Form RZ-NA-IRHB

REZNOR®

INFRARED HEATING HANDBOOK

$4.95 U.S

FORWARD

This handbook has been prepared by Reznor to assist in the selection, sizing, installation and service of both low and high intensity infrared heating appliances. In addition to this information, general data on fuel gases, heat transfer and the combustion process is included.

We believe that this booklet will be most helpful to students or individuals who are apprentices in the heating industry. Additionally, engineers and architects may find the information helpful in the selection and specification of infrared systems.

As a primer to this manual, it is suggested that you read Reznor's SPACE HEATING HANDBOOK, which is available from most Reznor distributors or directly from a Reznor representative.

TABLE OF CONTENTS

NOTE: Values and equations quoted in this handbook are from reliable sources and apply to most applications. Actual results are subject to several variables so results may vary.

HEAT TRANSFER

There are three modes of transferring heat. They are Convection, Conduction and Radiation.

CONVECTION

The dictionary defines convection as follows: Transference of heat by moving masses of matter, as by currents in gases or liquids, caused by differences in density and the action of gravity.

When a difference in density occurs, the mass of the specific unit volume changes causing a change in weight. When air is heated, its density changes in that its mass becomes less per unit volume.

When air comes in contact with a hot surface, it heats and becomes less dense. Due to the change in mass, the heated, less-dense air rises.

An example of heat transfer by convection is the old potbellied stove, or in more modern times, the finned tube used in residential hot water heating systems. Cooler air, when it comes in contact with the finned tube, warms and becomes less dense. It then rises and as it does, creates a void into which more cool air moves. This continuing process creates a circular air pattern across the finned tube warming all the air in the space. Modern gas-fired convection heating equipment does not depend solely on gravity but uses an air mover in the form of a fan or blower to circulate the air, hastening warm-up of the space.

CONDUCTION

The transmission of heat through a conductor. When two objects are in contact with each other, and barring any other phenomenon, the two objects should be the same temperature. If they are not, the heat from the hottest flows to the object that is the coolest, until both objects attain the same temperature. From this we might say that heat flows down hill (Heat always flows toward the coolest objects). While conduction is not normally used in the heating industry, it does appear in the appliances that are used to supply heat. For example, conduction very often is used to convey heat to sensing devices within the appliance, that provide such things as high heat limiting of the appliance temperature.

A good example of conduction is in cooking utensils, where heat is applied to one side of the utensil and the surface then conducts this heat to the food inside for proper preparation. A more dramatic example of conduction is found when one touches a hot surface with the bare finger. The transfer of heat through conduction is very vivid to the individual owning the finger.

RADIATION

The transmission of heat through rays emitting from a hot surface. The best example of radiation is the sun. The extreme temperatures of the sun emits rays which travel through space and are absorbed by Earth. The earth's proximity to the sun results in extreme warmth at the equator because the rays are generally at a right angle to this area. Since the earth is spherical in shape, the rays from the sun tend to deflect off the earth's surface as they approach the north and south poles. Consequently, with less heat absorption, colder climates result.

In the gas heating industry, radiation has been in use for a much longer time than convection. As early as the 1920's gas heaters were used for spot heating in residences and commercial buildings. Heat was supplied by a gas flame and was reflected from polished surfaces designed to broadcast the heat rays throughout the space. These polished surfaces were soon replaced by clay blocks with highly irregular surfaces which, when heated, did a more efficient job of distributing the heat rays, through radiation.

This handbook will deal primarily with radiation principles and radiant heating appliances.

FUELS

Over the centuries, man has used many forms of fuel to provide heat for his own comfort. Beginning with prehistoric man, we would have to assume that his preference for fuels would most likely have been wood. The next prominent fuel would have been coal. It may surprise you to know, however, that natural gas was discovered and used by the Chinese 2500 years ago. Although we are not certain of its use, we do know that they transported the natural gas through bamboo poles, and can assume that the flame may have found some ritualistic use in their villages.

Other energies that were gradually harnessed by mankind are: Oil, Electricity, Liquefied Petroleum Gases, Nuclear, Geothermal, and finally, Solar Energy (Back to the sun).

BRIEF HISTORY OF NATURAL GAS

At this point we want to expand somewhat on the history of natural gas since most infrared heaters are fueled by this particular gas and to a lesser degree, LP gases.

Modern natural gas began in United States in 1821 when William Hart dug the first gas well (a depth of 27 feet) near Fredonia, New York. The gas was distributed for use in illumination of homes and offices. For the next 35 to 40 years, wells sprung up throughout the eastern states and by 1900 there were gas wells in 17 states. The gas industry had essentially begun. Today nearly all of the lower 48 states and Alaska have gas wells, and all have immense distribution networks to supply natural gas to nearly every village, town and city in the USA.

Natural gas, in addition to being the most economical form of fuel energy, also has clean effluents and is the most dependable of all the fuels. Supplies of natural gas are in such quantities that it will be reliable as a source of energy, well into the 21st century. In addition to active fields, there are huge quantities yet to be tapped which should fill our requirements beyond the middle of the 21st century. Add to this the increasing availability of liquefied natural gas (LNG) from foreign producers, and it appears that natural gas will be our major fuel source for many years to come.

LIQUEFIED PETROLEUM GASES

One of the by-products of oil refining is LP gas. This fuel is extracted during the cracking process. It is then pressurized until it becomes a liquid. It is in this liquid form that LP gases are transported to the end user. The most common of these liquid gases is propane, although butane is sometimes available, and is restricted for use in warmer climates. When the storage vessel or tank is tapped, the gas vapor over the liquid is released for use in the gas burning process. The pressure within the vessel maintains most of the gas in liquid form, but as the vapors are drawn off, the liquid will boil and generate more gas.

Therefore, the demand rate determines the size of the storage vessel that will be needed for each application.

BTU (BRITISH THERMAL UNIT)

A British Thermal Unit (BTU) is defined as the amount of heat required to raise one pound of water, one degree Fahrenheit. Here are a few expressions that refer to BTU's and will be found in the following text.

BTUH	British Thermal Unit - per Hour
BTU/FT^3	British Thermal Unit - per cubic foot.
BTUH/FT^2	British Thermal Unit - per hour - per square foot.
BTUH/FT^2/°F	British Thermal Unit - per hour - per square foot - per degree Fahrenheit

GAS CHARACTERISTICS

In order to properly size gas piping and orifices, the characteristics of the gas in use must be known. Here then is the pertinent data as it relates to the most popular gaseous fuels:

HEAT CONTENT

FUEL	BTU/FT^3	SPECIFIC GRAVITY
Natural gas	1020 BTU	.65
Propane gas	2550 BTU	1.52
Butane gas	3200 BTU	1.95

The specific gravity is the weight of the gas as compared to air. (Specific gravity of air = 1) Therefore, you will note that the LP gases are heavier than air and that Natural gas is lighter than air. This is important to know because should the gas inadvertently escape during service, installation or the remote possibility of control failure, knowledge of the fuel characteristics is helpful in determining suitable purging to clear the space of potential explosive conditions.

Specific gravity is also important, along with BTU content and gas supply pressure, to properly size the main burner orifices. The manufacturer will publish correct orifice sizes for each unit in a service manual, making it unnecessary to do these calculations in the field. Further to this, each gas fired appliance has the proper gas orifice when it leaves the factory, providing that correct gas characteristics have been supplied to the manufacturer by the purchaser.

COMBUSTION

Combustion, by definition, is the rapid oxidation of solids, gases or liquids. It is therefore safe to assume that combustion cannot take place without the presence of oxygen. In the following text, we will deal with the controlled use of air (oxygen) for proper combustion of gaseous fuels. Such control is accomplished in the design of the gas burning equipment, both in the pilot/burner configurations and in the design of the combustion air and flue gas passageways found in and around each gas heating appliance.

Further, we will discuss pilot/burner aeration, by means of either atmospheric pressures or by power assist using blowers or exhausters.

FLAME

There are three ingredients needed to create a flame. They are: Fuel, air, and heat. Fuel is required to supply the carbon, air is required to supply the oxygen, and heat is required to raise the mix to its ignition temperature.

Natural gas is composed primarily of methane having a chemical formula of CH_4 (C = Carbon and H = Hydrogen). Each molecule of methane consists of one atom of carbon and four atoms of hydrogen. Thus, methane in natural gas can provide the carbon required to create a flame. Air which consists of 21% oxygen provides the second ingredient required to create a flame. These two gases (natural gas and air) contain other ingredients but for the purpose of illustrating the resultant chemical formula when complete combustion occurs, only carbon, hydrogen and oxygen will be used. Fig. 1 shows the chemical transition that occurs when methane burns. Note that the combustion effluents contain carbon dioxide (CO_2) and water (H_2O).

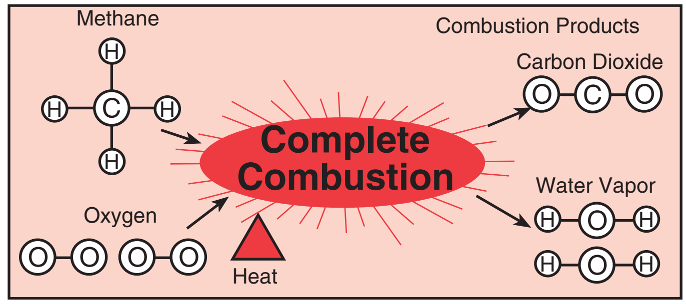


FIG. 1 - Complete combustion - forms only water and carbon dioxide.

When a proper mix of oxygen and methane are heated to the point of ignition, we obtain a flame. This heating may occur by any one of several processes. The one we are most familiar with is the use of a match. Presently many gas fired appliances are initially ignited through the use of a spark or hot surfaces energized by electricity may also be used to heat gas/air mix for ignition. Once ignition takes place, the burning process gives off carbon dioxide. If the mix of air and gas is not within the proper ratio, carbon monoxide will also issue from the flame and can reach unacceptable levels. Gas/air mixes may not even ignite if the ratio of air to gas is not within a certain range. It is important that these mixes are at an acceptable level for the most efficient burning characteristics. Such mixes are controlled in the design of the pilot, burner internal passageways, aeration methods, orifices and gas pressures. Therefore, it would be detrimental to the safety of the user if modification of any kind, beyond those prescribed by the manufacturer, were made on any of these gas heating products. Fig. 2 shows the effects of carbon monoxide at various levels, given in PPM (parts per million).

Carbon dioxide concentrations up to 5000 PPM may be present in a given space with no ill effect on humans.

Carbon Monoxide: (CO)—Product of Incomplete Combustion	
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
1000 PPM -	Death on long exposure
1500 PPM -	Death after one (1) hour
Most codes specify that CO Concentrations shall not exceed 50 PPM	

FIG. 2 -Effects of carbon monoxide

EXPLOSIVE LIMITS

When natural gas and air are joined together, the mix may or may not oxidize. For instance, if natural gas in the mix is between 4% and 14%, there is potential for explosion or burning, depending how the mix is handled. In a heating appliance the combination of burner, pilot and aeration design will cause the mix to burn under controlled conditions. If the mix is simply in a space such as a room, and it by some means is ignited, it most likely will explode. When the mix is outside the 4% to 14% limits, there will be no ignition, consequently no flame or explosion. This points out the importance of creating a proper mix within the gas burning appliance and also points out the hazards of allowing gas to escape indiscriminately into a confined area. (Fig. 3)

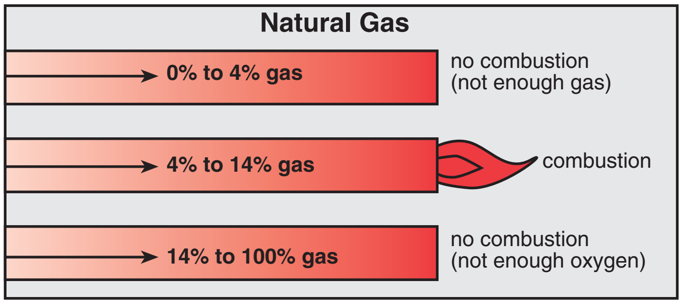


FIG. 3 -Flammability limits of natural gas.

Propane gas acts in the same way but the percentage of gas in the mix changes somewhat and is shown in Fig. 4.

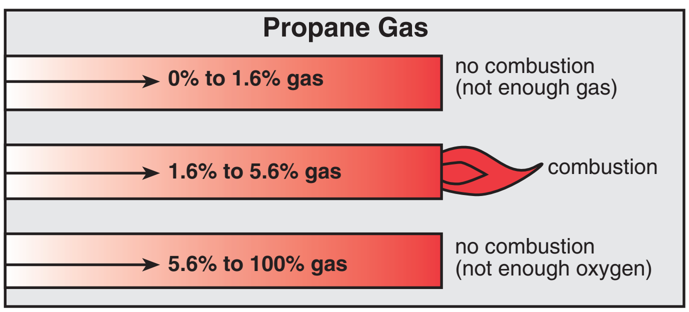


FIG. 4 -Flammability limits of propane gas

PRIMARY AND SECONDARY AIR

In the design of pilots and burners, considerations are given to the practicality of aeration of the pilot and burner. Primary air is air that is introduced with the gas, directly downstream from the orifice. The gas jet entrains air as it moves from the orifice into the burner chamber. A venturi design within the burner creates a vacuum which causes air to be sucked into the burner along with the gas, providing the gas/air mix that is necessary for proper ignition and combustion.

Secondary air is air that is introduced into the flame after the burner ports. Fig. 5 is an illustration of a Bunsen Burner, showing both primary and secondary air. Note that there are two distinct flame patterns.

PILOTS

In many gas fired heating appliances, ignition of the main burner is accomplished through the use of a pilot burner whose flame is located adjacent to the main burner. Pilots generally burn far less gas than the individual burners they are required to ignite. This

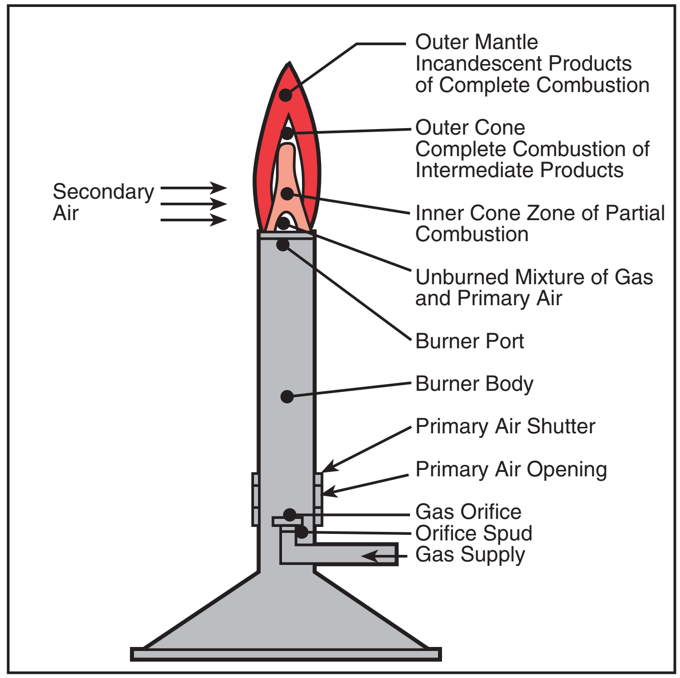


FIG. 5 -Bunsen burner

eliminates the hazard of large accumulations of gas/air mix while in the initial trials for pilot ignition.

Pilots are usually constructed of coated or stainless steel. For many years now, pilots operate on secondary air only, therefore the flame is disbursed through the use of a specially designed head. This makes it necessary to use stainless steel in the construction of the burner head due to the high flame temperatures involved. Figure 6 illustrates one of these pilots and demonstrates the exclusive use of secondary air for flame support. This design was introduced some 30-40 years ago and was selected because it eliminated the need for primary air. Older pilot designs used both primary and secondary air, but it was found that primary air tended to create buildups of dust within the pilot gas/air passageways and consequently was a source of constant service problems. Buildup of dust within a burner is not nearly as critical since most burners have large chambers that will permit dust accumulation. Nevertheless, it is good practice to clean burners and pilots on a regular basis to prevent buildups that may alter or disrupt the normal flame patterns. THIS IS ESPECIALLY IMPORTANT WITH HIGH INTENSITY INFRARED BURNERS.

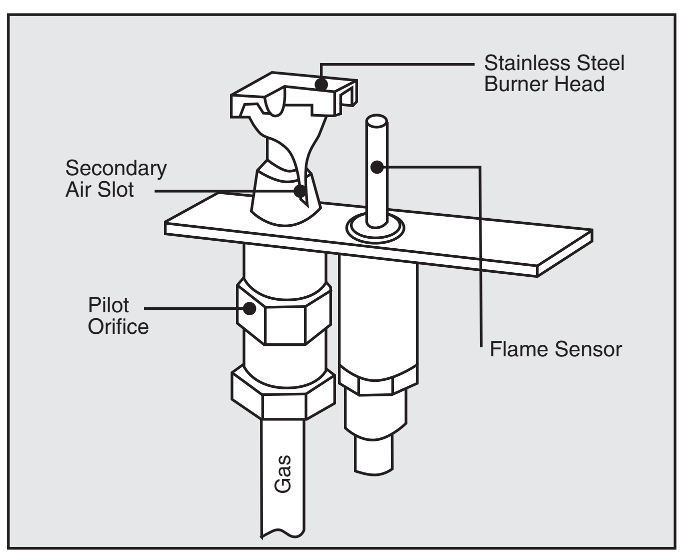


FIG. 6 - Secondary air pilot

PILOT/BURNER AERATION

During the design of gas heating appliances, the most critical design consideration is in properly aerating the combustion zone. Too little air can result in gas rich air/gas mixtures that can result in undesirable combustion results ranging from poor efficiency to hazardous effluents containing dangerous amounts of carbon monoxide. On the other hand, if too much air is introduced into the air/gas mix, total appliance efficiencies fall to unacceptable levels, and there is also a potential for undesirable combustion effluents, since the air/gas mix may not burn totally. Excessive air very often distorts the flame, causing carbon monoxide to form.

It can be seen then, that the air in the combustion zone must be controlled at all times, and this is done in the engineering design of the appliance.

ATMOSPHERIC AERATION

The most common method of pilot/burner aeration is to in some way persuade the air to enter the combustion process without the need for powered air moving devices. The high velocity gas jet emitting from the orifice is capable of entraining air, along with the gas and directing the mix into the burner. This method of inducing air into the mix is usually enhanced by the use of a venturi as shown in Fig. 7.

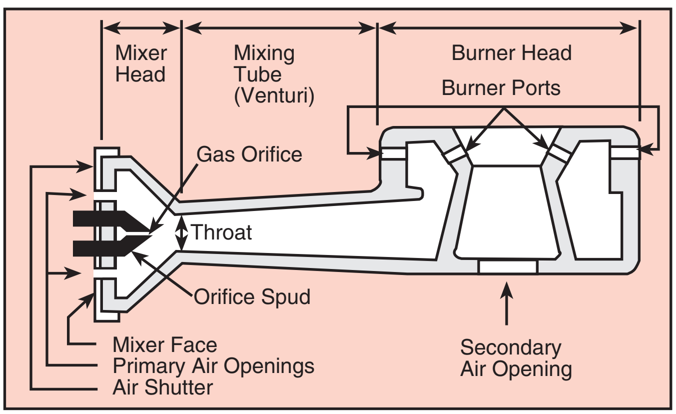


FIG. 7 - Basic burner

Secondary air is induced into the combustion zone when the hot flue gases lift (as in convection) upward to escape from the combustion zone. As they rise, a void is generated which in turn inspires more air to enter the zone. This continual action during combustion, insures that ample air is available to support complete burning of the mix. In order to control the quantities of air entering the combustion zone, care is taken in the appliance design to meter proper amounts of air for clean and efficient combustion. This further emphasizes the fact that alterations of the unit in any way could, at minimum, adversely affect the total efficiency of the unit or, at worst, could create extremely hazardous conditions.

