Ceramic Infrared E-Mitter Technical Data

Heat Transfer Theory Summary

A heat transfer mode that will naturally occur at the surface of the heater is called radiation. Its intensity does not depend on the characteristics of the surrounding fluid (it works in a vacuum too) but on the characteristics of the heater and the surrounding bodies.

Therefore, the efficiency of radiation heat transfer exchange between bodies depends on:

1. ***The emissivity values of the emitter (i.e. ceramic heaters).***
2. ***The absorption, reflection and transmission properties associated with the receiving medium.***
3. ***The relative temperature differences.***
4. ***The surface characteristics.***
5. ***Relative position and physical geometry.***

The Technical References presented here are intended to enhance your knowledge of various aspects of infrared radiant heating, enabling you to make better choices when selecting Tempco ceramic infrared E-Mitters.

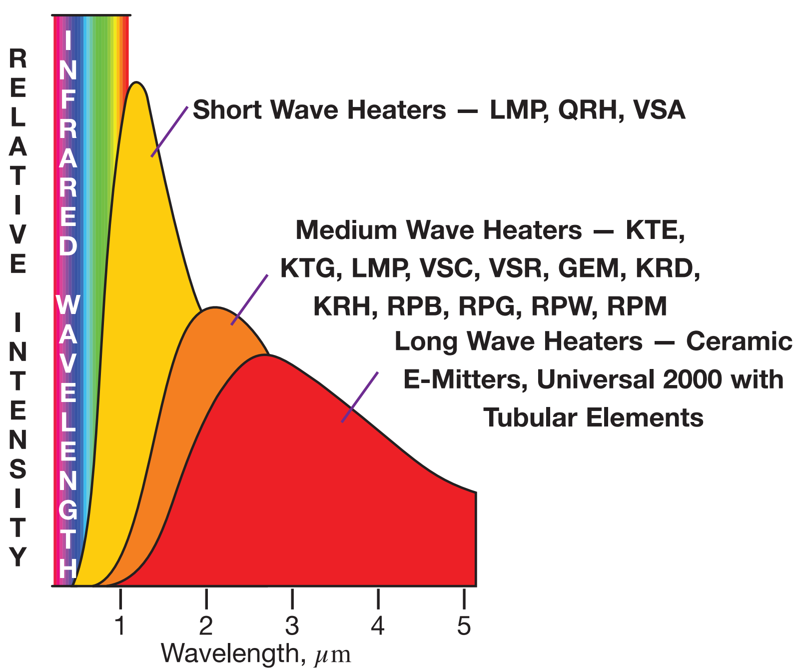
Many applications in the field are unique and present substantially different operational parameters and characteristics. This application diversity should be evaluated accordingly, and while the material presented in this section is intended to provide some background reference, it is very generalized and is not to be construed as application specific.

Note: It is highly recommended that you contact our staff of knowledgeable sales engineers with specific technical questions relating to your application.

Infrared radiant energy is transported through space by electromagnetic waves without the need of a conductive media (as opposed to conduction or convection processes). Consequently, ***heat can be delivered in concentrated areas at very fast rates***.

Understanding these important characteristics will lead to a better utilization of infrared heating technology.

Taking the Mystery Out of Infrared Energy



All matter emits radiant energy as a consequence of its finite temperature.

Only at absolute zero (–273°C), when all molecular activity ceases, does matter stop emitting radiant energy. In solids and liquids, emission of radiant energy is considered a surface phenomenon, while for gases and certain semi-transparent solids, such as glass and salt crystals (at elevated temperature), emission is considered a volumetric phenomenon.

WHY CAN'T WE SEE INFRARED RADIATION?

Electromagnetic radiation is measured in wavelength "λ" or in frequency "f." Both quantities are related by the equation:

$$\lambda = c \div f$$

"c" is the speed of light (3×10^{-8} m/s)

