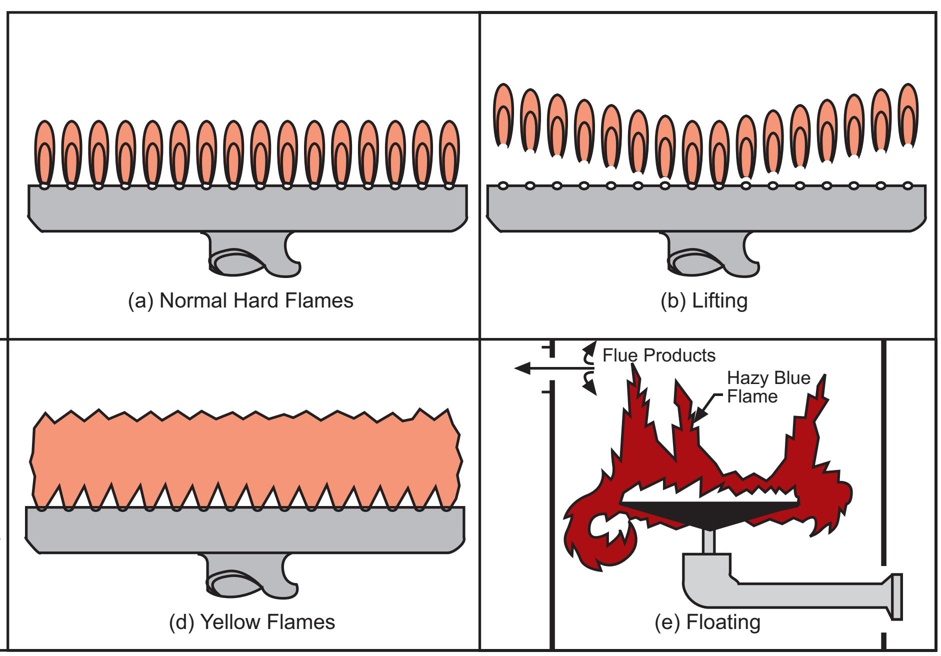
The usual signs of improper air control are lighting yellow tipping, and floating flames (illustrated in Figure 2-15). Lifting refers to the rising of the flame off the port with no incandescent gases visible between the flame and the top of the burner port. This condition is caused by too much primary air; it is easily corrected by reducing primary air flow, using the air shutter as a throttling device. Yellow tipping indicates too little primary air and can be corrected by increasing primary air flow (by opening the air shutter) until the blue inner cone becomes visible. A sever lack of primary air (or none at all) causes flames to become completely yellow. Floating describes flames that wander erratically as if blown by a soft wind. This condition results from too little secondary air.

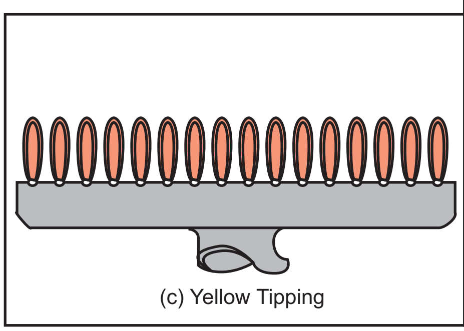
Flashback and Extinction Pop. Under some conditions, combustion can proceed backward through a burner port, resulting in a cone that inverts and extends back through the port. This flashback happens when the speed at which a gas mixture will burn is higher than the speed at which the gas mixture moves through the gas port. Natural gas does not have a great tendency to flash back because it is a relatively slow-burning fuel. Flashback will not occur during normal operation of a properly designed and adjusted burner. Turning a gas burner off can temporarily create conditions that result in a short-lived flashback--a tiny explosion known as extinction pop. This type of flashback is annoying but not hazardous, and can occur in even the best designed and adjusted burners.

Burner Operation at High Altitude. In burners operated at atmospheric pressure, altitude is an important factor because increased altitude causes air density (weight) to decrease (that is, the air becomes "thinner"). At high altitudes, therefore, the lower air density (less oxygen per cubic foot of air) results in combustion effects that are different than those at normal altitudes. For this reason, the heating system designer or equipment buyer should specify the altitude of the location where the heater will operate, if it is significantly above sea level (2000 feet altitude and higher is considered "high altitude"). The manufacturer can then make adjustments in orifice sizing to accommodate the less dense air.



2-14 Burner orifice.





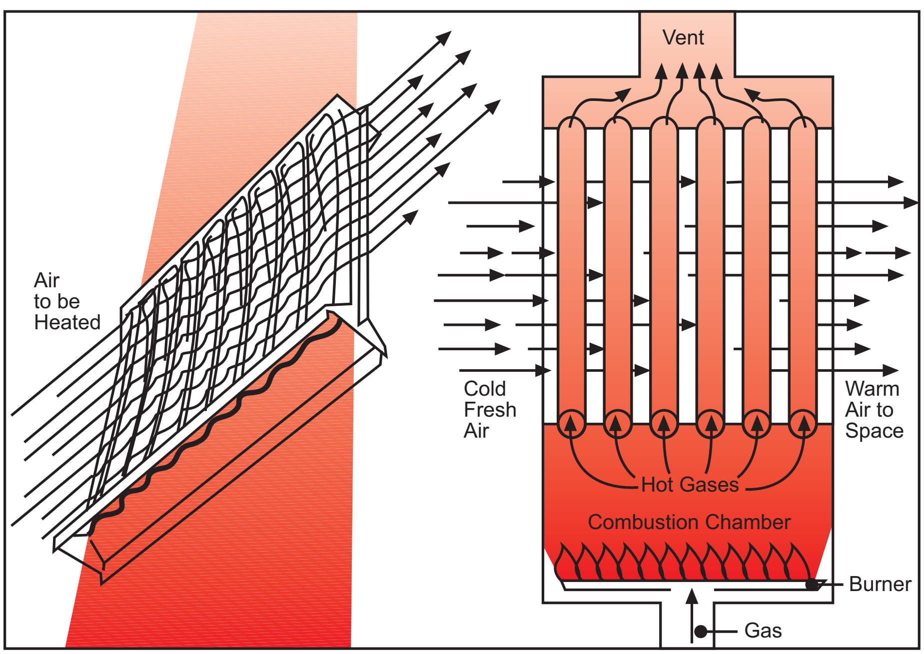
2-15 Symptoms of incorrect air adjustment or overfiring. Burner flame appearances: Good (a); Bad (b, c, d, e).

Heat Exchangers. Heat exchangers are used in indirect-fired gas space heaters. Their purpose is to provide efficient transfer of heat from the inside of the combustion chamber to the air on the outside. For good heat transfer, they have a series of tubes to provide a large surface area, as shown in Figure 2-16.

Heat exchangers see rather sever service. They are subjected to high temperatures, so they require a material that will not blister or peel. Because the heating and cooling cycle creates repeated expansion and contraction, heat exchanger material must withstand cyclic stresses. During warm-up or when the air-temperature-rise across the heat exchanger is extremely low, a heat exchanger is subjected to lower temperatures. This creates corrosive conditions that result when condensed moisture combines with combustion products. In addition, chlorine and halogenated hyrocarbons, if present in the atmosphere, can cause serious and rapid corrosion of heat exchangers. Manufacturers do not warrant their equipment when such contaminants are present.

Indirect-fired Heat Exchangers. Four materials are commonly used in today's heat exchangers: uncoated 1010 carbon steel, fused-ceramic coated 1010 steel, stainless steel, and aluminized steel. Uncoated 1010 steel is by far the least expensive but it will not adequately withstand corrosion or scaling and is not recommended for high temperatures. Fused-ceramic-coated steel has excellent corrosion and scaling resistance as long as the coating remains intact; unfortunately, ceramic coatings are somewhat brittle and may not stay intact. All things considered, stainless steels are the best, but they cost much more than the others. Type 321 stainless steel is one of the best (and costliest) heat exchanger materials available. Type 409 can provide excellent corrosion resistance at a lower cost.

Aluminum-coated steel (hot-dipped 1010) offers what is probably the best combination of serviceability and cost. It has excellent resistance to corrosion and scaling and costs considerably less than stainless steel but only slightly more than uncoated 1010 steel.



2-16 Heat exchanger.

Aluminized-steel heat exchangers can handle entering-air temperatures as low as 40°F and outlet air temperatures as high as 160°F, with a temperature rise across the heat exchanger in the range of 30 to 90°F, under normal atmospheric conditions. For lower entering-air temperatures (as low as minus 20°F) and higher outlet temperatures (above 160°F), or where corrosive conditions exist, stainless steel is the recommended heat-exchanger material. Stainless steel exchangers will tolerate high inlet-air temperatures, providing the rise through the unit does not exceed 70°F--a highly useful and desirable characteristic for some process work.

Heat Exchangers in Infrared Heaters. The heat exchanger in radiant heaters is a radiating, rather than a conducting, device.

Heat-intensity Radiant Heaters. Such heaters contain a ported ceramic block in which the flame burns within the individual ports to create extreme temperatures on the ceramic surface. Surface temperature reaches approximately 1950°F.

Low-intensity Radiant Heaters. These heaters have a metal heat exchanger which, when heated, radiates heat. The surface temperature usually does not exceed 1,000°F.

Direct-fired Units. Direct-fired equipment does not employ heat exchangers since the flame is burned directly in the circulated air.

Basic System Components

Ignition Systems. In most space heating systems, temperature is controlled by turning a fixed flame on and off rather than adjusting the size of the flame to vary the heat input to the building. Automatic gas pilot-light systems are used to ignite the heater's burner every time heat is needed. In addition, these systems have a safety feature which shuts off the gas supply to the burner if the flame at the pilot goes out (See Flame-proving Systems, page 2-10).

There are four general types of ignition systems: manual constant pilots, automatic spark-ignited pilots, automatic hot-surface direct-ignited systems, and automatic direct spark-ignited systems.

Manual Pilots. Manual systems have pilot burners that must be lighted by hand with a match and remain "on" continually, ready to ignite the main burners when the gas is turned on automatically by other controls.

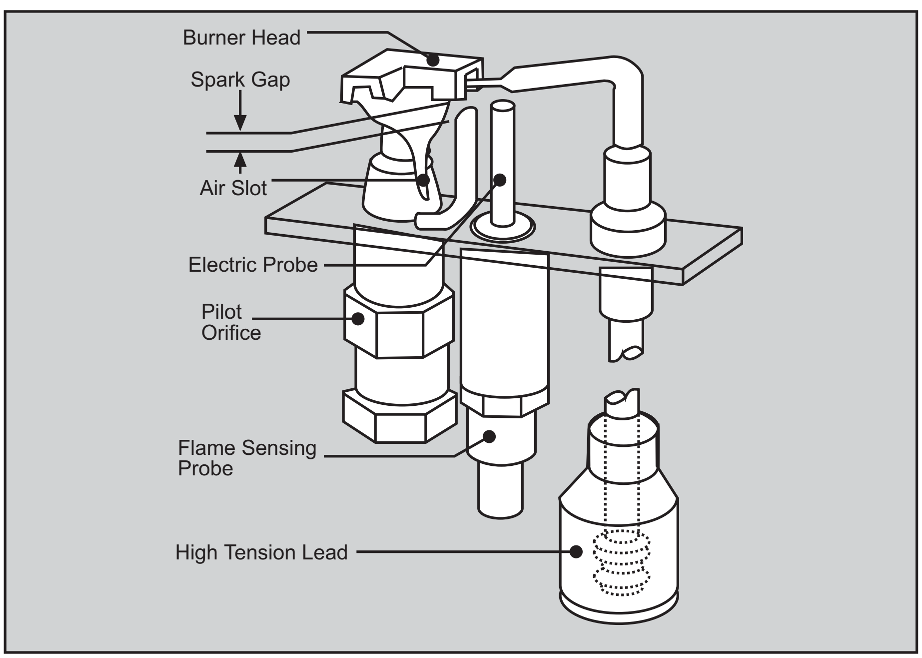
Automatic Pilots. Automatic spark-ignited pilots (Figure 2-17) are ignited first by an electric spark, then the pilot flame ignites the main burner. In a hot-surface system, an electric resistance coil heats up to a glow hot enough to ignite the pilot which in turn ignites the main burner. In automatic direct-spark-ignited systems, an electric spark ignites the main burner without the aid of a gas pilot burner. Hot-surface igniters may also ignite the main burner directly.

All four types of systems have provisions for automatic safety gas shutoff in case of ignition failure.

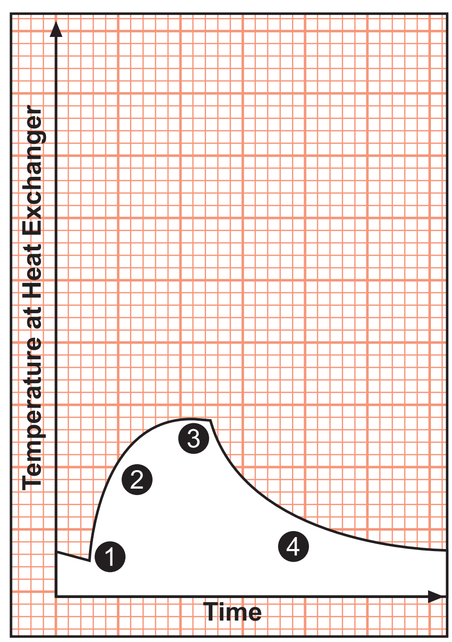
Carryover. To light the main burner, all pilots depend on the phenomenon of "carryover"--the spread of flame from one port to another. Additionally, where more than one burner is ignited from a single pilot, a "carry-over" system is employed to assure that each subsequent burner is ignited. This is done either by apparatus designed as part of the burner or is added as an accessory to the burner assembly.

Space-Temperature Controls. The purpose of a space heating system is to maintain a given temperature within a space or structure. To accomplish this purpose, space heating systems include an electrical control system which usually consists of thermostat safety controls, and related power transformer and wiring; forced air systems also include fan or blower controls.

Figure 2-18 shows a typical forced-air-system heating cycle in graph form. At point 1, the room temperature has dropped below the room thermostat's setpoint, so the thermostat contacts close, energizing the burner circuit. The combustion-chamber temperature begins to rise. After this temperature has reached a predetermined level (2) the fan cuts in. When the heated space exceeds the setpoint temperature, the thermostat contacts open and the burner flame goes out (3), but the fan continues to operate and extract residual heat from the heat exchanger. Finally, when the combustion chamber temperature cools to the point where moving air would be uncomfortable, the fan cuts out (4). This cycle repeats throughout the heating season, as needed.



2-17 Conventional pilot with spark ignitor added.



2-18 Typical heating cycle.

A number of different room temperature control options are available. The options vary from a simple system with ON-OFF control for a warehouse to sophisticated systems having a temperature-control accuracy of plus or minus one-tenth of a degree for storage of temperature-sensitive materials or laboratories where environmental conditions must be precisely controlled.

Thermostats. The thermostat is a temperature sensitive electrical switch. The most common temperature-sensitive element found in thermostats is a bimetallic strip that changes shape with temperature change. Figure 2-19 shows a basic thermostat control system and three basic types of bimetal elements used in space-heater thermostats. Attached to the bimetal element is a set of electrical contacts, constructed so that when the space temperature drops, the change in shape of the strip closes the contacts. This contact closure completes the circuit to the gas valve, opening the valve and allowing gas to flow to the burner.

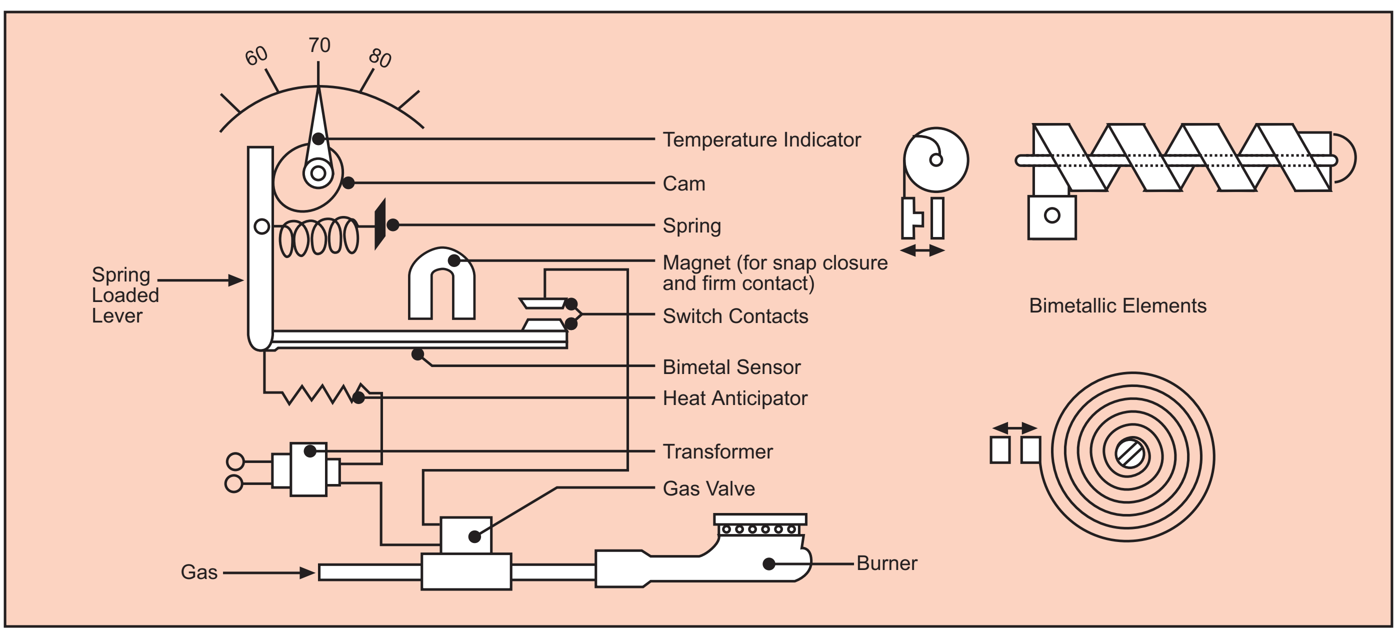
Location of Thermostats. Thermostats must be carefully located so that they detect average conditions and make the equipment respond promptly to heating requirements. Thermostats should be placed out of the path of warm discharge air and where they will not be affected by radiation from the sun, powerful lights or other heat sources.

In multiple-heater installations, individual thermostats can be used with each heater, but in some installations it may be desirable to control several heaters with one thermostat. Several types of thermostats are available to match the control options which are offered with heating equipment.

Thermostat Adjustment. Many types and styles of thermostats are in use in space heating. They can have as many as three adjustments. Normally, they can be easily adjusted from the outside of the case to set the system to the desired room temperature; this temperature is sometimes called the setpoint. Some thermostats have a compensator adjustment that can be used to prevent temperature overshoot or underheating due to the time it takes heated air to reach the thermostat. Such compensators are referred to as heat anticipators. Some thermostats also have a differential adjustment. This adjustment makes it possible to adjust the difference between the temperature at which the thermostat opens its contacts and the temperature at which it closes them. Setting this temperature difference as small as possible results in more nearly constant temperature control.

Safety Controls. Safety devices are necessary to prevent fire, explosion or damage to the heater in case of a malfunction of an operating part.

Flame-Proving Systems. A safety pilot is a device designed to prevent gas flow when ignition cannot take place. If the pilot flame is not adequate for smooth ignition, a sensing device signals a magnetically operated valve or a safety relay circuit to prevent the main gas valve from opening.



2-19 Basic thermostat system and examples of bimetal elements.

Basic Systems Components

The safety pilots now on the market may contain one of two types of sensing devices to prove the presence of flame at the pilot. The most common sensing device in use today is the thermocouple--a device that produces a low electrical voltage and current when heated. It is used in constant-pilot systems. The thermocouple is placed so that the tip is heated by the pilot flame and, when heated adequately, generates an electrical current that is directed to an electromagnet. This electromagnet may hold relay contacts closed or it may hold a manually set valve in the open position. If the pilot flame goes out, the thermocouple's output ceases--causing the relay to open or the valve to close, shutting off all gas flow to both the main burner and the pilot burner.

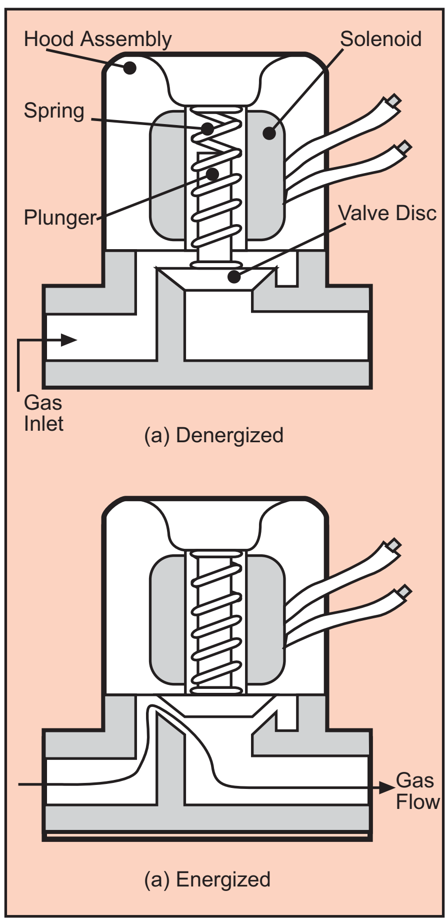
Spark ignition systems employ a sensor that does not depend on heat as the thermocouple does. In this system, the pilot-burner head and a probe near the pilot-burner head serve as electrodes that allow the pilot flame between them to be part of an electrical circuit. (See Figure 2-17). The electrical current will not flow between them through air or air-gas mixture, therefore there is no signal without a flame. When a flame appears, current flows form the probe through the flame to the pilot burner head, activating the main burner through an electronic device which in turn energizes a control relay or a solenoid- or hot-wire-operated valve.

Safety and Gas Valves. Gas valves perform two functions in gas-fired space heating equipment: temperature control and safety.

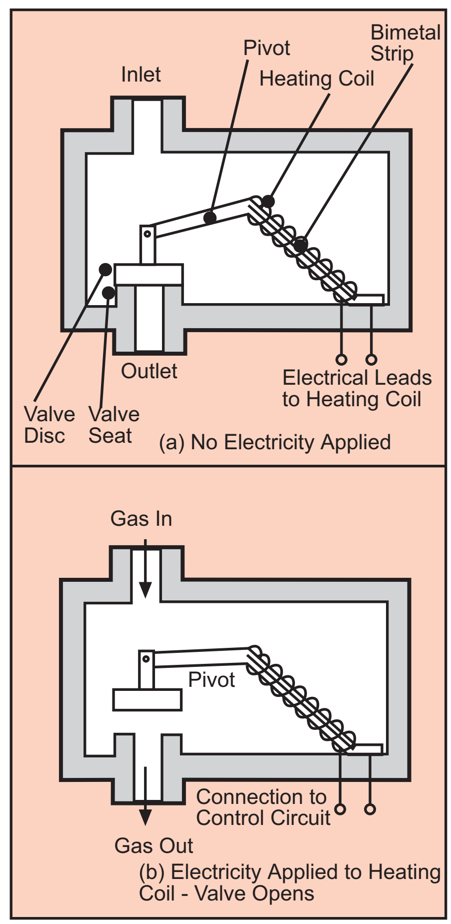
Modern space heating equipment employs an automatic or semiautomatic device for turning on and shutting off gas to the burner. This device usually consists of a valve in the gas supply line coupled to an electro-mechanical, electro-thermal or electro-pneumatic mechanism for opening and closing the valve.

Redundant valves (two safety shutoff valves in the same gas train) are currently required by ANSI (American National Standards Institute). These valves are placed and arranged to shut off the gas to the main burner and the pilot when certain conditions occur (e.g. pilot light goes out, heat exchanger temperature gets too high).

Solenoid Valves. Probably the most common type of control valve is the solenoid valve (Figure 2-20) in which an electrical coil is used to create a magnetic field to move the valve disc. When no electric current is supplied to the solenoid coil, the spring, gravity and inlet-gas pressure hold the disc in the closed position, but when current is supplied the coil's magnetic force raises the disc to the open position. As with all gas valves, this design meets the requirements for fail-safe operations, that is, in case of electric-power failure the valve closes due to action of the spring, the weight of the disc and plunger, and the pressure of the gas in the supply line. Most solenoids act quite rapidly, making a loud click on opening or closing. Some heating equipment contains solenoids having an oil bath to slow the action and soften noise. Most solenoid valves operate on either 24 or 120 volts AC.



2-20 Solenoid gas valve.



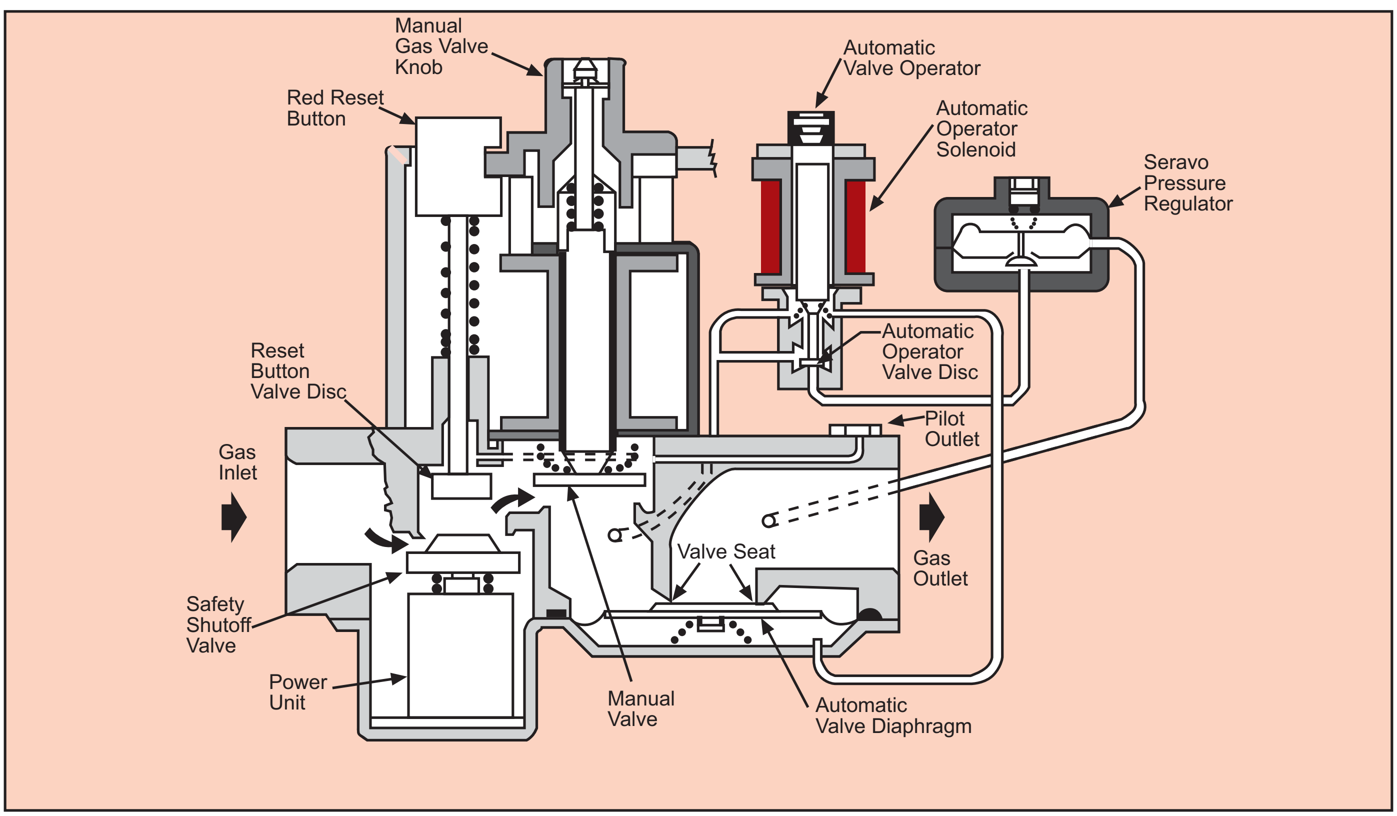
2-21 Hot-wire type of gas valve.

