INFRARED HEAT

A Simplified Approach

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This book is a response to the
many questions our
office has received
concerning wavelength
output of our heaters.
We hope it dispels
the confusion!
Solar
Products

NEVER HEARD OF FAR-INFRARED? THE JAPANESE SURE HAVE

What's the best thing for cooking your fish, warming your bed, or relieving a stiff neck? For Japan's irrepressible nouveau riche, the answer is far-infrared rays. Even at twice the normal price, Japanese shoppers are snapping up grills, toasters, and coffee roasters fitted with ceramic rods that emit far-IR energy when heated by a conventional heating unit.

Until now, there's been no mystique to far-IR. They are merely microwaves with a wavelength of 3 to 1,000 microns. Industry has long used far-IR heaters in drafty factories because their energy is spent warming moist objects, such as human bodies, not the surrounding air. But now some Japanese researchers claim the rays may account for the tasty texture of stone-baked foods and even the sense of well-being that accompanies sun bathing. Matsushita is cranking out portable saunas to exploit those reputed properties, and Sanyo has an entire line of appliances. Analysts say far-IR could become a multibillion-dollar industry over the next decade.

No Way!

LET'S START WITH THE BASICS.

For some unknown reason the heating industry has created a shroud of mystery over the infrared spectrum. Many companies, for their own marketing purposes, have given heaters names which actually have no basis in engineering reality. In this paper we'll prove this point by quickly reviewing some of the principals of physics which we all learned, or re-learned in our educations, and apply them to a simple selection criteria. This quick exercise will give a clearer understanding of what truly makes radiant/infrared heaters tick, and therefore enable you to better select the type of infrared heater needed for a particular job.

There are only three ways in which to transfer heat:

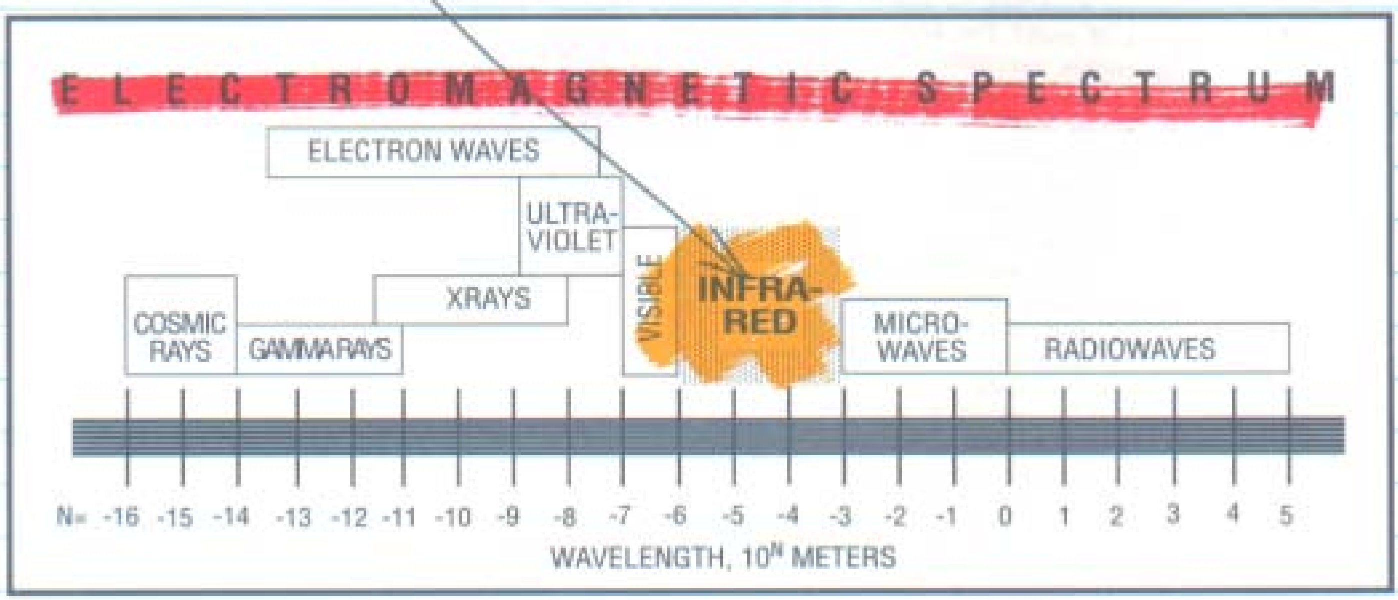
- Conduction, *via contact*
- Convection, *via gas/hot air*
- Radiation, *via electromagnetic radiation*

Blow Up Next Page

In this paper we are concerned only with radiant heaters. Many people question the difference between *radiant* and *infrared* heat when in actuality there is none. Infrared is one of four ways in which to transfer heat via radiation.