INDUCED DRAFT AERATION

In order to more closely control primary and secondary air and to also provide more flexibility in the combustion air introduction and venting of gas fired appliances, a trend of design over the past several years has been to do this through the use of power inducers (blowers or impellers). This method of aeration has been instrumental in providing units with extremely high efficiencies. The bulk of the improvements occur in the vent process where much smaller quantities of room air are required to support the combustion and venting processes. Venting will be covered later in this section.

With INDUCED DRAFT, an electrically powered exhauster is located at the discharge of the unit and is used to draw off the products of combustion under controlled metering. As the products of combustion are drawn off, a void is established in the combustion zone which entices more air to enter the system. (Fig. 8)

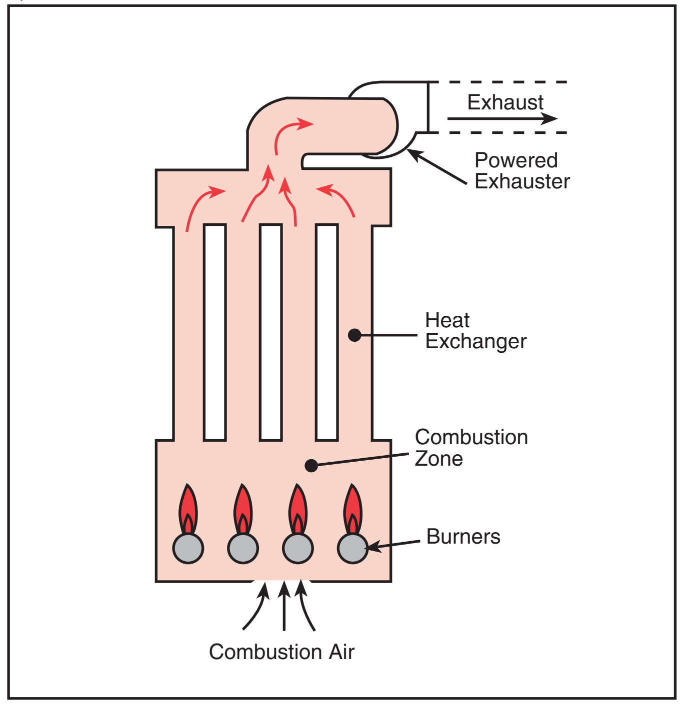


FIG. 8 - Induced draft system

FORCED DRAFT works in much the same way except the powered device, usually a blower or impeller, is located at the entrance to the combustion zone and under metered conditions, supplies air to the pilot/burner. (Fig. 9) This method is used widely in the design of low intensity infrared appliances and will be covered later.

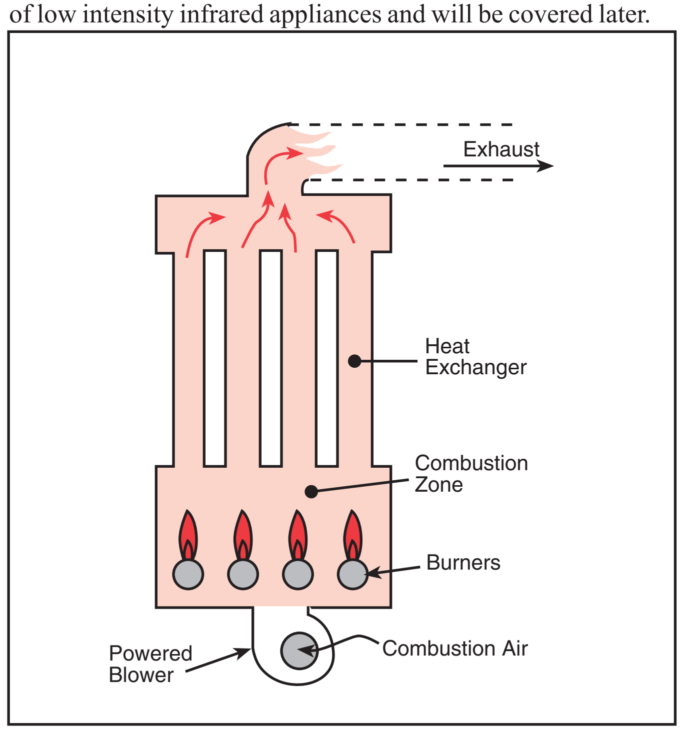


FIG. 9 - Forced draft system

In either case of INDUCED OR FORCED DRAFT the exhaust gases are under positive pressure and may be directed to the outdoors through vent pipes that are by comparison, much smaller than the pipes used to vent atmospheric units.

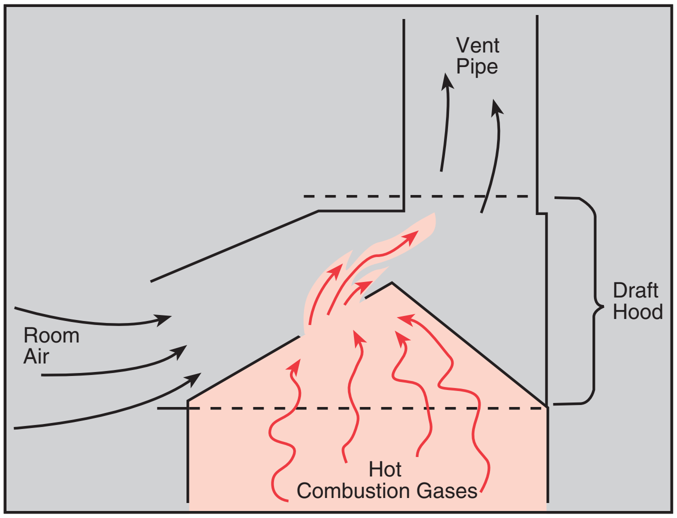


FIG. 10 - Typical draft hood

DRAFT HOODS

Atmospheric units rely solely on convection to vent the flue gases to the outdoors. However, if you would connect a vent (flue) pipe directly to an atmospheric unit, the combustion can be at the mercy of the surrounding conditions. High winds, negative or positive pressures in the building, and even surrounding temperatures can change the amount of air passing through the combustion zone. For these reasons, atmospheric units are equipped with draft hoods. These devices are always supplied with atmospheric units and may be factory or field installed. Fig. 10 shows a typical draft hood. As can be seen in the illustration, room air is used to balance the amount of draft over the combustion zone. Also, the draft hood is designed to guard against the effects of downdrafts, which are situations usually caused by unusual wind currents or wind pressures at the outside terminus of the vent system. Unfortunately, room air is lost through the draft hood to the vent during normal exhausting or even when the burner is turned off. Such losses must be considered in the overall efficiency of the heating appliance because the air passing through the draft hood is heated room air. The induced draft system shown in Fig. 8 creates a positive vent pressure that is not affected by wind or wind pressure conditions. Room air is no longer lost in the venting process since the induced draft system requires no draft hood. The forced draft system shown in Fig. 9 enjoys the same venting advantages as the induced draft system. Consequently, induced draft or forced draft systems show a much more favorable total efficiency than does the atmospheric system because far less room air is used.

IMPORTANT NOTE ON COMBUSTION AIR: Provisions for combustion air must be met according to the National Fuel Gas Code (ANSI Z223.1), and the manufacturer's installation instructions when the combustion air is being drawn from the indoor space. Some infrared heating equipment have provisions for drawing the combustion air from outdoors. Combustion air from outdoors is normally recommended when

(1) the pressure in the building is negative,

(2) the atmosphere is dirt laden,

(3) the atmosphere contains any substance that will cause toxic gas when passed through the flame, or

(4) the heater is installed in a tightly closed room that does not provide required air for combustion.

Consult the heating equipment manufacturer, and their installation instructions for requirements on drawing combustion air from outdoors.

BURNERS

Modern burner designs operate similar to the Bunsen Burner except that in most current burner designs, the gas is introduced in a horizontal direction, and the flame port design is different to accommodate the overall design of the heat exchanger.

Fig. 11 illustrates a typical horizontal burner. Again you will see the two distinct flame patterns (cones) which are derived from the use of both primary and secondary air. Also, a venturi is shown and as mentioned earlier, this persuades more primary air to enter with the gas jet stream, allowing for much higher input ratings in the individual burner designs.

Fig. 12 illustrates a burner used in HIGH INTENSITY infrared units. Of extreme importance is the port arrangement on these burners. Port diameters are small but by comparison to Fig. 11, there are many more of them. This fact points out the importance of air/gas velocity in such a design. The flame must occur within the port, therefore this velocity must closely match the velocity of oxidation as the gas burns. The reason for this is so the flame is contained within the port to heat the clay or ceramic to an extremely high temperature (usually between 1650°F and 1850°F) for maximum surface temperature and optimum heat radiation. Obviously, with the flame withdrawn into the ports, no secondary air is available to the combustion process.

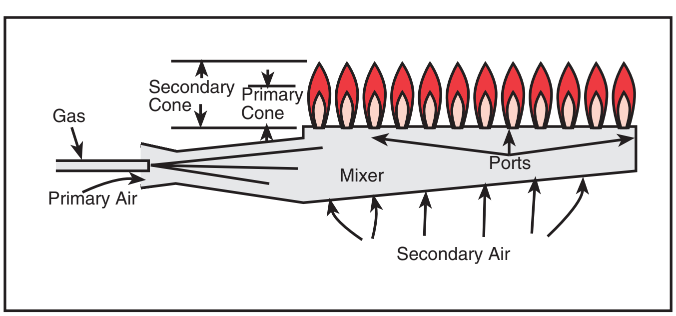


FIG. 11 - Typical horizontal burner

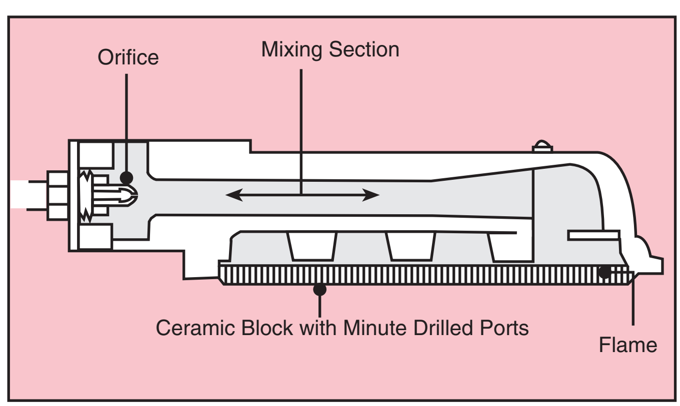


FIG. 12 - High-intensity burners have these basic parts.

FIG. 13 - A reflector-type radiant heater

RADIANT HEATING

As mentioned earlier, radiant heat was the earliest form of comfort heating. Early man found that fire provided warmth in the absence of the sun, and this warmth was absorbed through radiation. Then fireplaces appeared in buildings and were the sole source of heat in the bitterest cold. These too offered radiation and it was soon discovered that the rays would heat other objects within the room which would reradiate to other objects. Then as all the objects warmed they would convect heat, and eventually the room or enclosure would become quite comfortable.

Fireplaces, while still in use generally for their esthetic value, gave way to stoves of various shapes and sizes. These stoves were fired with wood and eventually coal and provided for the most part, radiant heat. However, because of their design and their location within the building, they were also capable of delivering heat through conduction (cooking) and also through convection.

Natural gas, while originally used for lighting, eventually was put to use providing comfort heating. The earliest heating device was in fact, a reflector heater quite similar to the one illustrated in Fig. 13. The gas was encouraged to burn with a yellow flame. The reflection from this flame was then directed into the space through the use of a highly polished, irregular faced metal reflector.

FIG. 14 - An early clay-type radiant heater

As in most technical development, better ways to broadcast heat were continually sought. The reflector gave way to a more sophisticated surface which was constructed of hardened clay. The burner was positioned to heat the clay to an orange glow, creating a more intense source of heat. This was the early beginnings of infrared radiational heating. Fig. 14 represents just one of these units and illustrates the ornamental design employed for period esthetics.

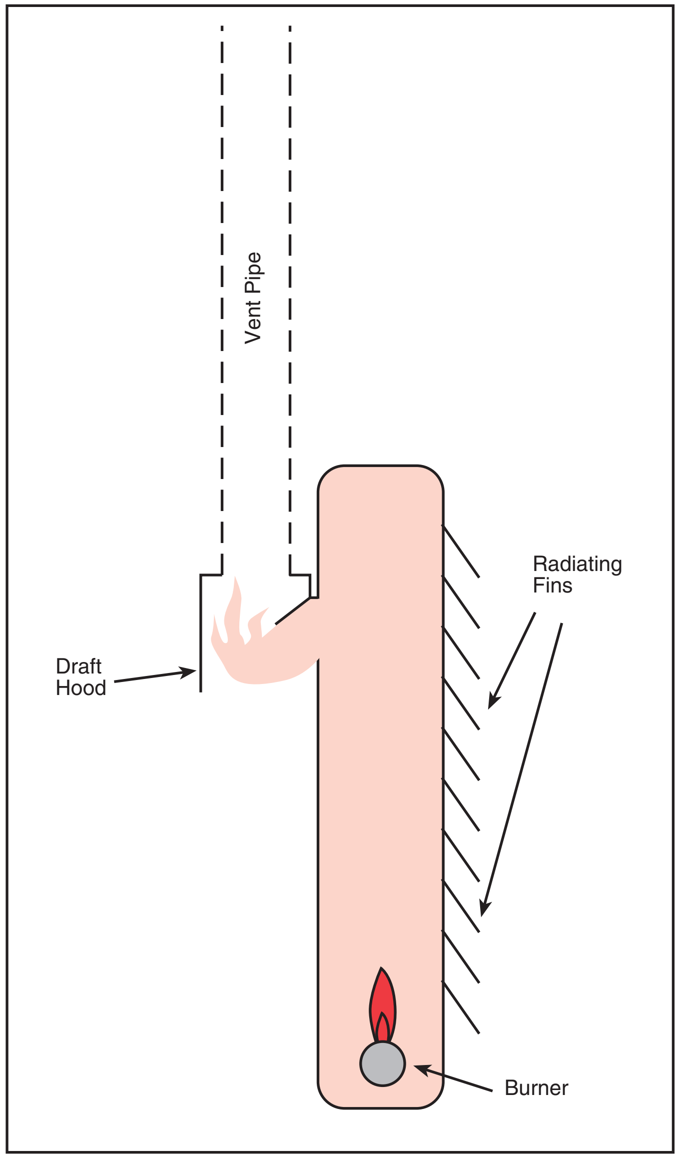


FIG. 15

Most of these units were unvented, and this eventually obsoleted such designs. In the days they were in use, the techniques in home building were such that great quantities of infiltration (leaks of outside air into the building) permitted operation of these units without vents. As building designs improved to reduce infiltration, the need for venting increased. So too did the design of the units change.

Fig. 15 illustrates a LOW INTENSITY radiant heater that was put into wide use in the late 1940's and early 1950's. Note that the burner is enclosed within the shell of the heater and that the outer walls have been embellished with fins to create a much larger surface from which radiation could be emitted. Also, the material and color of the radiant surface was dark, to enhance its emitting power. (Emission-emissivity will be covered later).

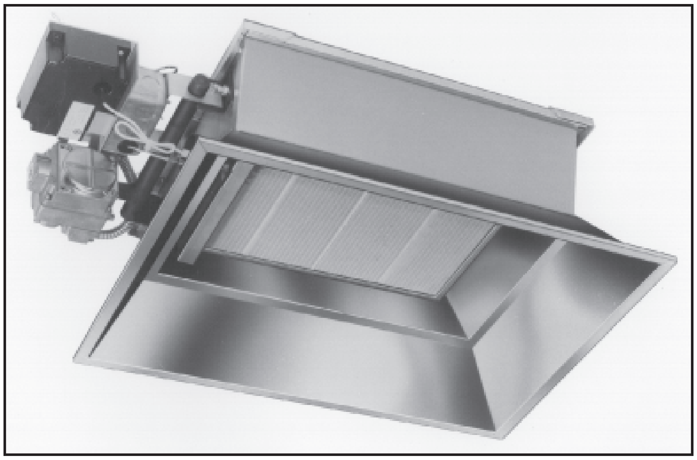


FIG. 16 - High intensity infrared heater

Additionally, draft hoods were put into use so the unit could be vented from the space.

Fig. 16 illustrates a HIGH INTENSITY infrared heater which is found in today's market. Such designs employ the high surface temperature approach of the earlier clay radiant unit but with greater uniformity of surface temperature. Also, the clay radiant was replaced with a ceramic material that is more acceptable to the high temperatures and much less susceptible to breakage and erosion through flame impingement. Ironically, these units for the most part are unvented. That is, they have no provisions for attaching a flue pipe. However, as you will find in later text, ventilation of the building in which they are used is of extreme importance.

Fig. 17 shows modern LOW INTENSITY infrared units. These designs operate in much the same fashion as the unit depicted in Fig. 15; however, the burner is supported by a FORCED AIR DRAFT fan, allowing for a more uniform temperature (between 600°F and 1000°F) of the radiant surface but more important, permits the designer to reduce the size of the heat exchanger. Such miniaturization of the heat exchanger allows for small diameter piping that can reach up to 60 feet in length, covering a much larger area of radiation and, at the same time, using a minimum amount of space in the building.

FIG. 17 - Two types of low intensity tube type infrared heaters

Some LOW INTENSITY infrared units may be operated with induced draft rather than forced draft. The products of combustion are drawn off using powered exhaust. The results are much the same. However, as is the case with most induced draft systems, high temperatures found in the flue gas present design problems which very often add cost to the unit.

TECHNICAL WORDS AND PHRASES

Because some of the words and phrases associated with infrared may be new to you, this section will define those that you should be familiar with. Here are a few that will be covered BLACK BODY, WAVE LENGTH and EMISSIVITY.

BLACK BODY

A BLACK BODY is any material which theoretically can absorb all the thermal radiation impinging upon it, reflecting none of these energies.

Please remember, a BLACK BODY is not necessarily black. If a list of BLACK BODIES could be generated, among those materials nearing such characteristic could be a whitewashed wall. While the color is far from black, this material absorbs infrared energies at very near the black body rate. There are other materials that may be near black body characteristics but for the most part, these materials fall short of the BLACK BODY rating of 1.

DO NOT confuse radiation with reflection. As stated earlier, a BLACK BODY has an emissivity of 1 which means that it absorbs ALL the thermal radiation directed at it (none bounce off-reflect). Conversely a black body can send or radiate all those energies away. On the other hand, a sheet of polished aluminum is highly reflective. It rejects a good portion of the infrared energies directed at it, because the infrared rays bounce off. Polished aluminum does absorb a small quantity of these energies. If we assumed that the polished aluminum reflected 95% of the infrared impinged upon it, we can then say the same material absorbs 5% of those energies, thereby disposing of 100% of the energy with which it comes in contact. For the reason of its reflectiveness, polished aluminum is used extensively in conjunction with both high and low intensity infrared units. Panels of this material are used to deflect the infrared rays for a more compact or more concentrated pattern giving much more definition to the area which these units are able to cover.

