Infrared radiation heating has been around for a long time. However, only in the last fifteen years have the many advantages been applied to satisfy a wide range of industrial processes. New applications arise continually, which take advantage of this highly efficient, highly controllable, fast responding heat source.

How it Works

Infrared heating is a direct form of heating. The source of the heat (the infrared emitter or lamp) radiates: *energy that is absorbed by the product directly from the emitter*.

That is, the heat energy is not transferred through an intermediate medium. This is one reason for the inherent high-energy efficiency of infrared systems. For example, hot air heating first needs to heat air; the air then heats the product by convection.

Infrared energy is directed to the product. When the product absorbs this energy, it is then converted into heat.

Infrared energy is dispersed from the source in much the same way as visible light. Exposed product surfaces easily absorb the infrared energy and become heated. Therefore, heating effectiveness is related to line-of-sight between the source and the product. Depending on the coating and/or product substrate material, this heat is further thermally conducted.

The ability of the product to absorb energy is also known as its “emissivity”. A theoretical body that absorbs all energy is termed a “black body”. A black body has an emissivity of 1. A highly reflective body would have a low emissivity value, approaching 0. (Reflectivity is the inverse of emissivity)

The potential of a product to become heated with infrared is related to the following:

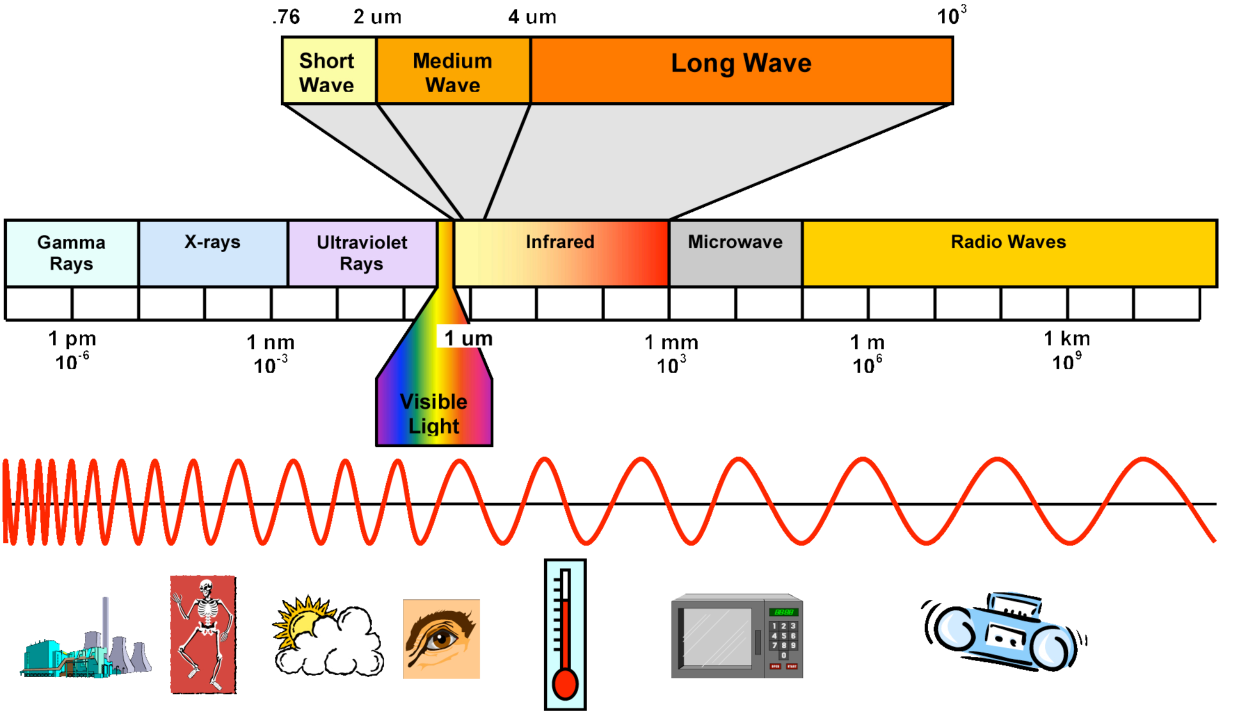
- Watt density (total output power) of the source
- Wavelength (temperature) of the source
- Distance from the source to the product
- Reflective characteristics of the oven cavity
- Air movement and temperature in the oven
- Time product is exposed to the source
- Ratio of exposed surface area to the mass of the product
- Specific heat of the product
- Emissivity of the product
- Thermal conductivity of the product