RADIANT SUBSET

- Ultra Violet
- Infrared
- Microwave
- Radio Frequency/Induction



Find the infrared spectrum within the electromagnetic spectrum. Notice that it is bordered by the visible spectrum on one end and the microwave spectrum on the other. The infrared region ranges between .72 and 1,000 microns.

Within the Infrared Spectrum there are short, medium and long wavelengths. What is the difference?

A

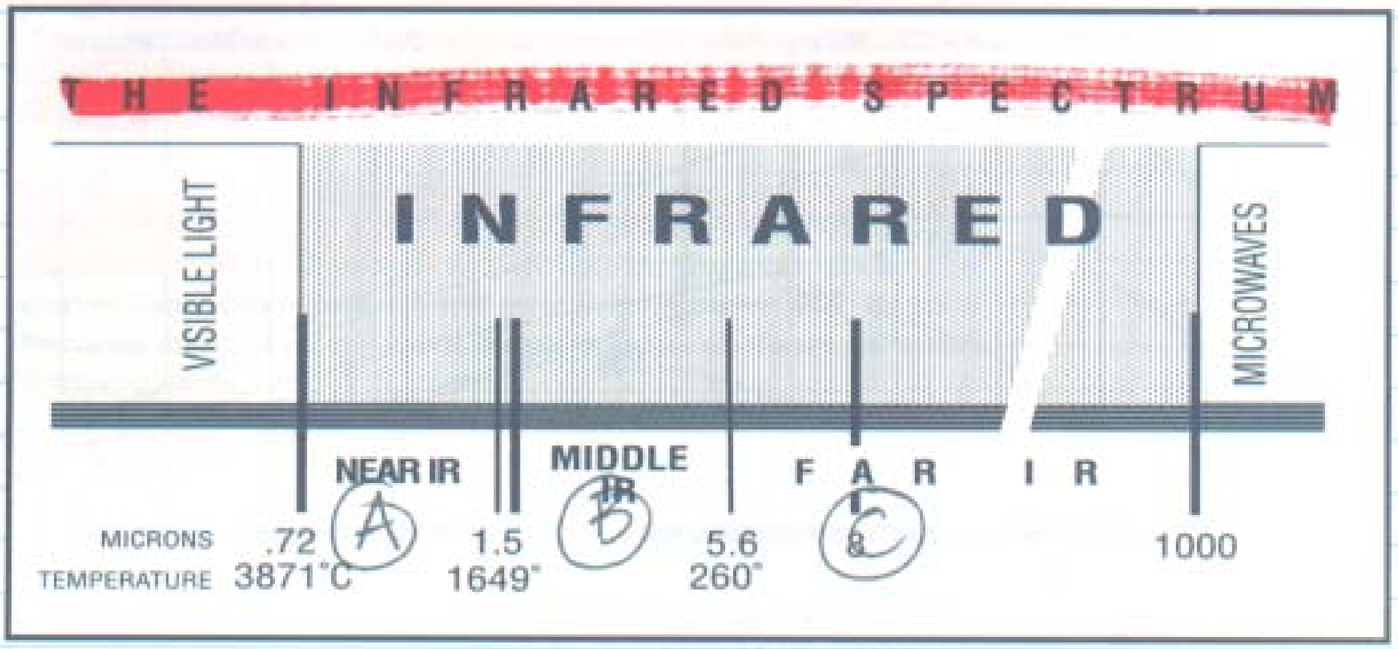
- Short wave, or Near IR (Infrared), is defined as the area from .72 to 1.5 microns

B

- Medium wave, or Middle IR, is defined as the area which ranges from 1.5 to 5.6 microns

C

- Long wave, or Far IR, is defined as the area from 5.6 to 1,000 microns.