Hot-wire Valves. Figure 2-21 shows one type of hot-wire valve. In this type of valve, the valve disc is connected to a bimetallic strip that is straight when cold and bends when heated. As the drawing shows, the straight bimetal strip (a) holds the valve disc in the closed position when no electrical current flows through the heating coil that surrounds the strip. When current is applied to the coil, the bimetal strip bends, (b) pulling the disc up and allowing gas to flow. In this instance, the heating coil is located where it is in contact with gas. The gas cannot be ignited by the heating coil because there is no air in the gas, therefore combustion cannot take place. Other types of hot-wire valves have the heater coil mounted outside the valve body, and utilize a sealed plunger to activate the valve disc.

Motorized Valves. Gas valves for temperature control can also be actuated by an electric motor or an hydraulic power generated by an electric motor. Such motorized valves are used in gas-fired space heating equipment when inputs exceed 400,000 BTUH. These motorized valves use a heavy spring to hold the valve closed. The spring usually exerts a force of approximately 50 pounds.

Diaphragm Valves. Solenoid, hot-wire, and motorized valves require significant amounts of electrical power for operation. Diaphragm valves can be designed to operate on very low current because they use the pressure of the gas to provide the actuating force. Figure 2-22 illustrates the operating principle. The drawing shows the valve in the open (electromagnet-energized) position. For operation as a safety shutoff valve, the electromagnet needs only to hold the rather small armature in the bleed-port-closed position. In this condition there is gas pressure below the diaphragm and atmospheric pressure above it and the higher gas pressure below holds the diaphragm up, keeping the disc unseated and allowing gas to flow. If the pilot light goes out, the thermocouple stops producing a current and voltage, the magnet de-energizes, the spring pulls the armature to close the bleed port and open the bypass. This allows gas to enter above the diaphragm, equalizing the pressure on both sides, and the weight of the disc and diaphragm seats the disc and stops gas flow.

When used as safety shutoff valves, some diaphragm valves are reset manually to restore gas flow after shutoff. Most diaphragm valves are designed to open and close automatically and are sometimes used as combination control and automatic pilot safety valves.



2-22 Diaphragm valve with safety pilot control - position of gas control components during "off" cycle.

Basic System Components

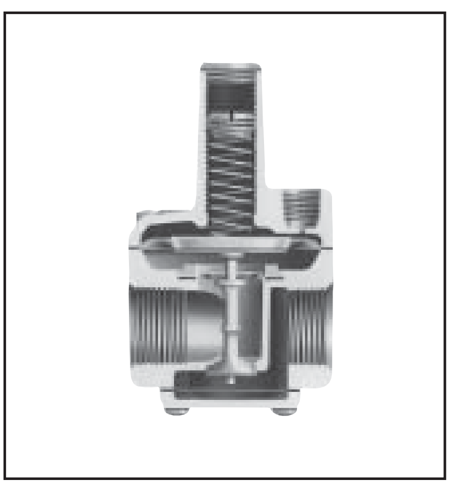
High-temperature Limit Controls. Various thermostatic devices can be used to prevent heaters from reaching abnormally high temperatures. These high-temperature limit controls usually resemble operating controls in design and principle of operation, except that they shut off the gas only when operating temperatures approach unsafe levels.

Indirect-fired Systems. The most common limit control found in indirect-fired heaters is the combination fan-and-limit switch. This two purpose device is a thermostat with 2 sets of contacts: operating contacts and limit contacts. One set turns the fan or blower on and off according to temperatures reached by the air coming out of the heater. To avoid blowing cold air when a heater first comes on, heater technicians adjust this set of contacts so the fan or blower "cuts in" only after the temperature at the heater has reached a level for comfort in the heated space. Conversely, for more economical operation, this set of contacts is set so the fan or blower does not "cut out" when the burner turns off, but remains on until the heater has cooled down somewhat. These cutin and cutout points are normally adjustable between 100 and 150° F.

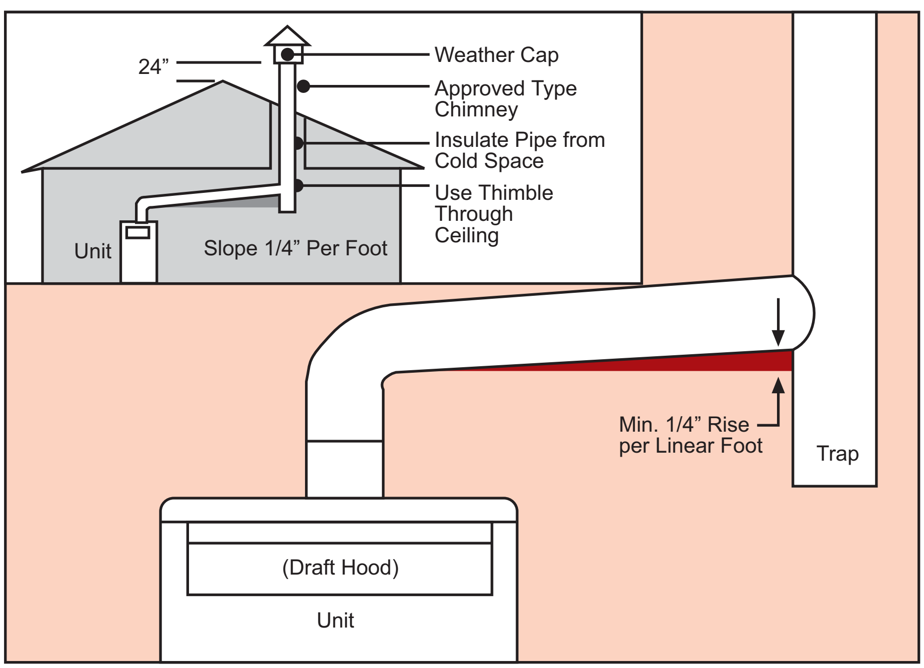
The second set of contacts on this control device protects the heater from damage from overheating. Such overheating can occur if the air flowing across the heat exchanger is interrupted or reduced appreciably. The limit contacts open the electrical circuit to the gas valve and cause the valve to close when the heater's combustion chamber or heat exchanger reaches a preset maximum temperature.

Gas-pressure Regulators. For continuously proper operation of a correctly designed and adjusted burner, the gas pressure at the burner orifice must be maintained at a given value, or within certain limits above and below a given value. Pressure Regulators are special valves used for maintaining pressure at a nearly constant level. All types of pressure regulators contain two basic parts: a pressure-standard device (spring or dead weight to which the outlet pressure is compared), and a valve with a continuously variable gas passage. The photo in figure 2-23 shows a typical regulator used in space heaters. The adjustment screw in the top of the regulator housing is used to establish the desired gas pressure to the burner by changing the pressure of the spring against the diaphragm. On indirect-fired equipment, regulators are usually adjusted to 3.0 to 3.5 inches W.C. for natural gas and approximately 10.5 inches W.C. on propane gas.

Combustion-Air Proving Switches. Power-vented units depend on combustion air as provided by a powered combustion-air blower. There are several devices that can be used to determine if this air is available to the burner. The most common is the pressure activated diaphragm switch, used on indoor equipment. This device monitors for correct air flow volume by sensing differential pressure of the air as it flows either to the burner or from the flue exhaust. Heating equipment installed outdoors usually has a sail switch in the air stream or a centrifugal switch on the blower motor, but also may employ a pressure switch as on indoor equipment.



2-23 Typical pressure regulator.



2-24 Basic vent system.

Venting Systems. The purpose of venting is twofold: 1. to remove the waste products of gas combustion; 2. to ensure efficient combustion in the heater.

Flue Products. In the case of complete combustion, the unwanted combustion products are water vapor, carbon dioxide, nitrogen, and possibly a trace of sulfur compounds. In case of incomplete combustion, the combustion-product mixture will also contain carbon monoxide. In either case these waste gases must be drawn or forced from the heater's combustion chamber and heat exchanger.

Flue Collectors. Venting is accomplished by connecting a heater's combustion section to the outer air through a ventpipe or flue. Flues are installed through the building's roof, wall or into a chimney. Flue pipes are usually made of 20-gauge, or thicker, galvanized steel, aluminum or other non-corroding metal.

A proper venting system consists of more than a pipe to discharge gases to the outdoors. An important item is the diverter, also called a draft hood (Figure 2-24). This device usually comes built into the heater or furnace by the manufacturer. However, most hot water heaters require an added draft hood. They must be supplied separately as part of the flue system and should be installed in strict conformance with the heater manufacturer's instructions. All diverters serve a number of important purposes:

1. provide a balance of draft over the burner to prevent unit efficiency from varying beyond acceptable limits;
2. prevent any down drafts in the chimney from entering the combustion zone;
3. prevent widely fluctuating wind velocities from creating varying drafts in the heater combustion chamber;
4. dilute the flue gas with interior air to reduce the likelihood of condensation in the flue pipe or chimney.

Because the condensate contains traces of sulfurous and carbonic acids, it is highly corrosive. Condensate collecting in the flue and chimney can drain back down into the heater and, in a short time, can form an acid that "eats through" the draft diverter, heat exchanger walls, and other parts of the heater.

Venting systems should be installed according to the heater manufacturer's instructions. After October 1987, venting systems have been required to be installed according to one of four categories:

Category	Burner type	Temperature above dew point
1	atmospheric	more than 140°F
2	atmospheric	less than 140°F
3	pressurized	more than 140°F
4	pressurized	less than 140°F

They should be inspected periodically for obstructions that cause improper venting and damage or deterioration that could cause improper venting or leakage of combustion products. A blocked flue will cause the release of combustion products into the area being heated. At the same time, it will reduce the intake of combustion air, causing incomplete combustion and production of carbon monoxide. The net result may be the "spilling" of combustion products containing carbon monoxide into the heated area.

Vent Dampers. Dampers have been developed to automatically close a vent during burner "off" cycles to prevent heat losses by escape of room air through the vent. Although installation of such dampers reduces off-cycle losses, on-cycle losses are not affected since the damper is driven to a full-open position during burner "on" cycles. If a vent damper is to be added to a heater vent system, the heater manufacturer should be consulted as to whether a particular damper model has been tested with the heater unit in question. Only dampers listed by AGA should be considered for use. Although AGA has certified several models for use with standing pilots, Reznor strongly advises against installing dampers on systems having standing pilots. Only a spark-ignited intermittent pilot should be used in conjunction with a vent damper.

Gravity and Power Venting. When a flue system depends on convection to draw the hot flue gases out of the heater and into the outdoors, it is said to be a gravity vent. Ordinarily, gravity vents perform quite satisfactorily, but some circumstances require power venting; that is, flue gases must be forced out under the power of an electric-motor-driven blower.

Multiple Venting. When heaters are gravity vented, more than one heater can be connected to a single vent provided the common vent is large enough. ANSI specifications should be followed for calculating the size of the common flue. Power-vented heaters should never be multiple-vented to a common flue when the system falls into category 1 or 2 in the table above. The danger is that combustion products from one heater could be forced into the heated space through one of the other heaters connected to the common flue. Venting should always follow the installation manual instructions closely.

The above discussion of venting applies to indirect-fired heating equipment only. Because direct-fired heaters allow the burned gas to mix with the air in the heated area, they are not vented but rely on fresh-air mixing with the products of combustion to meet health standards.

Selection Considerations

In applying heating equipment for industrial and commercial purposes, three factors should be considered: fuel availability, occupancy, and building function.

Fuel Availability. The first step in the process of selecting space heating equipment involves determining the fuel to be used. Obviously, if only one fuel is available, no decision is necessary. If several fuels are available and one is natural gas, the choice is made simpler because natural gas offers the best combination of ready availability, reliability, continuity of supply, low cost, nonpolluting combustion, and good control for accurate uniform heating. Where pipeline natural gas is not available, propane makes a sound alternative choice--it is a clean-burning, nonpolluting and controllable as natural gas. Although its cost may be higher on a per-cubic-foot basis, propane has a higher heating value and is competitive on a per-BTU basis.

Occupancy. A number of questions need to be answered about how the space to be heated is occupied and used. How may hours per day and how may days per week do people regularly use the space? Do the people usually sit (e.g. office) or do they engage in heavy physical work (factory?) Does the space store materials that are perishable? Does the space to be heated include sleeping quarters? (Equipment certified to ANSI Z83 must not be used to heat any space where people sleep.) Answers to these questions will determine what equipment to use, what temperature should be maintained and how much temperature variation is tolerable.

Building Function. A number of questions are related to the function, use and construction of a building. What are the dimensions of the space to be heated? What is the total window area? What is the material of construction of the walls and roof, and how are they insulated? Are walls exposed directly to outdoor conditions or are they shielded by another heated building?

The choice of type of system to best fit the job can quickly be narrowed down through the process of elimination. Can the situation use a direct-fired heater? Does the use of the space require exhaust fans to remove large quantities of air, i.e., is heated makeup air indicated or advisable? Must air or heat be distributed uniformly? Is dust removal necessary or desirable? Do different rooms or areas in the space have different heating requirements? Answers to these questions quickly rule out certain types of equipment, for example radiant heaters do not provide any dust filtration.

Application and Equipment Considerations

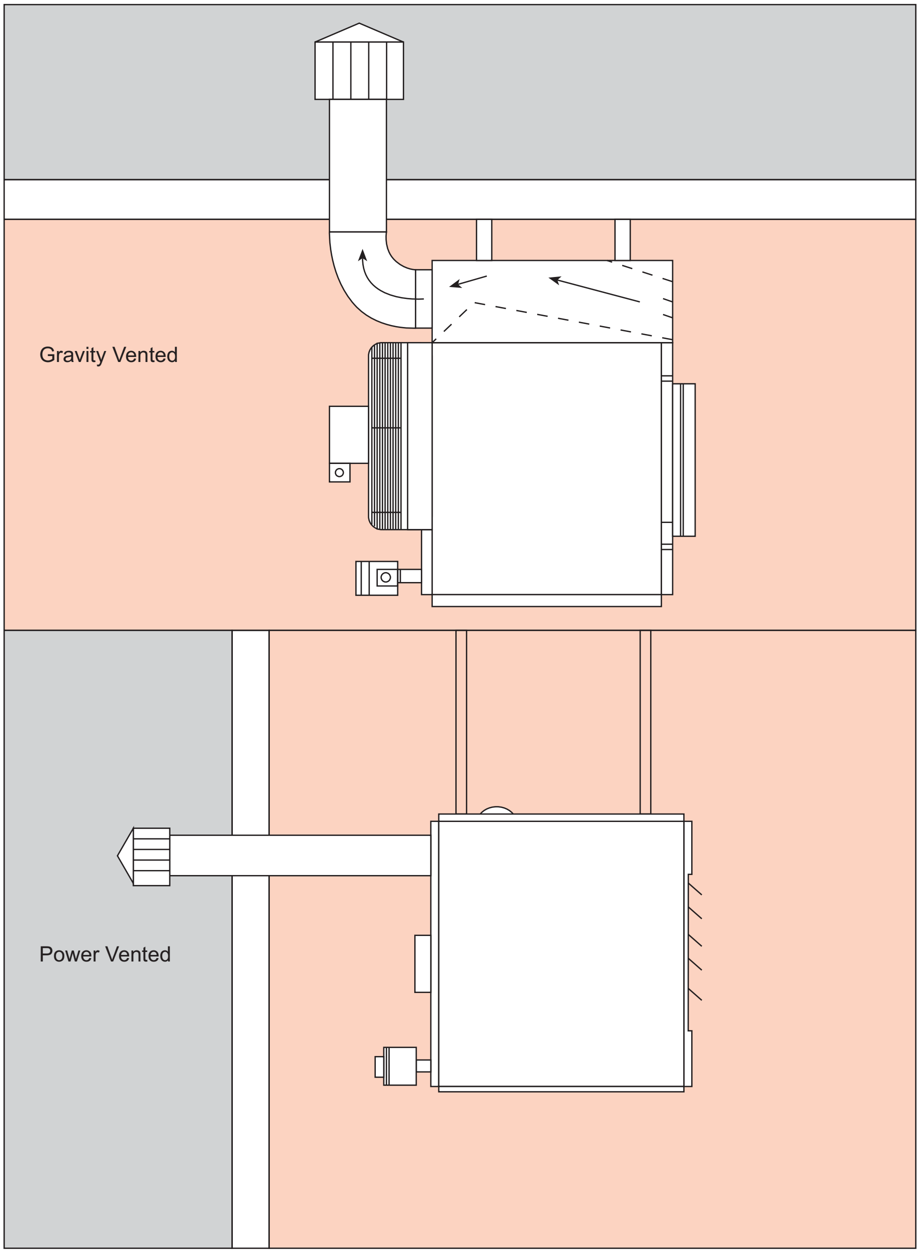
In addition to being categorized by their method of heat transfer (indirect-fired, direct-fired, radiant), heaters are categorized according to their construction-application features. Forced-air heaters fall into three types in this category: unit heaters, duct furnaces, and packaged heaters. Logically, radiant heaters could be classified as unit heaters, but the heating industry traditionally has put them into a category all their own because they are radically different in principle. There are no radiant heaters comparable to duct furnaces and packaged units.

INDIRECT-FIRED COMBUSTION

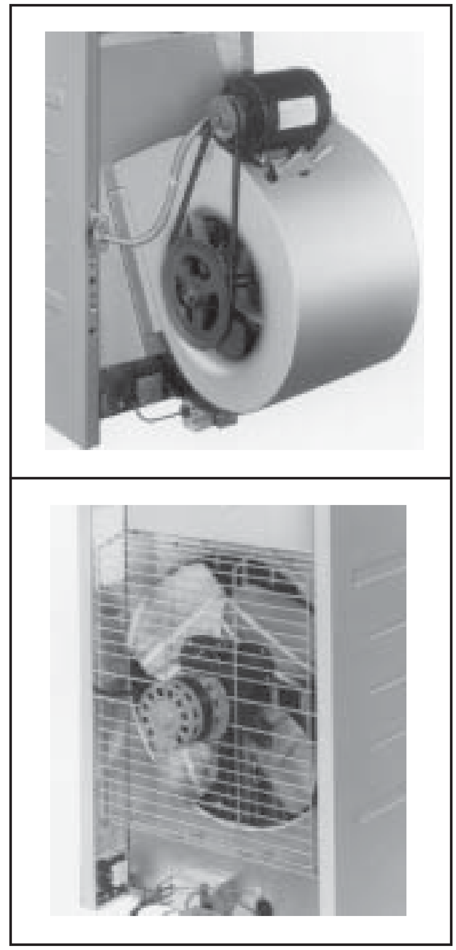
Vent Systems. Modern indirect-fired equipment is designed to operate *safely* and efficiently with single-wall vent pipe in runs 5 feet to 50 feet long. Double-wall pipe is often substituted for single-wall pipe and in many areas is required by local standards. For power-vented heating equipment, the vent pipe can run vertically or horizontally. (See Figure 3-1.) Horizontal vent pipe allows less room heat to escape through the flue than vertical pipe, saving fuel.

Gravity-vented equipment must have vertical venting, but may have horizontal runs that do not exceed 75% of the vertical flue height dimension.

The heating-equipment manufacturer's venting directions should be followed closely as to terminal arrangement, pipe size, pipe connections, pipe support, etc. All pipes must be sealed to prevent leakage of flue gas. Aluminum or Teflon tape rated 550°F service is recommended.



3-1 Vent pipes may run vertically or horizontally, depending on the type of equipment in use.



3-2 Blower-type (top) and fan-type unit heaters.

Combustion Air. Gas-fired heating equipment needs adequate air for proper and efficient combustion. For this reason, heating equipment must not be installed in tight enclosures that do not allow sufficient air volumes to enter to replace the air exhausted through the vent system. When a building's construction includes extensive insulation, vapor barriers, tight-fitting and gasketed windows and doors, and weather stripping, the need for combustion air requires the introduction of outside air through properly sized wall openings and ducts.

Under all conditions, enough air must be provided to make sure there will not be a negative pressure within the equipment room. When the space containing a gas-fired unit is confined (less than 50 cubic feet of space for each 1000 BTUH *input*), special openings must be included to permit outside air to be introduced to support combustion. Size and location of these openings are specifically described in the manufacturer's installation instruction manual.

UNIT HEATERS

The unit heater is the workhorse of commercial and industrial space heating. Unit heaters (Figure 3-2) are compact, versatile, completely self-contained, and are designed for mounting near the ceiling in the space to be heated. A wide range of facilities can be heated for occupant comfort with unit heaters: factories, garages, storerooms, supermarkets, gymnasiums, swimming-pool enclosures, auto showrooms, etc.

Indirect-fired Combustion, Unit Heaters

Fans and Blowers. Unit heaters are available with either fan-powered or blower-powered recirculated air movers. A fan is a propeller-type air mover; a blower is a centrifugal device. (See Figure 3-3.) Fans deliver air at large flow rates against low resistance. Blowers are used to distribute air through ductwork where resistance is high and lower volumes are required or to "throw" heated air a considerable distance in a ductless system. Most unit heaters employ a fan, which is cycled on and off in a sequence related to the on-and-off cycling of the burner.

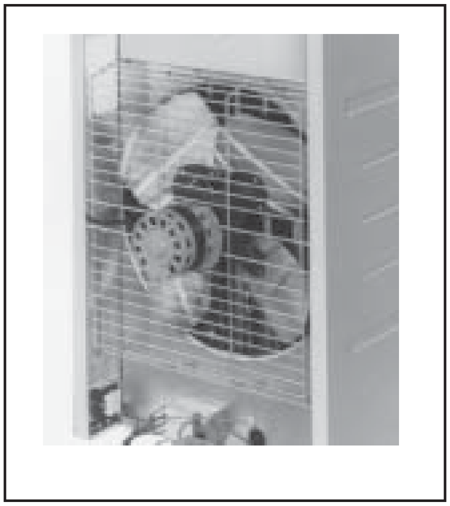
Location of Unit Heaters. Heaters should always be located as close to the ceiling as possible, within the above-the-floor mounting- height range recommended by the manufacturer for the size and design of the specific heater. Mounting at heights greater than recommended results in poor heat distribution and stratification at the floor and ceiling levels, which can cause occupant discomfort. On the other hand, mounting the units too far below the ceiling results in accumulation of warm air at the ceiling, increasing heat loss and heater operating costs. Obviously, the ceiling height is an important consideration in selecting and sizing a unit heater.

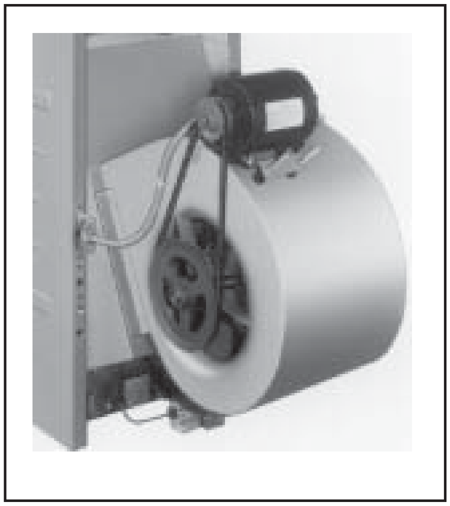
Heaters with standard horizontal louvers, mounted at a height of 8 to 16 feet, can provide adequate mixing and coverage at the floor level. Vertical mixing becomes difficult and requires careful requires careful size selection of optional vertical louvers or some other nozzle option mounted on the outlet supply air opening of the heater.

NOTE: Be certain to maintain the fire hazard clearances that are required for these units. These distances, determined through test, are found in the installation instructions and on the rating plate on the unit.

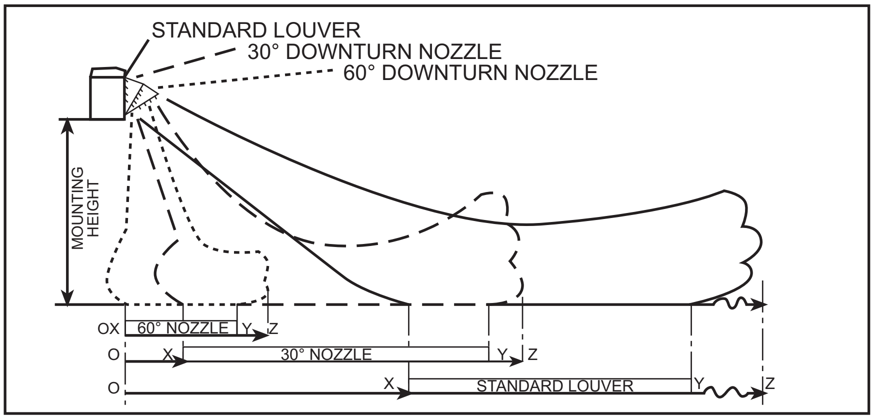
Sizing of Unit Heaters. The tables in Figure 3-4 give the approximate coverage distances in feet for fan and blower heaters equipped with standard adjustable louvers, 30° nozzles, and 60° nozzles. Once the heat loss of the building has been calculated (see Section 4), this table can help in selection of number, size and type of unit heater for the desired heating pattern and the ceiling height of the space to be heated.

Heater size should be determined according to the ambient temperature to be maintained and whether the heater will operate overnight or will be shut down. Overnight shutdown may require a larger unit heater with greater air "throw" to ensure breakup of the cold-air layer that develops at the floor during shut down. A rule-of thumb for applying the tables in Figure 3-4 for overnight shutdown conditions is to assume a mounting height 2 feet greater than actual for each 5 degrees that the start-up ambient temperature is below 50°F.





3-3 Propeller-type fans (left) are more common on unit heaters than centrifugal blowers (right)



NOTE:
O-X = Feet from heater to start of floor coverage
O-Y = Feet to end of floor coverage
O-Z = Feet to end of throw (50 feet per minute velocity).
Table data based on louvers set at maximum deflection.