Not all Infrared is Created Equal

The infrared spectrum is broken into short, medium and long wavelengths…

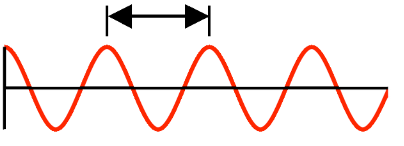
The Electromagnetic Spectrum

Infrared radiation is a form of electromagnetic radiation. The electromagnetic spectrum also includes gamma rays, X-rays, ultraviolet waves, visible light, microwaves and radio waves. All of these wavelengths travel at the same speed – the speed of light (186,000 miles per second). Their individual wavelength is the only difference between them.



<u>Wavelength</u>

Electromagnetic energy travels in waves. Wavelength is defined as the length of one complete cycle of the waveform.



The infrared band spans from .76 um to 1000 um. T his is also known as the "thermal band".

An infrared emitter heats when voltage is applied across it. The internal resistance to current flow results in heating of the filament or internal resistance element. The wavelength is solely determined by the temperature that the filament can attain. For example, a 3000°F source has a peak wavelength of 1.5 um; a 1000°F source has a peak wavelength of 3.6 um.

Infrared emitters disperse energy in a "bell" shaped pattern. The bell has a "peak" wavelength where the highest amount of energy is given off. The bell extends in either direction showing that the emitter provides energy at shorter and longer wavelengths. For this reason, we see a short or medium wave lamp glow since infrared borders on the visible spectrum.

The infrared spectrum is divided into:

Shortwave Infrared	Also known as "near" or "high intensity" infrared
Medium Wave Infrared	*Also known as "middle" or "medium intensity" infrared*
Long Wave Infrared	*Also known as "far" or "low intensity" infrared*

The Infrared Emitter

Also called an infrared "lamp", this is the source of the infrared energy. Construction materials and construction methods determine the energy output characteristics of the lamp. The construction determines the temperature that the emitter can operate at, the temperature of the emitter determining the wavelength output.

Emitters are specifically designed for different energy output characteristics, since the wavelength of an infrared emitter is solely dependent on its temperature.

<u>Long Wavelength</u>
A resistance element is sandwiched in hardened glass or vitrified ceramic. Generally considered a low temperature heat source, since the resistance element has high mass, it is slow to react to changes in applied voltage.

<u>Medium Wavelength</u>
A chromium alloy filament is suspended in a quartz or metal sheath. Due to the material used and the relatively low temperatures, the filament can operate in open air.

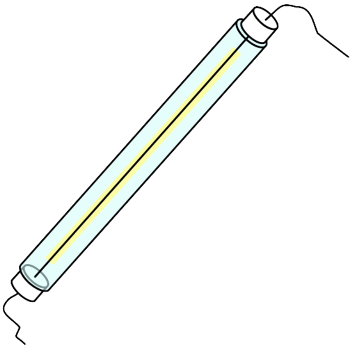
<u>Short Wavelength T3</u>
A tungsten filament is sealed in a quartz envelope in halogen gas. The thin filament, being of little mass, is very reactive to the voltage applied to it. This means that the infrared heat output changes immediately with changes in applied voltage. The T3 emitter far outperforms the others in reference to high emitter temperature and rapid response time. The tungsten filament has a life of 5000 hours when the lamp is used at full voltage.

