SYMMETRY

Some Radiation Thermometers

[-; Transactions In Measurement and Control, Volume 1, 2nd Edition, Non-Contact Temperature Measurement; Omega, 1998.]

Narrow Band Radiation Thermometers

As the name indicates, narrow band radiation thermometers operate over a narrow range of wavelengths. Narrow band devices can also be referred to as single color thermometers. The specific detector used determines the spectral response of the particular device. For example, a thermometer using a silicon cell detector will have a response that peaks at approximately 0.9 µm, with the upper limit of usefulness being about 1.1 µm. Such a device is useful for measuring temperatures above 600 °C. Narrow band thermometers routinely have a spectral response of less than 1 µm.

Narrow band thermometers use filters to restrict response to a selected wavelength. Probably the most important advance in radiation thermometry has been the introduction of selective filtering of the incoming radiation, which allows an instrument to be matched to a particular application to achieve higher measurement accuracy. This was made possible by the availability of more sensitive detectors and advances in signal amplifiers.

Common examples of selective spectral responses are 8 to 14 µm, which avoids interference from atmospheric moisture over long paths; 7.9 µm, used for the measurement of some thin film plastics; 5 µm, used for the measurement of glass surfaces; and 3.86 µm, which avoids interference from carbon dioxide and water vapor in flames and combustion gases.

The choice of shorter or longer wavelength response is also dictated by the temperature range. The peaks of radiation intensity curves move towards shorter wavelengths as temperature increases, as shown in Figure 1. Applications that don't involve such considerations may still benefit from a narrow spectral response around 0.7 µm. While emissivity doesn't vary as much as you decrease the wavelength, the thermometer will lose sensitivity because of the reduced energy available.

Narrow band thermometers with short wavelengths are used to measure high temperatures, greater than 500 °C, because radiation energy content increases as wavelengths get shorter. Long wavelengths are used for low temperatures -45.5 °C.

Narrow band thermometers range from simple hand-held devices, to sophisticated portables with simultaneous viewing of target and temperature, memory and printout capability, to on-line, fixed mounted sensors with remote electronics having PID control.

Standard temperature ranges vary from one manufacturer to the next, but some examples include: -37.78 to 600 °C, 0 to 1000 °C, 600 to 3000 °C and 500 to 2000 °C. Typical accuracy is 0.25 % to 2 % of full scale.

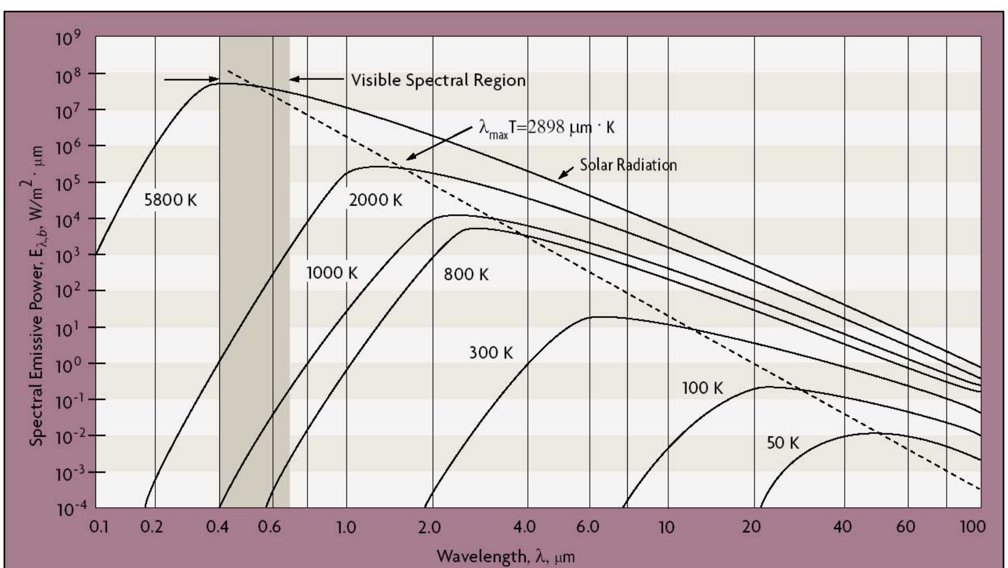

Figure 1 Planck Prediction of Blackbody Emissive Power

Ratio Radiation Thermometers

Also called two-color radiation thermometers, these devices measure the radiated energy of an object between two narrow wavelength bands, and calculates the ratio of the two energies, which is a function of the temperature of the object. Originally, these were called two color pyrometers, because the two wavelengths corresponded to different colors in the visible spectrum (for example, red and green). The temperature measurement is dependent only on the ratio of the two energies measured, and not their absolute values as shown in Figure 2. Any parameter, such as target size, which affects the amount of energy in each band by an equal percentage, has no effect on the temperature indication. This makes a ratio thermometer inherently more accurate. However, some accuracy is lost when you're measuring small differences in large signals.