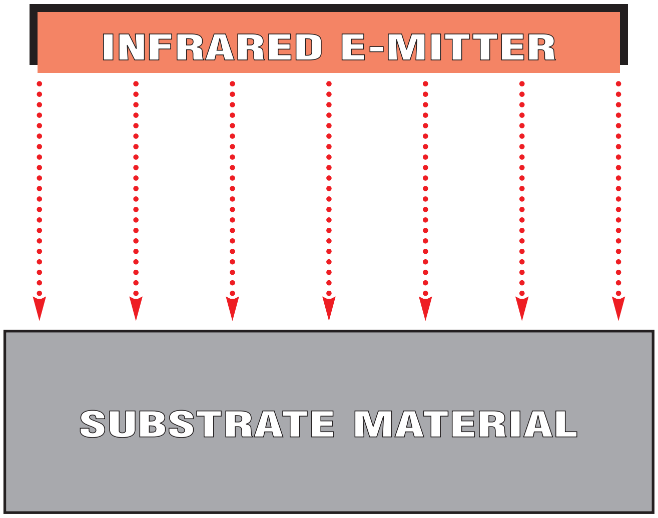
Infrared radiation wavelengths fall outside the visible range in the electromagnetic spectrum; see adjacent figure. One micrometer, μm, is equal to 10^{-6} meter.

The total radiant energy "W" in watts per square centimeter emitted by an object is found with the Stefan-Boltzmann law:

$$W = \varepsilon \sigma T^4$$

"ε" is the emissivity factor
"σ" is the Stefan-Boltzmann constant (5.67×10^{-12} W/cm^{2}K^4)
"T" is the surface temperature of the object in °K
(0°C equals 273°K).

Ceramic Infrared E-Mitter Technical Data



What Kind of Material Do You Want to Heat or Dry?

This information is used to compare the absorption spectra of the material with the emission spectra of the infrared heaters. A good match ensures that the radiant energy from the E-mitter will be effectively absorbed by the material with minimum losses due to transmittance or reflectance. The table below was prepared to help you select the best heater rating for your particular application. If you need additional information, contact **Tempco** for technical assistance.

CAUTION In situations where the material or its released solvents/vapors are easily flammable, special protection is required. Explosion-protected types of E-Mitters are not available. You will have to take proper steps to prevent the flammable media from coming into contact with the hot heater surfaces and electrical wiring. Current regulations and electrical codes must be complied with to prevent unsafe conditions.

Examples of Common Applications

The table below presents some of the most common infrared applications encountered in several industries. The wavelength of the infrared energy was matched to the absorption characteristics of the material to be heated. Various wattages for the same application are recommended due to the absorption characteristics and variables of the application. Select the wattage according to the application requirements. Testing is strongly recommended before final selections are made.

CRB Infrared Heater Ratings

Industry	Wattage	150	250	300	350	400	500	650	750	1000
	Surface Watt Density	6.48	10.8	12.95	15.11	17.27	21.59	28.07	32.39	43.18
PAPER										
• Heating paper pulp and papier-mâché before pressing/molding								■		
• Quick drying of lacquered paper, gummed or glued paper and cardboard									■	■
PLASTICS & RUBBER										
• Drying/curing plastic/latex emulsion/surfacing					■	■				
• Gelling PVC paste/film on fabrics etc.					■	■				
• Preheating plastic foil/sheet/vacuum forming					■	■	■	■	■	■
• Preheating rubber sheeting prior to extrusion						■	■			
TEXTILES, SILK & FIBERS										
• Drying washed, dyed and finished textiles		■						■	■	■
• Fiberglass layup and molding; Resin curing			■	■	■					
• Silk-screen printing; Fusing metallic inks					■	■	■			■
• Stress curing ovens for synthetic fibers				■	■	■	■			
TOBACCO & FOOD INDUSTRY										
• Heating food in restaurants		■	■	■						
• Tobacco drying; Grain drying		■	■							
GENERAL										
• Activation of adhesives and surface sealing					■	■				
• Drying/baking lacquered tin components			■	■	■	■	■			
• Heat/dry/fixing adhesives (boot and shoe trade)								■	■	■
• Low temperature drying of atomized chemicals				■	■	■	■			
• Ore drying and sampling for laboratory work					■	■	■			
• Preheating large metal embossing rollers					■	■	■			
• Powder coating processes				■	■	■	■			
• Setting Nylon® and Perlon® threads, etc.			■	■	■	■				
• Water evaporation		■							■	■

How to Select a Ceramic Infrared Heater

Safe, economical and efficient infrared radiation heating systems can be designed, installed and operated by following some basic rules and guidelines.