Mounting Height to Heater Bottom	Heater Size																	
	125			165			200			250			300			400		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
	With Standard Horizontal Louvers																	
8 ft	14	24	65	14	35	75	13	38	83	12	44	94	12	36	105	12	55	118
10 ft	16	22	58	16	32	72	15	36	78	15	40	88	14	38	96	14	53	112
12 ft	18	20	54	18	30	66	17	34	72	17	38	84	16	35	90	16	49	108
14 ft	--	--	--	--	--	--	20	31	68	19	33	77	18	30	85	18	45	100
16 ft	--	--	--	--	--	--	--	--	--	22	30	72	20	27	80	20	40	92
18 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	23	35	85
	With Downturn Nozzle with 25-65 degrees Range of Air Deflection (30 degree Nozzle)																	
10 ft	10	22	28	10	24	33	10	31	45	8	40	53	8	38	51			
12 ft	13	18	26	12	22	30	12	29	43	10	38	50	10	36	48	10	50	70
14 ft	16	16	22	15	20	25	14	26	40	12	36	47	13	34	44	12	47	66
16 ft	--	--	--	--	--	--	16	23	36	14	33	42	15	31	40	14	43	62
18 ft	--	--	--	--	--	--	18	20	30	16	28	36	18	26	34	16	38	58
20 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18	34	53
22 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	21	30	46
	With Downturn Nozzle with 50-90 degrees Range of Air Deflection (60 degree Nozzle)																	
12 ft	0	8	20	0	8	22	0	8	25	0	12	30	0	10	28			
16 ft	0	10	18	0	10	20	0	10	23	0	14	28	0	12	26	0	12	32
20 ft	0	14	16	0	14	18	0	12	21	0	16	26	0	14	24	0	14	30
24 ft	--	--	--	--	--	--	0	14	18	0	18	24	0	16	20	0	16	28
28 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	18	26
32 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	20	24
36 ft	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	22	22

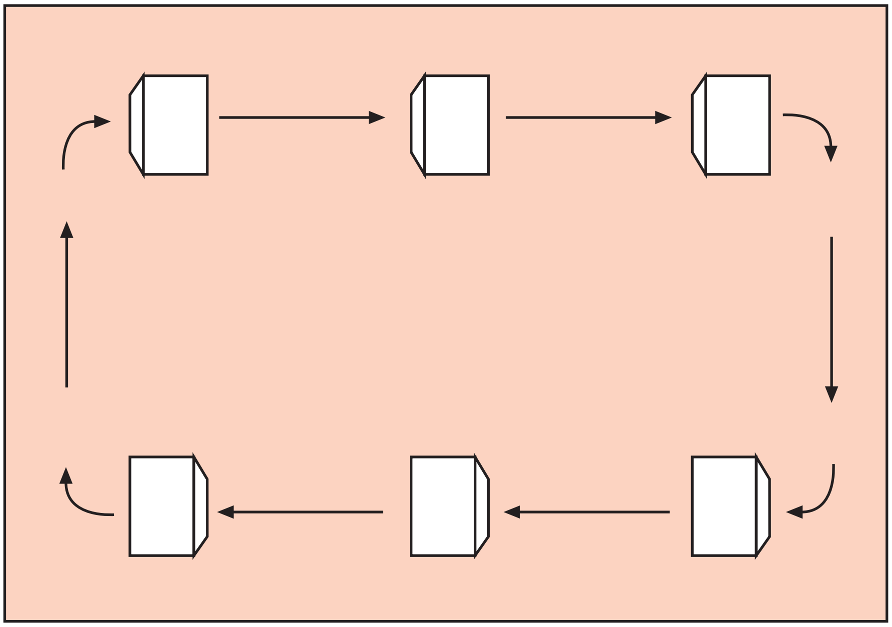
NOTE: Data based on 80° entering air and 60° rise through unit, standard louver effective as indicated when ceiling height above heater is not over 4 feet. For high mounting or where spot heating is required, choose outlet and mounting height giving coverage to floor. Mounting close to ceiling provides maximum heat utilization.

3-4. Unit-heater throw pattern and capacity tables. Such tables can be used for selecting heater sizes and locations.

Indirect-fired Combustion, Unit Heaters

Multiple-unit Heaters. Most commercial and industrial spaces require more than one heater for both adequate heating capability and properly uniform heat distribution throughout the heated space. Multiple heaters should be located and spaced so that the air stream "wipes" the outer walls as it moves in a circular pattern around the space. See Figure 3-5. For minimum turbulence, uniform heating, and proper air flow through the space, the airflow pattern of each heater should overlap the pattern of the heaters adjacent to it, as suggested in Figures 3-6, 3-7, and 3-8.

3-5

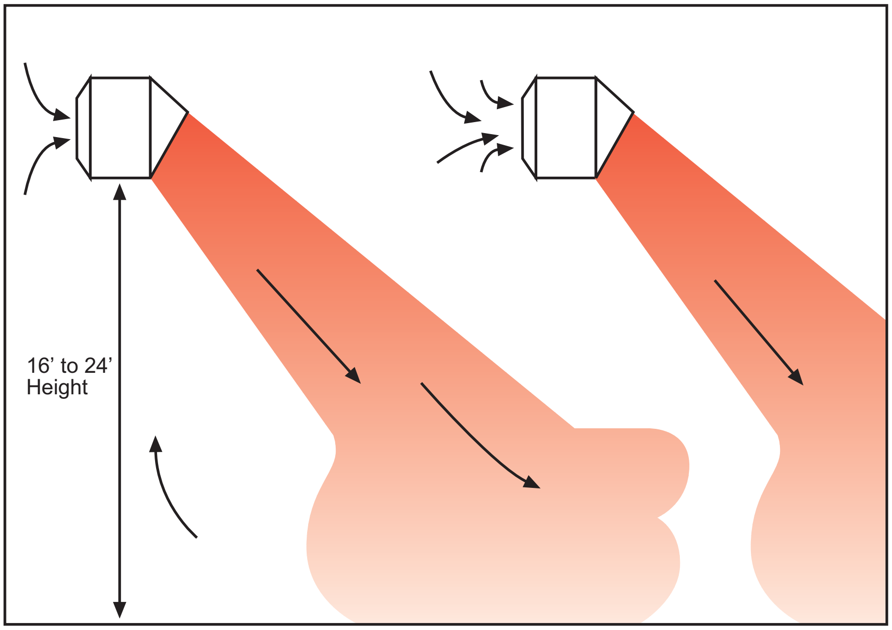


3-5 Air flow of simple multiple-heater system (plan view).

Paddle Fans. Most unit heaters now on the market are designed to drive heated air down from fairly high ceilings. But, even with downturn nozzles, these heaters may not force the air down to the floor from excessive heights. When units are unable to drive air down to floor level, paddle fans (also known as ceiling fans) can be used to help push hot air down to reduce the temperature difference between floor and ceiling.

NOTE: When used in conjunction with atmospheric unit heaters, paddle fans must be located so as not to affect the drafthood relief opening.

Paddle fans can work effectively from heights up to 80 feet. With paddle fans as part of the air-circulation system, unit heaters can be mounted at any height that does not interfere with headroom. Unit heaters and paddle fans working together can reduce fuel consumption by as much as 30% and create a more comfortable heated environment.



3-6 Throw pattern with 30° outlet nozzles (side view).

Unit Heater Controls. In unit heater applications for small areas (or multiple unit heaters for larger open areas) individual room thermostats for ON-OFF operation provide an adequate and simple means of control. Unit heaters are available with summer/winter switches to permit fan operation without burner operation during warm weather when only air circulation is desired.

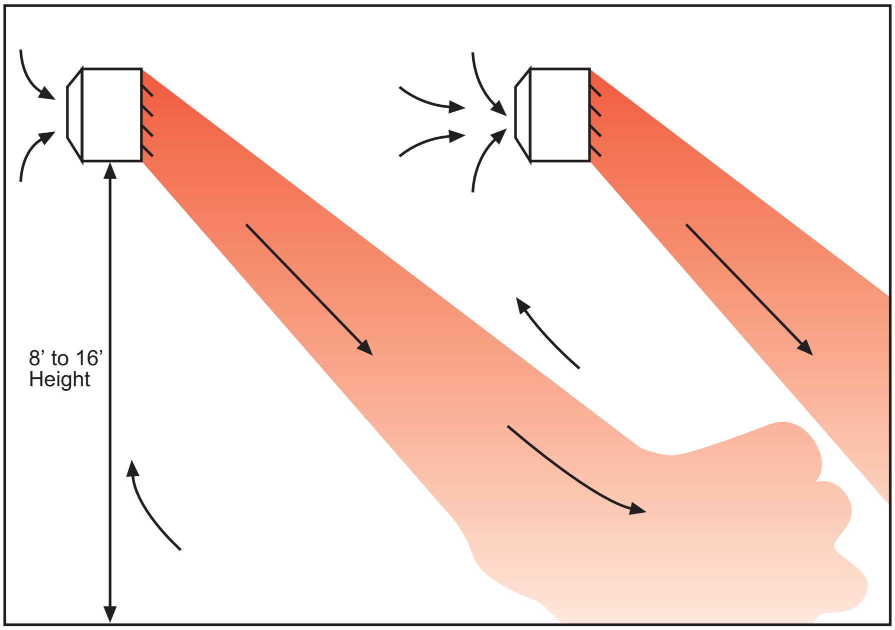
Pilot-ignition Control Systems. Unit heaters contain one of the following types of ignition systems:

1. Manual match-lit gas pilot with 100% shut off;
2. Spark-ignited intermittent gas pilot;
3. Spark-ignited gas pilot with timed lock-out;
4. Direct spark--an electrical spark ignites the main burner;
5. Hot surface ignited gas pilot;
6. Hot surface ignited main burner.

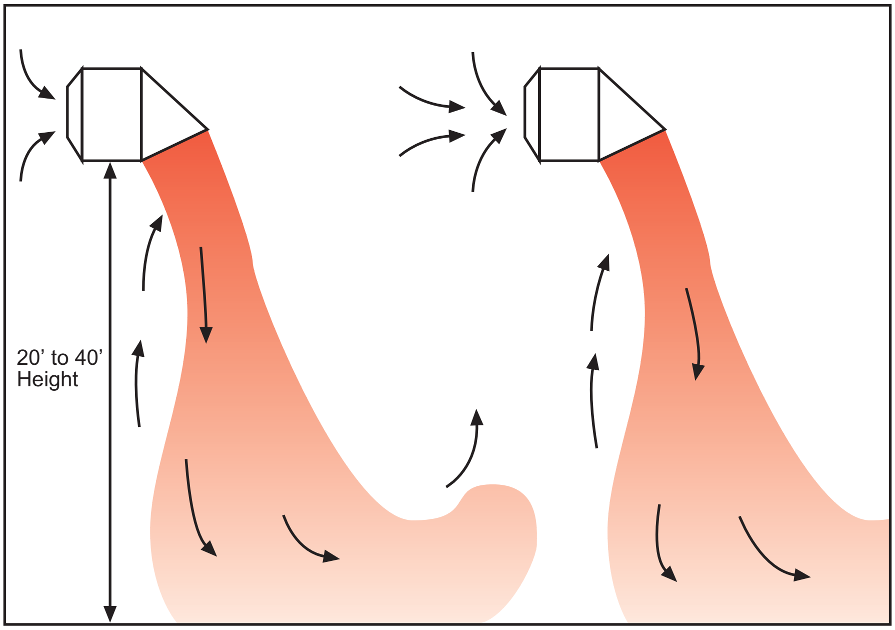
Gas-control Systems. Unit heater gas-control systems may contain a single-stage gas valve (which provides full fire on a call for heat) or a two-stage valve (which fires at either 100% or approximately 50% as required by a remote two-stage thermostat).

Unit Heaters in Low Ambient Temperatures. Gas equipment for indoor use is designed and tested for ambient temperatures of about 70°F. When such equipment is put to use at significantly lower temperatures, unusual performance (and sometimes equipment damage) may occur.

The lower the ambient temperature, the more likely problems are to arise. First, trouble with the fan operation may show up at about 60°F or below. The fan switch may cycle the fan during the heating cycle: when the fan first comes on in answer to heat demand signals, the low entering-air temperature may cool the fan-switch thermostat below the fan cutout temperature, shutting the fan off; then, with the fan off the thermostat element warms up again and restarts the fan. This on-and-off cycling every few seconds may persist as long as the incoming-air temperature remains at 60°F or less.



3-7 Throw pattern with standard louvers (side view).



3-8 Throw pattern with 60° outlet nozzles (side view).

More serious, less obvious trouble may occur if the ambient temperature is controlled to even lower temperatures like 50°F or below. Condensation may occur inside (combustion side) of the heat exchanger. The most common site for such condensation is at the top of the exchanger and on the side nearest the fan. This condition will eventually corrode the heat exchanger wall because an acid forms by chemical reaction between the condensed water and the combustion products. The acid will actually eat holes in the exchanger wall, rendering the unit unsafe.

A third possible problem resulting from low ambient temperature is that automatic spark-ignited pilots may be slow to light. With the combination of low ambient and low stack temperatures, a downdraft can occur over the burner and pilot, cooling the pilot and igniter sufficiently to interfere with ignition. After long shutdowns, the pilot may fail to light altogether and may require manual resetting if the igniter is the lockout type. Gas sometimes diffuses out of the pilot tubing over a long period and the ignition system can go into lockout before the air can bleed out of the pilot tubing. Lockout systems of more recent design have longer timing (120 seconds) that should preclude this problem from occurring. There are few remedies for these problems when equipment is already in place. However, they can be avoided if low ambient temperature is anticipated in the selection of the heating equipment. To avoid the corrosion problem, the buyer should insist on a stainless steel heat exchanger. The buyer should specify that the thermostatic fan switch have a manual override switch to make the fan run continuously when necessary. The fan cycling problem can also be solved with a time-delay relay whose contacts are wired in parallel with the fan control contacts.

Duct Systems for Unit Heaters. As most commonly applied, unit heaters are fan models and are not suitable for connection to duct systems, however blower models may be equipped with limited ductwork. The limitations are generally controlled by available static pressure as it relates to the air volume in use. For information about sizing duct systems, see page 4-8.

Duct Furnaces

Heaters specifically designed for use with duct systems (Figure 3-9) are called duct furnaces. Although duct furnaces are designed for forced-air circulation only, manufactures supply them without blower and filter sections which must be selected and purchased separately or provided as part of the air-distribution network. Duct furnaces are available for installation indoors or outdoors, depending on their design and their certification through national standards tests.

Combustion Air. Duct furnaces are available only as indirect-fired models. Although combustion products are separated from the heated air, combustion air is usually supplied from the heated space on units installed indoors. When the heated space contains contaminants, combustion air should be drawn from outdoors through special air-intake ducts (see separated combustion application, page 3-22).

3-9 Typical duct furnace.

Duct Systems. A duct furnace is a part of a rather complex air heating and distribution system. For efficiency and satisfactory heating results, its selection must be coordinated with the rest of the system. In other words, the furnace, blower, filters, and the duct network should be designed and engineered to work as a system for the specific structure or facility to be heated.

Airflow and Heat-distribution Considerations. Basically, a duct furnace must meet two requirements. It must have sufficient heating capacity to offset the heat loss of the structure to be heated; it must be capable of transferring its heat at a sufficient air flow rate. Manufacturers provide technical data giving relevant ratings of thermal input and output capacity and maximum and minimum airfoil rates. The table in Figure 3-10 is an example of such data for ONLY ONE STYLE of duct furnace. The requirements for airfoil capacity depend on the structure and the design of the duct network of which there are an infinite number of possible variations. Manufacturers' installation instructions should be reviewed because they recommend types of duct connections for good air coverage of the heat exchanger.

Duct furnaces must always be installed downstream from the blower. National Standards do not permit upstream installation because the negative pressure at the heat exchanger could contaminate the room air with combustion products if the heat exchanger develops a crack. Moreover, cracks are much more likely in a "pull-through" system.

Bypass Ducts. Some duct furnaces require bypass ducts to avoid unnecessary pressure drop through the heat exchanger when large volumes of air must be circulated, especially in combination heating/cooling systems.

Insulation. Warm air ducts should not come into contact with masonry walls or be otherwise exposed to cold surfaces. Ducts that pass through masonry walls should be covered with insulation of 1/2 inch thickness or more. Ducts that pass through unheated space should also be covered with insulation that is at least 1/2 inch thick.

Controls. Duct furnaces contain one of five types of ignition systems:

1. Manual match-lit pilot with 100% shut off;
2. Spark-ignited intermittent safety pilot;
3. Spark-ignited safety pilot with timed lockout;
4. Direct hot-surface-ignition of main burner with timed lockout;
5. Direct spark ignition of main burner with timed lockout.

Gas-control Systems. Duct furnaces may be equipped with any of several gas-control systems:

1. Single-stage control--a single stage gas valve (which provides full fire on a call for heat);
2. Two-stage control for heating applications--a two-stage valve (which fires at either 100% or approximately 50% as required by a remote two-stage thermostat);
3. Two-stage control for makeup-air applications--a two-stage valve (which fires at either 100% or approximately 50% as required by a two-stage duct-mounted thermostat);
4. Electronically modulated control for heating applications--close temperature control with solid-state circuitry that smoothly varies the gas input between 50% and 100% of the unit's rated capacity, as required by a call for heat from a wall-mounted room sensor. Such systems may or may not be certified for use with propane gas;
5. Electronically modulated control for makeup-air--close temperature control with solid-state circuitry that smoothly varies the gas manifold pressure between 50% and 100% firing, as required by a call for heat from a unit-mounted duct sensor (such systems may or may not be certified for use with propane gas);

SIZE	75	100	125	140	170	200	225	250	300	350	400
BTUH input	75,000	100,000	125,000	140,000	170,000	200,000	225,000	250,000	300,000	350,000	400,000
Thermal Output Capacity	60,000	80,000	100,000	109,200	132,600	156,000	175,500	195,000	234,000	273,000	312,000
Full Load Amps (115V)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Full Load Watts	120	120	120	120	120	120	120	120	120	120	120
Unit Control Amps (24V)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Maximum CFM	1850	2465	3085	3455	4195	4935	5555	6170	7405	8840	9875
Minimum CFM	615	820	1030	1150	1395	1645	1850	2055	2470	2880	3290
Net Weight (lbs)	104	104	126	128	150	172	194	216	262	306	328
Shipping Weight (lbs)	128	128	142	144	168	192	216	240	292	338	362
Gas Connection (in)	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3/4	3/4	3/4
Venter Outlet Size (in)	4	4	4	4	4	4	5	5	6	6	6

3-10. Example of a duct-furnace capacity and air-flow table.

Indirect-fired Combustion, Duct Furnaces

6. Electronically modulated control for makeup air with remote temperature selection--close temperature control with solid-state circuitry that smoothly varies the gas input between 50% and 100% of the unit's rated capacity, as required by a call for heat from a unit-mounted duct sensor which can be set for a desired temperature from a remote selector (such systems may not be certified for use with propane gas).

   NOTE: Electronic modulation is available for both direct-fired and indirect-fired equipment. Check the manufacturer's specifications for availability with certain gaseous fuels;

7. Mechanically modulated control--a nonelectric, capillary-actuated system which smoothly varies the gas manifold pressure between 50% and 100% firing as required on a call from a thermostatic sensor. This system cannot be used on power-vented equipment unless the air mover is operated continuously.

Duct Furnaces in Drying Applications. Duct furnaces are used for drying in some industrial processes. In each such application, a certain amount of ventilation and exhaust is needed to carry away the moisture driven from the material being dried. Practice has shown that, for most applications, ventilation (makeup air) should be approximately 105% of the total volume of heated air.

Sizing of the furnace is important to ensure both efficient and timely drying. The furnace must supply sufficient heat to offset the normal radiational heat losses of the drying oven as well as to dry the material. In addition, allowance must be made to heat the air added for ventilation to provide the 10% ventilation required to remove the process moisture, the total of oven BTU losses and the drying BTU losses should be multiplied by a factor of 1.30 as shown by the formula below. The result is the total number of BTUs needed to complete the drying process in one hour.

$$H = 1.30\,(0 + D)$$

where

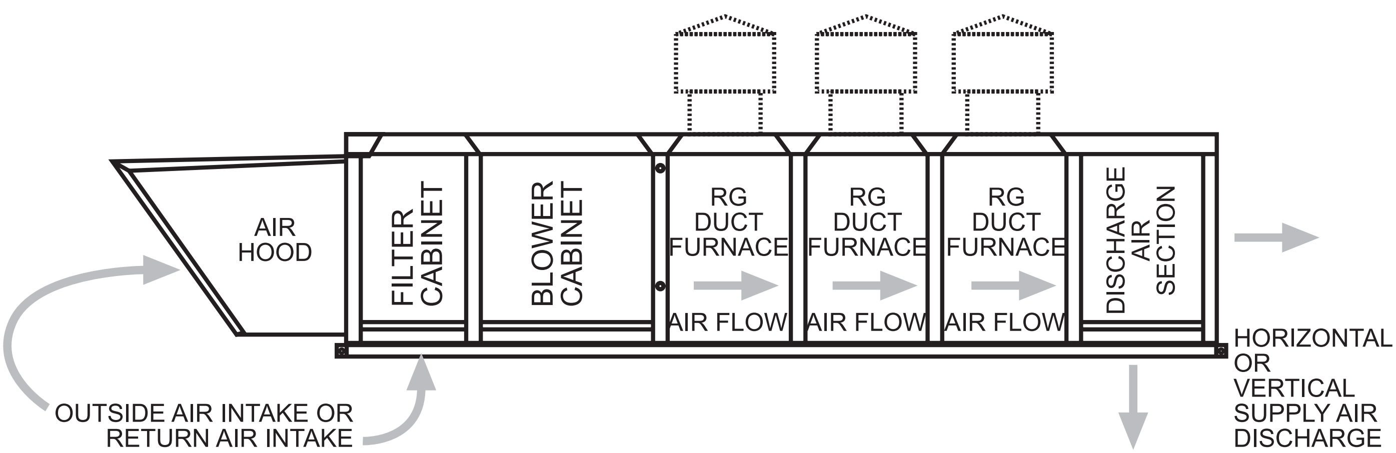
O = Oven radiational losses in BTUH

D = BTUH required to dry material

H = Total BTUH required to complete drying in one hour, including 10% ventilation.

For drying times other than one hour, ventilating and oven-loss requirements are reduced or increased proportionally for the drying time desired, but the drying-heat requirement is not changed because the heat required to dry a given batch of material stays the same regardless of the drying time. The following example shows the complete calculation of required furnace size for 1/2 hour drying time:

Drying oven losses	=	5,000 BTUH
Heat required to dry material	=	40,000 BTUH
Heat requirement	=	165,000 BTUH
Multiplier to add ventilation	=	x1.3
Total heat requirement	=	214,500 BTUH



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Heat required for ventilation (214,500 - 165,000)	=	49,500 BTUH
BTUs required to dry material in 1/2 hour:		
Drying oven losses = 25,000 x 0.5	=	12,500
Heat required to dry material	=	140,000
Heat for ventilation = 49,500 x 0.5	=	24,750
Total BTUs for 1/2 hour drying time	=	177,250
Output Required:		
Total BTUs for 1 hour = 177,.250/0.5	=	354,500
Furnace capacity required = output/efficiency	=	354,500/0.77
	=	460,389 BTUH

PACKAGED UNITS

Packaged units are complete, pre-engineered forced-air heaters (Figure 3-11) consisting of one or more duct furnaces, with blowers and filters in appropriate cabinet enclosures, complete with air-duct, gas-supply and vent-pipe connections. Manufacturers offer a wide variety of factory-installed and field-installed accessories and options. Most packaged heaters are available for use with either natural gas or propane, in heat input capacities ranging up to 1,200,000 BTUs per hour. Packaged units are available as both indirect-and direct-fired models.

Packaged heaters (Figure 3-11) are available in models for indoor, outdoor, and rooftop installation. They are used for conventional indoor heating or for the heating of makeup air in heating systems of schools, churches, office buildings, shopping centers, laboratories, and a variety of industrial buildings.

Combustion Air. Indoor indirect-fired packaged systems normally draw combustion air from the heated space. Outdoor and rooftop systems draw combustion air from outdoors.

Duct Systems. A packaged unit is a part of a rather complex air heating and distribution system. For efficiency and satisfactory heating results, it is designed by the manufacturer so the furnace, blower, filters and ducts operate as a system. A packaged unit should be carefully selected to match the specific structure or facility to be heated, and a proper duct network should be designed for it. Two important selections are the horsepower and drive to be used. These choices are based on the air flow rate (CFM) and total static pressure (inches, W.C.) involved in the system. Each manufacturer publishes performance data charts or curves for making these selections.

Insulation. Warm air ducts should not come into contact with masonry walls or be otherwise exposed to cold surfaces. Ducts that pass through masonry walls should be covered with insulation of 1/2 inch thickness or more. Ducts that pass through unheated space should also be covered with insulation at least 1/2 inch thick. Usually, the packaged unit has been insulated by the manufacturer according to its end use or its location. (Outdoor units are always insulated--indoor units may be insulated upon request.)

Filter Requirements. Package systems have filter sections ahead of the blower sections to remove dust particles from the air stream. These filters are usually 1 or 2 inches thick, and come in both throwaway and washable types. Bag filters and other special types are available for high filtration rates.

Filters should be replaced or washed frequently because filters, especially dust-laden filters, offer considerable resistance to air flow. Dust and lint accumulation can double the original airflow resistance of a clean filter.

Filter resistance is the largest single varying resistance in a duct network. It should be included in airflow calculations in designing ductwork for a packaged system.

Heating-only Use

Sizing. If a single unit is to be used to supply all the required BTUs to the space, the total heat loss of the space must be divided by the efficiency of the unit to be used to determine the heat input.

(Load/Efficiency = Input)

The efficiency is usually listed in the manufacturer's specifications.

Pilot-ignition Control Systems. The furnaces of packaged systems may be equipped with one of six types of pilot ignition systems:

1. Manual match-lit pilot with 100% shutoff;
2. Spark-ignited intermittent safety pilot;
3. Spark-ignited safety pilot with timed lockout;
4. Direct spark of main burner (with timed lockout).
5. Hot surface ignition of gas pilot (with timed lockout);
6. Hot surface ignition of main burner with timed lockout.

Indirect-fired Combustion, Packaged Units

Gas-control Systems. Packaged systems for heating-only use may be equipped for one of three types of gas control:

1. Single-stage control--a single-stage gas valve (which provides 100% fire on a call for heat);
2. Two-stage control--a two-stage valve which fires at either 100% or 50% as required by a remote two-stage thermostat;
3. Electronically modulated control--close temperature control with solid-state circuitry that smoothly varies the gas input between 50% and 100% of the unit's rated capacity, as required by a remote electronic sensor. Most of these systems are not certified for propane gas.

Air Controls. In packaged systems, a heat sensitive device turns the blower on and off when the heat exchanger temperature reaches a preset temperature, normally about 125°F. This control provides a delay on startup (to prevent blowing cold air) and a delay after burner shutdown (to extract residual heat).

Heating and/or Makeup Air Use

Makeup Air. In some facilities, fairly large amounts of air are lost to the outside either through an exhaust fan used to remove smoke, fumes, dust or objectionable odors and undesirable gases or vapors from a process (e.g. restaurant kitchen range and oven hoods) or by the nature of the operation (e.g. large doors remaining open for passage of railroad cars or trucks). Air brought in from outdoors to replace the lost air is known as makeup air. Packaged units are frequently used to supply heated makeup air.

Sizing. When a unit is to be used to introduce makeup air *and* provide the heat required to offset radiational losses of the building, the volume (CFM) of air to be introduced provides one load while the radiational loss of the building provides a second load. These two BTUH input loads must both be accounted for to properly size the unit. A convenient formula for determining the BTUs required to heat the outside air, is as follows:

HR = (MAX 1.085 X T) / E

where

HR = Heat required for unit (BTUH)

MA = Makeup air (CFM)

T = Indoor design temperature minus outdoor design temperature

E = Unit efficiency

If the makeup air unit is to supply heat for offsetting radiational losses, this quantity must be added to the "HR" determined above.