HOW THIS APPLIES TO HEATERS

To determine whether a heater falls into the category of a short, medium or long infrared heater, 80% of your effective output should be within a defined range.

FOR EXAMPLE

- A short wave IR heater should emit 80% of its energy from 72 to 1.5 microns. To do this most of its points should be between 3,538°C (6,400°F) and 1,658°C(3,016°F).

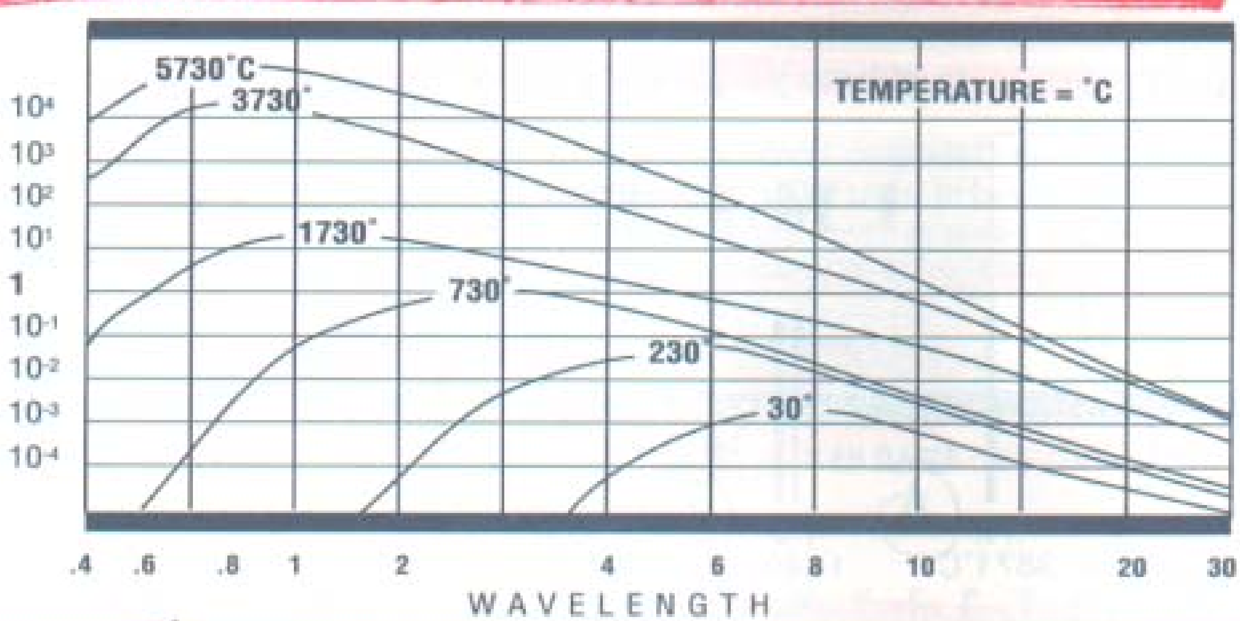
- A medium wave IR heater should emit 80% of its energy from 1.5 to 5.6 microns. To do this most of its points should be between 1658°C (3,016°F) and 244°C (471°F).

- A long wave/far IR heater should emit the majority of its energy from 5.6 to 1,000 microns. To do this most of its points should be less than 244°C (471°F).

HOW MUCH HEAT?

So now that we've established the ground rules for determining the output of the only three types of infrared heaters, you should have the confidence to circumvent any company's marketing hype - and thus the confusion - and get right into the facts.

PLANCK'S LAW: WAVELENTH VS RADIANT EMITTANCE



1 micron = 10^{-6} meters

We know where the infrared area is and how it is divided, but what determines if a heater will fall into the near, middle or far area of the infrared spectrum? We know it must peak within a particular wavelength. Wavelength output is a function of temperature - the higher the temperature, the shorter the peak wavelength.

Study the graph above, it illustrates Planck's Law.

Planck inserted a point source into a glass sphere. Then he changed the temperature inside by raising the power. This resulted in a higher temperature and shifted the peak of the output curve to shorter wavelengths.

Planck's Law defines the relationship of wavelength output to temperature. The output curves of infrared energy are governed by Planck's Law. This law applies to Blackbody Point Sources in a vacuum. But what does this really mean? What was Planck doing, and what is the significance of the curves?

