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A.S.G.E SPEECH - NATIONAL CONFERENCE

EVERYTHING YOU WANTED TO KNOW ABOUT INFRARED, BUT WERE AFRAID TO ASK

INTRODUCTION

Gas infrared heating devices have become of particular importance during the last few years for two main reasons, HIGH efficiency and LOW air pollution. You may be required to apply gas infrared burners to your equipment to meet higher efficiency or air pollution standards. For these reasons, I hope the information that is being presented will assist you in dealing with gas infrared applications.

HISTORY

The planet Earth receives its energy from the sun, NOT by conduction, NOT by convection, but by RADIATION. When Gilbert and Sullivan wrote their humorous song with the words "Only Mad Dogs and Englishmen stay out in the Noon Day Sun", they were talking about the MAXIMUM INTENSITY of the Sun's radiant heat output. Those heat rays travel from the Sun to the earth at the speed of light or electricity, 186,000 Miles per second. Intense as the sun's heat rays are at noon-day, they can be blocked by a passing cloud that absorbs or reflects the heat rays causing you to feel instantly cooler. When that occurs, you know that the air temperature did not instantly change. The temperature change was due to an instant block of heat radiation from the Sun. So we know that we can become instantly warm when exposed to heat radiation.

Early man was very familiar with the benefits of radiant warmth produced by an open fire. It provided instant warmth and a means of cooking foods. The "pot bellied" and Franklin wood burning cast iron stoves were most efficient in providing radiant warmth and saving fuel.

With the availability of electricity and Manufactured gas, the first modern heating appliances were designed with exposed radiants. Electric radiant heaters having ceramic cores surrounded by coiled nickel-chrome heating elements became immediately popular. The first ceramic radiant domestic gas infrared heaters were produced about 1910. Most of these had several open lattice type vertical ceramics, called castles, with the burner flames licking up from below and causing a fiery glow. My parents enjoyed one of these very picturesque heaters for about 60 years. They were manually lit, had no safety controls, and one would often adjust the burner flame to a very low level because of the high radiant intensity from the glowing ceramic radiants. So our forefathers were quite familiar with radiant heating appliances, both gas and electric.

Changes in public law regarding unvented gas heaters occurred in 1947. California outlawed the installation of unvented gas heaters as a health hazard in residences as did many states. So the fiery radiant gas heaters were to become a thing of the past. However, the story did not end here.

An advertised new design of ceramic grid was introduced in the United States in 1956 for industrial and commercial heating. The prohibition of unvented heating had been limited only to domestic heating. The new design was publicized as the Schwank patented burner and then licensed throughout the world by the American Infrared Company. A lawsuit involving the licensing of Schwank grids occured in the mid-sixties that revealed that the invention had been patented in 1915 in England by a Britisher named McCourt.

The design for the flat perforated grid became public property allowing anyone to produce these new perforated ceramic plaques.

It was at that time that my company, Infrared Dynamics, started the manufacture of Gas infrared burners.

THEORY

The theory of infrared heating is of basic importance to anyone who wants to understand the subject. Infrared heat rays are produced by any hot body. Infrared heating generally refers to heating devices operating in the range of 900 to 3,000 degrees Fahrenheit. Most gas infrared burners have a radiant surface temperature in the range of 1550 to 1750 deg. Fahr. The radiant surface has an average input loading of 300 Btu/Hr/Sq. Inch of surface.

Radiant heat exchange between the surfaces of solid objects is proportional to the fourth power of its ABSOLUTE temperature measured in degrees Rankine. Absolute zero is 460 degrees Fahrenheit below zero degrees temperature. A 1600 degree Fahrenheit emitter has an absolute temperature of 2060 degrees Rankine. In thermal convection or conduction, the heat exchange is directly proportional to the temperature difference For example, raising the temperature of a surface from 1500 deg. Far. to 1600 deg. Fahrenheit increases convective or conductive heat transfer by only 6.7%. That temperature rise produces an increased radiant heat transfer of 22% according to the fourth power of its absolute temperature. This is known as the Stephan-Boltsman law. In this example, the radiant heat transfer increased three times as fast as the conductive or convected heat transfer. A slight increase in radiant surface temperature produced a large increase in emitted heat.