Black bodies are only theoretical, however, many surfaces are capable of absorbing a large percentage of the infrared energies directed at them while others, like the polished aluminum, will reflect a high percentage of this energy. You should keep this in mind when working in the infrared heating field.

WAVE LENGTH

Heat may be lost from a body, even though no substance is in contact with the body. Such energy is sent from the surface in every direction. Picture the sun, theoretically in contact with no matter, and throwing off heat which is ultimately intercepted by the earth. The heat cannot be seen, nevertheless, it is transmitted millions of miles by electromagnetic waves. Most of this passage is through a vacuum (outer space).

Infrared, ultraviolet rays, gamma rays, x-rays, radio and visible light are transported in the same manner. However, these energies all travel in different WAVE LENGTHS (impulses).

A WAVE LENGTH is the distance measured in the progression of a wave from one point to the next point, much the same as the waves in the ocean as they travel across the surface of the water.

Infrared wave lengths are measured in microns (A micron is 0.000001 or 1/1,000,000 of a meter.)

By comparison, visible light travels in wave lengths of .4 to .8 microns, while infrared travels within a range of .8 to 400 microns. From a practical standpoint, infrared heating wave lengths are found in the 2 to 20 micron range, however, infrared heating devices operate most efficiently within the 2 to 7 micron range.

Infrared rays do not lose their energy until they are intercepted by liquids or solids. Air does not absorb the rays, therefore, none of the energy is lost to air. This would explain the fact that when infrared heating is in use, it can be noted that upon start up, the air in the space is slow to heat. The air is finally warmed as the heated objects within range of the infrared source give off some of their heat through convection.

Fig. 18 is an illustration of the effects that wave length has on the emitting power of a black body. Note that a black body at 2200 degrees Rankin (1740° F) has peak radiation (BTU/HR OUTPUT) at a wave length of approximately 2.3 microns. Also note that the peak output of a given temperature is at a lower micron level. The shaded portion of the graph is the ultraviolet range. Note that the output level descends sharply when the ultraviolet range is approached. This means that wave lengths that fall into the ultraviolet range are not effective for providing heat.

EMISSIVITY

EMISSIVITY is the relative power of a surface to emit heat by radiation. The emissivity of a surface is rated based on its ability to radiate compared to a black body. By comparison, a black body has an emissivity value of 1. The emissivity value of 1 serves as a basis for all studies relating to the emitting power of a given surface and is used in formulating not only the emission rates but also the ability of a surface to absorb radiated heat. As the emissivity of a material decreases from 1, the reflecting quality of the same material increases. For instance, if a material has an emissivity of .9, it will reflect 10% of the infrared energies impinging upon it.

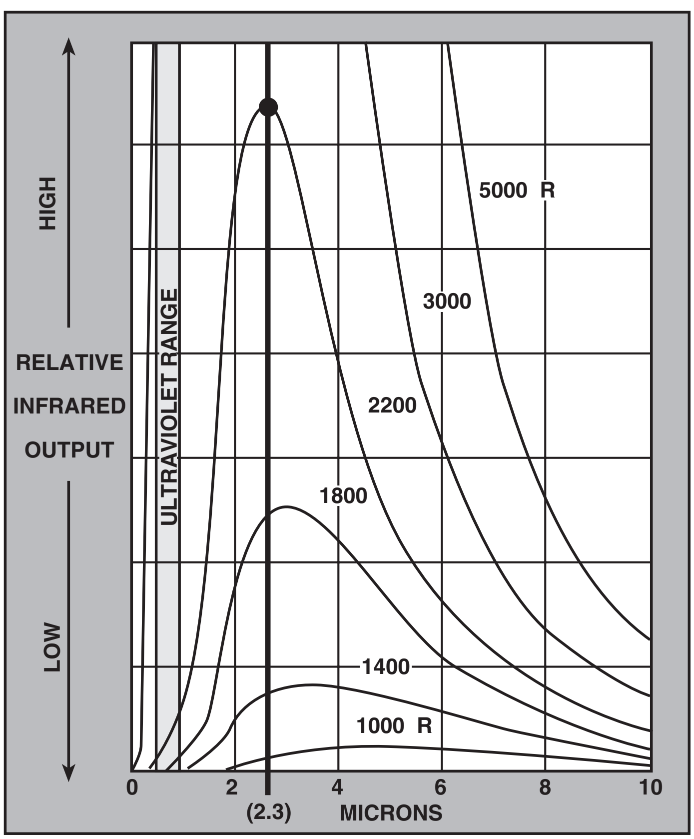


FIG. 18

MATERIAL	EMISSIVITY	REFLECTIVENESS
Aluminum (Polished)	0.07	0.93
Aluminum alloy	0.33	0.67
Asbestos board	0.96	0.04
Brick (Rough red)	0.93	0.07
Glass	0.9	0.1
Gravel	0.28	0.72
Iron (cast)	0.44	0.56
Iron (Rusted)	0.61	0.39
Lacquer (Flat black)	0.96	0.04
Lacquer (Flat white)	0.8	0.2
Marble	0.56	0.44
Plaster	0.91	0.09
Sand	0.76	0.24
Sand stone	0.83	0.17
Sawdust	0.75	0.25
Slate	0.67	0.33
Steel (galvanized)	0.45	0.55
Steel (sheet)	0.66	0.34
Steel (18-8 stainless)	0.45	0.55
Stonework	0.93	0.07
Varnish (Glossy)	0.89	0.11
Water	0.68	0.32
Wood (planed oak)	0.91	0.09

No material has an emissivity greater than 1.

If a material with an emissivity of .8 has been found to radiate 25,000 BTUH, then that same material contains heat in the amount of 31,250 BTUH. Conversely if the same material is impinged upon by 31,250 BTUH, it will absorb 80% of this quantity or 25,000 BTUH. 20% (6250 BTUH) will reflect (bounce) away from the material.

Following is a list of various materials and their approximate emissivity value. In general, a rough surface with no sheen whatsoever will have a comparably high emissivity rate, while a smooth surface that is highly polished, will have a relatively low emissivity rate. Both emissivity and reflectiveness are shown for each material.

STEFAN BOLTZMAN

Stefan Boltzman suggested that the total radiation from a heated body is proportional to the 4th power of its absolute temperature. Ludwig Boltzman furthered this theory through thermodynamic reasoning. Thus the following formula may be reliably adapted.

$$e(bb) = KT^4$$

Where:

e(bb) = emissive power of a black body

K = Stefan Boltzman constant

= $.172 \times (10)^{-8}$

= .00000000172

T = Absolute temperature °R

= °F - 460

Example: Determine the emission rate (btu/ft²/h) of a black body having an area of 1 square foot and at a temperature of 1600°F.

$$e(bb) = KT^4$$
$$e(bb) = .00000000172 \times (1600 - 460)^4$$
$$e(bb) = 30{,}974 \text{ btuh/ft}^2$$

Using the Stefan Boltzman constant and adding the emissivity value of a material, the following can be used:

$$e = KT^4 \times E$$

Where: e = emissive power

E = emissivity value (%) of the

$$\frac{T1}{T2} = \frac{(D2)^2}{(D1)^2}$$

material

If the material in the example above had an emissivity of .8, then "e" would be 30,974 x .8 or 24,779 btu/ft²/hr.

SPOT HEATING WITH HIGH INTENSITY INFRARED

When a high intensity infrared has reached peak temperature, the surface glows brightly since the material has reached a temperature of approximately 1650 to 1850°F. A close observation of this appli-

$$\frac{102}{T2} = \frac{(20)^2}{(10)^2}$$

$$\frac{102}{T2} = \frac{400}{100}$$

ance indicates that the intensity is so great near the surface that it is impractical or even dangerous to expose objects or materials at close distance. It is when you draw away from this surface that more acceptable levels of radiation are found. The intensity diminishes as the inverse square of the distance and can be calculated using the following formula:

Where T1 = Known BTUH/FT² intensity

D1 = Distance at which T1 was measured

T2 = New BTUH/FT² intensity

D2 = New distance

For example, let's assume an intensity of 102 BTUH/FT² has been measured beneath an infrared unit at a distance of 10 feet from the surface. We know that if we measure the intensity again at a distance of 20 feet, the BTUH/FT2 will have fallen off. In order to calculate the new intensity, we can use the formula:

$$10200/400 = 26$$
$$T2 = 26 \text{ BTUH}$$

As you can see, the intensity recedes as you move away from the source. However this does not indicate a reduction of total output. What it does demonstrate is that as the distance increases the focus widens. Consequently the BTU's are spread over a larger area, thereby reducing the temperature at the greatest distances from the source, while the original output remains constant.

When you recognize the distance/intensity relationship of infrared heat, it is easier to understand the importance of the correct mounting height. Because BTU intensities vary with the size, surface temperatures, and infrared patterns of the heater, specific mounting height versus BTU intensity can only be determined through testing of a particular model and size of heater. For this reason, mounting height information varies with manufacturers, with the most common being a recommended minimum mounting height chart such as the one illustrated below.

Recommended Minimum Mounting Height		
		Heater Position
BTUH/Size	Horizontal	30 degree Angle
30,000	11'0"	10'0"
50,000	13'6"	12'6"
60,000	14'6'	13'0"
90,000	16'0"	14'6"
100,000	17'0"	15'0"
120,000	17'6"	15'6"
150,000	18'6"	15'7"
160,000	19'0"	17'0"

Some high intensity infrared heater manufacturers publish flux density graphs that can be interpreted to accurately determine the desired mounting height. The most complete information provided is when the manufacturer further interprets the flux density graph information and publishes a BTUH per square ft. table (See Figure 20). These tables not only provide specific mounting heights based on the BTU's required at the floor or at a specified height but also the horizontal distance in an easy-to-interpret format. However, to generate the information required to publish flux density graphs or BTUH per sq. ft. tables, testing is required on each specific Model, size, and potential variation of the heater. Unfortunately, therefore, this type of specific information is most often not available. When

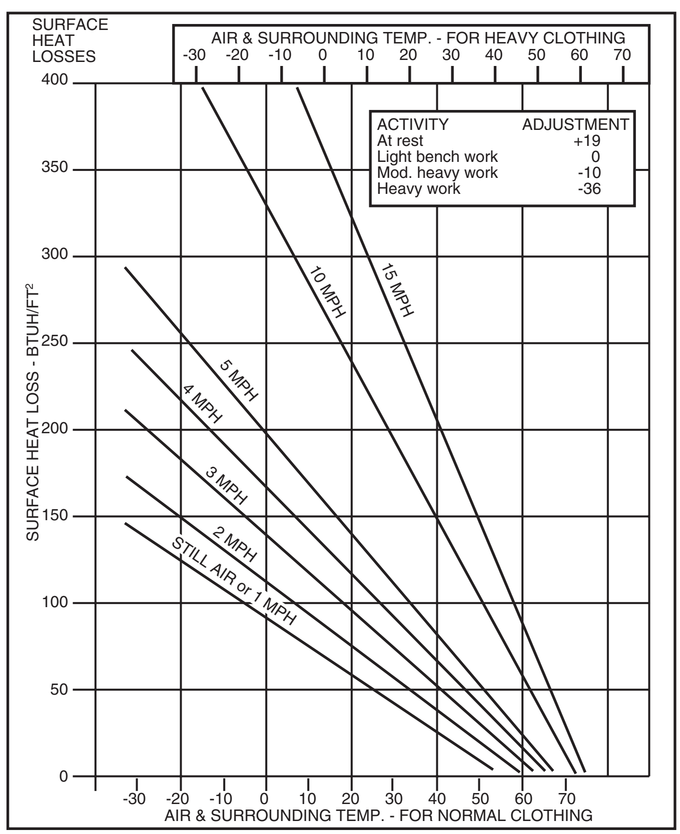


FIG.19 - Surface heat loss nomograph

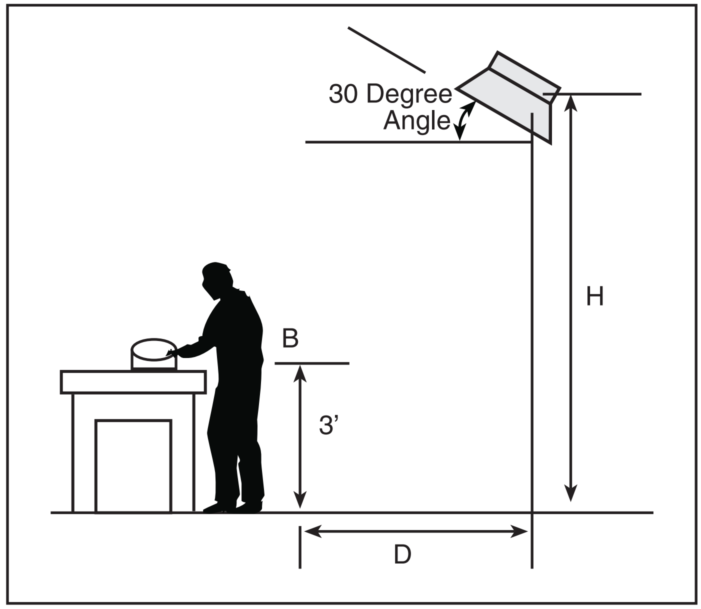
flux density graphs or BTUH per sq. ft. tables are available, use them to determine the mounting height for the heat required. When this specific test-generated information is not available, determine the most favorable mounting height from the recommended minimum mounting height chart and the floor coverage required.

A simple rule to follow in floor coverage is that the coverage of a horizontal unit is two times the mounting height. At a 30° angle, the length of dispersion extends to four times the mounting height. However, the distance/intensity relationship not only applies to the mounting height but also affects the intensity pattern of the infrared dispersion or floor coverage.

The first step in spot heating with high-intensity infrared is to determine what BTU level is needed. Most spot heating is installed to provide comfort for people. With this in mind, let's take a look at how the BTU requirements vary under different ambient conditions and also as the activity of the people changes.

Fig. 19 is a SURFACE HEAT LOSS NOMOGRAPH showing BTU levels that would be necessary to provide comfort conditions for people as they work within the confines of a given area. Note that the activity level, with ambient temperature, air movement and clothing, affect the BTU's lost from a person's body. The greatest influence is the activity level. As the level rises, less comfort BTU's are required since the body will be generating much of its own heat requirements. As the activity level decreases, more comfort BTU's must be added. These variations are displayed in the small inset, upper right on the chart and must be added or deducted from the Surface Heat Loss determined on the left column. A sample application later will put this chart to use.

Figure 20 illustrates examples of BTUH per square ft. tables. As was explained, BTUH per square ft. tables display the radiating capability and provide the mounting heights based on testing of specific heaters. These tables are for specific Reznor® Models of high intensity infrared heaters. Each table is based on testing of the heater installed in the most common spot heating application—a 30° angle measuring the BTUH intensity 3 feet above the floor.



MODEL RIH60 (60,000 BTU's)

D - DISTANCE (FT)		2	4	6	8	10	12	14	16	18	20	22	24
H - HEIGHT (FT)	7	212	174	105	66	43	29	20	15	11	9	7	6
	9	70	99	77	55	39	29	22	17	13	10	8	7
	11	29	53	54	44	33	26	20	16	13	11	9	7
	13	15	30	36	34	28	23	18	15	12	10	9	7
	15	9	17	24	25	23	19	16	14	12	10	8	7
	17	5	11	16	**18**	18	16	14	12	10	9	8	7
	19	4	7	11	13	14	14	12	11	10	8	7	6
	21	2	5	8	10	11	11	10	10	9	8	7	6
	23	2	4	6	7	8	9	9	8	8	7	6	6
	25	1.4	3	4	6	7	7	7	7	7	6	6	5
	27	1	2	3	4	5	6	6	6	6	6	5	5
	29	0.8	1.7	3	3	4	5	5	5	5	5	5	4
	31	0.7	1.4	2	3	3	4	4	5	5	4	4	4
	33	0.5	1.1	1.7	2	3	3	4	4	4	4	4	4

MODEL RIHV100 (100,000 BTU's)

D - DISTANCE (FT)		2	4	6	8	10	12	14	16	18	20	22	24
H - HEIGHT (FT)	7	354	290	174	110	72	49	34	25	18	14	12	9
	9	116	165	129	91	66	49	36	28	22	17	13	11
	11	49	88	90	72	56	44	34	27	22	18	15	12
	13	25	49	59	56	46	38	31	25	21	18	15	12
	15	14	29	39	41	38	32	27	23	19	16	14	12
	17	9	18	26	30	30	27	24	20	17	15	13	12
	19	6	12	18	22	23	22	20	18	16	14	12	11
	21	4	9	13	16	18	18	18	16	14	13	11	10
	23	3	6	9	12	14	15	15	14	13	12	10	9
	25	2	5	7	9	11	12	12	12	11	10	10	9
	27	2	4	5	7	9	10	10	10	10	9	9	8
	29	1.4	3	4	6	7	8	9	9	9	8	8	7
	31	1.1	2	3	5	6	7	7	8	8	7	7	7
	33	0.9	1.8	3	4	5	5	6	6	7	7	6	6

FIG. 20 - The charts to the right show the BTUH/FT² Heat Delivery at point "B" in the illustration above for three different sizes of Reznor Radiant Heaters. These values are valid for heaters mounted at height "H" at a distance "D" from point "B" when a standard reflector is used and the heater is mounted at a 30° angle.

Example: A 60,000 BTUH radiant heater (Model RIH60) mounted at a 30° angle, 17 feet off the ground ("H"), at a distance of 8 feet ("D"), will deliver **18** BTUH/FT² to point "B" as shown in the table to the right.

MODEL RIHV150 (150,000 BTU's)

D - DISTANCE (FT)		2	4	6	8	10	12	14	16	18	20	22	24
H - HEIGHT (FT)	7	531	435	262	164	108	73	51	37	28	22	17	14
	9	174	248	193	137	98	73	54	42	32	25	20	16
	11	74	133	135	109	84	66	51	41	33	27	22	18
	13	38	74	89	84	70	56	46	38	31	26	22	18
	15	22	44	59	62	58	48	40	34	29	24	21	18
	17	14	28	40	45	45	41	36	30	26	23	20	17
	19	9	18	27	33	34	34	31	27	24	21	18	16
	21	6	13	19	24	27	28	26	24	22	19	17	15
	23	4	10	14	18	21	22	22	21	19	18	16	14
	25	3	7	11	14	17	18	18	18	17	16	14	13
	27	3	5	8	11	13	15	15	15	15	14	13	12
	29	2	4	6	9	11	12	13	13	13	13	12	11
	31	2	3	5	7	8	10	11	11	11	11	11	10
	33	1.3	3	4	6	7	8	9	10	10	10	10	9

Most infrared units have standard reflector systems that serve to delineate the radiation pattern and in effect, provide a better concentration of BTU intensities. Fig. 21 illustrates the long axis pattern while Fig. 22 illustrates the short axis pattern. The maximum spread of 12 feet is typical but will vary with unit size. Also, the manufacturer has selected these dimensions based on acceptable intensity levels for the average installation. Intensities beyond these dimensions exist but in many cases, are considered fringe BTU's that do not figure into considerations for spot heating.