Remember that the reason the curve (total power) is bigger as we go to higher temperatures is that Planck had to apply more power to achieve a higher point source temperature.

FOR EXAMPLE

A curve for 2000°C, might have required Planck to apply 10 watts to the point source, whereas to get a 500°C curve, perhaps only 3 watts.

A heater is made up of many millions of point sources, not just one as in Planck's curve. Depending on a heater's construction, these point sources can all be at one temperature, or many different temperatures. The total output of a heater is the sum of all point sources.

To calculate the output curve of a particular heater, plot the curve for each point of the heater and then add all of the curves together. The total power output will be the area under the curve. Remember this will not be a smooth curve like Planck's because most heaters have many points, at many different temperatures.

FOR EXAMPLE

Let's say we have three heaters, each covering a 10" x 10" area, with an output of 1000 watts.

- Heater A is one 1000 watt quartz lamp in a 10" x 10" reflective housing. The operating temperature of the lamp is 2200°C. The reflective housing is at 150°C because it is water-cooled.

- Heater B is two quartz tubes, each at 500 watts with internal reflectors in a 10" x 10" housing. The operating temperature of the tube is 1000°C.

- Heater C is a ceramic face with 10 imbedded coils, each at 100 watts. The operating temperature of the coil is 650°C. The ceramic in between the coils is at 300°C.

graph next page

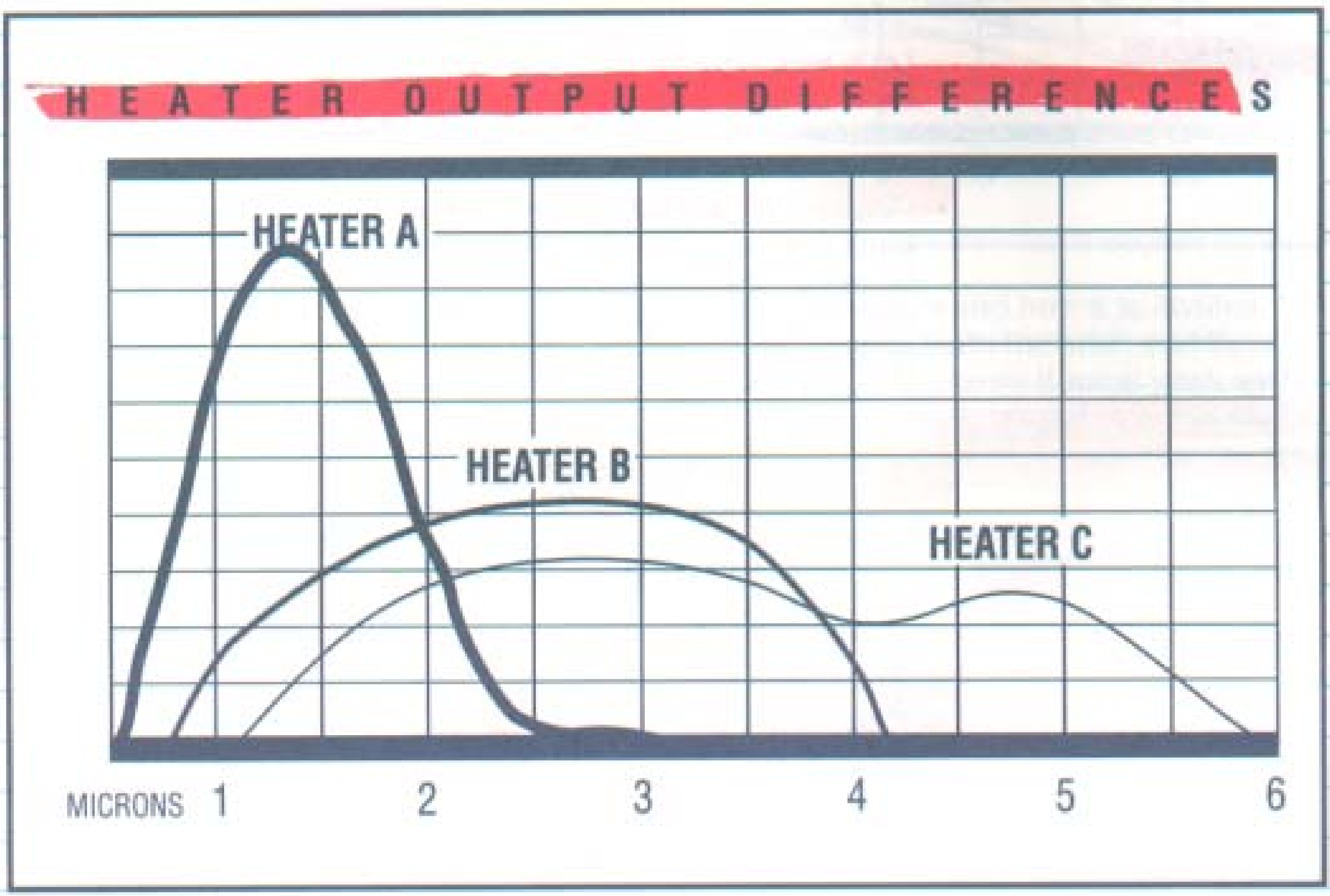
So what do the output curves of these three heaters look like? Let's say that a 10" x 10" area has a million points. That's 10,000 points per square inch. Differences are shown in the graph below.