Heating Distance for Stationary and Moving Systems

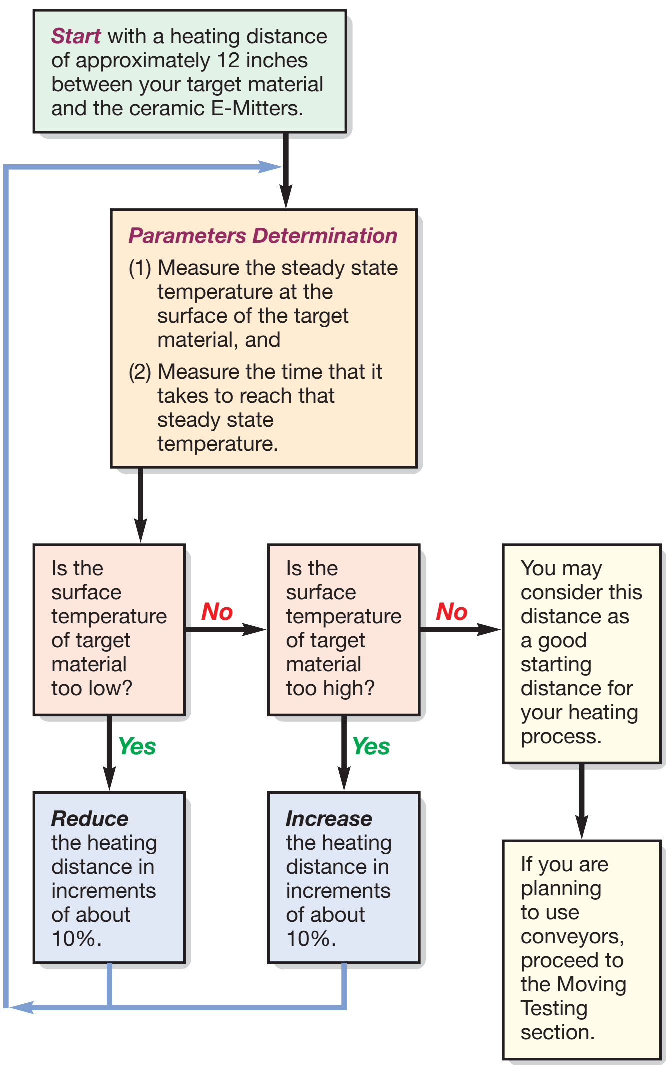
The optimum heating distance cannot be accurately determined for a given application without some preliminary testing because of the many different factors that affect the radiation transfer of heat. Therefore only general guidelines can be offered here.

In any heating application, it is recommended that Stationary Testing be done first. This can be accomplished by following some simple steps.

Stationary Testing

OBJECTIVE

Determination of the heating distance



DESIGN GUIDELINE A General Information

1. Use the table on page 7-98 to match your target material with its corresponding ceramic E-Mitter rating. If the table does not list your target material, consult Tempco for assistance.

2. Select and order the ceramic E-Mitter based on the wattage rating. Tempco offers a complete line of industrial ceramic infrared heaters for you to choose from. Other wattage and voltage combinations can be designed and manufactured to suit your particular application. Consult Tempco with your requirements.

3. Next, what heating process are you going to apply to your target material: Process Heating, Drying, Curing, Cooking or another process? ***Your answer will dictate the next design guideline and how to proceed for the determination of the correct heating distance.***

DESIGN GUIDELINE B Process Heating

In many industrial applications, heat has to be applied to a target material before being processed further. In some cases, hot spots or large temperature gradients must be avoided. For this reason, it is highly recommended that several temperature controllers be used together with ceramic E-Mitters and integrated thermocouples. Three main processes require special attention:

1. *Plastic sheets* The fact that plastics have very low internal thermal conductivity causes localized heating if the applied heat is not uniformly distributed or if the sheets are too thick. In this situation, it is recommended that heat be applied to both sides of the sheet for the heat to be distributed throughout the material.

2. *Metallic sheets or strips* Metals are better internal conductors of heat than plastics but they absorb much less radiant energy because most of it is reflected at the surface. To overcome this problem, match the emission spectra of the radiant heater with the absorption spectra of the metal. Tempco's sales engineering staff will gladly help you in this endeavor.

3. *Granular form material* A relatively uniform heating of granulated compounds can be achieved by placing a thin layer of granules on a vibrating surface or conveyor to aerate the material while heating.

DESIGN GUIDELINE C Drying, Curing & Cooking

Drying involves the release of water vapor, solvents or other materials that are vaporized during the process. In some cases, the solvents may be harmful or explosive and would require special protection. The user is solely responsible for the installation of the heating system and the strict observance of all applicable regulations.

Water vaporization, on the other hand, does not present this problem, but offers other related ones that also require special handling, such as how to remove the water vapor as it comes off the material being processed.