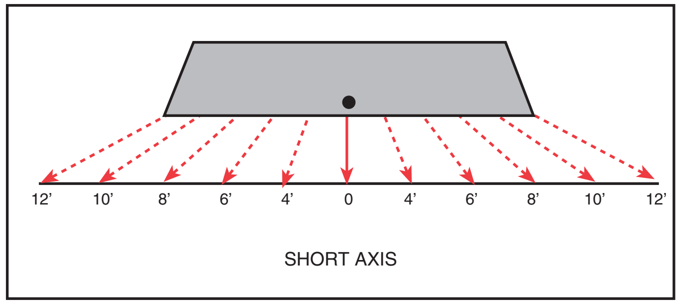


FIG. 22

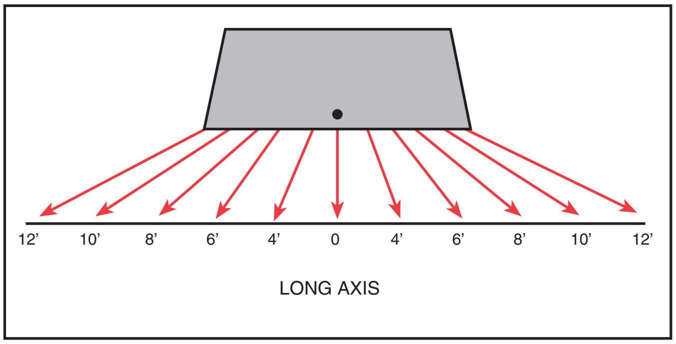


FIG. 21

LINE OF SIGHT

BTUH/FT^2 intensity tables are determined based on extensive testing. The values and boundaries are considered by the manufacturer to be the most useful in applying infrared. However, the infrared pattern extends beyond these boundaries by simple "line of sight" considerations. If you can see the glowing surface, then there will be energies however small, radiated to the point of sighting. Fig. 23 depicts the typical line of sight pattern for both long and short axis. Intensities are small but nevertheless do exist. Keep this in mind when selecting a room thermostat location.

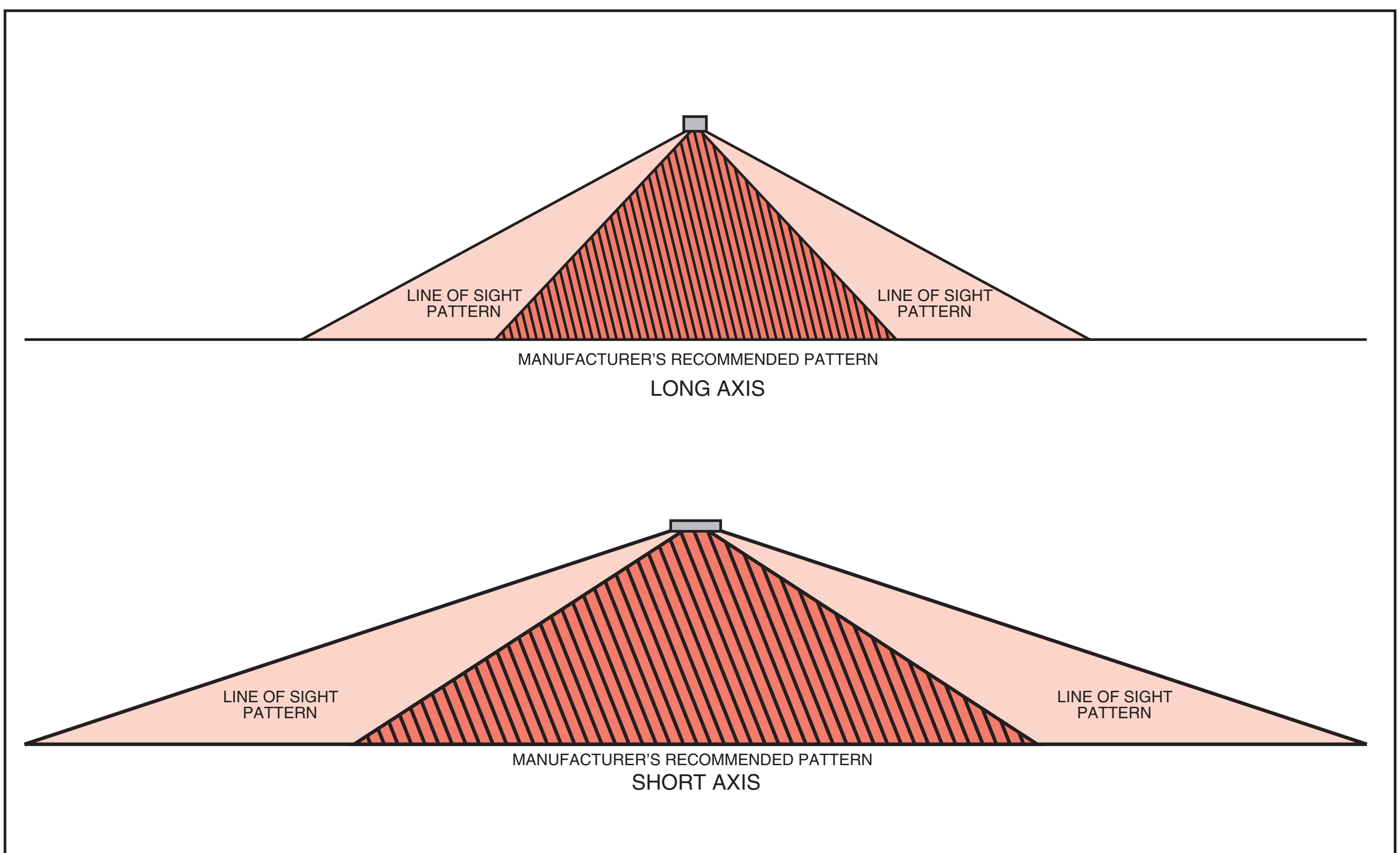


FIG. 23

SPOT HEAT SAMPLE

Remember, spot heating is most often used for people comfort in buildings which have either partial or no heating. Many warehouses fall into this category because very often warehouses are unheated or only partially heated to guard against freezing of product or sprinkler systems. We will use such a building for our example. The spot heating requirement stems from the fact that a worker engaged in packaging of product in preparation for shipment is located in a small section of the warehouse.

Here is the pertinent design criteria:

Building .... Medium sized warehouse

Surrounding temperature .... 35°F

Work area .... 8 ft x 8 ft

People .... One (Standing)

Clothing .... Heavy*

Activity .... Light bench work

Available mounting height .... 20 ft. max., no min.

Available mounting space .... 20 ft x 40 ft

Air velocity in building .... 2 MPH

*Light clothing consists of undershirt, cotton shirt, shorts, and cotton trousers. Heavy clothing would be double this amount.

Every person loses body heat, even when asleep. As activities increase, the body generates additional heat which warms the individual, even under extremely cold conditions.

Most of this body heat is lost through convection, radiation and perspiration. It is when the activity level is reduced and the surrounding temperature is below 70°F, that some type of heat must be added or the individual must be in some way protected against the cold. It is the intent of SPOT HEATING to provide the heat that the body is not generating so that comfortable conditions exist.

By referring to the surface nomograph (Fig. 24), the surface (clothing) loss for our example can be determined. Follow the 35°F temperature line down vertically from the HEAVY CLOTHING line at the top. When this line intersects the 2 MPH line, move directly horizontal to the BTU/FT² line and read the value at that location. You should read 25 BTUH. By referring to the Activity Adjustment table, you will note that for light bench work there is no BTU adjustment. Had the subject in our example been engaged in heavy work, there would be no need for heat whatsoever since 36 BTUH must be deducted from the 25 BTUH value we have just determined. Conversely, if our subject would be at rest, we would be adding 19 BTU to the 25 BTU already determined.

For SAFETY OF DESIGN, multiply the 25 BTUH by 120%, giving a BTU/FT² value of 30 as our target intensity requirement. Therefore 30 BTUH/FT² must be directed at the subject in our example at a point 3 feet above the floor (approximately belt height) for person standing. If the person were seated, the distance above the floor would be 2 feet. Ideally, an attempt should be made to cover the subject from all four sides, however, spot heating may be adequately provided by using only two infrared units, installed as illustrated in Fig. 25.

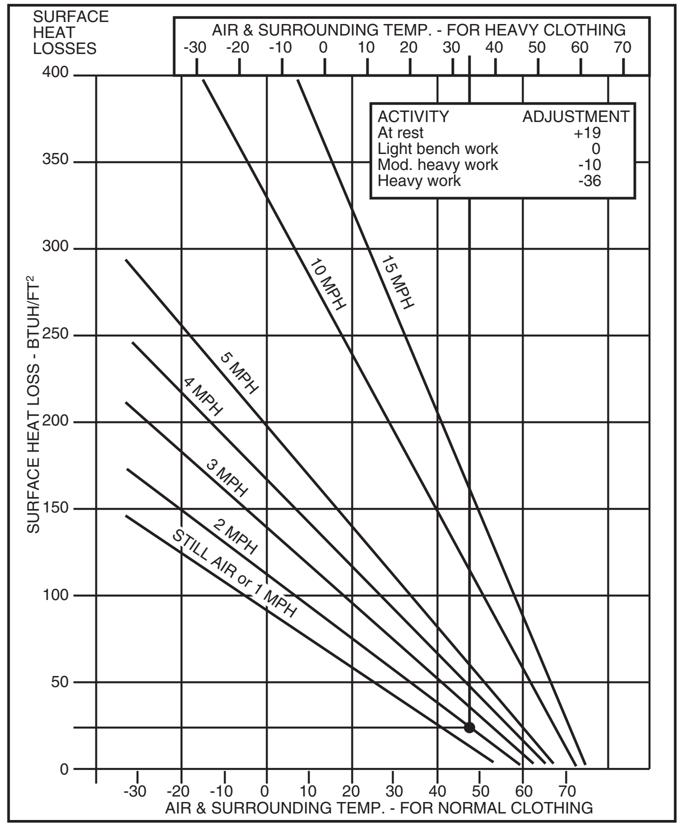


FIG. 24 - Surface heat loss nomograph

High-intensity infrared used in spot heating is most often installed at an angle. Most infrared units are certified for both angular or horizontal installation. According to the recommended minimum mounting height chart, a Size 30,000 BTUH heater at a 30° angle should be installed at a minimum mounting height of 10 feet. When spot heating is being used to heat a person or persons, in addition to the activity and clothing, you should also consider the normal position of the person. If the subject is standing, the infrared heat should be directed at a point three feet above the floor (See Figure 25). If the subject is seated, use a point two feet above the floor. For our example, we are using a 13’3" mounting height from the floor with the heater at a 30° angle.

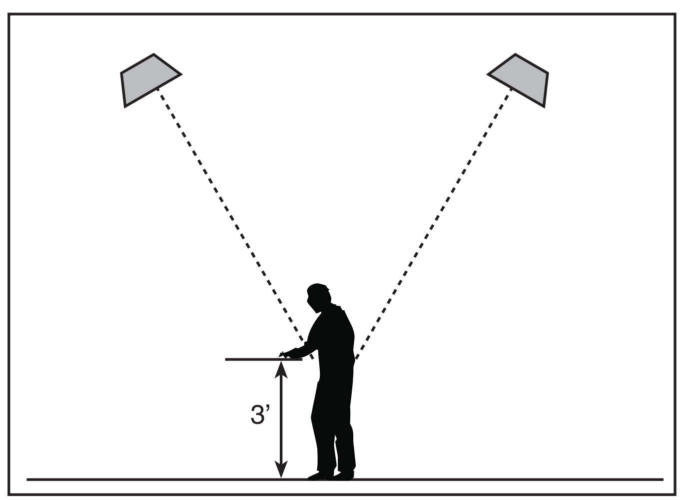


FIG. 25

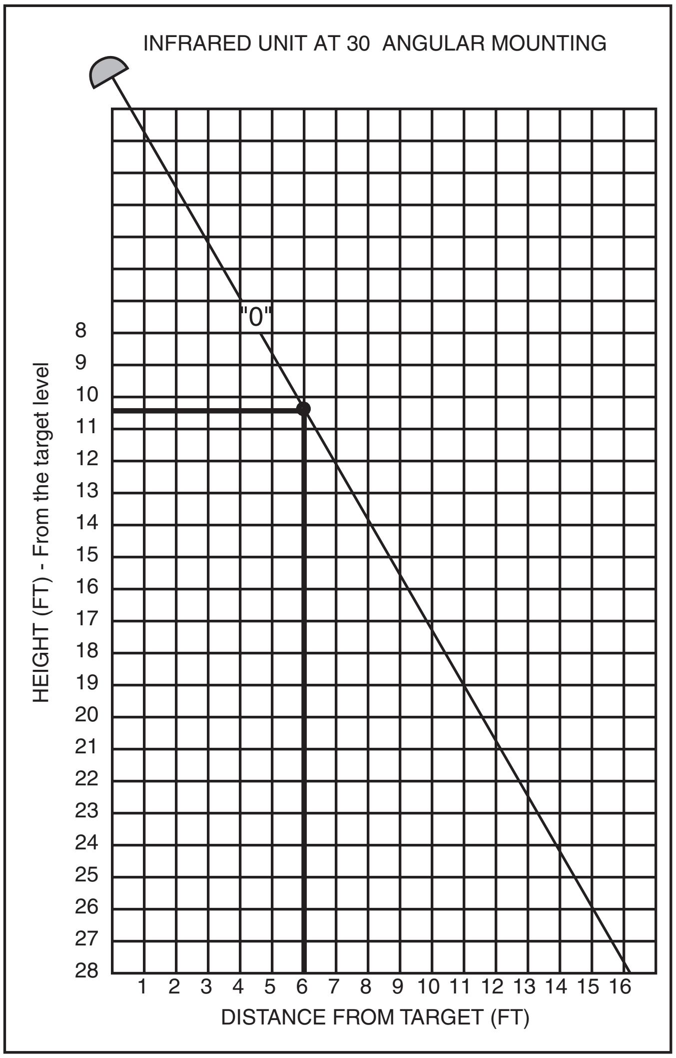


FIG. 26

With the mounting height determined, refer to Figure 26 to determine the distance horizontally that the unit must be located from the subject. From the 10¼ ft. height line (left column) move right until you intersect the sloped "0" line. From this point, drop vertically down to the horizontal dimension line. You should read approximately 6 feet. This dimension, when doubled, gives you center to center distance (12 ft.) between the two infrared units and they will be located as illustrated in Fig. 27.

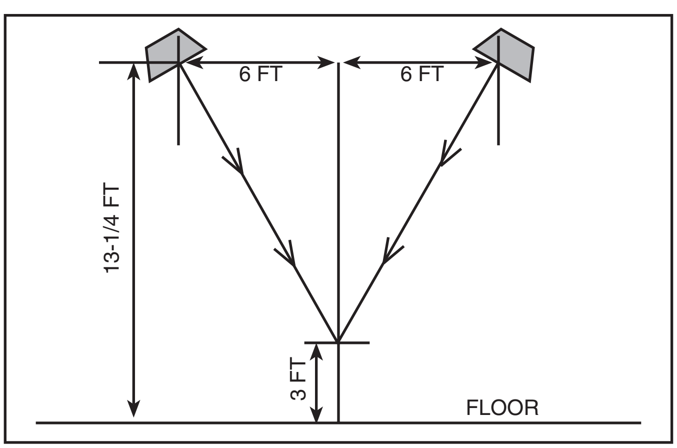


FIG. 27 - End view - two unit application

If you wish to guarantee coverage for all four sides of the subject and have elected to use four units rather than two, refer to Fig. 28 for a plan view of the four unit layout. Remember, the same height of 13 1/4 feet is used with either 2 or 4 units.

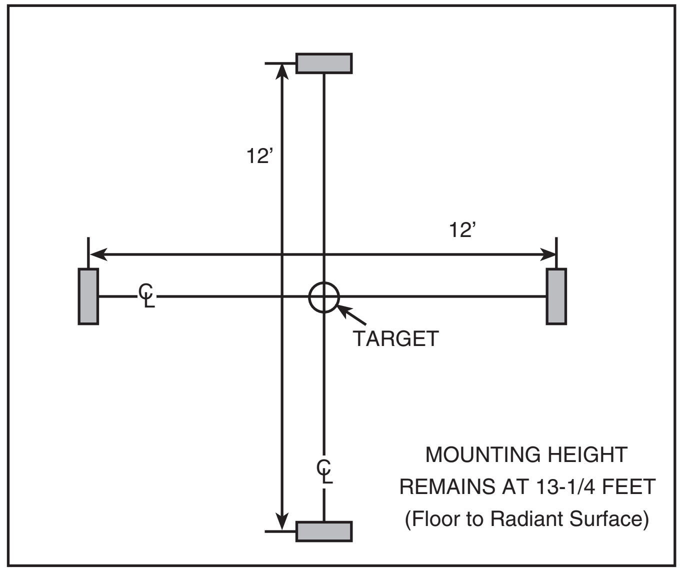


FIG. 28 - Plan View - four unit application

LARGER WORK AREA

If we find that the work area in our example is larger and accommodates more workers, we must first determine the coverage area. Let's assume that we will have 3 workers doing the same work and that the area will be expanded from 8'x8' to 8'x30'.

Now, we must plan on at least two units on each side of the workers. Also, we must be careful not to create too much intensity by overlapping the focus of the two units. Remember, our original determinations required 30 BTUH/FT2 intensity at a recommended minimum of 10 feet. (We are using 10'3" plus 3' for standing workers or a mounting height of 13'3".)

Figuring that the coverage (measured at 3' above the floor) is approximately twice the mounting height, Figure 29 illustrates two heaters with a centerline distance of 20 feet. Since the coverage overlaps, the average of the total BTU's radiated will increase allowing for a slightly higher mounting height to achieve the same comfort level. By referring back to Figure 26, you will note also that if the mounting height changes, the distance from the target will also change. See Figure 30 for an example of a plan view using the four units.

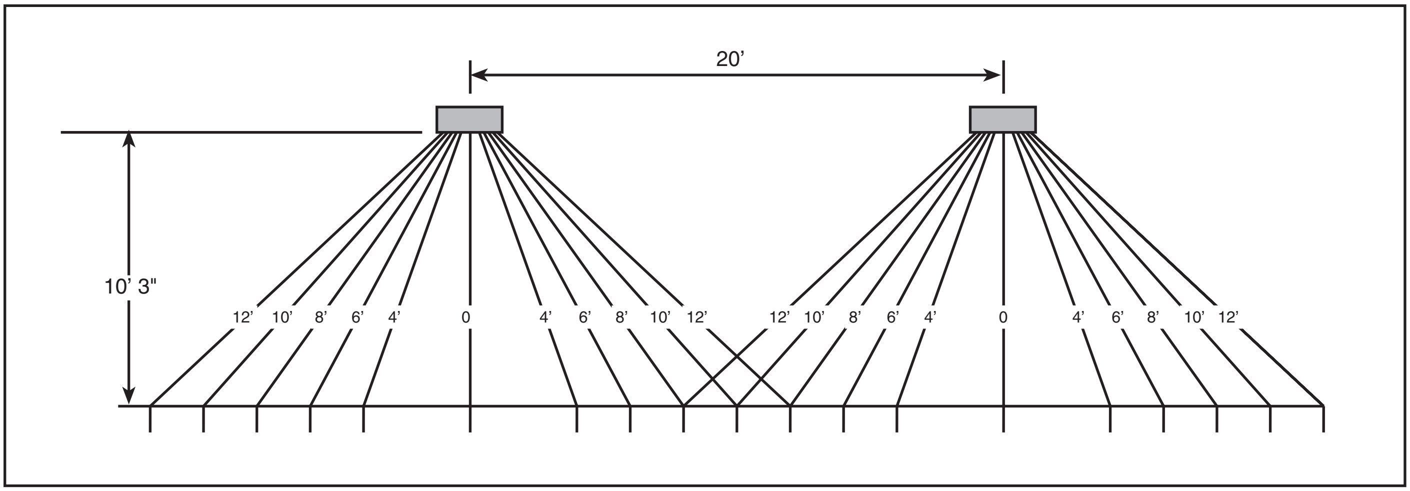


FIG. 29

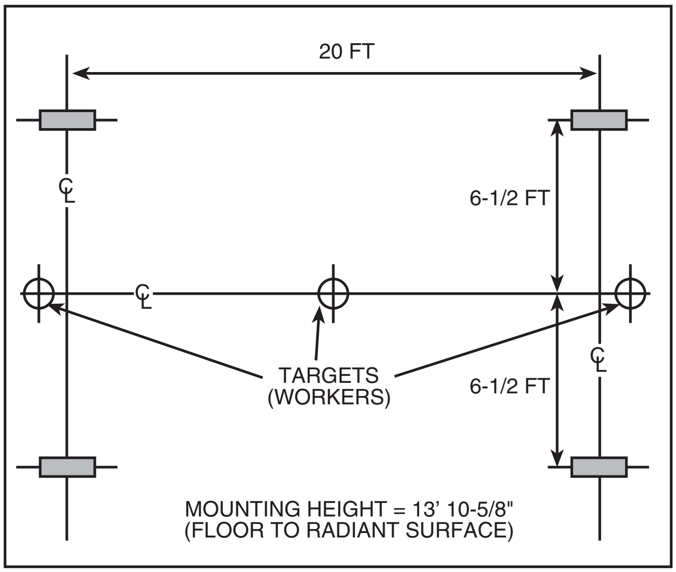


FIG. 30 - 4 Unit, 2 Bank Application

SPOT HEATING WITH LOW INTENSITY INFRARED

While spot heating with low intensity (tube type) infrared units is feasible, you will find that most tube type units have a much higher input rating than would be necessary on a small spot heating job such as described in the example above. Tube type units could best be used in an application where the spot to be heated is unusually long and where the mounting height may be relatively low. Some examples of this would be an assembly line or a service counter. (Fig. 31) Care should be used in the selection of unit size due to restrictive mounting heights.