Intensity of radiant heat varies inversely as the square of the distance from the heat source. For example, picture all of the heat rays from a single point source passing through a one foot square window one foot from the source. As the rays normally travel in a straight line, the same quantity of heat rays would pass through a two foot square window at a distance of two feet .

The two foot square window has four times the area of the one foot square window. Therefore, the quantity of energy, being unchanged, would have one-fourth the intensity per square foot at two feet vs. the one foot distance. So we now understand that radiant heat intensity varies as the square of the distance from the heat source.

WAVE LENGTH

We have just described the quantity of heat rays emitted. Now lets talk about the quality. Why do some objects heat up faster than others? How does the wave length of emitted heat rays effect the rate of heat transfer. I'm sure you have all heard of ultraviolet rays which have a very short wave length. They give you a sun burn. Infrared heat rays are relatively long and can't give you a sunburn, only the feeling of heat. If you think about the variations of types of waves emissions from the Sun, such as ultraviolet or infrared red, or radio waves, you would come to the conclusion that the variations in emitted waves from the sun produce different effects and so they do.

Infrared gas burners release most of their radiant energy in the wave length range of 2 to 6 microns or millionth of an meter.

The wave length at which most of the radiant heat from an emitter is released is very important in maximizing the efficiency of heat transfer from the radiant emitter to the heat receiver. Inasmuch as radiant gas burners emit energy with heat wave lengths from about 1.4 to 16 microns, one can only attempt to match the principal emission waves length of 2 to 6 microns from the infrared heat generator with that of the heat receiver or absorber. A.G.A. Research Bulletin No. 92 called "A Study of Infra-red Energy Generated by Radiant Gas Burners", published in 1962, described absorption characteristics of some of the common load materials. For examples, paints have a higher absorptivity of the longer heat waves produced by gas infrared generators. A quartz electric infrared heater has about the same intensity output as a gas infrared heater. However, the 3000 to 3500 deg. Fahr. electric element emits from 48 to 65% of its energy at shorter wavelengths between 3/4 and 2 microns, rather than at the more desirable 2 to 6 micron waveband. Further, the life of most of the electric filament type heat generators is only about 5000 hours. Gas infrared burner ceramic can have a much longer life, such as ten to twenty years.

We can now understand why the radiant energy absorbed by a load depends upon how well the emission characteristics of the heat source match the absorption characteristics of the load. Because gas infrared generators emit energy at longer wave lengths than electrical infra-red generators, infra-red burners are more effective in transmitting heat than electric heaters and still cost two-thirds less to operate than with electricity. With longer life gas infrared ceramic elements and higher efficiencies, there is a significant greater cost saving to the user in industrial heating if only he would specify gas infrared. Unfortunately, most of the designers and builders of infrared infrared ovens are unfamiliar with the technical application of gas infrared burners and the cost advantage of gas infrared is ignored. They simply install electric elements and the user have to pay those three times higher electric bills. The cost difference may make or break that company.

REFLECTION AND ABSORPTION

If you assume a gas infrared heat source is the radiant emitter, one might question how much of the heat rays are absorbed by the receiver and how much is reflected. Shiny surfaces such as polished aluminum or bright stainless surfaces will reflect a majority of the heat rays. Surfaces that are not shiny or polished will absorb a majority of the heat rays. There is only a slight difference in absorption between a grey surface and a dull black surface. Every surface has a different wavebands absorbing different amounts of energy when exposed to light or heat waves. The compatibility of the wavebands of energy emitted from the source and the receptive wavebands of the absorber determines the percentage of total energy absorbed.

RADIANT HEAT TRANSMISSION

Only a very small percentage of radiant energy is absorbed by air when heat rays pass through space. However, a large part of the radiant heat may be absorbed by solid translucent materials such as glass. Window glass will typically absorb 50% of the radiant heat from a gas infrared burner causing a heating up of the glass. Quartz glass only absorbs about 25% of the radiant heat and allows 75% of the heat rays to pass through the glass. The difference here is the wave length of the materials and structure of the glass itself. Man made glasses such as CERAM or CERCOR are designed to have high transmission of infrared heat rays for use with domestic cook tops where the heat source is placed beneath the glass and the cooking utensil placed on top of the glass. The glass will still heat up depending on the amount of heat rays absorbed and those transmitted.

CONSTRUCTION OF THE GAS INFRARED BURNER.

