Emissivity compensation for Fluke Calibration 4180 Series Precision Infrared Calibrators

Application Note

To perform accurate infrared thermometer calibration, it's important to properly adjust the emissivity settings for both the Fluke Calibration 4180 Series Precision Infrared Calibrators and the infrared thermometer. The emissivity setting of the Fluke Calibration 4180 or 4181 should be set to the same setting as the infrared thermometer's emissivity setting during a calibration. If an infrared thermometer has adjustable emissivity, this setting should be 0.95 on both instruments. If this is not possible, the 418X can compensate for a limited number of emissivity settings other than 0.95.

The Fluke Calibration 418X models use a band limited version of Planck's Law for the emissivity compensation. This method has been patented[1]. The band limiting is based on the 8 µm to 14 µm band. The Sakuma-Hattori Equation and measurement equations as found in ASTM E2758 can be used to determine this effect in place of Planck's Law[2]. The Sakuma-Hattori Equation is shown in Equation 1. When using the Sakuma-Hattori Equation, always convert the temperature values to Kelvins. To convert from degrees Celsius to Kelvins, add 273.15. The values for the constants are shown for the 8 µm to 14 µm band[1]. More information on the Sakuma-Hattori Equation can be found online[3]. The measurement equation is shown in Equation 2.

$$S(T) = \frac{C}{\exp\left(\frac{c_2}{AT+B}\right) - 1}$$

Equation 1. Sakuma-Hattori Equation.

Where:
A: constant (9.364 µm for the 8 – 14 µm band)
B: constant (178.4 µm·K for the 8 – 14 µm band)
C: constant (1.0)
c_2: constant (14387.752 µm·K)
T: temperature (in K)
S(T): radiometric signal

$$\varepsilon_{instr} S(T_{meas}) + (1-\varepsilon_{instr}) S(T_d) = \varepsilon_S S(T_S) + (1-\varepsilon_S) S(T_W)$$

Equation 2. Measurement equation.

Where:
T_{meas}: readout temperature of the infrared thermometer
T_S: temperature of the calibration source
T_d: infrared thermometer detector temperature
T_W: reflected temperature
ε_S: calibration source's emissivity
ε_{instr}: infrared thermometer's emissivity

The measurement equation is rewritten to determine the adjusted source temperature as shown in Equation 3. The detector temperature is assumed to be the same as the reflected temperature. The 418X uses the same equation to compensate for emissivity.

$$S(T_S) = \frac{\varepsilon_{instr}}{\varepsilon_S} S(T_{meas}) + \frac{\varepsilon_S - \varepsilon_{instr}}{\varepsilon_S} S(T_w)$$

Equation 3. Measurement equation solving for adjusted source temperature.

As an example, consider that we want to measure a temperature on an infrared thermometer of 100 °C. The infrared thermometer has a fixed emissivity setting of 0.99. Our source is calibrated at an emissivity of 0.95. The reflected temperature in our laboratory is 23.0 °C. What do we need to set our source to in order to compensate for this difference in emissivity?

The values we know are, T_{meas} = 100 °C, T_W = 23.0 °C, ε_S = 0.95, and ε_{instr} = 0.99. The next step is to calculate $S(T_{meas})$ and $S(T_W)$, which are calculated to be S(373.15 K) = 0.020292 and S(296.15 K) = 0.007697. At this point we are ready to calculate $S(T_S)$. This is done in Equation 4. This type of a calculation is best implemented in a spreadsheet.

$$S\left(T_S\right) = \frac{0.99}{0.95} 0.020292 + \frac{0.95 - 0.99}{0.95} 0.007697 = 0.020822$$

$$T_S = 375.70\ K = 102.55\ °C$$

Equation 4. Example calculation of adjusted source temperature.

The Fluke Calibration 4180 Series Precision Infrared Calibrators automatically perform this mathematical process when compensating for emissivity.

References

1. US Patent 7,661,876, Infrared Target Temperature Correction System and Method, 2010.
2. ASTM E2758 - 10 Standard Guide for Selection and Use of Wideband, Low Temperature Infrared Thermometers, 2010.
3. Sakuma–Hattori equation, retrieved from http://en.wikipedia.org/wiki/Sakuma-Hattori_Equation on 12 January 2012.

Fluke Calibration
PO Box 9090,
Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (877) 355-3225 or Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or Fax +31 (0) 40 2675 222
In Canada (800)-36-FLUKE or Fax (905) 890-6866
From other countries +1 (425) 446-5500 or Fax +1 (425) 446-5116
Web access: http://www.flukecal.com

Printed in U.S.A. 10/2012 4276605A_EN
Pub_ID: 11981-eng