A sample of a recommended minimum mounting height chart by size and reflector position is printed below.

Recommended Minimum Mounting Height (feet)			
BTUH Size	**Reflector Horizontal**	**Reflector at 30 degree Angle**	**Reflector at 45 degree Angle**
50,000	11	9	8
75,000	12	10	9
100,000	13	11	10
125,000	15	13	11
150,000	16	14	13
175,000	17	15	14
200,000	18	16	15

Consideration should also be given to the use of the “U” tube configuration for low intensity units because of the wide temperature difference that exists from burner end to exhaust end.

If flux-density (BTUH/FT^2) data is available for low intensity tube type infrared units, design applications using that precise, test-generated information.

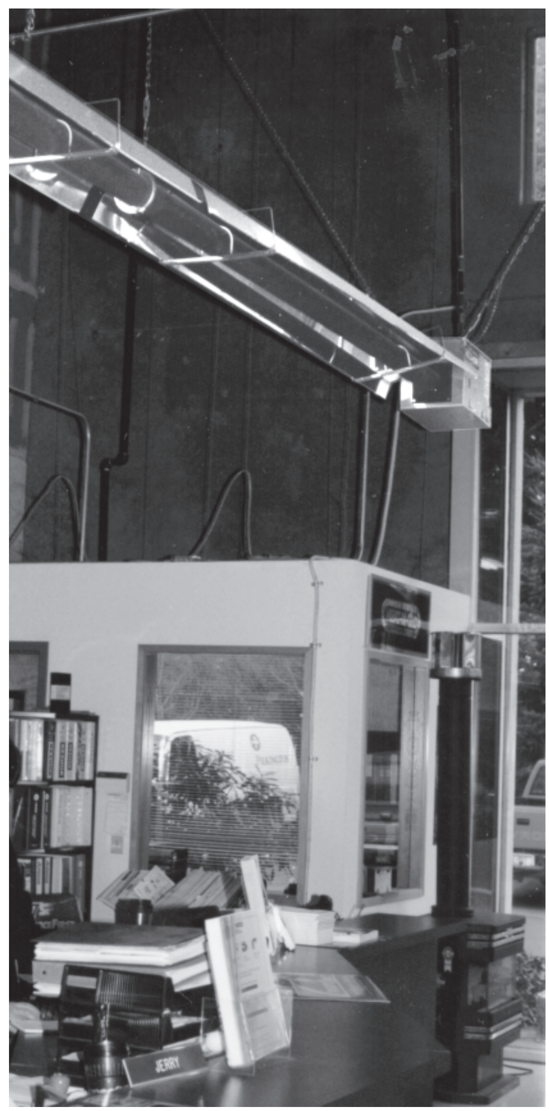


FIG. 31 - Service Counter Heating with Low Intensity Tubular Units

In the absence of flux density test information, select the tubular infrared size based on mounting height, BTU input, and unit length. Tubular units are usually equipped with reflectors which fasten directly to the emission tube. These reflectors may be rotated between 0° and 45° in order to direct the rays as needed. Remember, if you are supplying heat to people, the best way to do this is with rays directed from a 30° angle in order to strike the subject on the side, rather than the top. Also, for a complete spot heating application, you should direct the rays against at least two sides (or front and back) of the person(s) within the target range of the units. Fig. 32 illustrates how low intensity tubular infrared units may be used to supply spot heating for the 8' x 30' work area. There are several details that should be noted.

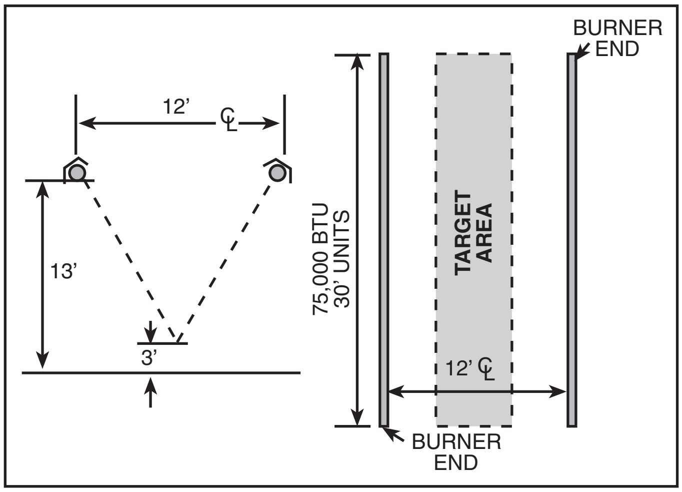


Fig. 32

1. Mounting height is 13'. Based on our earlier selection of two 30,000 BTUH units per side, select one 75,000 BTUH tubular unit per side.

2. Reflectors are positioned at 30º (facing target)

3. Centerline distance between units is 12' and is obtained from Fig. 26.

4. Burners are located at opposite ends. (Actual intensity patterns show greater BTU production at the burner end of the unit. By locating as shown, a better intensity balance will be obtained).

5. Unit length is 30'.

FULL BUILDING HEATING WITH INFRARED

All types of commercial and industrial buildings may be heated very successfully with infrared units. Placement, number and size of the units are extremely important to guarantee a good application. We will be discussing these considerations in the following text.

When heating with infrared, bear in mind that floors (slabs) and stationary objects will be heated and that they in turn will radiate, conduct and convect their accumulated heat to the space. So it is important that the infrared rays are wisely directed and that they are not wasted on walls, particularly outside walls or windows. Placement, angle of installation and intensity patterns will be very important in making sure that the heat is put to its very best use.

Another noteworthy facet of infrared full building heating is start-up. It must be recognized that by heating the floor (slab) and other stationary objects, time must be given to generate this buildup, particularly from a cold start. If start-up heating is initiated during the winter months, it may require one or two full days of heating with infrared before such a buildup (heat sink) is obtained. However, once the heat sink has been established, comfortable conditions should prevail throughout the remainder of the heating season with normal cycling of the heating equipment.

The heat sink infrared method is best appreciated in buildings where doors are opened frequently, or in buildings that due to their construction, permit high levels of infiltration (leaks of outside air into the space) to occur. Other buildings that come to mind are those that have walls with high rates of heat loss, such as uninsulated steel buildings. In all cases, when the heat from the infrared units is directed into the floor (slab), the heated floor, in turn, provides heat to the space. For this reason it is advantageous to have a slab that has ample edge insulation to limit the conduction of heat from the slab into the surrounding grade.

FULL BUILDING HEAT LOSS

Like all applications of heating apparatus, a determination of the BTU H needs must be made when infrared heating is planned. For buildings, such information is very often available from the Architect or Engineer who was instrumental in the original design of the building. In cases where it is not available from these sources, you will be required to develop it on your own or enlist the aid of someone knowledgeable in heat loss studies to make these determinations.

With the aid of the following data you should be able to generate much of your own heat loss information for commercial and industrial buildings.

BUILDING HEAT LOSSES

Buildings lose their internal heat by radiation, convection, conduction and by infiltration (outside air leaking into the building). These losses occur when the outdoor temperature is lower than the indoor temperature.

DESIGN TEMPERATURE

When determining heat loss through a wall, roof or other parts of a building enclosure, the design temperature difference (DT) will be used in the final calculation. The outdoor temperature at winter design conditions is needed.

Fig. 33 is a short list of cities throughout the USA and Canada, along with their winter outdoor design temperatures. Annual degree day information that can be used to estimate fuel consumption is also shown for each city. Such data is also available from the nearest US weather station or from ASHRAE.

The indoor temperature is a matter of choice or possibly is dependent upon the use of the building. As mentioned earlier, some warehouses are unheated. Others are maintained at a temperature just above freezing for the protection of materials or equipment stored within. However for comfort conditions, most building owners or users currently observe an indoor design temperature of 68°F which offers adequate heating while providing the most economical fuel costs. By subtracting the outdoor temperature from the indoor temperature, we obtain the ΔT (temperature difference) to be used in the heat loss determinations.

SURFACE LOSSES
(By convection and radiation)

The outside surface of all buildings will lose the heat stored inside. The construction of the building dictates at what rate this will occur.

All building materials have a certain resistance to the flow of heat. For computing heat losses, the heat flow rate through the outer shell must be known. Heat flow rates are expressed in several ways.

A "K" factor is the flow of heat, expressed in BTUH through one square foot of a specific material that is 12 inches thick and is based on a temperature difference of 1°F. However, since most buildings are constructed with partitions much thinner than 12 inches, and very often are constructed of various layers of differing materials, the "K" factor is not a very practical or efficient tool for determining heat loss.

Another measure of the resistance of heat flow is the "R" factor. The "R" factor is a rating assigned to insulation which identifies, by number, the power of the insulation to resist the flow of heat. The higher the number, the greater the resistance. However, the "R" factor alone is insufficient for computing heat loss. (Please turn to page 18)

Fig. 33

City	Outdoor Design Temperature Degrees F	Annual Degree Days	City	Outdoor Design Temperature Degrees F	Annual Degree Days
Albuquerque	0	4348	**Los Angeles**	35	1349
Atlanta	10	2961	**Little Rock**	5	3219
Atlantic City	5	4812	**Louisville**	0	4660
Bismarck	-30	8851	**Memphis**	0	3232
Boise	-10	5809	**Miami**	35	214
Boston	0	5634	**Milwaukee**	-15	7635
Buffalo	-5	7062	**Minneapolis**	-20	7635
Casper	-20	7410	**New Orleans**	20	1385
Chattanooga	10	3254	**New York**	0	4871
Chicago	-10	5882	**Oklahoma City**	0	3725
Cincinnati	0	4410	**Omaha**	-10	6612
Cleveland	0	6351	**Philadelphia**	0	4486
Columbus	-10	5211	**Pittsburgh**	0	5053
Dallas	0	2363	**Phoenix**	25	1765
Des Moines	-15	6588	**Portland**	10	4109
Denver	-10	5524	**Rapid City**	-20	7345
Detroit	-10	6293	**Reno**	-5	6332
El Paso	10	2700	**Rochester**	-5	6748
Flagstaff	-10	7152	**Salt Lake City**	-10	6052
Great Falls	-35	7750	**San Diego**	35	1458
Houston	20	1278	**San Francisco**	35	3000
Indianapolis	-10	5699	**Seattle**	15	4424
Jacksonville	25	1239	**St. Louis**	0	4900
Kansas City	-10	4711	**Toronto**	-10	6827
Lansing	-10	6909	**Washington, D.C.**	0	4424
Las Vegas	25	2709			

This is a select list of cities. For other cities, consult ASHRAE or other sources.

The “U” Factor

The “U” factor is a value that is expressed in BTUH/FT²/°F and represents the amount of heat that, in one hour, will flow through one square foot of a material having a specific thickness and further is based on a 15 MPH wind effect on the cold side. The values are scientific expressions that advise the anticipated loss when there is a temperature difference (ΔT) between the two sides amounting to 1°F. All “U” factors are given for not only individual materials but for specific wall and roof construction which may or may not include insulation. Therefore, the “U” factor provides the correct heat flow information for computing heat loss.

Fig. 34 is a list of construction configurations with the “U” factors shown in the right-hand column. For materials not listed here, you may have to refer to the ASHRAE guide or other sources.

The “R” Factor

The “R” factor discussed above, can be converted to a “U” value by simply dividing the R number into 1. (Example: R 19 = 1/19 = .05 BTUH/FT²/°F). However, since insulation is never singularly used in construction, you should only use this information to make comparisons between insulations for the purpose of studying fuel consumption. For instance, let’s assume that a ceiling having a surface area of 10,000 FT² is under study to choose the most cost effective insulation. R10 and R19 are being considered. First, convert the R factors to BTUH/FT²: R10 = 1/10 = .1/BTUH/FT² R19 = 1/19 = .0526 BTUH/FT². With a ΔT of 70° F (indoor = 70°F, outdoor = 0°F) calculate the BTUH loss for each as follows:

R10 = 70 x 10,000 x .1 = 70,000 BTUH loss

R19 = 70 x 10,000 x .0526 = 36,820 BTUH loss

FIG. 34 - “U” Factors

WALL CONSTRUCTION		“U” FACTOR
1	Wood frame 4" thick with wood siding, .5" sheathing and .5" Gypsum wallboard	0.80
1-A	Above with 3.5" R-11 Blanket insulation	0.08
2	Common brick 8" (4" double row)	0.41
2-A	Above with 5" R-1 1 Gypsum wallboard	0.26
3	Concrete block cinder aggregate, .8"	0.39
3-A	Above with face brick 4"	0.33
3-B	Above with .5" Gypsum wallboard	0.19
3-C	Above with face brick 4" and .5" Gypsum wallboard	0.17
4	Concrete block stone aggregate, .8"	0.57
4-A	Above with face brick 4"	0.44
4-B	Above with face brick 8"	0.29
4-C	Above with face brick 4" and .5" Gypsum wallboard	0.20
4-D	Above with face brick 8" and .5" Gypsum wallboard	0.16
5	Steel sheet over sheathing—hollow baked	0.69
5-A	Steel sheet w/.375" insulating board	0.38
5-B	Steel sheet w/.375" insulating board w/foil back	0.26
5-B	Steel sheet w/1" expanded polystyrene	0.21
5-D	Steel sheet w/3" mineral fiber blanket insulation	0.08
6	Poured concrete:	
6-A	Lightweight aggregates 120 lb./cu. ft. 4" thick	1.32
6-B	Lightweight aggregates 80 lb./cu. ft. 4" thick	0.63
6-C	Lightweight aggregates 40 lb./cu. ft. 4" thick	0.29
6-D	Gypsum fiber concrete 87.5" Gypsum, 12.5% wood chips, 4"	0.42

WINDOW CONSTRUCTION		“U” FACTOR
1	Vertical in walls	
1-A	Single glass with wood sash	0.99
1-B	Single glass with metal sash	1.10
1-C	Double insulated glass with wood sash	0.55
1-D	Double insulated glass with metal sash	0.70
2	Horizontal skylights:	
2-A	Single glass with wood sash	1.11
2-B	Single glass with metal sash	1.23
2-C	Double insulated glass with wood sash	0.55
2-D	Double insulated glass with metal sash	0.78

DOOR CONSTRUCTION		“U” FACTOR
1	Wood — solid 1.5"	0.49
2	Steel 1.75"	0.59
3	Insulated steel 1.75" w/foam core & thermal break	0.20

ROOF CONSTRUCTION		“U” FACTOR
1	Wood built up with (deck insulation: R-1.39)	0.28
1-A	Above with acoustical tile .5"	0.17
1-B	Above with 6" R-19 blanket insulation	0.05
1-C	Above with acoustical tile .5", and R-19 blanket insulation	0.04
1-D	Above with .3.5” R-11 blanket insulation	0.07
1-E	Above with acoustical tile, and 3.5" R-11 blanket insulation	0.06
2	Steel built up (deck insulation: R-4.17)	0.18
2-A	Above with metal lath and plaster .75"	0.16
2-B	Above with suspended ceiling .75" panels	0.12
2-C	Above with 3.5" R-11 blanket insulation	0.06
2-D	Above with 6" R-19 blanket insulation	0.04
2-E	Steel or aluminum over sheathing hollow-backed	0.69
3	Concrete built up	
3-A	Above with suspended ceiling .75" panels	0.19
3-B	Above with 3.5" R-11 blanket insulation	0.07
3-C	Above with 6" R-19 blanket insulation	0.05
3-D	Above with R-11 insulation and suspended ceiling per 3-A.	0.06
3-E	Above with R-19 insulation and suspended ceiling per 3-A.	0.04
4	Sloped 45° wood with Gypsum wallboard .5" and asphalt shingles	0.21
4-A	Above with 3.5" R-11 blanket insulation	0.06

FLOOR CONSTRUCTION		“U” FACTOR
1	Slab on Grade is 4 inch concrete with sand aggregate. 140 lb./sq. ft. and 1 inch edge insulation.	0.30
2	Over a heated basement	No Heat Loss
3	If basement heat loss is required, it must be calculated separately. For the portion of the wall below grade, use the following “U” values:	
3-A	Concrete Basement Walls	0.20
3-B	Concrete Basement Floor	0.10

The annual fuel consumption for each insulation may be computed using the following formula:

$$\frac{HL \times 24 \times DD}{EFF \times DT} = \text{Annual fuel consumption (BTU)}$$

Where: HL = Hourly heat loss for area studied.
DD = Annual degree days.
EFF = Efficiency of heating equipment.
ΔT = Temperature difference at design (70°F).

For this example we will use 90% heater efficiency.

Therefore:

$$\frac{70{,}000 \times 24 \times 6{,}000}{.90 \times 70} = 160{,}000{,}000 \text{ BTU}$$

and R19

$$\frac{36{,}820 \times 24 \times 6{,}000}{.90 \times 70} = 84{,}160{,}000 \text{ BTU}$$

To determine the fuel costs, divide the annual BTU used by BTU per unit of fuel (1,000,000 BTU = 1 unit of natural gas)

160,000,000 ÷ 1,000,000 = 160 units
84,160,000 ÷ 1,000,000 = 84.16 units

If the cost per unit is $8.37, then multiply the units by this value.

160 x $8.37	=	$ 1,339.20 for R10
84.16 x $8.37	+	$ 704.42 for R19
DIFFERENCE	=	$ 634.78

At this point, a decision on which insulation to use will be made based on insulation cost difference vs. fuel cost during years of amortization.

SURFACE AREA

The best way to develop surface area for an entire building is to first, list all of the various construction types found in the shell of the building. This would include:

Wall construction (There may be several different types of construction employed so be sure to list them all.)

