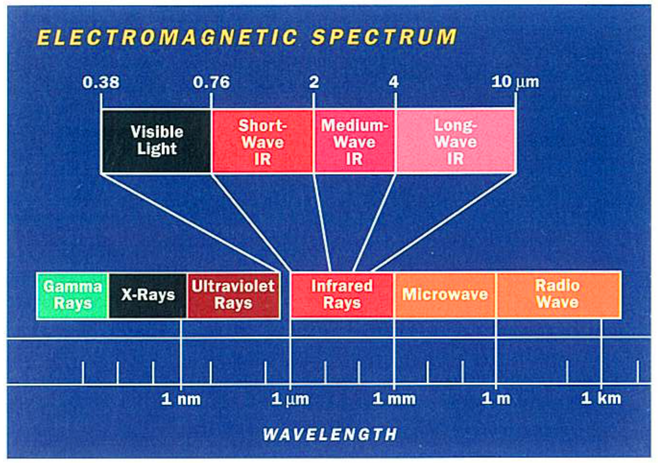
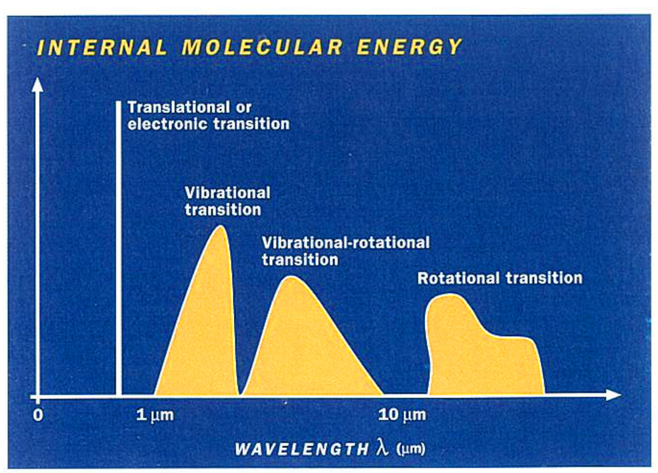
HARNESSING THE POWER OF INFRARED ENERGY



Infrared (IR) energy or radiant energy consists of electromagnetic waves or photons. All materials continuously emit or absorb electromagnetic waves. Therefore, all materials emit or absorb infrared. Infrared is a form of light that is invisible to human eyes but detectable by the feeling of heat on the skin. Infrared occurs at wavelengths just below red light on the electromagnetic spectrum.



Compare this information to the Electromagnetic Spectrum chart (above) and align the wavelengths.

THEORETICAL PRINCIPLES

Infrared energy is within the electromagnetic spectrum between .76 and 1000 µm. Infrared is divided into three ranges: short, medium and long wave infrared. The wavelength of short infrared ranges from .76 to 2 µm. Medium infrared is from 2 to 4 µm. Long infrared for process heating uses from 4 to 10 µm. As the wavelength decreases, the temperature of the radiant source increases. Some emitters crossover into more than one category of radiance. For example, an emitter that is considered to be medium wave infrared operating at a lower temperature can fall into the long wave region.

INTERNAL MOLECULAR ENERGY

All substances absorb and emit radiative energy. Their atoms or molecules carry a certain amount of energy, consisting of kinetic energy and internal molecular energy. The internal molecular energy consists of levels of electronic or translational, vibrational and rotational energy states. Also, higher molecular energy levels are associated with higher temperatures. When molecules collide, photons are absorbed only if they are at the same energy states, or frequency and phase. Therefore, when the molecules are absorbed, they vibrate more and increase the frequency. As the energy increases, the temperature rises.

It is seen that shorter wavelengths are at higher frequency and energy level. Therefore it takes a higher level of energy to be absorbed by atoms at translational level than at rotational levels.

Therefore, all substances are affected by all of these energy states at levels dependent upon the molecular composition of the substance.

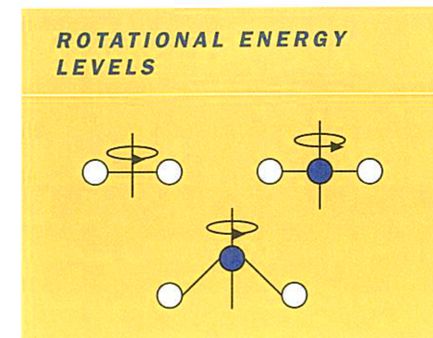
Translational transitions occur in the ultraviolet (UV) range of the spectrum.

Vibrational and rotational transitions occur in the spectrum from short infrared to long infrared.

This is why testing is very important.

INFRARED AND MOLECULAR INTERNAL ENERGY

A molecule increases its energy only when it absorbs a passing photon that has the same frequency and phase. This is how curing and drying occur in infrared heating processes.



MOLECULAR ROTATION

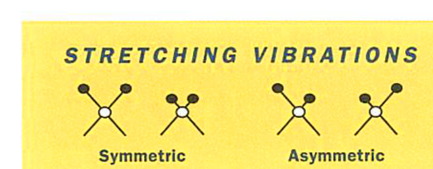
Changes in rotational energy levels take the least amount of energy. Rotational lines are found in the long infrared region (>20 µm). In liquids or solids, these lines broaden into a continuum due to molecular collisions and other interactions.

MOLECULAR VIBRATION

Atoms in a molecule are subject to a number of different vibrations. Vibrations fall into the two main categories of stretching and bending. Vibrational energy levels are found in the medium infrared region (between 1.5 µm and 20 µm). Water and glass absorb energy above 2 µm.