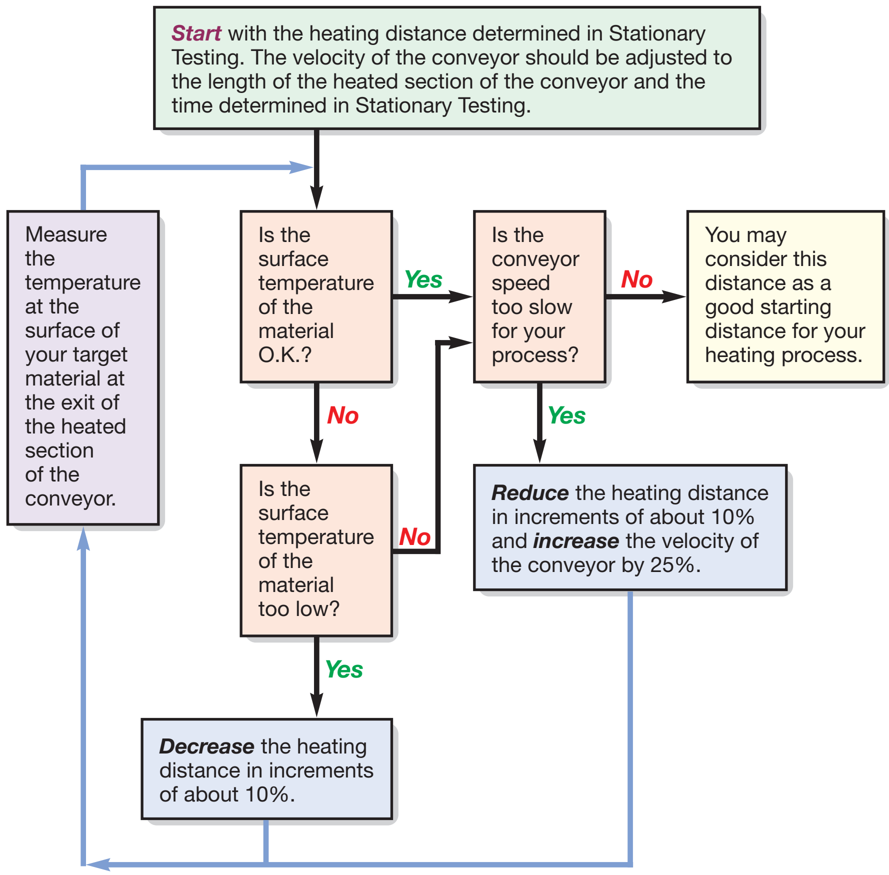
As for ***curing and cooking***, because of the many different applications encountered within various industries, no specific rules can be offered in this general guideline. Testing of the application is recommended to determine the process requirements. Contact Tempco's sales engineers if assistance is needed.

Ceramic Infrared E-Mitter Technical Data

Moving Testing

OBJECTIVES

Determination of the heating distance and the velocity of the conveyor



Tips for Infrared Heating Systems

Infrared heating works best with materials that are thin enough for the heat to be absorbed and/or when the target material has high internal thermal conductivity. In metals, for example, heat is easily conducted from the surface to the interior of the material.

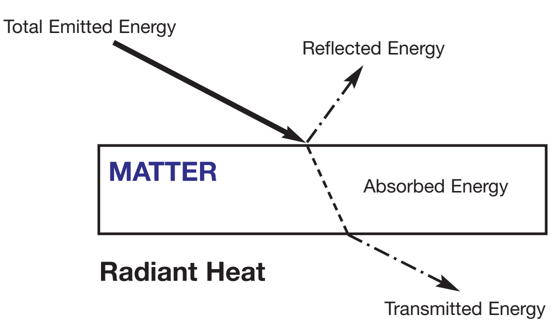
Multilayer materials present some difficulties when they are to be heated with infrared heaters. The top layer dries faster than the lower layers, causing different rates of shrinkage throughout the material. Infrared heat energy is transmitted with the speed of light from the surface of an emitter source (i.e. a ceramic heater) to the surface of the target material. Consequently, the top layer may be subjected to thermal loads that are too high for the composite target material to handle without degradation. In such cases, detection systems and/or overtemperature controls must be incorporated into the heating system to detect changes in normal operating conditions and trigger safety devices.