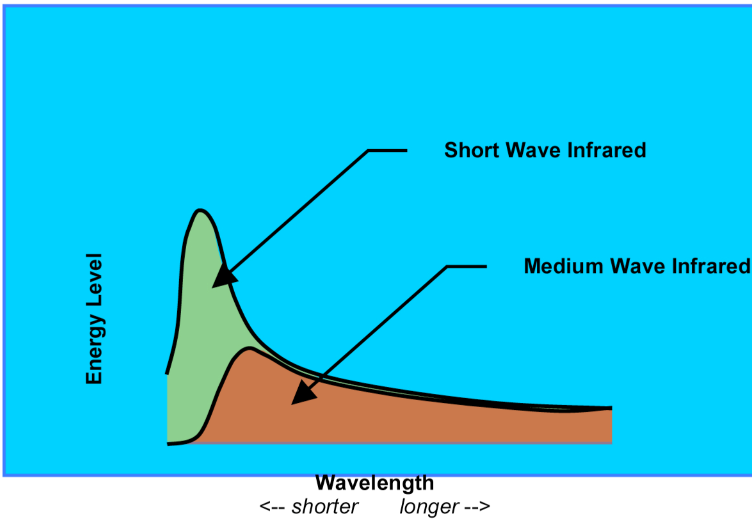
Emitter Wavelength Comparison

Infrared Type	Source temperature	Peak wavelength	Response time
Short Wave	Up to 4000°F (2200°C)	1.2 um	<1 second
Medium Wave	Up to 1800°F (980°C)	2.3 um	30 seconds
Long Wave	Up to 1000°F (540°C)	3-5 um	5 minutes

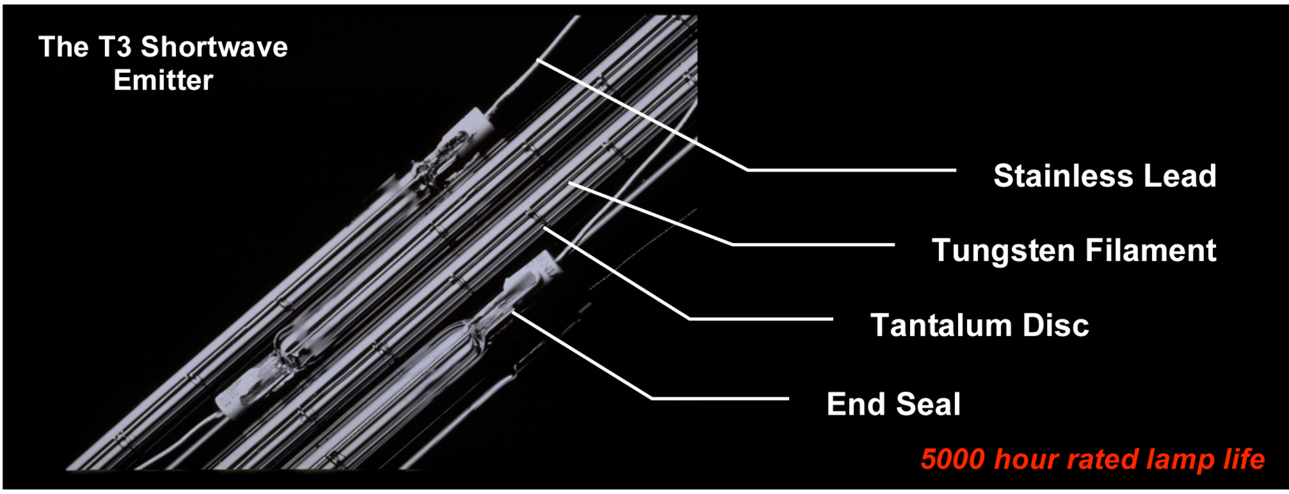
The Advantages of Using Shortwave Infrared