Pilot-ignition control systems. Packaged systems may employ one of six types of pilot ignition systems:

1. Manual match-lit pilot with 100% shutoff;
2. Spark-ignited intermittent safety pilot;
3. Spark-ignited safety pilot with timed lockout;
4. Hot surface pilot ignition;
5. Hot surface burner ignition (with timed lockout);
6. Spark ignited main burner (with timed lockout).

Gas-control Systems. Packaged systems for heating and/or makeup applications may be arranged into many types of gas control systems. Some examples are:

1. Two-stage control--a two-stage valve (which fires at either 100% or 50% as required by a two-stage duct-mounted thermostat (ductstat).
2. Two-stage control using two furnaces--in such systems, each furnace is equipped with a single-stage valve. The two valves are operated by a two-stage duct-mounted thermostat (ductstat). The furnace nearest the blower turns on first and the downstream furnace comes on second when additional heat is called for.
3. Three-stage control using three furnaces--in such systems, each furnace is equipped with a single-stage valve. The three valves are staged by two unit-mounted two-stage ductstats. The furnace nearest the blower turns on first, the center furnace comes on second, and the downstream furnace operates last.
4. Four-stage control using two furnaces--each furnace is equipped with a two-stage valve. These valves are staged by two unit-mounted two-stage ductstats: the furnace nearest the blower is staged first on low fire, second on high fire. In the third stage the downstream furnace operates on low fire followed by high fire for the fourth stage.
5. Six stage control using three furnaces--in such systems, each furnace is equipped with a two-stage valve. The three valves are staged by three unit-mounted two-stage ductstats and the operating sequence is similar to the sequence for the four-stage-two-furnace system: the furnace nearest the blower turns on first, the center furnace second, and the downstream furnace last.

6. Electronically modulated control--close temperature control with solid-state circuitry that smoothly varies the gas input between 50% and 100% of the unit's rated capacity, as required by a call for heat from a unit-mounted duct sensor.

7. Electronically modulated control air with remote temperature selection--close temperature control with solid-state circuitry that smoothly varies the gas input between 50% and 100% of the unit's rated capacity, as required by a unit-mounted duct sensor which can be set for a desired temperature from a remote selector.

8. Mechanically modulated control—a nonelectric, capillary-actuated system which smoothly varies the gas input between 50% and 100% of the unit's rated capacity, as required on a call from a thermostatic sensor. This system cannot be used on power-vented equipment unless the exhauster is operated continuously.

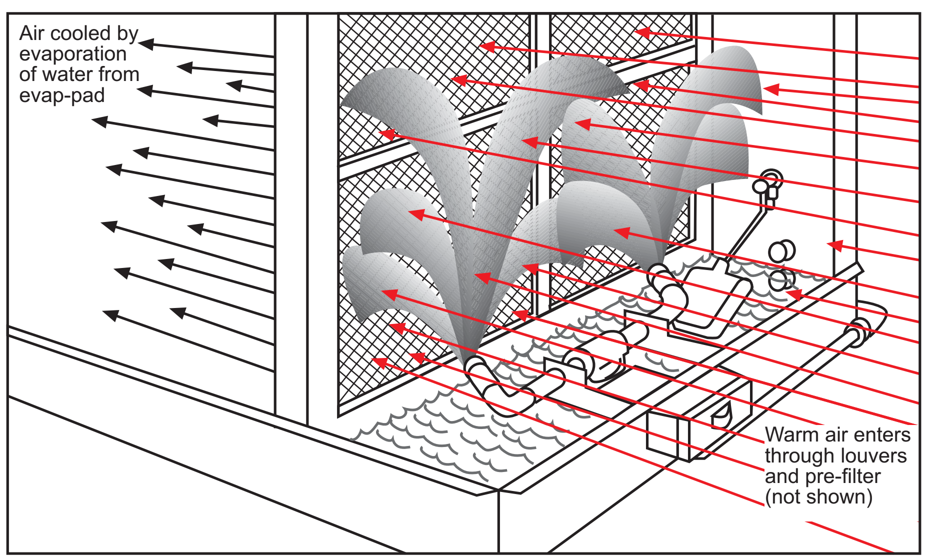
Air Controls. Air control systems for makeup-air application consist of some combination of outside air damper, return-air damper, damper motors, mixed-air controller, and electrical controls such as relays, potentiometers, switches, and thermostats. These elements are combined in a great variety of ways to meet specific makeup-air requirements. Systems can be designed to provide 100% makeup air (continuously or intermittently) or they can be arranged to provide variable volumes of makeup air geared to varying requirements. These systems may use: 2-stage, 3-stage, or continuously modulated dampers; time-clock or manual-switch startup and shutdown; or automatic opening and closing of outside air dampers.

Use with Cooling Systems. When cooling is required, packaged units include a cooling unit, which may be either mechanical (compressor) or evaporative. In combination heating-cooling systems of either type, the airflow requirement for cooling is greater than the requirement for heating. Therefore, air flow requirements should be based on the maximum CFM, and the motor horsepower and drive should be selected for such capacities.

Mechanical Cooling. Cooling through the use of DX (Direct Expansion) coils or chilled water coils is possible with packaged systems. However, in most cases, the coil must be added to the ductwork, downstream from the package. Care should be used in sizing coils so that air velocities are acceptable for the duty to which the coils are to be placed. Low velocities are desired when cooling outside air, while greater velocities may be employed when cooling recirculated air.

Evaporative Cooling. Most areas of the United States have the climatic conditions for effective evaporative cooling (i.e. high temperatures and low relative humidity). This type of cooling is applicable where the difference between dry-bulb temperature and wet-bulb temperature is 17 to 19 degrees. In most applications, evaporative coolers operate at efficiencies of 75 to 85 percent.

Evaporative coolers use the heat-absorbing action of the water-evaporation process to remove heat from air for circulation in a building. The coolers in packaged systems consist of nozzles that spray water onto evaporation pads, a water reservoir with float and bleed valve, a water-recirculation and spray pump, and air filter (See Figure 3-12). In addition to providing a large surface area for water evaporation, the evaporation pads act as a heat exchanger--air for the building cools as it passes on inside walls of the pads as evaporation takes place on the outside.



1. Evap-pad filters
2. Spray nozzles
3. Float Valve
4. Overflow
5. Float bulb
6. Drain
7. On-off switch for pump
8. Junction box
9. Spray pump

3-12 Evaporative cooling system

Direct-Fired Combustion

Makeup Air. In some facilities, fairly large amounts of air are lost to the outside either through an exhaust fan used to remove smoke, fumes, dust or objectionable odors and undesirable gasses or vapors from a process (e.g. restaurant-kitchen range and oven hoods) or by the nature of the operation (e.g. large doors remaining open for passage of railroad cars or trucks). Air brought in to replace the lost air is known as makeup air.

Direct-fired packaged units are frequently used to supply heated makeup air. Since the combustion products mix with the circulated air, direct-fired packaged heaters usually are limited to makeup air applications. Some examples are lumberyard and builders' supply warehouses, foundries, shipping and receiving buildings of heavy industrial plants, large aircraft hangars, etc. Although indirect-fired packaged heaters can be used for heating makeup air, direct-fired package units are more widely used for this purpose and offer the more economical way to provide makeup air.

Forcing heated makeup air into a building offsets the negative pressure created by exhaust fans and creates a slightly positive pressure inside the building. This positive pressure eliminates infiltration, drafts, and makes an exhaust system more effective. At the same time, the heated makeup air helps maintain a more uniform, comfortable temperature inside the building even though inside air leaves and fresh air enters. Because heated makeup air eliminates uncomfortable drafts, it saves fuel by eliminating "thermostat jockeying" the frequent changing of the thermostat setting by occupants to try to improve comfort.

Combustion/Dilution Air. As the term, direct-fired implies, the gas is burned in the circulated air stream. This can be accomplished through the use of special burner designs which contain the flame within a small zone of the air stream. The air/gas ratio is 4 to 1 in the flame but the air downstream from the burner has an air-to-combustion-gas ratio of 600 to 1. This high ratio results in approximately 5 PPM of carbon monoxide and a maximum of 2000 PPM of carbon dioxide in the delivered air stream.

Duct Systems. Direct-fired makeup-air packages may be attached to distribution duct systems. As in the indirect-fired packages, the airflow rate (CFM) and the external static pressures must be projected to size the horsepower and drive properly.

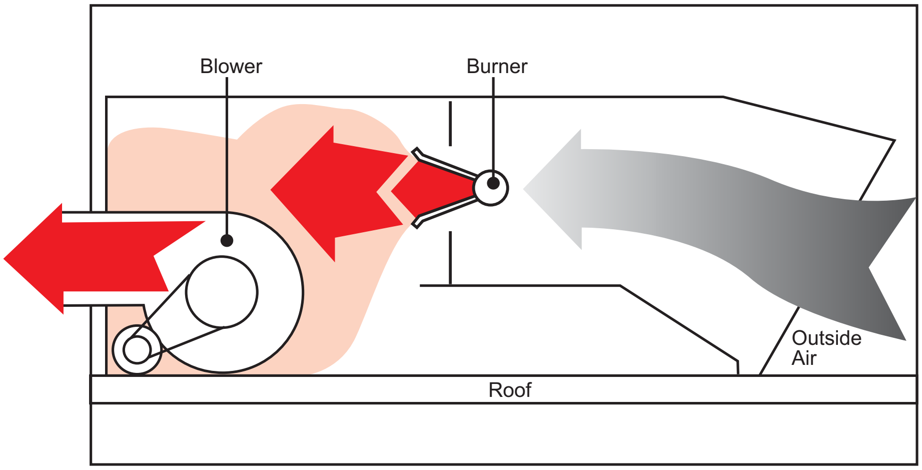
Exhaust/Relief. While some direct-fired units are used for pressurized heating, most makeup-air systems are accompanied with mechanical exhausters or gravity-relief dampers. The mechanical exhausters are usually the reason for needing makeup-air; power-relief dampers normally are used in pressurized buildings where ventilation is the prime reason for the makeup-air unit.

Makeup-air-only Systems. Figure 3-13 illustrates one of three basic arrangements for which packaged heaters are available for providing makeup air. This arrangement provides 100% makeup air at constant airflow rate to match the constant rate of exhaust of a specific process (restaurant-kitchen hood, for example) or a diversified industrial process which might be operated on an intermittent basis.

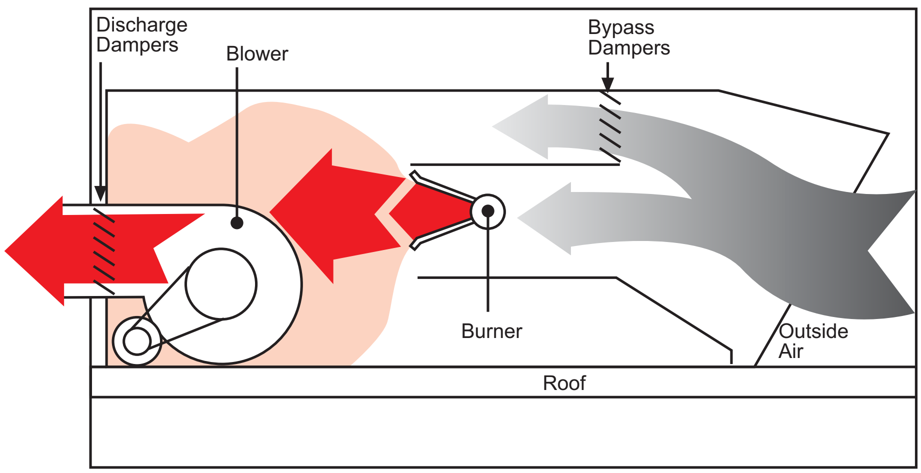
Units are also available to provide 100% makeup air at a variable air flow rate (Figure 3-14). This arrangement is often used to supply general makeup air to a space having variable rates of exhaust. In this type of system, a building-pressure sensor controls the makeup air to keep the building slightly pressurized even though the exhaust systems operate intermittently. This is accomplished by a discharge damper which may be positioned to adjust the quantity of air needed to match the air being exhausted. This system is the most efficient because it eliminates the need to heat excess amounts of makeup air and reduces blower-motor power consumption, as the air throughput is reduced. Forward-curved blowers are generally used, therefore as the air is throttled, the brake horsepower requirements diminish. In the system illustrated in Figures 3-14 and 3-15, a bypass damper is also repositioned by internal controls, so the air velocity (volume) over the burner remains constant.

Sizing. Direct-fired packaged systems are sized to heat and admit just the right amount of air to either pressurize the building slightly or to create a slight vacuum within the space, depending upon the type and amounts of contaminants present and the use of the space.

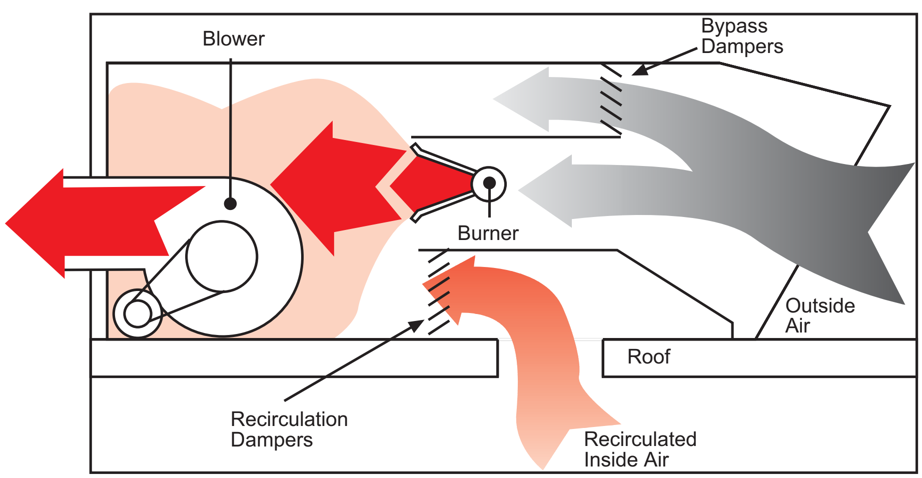
Process Makeup Air. If a building is served by a single separate packaged system and a single fan exhausts process contaminants that should not be allowed to migrate to other parts of the building, makeup air volume should provide about 90% of the exhaust-air volume. This ratio of makeup air to exhaust air would create the slight vacuum needed to ensure that contaminants do not seep into the adjoining spaces. If a building is equipped with a number of exhausters to evacuate contaminants that are not threatening to the occupants, the makeup-air volume should be 110% of the exhaust-air volume. This ratio will provide the mild pressurization needed to reduce infiltration. To reduce or eliminate infiltration, this part of the calculated heat loss may be omitted from the total building heat loss, reducing the BTUH requirements for the convected heat loss.



3-13 System for providing 100% makeup air at constant air-flow rate.



3-14 System for providing 100% makeup air with a variable air-flow rate.



3-15 This makeup air system varies the volume of makeup air while keeping the recirculated air-flow rate constant.

To develop the most efficient makeup-air system, the exhaust CFMs must be carefully calculated so that the makeup-air volume can be accurately identified and sufficient capacity incorporated into the makeup-air equipment. Duct, diffuser, and filter losses must also be determined to establish the blower-motor horsepower and speed required.

Building Makeup Air. Full-building heating can be accomplished with makeup air. Makeup-air volume should be at least 150% of the building's infiltration rate. This ratio will result in pressurization sufficient to completely eliminate infiltration and distribute heated air throughout the building. To determine the total BTU output required of the packaged unit, add the heat losses of the building (excluding infiltration losses) to the BTUs necessary to heat the makeup air.

Gas Controls. Gas controls on direct-fired packages are usually of the modulating "A" type where the input to the main burner can be reduced to 4% of the rated burner input when the unit is at full fire (i.e. maximum BTU input for the length of the burner). This allows for nearly infinite control of the discharge temperature. Appropriate safety controls are always supplied and are suitable to meet any of the following codes: ANSI, FM or IRI.

Direct Fired Combustion

3-15 **Air Controls.** Variable air volume systems include a modulating discharge damper which is controlled by either a manual potentiometer or a pressure-sensing control for monitoring space pressures.

A trim damper is used. It is located in an air duct which bypasses the burner duct. This trim damper operates independently from the discharge damper and automatically controls the velocity of air over the burner.

Heating and Makeup Air Use. Packaged systems are available for providing both makeup air and heated recirculating air. Figure 3-15 illustrates a system that combines variable-flow-rate makeup air with variable-rate recirculation of inside air. By providing variable amounts of heated makeup air while reheating the inside air, such a system eliminates the need for separate space heating equipment.

Sizing. When sizing a makeup air unit for both heating and makeup air, the designer must be certain that the unit can furnish all the BTUs necessary to temper the air and heat the building when the air passing through the unit is delivered from the outside. Therefore he must calculate the BTUH needed to heat all the air from outside and must then add the BTUH needed to actually heat the building.

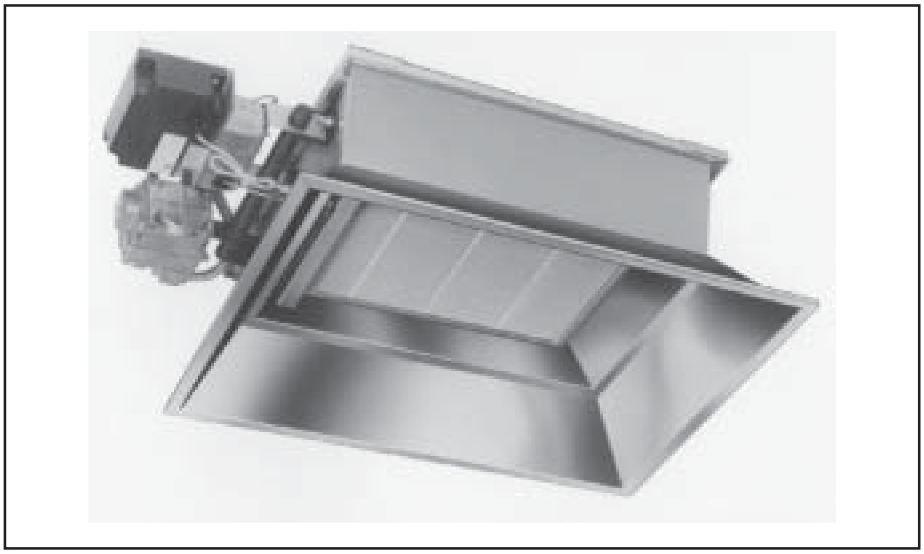
Gas Controls. Since the unit is operated to create a desired temperature level within the space, it is recommended that a space thermostat be used. Space thermostats are available to reset the discharge temperature of the heating package to either add heat as required or to supply air at lower temperatures to accommodate cooling when heat gain in the space has driven the temperature above the setting of the space thermostat.

Air Controls. Recirculating units are equipped with return air dampers that are controlled by a manual potentiometer or by a pressure-monitoring device located in the space. This system also contains a trim damper that is located in a duct just above the burner. The trim damper operates independently of the recirculated-air damper and automatically maintains the proper air velocity across the burner.

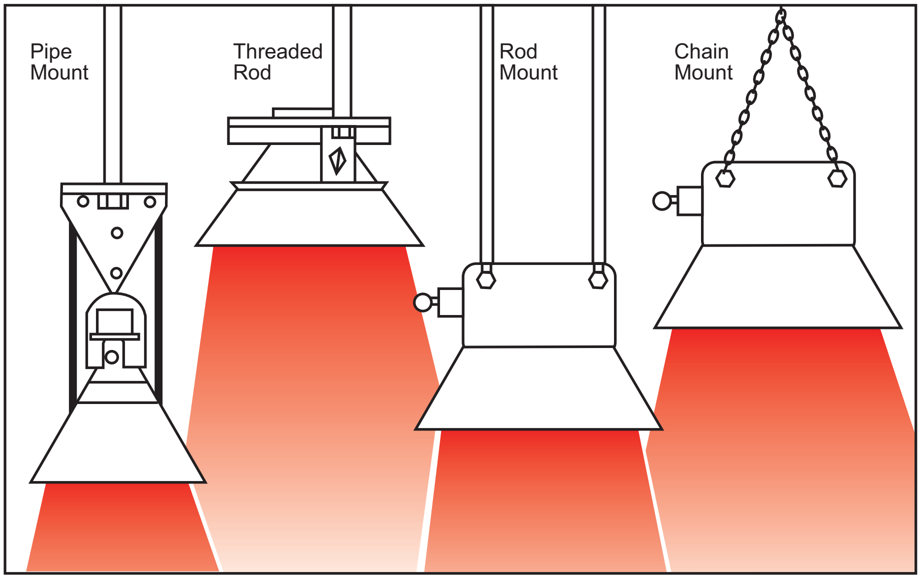
Use of Heating Units with Cooling Systems

Mechanical Cooling. In mechanical cooling through the use of DX (Direct Expansion) on chilled water, the coils can be located in the discharge duct. Care must be used in sizing the motor and drive since all coils resist air flow and will add external losses that must be overcome.

Evaporative Cooling. Use of evaporative cooling with direct-fired equipment is a special case. The heating equipment manufacturer should be consulted to see if evaporative cooling is applicable to specific equipment.



3-16 Example of commercial infrared heater.



3-17 Usual methods of suspending infrared heaters from ceiling.

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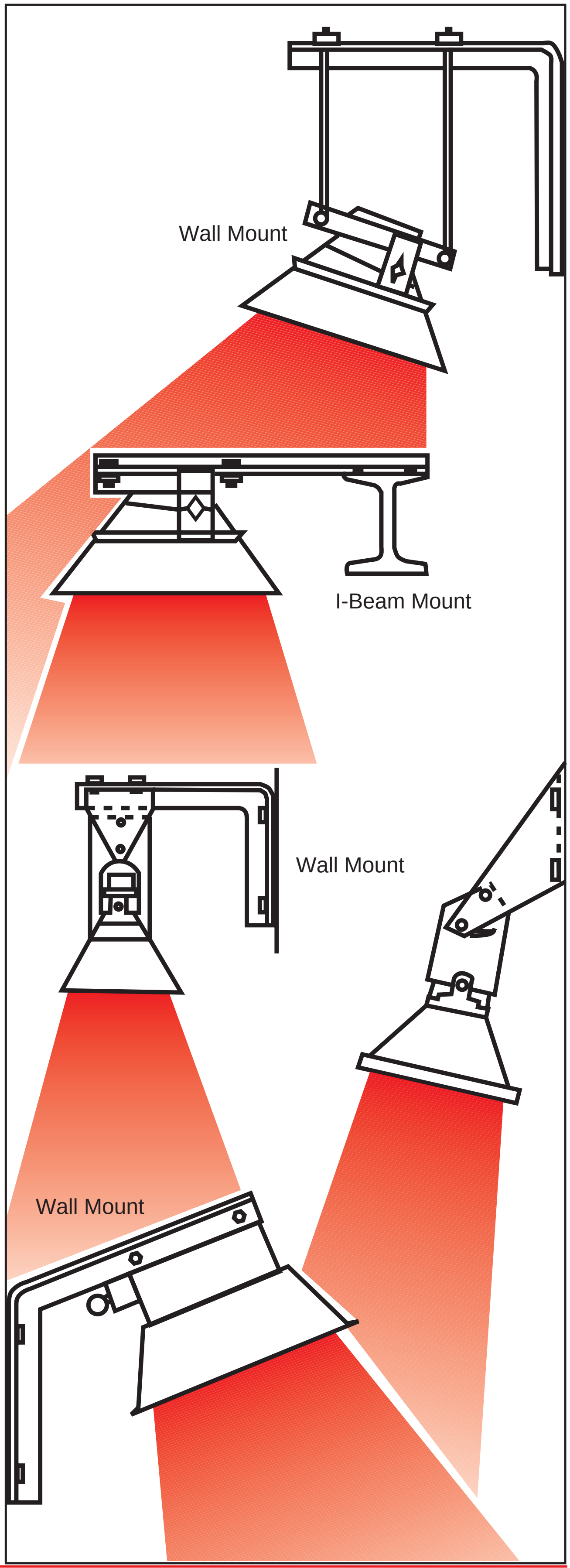
Infrared Radiation Heating

Radiant heaters are comparable in some ways to unit heaters. These compact, self-contained units (Figure 3-16) are usually mounted near the ceiling. They are better suited to spot heating than unit heaters but are also excellent for space heating. A wide range of facilities can be heated for occupant comfort with radiant heaters: factories, auto repair shops, storerooms, supermarkets, gymnasiums, swimming-pool enclosures, auto showrooms, public parking garages, etc. Unlike unit heaters, radian heaters require no fans or blowers. They are quiet and incur no significant electrical energy cost. Because they contain a minimal number of moving parts, service requirements are lower than with comparable forced air units. Installation costs are low because their light weight allows them to be easily suspended from the ceiling (Figure 3-17) or mounted on walls (Figure 3-18).



3-18 Methods of mounting infrared heaters on walls and other vertical surfaces.

Infrared Radiation Heating

High-intensity Infrared. Heater manufacturers offer high-intensity radiant heaters in capacities commonly ranging from 22,000 BTUs per hour to 100,000 BTUs per hour for natural gas or propane, but heaters well above 100,000 BTU per hour are also available. Because they transfer heat by radiation, infrared heaters warm people, floors, walls, machinery, and other surfaces without heating the air in between. As a result, they eliminate the costly ceiling heat losses and the discomforts of cold-air stratification that can occur with forced air systems. Fuel savings are sometimes available (compared to forced-air system costs) because roof and wall losses generally are insignificant in sizing for full building heating with radiant heaters.

Combustion Air. An advanced infrared burner is shown in figure 3-19. The fuel gas is metered through the orifice (1) to the venturi mixing tube (2) where the gas stream draws in the primary air required for combustion. The enrichment port supplies a rich gas mixture to the ignition area on startup for improved light-off. The orifice and venturi are designed to supply 100% primary air for complete combustion. If insufficient air were aspirated, incomplete combustion would result; if too much air were aspirated, burner efficiency would be reduced by the heat loss of this excess air.

Infrared burners may need to be re-orificed for operation at high altitudes. You should check with the individual manufacturer for this information. Usually a smaller orifice operating at higher gas pressures will compensate for the thinner air because it will produce a higher velocity gas stream which will aspirate more air, insuring sufficient oxygen for complete combustion.

Exhaust/Relief. Radiant heaters are not normally vented through a flue to the outside, but certain models require venting which is accomplished with normally available vent pipe.

