3. Theory of Blackbody

3.1 Blackbody Radiation

Any object with a temperature higher than absolute zero radiates to its surrounding environment and this radiation is called thermal radiation. Blackbody is a perfect thermal radiation object, meaning that the radiation flux of any non-blackbody is less than that of a blackbody at the same temperature. Furthermore, the radiation ability of a non-blackbody depends not only on its temperature, but also on the characteristics of its surface material. By contrast, the radiation ability of a blackbody depends solely on its temperature. Moreover, the radiation of a blackbody is uniform with no directivity and thus a blackbody is a perfect Lambertian radiator. Any other object whose radiation ability is less than that of a blackbody while sharing a similar radiation spectrum, are called "grey body".

3.2 Law of Blackbody Radiation

3.2.1 Spectral Distribution of Blackbody-Planck's Law of Blackbody Radiation

Planck's Law describes the radiant emittance of a perfect blackbody as a function of its temperature and the wavelength of the emitted radiation

$$E_{\lambda T} = \frac{C_1}{\lambda^5 (e^{\frac{C_2}{\lambda T}} - 1)} \quad (\mathrm{W/m^3}) \tag{1}$$

where C_1 is the first radiation constant (3.74×10^{-16} W•m^2), C_2 is the second radiation constant (1.4398×10^{-2} m•K). The intensity of blackbody radiation is given by following:

$$L_{\lambda T} = \frac{E_{\lambda T}}{\pi} \quad (\frac{W}{m^3 Sr}) \tag{2}$$

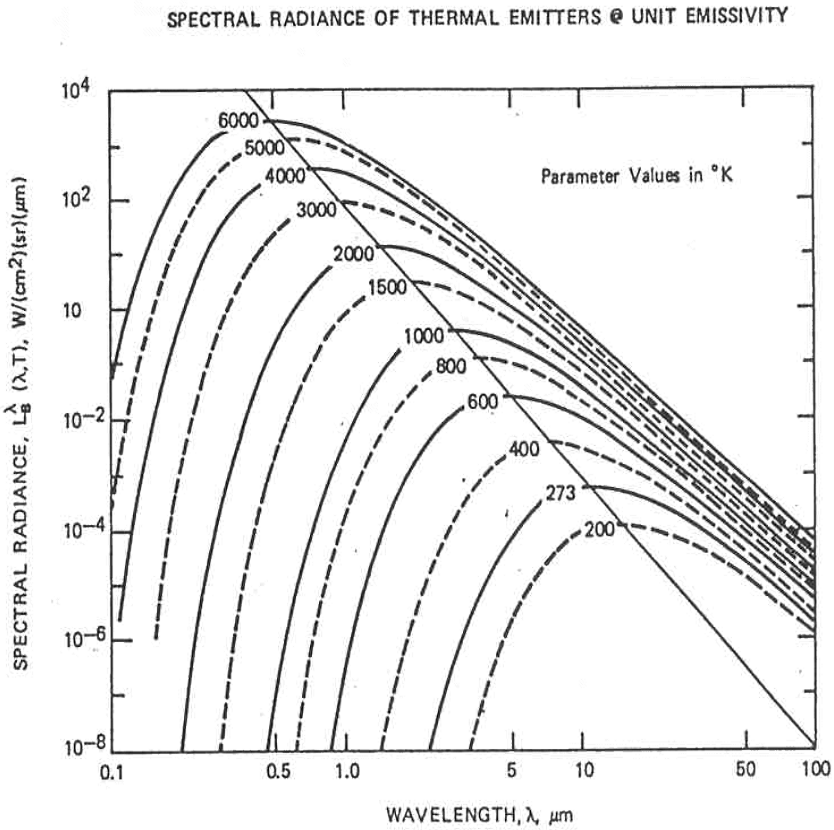

Figure 1 Spectral radiance of thermal emitters at unit emissivity derived from Planck's equation. These curves give the radiance of a blackbody at various temperatures (in degrees Kelvin)

3.2.2 Integration of Blackbody Radiation - Stefan-Boltzmann Law

The total intensity emitted by a blackbody at absolute temperature T is described by the Stefan-Boltzmann law:

$$E_T = \int_0^\infty E_{\lambda T} d\lambda = \delta T^4 \quad (\mathrm{W/m^2}) \tag{3}$$

where δ is the Stefan-Boltzmann constant

$$\delta = \frac{2\pi^5 k^4}{15 h^3 c^2} = 5.670\times10^{-8} \left(\frac{W}{m^2 K^4}\right)$$

where k is the Boltzmann constant, h is the Planck constant, and c is the speed of light in vacuum. Because blackbody radiation is uniform with no directivity, the radiation intensity of a blackbody depends on radiant emittance as

$$L = \frac{E_T}{\pi} \tag{4}$$

Then the Stefan-Boltzmann Law can be expressed in terms of radiation intensity

$$L = \frac{\delta}{\pi} T^4 \quad (\frac{W}{m^2 Sr}) \tag{5}$$

3.2.3 Wien's Displacement Law

According to Wien's displacement law, a peak wavelength at which the emitted intensity per wavelength interval by a blackbody is the largest, is inversely proportional to the absolute temperature of the blackbody.

$$\lambda_{\max} = \frac{A}{T} \tag{6}$$

where A is constant (2.896×10^{-3} m•K). As the temperature increases, the peak wavelength of the absolute blackbody emission shifts to shorter wavelengths.