10. Infrared Radiation Thermometers

Monochromatic optical pyrometers working at wavelengths in or near the visible spectrum are generally calibrated using tungsten strip-filament lamps as transfer standards. For temperatures below 1100 K (or 700 °C) such a procedure is not possible, even when the instrument is monochromatic, because there is insufficient short-wavelength radiation at these lower temperatures. Much radiation thermometry, moreover, relies upon infrared wavelengths over broad bands. These infrared pyrometers must be calibrated against blackbodies. A calibration on the ITS-90 would demand that the radiation thermometer be sighted on a blackbody the temperature of which was simultaneously measured with a standard platinum resistance thermometer. An alternative secondary realization that is just as accurate as a primary calibration below 1064 °C has been devised by Sakuma and Hattori (1982b). They use a set of metal freezing point (Cu, Ag, Al, Zn, and optionally Sb) blackbody furnaces, each of rather small dimensions and housing a graphite blackbody crucible containing 26 cm^3 of 99.999% pure metal (see Sec. 3.4). Freezing plateaux of about 10 minute duration are shown to be accurate to -0.1 ± 0.1 K. A monochromatic infrared radiation thermometer with a silicon-photodiode detector operating at 900 nm with a passband halfwidth of 14 nm is used as a transfer with these furnaces. It is known that in general the mean effective wavelength (λ_e) of a monochromatic radiation thermometer varies with temperature as

$$\lambda_e = A + (B / T) \qquad (10.1)$$

So long as the detector current is sufficiently small (say, < 1 μA), the signal voltage (V(T)) is proportional to the blackbody spectral radiance, i.e.

$$V(T) = C \exp(-c_2/\lambda T) , \qquad (10.2)$$

where Wien's equation is taken as a close enough approximation to Planck's equation. Substituting for λ in Eq. (10.2) from Eq. (10.1) gives

$$V(T) = C \exp\left(- \frac{c_2}{AT + B} \right) \quad . \qquad (10.3)$$

In principle the parameter C, which depends on geometrical and spectral factors and on the detector responsivity, contains a quantity λ_e^{-5}; it is assumed that λ_e is constant insofar as the parameter C is concerned. The three parameters A, B, C are calculated from a least-squares fit of V(T) to the voltages measured at the four (or five) fixed points and Eq. (10.3) is used to interpolate from 400 °C to 2000 °C. A typical calibration is shown in Fig. 10.1. In this way a secondary realization is obtained that is accurate to within ± 0.3 °C at the fixed points, ±t 0.5 °C from 600 °C to 1100 °C. and ± 2 °C at 1500 °C. The scale can be disseminated by calibrating sets of fixed-point furnaces against which other pyrometers are calibrated as above (the preferred way), or by using a variable-temperature blackbody radiator to compare an uncalibrated thermometer with the standard radiation thermometer at a number of temperatures.

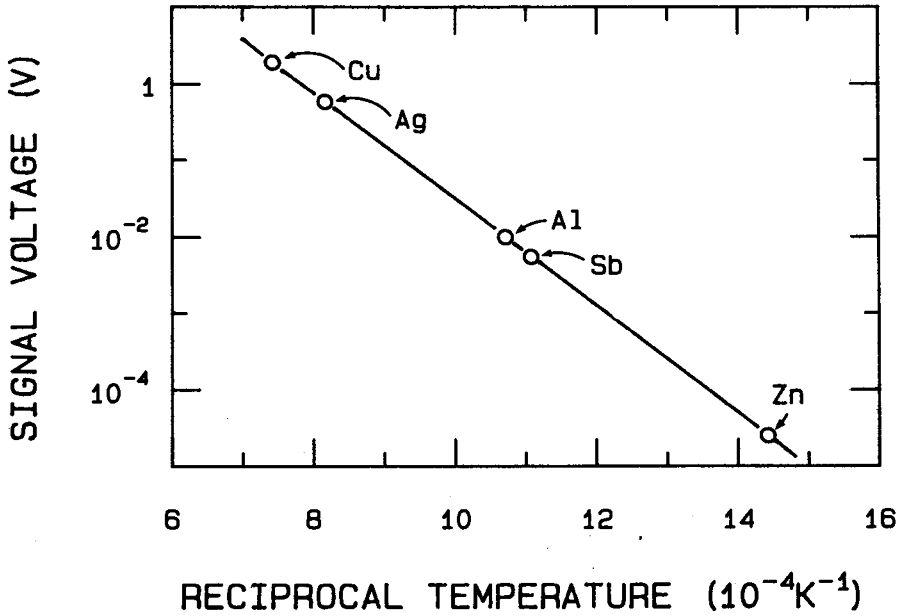

Fig. 10.1: Relationship between signal voltage of an infrared radiation thermometer and reciprocal temperature after calibration at five metal freezing points [after Sakuma and Hattori (1982b)].

Continuous advances in photodetector technology in recent years have also led to new precision pyrometers working in the visible and near infrared. Typical examples are the instrument developed by Woerner (1982) that works at the conventional 650 nm, and those of Rosso and Righini (1984) and Ruffino (1984) that use silicon detectors and are thus capable of operation either in the visible or in the near infrared near 900 nm. Each of these newer instruments is based on a single optical channel and the temperature scale realized with the original calibration is then maintained for long periods of time on the detector itself and its related optical and electronic components. This is made possible by the good stability and linearity of the photodetectors so that corrections for linearity are almost negligible. The final accuracy achievable with these instruments depends on the overall stability of the various optical components over long periods of time and on the possibility of recalibration at one point using an external lamp or freezing-point blackbody. The long-term stability of these instruments and the preferred calibration techniques for them have still to be assessed.