Introduction to Infrared Radiation.

1. Starting at the source – the Heating Coil.

- Ceramic long wave emitters – Fe Cr Al or Ni Cr
- Quartz medium wave emitters – Fe Cr Al
- Quartz Halogen Emitters - Tungsten

Ni Cr	=	Nickel Chromium ⇒ 1100°C – 1200°C
Fe Cr Al	=	Iron Chromium Aluminium (Kanthal D or equivalent) ⇒ 1200°C – 1300°C
Fe Cr Al	=	Iron Chromium Aluminium (Kanthal AF or equivalent) ⇒ 1300°C – 1400°C
Tungsten	=	3000°C +

Once the correct wire specification is known:

- Electrical calculations are performed to determine coil specifications.

- Heating coil (made from Tungsten or resistance wire) is produced on the appropriate coiling machine at the required rating.

- Terminations added to the required length (resistance wire only at this stage)

- Heating coil is inserted/imbedded in the heater body.

- Oxidation of coil

2. Electrical Issues – some basic calculations

We need to know: - Wattage
- Voltage

Resistance = $\dfrac{\text{Voltage squared}}{\text{Wattage}}$ = V^2/P = Ω (Ohms)

⇒ Gives hot resistance of coil

But

- This value will change due to the temperature coefficient of resistance or temperature factor.

Fe Cr Al (typically) ⇒ 1.01 @ 200°C
⇒ 1.07 @ 1400°C

Tungsten (typically) ⇒ 1 @ 200°C
⇒ 12 @ 3000°C

- Allowance must be made at design stage to determine ideal cold resistance.
- Additional kiln firing factor affecting ceramic emitters ⇒ causing decrease in tolerance (+/-5%)

Once ideal cold resistance (Fe Cr Al only) is obtained:

- We can vary heater response/coil operating temperature by:

  - Altering coiling mandrel diameter
  - Altering wire diameter ($R = \rho L/A$)

  $\Rightarrow$ Effectively altering overall coil Watt density.

(This principle also applies to Tungsten but we cannot use resistance to design coil.)

- Electrical energy is then consumed in J/s and converted to thermal energy.

- Effects of under and over voltage:

  By rearranging the formula above we get;

  $$\text{Power (P)} = \frac{\text{Voltage}^2\ (V^2)}{\text{Resistance (R)}}$$

  ⇒ This means for a heater of a give resistance an increase in voltage of 10% (1.1) will cause an increase in power output of 1.1^2 or 1.21 (21%).

- Example of "worst-case" scenario:

  1000W, 230V Ceramic emitter is manufactured at lowest resistance tolerance (-5%). The supply voltage is 10% over at 253V.

  Heater hot resistance: 50.3Ω

  Power output = $253^2/50.3$ = 1273W
  ⇒ 27.3% increase in power.

3. The Basics of Heat Transfer.

3 Types:

- Conduction
- Convection
- Radiation

Electrical Energy is produced by heating coil
And converted to thermal energy.
⇓
Thermal energy in coil is transferred
to heater surface by conduction.
⇓
Thermal energy in heater is transferred
to surroundings/source by Radiation/Convection.

- We need to ensure maximum value of Energy is transferred to target by:

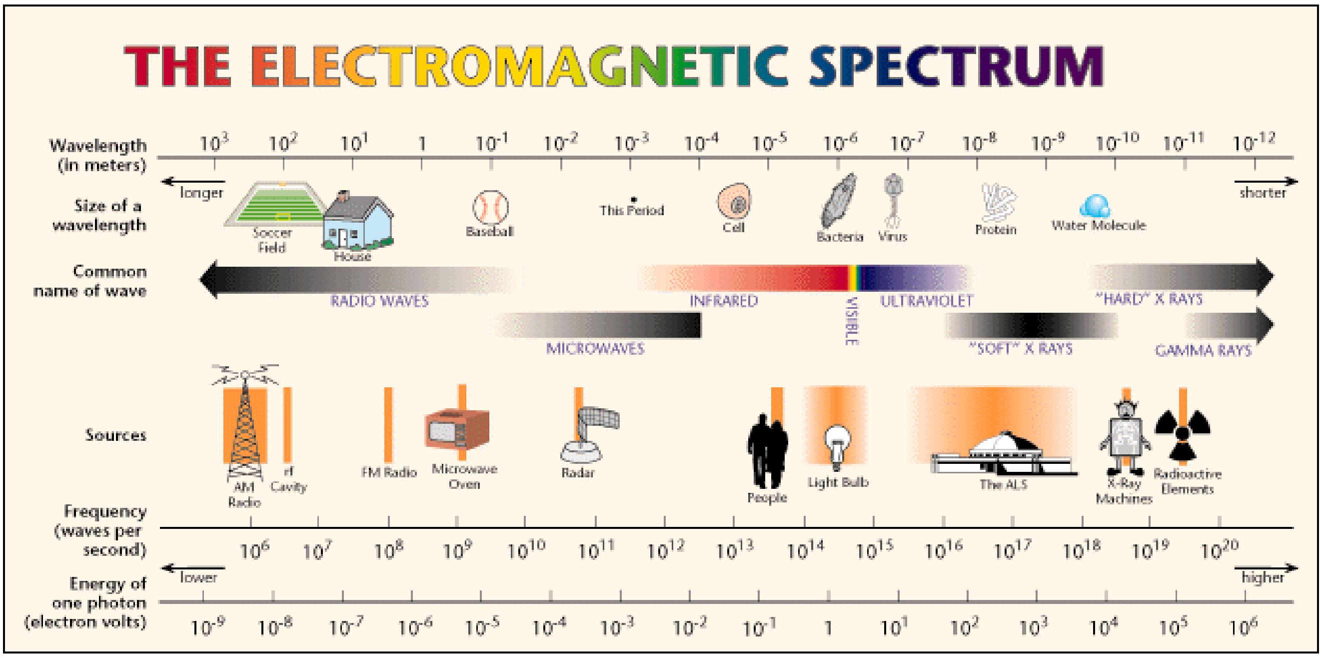
  a) Ensuring minimum heat loss via conduction through back of emitter.

