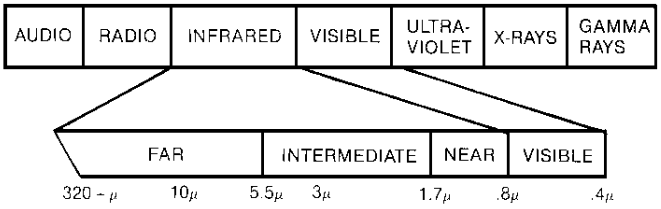
PROCESS INFRARED HEATING

As stated and defined in the Thermal System design section, all heat in every process is transferred by conduction, convection or radiation. Infrared falls into the category of radiation. Often contact of the heat source to the transfer medium or the material being processed is not possible (conduction). The application also might not be practically heated with high-velocity air (convection). In these and many other situations, infrared can be an effective heat transfer method. Infrared is utilized in processes such as:

- Conveyor ovens for drying or curing thin surface films such as paint, lacquer, powder coatings, printing ink or adhesives.
- Heat setting or curing a continuous, fast moving web of uniform thickness material such as textiles.
- Removing surface water or absorbed moisture from materials such as paper, fabrics or chipboard.
- Heating conveyor loads of similar small parts or granular materials.
- Vacuum forming thermoplastic sheet and other processes in the manufacturing of plastics and synthetic materials.
- Localized heating of large parts or assemblies.

Infrared is a form of radiation that falls between visible light and radio waves as shown on the electromagnetic spectrum. Heat is transferred from the source to the work by invisible electromagnetic energy. When the infrared energy reaches the surface to be heated, the molecules vibrate intensely, converting to heat energy. Heat then travels through the product by conduction. Most useful infrared energy for industrial processing results between 2 and 4 microns (μ). A micron is the unit of measurement of infrared wavelengths. ($1\ \mu = 10^{-4}$ cm)

Fig. 14: Electromagnetic Spectrum



INFRARED

- TRAVELS AT SPEED OF LIGHT
- PRODUCES HEAT WHEN ABSORBED
- CAN BE REFLECTED & FOCUSED

The basic infrared theory is that the intermediate heating of the air between the heat source and the product is not required. Because radiant energy travels at the speed of light, heat transfer is very efficient when the characteristics of the material being heated absorbs infrared well. Also, the energy can be directed into specific patterns by the use of reflectors.

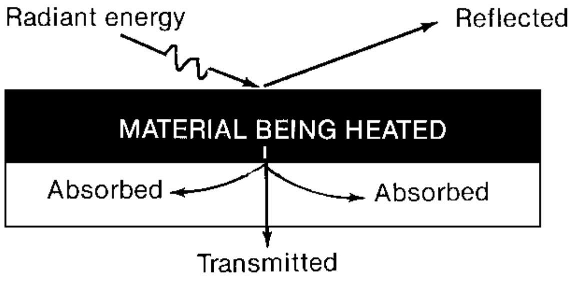
How well a material emits or absorbs infrared is it's emissivity factor. The perfect black body is an ideal surface which completely emits or absorbs all radiant energy. The black body's emissivity factor is 1.00. All other surfaces have lower emissivities, and factors less than 1.00. A practical assumption is that a good emitter is also a good absorber. Hence, a polished aluminum surface with an emissivity of .04 would absorb far less radiant energy (everything else being equal) than roofing paper at .91. The energy that isn't absorbed is either reflected or transmitted.

25T: Emissivity Factors for Various materials

Solid Materials	Emissivity	
	polished	oxydized
Aluminum	.05	.15
Asphalt		.85
Brass	.09	.6
Brick/Masonry		.83
Carbon		.96
Concrete		.9
Copper	.02	.6
Enamel, white		.92
Flour		.9
Glass		.95
Gold		.02
Gypsum		.9
Ice		.97
Iron, cast	.21	.7
Iron, wrought	.28	.7
Lead	.08	.7
Leather		.95
Limestone		.95
Linoleum		.9
Marble		.9
Meat		.95
Nickel	.06	.9
Paper		.85
Paint		.85
Pitch, hard		.95
Plaster		.79
Porcelain		.92
Rubber		.95
Salt, rock		.95
Sand, dry		.76
Silver	.03	.8
Stainless Steel	.17	.85
Steel	.11	.75
Tin	.18	.6
Wood		.95
Zinc	.03	.5
Liquid Materials		
Mercury		.1
Oil, Machine		.82
Water		.96

Depending upon a materials' emissivity factor, reflective losses can be high. Where the system design allows, built-in reflectors can re-direct these losses back to the material being heated to where almost all energy is absorbed. Long and medium wavelength infrared emitters such as Incoloy sheath tubulars, quartz, and Black Body Ceramic heaters lose little if any energy by being transmitted through a material. Almost without exception, radiant energy is either absorbed or reflected.