Let us now turn to the construction of the burner itself. Because the ceramic grid is a relatively large flat surface with continuous porting, there is no opportunity for secondary air to complete combustion of the gases at the center of the burner. Therefore, the infrared burner mixer must inject at least 100% of the air required for complete combustion of the gases. The typical burning rate is 300 Btu/Hr per square inch of burner surface.

MULTIPOISE USAGE

Infrared burners are uniquely different from conventional secondary aerated burners in appearance and operation. With its lack of dependency on entrained secondary air to complete combustion, positioning of the burner is no longer critical. The burner can function well burning upside down, sideways, upside right or vertically. A conventional atmospherically air injected burner, depending on secondary air, can only be positioned to allow secondary air to complete the combustion process.

COMBUSTION IN AN INERT OR FOULED ATMOSPHERE

An infrared burner can burn cleanly in an inert or fouled atmosphere, as in the presence of Nitrogen gas atmosphere, because the mixer or injector furnishes all the air required for complete combustion. Oxygen is not required in the flame zone. Therefore, it may be used as an afterburner to clean up foul exhaust gases or oxidize smoke issuing from an exhaust system.

LOW PORT LOADING AND LOW BACK PRESSURE

In order to inject the 100% primary air required at low injection pressures and without the use of a power blower, a very low port loading is required. A 6,000 Btu/Hr burner requires about 4,000 burner ports of approximately .050" dia. This construction produces a very low back pressure in the burner of the order of .001" w.c.

CERAMIC AND OTHER BURNER MATERIALS

The actual ported surface is normally cast from ceramic material with about 1/2" of thickness. The reason for using a ceramic material is two fold. First, the casting of the ported surface is a relatively easy way to produce the large number of ports required. Secondly, the ceramic material is a poor heat conductor and can stand highly elevated temperatures such as 1600 to 1800 degrees Fahrenheit without deteriorating. The glowing surface penetrates the ceramic to only a few thousandths of an inch. The temperature gradient across the 1/2" thickness of the grid is such that while the high temperature front side is at 1600 deg. Fahr., the back side of the ceramic seldom reaches a temperature over 800 deg. Fahr.

HARD CERAMIC MANUFACTURE

The harder ceramic grids are made from natural materials such as cordierite and ball clays. These materials are carefully mixed with a controlled moisture content to form a soft clay mixture. The mixture is then fed into a steel die in a hydraulic press and compressed into a related hard shape under several tons of pressure. The ejected formed parts are then loaded on a gondola car and fired at a temperature of 2300 deg. Fahr. for 24 hours to harden the clays and burn out impurities. The ceramic grids is then cut to size with a diamond saw or abrasive grit material.

LO-DENSITY CERAMIC MANUFACTURE

Lo-density ceramic plaques are made in an entirely different manner. Ceramic plaques are made from man-made materials such as aluminum silicate fibres. They are normally cast in a slurry or water bath in which the aluminum silicate fibres are suspended in water containing stiffening or binder materials such as aluminum or sodium silicates or starch in a liquid form. The mold is then lowered into the slurry and a vacuum is pulled on the mold filling its cavity with the fibrous silicate material. The mold is then raised out of the slurry and the ceramic part is ejected by reversing the air pressure. The part must now be fired at at 2300 deg. Fahr is a similar manner to the harder ceramics. The lo-density ceramic plaques, such as that produced by the Tennant Radiant Heat Co. of England, has very low density and heats up to a glowing condidtion three times as fast as the harder ceramics. Cheese melters are now being produced that feature an automatic turn on of the infrared heat after the food is placed in the oven and turn off automatically when the food plate is removed. Preheat has been eliminated with considerable savings in fuel.

CERAMIC FIBRE TUBES

Ceramic fibre tubes have been made for at least the last 20 years and were originally developed at downspouts in cast iron foundry molds. The are made in a similar manner and with similar materials to the lo-density ceramic plaques. They are cast on fine mesh stainless cylinders in a slurry bath by pulling a vacuum inside the the and controlling the thickness of the cylinder wall by the duration of time in the solution. The ceramic fibre tubes all require a high pressure blower to pass the gas-air mixture through the ceramic fibre wall of the tube to the exterior radiating surface. Heat up is very quick and maximum loading is approximately 100,000 Btu/Hr per square foot of surface. Inputs can be modulated over a wide range as long as gas-air ratios are maintained. A 4" dia ceramic fibre tube of 4 foot length and weighing about 3 pounds can burn approximately 400,000 Btu/Hr.