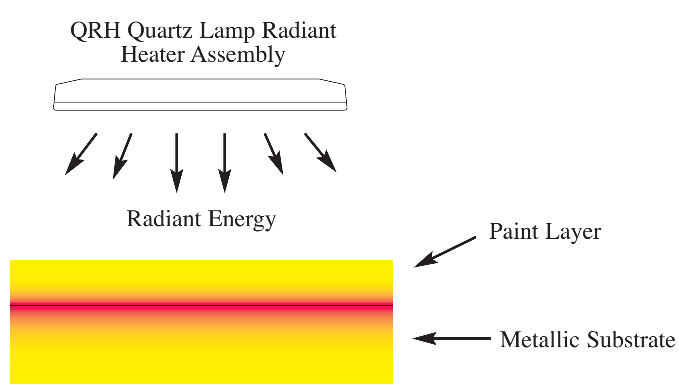
Higher heating rates can be achieved in moving systems that result in higher production output. This higher output can be easily accomplished without complications on properly designed, installed and maintained infrared heating systems.

Material Thickness

The thickness of any given material is very important for most infrared heating applications. This is because many materials do not transmit the infrared energy past a few tenths of an inch; therefore, the heat is either reflected or absorbed.

The absorbed heat is conducted in all directions. In some paint processes, it is more convenient to select an infrared heater based on the absorption characteristic of the substrate and the transmittance characteristic of the paint. By doing so, the radiant energy will be transmitted farther within the material and absorbed mostly in the substrate material. The temperature in the top layer of the substrate material will rise and heat the material above, heating from the inside out. Blistering is avoided or reduced to a minimum by employing this technique.

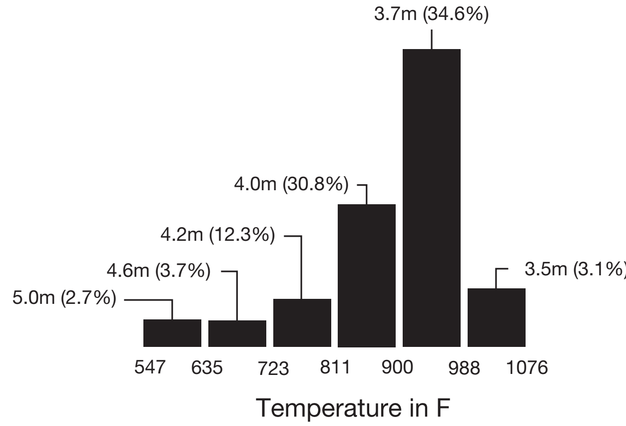




Ceramic Infrared E-Mitter Technical Data

An Example of Emissive Power

All E-Mitter ceramic infrared heaters emit infrared energy in various wavelengths depending on their surface temperature. The CRE00002 E-Mitter (bulb style, 250W, 120V, white) was tested as an example with the results shown on the right. The values associated with temperature, emitted wavelength distribution and percentages were obtained when the heater reached steady state conditions in room ambient. The value of the peak wavelength λ_{max} (3.7 microns) was calculated using Wien's displacement law for a blackbody from the peak temperature obtained in the tests. This calculation is valid since the spectral emissive power of our ceramic E-Mitter closely approximates the theoretical values in the Planck's formulation for infrared wavelength distribution.



An Example of Emissive Power

Wien's Law is expressed by the following formula:

$\lambda_{max} = 5215.6\mu m/°F \div (T + 460)$

T = Temperature °F

λ_{max} = Peak Wavelength

Example:

What is the optimum peak E-Mitter surface temperature for heating a target material that has its best absorption in the infrared wavelength range of 4.0 to 3.4 microns (μm)?

Average peak wavelength = $(4.0 + 3.4) \div 2 = 3.7\mu m$

Using Wien's law, we have:

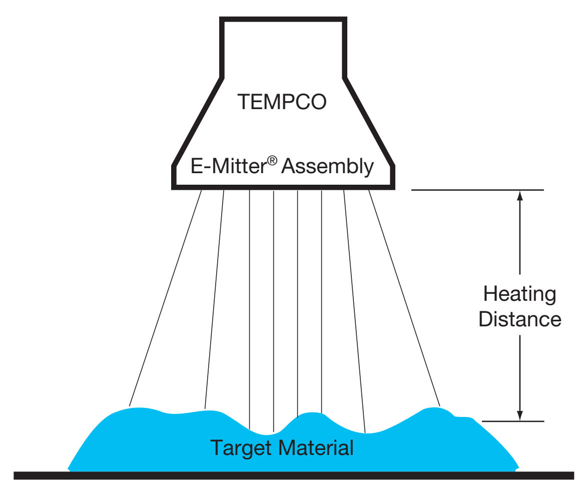
$$3.7\mu m = 5215.6 \div (°F + 460) \text{ or } °F = (5215.6 \div 3.7) - 460 = 949.6°F$$

This temperature is only a starting point and should be confirmed by testing and simulation of the exact conditions of the application. As you can see from the bar graph, this 950°F point coincides with the highest % of the radiated energy from the CRE E-Mitter that was tested. Once the heater temperature has been established, the charts included in the various individual heater sections can be used to select the proper heater wattage starting point.