  b) Designing the emitter with as a high a level of radiant efficiency as possible.

c) Matching the emitters IR emission to the targets absorption characteristics.

5. Infrared Energy.

- Any body which has a temperature emits IR radiation
- As source temperature increases the wavelength of the emitted IR becomes shorter.
- Emitted IR energy is either:
  - Absorbed
  - Reflected
  - Transmitted
- The energy levels produced from the above will always total 100% of the total radiant energy emitted from an IR emitter.


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10³ 10² 10¹ 1 10⁻¹ 10⁻² 10⁻³ 10⁻⁴ 10⁻⁵ 10⁻⁶ 10⁻⁷ 10⁻⁸ 10⁻⁹ 10⁻¹⁰ 10⁻¹¹ 10⁻¹²
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10⁶ 10⁷ 10⁸ 10⁹ 10¹⁰ 10¹¹ 10¹² 10¹³ 10¹⁴ 10¹⁵ 10¹⁶ 10¹⁷ 10¹⁸ 10¹⁹ 10²⁰
Energy of one photon (electron volts)
lower
higher
10⁻⁹ 10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10¹ 10² 10³ 10⁴ 10⁵ 10⁶

6. Emissivity

- A blackbody is an ideal infrared source that radiates and absorbs 100% of all radiant energy.

- Emissivity is the ratio of the emitted radiant energy emitted by an object at a given temperature and the radiant energy emitted by a black body at the same temperature.

$$e = W_s / W_{bb}$$

Where: **e = emissivity of source**

W_s = Total radiant energy emitted from a source at temperature T_1

W_{bb} = Total radiant energy emitted from a blackbody at temperature T_1

Relevant spectral radiation laws

- ***Stefan-Boltzmann law*:** Gives the total power radiated at a specific temperature from an infrared source. That is, the entire amount of infrared radiation (at a specific temperature) emitted from a given source at all wavelengths.

- ***Planck's law*:** Gives the spectral distribution of radiation from a blackbody source. That is, a source that emits 100% infrared radiation at a given single temperature.

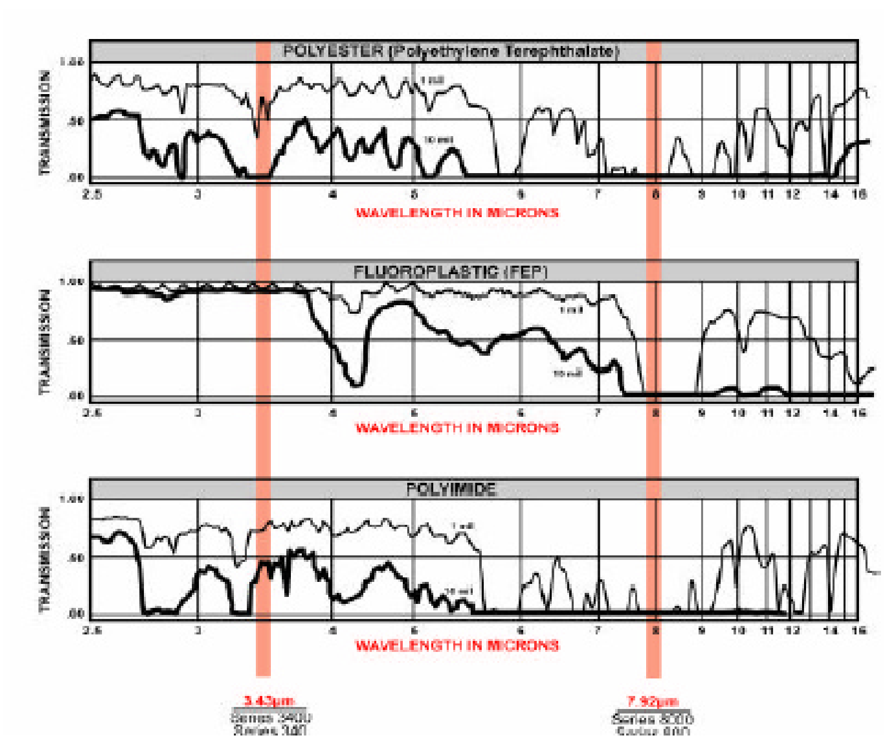
- ***Wien's law*:** Gives the wavelength at which the spectral distribution (given by Planck's law) of the radiation emitted by a blackbody is at a maximum point.