Generally, exhaust fans are used in conjunction with radiant heaters to meet dilution requirements of 3.78 CFM per 1000 BTUH of natural gas or 4.55 CFM per 1000 BTUH of propane. Unvented infrared heaters require minimum amounts of ventilation air for dilution of the products of combustion. The following formula gives the minimum ventilation required to maintain adequate dilution:

$$V = C/60{,}000 \times k$$

where

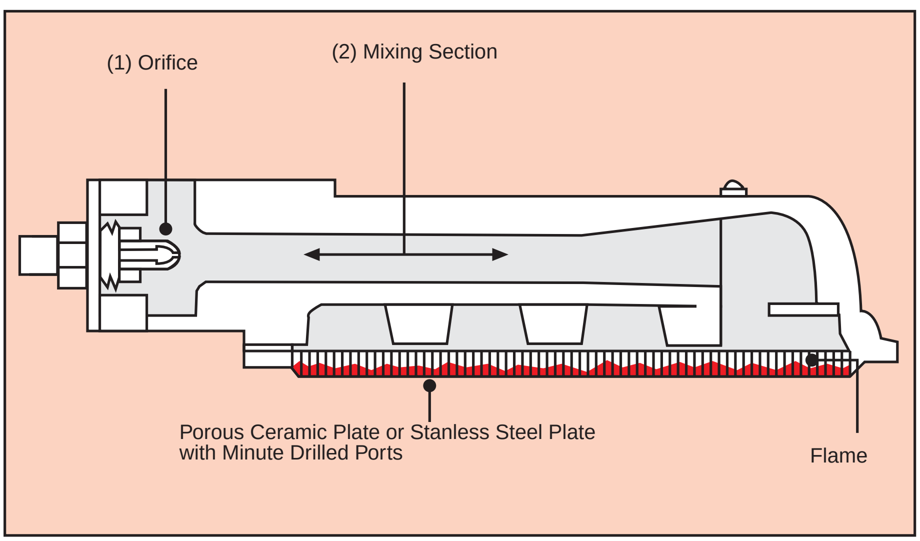
V = minimum ventilation (CFM per 1000 BTUH of fuel)

C = total required infrared capacity (BTUH)

k = a constant (227 for natural gas; 273 for LP gas)

If ventilation or infiltration rates are not sufficient to meet this requirement, power ventilation should be added to provide the necessary dilution air and exhaust combustion products. If the combustion products are not eliminated from the building, there is a definite possibility that they will condense in the ceiling or on metal frames and structures. Such condensation can be extremely harmful to any materials on which it forms.

Unvented infrared heaters should not be used in buildings that conduct degreasing or dry cleaning with chlorinated solvents like perchlorethylene unless all solvent operations are individually and efficiently vented. Reason: the vapors of such solvents decompose to hydrochloric acid and other dangerous and corrosive products when they pass through an open flame.



3-19 High-intensity burners have these basic parts.

Sizing. For full building heating the radiational losses of the building must be established. Then this value is multiplied by 0.85 to ascertain the necessary input. Sizes of units are determined by the area and the mounting height. For spot heating, special intensity charts must be used and are available from the manufacturer.

Location. Radiant heaters are inherently versatile and can be installed in a variety of locations and orientations. Most models on the market can be mounted with the radiant ceramic plate horizontal or tilted through any angle within 30 degrees of the horizontal position. For horizontal mounting they can be suspended from the ceiling by chains, threaded rods, or pipe brackets; angle-mounting from walls may be made with a wide variety of brackets.

Whole Building or Spot Heating. Average floor-to-burner mounting heights for high-intensity infrared heaters range from 12 feet to 28 feet for space heating; almost any height for spot heating, as required. Figure 3-18 shows a number of common mounting methods.

Controls. High-intensity radiant heaters for commercial and industrial use come complete with direct spark ignition, operating and safety valves and controls, gas-supply connections, and mounting flanges. Generally, exhaust fans are used in conjunction with radiant heaters to meet dilution requirements. In many cases, fans are integrated with thermostats to provide ventilation when heaters are on and prevent unnecessary ventilation and heat loss when heaters are not operating.

Low-intensity Infrared. Low-intensity radiant heaters are generally constructed of round pipe. The portion of the pipe nearest the burner is either made of stainless steel or is ceramic coated. The temperature of the radiational tubes does not exceed 900°F (1100°F with aluminized tubes) and may drop as low as 100°F near the exhaust end. Low-intensity infrared units are generally equipped with power burners and often include powered exhausts.

Sizing. Low-intensity radiant heaters are sized much the same as the high-intensity units, but their mounting height is usually restricted to lower heights than the high-intensity units because the source temperature is approximately half that of the high-intensity units.

Location. Low-intensity units are available in various lengths and some versions are connected in series so that fairly long continuous runs may be used. In most full-building infrared applications, the units are located around the perimeter and their shades or reflectors are positioned to minimize the infrared rays striking the wall. Infrared units are used primarily to heat the floor; with this in mind the importance of placement and angles of deflection becomes clearer.

Controls. Controls for radiant heaters are fairly simple except for the fact that power blowers are used for burner aeration. This dictates the need for other devices such as flow switches and spark ignitors. Flame-rectification, direct-spark ignition systems have been generally used since standing pilots or even spark-ignited pilots have not been considered practical because of the velocity of the gas-air mixture passing through the system. However, hot-surface ignition systems are becoming increasingly common.

Whole-building Heating and Spot Heating. Average floor-to-burner mounting heights for low-intensity radiant heaters range from 8 feet to 12 feet for space heating; and approximately the same heights for spot heating. Figures 3-17 and 3-18 show a number of common mounting methods.

INDIRECT-FIRED HEATING

UNIT HEATERS

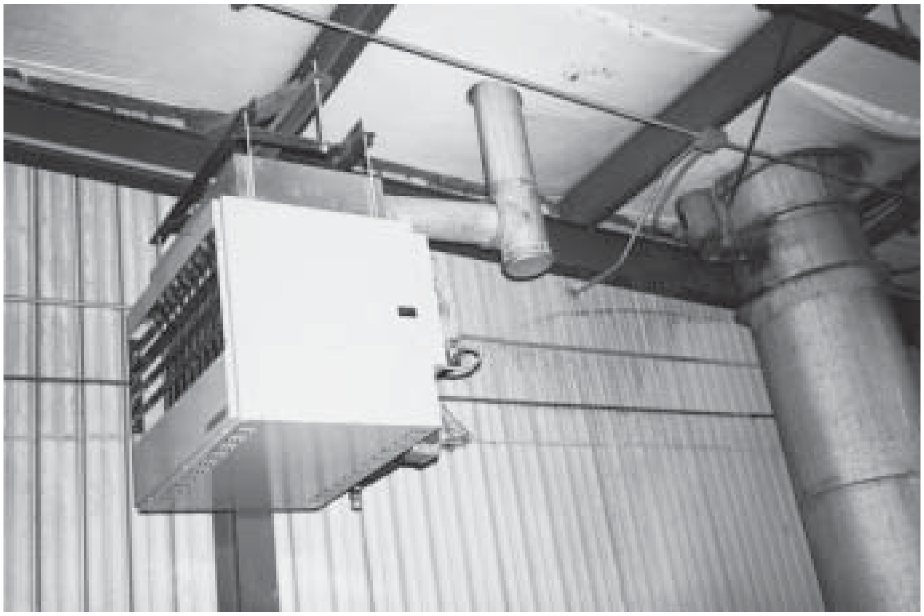
Unit heaters can be applied in a great variety of ways. They provide a particularly convenient way to replace old heating systems, especially steam and water systems because new ductwork need not be installed in the existing building. The following examples show how they have been used in both new construction and retrofitting.

Manufacturing Plant

Facility: Cutting tool manufacturing shop covering 40,000 square feet, previously equipped with 3-million BTUs, low-pressure, gas-fired steam boiler.

Conditions: severe machine shop conditions with metal cutting, grinding, and heat-treating operations carried out routinely.

Equipment installed: Six 300,000 BTU/hour fan-type unit heaters for main shop area and one 140,000BTU/hour unit heater for the separate heat-treating room.



Greenhouse

Facility: Cluster of five new greenhouses, each 42 feet wide by 232 feet long.

Conditions: High humidity, seacoast salt-air climate, agricultural chemicals environment.

Equipment installed: Fifteen 250,000-BTU/hour blower-type unit heaters with stainless steel heat exchangers, burner, spark pilot and OSHA belt guards. Units were specially equipped with galvanized blowers for corrosion resistance against the chemical environment.

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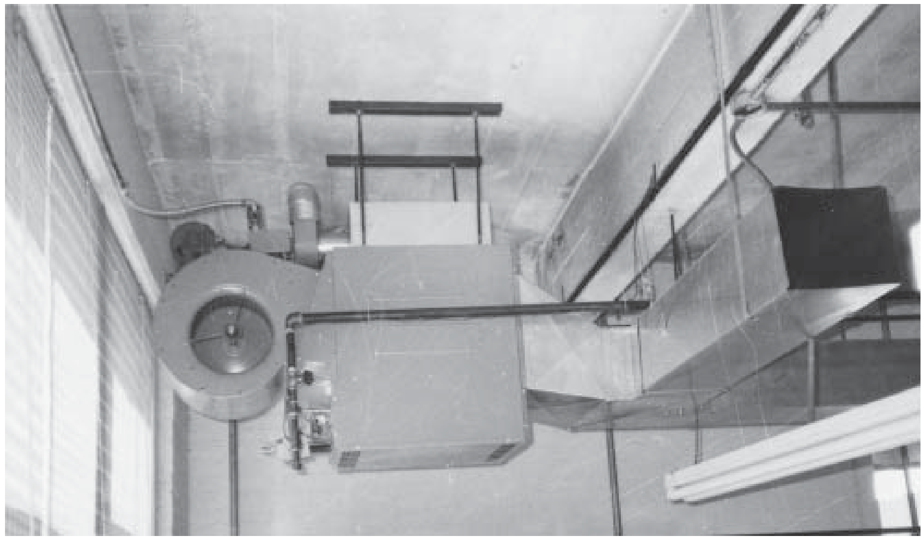
School Building



Facility: Two-story school building, 50 feet wide by 300 feet long, with 25 classrooms and laboratories, formerly served by 50-year-old oil-fired steam boiler system.

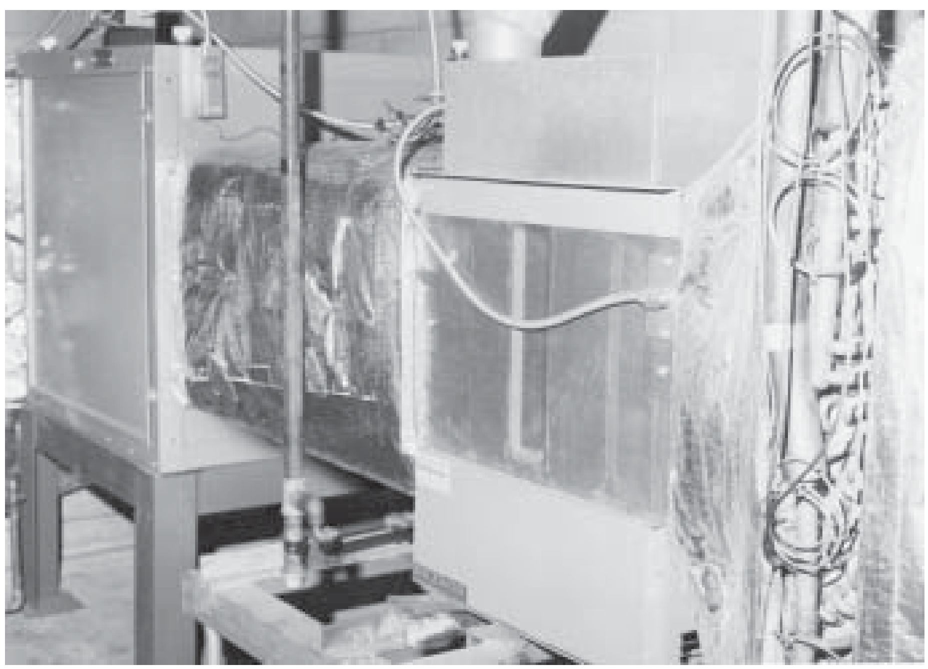
Conditions: separate room

temperature control and maximum energy savings required .

Equipment installed: Twenty-five

125,000-BTU/hour blower-type unit heaters.

DUCT FURNACES



Commercial

Facility: Supermarket.

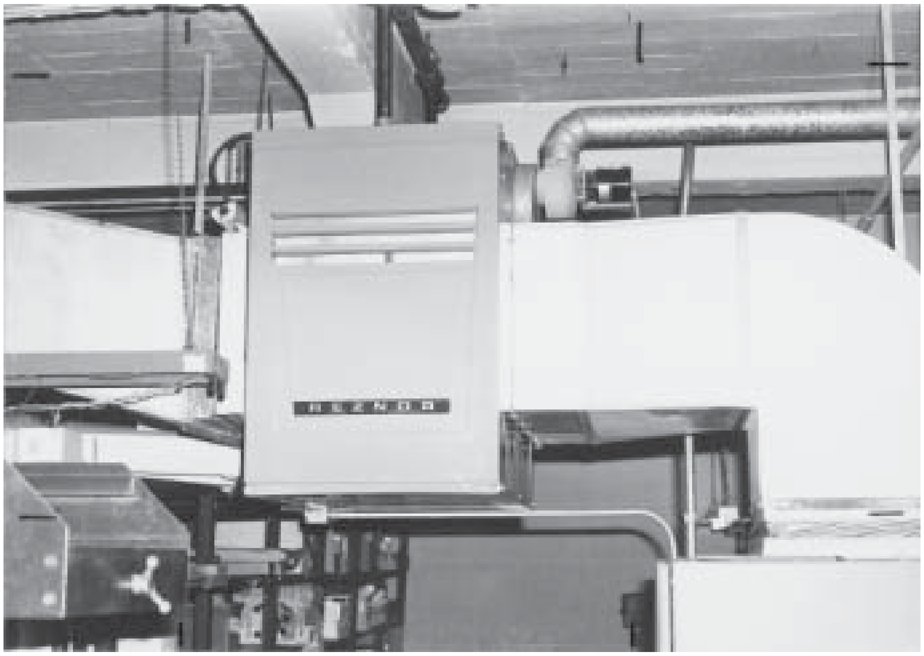
Equipment installed: A 225,000-BTU duct furnace with blower package and cooling coils was installed in an enclosed roof-top shelter. The furnace includes a stainless steel heat exchanger and power venting.

PACKAGED SYSTEMS

Manufacturing, Heating Only

Facility: Factory with 40,000 square feet of floor space.

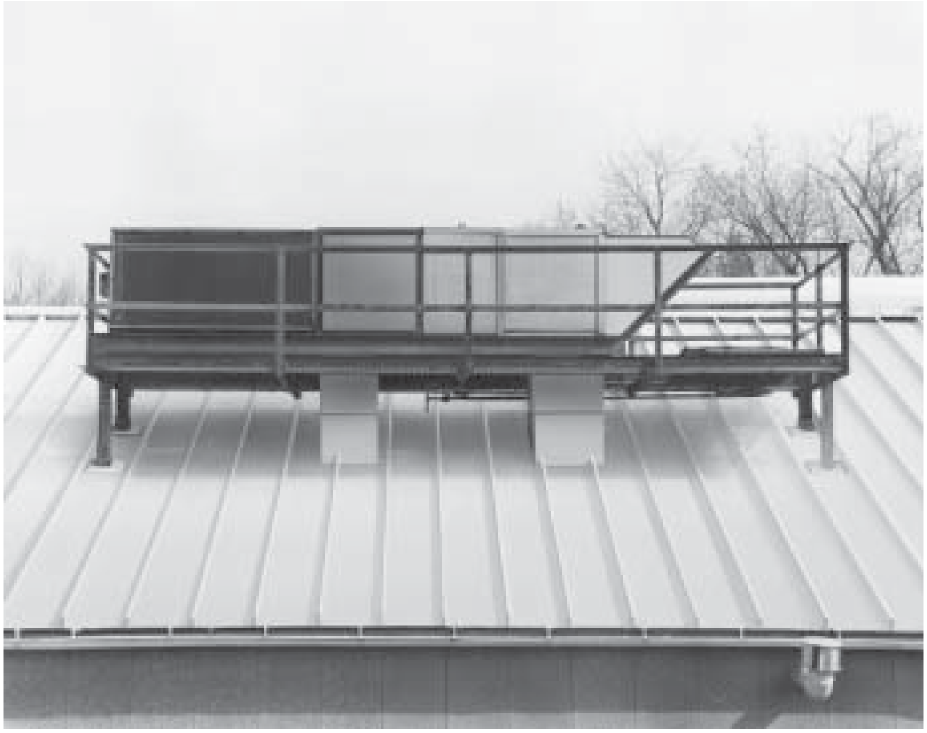
Equipment installed: Six duct furnaces of 200,000 BTUH input capacity each, attached to blower-filter packages to alleviate dust condition created by plant processes.



Manufacturing, Heating and Makeup Air with Cooling

Facility: Factory engineering section which required heating, cooling, and fresh-air introduction.

Equipment installed: The packaged system contained a 225,000-BTUH furnace and 15-ton air conditioner to handle the fresh-air load.



SEPARATED COMBUSTION

Manufacturing

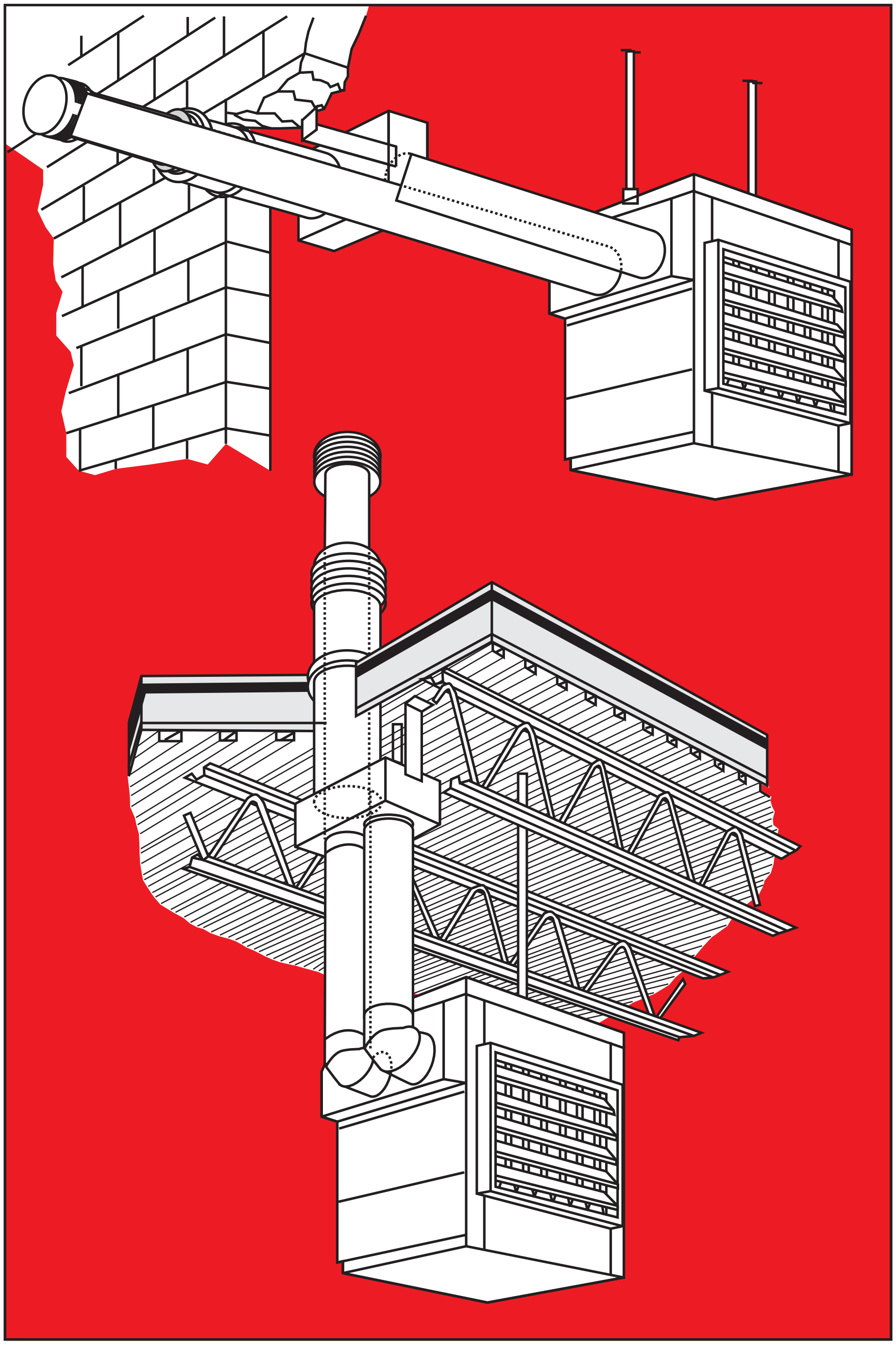
Facility: One of the largest plants in the U.S. in which vitreous-china plumbing fixtures are manufactured under one roof, with a total area of 75,000 square feet and a ceiling height of 18 feet. The original heating system had 50 sets of steam-heated coils and blowers in the ductwork of the air-distribution system.

Conditions: Very dusty atmosphere; process required area to be maintained at normal room temperatures during the day, then heated up to

110 degrees F overnight to dry the work in process, remove the

moisture from the building, and be ready for the next day's operations at normal working temperatures.

Equipment installed: Fifty 400,000-BTUH duct furnaces were installed in place of the steam coils, in the same space between the two ducts at each blower location. Separated combustion furnaces were used for higher efficiency and because of the dusty atmosphere.



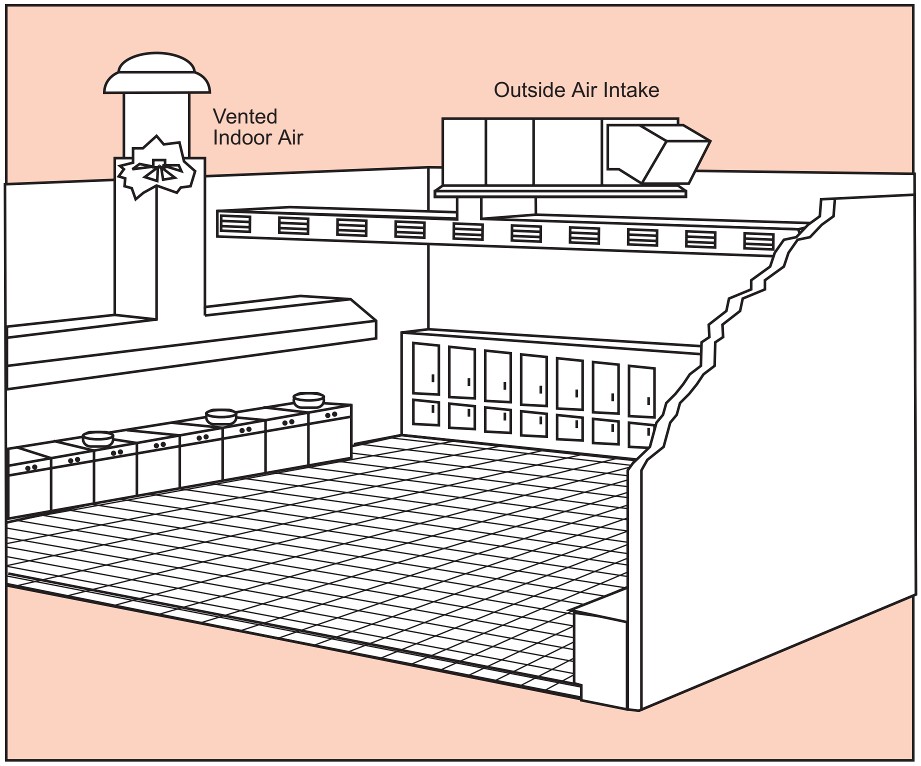
3-23

DIRECT-FIRED COMBUSTION

Kitchen Makeup Air

Facility: Commercial kitchen using 10,000 CFM of exhaust.

Equipment installed: Roof-mounted unit designed to supply 9,000 CFM of fresh air the lower supply of makeup air compared to exhaust prevents cooking odors from entering the dining area.

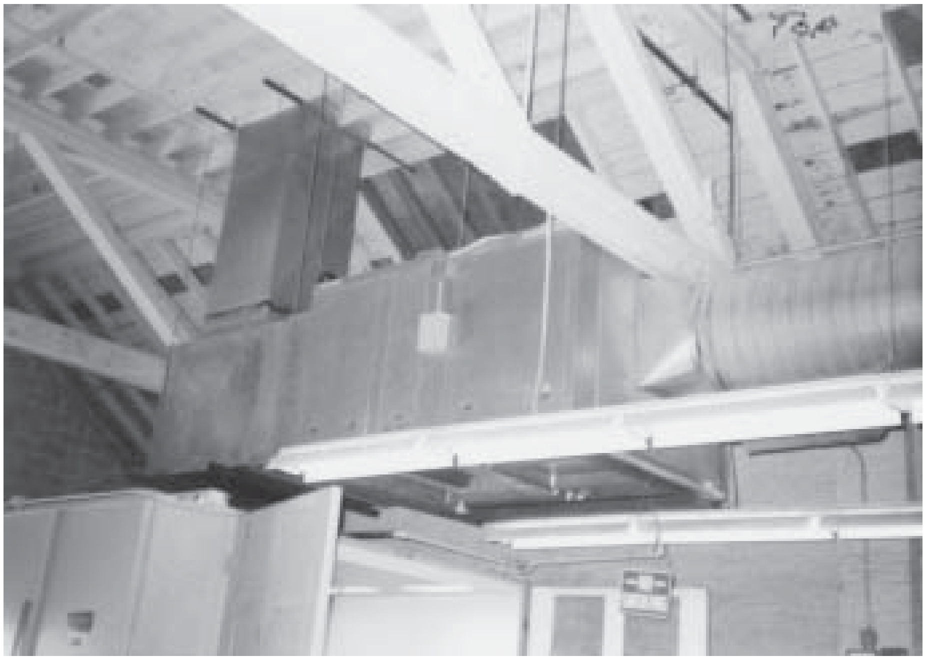


Factory Heating and Makeup Air

Facility: Factory with exhausts for paint spray booths.

Conditions: 15,000 CFM exhaust volume; 13,500 CFM makeup-air volume to prevent migration of paint overspray.

Equipment installed: Direct-fired unit installed indoors to eliminate extensive roof revision that would have been necessary with roof-mounted unit. Burners sized for 1,250,000 BTUH to maintain 70-degree temperature.

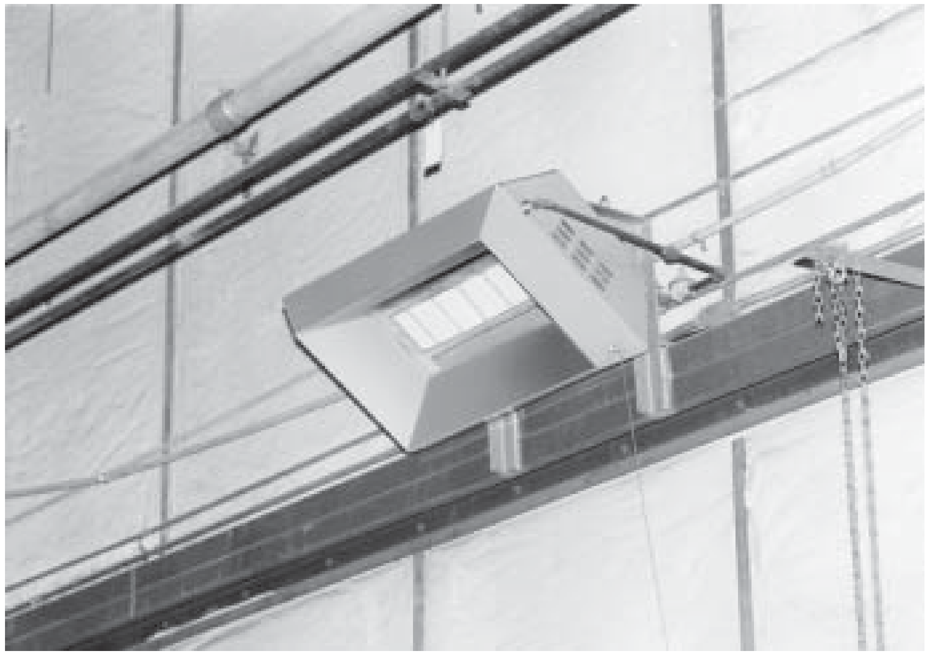


Whole-building Heating

Facility: Manufacturing plant.