- Heater A has 50,000 points at 2200°C which has a peak of 1.17 microns. It has 950,000 points at 150°C which has a peak of 6.8 microns.

- Heater B has 100,000 points at 1000°C which has a peak of 2.27 microns.

- Heater C has 500,000 points at 650°C which has a peak of 3.1 microns. It also has 500,000 points that are around 300°C which has a peak of 5 microns.

As you can see, three heaters that are rated the same, actually have different outputs. These curves can change again if we



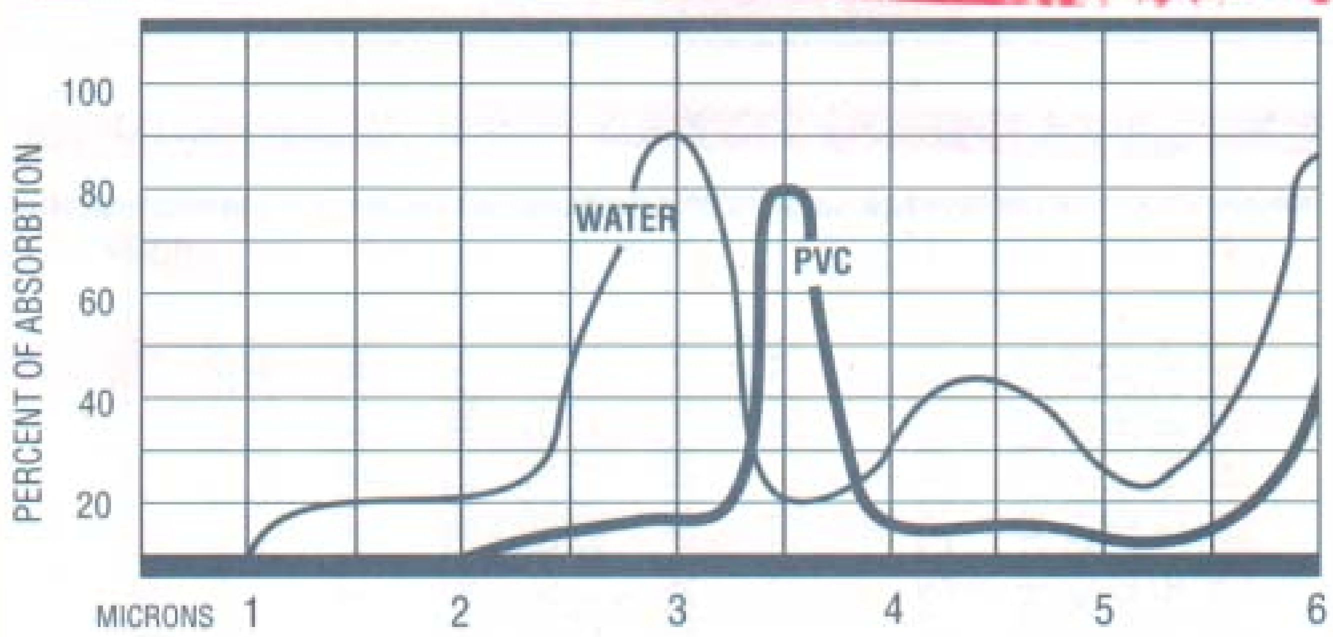
use a controller to regulate the temperature. From the above examples, we can conclude that same-watt heaters can deliver totally different outputs.