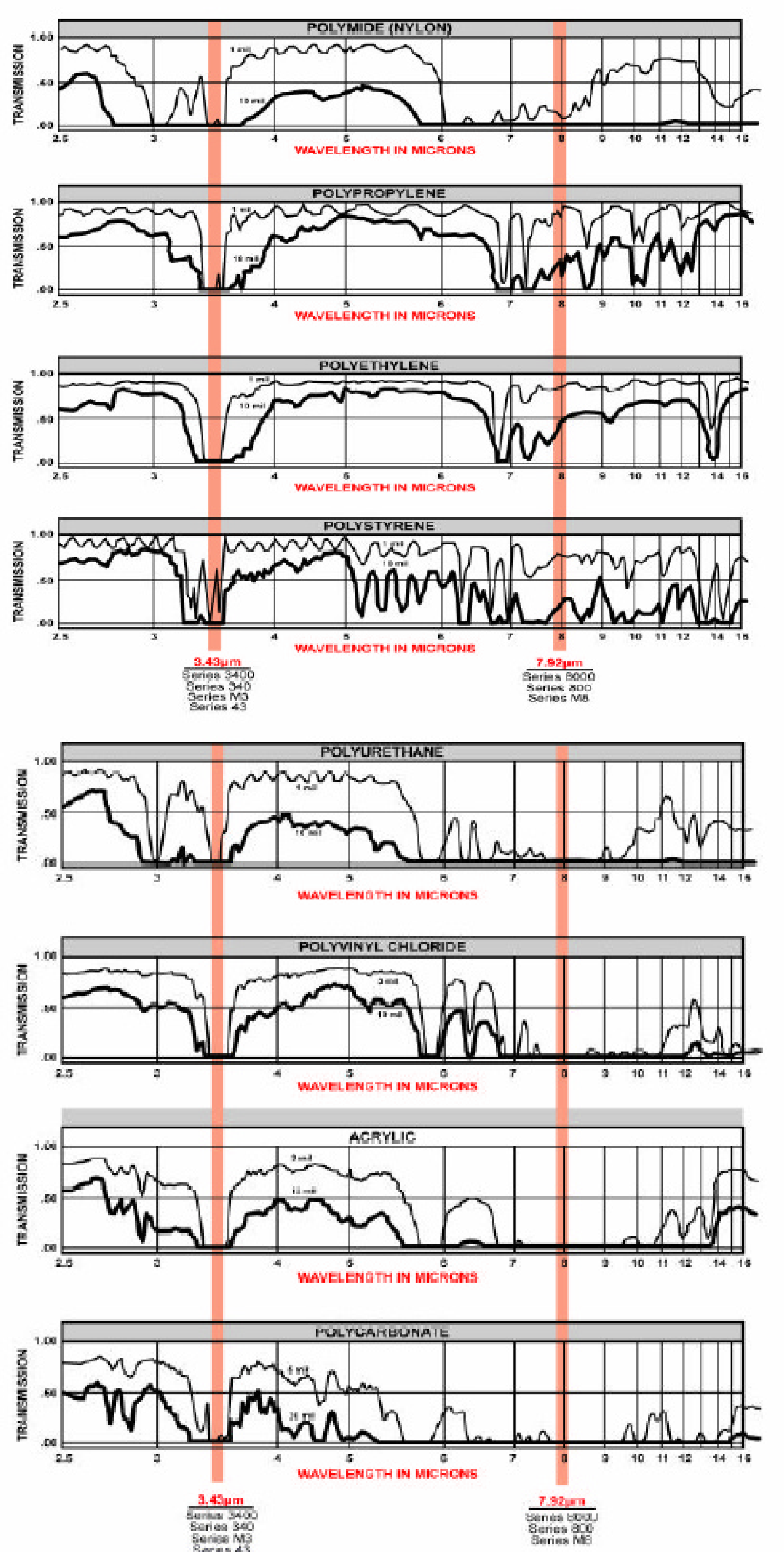
7. Material Properties

- The ability of a material to absorb infrared radiation at particular wavelengths is given by its spectral absorption curve.

- Most plastics absorb radiation in the 2.5 – 15 micron wavelength.

- To obtain fast material processing in any application it is imperative that the absorption characteristics of the material correspond as closely as possibly to the emission characteristics of the IR Emitter.




POLYMIDE (NYLON)
POLYPROPYLENE
POLYETHYLENE
POLYSTYRENE
POLYURETHANE
POLYVINYL CHLORIDE
ACRYLIC
POLYCARBONATE
TRANSMISSION
WAVELENGTH IN MICRONS
3.43µm
Series 3400
Series 340
Series M3
Series 43
7.92µm
Series 8000
Series 800
Series M8