Conditions: 27,000 square-foot area; gravity vent at roof peak to release flue products.

Equipment installed: Thirty-two 50,000-BTUH high-intensity heaters, equally spaced on outside wall, cantilever-mounted at 30-degree angle.



Spot Heating

Facility: Factory quality-control area.

Conditions: workspace area measuring 20 feet by 16 feet, located next to high-traffic warehouse door with vinyl curtain.

Equipment installed: A single 75,000-BTUH high-intensity infrared unit mounted horizontally at height of 18 feet for comfort of technicians performing tests.

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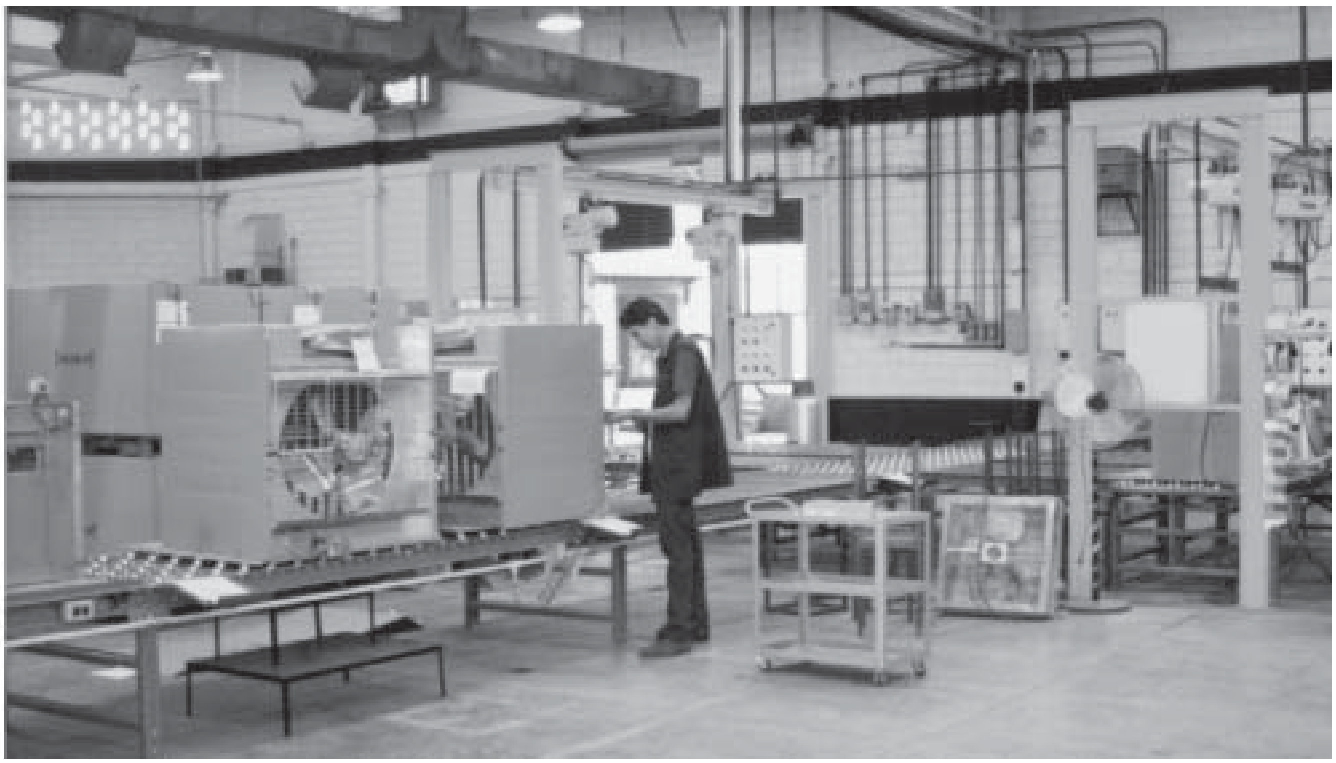
Example Applications

LOW-INTENSITY HEATERS

Whole-building Heating

Facility: Warehouse area, approximately 25,000 square feet.

Equipment installed: 400 linear feet of low-intensity infrared heaters with reflectors, located at 20-foot height and spaced for optimum coverage.



Assembly-line Heating

Facility: Factory production line.

Conditions: Well-Ventilated area, workers located within 15 feet of assembly line.

Equipment installed: 1200 feet of low-intensity heaters, mounted 12 feet above floor, made up of 40 sections spaced to warm floor and stationary objects where needed to radiate heat to workers. Workers also receive warmth directly when they are within the radiation pattern of the units.

Standards, Codes and Testing

INDUSTRY STANDARDS

Industry standards are voluntarily followed rules and regulations governing the design, manufacture, installation, operation, and use of manufactured products. In the United States, a large number of organizations (engineering societies, manufacturers' trade associations, federal government agencies, etc.) formulate and maintain the thousands of industry standards in effect today. Any nationally recognized laboratory may test to ANSI standards.

American National Standards Institute (ANSI). A number of organizations issue standards that apply to gas-fired space heating equipment. The American National Standards Institute (ANSI) performs the clearinghouse role of coordinating the standards of these organizations. ANSI committee Z83 works with the various standards for industrial gas equipment; committee Z223 oversees compliance with the National Fuel Gas Code. The work of both of these committees applies to indirect- and direct-fired equipment and to radiant infrared heaters.

CODES

Codes are industry standards given the force of law by legislative action of federal, state or local government. The legislative bill or ordinance may adopt an industry standard by incorporating it as a verbatim or modified text; simply referring to the standard by name or number is a common means of adoption. Either way, the standard is no longer voluntary in the jurisdiction of the legislation and failure to comply may make the contractor or owner subject to penalties as prescribed by the legislation.

National Fire Protection Association (NFPA). One of the codes that applies to all types of heating equipment is the NFPA code. This code is solely concerned with fire safety and prescribes "reasonable provisions based on minimum requirements for safety to life and property from fire." Everyone engaged in installation, maintenance, servicing, operation, and care of heating equipment of all types should be thoroughly familiar with the NFPA code.

National Fuel Gas Code (Z223). The installation, maintenance, operation and safety of gas-burning devices is covered by the National Fuel Gas Code. In matters of safety this code is similar to the NFPA code and the two overlap to some extent. Everyone working with gas-fired equipment should be thoroughly familiar with this code.

Insurance Codes. Insurers of buildings may have certain requirements or limitations on heating equipment installed in buildings which they insure. Two such insurers are

FM - Factory Mutual

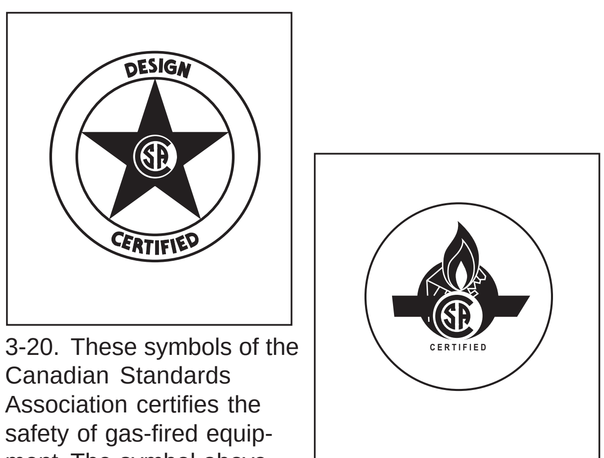
IRI - Industrial Risk Insurers (Formerly FIA)

These two agencies often require that additional controls and accessories be added to the equipment. If a building will be insured by either of these two agencies, it is essential to contact the agency's local inspector to obtain a clear definition of what is required to meet its standards for any heating, makeup air or infrared application that is planned.

CERTIFICATION TESTING The following agencies will certify or may influence the general makeup of equipment (as in the case of independent insurers). All test agencies observe ANSI standards when involved in investigating individual appliances.

Canadian Standards Association (CSA)

Manufacturers of gas-fired space heating equipment submit their products to CSA for detailed examination and testing to determine compliance with ANSI (United States), CSA (Canada) and other national and international standards. Scrutiny by CSA is concerned with safety and performance reliability, efficiency, and durability. The CSA seal of approval, Figure 3-20, is the buyer's assurance that the particular model of heater or furnace has passed rather stringent tests, and that the unit has been found in compliance with ANSI approval requirements.



3-20. These symbols of the Canadian Standards Association certifies the safety of gas-fired equipment. The symbol above certifies that the equipment complies to ANSI Standards for The United States. The symbol to the right certifies that the equipment is approved for use in Canada.

3-21. This seal of the Underwriters' Laboratories, Inc., shows that equipment is listed as having complied with ANSI standards.

Underwriters' Laboratories, Inc. (UL). Underwriters' Laboratories tests to ANSI standards for safeguarding people and property from fire and accidents in the use of electrical equipment of all kinds. This organization also tests and evaluates electrical equipment and components as to compliance with ANSI standards when installed according to the National Electrical Code. Although UL issues a seal (Figure 3-21) denoting that the equipment bearing the seal is listed as having complied with ANSI standards, the electrical components of space heating equipment must be installed to comply with the National Electrical Code for the UL seal to be meaningful.

ETE (formerly Electrical Testing Laboratories). An independent source of testing to determine quality, safety, and performance of many types of manufactured products. ETL also verifies conformance to specifications and provides third party certifications. In 1986, this organization changed its formal name to its initials, ETL, because its scope expanded beyond electrical testing and into gas combustion testing.

CGA (Canadian Gas Association). The Canadian Gas Association is the Canadian counter part of AGA and operates to certify, by test, all gas appliances, according to standards issued by The National Standards of Canada.

Independent Laboratories. Laboratories like those listed above (i.e. AGA, UL, ETL, CGA) only test to standards. They do not generate standards, although they often contribute to standards writing along with representatives from manufacturers, utilities, and interested government agencies.

Local Code Requirements. Most major cities have their own codes covering fire prevention, plumbing and heating and related matters. These codes are applicable *in addition to* national and industrial codes and may have special requirements not covered in the more broadly applicable codes. These jurisdictions usually require that installed appliances comply with ANSI standards and accept AGA certification of compliance. Local authorities should be consulted about how these codes apply to specific installations.

Clearances. In the context of installing or locating space heating equipment, *clearance* refers to the minimum clear, unobstructed distance between a heater, or a specific part of it, and the nearest combustible object or surface.

Manufacturers specify the clearance from combustible objects or surfaces for each piece of equipment, and the involved test agency confirms suitability of these clearance dimensions. Installation of heaters must conform to these specified clearances strictly and to any applicable local codes. The following table gives typical "clearances from combustibles" for the various types of space heating equipment.

CAUTIONS AND LIMITATIONS

Hazard Intensity Levels. I In the interest of clarity of communications where safety is concerned, the industry has adopted standard definitions for words calling attention to hazards in dealing with heating fuels and heating equipment. These standard words are defined below; any statements or instructions following these words in manufacturers' literature should be heeded exactly and carefully.

1. **DANGER:** Failure to comply will result in severe personal injury or death.
2. **WARNING:** Failure to comply could result in severe personal injury or death.
3. **CAUTION:** Failure to comply could result in minor personal injury or property damage.

Common Precautionary Statements. Every item of heating equipment will have features that require specific precautions for safe use. Anyone installing, servicing, or operating gas-fired heating equipment should thoroughly read the manufacturer's manual covering the specific equipment for hazard information peculiar to that equipment. In addition, they should also know the general safety precautions common to all equipment. Some of the more common precautions found in manufacturers' literature are quoted below. Most warning statements in use today are required by ANSI and must be given verbatim, therefore they are quoted word-for-word by all manufacturers.

CLEARANCES* FROM COMBUSTIBLES (inches) EXAMPLE ONLY

	At Top	At Rear	At Sides	At Front	At Bottom
Unit Heaters	6	32	18	+	12
Duct Furnaces	6-36**	-	6	-	3-6
Packaged Units	6-36**	-	6	-	3
Radiant	30-42	24-36	24-42	54-180#	54-180++

* Typical, consult manufacturer for specific equipment

\+ Air flow from front, should not be obstructed at any distance

** Varies with size and design

++ Some heaters have optional shades that require greater clearance

\# With unit at 30 degree tilt

Safety and Maintenance

WARNING: Gas-fired appliances are not designed for use in hazardous atmospheres containing flammable vapors, combustible dust or chlorinated or halogenated hydrocarbons.

WARNING: All components of a gas supply system must be leak tested prior to placing equipment in service. NEVER TEST FOR LEAKS WITH AN OPEN FLAME.

WARNING: For best operation gravity-vented outdoor heaters should be located on roof or slab with at least a 20-foot radius between the center of the vent cap and obstructions such as walls, parapets or cupolas.

WARNING: Failure to provide proper venting could result in death, serious injury, and/or property damage. Unit must be installed with a flue connection and proper vent to the outside of the building. Follow installation codes and venting recommendations in the installation manual for this heater. Safe operation of any gravity-vented gas equipment requires a properly operating vent system, correct provision for combustion air and regular maintenance and inspection.

WARNING: The use and storage of gasoline or other flammable vapors and liquids in open containers in the vicinity of this appliance is hazardous.

CAUTION: Joints where flue ducts attach to furnace must be sealed securely to prevent air leakage into draft hood or burner rack area. Leakage can cause poor combustion, pilot problems, shorten heat exchanger life and cause poor performance.

CAUTION: Make sure the thermostat has an adequate volt-ampere rating for the total load to be placed on it. Add up the amperage ratings of all relay coils, valve-solenoid coils or valve hot-wire coils, etc., and match thermostat rating to the total.

CAUTION: If any of the original wire as supplied with the appliance must be replaced, it must be replaced with type TEW 105°C wire or its equivalent, except for energy cutoff or sensor lead wire which must be type SFF-1 (150°C) wire or its equivalent.

CAUTION: The appliance is equipped for a maximum gas supply pressure of 1/2 pound, 8 ounces or 14 inches water column. NOTE: supply pressure higher than 1/2 pound require installation of an additional service regulator external to the unit.

CAUTION: The appliance must be isolated from the gas supply piping system by closing its individual shutoff valve during any pressure testing of the gas supply piping system at test pressure equal to or more that 1/2 PSIG (3.45 KPa).

CAUTION: Due to high voltage on pilot spark wire and pilot electrode, do not touch when energized.

CAUTION: The operating valve is the prime safety shutoff. All gas supply lines must be free of dirt or scale before connecting the unit to insure positive closure.

Miscellaneous Precautions. Some heaters are equipped with built-in diverters which prevent the return of burned gases to the combustion chamber by releasing them from the heater, in case their passage through the flue is retarded or prevented. This is as far as any manufacturer can go to insure the safety of his product; the responsibility for safely and properly venting such heaters from this point on lies wholly with the installer.

Important Note: Proper operation can be impaired if drafts are permitted to strike the relief opening of atmospherically vented appliances. Therefore, locate unit in an area that is reasonably free from such drafts.

General Safety Tips.

If you smell gas:

1. Open windows.
2. Don't touch electrical switches.
3. Extinguish any open flame.
4. Immediately call your gas supplier.

Manufacturers' warranties usually are void if...

(a) furnaces are used in atmospheres containing flammable vapors or atmospheres containing chlorinated or halogenated hydrocarbons;

(b) wiring is not in accordance with the diagram furnished with the heater;

(c) the unit is installed without proper clearances from combustible materials or is located in a confined space without proper ventilation and air for combustion;

(d) furnace air throughput is not adjusted to fall within the range specified on the rating plate;

(e) other specific qualifications of warranty are not observed by the installer or user.

MAINTENANCE

Quality gas-fired heating equipment operates reliably with a minimum of maintenance. However, to ensure good performance over a long service life, heating systems should be regularly inspected, cleaned, and (if necessary) appropriate components adjusted and lubricated as recommended by the manufacturer.

Good Housekeeping is Important. The single most common cause of unsatisfactory performance and below-standard operating efficiency is the lack of general cleanliness. Any heating system that has not received periodic cleaning will not perform up to standard. Air filters, if used, should be cleaned or changed periodically, and all combustion-chamber and air handling components should be brushed or blown clean by compressed air.

Cleaning schedules should be established. In the absence of specific recommendations by the manufacturer, the first cleaning after installation should be performed about three months after the equipment has been in steady use. Subsequent cleanings should then be scheduled according to the amount of dirt and dust observed at the initial cleaning. Some environments require cleaning of equipment on a monthly basis, but in most cases annual cleaning is adequate.

Inspection. Most manufacturers recommend inspecting equipment annually, preferably at the start of the heating season. If heating equipment serves an area that puts a high amount of dust, soot or other impurities into the air, inspection and cleaning should be more frequent. Visual inspection can reveal many of the causes of poor performance.

Equipment will perform poorly if is has any of the following defects: cracks, warpage, deterioration or sooting in the exchanger; clogged, warped or corroded burners; warped or corroded burners; warped, deteriorated or sooted draft hoods; deteriorated, damaged, clogged or sooted vent pipes; continual downdrafts through the vent pipes; and damaged or clogged vent caps.

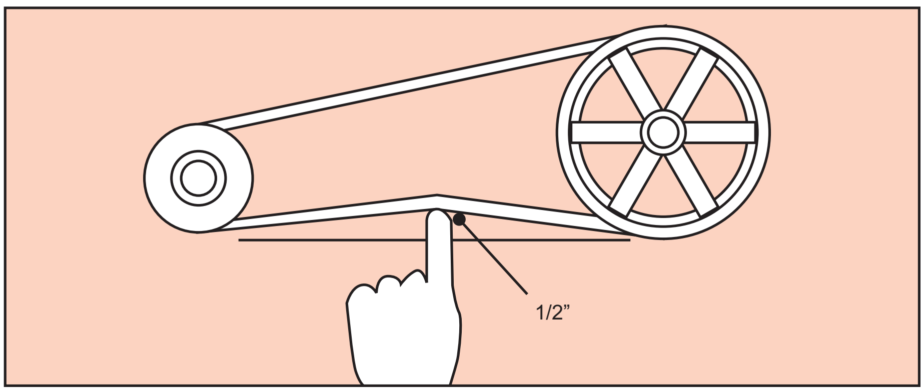
Some of the control and operating defects that the maintenance personnel should check for are: dirty thermostat contacts, which can cause short cycling or intermittent operation; regulators that do not maintain a steady inlet pressure to the main burners; erratic fan controls that create long delays before energizing the fan; encrusted fan blades, which can reduce air volumes; fans or blowers that are not up to speed, which could indicate imminent bearing seizure; defective capacitors, worn or loose belts, and possibly low voltage. In duct systems there is always the possibility that the distribution openings may become obstructed.

Forced-air Equipment, Cleaning and Servicing. The fan or blower and the motor should be checked for cleanliness and for loose parts that might result from vibration. Grease and dirt should be removed from fan or blower-wheel blades and the outside of the motor frame, especially around the shaft. In dusty conditions, the inside of the motor should be blown out through its ventilation openings with compressed air. If the fan or blower is belt driven, the belt should have the proper tension (see Figure 3-22) and the pulleys should be firmly secure on their shafts.

In the combustion chamber, primary and secondary air-inlet openings should be free of grease and dirt. The heating system should be operated through a heating cycle for a check of the operation of the pilot, ignition, and burners. The burner should be checked for a stable flame with no lifting, flashback or floating. Most natural gas units have no air shutters and, since orifices are factory sized for the BTUH content and specific gravity of the gas, they should require no adjustment. Incorrect flames are usually traceable to non-adjustment-related causes like low gas pressure, plugged ports, etc.

Propane units usually have air shutters for adjusting primary air input. Whenever possible, specific adjustment instructions of the manufacturer should be followed. In general, the heater should be allowed to heat up for about 15 minutes before resetting the shutters to adjust the flame. To adjust, close the shutter until the flame turns yellow, then open slowly until the yellow just disappears, then lock the shutter into place at this point.

Cleaning of heat exchangers usually requires some heater disassembly to gain access, especially to the inside (combustion side) surfaces. In many cases, a bottom panel and the burner rack are removable. When disassembling without an instruction manual and drawings of the unit, the maintenance personnel who is unfamiliar with the unit should note carefully the position of parts as they are removed so he/she can replace them in the same manner. The inside of heat exchanger passages are best cleaned with a stiff long-handled brush of a suitable diameter--small enough to fit into crevices and large enough to exert sufficient self-pressure to remove soot and dirt. The brush should be worked vigorously up and down until substantially all foreign matter is removed.



3-22. A properly tensioned belt should deflect about 1/2 inch when pressed with moderate effort.

Radiant Heaters, Cleaning and Servicing. Because of their simpler, more open construction, radiant heaters are easier to maintain than forced-air heating equipment. In general, radiant heaters should be inspected and cleaned about once a year, preferably before the heating season starts. In extremely dirty environments, they should be inspected more frequently and cleaned as necessary.

There are three main areas of concern in maintaining radiant heaters: the burner ceramic plate, the pilot burner, if used, and the reflector. Dust deposits can accumulate on the back of the ceramic plate by entering through the primary air inlet of the burner. The best way to remove such deposits is by applying a soft stream of air (from a low-pressure air hose) first against the face of the ceramic plate and then into the primary air inlet--alternating a number of times between the plate and inlet until both the back of the plate and the air inlet passages are clear.

The pilot burner can accumulate dust and dirt that can cause it to burn too low for the heater to turn on when needed. It should be cleaned with compressed air from an air hose. In extremely dusty conditions, it should be dismantled occasionally and brushed thoroughly.

Reflectors have a highly polished aluminum surface. Accumulations of airborne dust and dirt on this surface can reduce reflectivity considerably. Especially in very dusty environments, reflection surfaces should be cleaned frequently with commercial aluminum cleaners.

General Troubleshooting Guide.

With proper maintenance, gas-fired space heating equipment gives years of trouble-free service. There is very little that can go wrong with the gas-combustion parts of the heater. Trouble is much more likely to develop with the controls and other auxiliary parts.

Most controls are set at the factory or upon installation. These settings should not be changed except on clear indication that poor or improper heater performance results from incorrect control settings.

Trouble that appears to reside in the control system often turns out to be something rather simple. So there are some easy checks that the service personnel should make before using the troubleshooting chart on the opposite page. First, the full cycle of the heater should be observed and the exact nature of the malfunction noted. Before looking for the fault, check that the pilot and burner produce a proper flame, make sure that primary air openings are clear of lint and dust and that the vent system is clear and working properly.

Electrical contacts are a common and easy-to-correct cause of equipment malfunctions. They should be checked and cleaned before any more complex and difficult repairs or adjustments are made. In servicing space-heating equipment, service personnel should follow manufacturer's directions as closely as possible.

The following table can help to determine the cause of common equipment problems.

TROUBLESHOOTING CHART

Trouble	Probable Cause	
Pilot will not light (match lit system).	1. Manual valve turned off. 2. Air in gas line. 3. Incorrect lighting procedure. 4. Dirt in pilot orifice.	5. Extremely high or low gas pressure. 6. Bent or kinked pilot tubing. 7. Failed energy cutoff device. 8. Gas not turned on.
Pilot lighted but magnetic gas vavle will not open. (All manual valves are open) Match lit system).	1. Power not turned on or thermostat not calling for heat. 2. Circuit to magnetic valve open. 3. Faulty transformer. 4. Faulty or dirty thermocouple or safety pilot switch.	5. Faulty thermostat. 6. Faulty magnetic valve. 7. High gas pressure (in excess of 1/2 pound).
Ventor motor will not start.	1. No power to unit. 2. No power to venter relay.	3. Venter relay defective. 4. Defective motor or capacitor.
Pilot will not light (spark ignition system).	1. Manual valve not open. 2. Air in gas line. 3. Dirt in pilot orifice. 4. Gas pressure too high or too low. 5. Kinked pilot tubing. 6. Pilot valve does not open. 7. No spark: A. Loose wire connections. B. Transformer failure. C. Incorrect spark gap.	D. Spark cable shorted to ground. E. Spark electrode shorted to ground. F. Drafts affecting pilot. G. Faulty ignition control. H. Ignition control box not grounded. 8. Optional lockout device interrupting control circuit by above causes. 9. Faulty combustion air proving switch. 10. Gas not turned on.
Pilot will light, main valve will not open (spark ignition system).	1. Manual valve not open. 2. Main valve not opening. A. Defective valve. B. Loose wire connections. 3. Ignition controller does not power main valve. A. Loose wire connections.	3. B. Flame sensor grounded; pilot lights - spark continues. C. Gas pressure incorrect. D. Cracked ceramic at sensor. E. Faulty ignition controller.
No heat (heater operating).	1. Dirty filters. 2. Incorrect manifold pressure or orifices. 3. Cycling on limit control.	4. Improper thermostat location or adjustment. 5. Belt slipping on blower. 6. Motor running wrong direction (three phase only.
Cold air is delivered on: a. startup b. during operation	1. Fan control heater element improperly wired. 2. Defective fan control.	3. Blower set for too low a temperature rise. 4. Incorrect manifold pressure.
Motor will not run.	1. Circuit open. 2. Fan control inoperative.	3. Contactor inoperative. 4. Defective motor.
Motor cycles on and off while burner is operating (see motor cuts out by overload device).	1. Fan control heater element improperly wired. 2. Defective fan control. 3. Motor overload device cycling on and off.	4. Three phase motor rotating in opposite direction. 5. Ambient temperature too low.
Motor cuts out by overload device.	1. Improper motor pulley adjustment. 2. Improper static pressure on duct system.	3. Low voltage. 4. High voltage.

Heat System Selection

The following guide summarizes steps and considerations for selecting space-heating equipment for a forced-air ducted heating system. Not all steps are relevant to radiant heaters and other non-ducted systems.

DETERMINING HEAT REQUIREMENTS

Calculate the sum of all heat losses of the space to be heated using ASHRAE design data and procedures. The following design data, formulas and information are provided as a convenience for estimating total heat loss for selecting equipment. The data and information cover only the most common types of commercial and industrial construction and represent the kind of information that the heating engineer or contractor will need. Since each heating installation has its own special conditions and requirements, the engineer or contractor must use experience and judgement in applying this data and information.

Design Temperatures. Table I presents average outside design temperatures for calculating heat gain.

Selection of inside temperature will vary with the preference of the owner or user of the space to be heated. Most commercial applications find an indoor design temperature of 68°F satisfactory. For warehouses and factories, the most common temperature specified is 55°F. Indoor temperatures must be maintained by the heating equipment when the outdoor temperature is equal to or above the outdoor design temperature. For example, a heater in a retail store in Pittsburgh, Pa., should be able to maintain 68°F indoors with -5°F outdoors.

Degree Days. The degree-day method is probably the best way to estimate a building's fuel requirements. It is based on the fact that an average outdoor 24-hour temperature of 65°F results in no demand for heat in most buildings in the United States. For example, if the temperature reaches a high of 70°F and touches a low of 60°F during the night, the *mean daily temperature is* 65 °F the temperature at which no demand for heat occurs *(on the average for the whole country). A degree-day is* a difference of one Fahrenheit degree between 65°F and the mean temperature maintained for 24 hours. Example: if the outdoor temperature averages 64°F, from midnight to midnight, the difference from 65°F is defined as a degree-day. For a day during which the mean daily temperature is 62°F, the number of degree-days for that day would be three.