EFFECTS ON OUTPUT

What about the heater you are considering... What do you want it do? To match the temperature output of a short-wave heater you must use a quartz lamp with an element enclosed in a vacuum. For medium-wave, all panel-type heaters, quartz tubes (non-vacuum) ceramics, and metal-sheathed rods emit the majority of their energy in the medium IR region. For a long-wave heater, you must control to less than 470°F. This is not very practical for most applications.

Now that we understand how to calculate heater wavelength output, the question becomes, how does wavelength effect my process? Infrared radiation is either reflected, absorbed or transmitted when it hits an object. All materials have absorption curves which show what wavelength the materials will best absorb.

ABSORPTION PERCENTAGES FOR WATER & PVC



As an example, the above illustrates the difference in absorption curves for water and PVC. Find the peak absorption areas of the graph above. For most plastics, the CH (carbon/hydrogen) bond will peak in the 3.2 - 3.4 micron area. For water, the OH (oxygen/hydrogen) bond will peak at 2.9 - 3.0 micron area. Ideally, you would like your heater to output the majority of its energy in the area where it will be absorbed best.

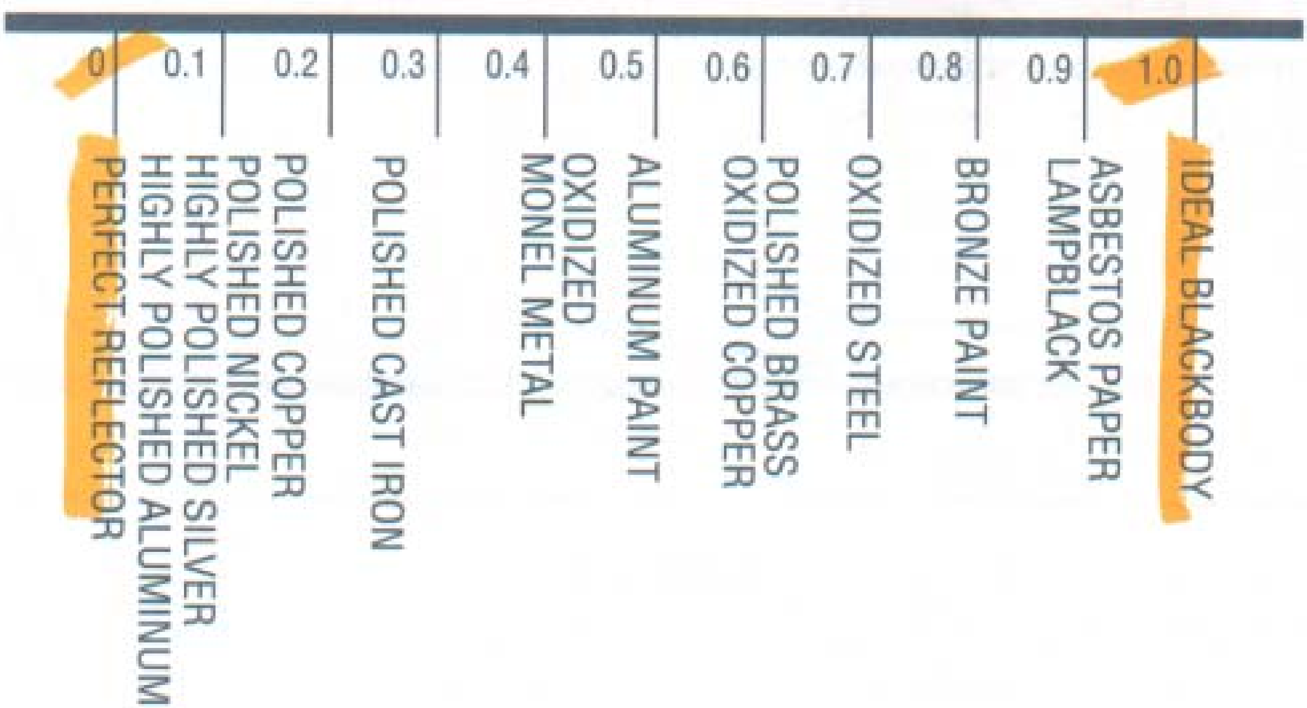
Some manufacturers sell their heaters on the ability of a customer to tune the output to a product, when in fact, every heater can do this if you have the ability to control the temperature of the heater.