Type of glass (List each type separately)

Ceiling or roof construction

Doors (List each size or type separately)

Basement or slab

Next, for each of the various surfaces or edges, measure carefully so that accurate areas or lineal dimensions can be developed. Be sure to deduct windows and door areas from the wall surface.

Next, review Fig. 34 and find the proper "U" factor for each different construction type listed.

When the ΔT, "U" factor and surface area are known, the surface losses can be calculated as follows:

Area $FT^2 \times \Delta T \times U$ = BTUH loss for area studied.

The sum of all surface area losses will be the total radiational and conventional losses for the building under study.

INFILTRATION

In all buildings, there is a certain amount of infiltration of outside air. This unheated air enters through cracks, usually around windows and doors, but also can seep through loosely constructed walls and joints. Such leakage adds considerably to the total heat loss. Determining the amount of infiltration is very difficult and time consuming. Devices are in existence which can provide measurement of such leakage but at considerable cost. An accurate assessment of infiltration is best compiled by the Architect or Engineer. If this information is unavailable, most estimators will arbitrarily enter an infiltration rate based on the volume of the building. For small buildings (less than 100,000 cubic feet) an infiltration rate of one air change/hr is generally used. For larger buildings the air change rate is lower but is never less than $^1/_3$ the volume of the building.

A more exacting method of determining infiltration rates is available from the ASHRAE guides and other sources. In these studies, lineal feet measurements of all window and door edges are necessary. Considerations must be given to the type of joints used in the construction of the building and to potential wind velocities and prevailing wind directions.

Later, you will find that certain amounts of ventilation are required in order to support combustion in the heating equipment selected. Many times, the infiltration rate will more than exceed these requirements. ANSI requires a minimum of 50 FT^3 of building volume for each 1,000 BTUH of firing rate, regardless of infiltration rate. If volume is less than this amount, some means of introducing fresh air for the combustion process will be necessary. This will be covered later (page 27).

If you elect to use the air change method, then simply multiply the building volume $FT^3 \times .018 \times DT$. This will give the BTUH loss for one air change of infiltration. If you elect to use other than one air change, or if you elect to use the ASHRAE method, you must make this adjustment before completing above calculation. (See example heat loss study for $^1/_2$ air change).

The infiltration loss will be added to the total radiational losses determined earlier.

EXHAUSTS AND VENTILATION

Many industrial and commercial buildings are equipped with exhausters to get rid of unwanted contaminants. Also, many of these buildings require ventilation. Both exhaust and ventilation are supplied under power to assure that the volume is as prescribed. Flow rates are expressed in CFM (Cubic feet per minute). If the building you are evaluating for heat loss includes either or both of these functions, then the following rules should be observed.

If the infiltration rate (CFM) is greater than the exhaust CFM and/or ventilation CFM, then calculate only the infiltration losses. Infiltration CFM may be calculated by dividing the volume of infiltration (FT^3) by 60 (Minutes).

If the infiltration rate (CFM) is less than the exhaust and/or ventilation CFM, then calculate the losses associated with these functions, and add to the radiational losses determined earlier. Be sure to omit the infiltration losses.

Exhaust and ventilation BTUH losses may be calculated using the following formula: CFM x 1.085 x ΔT = BTUH loss.

LOSS BY CONDUCTION

Conductive losses occur at grade and are most prominent in buildings that use a slab, rather than a basement. It is important that the slab edges are adequately insulated to guard against excessive losses at this point. This is particularly important when using infrared as a heat source since the object with infrared is basically to heat the slab.

In order to calculate the BTUH loss for the edges of the slab, use the following:

Slab with uninsulated edge: .81 BTUH x Lineal feet x ΔT

Slab with insulated edge: .30 BTUH x Lineal feet x ΔT

This quantity is then added to the radiational, infiltration or exhaust and ventilation losses determined earlier. The total represents the hourly building BTU loss at design conditions.

HEAT LOSS STUDY AND SAMPLE CALCULATIONS

To help in understanding the heat loss calculation process more fully, the following sample heat loss study is offered.

Building: Commercial
200'L x 150'W x 20'H equals 600,000 ft³

Windows: Thirty (30) double insulated windows with steel sash
48" x 48" each
"U" Factor is .70 (refer to Figure 31)
1) Surface area equals 4' x 4' x 30 windows or 480 ft² (to be deducted from sheet metal wall surface area)

Doors: Three (3) Insulated steel service doors
7'H x 4'W x 1.75" thick with foam core and thermal break
"U" Factor is .20 (Figure 31)
2) Total surface area equals 7'H x 4'W x 3 doors or 84 ft²
3) Surface area below 5'H to be deducted from brick wall surface area equals 5'H x 4'W x 3 doors or 60 ft²
4) Surface area above 5'H to be deducted from sheet metal wall surface area equals 2'H x 4'W x 3 doors or 24 ft²

Two (2) Steel rollaway doors
12'W x 16'H x 1.75" thick
"U" Factor is .59 (Figure 31)
5) Total surface area equals 16'H x 12'W x 2 doors or 384 square feet
6) Surface area below 5'H to be deducted from brick wall surface area equals 5'H x 12'W x 2 or 120 ft²
7) Surface area above 5'H to be deducted from sheet metal wall surface area equals 11'H x 12'W x 2 doors or 264 ft²

Walls: Split Construction
Bottom wall: 5'H, consist of 2 rows of 4" wide common brick (8" thick total)
"U" Factor is .41 (Figure 31)
8) Surface area for the side walls equals 5'H x 200'L x 2 walls or 2,000 ft²
9) Surface area for the end walls equals 5'H x 150'W x 2 walls or 1,500 ft²
10) Total brick wall surface area equals 3,500 ft² less surface area for doors (lines 3 and 6 above)
11) 3,500 ft² - 60 ft² - 120 ft² = 3,320 ft²

Top wall: 15'H, consist of sheet metal with 1" expanded polystyrene
"U" Factor is .21 (Figure 31)
12) Surface area for the side walls equals 15'H x 200'L x 2 walls or 6,000 ft²
13) Surface area for the end walls equals 15'H x 150'W x 2 walls or 4,500 ft²
14) Total sheet metal wall surface area equals 10,500 ft² less surface area for windows and doors (lines 1, 4 and 7 above)
15) 10,500 ft² - 480 ft² - 24 ft² - 264 ft² = 9,732 ft²

Roof: Flat, built up with 6" R19 insulation
"U" Factor is .05 (Figure 31)
16) Surface area equals 200'L x 150'W or 30,000 ft²

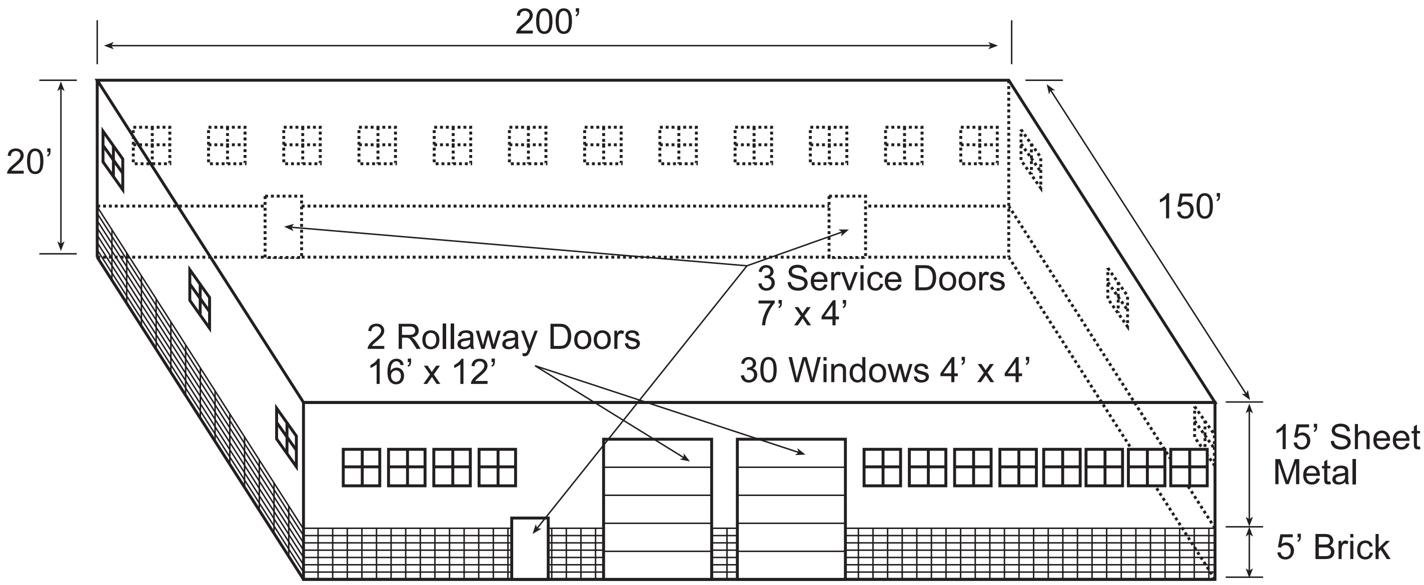
Floor: Slab on grade with edge insulation
"U" Factor is .30 (Figure 31)
17) Lineal feet equals length of four walls 200' + 150' + 200' + 150' or 700 lineal feet

For convection type heating this is the amount of heat that must be supplied to the building under design conditions of +10°F outdoors and 68°F indoors. The convection type heaters would have to be sized based on their BTUH OUTPUT rating which is listed in the manufacturer's specifications.

Outdoor design: +10°F
Indoor design: 68°F
ΔT: 58°F
Infiltration Rate: ½ air change per hour

Figure 35 shows the sample building layout and the final heat loss calculations.

When heating with infrared, we will be able to reduce the calculated heat loss by 15%, and we will be sizing the units based on their INPUT rating. Therefore, 643,468 x .85 = 546,948 BTUH. The 15% reduction is permissible due to the fact that with infrared, we will be avoiding direct radiation against the ceiling and outside walls. This, in effect, keeps the ΔT at a minimum. That is why it is so important to avoid directing the infrared rays against outside walls, windows and doors. Of course, with the reflectors, no infrared energies should contact the ceiling or roof.



HEAT LOSS CALCULATION

RADIATIONAL LOSS:	Surface Area (FT²) x ΔT x "U" Factor = BTUH LOSS		
	Windows:	480 ft² x 58°F x .70 "U" =	19,488 BTUH
	Service doors:	84 ft² x 58°F x .20 "U" =	974 BTUH
	Rollaway doors:	384 ft² x 58°F x .59 "U" =	13,140 BTUH
	Brick wall:	3,320 ft² x 58°F x .41 "U" =	78,950 BTUH
	Sheet metal wall:	9,732 ft² x 58°F x .21 "U" =	118,536 BTUH
	Roof:	30,000 ft² x 58°F x .05 "U" =	87,000 BTUH
TOTAL RADIATIONAL LOSSES			318,088 BTUH
INFILTRATION:	Volume (ft³) x Air Change x .018 x ΔT = BTUH LOSS		
	600,000 ft³ x 1/2 x .018 x 58°F =		313,200 BTUH
SLAB EDGE LOSS:	Lineal Feet x ΔT x "U" Factor = BTUH LOSS		
	700 ft x 58°F x .30 "U" =		12,180 BTUH
HOURLY HEAT LOSS			**643, 468 BTUH**

FIG. 35 - Sample building layout and heat loss calculations

INFRARED APPLICATION FOR TOTAL BUILDING HEATING

The first consideration in selecting infrared heaters is the available mounting height. Low mounting heights dictate that larger numbers of small high intensity units may be required or low intensity units. High mounting heights may require large high intensity units in lesser quantities and will possibly rule out low intensity units. The one thing to remember is that the most effective application will allow the intensity patterns of adjacent units to overlap. If you allow voids between unit patterns, the results will be less than ideal.

Let's continue with the sample heat loss above, and make our unit selections. The ceiling height as you recall, was 20 feet, however, this does not mean that the units will be installed at or even near this height. First of all, clearances from combustibles must be examined. If we find that in the built-up roof, some combustible material exists, then we must be certain that we observe the manufacturer's recommended clearances, and this would be the closest we dare install the selected units. (Fire hazard clearances are clearly stated and will vary for each Manufacturer and for each individual unit. These dimensions must be known before planning any unit selections or installations)

Let's assume that 24" top clearance is required for high intensity units and 12" top clearance for low intensity units. We know from this that the maximum mounting height for high intensity units will be 18' and will be 19' for low intensity units. This dimension is measured from the floor to the top of the unit. Remember, our example building has 700 lineal Ft. of wall. With this as a beginning, we can now commence to analyze for our equipment selections.

Most high intensity infrared units are available in sizes of 30,000 BTUH input to 160,000 BTUH input with three or four sizes in between. Low intensity units are generally available in sizes of 50,000 BTUH input up to 200,000 BTUH input with four or five sizes in between. You should determine exactly what sizes are available from the manufacturer.

For our example, let's see how many of the largest and smallest units we might need. We can also determine what initial centerline distance (CLD) between units might be needed.

HIGH INTENSITY

546,948	÷	30,000	=	18 UNITS.	700	÷	18	=	38.9 Ft CLD
546,948	÷	100,000	=	6 UNITS.	700	÷	6	=	116.6 Ft CLD
546,948	÷	150,000	=	4 UNITS.	700	÷	4	=	175.0 Ft CLD

LOW INTENSITY

546,948	÷	50,000	=	11 UNITS.	700	÷	11	=	63.6 Ft CLD
546,948	÷	75,000	=	8 UNITS.	700	÷	8	=	87.5 Ft CLD
546,948	÷	150,000	=	4 UNITS.	700	÷	4	=	175 Ft CLD
546,948	÷	200,000	=	3 UNITS.	700	÷	3	=	233.3 Ft CLD

HIGH INTENSITY APPLICATION

Of the above unit types, the 30,000 BTUH high intensity infrared units has the shortest CLD. Also remember there is a limit to the mounting height in our example building (18'). Therefore, we will proceed with this size and style, using the greater number of units to hopefully get total coverage of the perimeter. The mounting height and the centerline distance from the wall must be determined. Selecting a 15-ft mounting height, Fig. 36 shows the units should be installed at a distance of 7’9" from the wall.

Fig. 37 is a sketch, showing a proposed layout for the 30,000 BTUH high intensity infrared units. This size has been selected for optimum perimeter coverage. Larger units would result in considerable pattern voids because of the limited mounting height and greater CLD.

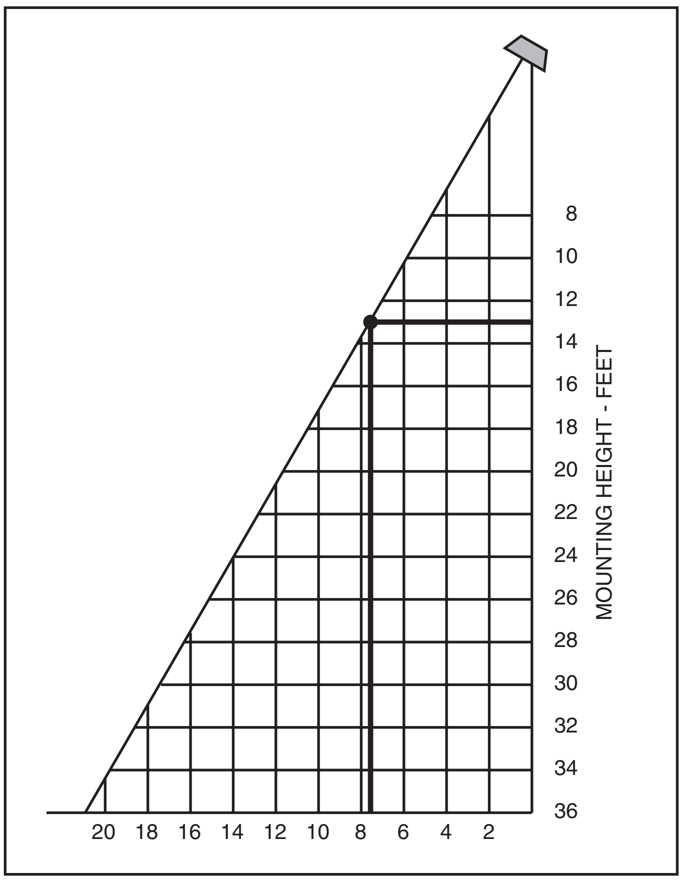


FIG. 36 - Minimum unit centerline to wall distance (feet) for a high intensity infrared heater installed at a 30° angle.

As mentioned earlier, this would provide less than ideal heating characteristics. Note that liberties were taken with unit placement so that a concentration of heat is available at the rollaway doors. Otherwise, the CLD of 38.9 Ft. was observed and the units are set at a 30° angle, facing the center of the building.

Two adjacent infrared heaters at 38.9 feet CLD will provide intense coverage to the floor over at about 30 feet of the CLD. This will leave 8.9 feet of diminished intensity (void). In this case, we could rely on the line of sight intensities to provide a small amount of heat to this area. As an alternate, we may elect to use more heaters for a shorter CLD.

A better solution, however, is to close the CLD by changing units to HORIZONTAL POSITION. This necessitates moving further from the wall. By referring to the following chart, the recommended distance between heater and wall is 18’ when the unit is installed at 14 feet high.

HORIZONTAL MOUNTING HEIGHT (FT)	SUGGESTED LONG AXIS DISTANCE FROM WALL (FT)
8	8
10	10
12	14
14	18
16	21
18	25
20	28
22	32
24	35
26	38
28	42
30	46
32	49
34	53
36	56

Fig. 38 illustrates how the layout would appear. Note that on the 200' walls, there will be no intensity voids. The 150' walls, however, will have voids of ½ foot which we could plan on allowing the line of sight intensities to cover.

Therefore, there are three choices of installation. They are as follows:

1. 18 units, 30° tilt with 8.9 feet of void between units. Since the number of units matches the heat load, we may elect to rely on the line of sight intensities to fill the voids. Mounting height is 15 feet.

2. 24 units, 30° tilt, with no voids. This would require 6 additional units which would represent a 33% increase in input beyond the calculated heat loss. Mounting height is 15 feet.

3. 20 units, HORIZONTAL installation. This represents a 11% increase in capacity over the calculated heat loss. (2 additional units). Mounting height is 14 feet.

If all three systems are acceptable insofar as their locations are concerned, it would appear that strategy number 3. should be selected to guarantee solid perimeter coverage.