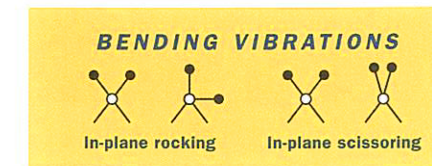
Stretching

Stretching consists of vibration along the central axis, which changes the distance between the atoms.



Bending

Bending consists of a change in the angle between two bonds.

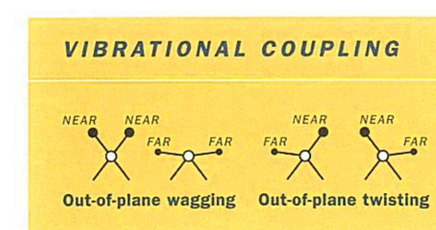


VIBRATIONAL-ROTATIONAL BONDS

Changes in vibrational energy may be accompanied by rotational transitions. These are called vibration-rotation bonds. Therefore, the infrared regions that affect these molecules are from the medium infrared to the long infrared regions.

VIBRATIONAL COUPLING

When a single central atom joins vibrating bonds, vibrational coupling can occur. Coupling between a stretching vibration and a bending vibration occurs if the stretching bond is one side of an angle varied by bending vibration. Vibrational coupling energy changes occur in the short infrared region (between 10^{-2} µm and 1.5 µm).



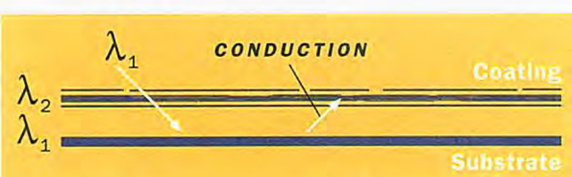
THEORY OF INFRARED ABSORPTION

IR radiation does not have energy to generate electronic transitions as seen with ultraviolet (UV). Absorption of IR only affects substances with small energy differences, or in the vibrational and rotational energy states. For a molecule to absorb IR, the vibrations or rotations within a molecule must cause a net change in the dipole moment of the molecule. If the frequency and phase of the energy radiated corresponds with the vibrational or rotational frequency of the molecule, the energy will be absorbed. The amplitude of the molecular vibration increases causing the substance to increase in temperature.

ABSORPTION

Materials absorb at different wavelengths (λ).

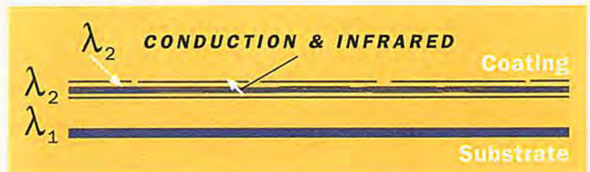
In the figure below, λ_1 represents the wavelength of the emitter and a substrate of a particular material with absorption characteristics whose molecular bonds are affected at a maximum level by the wavelength represented by λ_1.



λ_2 represents a different wavelength. The coating's molecular bonds are affected by λ_2.

λ_1 passes through the coating and adds energy (heats up) to the molecular bonds of the substrate. The coating is cured by conduction, effectively from the inside to the outside or from the bottom up.

In the figure below, λ_2 represents the wavelength of the emitter and a coating of a particular material with absorption characteristics whose molecular bonds are affected at a maximum level by the wavelength



represented by λ_2. λ_1 represents a different wavelength. The substrate's molecular bonds are affected by λ_1. λ_2 heats the surface of the coating and adds energy (heats up) to the molecular bonds of the coating with infrared. The coating is cured by direct infrared and conduction.

CONVECTIVE AND CONDUCTIVE PROPERTIES OF INFRARED

While an infrared emitter is heating an object, certain molecules in the air surrounding the object are also absorbing the infrared energy. This causes convection. Also, as the object is heated, it is losing heat due to losses from the object being hotter than the air. This heat transfer is increasing the temperature of the air causing convection. Also, there is conduction on the surface of the part. Because this process contains convection, conduction, and infrared, the entire object has the opportunity to be heated over its entire surface. Thus, line of sight problem is overcome. Each wavelength of infrared energy has a convective to radiant energy ratio. Short wavelength infrared has the lowest and long wavelength has the highest ratio.

INFRARED-RELATED DEFINITIONS

Planck's law/Planck's distribution:
(blackbody emissive power distribution)

1. The emitted radiation varies continuously with wavelength.
2. At any wavelength the magnitude of the emitted radiation increases with increasing temperature.
3. The spectral region in which the radiation is concentrated depends on temperature, with comparatively more radiation appearing at shorter wavelengths as the temperature increases.
4. A significant fraction of the radiation emitted by the sun, which may be approximated as a blackbody at 5800˚K (9980˚F), is in the visible region of the spectrum. In contrast for $T \leq 800$˚K (980˚F), emission is predominately in the infrared region of the spectrum and is not visible to the eye.

View factor:
Also: configuration factor, angle factor, shape factor, diffuse view factor.

The fraction of radiation leaving a surface area in all directions that is intercepted by another surface area.

Wein's displacement law:

For a blackbody, the product of the wavelength corresponding to the maximum radiancy and the thermodynamic temperature is a constant, Wein's displacement law constant. As a result, as the temperature rises, the maximum of the radiant energy shifts toward the shorter wavelength (higher frequency and energy) end of the spectrum.

Flux:

Amount of energy (watts) per square inch of emitter. Watts density.

Stefan-Boltzman Law:

Calculates the maximum flux, which may be emitted from a surface at the absolute temperature of the surface. Thermal radiation flux is proportional to the fourth power of the temperature.

$$q \propto T^4$$

For convection, the heat flux is directly proportional to the temperature.

$$q \propto T$$

Emissivity:

Property that indicates how efficiently the surface emits compared to an ideal radiator (blackbody). Radiative efficiency.

Blackbody:

Perfect absorber. Emissivity = 1