Conveyor Systems

Moving heating systems generally achieve higher output per hour than is possible with static systems. The radiant heater's setpoint temperature is set higher in conveyor systems than static systems due to the limited time the product is under the heaters. Tests should be carried out to determine the optimum conveyor speed, heating distance, and E-Mitter operating temperature.

CAUTION In applications such as drying pulp paper, the higher power level required can potentially create a fire hazard if there are not safety mechanisms built into the system. If a malfunction of the conveyor system slows down or stops the conveyor completely, safety mechanisms should be triggered that would shut down power to the heaters to avoid burning the material being cured or dried.



Maximum Operating Temperature

Every heater has its maximum operating temperature printed on it. This temperature was measured with a thermocouple and with the heater facing down on a highly reflective material.

In many practical situations, however, this maximum temperature is rarely reached because most of the industrial materials absorb and transmit the heat while reflecting only a fraction of the infrared energy.

Ceramic E-Mitter Infrared Radiation Images

Infrared Radiation Images of Tempco's Ceramic E-Mitters

(White, 240V, 400W)

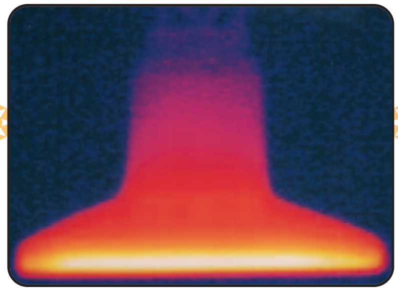
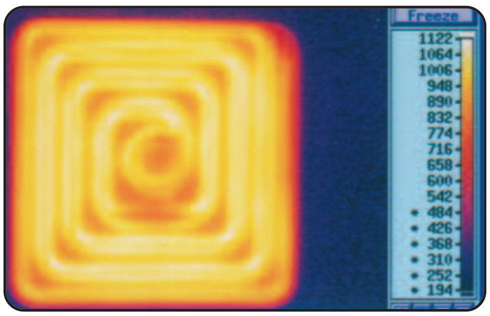
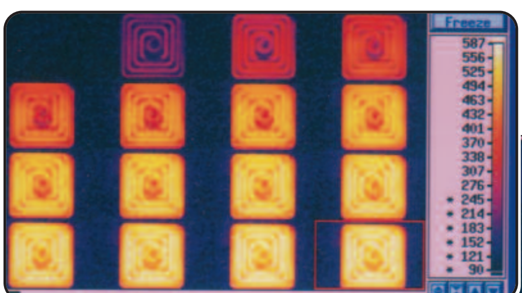


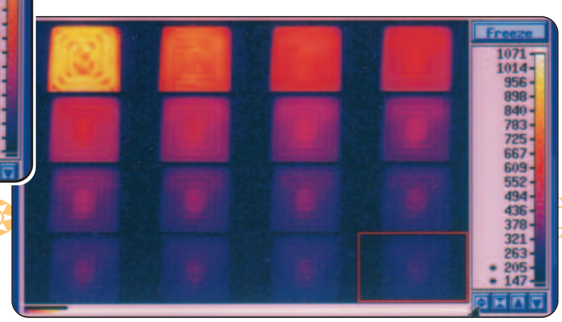
Image of Part Number CRD00002

Side View The lighter color (yellow) represents the hottest area(s), while the black (background) represents the ambient temperature. The air gap and the ceramic fiber insulation produce a dramatic temperature gradient between the heating elements (yellow region), and the supporting clamps (purple region).



Bottom View The temperature distribution in this face is particularly homogeneous, assuring a uniform radiant heat to a given application. The convective heat losses are more noticeable at the edges of the heater. Except in vacuum conditions, convective losses must always be considered in a heating application.





Infrared Images

These infrared images were recorded at 30-second intervals. The photo sequence on the left illustrates how the elements heat up over time. The photo sequence on the right illustrates how the elements cool down.

Note: The temperature scale (°F) corresponding to each color is on the right side of the images.