Degree-day values are available from the U. S. Weather Bureau and the Canadian Meteorological Division, Department of Transport.

The yearly total of degree-day values for a given locality can be used to calculate a building's heat loss for an entire season with the following formula:

(I) $Q = 24 \times H \times D \div \Delta T$

where:

Q = heat loss in BTUs per heating season

D = total number of degree days in season

ΔT = the design temperature difference between indoor and outdoor temperatures

H = design heat loss in BTU H

Table I

CITY	OUTSIDE DESIGN TEMPERATURE (°F)	
	HEATING	COOLING
Albany, NY	-10	90
Atlanta, GA	10	95
Baltimore, MD	10	90
Boston, MA	0	85
Buffalo, NY	-5	85
Cheyenne, WY	-20	90
Chicago, IL	-10	95
Cleveland, OH	-5	90
Dallas, TX	10	100
Denver, CO	-10	95
Detroit, MI	-5	90
Houston, TX	20	95
Jacksonville, FL	30	95
Kansas City, MO	-10	100
Los Angeles, CA	40	90
Milwaukee, WI	-15	90
Miami, FL	45	90
Minneapolis, MN	25	90
New Orleans, LA	25	95
New York, NY	5	90
Phoenix, AZ	35	105
Pittsburgh, PA	-5	90
San Francisco, CA	35	80
Spokane, WA	-15	80
Montreal, Que., Canada	-10	90
Toronto, Ont., Canada	0	90
Winnipeg, Man., Canada	-30	90

Infiltration Load. Wind pressure outside of a building continually forces a certain amount of air to infiltrate through openings around doors and windows. Additional air rushes in each time a window or door opens. This cold air must be included as part of the heat load and extra equipment capacity must be added to accommodate this extra load. The formula to be used is:

(II) Q = CFM X 1 .085 X ΔT

where:

Q = infiltration heat load, in BTUH

CFM= outside air that enters, in cubic feet per minute

1 .085 = a constant

ΔT = temperature difference between inside and outside, °F

The rate of air infiltration is difficult to determine. For calculation purposes it can be estimated by using what is known as the "air change" method:

(III) R = VxCx1/60

where:

R = infiltration rate in cubic feet per minute

V = room volume in cubic feet

C = air changes per hour

Air changes are based on judgment, previous experience, and empirical data (see air change requirements, page 4-3).

When specific data and information are not available, infiltration may be assumed to average one air change per hour.

Ventilation Load. To expel smoke and odors, and to provide general ventilation, it is sometimes desirable to introduce outside air with a fan or blower rather than rely on air to "leak in". Often this forced-air ventilation is required by local codes--especially in spaces that are used for public purposes. It is also necessary to provide for the amount of air that is deliberately exhausted from spaces like washrooms, kitchens, spray booths, laundry rooms, etc.

When ducts bring outside air in directly to the intake side of a heater, this additional heat load must be figured into the overall determination of total heat capacity required. Both the ventilation load (Formula IV) and the infiltration load (Formula II) should be calculated but only the greater of the two should be included in the total heat-load estimate. In applying unit heaters for general applications, many contractors allow about 10% of total air quantity for outside air. Values of ventilation load for given air temperatures are listed in Table II.

The formula for calculating ventilation load is:

(IV) V = CFM x 1.085 x ΔT

where:

V = ventilation load, BTUH

CFM= outside air brought in through the system, cubic feet per minute

ΔT = temperature difference between inside and outside air, °F

1,085 = a constant

TABLE II. HEATING LOAD DUE TO OUTSIDE AIR

Final Air Temperature °F	Initial Air Temperature, °F						
	-10	0	10	20	30	40	50
	TOTAL BTUH PER CFM						
60	75.9	65.0	54.2	43.4	32.6	21.7	10.8
62	78.0	67.3	56.4	45.6	34.8	23.9	13.0
64	80.3	69.4	58.6	47.7	36.9	26.0	15.2
66	82.4	71.6	60.7	49.9	39.0	28.2	17.4
68	84.5	73.8	62.9	52.0	41.2	30.4	19.5
70	86.8	75.9	65.0	54.2	43.4	32.6	21.7
72	89.0	78.0	67.3	56.4	45.6	34.8	23.9
74	91.1	80.3	69.4	58.6	47.7	36.9	26.0
76	93.3	82.4	71.6	60.7	49.9	39.0	28.2
78	95.6	84.5	73.8	62.9	52.0	41.2	30.4
80	97.8	86.8	75.9	65.0	54.2	43.4	32.6

TABLE III

RECOMMENDED PERIODS OF AIR CHANGE, Minutes	
Assembly Halls	5 to 10
Auditoriums	5 to 15
Bakeries	3 to 5
Boiler Rooms	1 to 4
Box Annealing	2 to 5
Breweries	2 to 8
Dry Cleaning Plants	1 to 6
Dye Plants	2 to 4
Electric Substations	8 to 1 2
Engine Rooms	1 to 2
Factories (light occupation, no contamination)	5 to 10
Factories (dense occupation, fumes, steam)	1 to 5
Forge Shops	1 to 3
Foundries	1 to 3
Furnace Buildings	1 to 2
Galvanizing Plants	1 to 3
Garages	3 to 5
Generator Rooms	2 to 5
Glass Plants	1 to 2
Gymnasiums	2 to 10
Heat Treating Buildings	1/2 to 1
Kitchens	1 to 3
Laboratories	3 to 10
Laundries	2 to 5
Machine Shops	3 to 6
Offices	4 to 8
Packing Plants	2 to 5
Paint Shops	1 to 3
Paper Mills	2 to 3
Pickling Plants	2 to 3
Plating Shops	1 to 4
Pump Rooms	8 to 12
Railroad Round Houses	1 to 3
Recreation Rooms	2 to 8
Restaurants	5 to 8
Shops (general, fabrication)	5 to 10
Steel Mills	1 to 5
Textile Mills	5 to 12
Toilets	2 to 5
Transformer Rooms	1 to 5
Turbine Rooms	2 to 6
Warehouses	10 to 30
Wood Shops	3 to 6

For swimming pools, ventilation rates may be based on occupation density: 20 to 25 CFM per occupant is the rate that should be used. A bare minimum of 15 CFM per occupant may be used if the occupation density is less than 25 people per 1000 square feet.

Makeup-air (Ventilation)

Requirements. When air-change specifications are dictated by code, the formula for determining the CFM requirement is simple. The building or room volume (in cubic feet) divided by the number of minutes per air change yields the makeup air required (in CFM). Air change quantities will vary as influenced by local, state, and federal codes. However, when such codes are not in effect, Table III may be helpful, as it recommends ventilation rates for various buildings.

Heat Loss and U-Factors.

Because of the difference between inside and outside temperatures, heat loss will occur. The heating engineer must determine the rate at which heat is lost. The basic formula used in making this calculation is:

(V) $H = A \times U \times \Delta T$

where:

H = heat loss, BTU H

A = area of the surface, square feet

U = heat transfer coefficient, BTUH per sq ft per °F

ΔT = temperature difference between inside and outside, °F

The rate at which heat will travel through a construction material depends on the thickness and nature of the material. This rate is the U-Factor (heat transmission coefficient) of a material. It indicates how many BTUs will flow through a material having a one-square-foot surface in one hour for each degree of temperature difference between inside and outside.

Table IV below lists common construction materials and components with their average U-Factors. These U-Factors may be applied to various types of construction encountered in commercial and industrial buildings. Many insulating materials are rated based on “R” factors. To determine “U” factor from “R” factor simply divide 1 by R(1/R=U). Conversely, to convert U to R divide 1 by U(1/U=R).

TABLE IV—U-FACTORS

SURFACE AND CONSTRUCTION	U-FACTOR**		
WALLS	**No Interior Finish**	**Plaster on Surface**	**Plaster or Dry Wall on Furring**
Transite, 3/8" thick on wood or metal frame	1.18	_	0.35
Corrugated iron on wood or metal frame	1 60	_	0 75
Flat transite on wood or metal frame	1.12	_	0 42
Flat iron on wood or metal frame	1.35	_	0.70
8" solid brick	0.48	0.45	0.31
12" solid brick	0.35	0.34	0 25
4" brick + 8" concrete block (hollow)	0 32	0 29	0 23
ROOF	**Insulation**	**Without Ceiling**	**With Ceiling*** **
Metal deck	none	0.95	0 47
	1”	0 24	0 20
	2"	0 15	0.13
Concrete, 2" thick	none	0 82	0.43
2" thick	1”	0.25	0.20
2" thick	2"	0.15	0 13
4'' thick	none	0.74	0.41
4" thick	1”	0.23	0.19
4" thick	2"	0 14	0.13
Wood, 1" thick	none	0 50	0.32
	1”	0 21	0.17
	2"	0.14	0 12
GLASS			
Single glazed, plate	1.13		
Double glazed, plate or single glass (with storm sash)	0.63		
Glass block	0.50		
DOORS			
Glass	1.13		
Metal	1 .35		
Wood	0.65		
FLOORS			
Basement floor on grade	0.04		
Below grade	UdT = 2 *		

*The combined U-Factor and temperature difference for floor below grade is figured at a value of two. Multiply the square feet of floor surface by this factor to arrive at the total heat loss for basement floors below grade.

**When using special materials not listed above, obtain U-Factor from manufacturer’s literature.

***Ceiling with air space between roof and ceiling. Factors apply to either dropped or conventional ceilings.

Heat System Selection

Determining Air-Flow Requirements. For a new system, the appliance air-flow rate will depend on the number of air turnovers per hour desired in the space. One and a half to two air changes is average.

Ventilation and Makeup Air. The rate of air change should be matched to the nature and use of the facility to be heated. For example, a drug store requires a more frequent change of air than a warehouse, and an office will require an even more frequent change. Table 111 (page 4-3) lists recommended air -change rates for various types of facilities.

If a duct furnace is to be installed in an existing system, check the fan speed, motor current, and duct pressure drop and determine the air handling capacity from blower manufacturer's data and graphs. See "Determining Optimum Duct System", page 4-8.

Entering-air Temperature. It is important to calculate the temperature of the air entering the duct furnace. This temperature can be calculated as follows:

(VI) $T_M = T_R T_O$

where:

T_M = mixed air temperature, °F

T_R = % return air x return-air temperature, °F

T_O = % outdoor air x outdoor-air temepraturе, °F

Temperature Rise. (Not relevant to radiant heaters). To select equipment with a heat exchanger made of appropriate material for the job, it is necessary to know the temperature rise through the heater required to meet design temperature conditions. This is the difference between the temperature at the cold-air inlet of the heater and the temperature at the hot-air outlet when the heater is operating under normal conditions.

It is relatively simple to calculate the required temperature rise of the air flowing through the duct furnace with the formula:

(VII) $\Delta T = (H/Q) \times 1.085$

where:

ΔT = air temepraturе rise, °F

H = heat loss, BTUH

Q = air quantity, CFM

1.085 = constant

This temperature difference will largely determine what kind of heat exchanger the heater should have. See the paragraphs of heat exchanger, page 2-8.

Static Pressure Requirement

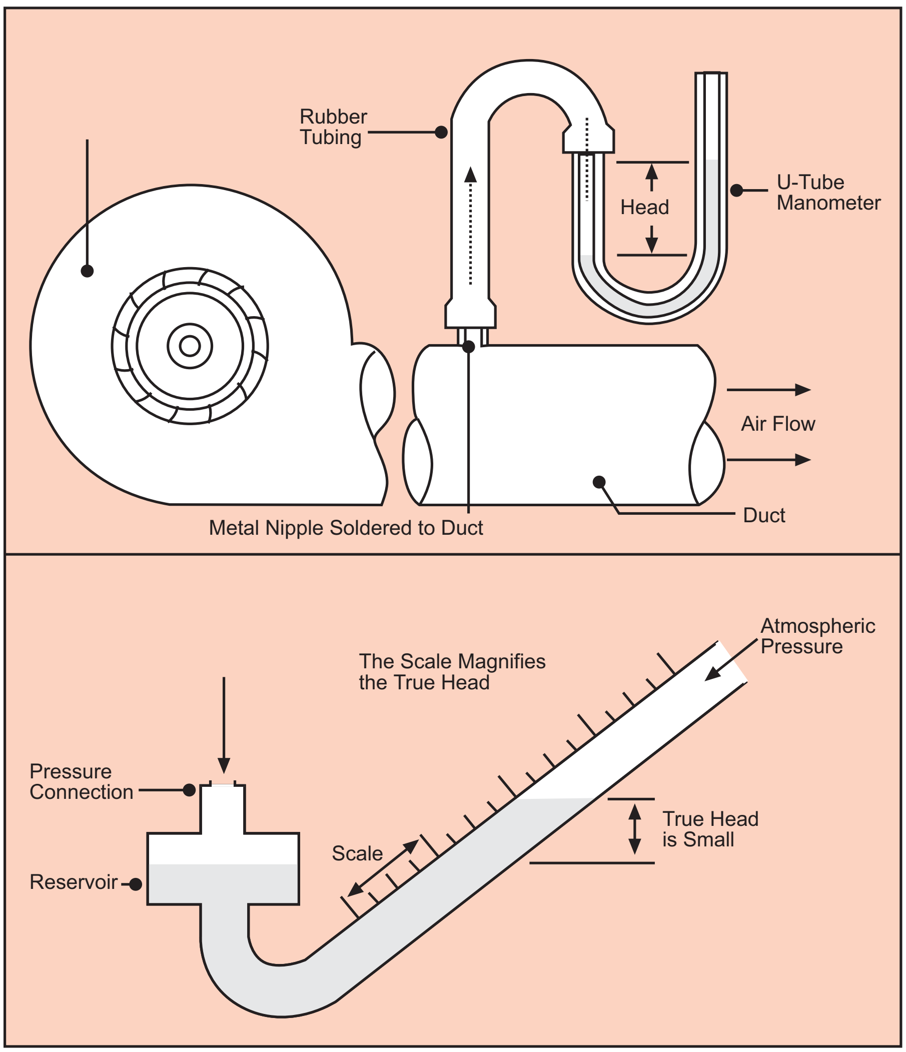
The total frictional losses of the air-handling system must be known so that the fan and drive can be selected. The total static pressure drop should include the individual drops through the furnace, ductwork, outlets and grilles, filters and fan. Such losses can be determined from the many charts and formulas published in the ASHRAE Guide and Data Book titled "Fundamentals and Equipment", or from information supplied by manufacturers.

If it is necessary to measure the static loss within an existing duct system, accurate measurements can be made with a slope gauge (also called an inclined manometer), provided the slope gauge range covers the pressure range to be measured. If the anticipated pressure exceeds the range of the available slope gauge, a U-tube manometer may be used. (See Figure 4-1.) Of the two instruments, the slope gauge is preferable because it magnifies readings so that even very small pressures can be read accurately and easily.

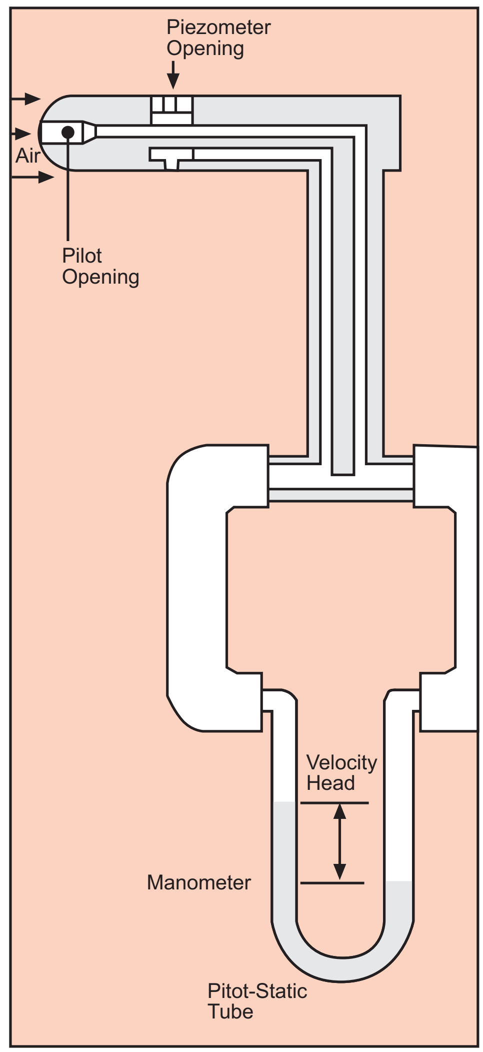
For best results, all static pressure determinations should be based on multiple-point readings to ensure a realistic average. It is also important to avoid false readings due to air-velocity impact pressure: the sensing device should always be located where it will not face the air stream. A Pilot tube (Figure 4-2) will eliminate such errors if it is positioned with the pointed end (which contains the velocity port) facing the air stream.

Relief, Exhaust Requirements. Exhaust requirements are established by code or by the fact that harmful dusts, vapors, or odors must be evacuated from the building. Collector hoods usually are used when the source of the contaminant is in a specific location. The amount of air needed to collect these contaminants is based on the velocity across the face of the hood. Capture velocities will vary but a good rule-of-thumb velocity would be 100 to 250 feet per minute (FPM).

Relief dampers are used to relieve building pressures when outside air is admitted under pressure. Inside pressure results from fully pressurized heating with 100% outside air.



4-1. U-tube and slope gauge.



4-2. Pitot tube.

Optimizing Distribution Systems

Heat distribution planning should include careful consideration of a number of factors: special requirements of the occupants; the location of large windows or other glass-wall areas' sources of high infiltration; and the location of partitions, counters, display cases, stacks of stored material, lighting fixtures and other items that might interfere with circulating air or the rays from a radiant heater.

Determining Optimum Forced-air Equipment Sizing

Theoretically, forced-air heating equipment can be sized exactly to meet heat requirements at the interior and exterior design temperatures. Usual practice, however, is to oversize the equipment for faster pickup after nighttime temperature setback.

Small sizes are usually selected to have about 30% more heat output capacity than required for continuous blower operation and large sizes are oversized by about 20%.

Determining Optimum Infrared Equipment Sizing

As with forced-air heating, determination of the size and number of radiant heaters starts with a building heat loss survey and calculation. With radiant heaters, heat losses due to convection currents at walls and stratification of warm air at the roof are reduced. Engineering studies have shown that a properly designed radiant heating system will burn about 85% of the fuel indicated by ASHRAE heat-loss calculations. Consequently, total installed input capacity of radiant heaters can be 85% of the capacity calculated by ASHRAE methods for forced-air equipment.

The size of radiant heaters depends on the maximum practical mounting height and the spacing required to maintain the desired comfort level and to prevent cold spots. Once the mounting height has been determined, manufactures' heater application tables can be used to select the size and placement of heaters. Here, considerable judgement must be used to place heaters so optimum coverage of the floor can be established. Rays from infrared units should be directed away from walls as much as possible and should be concentrated on the floor area for the best application. Heaters will not necessarily be spaced at uniform intervals.

Zoning. Central heating or heating-cooling systems can be single- or multi-zone distribution systems. Single-zone systems usually employ a single furnace and a single duct to deliver air to the entire space, under control of a single thermostat. A multi-zone system may consist of one or more heating (or heating-cooling) units serving several separately ducted space zones. A thermostat in each zone controls the temperature of the air delivered to the zone.

The heating engineer or contractor must exercise judgement in determining the number and location of heaters, duct outlets and cold-air-return inlets. Sometimes the shape of the space requires a decision as to whether one heater or several heaters will provide better service. For example, in an L-shaped structure, it might be desirable to place one or more unit heaters or radiant heaters in each section. Each heater would then be sized to meet its zone requirements and carry its share of the total load.

Cost/Benefits. First cost and operating costs of single-zone systems are low but flexibility is limited. Such systems do not readily met changing space needs or space use.

First cost of multi-zone system is higher than for an equivalent single-zone system because it would contain more ductwork and multiple control dampers and thermostats. Operating costs may also be higher (especially for heating-cooling units), but the flexibility results in greater comfort for occupants and greater adaptability to changing needs and use patterns.

Determining Optimum Equipment Location

Determine which locations are suitable and available for the equipment. If floor space is limited (and other conditions permit) suspended unit heaters, radiant heaters or rooftop packaged units may be the best choice. For an existing building, check the spaces available for heating equipment and consult with the owner to make sure they are not reserved for another purpose.

For new construction, advise the builder or owner as to where the heating equipment should be placed for the best heating results, and request allocation of the space (or spaces) in the building design.

Coverage. Convection-type units, whether unit heaters or packaged units, must be ample in numbers or be attached to duct systems that can adequately cover the space to be heated. In connection with coverage, it has been expressed that the CFM must be adequate to turn over the air in the building at least one and a half times. The turnover rate can be determined by adding the CFM's from all units and multiplying by this total by 60, and then dividing this number into the building volume.

Infrared units must be located so that infrared patterns strike the floor at the perimeter of the building. Care must be exercised in limiting the pattern to as little wall area as possible. All the available pattern should be directed onto the floor so that the floor becomes a heat sink and ultimately provides heat to the space.

Determining Optimum Duct System

The simplest forced-air system has no ducts. A fan blows air directly from the heater into the space to be heated. This method of heat distribution is satisfactory for small areas and large areas that can be divided in small zones. The disadvantage of this method is that air velocities may need to be rather high, therefore such systems tend to be noisy and the fast-flowing air may feel uncomfortable to occupants.

For more uniform distribution to larger areas with more remote points of need, an air-distribution duct network is used. The basic elements of the system are a centrifugal blower belt-driven by an electric motor, a series of main and branch ducts, a filter and duct dampers. A duct system can selectively heat a number of separate rooms or areas.

In a duct system, the blower causes cool air to be drawn into the return intake duct and through an air filter. It then pushes the air through the heat exchanger and on through the hot-air ducts to the outlets. This air-circulation pattern continues as long as the blower operates - and the blower operates only when the temperature at the heat exchanger is above the blower "cut-in" and "cut-out" settings. The blower may be programmed to operate continuously where ducted air-distribution systems are in use, providing the air velocity at the discharge opening is not greater than 500-700 FPM.

Duct systems need to be carefully and knowledgeable designed. Supply outlets should be located to give desired air distribution patterns. Air streams leaving the system outlets should be directed toward the area where most heat is desired, but blowing heated air on personnel within work zones should be avoided. Horizontal and vertical louvers may be used to direct the heated air where needed. Air should be kept in continuous but not too-rapid circulation. The use of proper outlets will minimize variations in air temperature throughout the room, and thus result in the maximum of comfort for the particular system used.

Duct layout should also provide for returning air to the heater, so that there is a completely closed circuit of air being reheated by the heater or furnace. The closed-circuit arrangement can be more easily achieved by placing the heater in a central area such as a corridor or other space, which connects with all adjacent occupied spaces; otherwise, a special return duct system must be used.

Good duct design provides the smallest-size duct that will produce the required air flow at the pressure available. Space and scope limitations of this handbook do not permit presentation of the large number of air-distribution-system design methods that are available. For best performance of space heating equipment, it is worthwhile to retain a qualified consultant. The recognized authority for duct-sizing information is the Air Conditioning Contractors Association, from whom a detailed manual on duct sizing and design can be purchased.

Control System Requirements. In modern space heating equipment, a variety of automatic controls are available to cycle the system in response to thermostat demand. The options range from a simple ON/OFF system to electronically modulated systems that can control temperatures accurately to maintain a temperature within one-tenth of a degree Fahrenheit. See the section on controls, page 2-9.

Selecting the Equipment

After the above mentioned information has been gathered, and the appropriate calculations and decisions have been made, manufacturers' catalogs and data sheets should be consulted to find the best fit.

In addition to heating capacity, air-handling capability and efficiency, other factors should be considered in evaluating and comparing specific equipment. Considering that a heating system is a long-term investment, the purchaser should opt for high quality in design and construction - the cost difference paid for quality can be insignificant, especially when spread over a 20- or 30-year economic payoff period. Economic justification calculations should include consideration of the costs of maintenance, repair, downtime, possible loss of income and profit, and inconvenience that can result from purchasing decisions motivated chiefly by first-cost considerations.

The heating equipment buyer should, whenever possible, purchase equipment bearing the AGA, ETL, or UL symbols and carrying the assurance that the equipment meets the standards of NFPA and NFGC.

Determining Pipe Sizes

To determine proper pipe size for your heating system, add up the longest line required, i.e., the distance between the main pressure regulator and the farthest heating unit in the system. Divide this total pipe length into the total available pressure drop.

(VIII) P_a

$$\frac{P_a}{L} \times 100 = P_b$$

where:

P_a = Total available pressure drop (Pressure from utility minus manufacturer's recommended minimum supply pressure);

l = Total equivalent pipe length in feet'

P_b = Allowable pressure drop per 100 feet.

Determine the required CFH of gas in that branch line and find this CFH in the lefthand column of Table V. Read across to the proper pipe size column and select pipe size based on Pb from formula VIII. Bear in mind that fittings may add to the total length (L), and you may wish to include these dimensions in a second evaluation. (See Table VI).

NOTE: For complex systems, it may be advantageous to divide the system into major trunk lines for closer calculations.

TABLE V - PRESSURE DROP PER 100 FEET
(1000 BTU GAS AT .60 SPECIFIC GRAVITY)

	PIPE SIZE, inches							
CFH	**1/2**	**3/4**	**1**	**1-1/4**	**1-1/2**	**2**	**3**	**4**
25	0.125	0.029	0.008	0.002				
50	0.500	0.118	0.033	0.008	0.003			
75	1.125	0.265	0.074	0.017	0.007	0.002		
100	2.000	0.471	0.132	0.031	0.013	0.004		
125	3.125	0.736	0.206	0.048	0.020	0.006		
150	4.500	1.060	0.297	0.070	0.029	0.009	0.001	
175	6.125	1.442	0.404	0.095	0.040	0.012	0.001	
200	**4.62 oz.**	1.884	0.528	0.124	0.052	0.015	0.002	
250	**7.23 oz.**	2.944	0.825	0.194	0.081	0.024	0.003	0.001
300	**10.4 oz.**	4.239	1.188	0.279	0.117	0.034	0.003	0.001
350	**14.16 oz.**	5.771	1.617	0.380	0.159	0.046	0.006	0.001
400	**1.16 lb.**	7.536	2.112	0.496	0.208	0.060	0.008	0.002
500	**1.81 lb.**	**6.81 oz.**	3.300	0.775	0.325	0.095	0.012	0.003
600	**2.6 lb.**	**9.8 oz.**	4.752	1.116	0.468	0.136	0.017	0.004
800	**4.62 lb.**	**1.09 lb.**	**4.88 oz.**	1.984	0.833	0.242	0.030	0.007
1,000	**7.22 lb.**	**1.7 lb.**	**7.63 oz.**	3.100	1.301	0.378	0.047	0.011
1,250	**11.28 lb.**	**2.66 lb.**	**11.92 oz.**	4.844	2.033	0.591	0.073	0.017
1,500	**16.25 lb.**	**3.83 lb.**	**1.07 lb.**	6.975	2.927	0.851	0.106	0.025
2,000	**28.88 lb.**	**6.8 lb.**	**1.91 lb.**	**7.17 oz.**	5.204	1.512	0.188	0.044
2,500	**45.13 lb.**	**10.63 lb.**	**2.98 lb.**	**11.2 oz.**	**4.70 oz.**	2.363	0.294	0.069
3,000	**64.98 lb.**	**15.3 lb.**	**4.29 lb.**	**1.01 lb.**	**6.77 oz.**	3.402	0.423	0.099

NOTE: Presusre drop data above not designated in pounds or ounces is expressed in inches water-column.