- Immediate responding heat source
- 0-100% control of the energy output
- High thermal differential between source and product provide rapid heating and short process times
- Independent heat zones provide process flexibility and energy savings
- Ramp-and-hold capability
- Efficient use of applied energy
- Flexible system configurations
- Compact designs use minimal space
- Eliminates need for preheating
- Minimal amount of supply air required
- Minimal amount of internal moving air optimizes product finish
- Minimal amount of exhaust air
- Consistent product quality
- Clean energy source with low environmental impact



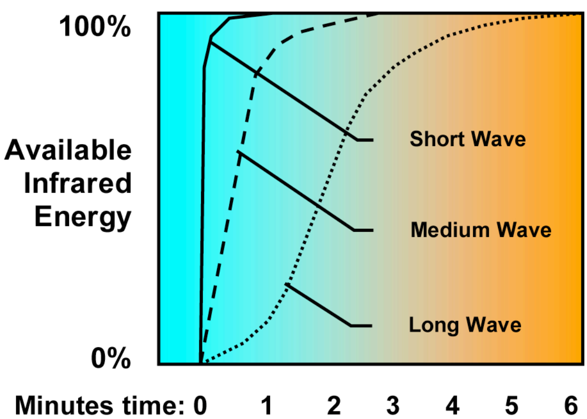


As shown at left, a shortwave infrared emitter can deliver all the infrared energy of a medium wave emitter, and will perform well beyond it when operated at full voltage

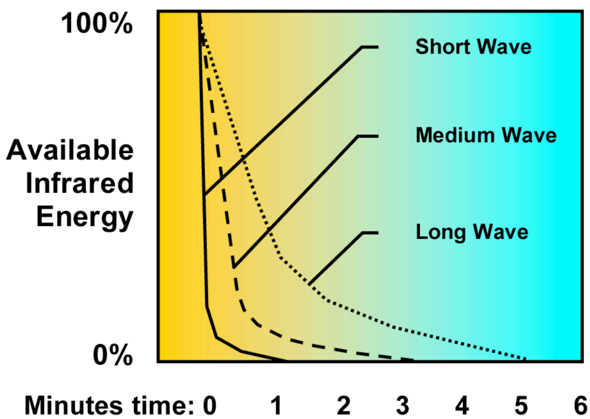


Response Time

The graphs below show a comparison between infrared emitter response times. Most industrial processes are inline, where it is critical that the heat source be able to rapidly adjust for changes in product speed, mass and shape. Shortwave infrared provides this.



Heat Up Rates



Cool Down Rates

Characteristics of Commercially Used Infrared Heat Sources

	Short Wave		Medium Wave		Long Wave
	Tungsten Filament Wire		Nickel Chrome Spiral Winding		Low Temperature Panel Heater
	T3 Quartz Lamp	Glass Bulb	Quartz Tube	Metal Sheath	Metallic Nickel Chrome
Source Temperature	3000°F – 4000°F (1649°C-2204°C)	3000°F – 4000°F (1649°C-2204°C)	1400°F-1800°F (760°C - 982°C)	1000°F-1400°F (538°C - 760°C)	400°F-1100°F (209°C – 593°C)
Brightness	Bright White	Bright White	Cherry Red	Dull Red	No Visible Light
Typical Size	3/8" Dia. Tube (9.525 mm)	G-30 Lamp	3/8" – 5/8" Dia. Tube (9.525 mm – 15.875 mm)	3/8" – 5/8" Dia. Tube (9.525 mm – 15.875 mm)	Flat Panels – Various Sizes
Peak Energy Wavelength Range	1.15 – 1.5 Microns	1.15 – 1.5 Microns	2.3 – 2.8 Microns	2.8 – 3.6 Microns	3.2 – 6.0 Microns
Relative Energy Distribution Range: Radiation	72-86%	72-86%	40-60%	45-53%	20-50%
Convection/Conduction	28-14%	28-14%	60-40%	55-47%	80-50%
Degree Of Heat	Best	Best	Better	Better	Poor
	Depth of penetration varies with the characteristics of the product. As a general rule, energy of shorter wavelengths penetrates deeper then energy of longer wavelengths.				
Response times: Heat Up	Seconds	Seconds	Minutes	Minutes	Several minutes
Cool-down	Seconds	Seconds	Seconds	Minutes	Several minutes
Color Sensitivity	Bodies of varying colors can be heated at more nearly the same rates with long wavelength infrared radiation than with shorter wavelength infrared.				
Ruggedness: Mechanical Shock	Good	Poor	Good	Excellent	Varies with panel
Thermal Shock	Excellent	Poor	Excellent	Excellent	Good dependant upon design