Fig. 15: Energy Equation



Energy Equation:

Energy Absorbed + Energy Reflected
+ Energy Transmitted =
Total Incident Radiation

As the distance from the heat source to the material is increased or decreased, the radiation intensity increases or decreases exponentially. In the initial sampling and testing a distance of 12" for a conveyorized process will produce uniform radiant distribution. Specific application considerations may require the distance to be adjusted.

Materials are selective as to the wavelength accepted to absorb infrared energy. As can be seen on 38T, PVC will absorb best at 3.5 microns. The wavelength produced by the heat source is dependent upon the source temperature. It is possible then to adjust the source temperature and thus the peak wavelength to match the best spectral absorption rate or wavelength. The formula is:

$$°F = \frac{5215}{\mu} - 459 \qquad °C = \frac{2897}{\mu} - 273$$

Thus, if the element temperature is known and the wavelength is desired:

$$\mu = \frac{5215}{459 + °F} \qquad \mu = \frac{2897}{273 + °C}$$

By applying the formula to PVC, based upon 3.5 microns being the desired wavelength, 1025°F (550°C) would be the emitter's surface temperature for the best heat transfer to the process. This principle holds true no matter what the construction of the heat source. An Incoloy® tubular heater, the resistance wire of a quartz heater, an FP Flat Panel heater or a Black Body Ceramic Infrared heater operating at 842°F (450°C) would all have the same peak energy wavelength of 4 microns. Other characteristics such as penetration and color sensitivity would also be the same.

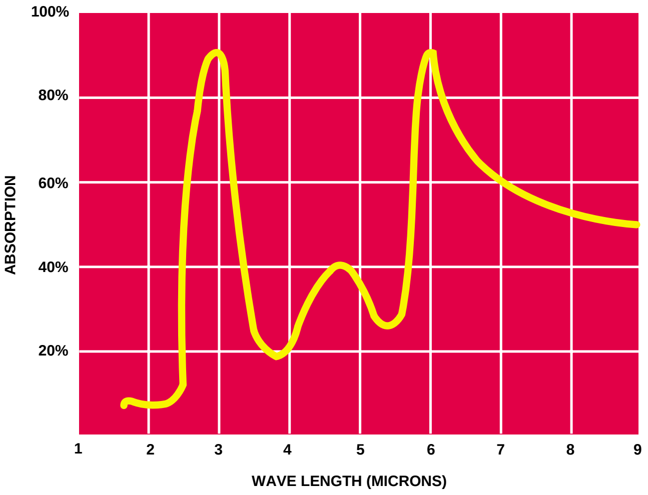
Other common methods of temperature control in infrared processes is by varying the voltage input to the elements or adjusting the amount of on-time versus off-time of the elements. These are open-loop control systems and usually require the constant attention of an operator. A closed loop control system would consist of infrared sensors or thermocouples attached or integral to the heat source, that would monitor the temperature of the process or heater, signal a control which in turn would signal an output device to deliver current (or turn off) the heat source. For complete information, see each respective catalog section, the Thermal System Design section or consult STS.

STS offers a number of choices of heating elements for infrared applications. The advantages, limitations and adaptability of each will determine which is most suitable. For instance, the emissivity/conversion ratio of an Incoloy® sheath tubular heater is about 55%, a quartz heater's is 60%, an FP Flat Panel's is about 80% and the Black Body Ceramic's is over 90%. This indicates that close to all of the infrared energy produced by the ceramic heater will be absorbed by the process. This type of efficiency may be the most important consideration. But the process may require a heat source with a quick response time. The quartz heater will likely be chosen, or an expensive retraction system may be necessary should a line stoppage occur. The Incoloy® sheath tubular heater could be the best selection because of its ruggedness and ability to be formed to suit spacing or confinement requirements. An FP Flat Panel heater may be selected because of the wide area coverage.