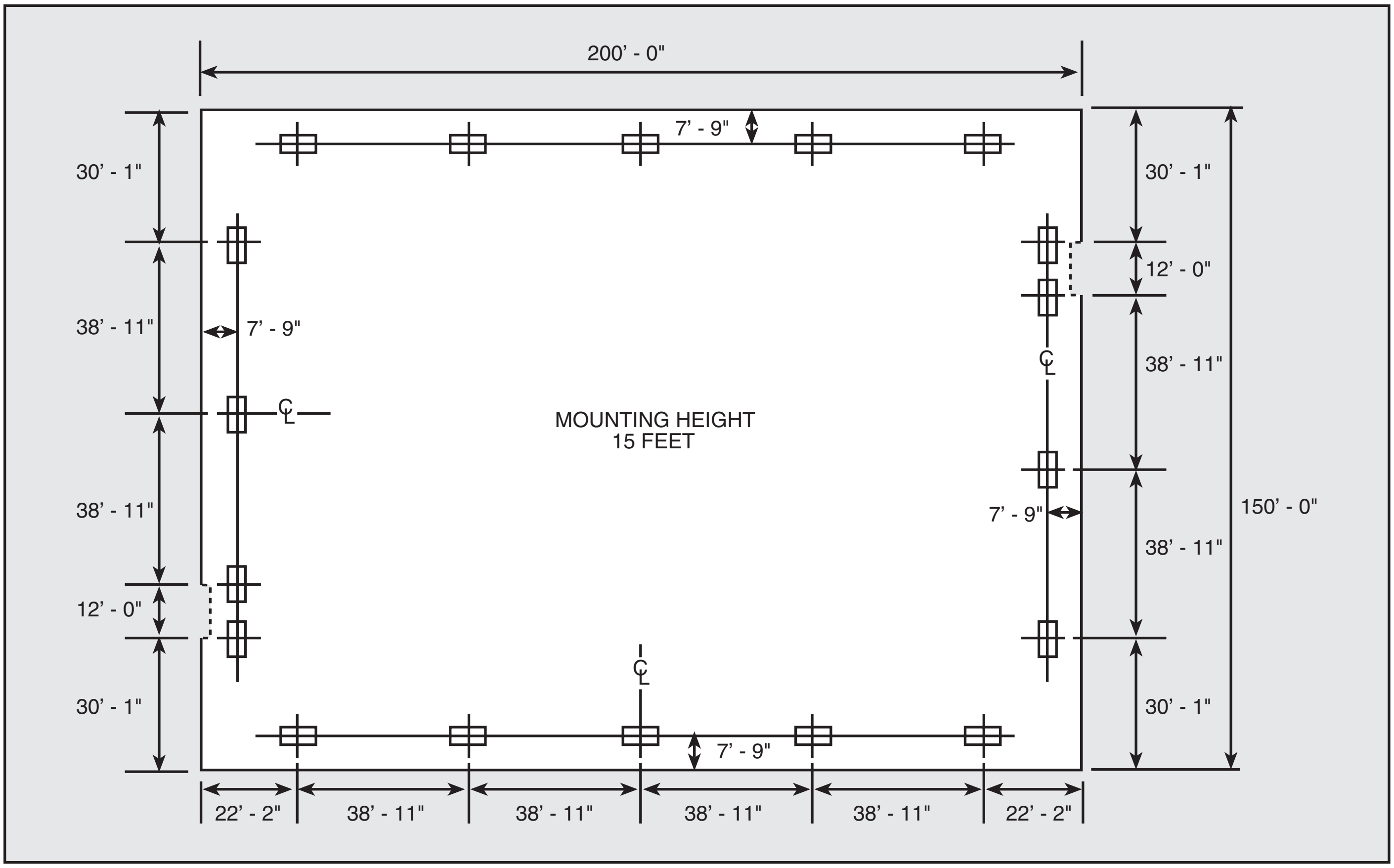


FIG. 37 -Sample layout of 18, 30,000 BTUH high-intensity at 30° angle

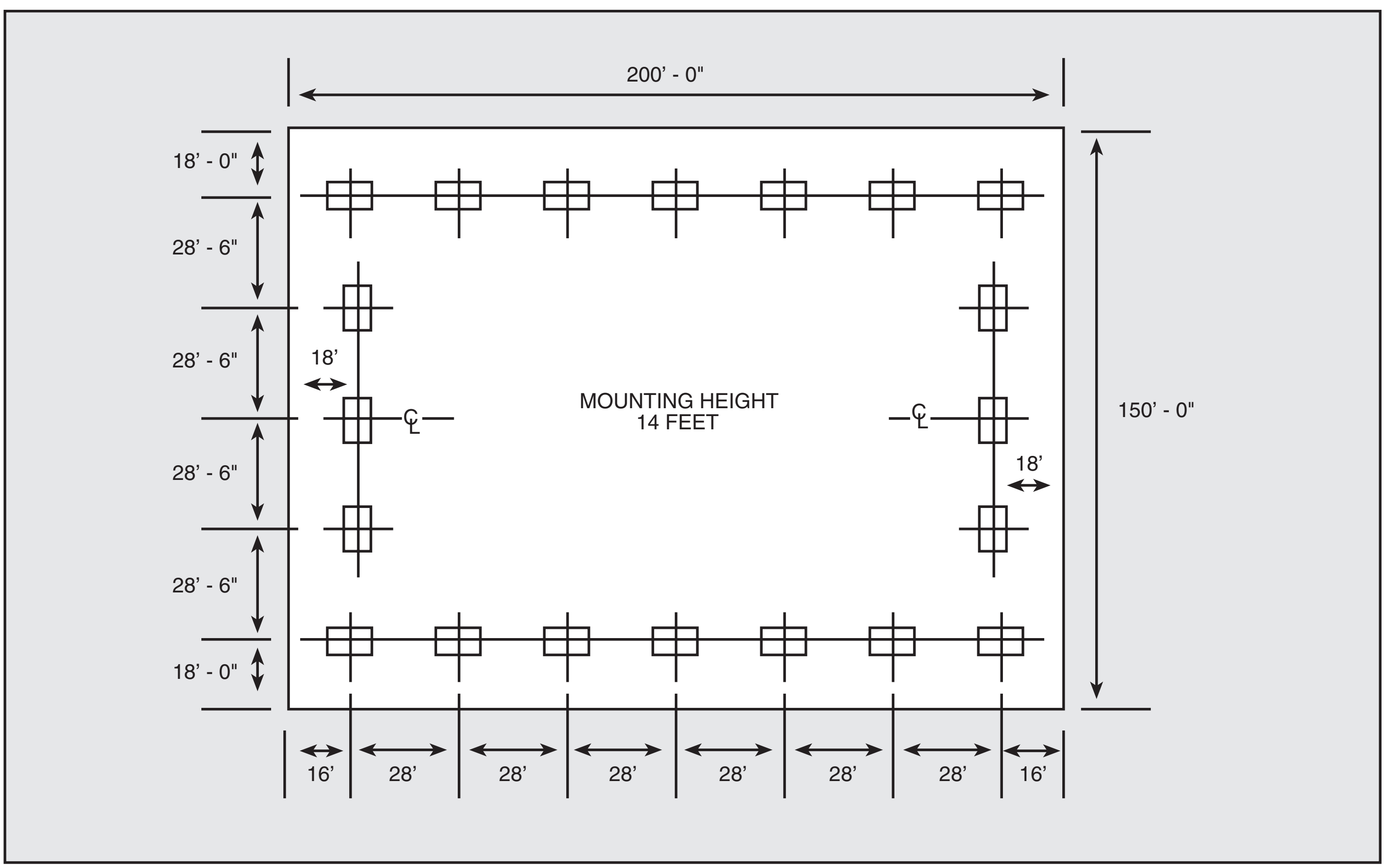


FIG. 38 - Sample layout of 20, 30,000 BTUH high-intensity units, installed horizontally

LOW INTENSITY APPLICATION

Fig. 39 is a sketch, showing a proposed layout for size 75,000 BTUH low intensity infrared units. Because of its design, this unit is available in 20, 30, 40, 50, 60 and 70 Ft. lengths. For our example, we have selected the 40 Ft. length. Note that there are voids in the patterns but that the units have been located at the points of highest loss (centered in front of doors). Also, two units have been angled across opposite corners of the building to help reduce the voids at the perimeter. The reflectors will be positioned horizontally on these two units only.

The determination for a mounting height for the low intensity unit, is based solely on the recommendations of the manufacturer. For example, the 75,000 BTUH unit in Fig. 39 has a recommended minimum mounting height of 10 Ft. when the reflector is positioned for a 30° angle. The recommendation changes to 12 feet when the reflector is positioned horizontally.

For our example we will assume that a compromise height has been determined due to interference with other equipment. Also, we have set up 6 locations based on 30° angle position of the reflectors, and two locations using horizontal reflector positions. Our mounting height is 11 feet.

The low intensity tubular units may also be installed with the reflectors in the horizontal position. However, they must be located further from the wall when doing this. The following chart gives these recommended distances depending on mounting height and unit input.

DISTANCE TO THE WALL (FT)-Horizontal Reflector							
MOUNTING	BTUH INPUT (1000 BTU)						
HEIGHT (FT)	50	75	100	125	150	175	200
12	12	14	15	—	—	—	—
13	13	15	16	—	—	—	—
14	—	16	17	18	—	—	—
15	—	—	18	19	21	—	—
16	—	—	—	20	22	24	—
17	—	—	—	21	23	25	26
18	—	—	—	22	24	26	27
19	—	—	—	23	25	27	28
20	—	—	—	—	26	28	29
— indicates height not compatible with unit size.							

Some tubular infrared units have optional shields that allow for closer-to-wall placement of units with horizontal reflectors. Consult manufacturer's information.

Fig. 41 shows a layout of eight, 75,000 BTUH tubular units with the reflectors in the horizontal position. The mounting height is 13 feet. By changing to this strategy, the centerline distance is reduced which will tend to lessen any voids that may have existed between units.

In either case of high or low intensity, the coverage may be improved using horizontal deflection, when the unit numbers are inadequate to provide full perimeter coverage. Of course, by using horizontal deflection, the wall dimensions are theoretically compressed and this results in more continuity of pattern from one unit to the next. The installation of units in either mode is solely dependent upon the building character and use. This must be examined carefully before any final decision on location and deflection mode is made.

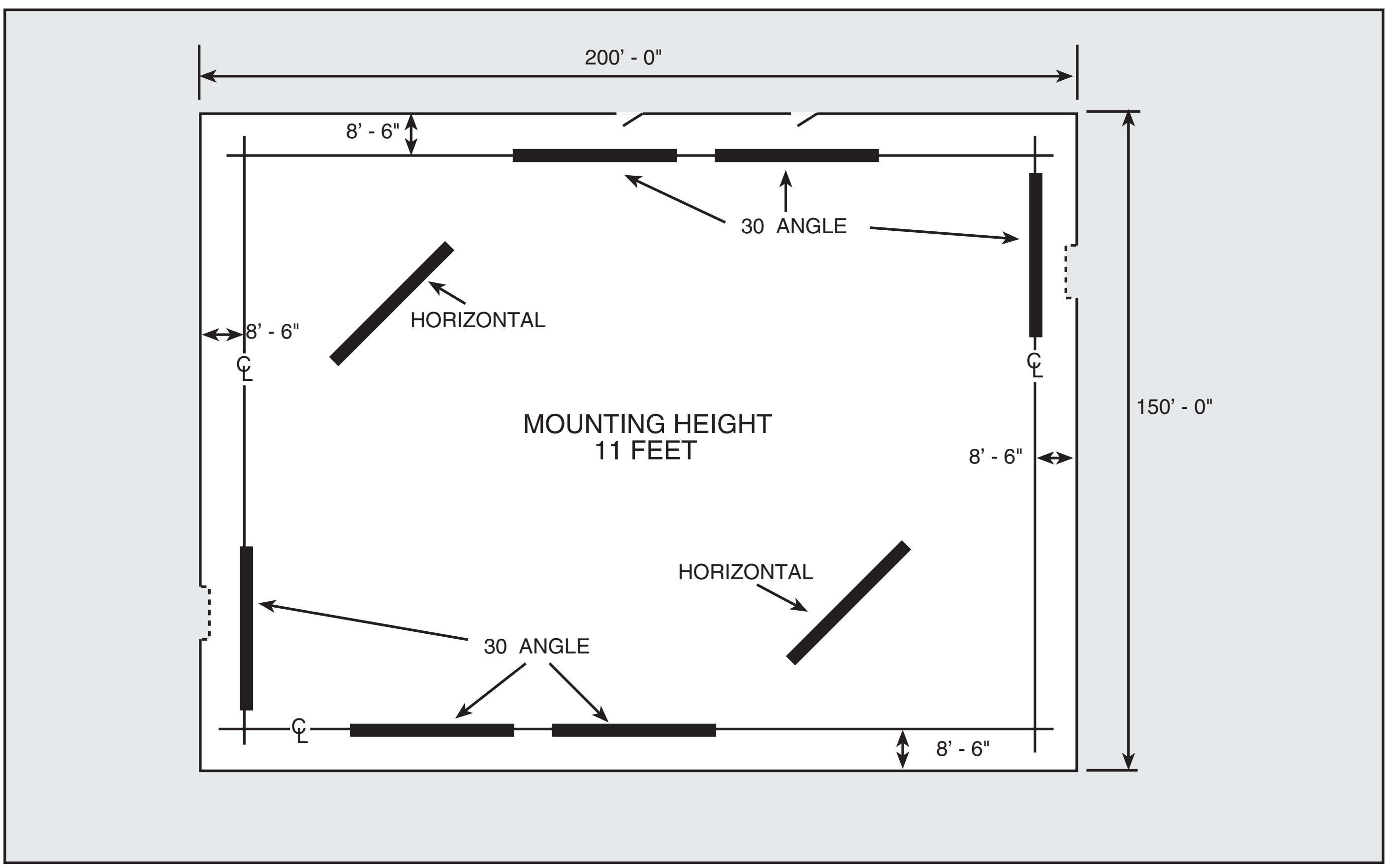


FIG. 39 -Sample layout of eight, 75,000 BTUH, 40-ft low-intensity tubular units

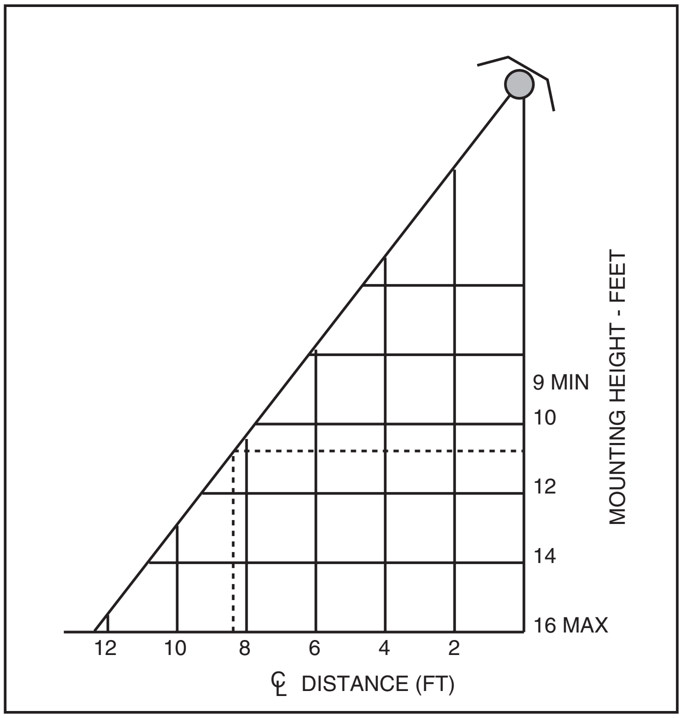


FIG. 40 -Centerline to wall distance for low intensity infrared heater with reflector positioned for 30° angle.

UNIT LOCATION SUMMARY

When using either high or low intensity infrared units for full building heating, keep in mind that the best heating job is the one that provides infrared energies over the greatest portion of the perimeter. The manufacturer's technical data regarding intensity patterns is the key to providing such an application.

Here are a few guidelines that should be considered when planning a full building heating application.

1. Never anticipate significant intensities beyond those expressed in the technical data.
2. Make every attempt to get full perimeter coverage of the slab.
3. Add units (oversize) as a last resort, to get full coverage.
4. 30° angle tilt is recommended to simplify installation and to provide further assurance that the outside walls, windows and doors are not impinged upon.
5. Horizontal deflection is certainly acceptable but very often, due to the distances from the wall, there are various interferences to contend with that may prohibit their location in these zones.
6. Always suspend units within the mounting height recommendations suggested by the manufacturer.
7. Carefully select unit size based on available mounting height and, if available, manufacturer's intensity pattern information.
8. Never install infrared units where combustibles might be stacked within the required fire hazard clearance dimensions.
9. Be sure that the long axis is parallel to the nearest wall.
10. Be careful that the infrared unit is not put into a position to activate fire alarms or sprinkler systems.

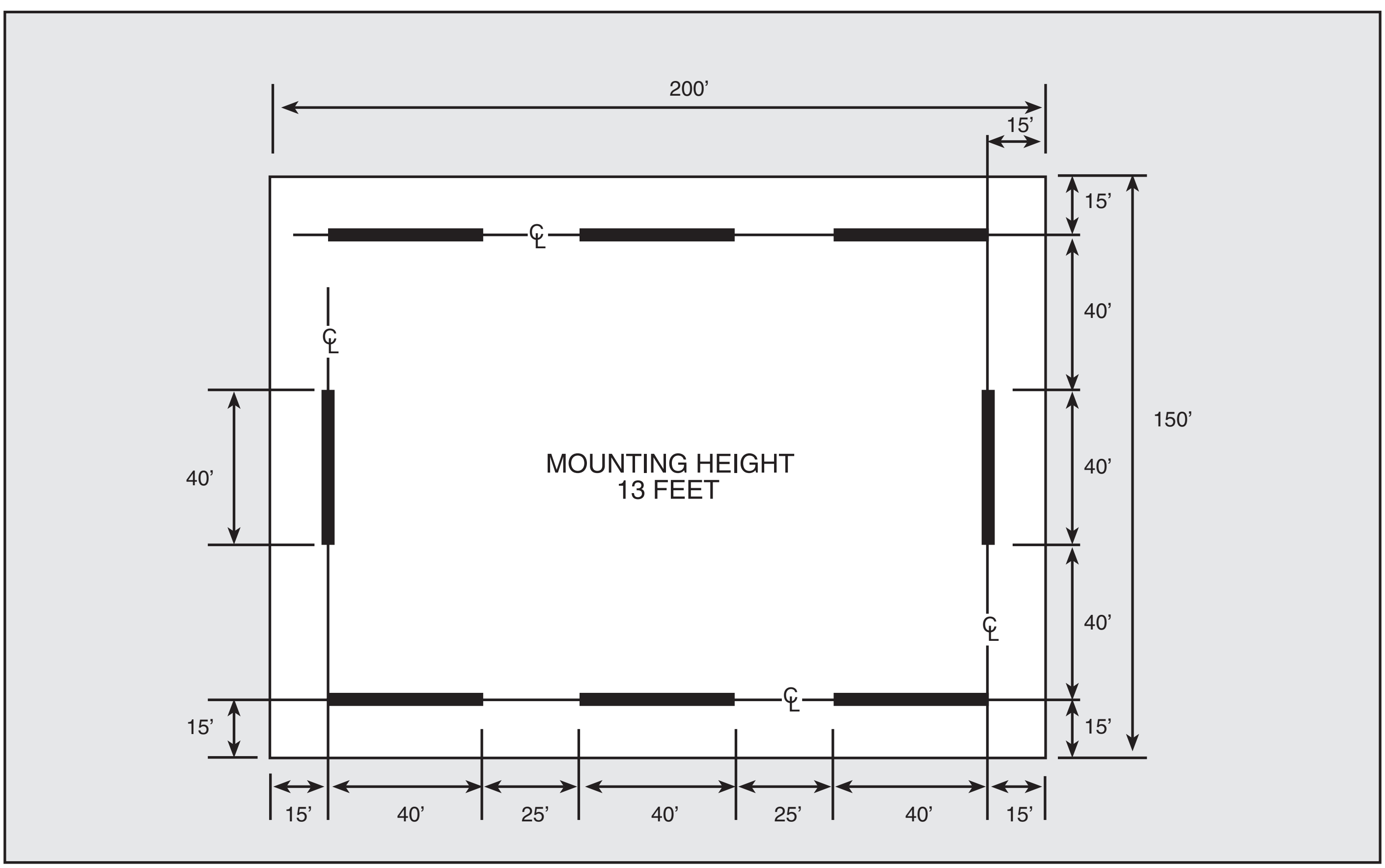


FIG. 41 - Sample layout of eight 75,000 BTUH tubular infrared heaters, horizontal position

SUSPENSION METHODS

High intensity infrared units are installed in a myriad of ways. Pipes, rods, chains and various support mechanisms are used. Figure 42 illustrates a few methods that have been used to suspend high intensity units. The important consideration is that the unit be at its prescribed attitude. That is, when horizontal, a level unit is the most effective. When at a 30° angle, care should be taken to assure the angle is accurate, otherwise the planning and location will have been wasted.