Delta T

Note that the higher the thermal head, the more rapidly a product can be heated. See typical Delta T ratios below. These values also relate to the size oven required.

Infrared Type	Source temperature	Part temperature	Delta T Ratio
Short Wave	4000°F (2200°C)	400°F (204°C)	10:1
Medium Wave	1800°F (980°C)	400°F (204°C)	4.5:1
Long Wave	1000°F (540°C)	400°F (204°C)	2.5:1

Infrared Equipment Packaging

Attaining the best heating results does not stop with selecting the proper emitter. Experience and knowledge allow using this tool to the best advantage.

The Reflector

Tubular emitters typically radiate heat energy in 360°. The energy not directed at the product needs to be harnessed to create an efficient system. For this reason, the reflector material can be as important as the emitter itself.

We have found that high-density ceramic reflectors provide the best solution. This proprietary material initially reflects the infrared energy, then absorbs and re-radiates it at longer wavelengths (3 to 5 microns). We line the entire interior surface of our ovens with this high-density ceramic, keeping the process as efficient as possible.

Most industrial processes give off vapors. It is important to keep these vapors from forming a film inside the oven cavity. The ceramic reflector reaches high temperatures and is able to burn off any contaminants.

The Heaters

Lamps must be securely mechanically and electrically mounted. Supply air must have free passage for lamp end seal cooling, which allows maximum lamp life. Heaters must be accessible for easy lamp replacement.

The Enclosure

Heavy-duty materials are necessary for equipment framework to ensure rigidity during heating cycles. Modular designs permit rapid placement at the installation site. Pre-wired junction boxes make for simple field interconnect.

Infrared Controls

Shortwave infrared emitters offer the highest level of flexibility and performance. To harness the full capabilities of the emitter, dedicated electrical controls are utilized. At the heart of the system is the SCR power controller.

SCR Power Controller

A solid state device that controls the voltage potential applied to the infrared emitter. A signal is typically input to the controller that varies the output voltage to the emitter, thereby varying the emitted power – full 0 to 100% control. Signals to the controller can be provided from potentiometer settings, PLC analog outputs, line speed and temperature measurement values.

Operator Controls

Several options exist which include manual to automatic to PLC operation. Low cost manual systems allow full adjustment of the oven settings. PLC recipe controls can automatically adjust the oven for varying products. Select the option that is right for you.

Infrared Safety

Equipment design cannot stop with just handling the process. Safety to personnel and plant needs to be built in. Ask your infrared supplier if his equipment provides the following:

- Wire type: wire insulation must handle operating conditions
- Wire sizing: wire must carry the current and be de-rated for temperature
- Airflow for solvent dilution: air volume must dilute airborne solvents to a safe level
- Fusing/disconnects: electrical protection for personnel and equipment
- Shorted SCR protection: thermal protection to personnel and equipment
- Instantaneous current trip ICT: protects equipment
- Pre-operation air purge cycles: insures environment is safe for oven operation
- Air presence test sensors: insures that blowers are on for safety ventilation and equipment protection

BGK Finishing Systems knows...The Facts.