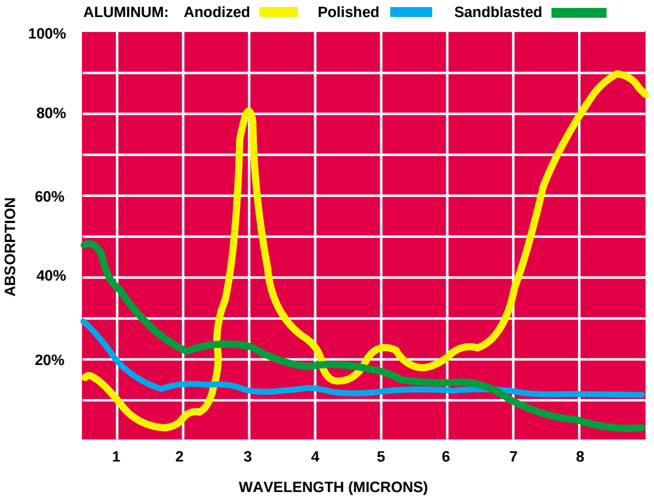
Although much technical information is available in this and other sources, trial and pilot testing are often necessary to establish if a process is suitable for infrared. The wattage required, watt density, process time cycle, distance from the heat source to the material and how well the material absorbs infrared can perhaps only be determined by this method. Should any uncertainty exist, contact **STS**. The information necessary may already be on file, because **STS** has successfully solved scores of infrared heating problems.

SPECTRAL ABSORPTION OF VARIOUS MATERIALS

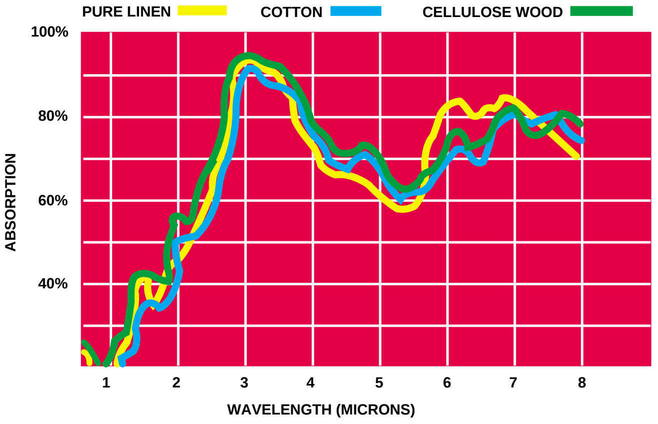
26T: Water



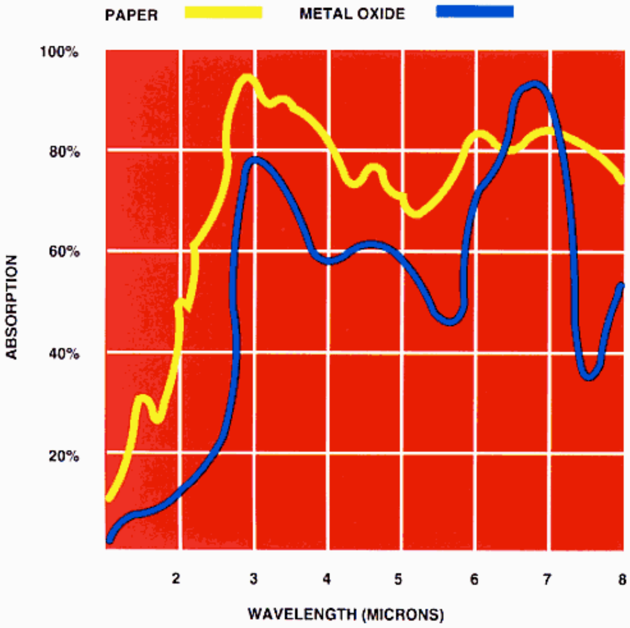
27T: Aluminum



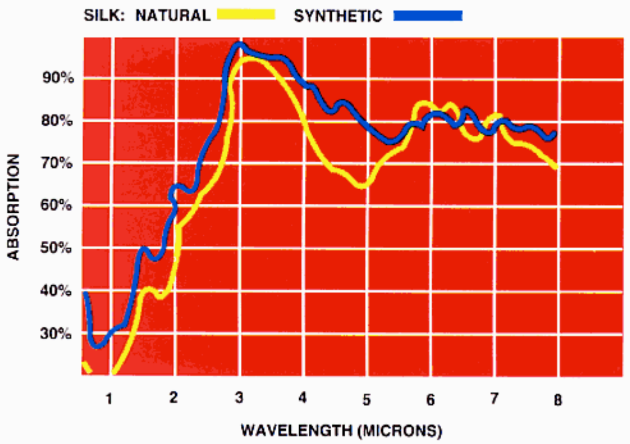
28T: Pure Linen, Cotton and Cellulose Wood