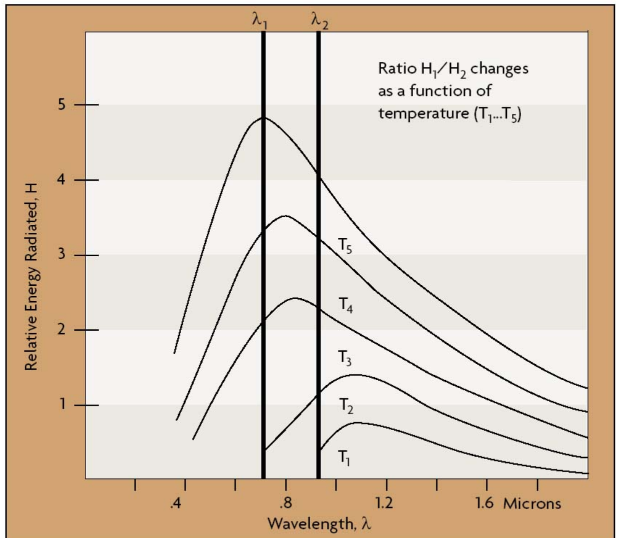

Figure 2 The 'Two-Color' IR Thermometer

The ratio technique may eliminate, or reduce, errors in temperature measurement caused by changes in emissivity, surface finish, and energy absorbing materials, such as water vapor, between the thermometer and the target. These dynamic changes must be seen identically by the detector at the two wavelengths being used.

Emissivity of all materials does not change equally at different wavelengths. Materials for which emissivity does change equally at different wavelengths are called gray bodies. Materials for which this is not true are called non-gray bodies. In addition, not all forms of sight path obstruction attenuate the ratio wavelengths equally. For example, if there are particles in the sight path that have the same size as one of the wavelengths, the ratio can become unbalanced.

Phenomena which are nondynamic in nature, such as the nongray bodiness of materials, can be dealt with by biasing the ratio of the wavelengths accordingly. This adjustment is called slope. The appropriate slope setting must be determined experimentally.

Figure 3 shows a schematic diagram of a simple ratio radiation thermometer.

Some ratio thermometers use more than two wavelengths. These devices employ a detailed analysis of the target's surface characteristics regarding emissivity with regard to wavelength, temperature, and surface chemistry. With such data, a computer can use complex algorithms to relate and compensate for emissivity changes at various conditions. A example of multiwavelength system makes parallel measurement in four spectral channels in the range from 1 to 25 µm. The detector in this device consists of an optical system with a beam splitter, and interference filters for the spectral dispersion of the incident radiation. This uncooled thermometer was developed for gas analysis. Another experimental system, using seven different wavelengths demonstrated a resolution of ±1 °C measuring a blackbody source in the range from 600 to 900 °C. The same system demonstrated a resolution of ±4 °C measuring an object with varying emittance over the temperature range from 500 to 950 °C.

Two color or multi-wavelength thermometers should be seriously considered for applications where accuracy, and not just repeatability, is critical, or if the target object is undergoing a physical or chemical change.

Ratio thermometers cover wide temperature ranges. Typical commercially available ranges are 900 to 3000 °C and 50 to 3700 °C. Typical accuracy is 0.5 % of reading on narrow spans, to 2 % of full scale.

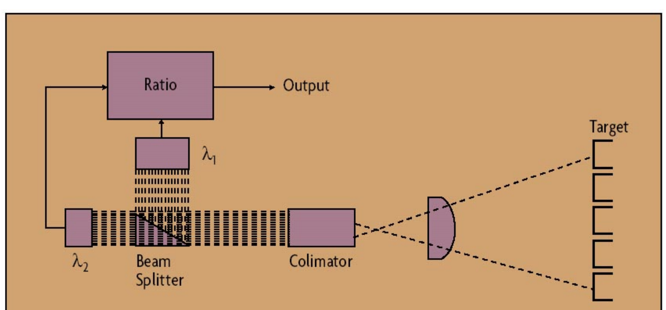

Figure 3 Beam-Splitting in the Ratio IR Thermometer

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