The Tennant Radiant Heat Co. in England has produced experimental ceramic fibre tubes or thimbles capable of functioning with low injection pressure and without the use of a power blower. Because of hoop stresses in the circular design, porting configuration have required a slotted port design rather than a circular porting.

GASKETING MATERIALS

Two different materials have been used to seal the periphery of the ceramic grids to the metal burner body. One material is a ceramic fibre compressed in a paper form about 1/8" thick and cut into strips which are temporarily glued to the edge of the ceramic and inserted into the open face of the burner body. The ceramic papers are made by The Carborumdum Co. under the trade name of Fibrefrax as well as by other refractory company under different trade names. The second method of sealing between the ceramic and the burner body is by ceramic fibre paste which hardens when exposed to air.

The ceramics and the burners body must be made to close tolerances, generally within plus or minus 0.015 inch. The compression of the gasket material is sufficient to seal any small gaps that might occur.

FLASHBACK CHARACTERISTICS

Flashback of flame through the burner ports is controlled by several factors. If the rate of flame propagation or burning exceeds the exit velocity from the ports, flashback can occur. Factors such as temperature of the ceramic porting, port diameter, and port depth can all affect flashback characteristics. A burner that is properly designed can be flashbacked by a cracked ceramic or excessive firing surface temperatures. Care must be taken to prevent to ignition flash from reaching the primary air opening which will also cause backfiring. Proper shielding of the injector will resolve the possible problem.

ORIFICE ALIGNMENT.

Burner orifices must be carefully drilled and aligned with the injector to achieve satisfactory results. Two identical burners fired side by side can appear distinctively different in color redness and heat output if one of the burners has a slightly different rate or is slightly misaligned. The orifice threads should be carefully sealed against leakage. With secondary aerated burners, alignment or exact firing rate does is not critical to burner flame appearance as it is with gas infrared burners.

EFFICIENCY

The 100% primary aerated flame is normally from 1/8 to 1/4" long. To the untrained eye, the glowing surface appears to be electrically heated because of the visual absence of long burners flames. Heat is conducted and radiated from this very short flame back to the ported surface of the ceramic. This causes the ported ceramic surface to become heated to a temperature of 1600 deg. Fahr in a short period of time. The heated ceramic surface then becomes a radiator of highly intense radiant energy emitting between 50 and 60% of the input gas energy in the form of radiant output energy. The balance of the heat is in the exhaust gases which, in some instances, can be used to produce higher efficiencies in appliances. For example, application of infrared burners for deep fat fryer utilizing both the radiant output and the exhaust gas heat has produced efficiencies of over 80%. Recent applications of infrared burners beneath flat top cooking griddles have increased heating efficiency by 50% and reduced gas consumption by one-third.

NOX AND AIR POLLUTION

But now comes the big surprise. Infrared gas burners were tested in the 1970's for NOX output. As you know, NOX is a term for Oxides of Nitrogen produced in combustion processes that disassociates Nitrogen in the air into an unstable form which is noxious air pollutant. It was found that gas infrared burners produce only 10% of the NOX output of conventional gas burners. We call this the "Infrared Bonus". One explanation of this phenomena is that the flame tip temperature is greatly lowered due to its close proximity to the ceramic surface and cannot readily exceed a temperature of much over 1700 deg. Fahr. High NOX output is associated with high flame tip temperature. The higher the flame tip temperature, the higher the NOX output. A test conducted by an independent test laboratory on a prototype infrared gas water heater for NOX resulted in a output of only 7.6 Nanogram per Joule of NOX compared to the present maximum standard of 40 nanograms per Joule for Water Heater and Forced Air furnaces required by Southern California's South Coast Air Pollution Control District. The typical appliance output prior to enforcement of these standards was 80 namograms per Joule.

The Gas Research Institute made a study entitled " Infrared and Catalytic Technology Assessment" in 1980. A summary of Infrared appliance benefits was listed in Table 1-1. That summary listed a potential NOX reduction of 80% on rangetops, 79% on Ovens and Broilers, 80% on deep fat fryers, 90% on water heaters, room heaters, and warm air furnaces.