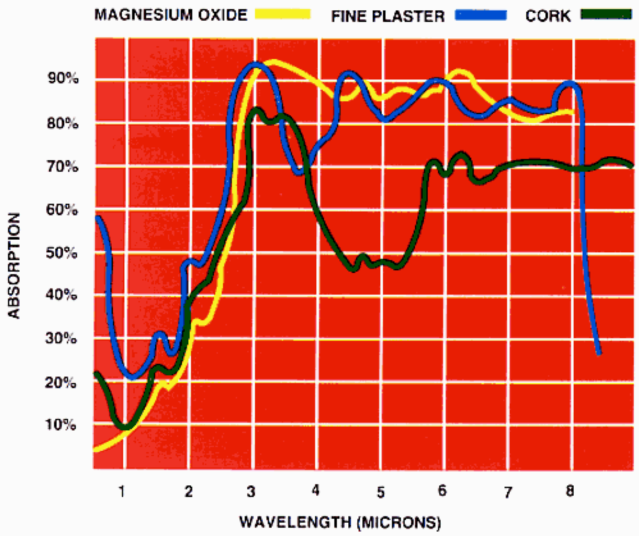
29T: Paper and Metal Oxide



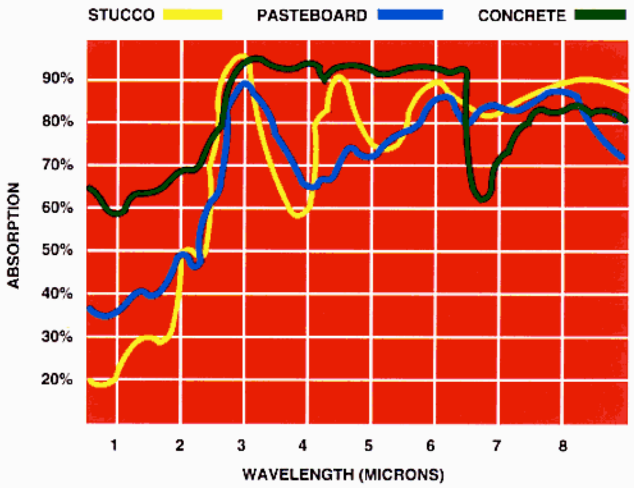
30T: Silk: Natural and Synthetic



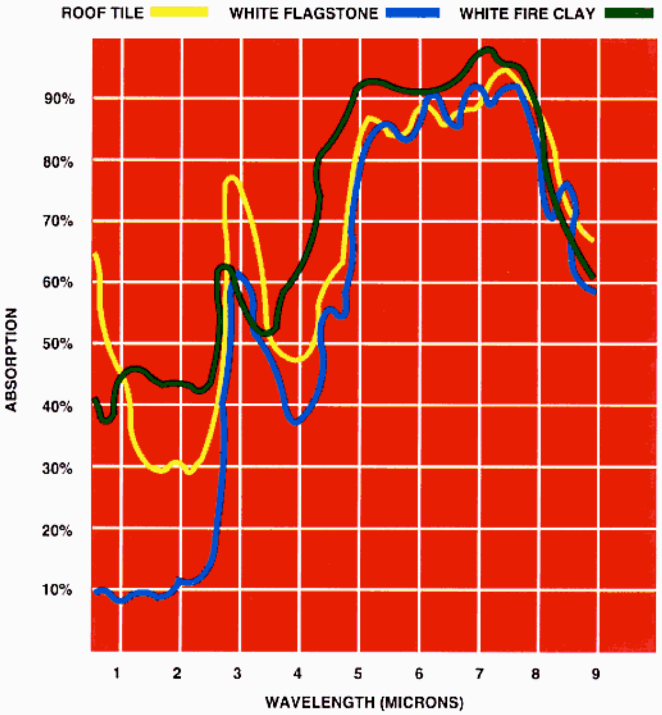
31T: Magnesium Oxide, Fine Plaster and Cork