WHAT IS EMISSIVITY?

Emissivity is defined as a measure of radiant efficiency. If an object has an emissivity factor of 1.0, then it is the perfect radiator and absorber. This is referred to as the perfect Blackbody. If an object has an emissivity of 0, then it is a perfect reflector, and does not absorb any radiant heat.

How does this affect your heater's performance? Imagine two heaters with the same wattage and voltage. One has an aluminum face, the other a black coated steel face. The aluminum is a poor radiator thus you can hold your hand close to the surface without feeling any heat. In contrast, the black steel is a good radiator, therefore when you hold your hand close, it is giving off heat. If the heater was constructed with a face that acts like a "window" allowing all the energy to pass through (as does quartz and vycor), then you are concerned with the emissivity of the source (coil or wire) of the energy. Most sources are very close to a 1.0 emissivity factor.

EMISSIVITY FACTORS FOR MATERIALS



WHAT'S QUARTZ?

Quartz is a highly misused term. Quartz glass is fused sand (SiO^2) and is available in plate or tube form in either clear or opaque materialization. Clear quartz is a very good transmitter of infrared, while opaque quartz blocks infrared. Quartz cloth is woven quartz fibers very similar to fiberglass and also blocks infrared.

APPLYING THESE THEORIES TO HEATERS

We have learned that an infrared heater must output wavelengths between .72 and 1,000 microns.

We also know that heaters can be short, medium or long infrared depending on where the majority of output falls within the infrared spectrum.

We know that temperature affects the curve of the wavelength, and therefore heaters that are rated the same but constructed differently, can have different energy output.

We know that all radiation is either reflected, absorbed or transmitted when it hits an object. The degree to which an object either reflects or absorbs radiant heat is measured by its emissivity factor.

We can now apply these facts in determining the kind of heater you need and how it should be constructed.

ALL HEATERS HAVE 3 PARTS:

- The SOURCE of the energy which can be coil, foil or wire
- The SOURCE SUPPORT OR REFLECTOR which supports the coil or directs the heat
- The FACE which electrically insulates the source and acts either as a "window" allowing all primary radiation to pass through or as an absorber which will absorb the heat and then release it as secondary radiation.

See chart next page

CONTROL METHOD - Infrared heaters can be controlled in one of two ways: (Open Loop) Percentage Timer or (Closed Loop) Temperature Control. The Temperature Control method is the most accurate way to control your heaters and keep them at a consistent temperature. If you choose to pursue the temperature control method, then you will need to decide whether to use a thermocouple or a pyrometer to measure temperature.

Armed with the answers to these questions the heater that fits your needs can easily be selected. Selecting one becomes a straightforward and simple procedure if you don't get bogged down in the vendor mumbo-jumbo. Just keep it simple, use common sense, and you'll find the right heater for your application.

what about panel heaters??

Infrared heat sources

In reviewing manufacturers' data on infrared systems, finishers will notice that different heat sources are available for these systems. Here is information on the two most common IR emitters for industrial heating, tungsten quartz lamps and quartz tube heaters.

Quartz lamps offer the fastest cure times because the filament temperatures can be greater than 4,000° F. The output can range from 0 to 200 watts per inch, depending on input voltage. The lamp has sealed ends and is filled with an inert gas that surrounds the tungsten filament. The filament is suspended so that it does not contact the quartz. These lamps have a response time (to changes in applied voltage) measured in fractions of a second. They can go from room temperature to 4,000° F in a few milliseconds.

Quartz tubes offer slower cure times than quartz lamps. The maximum element temperature in a quartz tube is limited by the maximum operating temperature of the nichrome (heating) wire coil (about 2,000° F), which is in physical contact with the quartz tube wall. The energy output can range from 0 to 50 watts per inch, again as a function of voltage. Quartz tubes are open on the ends and have a response time on the order of 120 seconds. Quartz tube emitters are appropriate for curing applications that require lower IR radiation heat density (for example, on slower production lines).

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