TABLE VI - STANDARD LENGTHS OF PIPE FITTINGS AND VALVES (IN FEET)

TYPE OF FITTING OR VALVE	NOMINAL PIPE SIZE, inches							
	1/2	3/4	1	1-1/4	1-1/2	2	3	4
Standard tee with entry discharge through side	3.4	4.5	5.5	7.5	9.0	12.0	17.0	22.0
Standard elbow	1.7	2.2	2.7	3.7	4.3	5.5	8.0	12.0
Medium sweep elbow	1.3	1.8	2.3	3.0	3.7	4.6	6.8	9.0
Long sweep elbow or run of a standard tee or butterfly valve	1.0	1.3	1.7	2.3	2.7	3.5	5.3	7.0
45° elbow	0.8	1.0	1.2	1.6	2.0	2.5	3.7	5.0
Close-return bend	3.7	5.1	6.2	8.5	10.0	13.0	19.0	24.0
Gate valve, wide open, or slight bushing reduction	0.4	0.5	0.6	0.8	0.9	1.2	1.7	2.3

TABLE VII - GAS METER FLOW-TIME TABLE (CUBIC FEET PER HOUR)

TEST METER DIAL

Seconds for 1 revolution	0.5 cu.ft.	1 cu. ft.	2 cu. ft.	5 cu. ft.	Seconds for 1 revolution	0.5 cu.ft.	1 cu. ft.	2 cu. ft.	5 cu. ft.
	Cubic Feet per Hour					Cubic Feet per Hour			
10	180	360	720	1800	47	38	77	153	383
11	164	327	655	1636	48	37	75	150	375
12	150	300	600	1500	49	37	73	147	367
13	138	277	555	1385	50	36	72	144	360
14	129	257	514	1286	51	35	71	141	353
15	120	240	480	1200	52	35	69	138	346
16	112	225	450	1125	53	34	68	136	340
17	106	212	424	1059	54	33	67	133	333
18	100	200	400	1000	55	33	65	131	327
19	95	189	379	947	56	32	64	129	321
20	90	180	360	900	57	32	63	126	316
21	86	171	343	857	58	31	62	124	310
22	82	164	327	818	59	30	61	122	305
23	78	157	313	783	60	30	60	120	300
24	75	150	300	750	62	29	58	116	290
25	72	144	2878	720	64	29	56	112	281
26	69	138	277	692	66	29	54	109	273
27	67	133	267	667	68	28	53	106	265
28	64	1269	257	643	70	26	51	103	257
29	62	124	248	621	72	25	50	100	250
30	60	120	240	600	74	24	48	97	243
31	58	116	232	581	76	24	47	95	237
32	56	113	225	563	78	23	46	92	231
33	55	1098	218	545	80	22	45	90	225
34	5	106	212	529	82	22	44	88	220
35	51	103	206	514	84	21	43	86	214
36	20	100	200	500	86	21	42	84	209
37	49	97	195	486	88	20	41	82	205
38	47	95	189	474	90	20	40	80	200
39	46	92	185	462	94	19	38	76	192
40	45	90	180	450	98	18	37	74	184
41	44	88	176	440	100	18	36	72	180
42	43	86	172	430	104	17	35	69	173
43	42	84	167	420	108	17	33	67	167
44	41	82	164	410	112	16	32	64	161
45	40	80	160	400	116	15	31	62	155
46	39	78	157	391	120	15	30	60	150

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NOTE: To convert to BTU per hour, multiply by the BTU heating value of the gas used.

Determining Orifice Sizes

TABLE VIII - UTILITY GASES (Cubic feet per hour at sea level)

Specific Gravity = 0.60 For utility gases of another specific gravity, select factor from Table X.

Orifice Coefficient = 0.9

Orifice Size Decimal or (DMS)	Gas Pressure at Orifice - Inches Water Column								
	3	3.5	4	5	6	7	8	9	10
0.008	0.17	0.18	0.19	0.23	0.24	0.26	0.28	0.29	0.30
0.009	0.21	0.23	0.25	0.28	0.30	0.33	0.35	0.37	0.39
0.040	0.27	0.29	0.30	0.35	0.37	0.41	0.43	0.46	0.48
0.011	0.33	0.35	0.37	0.42	0.45	0.48	0.52	0.55	0.59
0.012	0.38	0.41	0.44	0.50	0.54	0.57	0.62	0.65	0.70
80.000	0.48	0.52	0.55	0.63	0.69	0.73	0.79	0.83	0.88
79.000	0.55	0.59	0.64	0.72	0.80	0.84	0.90	0.97	1.01
78.000	0.70	0.76	0.78	0.88	0.97	1.04	1.10	1.17	1.24
77.000	0.88	0.95	0.99	1.11	1.23	1.31	1.38	1.47	1.55
76.000	1.05	1.13	1.21	1.37	1.52	1.61	1.72	1.86	1.92
75.000	1.16	1.25	1.34	1.52	0.16	1.79	1.91	2.04	2.14
74.000	1.33	1.44	1.55	1.74	1.91	2.05	2.18	2.32	2.44
73.000	1.51	1.63	1.76	1.99	2.17	2.32	2.48	2.64	2.78
72.000	1.64	1.77	1.90	2.15	2.40	2.52	2.69	2.86	3.00
71.000	1.82	1.97	2.06	2.33	2.54	2.73	2.91	3.11	3.26
70.000	2.06	2.22	2.39	2.70	2.97	3.16	3.38	3.59	3.78
69.000	2.25	2.43	2.61	2.96	3.23	3.47	3.68	3.94	4.14
68.000	2.52	2.72	2.93	3.26	3.58	3.88	4.14	4.41	4.64
67.000	2.69	2.91	3.12	3.52	3.87	4.13	4.41	4.69	4.94
66.000	2.86	3.09	3.32	3.75	4.11	4.39	4.68	4.98	5.24
65.000	3.14	3.39	3.72	4.29	4.62	4.84	5.16	5.50	5.78
64.000	3.41	3.68	4.14	4.48	4.91	5.23	5.59	5.95	6.26
63.000	3.63	3.92	4.19	4.75	5.19	5.55	5.92	6.30	6.63
62.000	3.78	4.08	4.39	4.96	5.42	5.81	6.20	6.59	6.94
61.000	4.02	4.34	4.66	5.27	5.77	6.15	6.57	7.00	7.37
60.000	4.21	4.55	4.89	5.52	5.95	6.47	6.91	7.35	7.74
59.000	4.41	4.76	5.11	5.78	6.35	6.78	7.25	7.71	8.11
58.000	4.66	5.03	5.39	6.10	6.68	7.13	7.62	8.11	8.53
57.000	4.84	5.23	5.63	6.36	6.96	7.44	7.94	8.46	8.90
56.000	5.68	6.13	6.58	7.35	8.03	8.73	9.32	9.92	10.44
55.000	7.11	7.68	8.22	9.30	10.18	10.85	11.59	12.34	12.98
54.000	7.95	8.00	9.23	10.45	11.39	12.25	13.08	13.93	14.65
53.000	9.30	10.04	10.85	12.20	13.32	14.29	15.27	16.25	17.09
52.000	10.61	11.46	12.31	13.86	15.26	16.34	17.44	18.57	19.53
51.000	11.82	12.77	13.69	15.47	16.97	18.16	19.40	20.64	21.71
50.000	12.89	13.92	14.94	16.86	18.48	19.77	21.12	22.48	23.65
49.000	14.07	15.20	16.28	18.37	20.20	21.60	23.06	24.56	25.83
48.000	15.15	16.36	17.62	19.88	21.81	23.31	24.90	26.51	27.89
47.000	16.22	17.52	18.80	21.27	23.21	24.93	26.62	28.34	29.81
46.000	17.19	18.57	19.98	22.57	24.72	26.43	28.23	30.05	31.61
45.000	17.73	19.15	20.52	23.10	25.36	27.18	29.03	30.90	32.51
44.000	19.45	21.01	22.57	25.57	27.93	29.87	31.89	33.96	35.72
43.000	20.73	22.39	24.18	27.29	29.87	32.02	34.19	36.41	38.30
42.000	23.10	24.95	26.50	29.52	32.50	35.24	37.63	40.07	42.14
41.000	24.06	25.98	28.15	31.69	34.81	37.17	39.70	42.27	44.46
10.000	25.03	27.03	29.00	33.09	36.20	38.79	41.42	44.10	46.38
39.000	26.11	28.20	29.23	34.05	37.38	39.97	42.68	45.44	47.80
38.000	27.08	29.25	31.38	35.46	38.89	41.58	44.40	47.27	49.73
37.000	28.36	30.63	32.99	37.07	40.83	43.62	46.59	49.60	52.17

For altitudes above 2000 ft. the input must be reduced by 4% for each 1000 ft above sea level. Example: 25 cubic feet at sea level must be reduced by 20% at 5000 ft. elevation. 25x0.8 = 20 cubic feet. The orifice must be changed accordingly. (At 3.5 pressure, a number 42 orifice would be replaced by anumber 45 orifice.)

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TABLE IX -LP GASES (BTU PER HOUR AT SEA LEVEL)

Description	Propane	Butane
Btu per Cubic Foot =	2500	3175
Specific Gravity =	1.53	2
Pressure at Orifice, Inches Water Column =	11	11
Orifice Coefficient =	0.9	0.9

Gas Input, BTU per Hour for:

Drill Size (Decimal or DMS)	Propane	Butane or Butane-Propane Mixtures
0.008	500	554
0.009	641	709
0.010	791	875
0.011	951	1,053
0.012	1,130	1,250
80	1,430	1,590
79	1,655	1,830
78	2,015	2,230
77	1,545	2,815
76	3,140	3,480
75	3,465	3,840
74	3,985	4,410
73	4,525	5,010
72	4,920	5,450
71	5,320	5,900
70	6,180	6,830
69	6,710	7,430
68	4,580	8,370
67	8,040	8,910
66	8,550	9,470
65	9,630	10,670
64	10,200	11,300
63	10,800	11,900
62	11,360	12,530
61	11,930	132,850
60	12,570	13,840
59	13,220	14,630
58	13,840	15,300
57	14,550	16,090
56	16,990	18,790
55	21,200	23,510
54	23,850	26,300
53	27,790	30,830
52	31,730	35,100
51	35,330	39,400
50	38,500	42,800
49	41,850	45,350
48	45,450	50,300
47	48,400	53,550
46	51,500	57,000
45	52,900	58,500

TABLE X - FACTORS FOR UTILITY GASES OF ANOTHER SPECIFIC GRAVITY

SPECIFIC GRAVITY	FACTOR	SPECIFIC GRAVITY	FACTOR
0.45	1.155	0.95	0.795
0.50	1.095	1.00	0.775
0.55	1.045	1.05	0.756
0.60	1.000	1.10	0.739
0.65	0.961	1.15	0.722
0.70	0.926	1.20	0.707
0.75	0.894	1.25	0.693
0.80	0.866	1.30	0.679
0.85	0.840	1.35	0.667
0.90	0.817	1.40	0.655

To select an orifice size for a desired gas flow rate:

1. Obtain the factor for the known specific gravity of the gas from Table X;
2. Divide the desired gas flow rate by this factor, which gives the equivalent flow rate with a 0.l60 specific-gravity gas;
3. Using the flow rate obtained in step 2, select the orifice size from Table VIII.

To estimate gas flow rate for a given orifice size and gas pressure when it is not possible to meter gas flow:

1. Use Table VIII to obtain equivalent gas flow rate with a 0.60 specific-gravity gas;
2. Obtain the factor from Table X for the specific gravity of the gas to be burned;
3. Multiply the rate obtained in step 1 by the factor from step 2 to estimate gas flow rate in cubic feet. Then multiply cubic feet by BTU content (ft^3) of gas in use.)

Space Heating Terms

A

AIR-GAS RATIO - The ratio of combustion-air flow rate to the fuel-gas flow rate.

AIR SHUTTER - An adjustable panel on the primary air opening of a burner for controlling the amount of combustion air entering the burner body.

ATMOSPHERIC BURNER - (See Burner.)

ATMOSPHERIC PRESSURE - The force exerted on one square inch of surface by the weight of the air above the earth. At sea level atmospheric pressure is 14.7 pounds per square inch.

ATOM - The smallest unit into which elementary matter can be divided and still have the same properties.

AUTOMATIC GAS PILOT - A gas pilot light with a sensing device that shuts off the gas supply to the burner when the pilot flame goes out.

AUTOMATIC GAS VALVE - An automatic or semi-automatic device consisting of a valve and an operator that controls the gas supply to the burner(s) during operation of a gas-fire appliance.

B

BIMETAL - A strip or coil made of two metals having different thermal expansion properties laminated together so that temperature changes bend the strip or twist the coil.

BRITISH THERMAL UNIT (BTU) - The quantity of heat required to raise the temperature of one pound of pure water one degree F.

BUNSEN-TYPE BURNER - A gas burner in which: 1. gas leaving the gas orifice draws combustion air into the burner; 2. the air mixes with the gas within the burner body and the resulting gas-air mixture burns at the burner port.

BURNER - A device for controlled burning of gas, or a mixture of gas and air.

1. **Injection Burner.** A burner employing the energy of a jet of gas to inject air for combustion into the burner and mix it with gas.
2. **Atmospheric Burner.** A burner in which the air injected into the burner by a jet of gas is supplied to the burner at atmospheric pressure.
3. **Power Burner.** A burner in which either gas or air or both are supplied at pressures exceeding: gas line pressure of gas or atmospheric air pressure.
4. **Yellow-Flame Burner.** A burner that depends on secondary air only for the combustion of the gas.

BURNER HEAD - The part of a gas burner that contains the burner ports.

BURNER PORT - (See Port).

BURNING SPEED - (See Flame Velocity.)

BUTANE - A hydrocarbon gas (C5H10) heavier than methane, ethane, and propane.

C

CASING LOSS - Heat lost through the walls of a heater or furnace to the space surrounding the heater.

COMBUSTION - The rapid oxidation of fuel accompanied by the release of heat or heat and light.

COMBUSTION AIR - Air supplied in a heater specifically for burning a fuel gas.

COMBUSTION CHAMBER - The part of a heater where combustion normally occurs.

COMBUSTION PRODUCTS - Constituents in the exhaust stream resulting from the combustion of fuel gas in air, including the inert gases like nitrogen and argon but excluding excess oxygen.

COMPOUND - A distinct substance consisting of two or more elements chemically combined in a definite proportion.

CONFINED SPACE - A heating equipment room that contains less than 50 cubic feet per 1000 BTUH of heater input capacity.

CONTROLS - Devices that regulate the gas, air or electricity used in a gas heater or furnace. A control device may be manual, semiautomatic or automatic.

CONVECTION LOSS - Heat lost through the walls and roof of a building through movement of heated air.

CUBIC FOOT OF GAS (Standard Conditions) - The amount of gas that has a volume of 1 cubic foot at a temperature of 60°F under a pressure of 30 inches of mercury.

D

DIAPHRAGM VALVE - A control valve which opens and closes according to gas pressure on a flexible diaphragm.

DILUTION AIR - Air deliberately mixed with the flue gases to make the combustion products less concentrated.

DIRECT-SPARK IGNITION SYSTEM - A system in which two high-voltage electrodes create a continuous spark to ignite main burner gas directly without an intermediate pilot flame.

DOWNDRAFT - Downward flow of gases or air in a chimney or stack.

DRAFT HOOD (Draft Diverter) - A device built into a heater or made part of the vent connector of a heater. It is designed to: ensure escape of combustion products in case of no draft, backdraft, or blockage in the chimney or stack; prevent a backdraft from entering the heater.

DUCT LOSS - Heat lost through the walls of ductwork to the space surrounding the ducts.

E

ENERGY CUT OFF (ECO) DEVICE - A thermostatic element in the safety control which shuts off gas supply when a malfunction occurs.

EXCESS AIR - Air that passes through a heater's combustion chamber and flues in excess of the amount required for complete combustion, usually stated as a percentage of the air required for complete combustion.

EXTINCTION POP - (See Flashback.)

F

FAHRENHEIT - The method of temperature measurement in the English system of units in which the freezing point of water is 32°F and the boiling point of water is 212°F at standard pressure.

FAN AND LIMIT CONTROL - Usually a combination control and safety device that: turns a heater fan or blower on and off according to preset temperatures; shuts off main burner gas in case a malfunction causes combustion-chamber temperature to rise above a preset limit. (See Controls.)

FLAME ROLLOUT - The spread of flame out of a combustion chamber as gas ignites at the burner.

FLAME VELOCITY - The speed at which flame travels through a fuel-air mixture.

FLAMMABILITY LIMIT - The percentage of fuel in an sir-fuel mixture above or below which the fuel will not burn.

FLASHBACK - An undesirable condition in which flames travel backward into a burner and combustion continues to occur there.

FLASHBACK ARRESTOR - A metal gauze, grid or any other element in a burner to prevent flashback.

FLOATING FLAMES - An undesirable burner operating condition in which flames move up off the burner ports and quietly "float" above them. This condition usually results from incomplete combustion.

FLUE GASES, FLUE PRODUCTS - Products of combustion and excess air in flues or heat exchangers.

FLUE LOSS - Heat lost as a result of the exhausting of flue gases.

FLUE OUTLET - An opening for the escape of flue gases.

FUEL GAS - A combustible gas used to create useful heat.

H

HEAT ANTICIPATOR - A thermostat compensating adjustment that prevents temperature overshoot or underheating.

HEAT EXCHANGER - A device for transferring heat from one medium to another.

HEATING VALUE - The number of British thermal units produced by the complete combustion of one cubic foot of gas at constant pressure. Heating value includes the heat involved in cooling the combustion products back to the initial temperature of the gas-air mixture and condensing the water vapor formed by combustion.

HOT-WIRE VALVE - A heat-actuated valve in which the valve is opened and closed by expansion and contraction of a taut wire heated by an electric current passing through it.

HYDROCARBONS - Chemical compounds composed of carbon and hydrogen.

I

IGNITION - The starting of combustion.

IGNITION VELOCITY - (See Flame Velocity.)

INCHES OF MERCURY COLUMN - Pressure defined by the height of a column of mercury measured in inches. One inch of mercury column equals a pressure of 0.491 pounds per square inch.

INCHES OF WATER COLUMN - Pressure defined by the height of a column of water measured in inches. One inch of water column equals a pressure of 0.578 ounces per square inch (.036 psi). One inch mercury column equals about 13.6 inches water column.

INCOMPLETE COMBUSTION - Combustion in which fuel is only partially burned.

INFRARED BURNER (Radiant Burner) - A burner that provides heat from a hot, glowing surface that radiates infrared energy.

INPUT RATING - The gas-burning capacity of a heater, in BTUs per hour, specified by the manufacturer.

L

LIFTING - An unstable burner flame condition in which flames lift or blow off the burner port(s), often producing a blowing or roaring sound. Lifting usually results from too much combustion air. (See Floating Flames.)

LOCKOUT - A deliberately induced condition in which a control system shuts down a heater and prevents further operation until a malfunction has been corrected and the system has been reset manually.

LPG - Liquefied-petroleum gas.

Space Heating Terms

M

MANUFACTURED GAS - A "synthetic" fuel gas produced by passing steam over coal at high temperature, consisting mainly of carbon monoxide and hydrogen.

METHANE - A hydrocarbon gas with the formula CH4, the principal component of natural gases.

MIXED GAS - A gas in which the heating value of manufactured gas is raised by mixing it with natural or liquefied-petroleum gas.

MIXER - The section of a Bunsen-type burner where air and gas are mixed for delivery to the burner ports.

MOLECULE - The smallest unit into which a chemical compound can be divided and still retain the identity and properties of the compound.

N

NATURAL DRAFT - The motion of flue products through a heater and flue system, caused by the convection force of hot flue gases.

NATURAL GAS - Fuel gas found in the earth, as opposed to gases that are manufactured.

O

ODORANT - A substance having a strong odor, added to odorless natural gas to warn of gas leakage and to aid in leak detection.

ORIFICE - A small hole through which gas is discharged, limited and controlled. (See also Universal Orifice.)

ORIFICE SPUD - A removable plug or cap containing an orifice which permits adjustment of the gas flow by substitution with a spud having a different size orifice or by motion of an adjustable needle into or out of the orifice. (Also known as an orifice cap or orifice hood.)

OVERRATING - Operation of a gas burner or heater at greater than its design capacity or manufacturer's rating.

P

PILOT - A small flame for igniting the gas at the main burner.

PORT - Any opening in a burner head through which gas or an air-gas mixture is discharged and burned.

PRESSURE REGULATOR - A device for controlling and maintaining a uniform outlet gas pressure.

PRIMARY AIR - The combustion air introduced into a burner and mixed with the gas before it reaches the port. Usually expressed as a percentage of the air required for complete combustion.

PRIMARY AIR INLET - The opening or openings through which primary air enters a burner.

PROPANE - A hydrocarbon gas (C3H8), heavier than methane but lighter than butane. It is used: as a fuel gas alone; mixed with air; and as a major constituent of liquefied petroleum gases.

R

RADIANT BURNER - (See Infrared Burner.)

S

SECONDARY AIR - Combustion air externally supplied to a burner flame at the point of combustion.

SENSOR - The component of a control or measuring system that detects or measures the level of a controlled variable.

SETPOINT - The temperature to which a thermostat is set to result in a desired heated-space temperature. This term can also apply generally to other types of control devices.

SINGLE-PORT BURNER - A burner in which the entire air-gas mixture issues from just one port.

SOFT FLAME - A flame in which the combustion zone is extended and the inner cone is ill-defined. A soft flame results from insufficient primary air.

SOLENOID - A wire-wound coil that creates a magnetic field when electricity flows through it. The magnetic field will pull a movable iron core within the coil.

SOLENOID VALVE - A valve actuated by a solenoid.

SOOT - A black substance, mostly consisting of small particles of carbon, which can result from incomplete combustion and may occur as smoke.

SPECIFIC GRAVITY - The ratio of the weight of a given volume of gas to the weight of the same volume of air, both measured at standard conditions of temperature and pressure.

STANDARD CONDITIONS - Pressure and temperature conditions selected for expressing properties of gases on a common basis, normally 30 inches of mercury and 70°F.

STATIC PRESSURE - The pressure exerted against the walls of an airway that is created by friction and impact of air as it moves through the airway.

T

THERM - A unit of heat energy equal to 100,000 BTUH.

THERMOCOUPLE - A device consisting of two wires or strips of dissimilar metals joined together at one end called the hot junction. Heating the hot junction produces a DC voltage across the other two ends.

THERMOSTAT - A temperature-sensitive switch for controlling the operation of a heater or furnace.

THROAT - (See Venturi.)

TOTAL AIR - The total amount of air supplied to a burner, the sum of primary air, secondary air and excess air.

TRANSFORMER - An electrical device for changing AC electricity from one voltage to another voltage.

TWO-STAGE PILOT - A pilot ignition system in which a small standing pilot lights a larger pilot which is cycled by the thermostat so that gas flow to the main burner is controlled by the automatic pilot valve.

U

UNIVERSAL ORIFICE - A combination fixed and adjustable orifice designed for the use of two different gases, like LPG and natural gas.

VENT - A pipe or duct for carrying flue products from a heater to the outdoors. This term also designates a small hole or opening for the escape of gas or air (as in a gas control).

VENTURI - A section in a pipe or a burner body that narrows down and then flares out again to increase gas velocity and create a negative pressure.

Y

YELLOW-FLAME BURNER - (See Burner.)

YELLOW TIPS (Yellow Tipping) - Yellow flicks in the tip of an otherwise blue flame; a symptom of the need for additional primary air.

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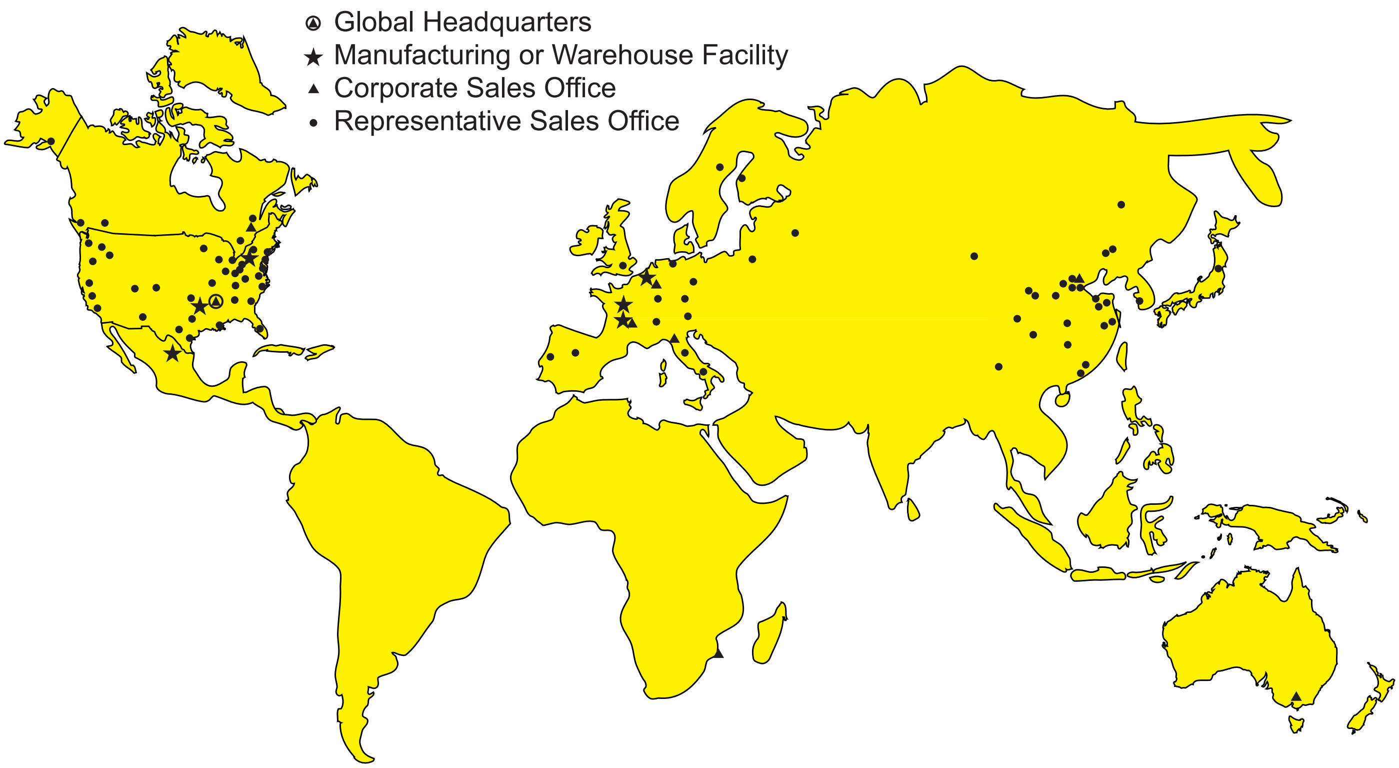

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