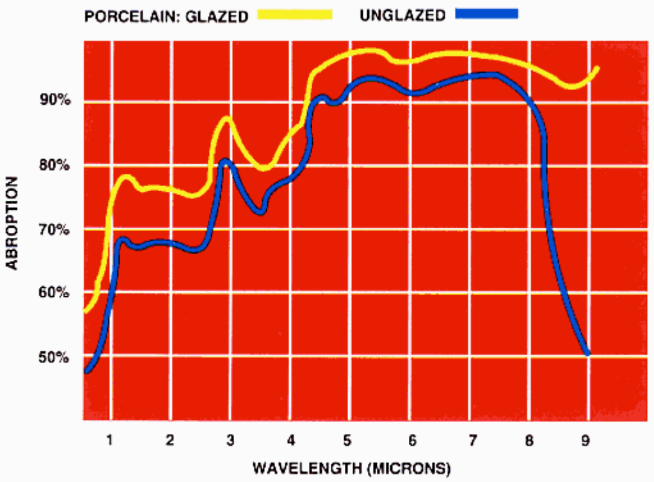
32T: Stucco, Pasteboard and Concrete



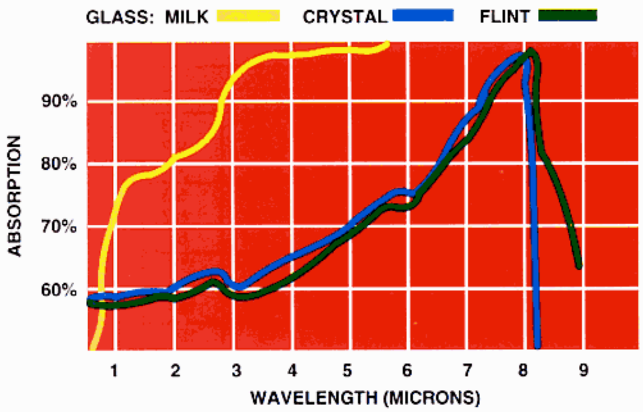
33T: Roof Tile, White Flagstone and White Fire Clay



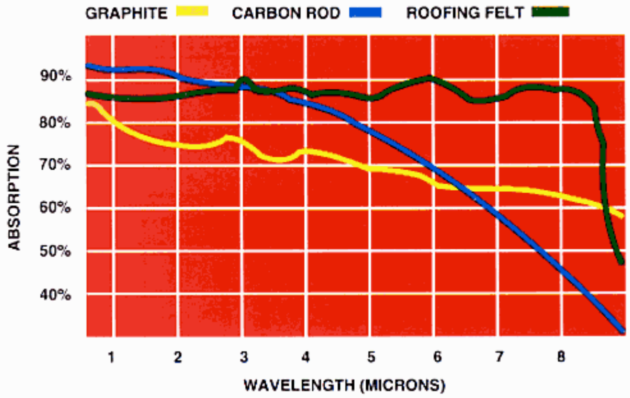
34T: Porcelain: Glazed and Unglazed



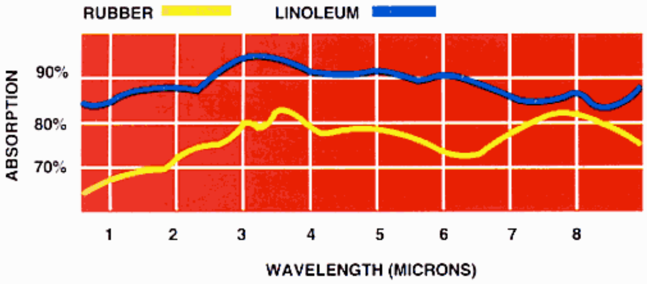
35T: Glass: Milk, Crystal and Flint



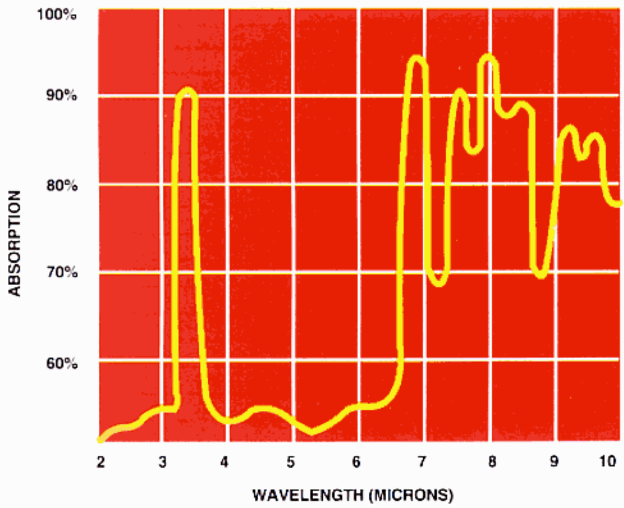
36T: Graphite, Carbon Rod and Roofing Felt