SEALED COMBUSTION CHAMBERS

Because infrared burners require 100% primary aeration, they can be installed in combustion chambers that are sealed off from secondary air. Test results have shown that complete combustion can occur up to 11% CO_2 values in the exhaust flue. The higher the CO_2, the higher the efficiency of the appliance.

EFFECT OF ELEVATED TEMPERATURES ON BURNER OPERATION

A cold infrared burner will inject up to 150% of the air required for complete combustion. Its ideal operating condition would be to inject exactly 100% of the air required for combustion at the heated equilibrium condition. This would provide the maximum radiant intensity but would probably generate some carbon monoxide. Actually, most burners require at least 10% excess air in the fully heated condition to obtain complete combustion of the gases.

APPLICATION TO APPLIANCES

This all leads up to the application techniques required to proper apply infrared burners to various appliances. Many of the earlier applications of gas infrared burners were unsatisfactory due to the engineers lack of knowledge of the limitations on the use of infrared burners. The engineer might simply replace a cast iron burner with an infrared burner in the belief that it should work just as well in the same environment. This was often not the case and resulted in field failures. As the gas engineer became more familiar with the infrared burner, he realized that very specific considerations should be made in their proper application. For example, the burner body should not exceed a temperature of 500 deg. Fahr even thought the ceramic face of the burner reached a normal temperature of 1600 deg. Fahr. This requires a reasonable air flow across the back side of the burner to keep its temperature under 500 deg. Fahr. Such considerations may require a partial redesign of the appliance when infrared burners are substituted, or specific design considerations when designing a new appliance using infrared burners.

The primary air supply should be clean and kept at a relatively low temperature. For a given size burner, excessive pre-heating of the primary air supply or the gas-air mixture by elevating the burner body temperature will reduce the gas burning capacity of the burner. A highly heated gas air mixture will be less dense than a cooler mixture. It will, in effect, theoretically function as a reduction in port area. When this occurs, burner input must be reduced to compensate for the lack of injected air supply. The cost of a burner is determined by its size. Failure to design the application of the infrared burner for relatively cool injected air supply or burner body temperatures is equivalent to blocking off part of the burner porting.

APPLIANCES NOW USING INFRARED BURNERS

Infrared burners are now widely used in gas cooking equipment such as cheese melters, fry top griddles, hotel steak broilers and deep fat fryers. One of the first applications was industrial plant heating where the burners are suspended from 8 feet to over 50 ft. feet above the floor level. Reflectors are used in the plant heating applications to concentrate the heat rays. Other applications include outdoor heating of restaurant dining patios.

FUTURE APPLICATIONS

Domestic heating appliances such as storage and instantaneous hydronic water heaters, space heaters, and vented flat cook tops are possible new applications. Consideration may be given in the future to unvented radiant heaters using the new carbon monoxide safety shutoff devices.

CONSULTATION

It is always helpful to discuss a new appliance design with representative of the infrared burner manufacturer before starting the development in order to save time by avoiding erroneous assumptions. One example is that of obtaining even heat radiation on a grille surface from an infrared burner above and parallel to that surface. If the burner has a uniform radiant output along its length, the radiant intensity at the cooking grille below will be much hotter at the center than at the ends of the grille.To compensate for this, the radiant output can be reduced with proper baffling at the center of the burner to obtain a uniform radiant intensity below the burner.

NEW CERAMIC MATERIALS AND DESIGNS

New designs and materials for infrared burners are being developed where there is sufficient interest. The Tennant Radiant Heat Co. in England developed a patented ceramic fibre plaque in 1974 that elevates to a glowing temperature within 5 seconds and cools almost as fast, certainly faster than an electric quartz tube. Its radiant output is nearly three times that of a conventional ceramic grid at the first minute of operation.

Experimental circular or thimble like ceramic burners are now being developed for circular or tubular combustion chambers.

FINALE

No,infrared gas heating is not a lost art. On the contrary, its future looks bright. If we continue to find new solutions to old problems through research and innovation of new design approaches, infrared gas heating will be an ever expanding field.

I hope this infrared story has been meaningful to you as the applications have become more extensive with each passing year. I thank you for the honor of being a participant at our Conference and hope that my participation has added to its success.

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