Real Time Emissivity Measurement for
Infrared Temperature Measurement

Pyrolaser®, Pyrofiber® & Optitherm® III Emissivity Technology

While infrared thermometry has been used for many years in industrial applications, the measurement of temperature utilizing this technology has been restricted due to inherent infrared weaknesses; the actual emissivity of the target material. The greatest deficiency is quite fundamental; infrared thermometers measure radiance received from a target i.e. one variable, while integration of Planck's radiation law governing the relationship between the radiance and temperature measurement requires knowledge of a second variable, the target surface emissivity. The solution has been a combination of operator estimates based on experience, or use of dual and multi-wavelength pyrometers, which attempt to sidestep the mathematical problem by ratioing-out the emissivity using two or more simultaneous measurements of the radiance. For many applications operator experience and multi-wavelength technology are not valid. Emissivity varies with surface condition, temperature, wavelength and time. Without determining a targets emissivity value, true target temperature cannot be determined. Use the ePyroCal emissivity Calculator to determine just how emissivity errors can impact infrared temperature measurements.

The Pyrolaser® & Pyrofiber® infrared thermometer instruments use a patented laser based infrared technology to determine a targets True Emissivity Correct Temperature (Te). Pyrolaser® & Pyrofiber® accomplishes this by automatically measuring the target diffuse reflectivity at the same location, temperature and wavelength as the radiance measurement to determine the precise target temperature.

Pyrolaser® & Pyrofiber® incorporates the passive characteristics of conventional infrared thermometers along with an active reflectometer technique to determine the target emissivity. A low-powered pulsed GaAS laser is fired at the target measuring zone via a dedicated optical path (Laser Channel) and both the laser return signal and infrared signal are detected via a secondary optical path (Radiance Channel); the laser signal being (AC) on top of the (DC) target signal. Having monitored the laser outgoing energy and knowing the geometry involved (including target distance), Pyrolaser® & Pyrofiber® can determine the reflectivity and thus the emissivity of the target measuring zone. The wave band of the collected target radiance is limited to a narrow (10-50nm) band centered in the laser wavelength typically 865nm, 905nm or 1550nm depending on the specific instrument or application.

Real Time Emissivity Measurement

The emissivity is measured by firing a pulsed laser of monitored output energy (**Lo**) to the target and measuring the reflected laser energy (**Lr**). Assuming that no energy is transmitted through the target (opaque material) the impinging energy (**Lo**) must either be absorbed or reflected. The unknown absorbed energy (**La**) can be calculated from the two measured quantities outgoing energy (**Lo**) and reflected energy (**Lr**):

$$La = Lo - L$$

Absorptivity (**a**) and reflectivity (**r**) of the target are the normalized values of this equation:

$$a = La/Lo = 1 - Lr/Lo = 1 - r$$

Since absorptivity (**a**) and emissivity (**e**) are equal, as discussed earlier, the target emissivity (**e**) is known as soon as the absorptivity (**a**) is known.

$$e = a = 1 - r$$

Above consideration is only true for the total hemispherical integral of the reflected energy(**r**). As the instruments optical sensor path captures only a small solid angle from the total hemisphere it must be guaranteed that the target has a Lambertian surface reflecting homogeneously into a hemisphere. Small specular portions are acceptable as long as it avoids the specular reflected energy from hitting the receiving channel. The provided optics guarantees this if mounted with its axis perpendicular to the target surface.

Temperature Measurement

The temperature is measured by collecting the radiance in a narrow band (10-50nm) at the same wavelength (865nm, 905nm or 1550nm depending on the specific instrument) where emissivity is measured with the laser. In a first step the measured radiance **Qm** is corrected with measured emissivity **e** to a black body radiance **Qb**:

$$Qb = Qm / e$$

Using this black body radiance, the Pyrofiber® then calculates according to Planck's radiance law for the true temperature (**T**) of the target.

$$T = CO / \text{1n}\,(C1/Qb + 1) \quad \text{With } CO = \frac{\mathbf{h * c}}{\lambda * k}$$

C1 is a calibration constant depending on the efficiency of the optics and electronics.

h = Planck's constant = 6.625*10E-34 Wss

c = velocity of light = 2.998*10E+8 m/s

k = Boltzmann's constant = 1.380*10E-23 Ws/K

λ = Pyrofiber® Wavelength = 865*10E-9 m

In case of irradiance being present the black body radiance **Qb** is calculated by taking this extraneous radiance **Qx** according to the measured reflectivity (**r**) into account to:

$$Qb = (Qm - r*Qx) / (1-r)$$

Once the radiance is corrected to black body radiance all temperature calculations use the same above temperature formula. Thus offering the highest degrees of temperature measurement accuracy.

For additional technical and research information, see
International Fair of Metallurgy industry article