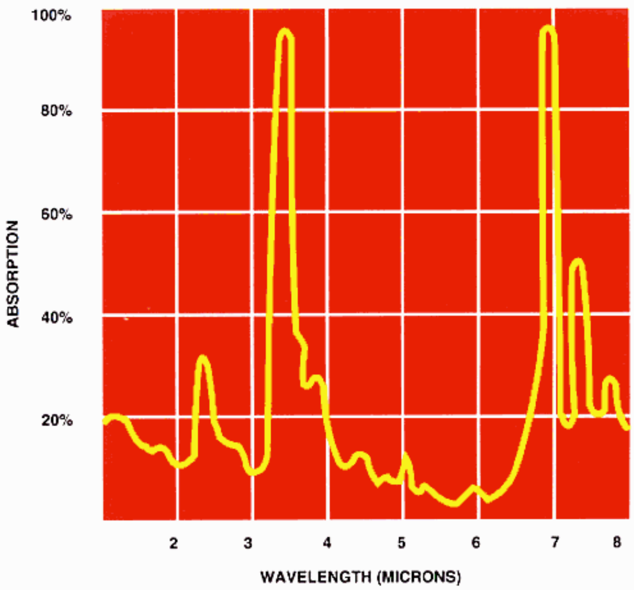
37T: Rubber and Linoleum



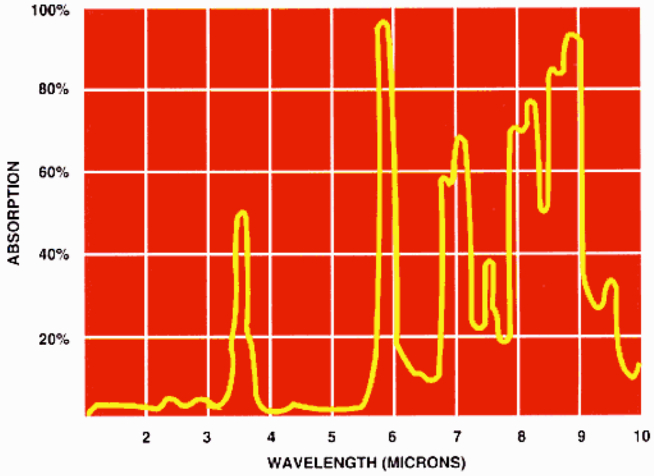
38T: PVC



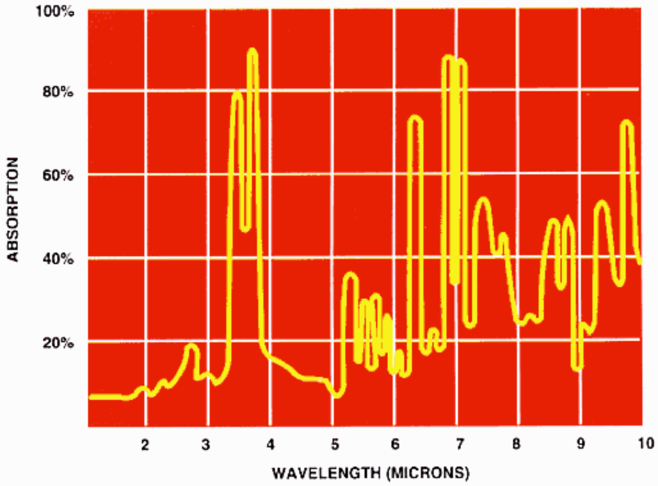
39T: Polyethylene



40T: Plexiglass



41T: Polystyrene



Radiation / Temperature Comparison Chart

Revision 1.0 16/NOV/99

Temp (°F)	Temp (K)	Peak Wave-length (μm)	Flux (watts / in^2)	Color
900	755	3.83	11.91	⬛
1000	810	3.57	15.82	⬛
1100	866	3.34	20.62	🟥
1200	922	3.14	26.44	🟥
1300	978	2.96	33.41	🟥
1400	1033	2.80	41.68	🟥
1500	1089	2.66	51.39	🟥
1600	1144	2.53	62.71	🟥
1700	2000	2.41	75.81	🟧
1800	1255	2.30	90.85	🟧
1900	1311	2.21	108.04	🟧
2000	1366	2.12	127.55	🟧
2100	1422	2.04	149.59	🟧
2200	1478	1.96	174.37	🟨
2300	1533	1.89	202.11	🟨
2400	1589	1.82	233.04	🟨
2500	1644	1.76	267.38	⬜
2600	1700	1.70	305.39	⬜
2700	1755	1.65	347.32	⬜
2800	1810	1.60	393.42	⬜