Low intensity units are generally suspended with combination chains and turnbuckles. The turnbuckle is used to make certain the tubing is STRAIGHT AND LEVEL. Fig. 43 is a typical manufacturer's sketch showing the correct and incorrect implementation of the turnbuckle. It also shows a variety of chain supports that may be considered.

Tubular infrared units will expand (lengthen) when they are heated and will contract when they are cooled. For this reason, chain supports, as illustrated in Fig. 43 are recommended. Also, due to expansion and contraction, special arrangements and hardware are suggested by the manufacturer for inlet air, electrical supply, and gas connection. This is a very important facet of installation and should be completed, based on total adherence to the manufacturer's instructions.

When installing either a high- and low-intensity infrared unit, refer to the manufacturer's installation data for specific information regarding suspension techniques and requirements.

AERATION

As pointed out earlier, the combustion process requires air. In most buildings, air for combustion is available from the infiltration. However, ANSI (American National Standards Institute) establishes a minimum building volume as follows: 50 FT^3 of building volume is required for each 1000 BTUH of total heat capacity. When a building's volume is less than this ratio, provisions must be made to introduce air for combustion. Instructions to this effect are found in the manufacturer's installation brochure. Fortunately, as you will see in the following text, other provisions for combustion air are available for infrared units. High intensity infrared units generally are unvented. This means the products of combustion are released into the space in which they are installed. For this reason, ventilation of the space is necessary to carry these products from the building. Since these gases are initially hot, they rise, by convection, to the top of the building. They will stratify at this point unless they are free to escape from the building. If these gases remain in this zone, they most likely will condense when they come in contact with the cold roof or cold roof supports. Such condensation and resultant dripping is generally intolerable. Therefore, it is necessary to provide an escape route for these gases. Fig. 44 illustrates how such ventilation can be provided. Either gravity or power may be enlisted to assure adequate ventilation.

High intensity, unvented infrared units require approximately 4 to 6 CFM of ventilation (Check manufacturer's specifications) for each 1000 BTUH of installed heaters.

Low intensity infrared units, because of the power draft, may be aerated directly from the outside of the building and conversely may be vented back to the outside. However, they may also receive their air from the space in which they are installed. Also, venting into the space is permissible, providing adequate ventilation is provided to the building. The ventilation rate for these units is 4 to

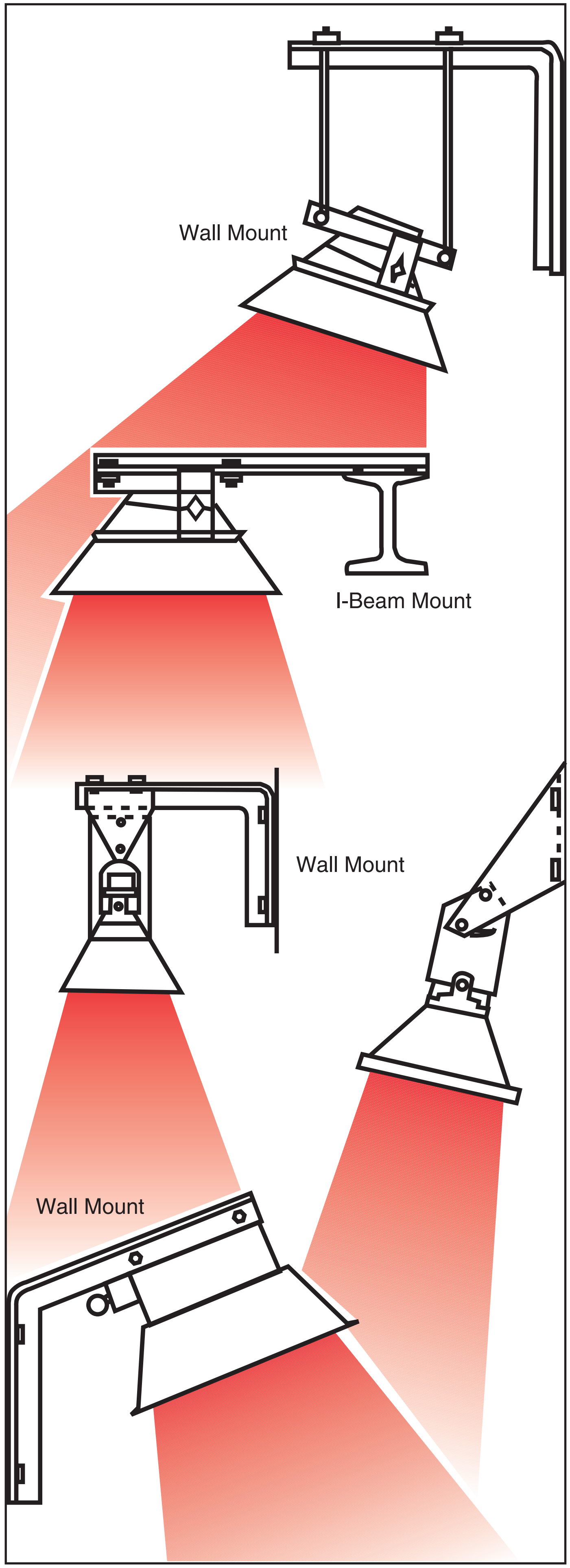


FIG. 42 - Methods of mounting infrared heaters on walls and other vertical surfaces.

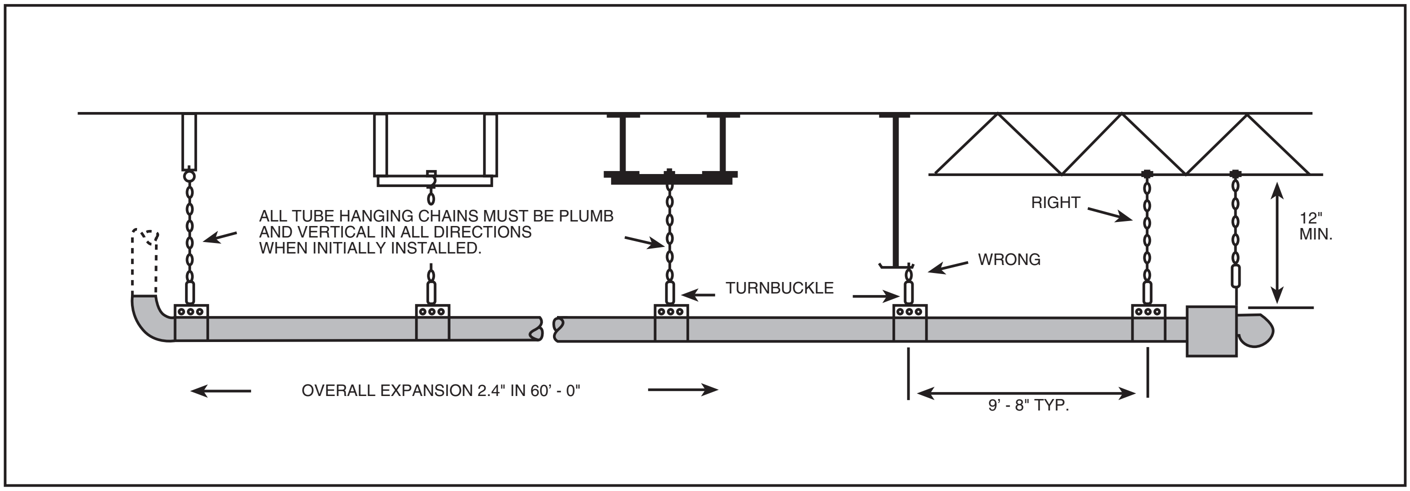


FIG. 43 -Typical support installation, tubular low-intensity infrared heater

6 CFM per 1000 BTUH input of natural gas and 5 to 7 CFM per 1000 BTUH input of propane gas. For the most part, these units are unique due to their power system which makes them most attractive for using closed circuit ventilation. (The combustion air inlet and exhaust outlet are connected directly to the out-of-doors). In all cases, however, consult the manufacturer's installation manual for recommended aeration volume.

CLEARANCES FROM COMBUSTIBLES

In previous text, we discussed required clearances above these units. There are other clearances that also must be observed. Each unit, regardless of design, has a hazard potential from high heat. High intensity units may reach temperatures of 1850° F, while low intensity units may reach temperatures in excess of 1000°F.

For these reasons, clearances from combustibles are necessary on all sides, top and particularly beneath these devices. For instance, many of the high intensity units require from 6 to 15 feet clearance between the radiating source and any combustibles that may be located beneath the unit. Distances of 5 feet to 7 feet will be required beneath low intensity units.

Do not attempt to install infrared units without first determining these clearances. Each unit is unique and will have its own requirements. Be certain you know what they are before proceeding with an application.

SPECIAL WARNING: Very often, when NON-combustible ceilings are involved, the specifier or contractor will plan on installing extremely close to this surface, possibly for headroom considerations. There is no problem in doing this except when the noncombustible material has electrical wiring or other heat sensitive equipment or devices imbedded within. High intensity infrared units will exhaust very hot flue gases that can heat the noncombustible surface. By conduction, these high temperatures may reach the wiring conduits or other devices in the area, causing melting and other related failures. If you discover these conditions exist, be sure to observe the manufacturer's TOP clearance requirements.

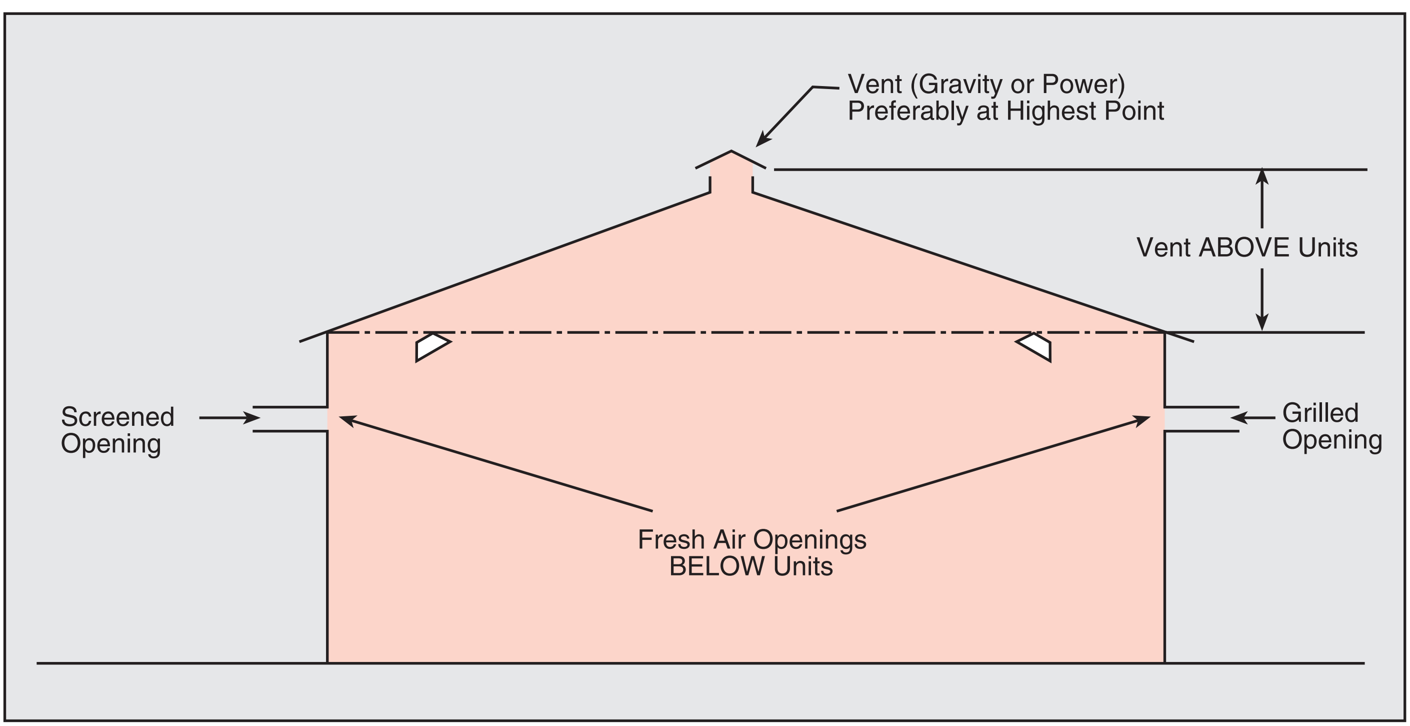


FIG. 44 - Ventilation system

TEMPERATURE CONTROL

Unlike most heating equipment, infrared heaters are often controlled using a manual switch. This is particularly true when spot heating. The reason should be obvious. In spot heating, an attempt is made to provide warmth for a confined space within an unheated area. Consequently, any temperature sensing (thermostat) that would be located in the spot heating area will be not only subject to heat requirements in that area but will be influenced by the lower temperature of the surrounding space. This situation becomes untenable. Therefore, the worker in the space is best suited to determine when heat is needed and when it is not and should be permitted to control on/off of units from a manual switch located at his work station.

With full building heating, thermostats are certainly acceptable as means of controlling the building temperature. However, here are a few rules that should be observed when controlling in this manner:

1. When locating the thermostat on an outside wall, you must provide an insulating board on which to mount the thermostat and also be sure to provide an air gap between the board and the outside wall.
2. Avoid installing the thermostat where "line of sight" intensities exist.
3. If line of sight intensity cannot be avoided, provide radiational shields (reflectors) for the thermostat.
4. Control no more than 4 or 5 units from one thermostat. (Electrical load may be a limiting factor so check the manufacturer's literature for multiple unit wiring).
5. Do not install thermostat in front of doors where they may be affected by incoming cold winds or drafts.
6. Avoid locating thermostat where it may sense heat that is being generated by machinery or other processes.

GAS CONNECTIONS

Flexible gas connections at the unit are recommended, providing local codes do not prevent this practice. Use a C.S.A. certified, stainless steel connector with a maximum length of 24" and minimum size of ½" O.D. Be aware of gas pressure drop through the connector. Gas lines should never be routed in full view of the radiation pattern nor should they be located directly above the infrared units. All manufacturers supply gas pipe sizing information for all gases. Use this information so as not to undersize supply piping. Undersized piping will result in total dissatisfaction and system condemnation, even when unit sizing and placement is correct in every detail.

TROUBLESHOOTING

The following troubleshooting information covers some of the application and startup related problems that may arise. Consult manufacturer's literature for specific information.

	HIGH INTENSITY UNITS		
	PROBLEM	**CAUSE**	**CORRECTION**
1	Darkened radiating surface	> Low gas pressure	Adjust pressure
		> Dirt or dust accumulation inside burner	Clean with air nozzle
2	Black spot on radiating surface	> Broken ceramic (or part missing)	Replace ceramic
3	Unit ignites but extinguishes after short run	> Low gas pressure	Adjust
		> Lack of proper ventilation	Correct ventilation volume (CFM)
4	Visible flame around ceramic burner head	> High gas pressure	Adjust
		> Dirt or dust on inside surface.	Clean
		> Cracked or missing ceramic	Replace
		> Angle greater than 30°	Correct
5	Spark or pilot on, no ignition or delayed ignition	> Incorrect gas pressure	Adjust
		> Dirt or dust accumulation	Clean
		> Cracked or missing ceramic	Replace
6	Burner roars, no glow.	> Cracked or missing ceramic	Replace

	LOW INTENSITY UNITS		
	PROBLEM	**CAUSE**	**CORRECTION**
1	Tube glows	> Gas pressure too high	Adjust pressure
		> Combustion air inlet clogged or damaged	Clean or replace
		> Clogged or damaged exhaust outlet	Clean or replace
2	Unit lights but goes out prematurely (Vented to space)	> Lack of adequate ventilation	Correct vent rate
3	Hot spots visible on tubing	> Unit not level	Level unit
		> Unit not straight	Straighten
4	Inadequate radiation	> Gas pressure low	Adjust
		> Unit incorrectly applied	Recheck

GLOSSARY

ANNUAL DEGREE DAYS: The total number of outdoor degrees F below the indoor design temperature (65°). Using the average deviation for each day, over a 365 day period.

ANSI: American National Standards Institute.

ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers

BLACK BODY: Matter which absorbs all the infrared energies impinged upon it.

BTU: British Thermal Unit. The amount of heat required to raise the temperature of one pound of water, one degree Fahrenheit.

BTU/FT^2: British thermal unit per square foot

BTU/FT^3: British thermal unit per cubic foot

BTUH: British thermal unit per hour

BUTANE: Fuel gas that is a derivative of oil cracking process.

COMBUSTION: Rapid oxidation of fuel when mixed with oxygen and ignited.

CONDUCTION: Heat being transmitted by physical contact.

CONVECTION: Transference of heat by moving masses of matter, as by currents in gases or liquids, caused by differences in density and the action of gravity.

DELTA T (ΔT): Temperature difference.

DENSITY: Mass per specific unit volume.

DRAFT HOOD: Device used to balance combustion over a combustion zone and stabilize unit efficiency in the face of varying vent conditions.

ELECTROMAGNETIC WAVE: An electrical impulse that transmits radio signals, infrared, visible light and other such energies.

EMISSIVITY: The power of a matter to emit heat.

EXHAUST GASES: Products of combustion

FLUX DENSITY: A measure of infrared intensity at a given distance from the infrared source.

FORCED DRAFT: Furnishing burner aeration by pushing air into the combustion zone under power.

INDUCED DRAFT: Evacuating a combustion zone under power, thereby causing fresh air to enter the combustion zone.

INFILTRATION: Air that enters a building indiscriminately through cracks in the building shell.

K FACTOR: A measure of the amount of heat (BTU/FT^2) that passes through one square foot of material that is 12" thick, in one hour, with one degree Fahrenheit difference between the two sides.

LONG AXIS: Imaginary center of infrared source running the length of the infrared radiating surface.

METHANE: A colorless, odorless gas that constitutes the major portion of all fuel gases.

NATURAL GAS: Fuel gas containing methane and other elements.

PRIMARY AIR: Air introduced with the gas before the flame.

PROPANE: A fuel gas that is derived from the petroleum cracking process.

R FACTOR: A measure of the resistance to the flow of heat. The greater the factor (number), the higher the resistance.

RADIATION: The flow of heat transmitted by electromagnet waves.

REFLECTION: When infrared energies bounce off a surface (are deflected)

SECONDARY AIR: Air that is introduced into the flame after ignition has occurred.

SHORT AXIS: Imaginary center of infrared source that runs across the width of a radiating surface.

SPECIFIC GRAVITY: The weight of gas when compared to the weight of air. (Weight of air given as 1.0)

SPOT HEATING: Supplying heat to a specific area located in a building that is essentially unheated.

U FACTOR: Amount of heat that will move through one square foot of a specifically defined surface in one hour with one degree F of temperature difference between the two sides.

VENTILATION: The introduction of fresh air into a building, under power, and exhausting a like amount back to the atmosphere.

15M 6/01 YL FORM RZ-NA-IRHB (Version 0.1)