

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 patented¹. 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 Law². 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 band¹. More information on the Sakuma-Hattori Equation can be found online³. The measurement equation is shown in Equation 2.

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

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)
- c₂: constant (14387.752 μm·K)
- T: temperature (in K)
- S(T): radiometric signal

$$\epsilon_{instr} S(T_{meas}) + (1 - \epsilon_{instr}) S(T_d) = \epsilon_s S(T_s) + (1 - \epsilon_s) S(T_w)$$

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.

$$S(T_s) = \frac{\epsilon_{instr}}{\epsilon_s} S(T_{meas}) + \frac{\epsilon_s - \epsilon_{instr}}{\epsilon_s} S(T_w)$$

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 in order to compensate for this difference in emissivity?

The values we know are, $T_{meas} = 100\text{ °C}$, $T_w = 23.0\text{ °C}$, $\epsilon_s = 0.95$, and $\epsilon_{instr} = 0.99$. The next step is to calculate $S(T_{meas})$ and $S(T_w)$, which are calculated to be $S(373.15\text{ K}) = 0.020292$ and $S(296.15\text{ K}) = 0.007697$. 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.

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

$$T_s = 375.70\text{ K} = 102.55\text{ °C}$$

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.



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