Infrared Thermometer Calibration

By Frank Liebmann

Training Objective: The objective of this article is to give laboratory personnel a basis to set up a calibration program for infrared thermometers. While this information is not a complete set of instructions, it contains a number of factors that commonly result in errors to people who are calibrating these devices.

What Is an Infrared Thermometer Measuring?

An infrared thermometer is a non-contact thermometer, since it doesn't touch the surface being measured. It measures thermal radiation in the infrared region of the electromagnetic spectrum beyond where the eye can see. A common spectral band for measuring temperatures from below ambient up to 500 °C or 1000 °C is the 8 – 14 µm band. This is partly because at room temperature, the peak energy occurs just below 10 µm.

As temperatures get higher, this peak wavelength becomes shorter. Most people have seen a "red hot" piece of metal. This is because the human eye can see this thermal radiation. The metal is red hot because the radiation has a significant enough amount of energy in the shorter wavelengths where the human eye can see, between 0.3 and 0.7 µm. This occurs at some point above 600 °C. The Sun's surface temperature is at a temperature between 5000 and 5500 K. The peak wavelength for these temperatures is roughly 0.5µm, right in the middle of the range visible to the human eye.

Pitfalls in Infrared Thermometer Measurement

There are a number of factors which can increase uncertainty and cause errors when using infrared thermometers. An adequate uncertainty budget should help point these out. There are two which cause people more problems than others, emissivity and size-of-source.

Emissivity

Emissivity is a material's ability to radiate compared to a perfect blackbody. It can have a value from anywhere from 0.0 to 1.0. Bare metal tends to have a low emissivity; oxidized metal tends to have a moderate emissivity; non metals tend to have high emissivity [1]. Typically, it is difficult to control a surface's emissivity to within ±0.01 [2]. In the 8 – 14 µm band, an uncertainty in emissivity of 0.01 translates to a uncertainty of 0.6 K at 100 °C and 3.4 K at 500 °C. This is illustrated in Figure 1.

Field-of-View

Handheld IR thermometers usually come equipped with a laser pointer. This serves as a guide to show where the infrared thermometer is pointed. However, these pointers can be misleading in two respects. First, the laser provides a finite point. In fact, the infrared thermometer is typically measuring a non-finite area or spot which will be discussed shortly. Second, typically the laser center does not represent the center of the spot.

Using IEC terminology, the measure for the size of this spot is field-of-view [3]. In a nutshell, field-of-view specifies that the infrared thermometer will measure a certain percentage of energy within a specified diameter at a given distance. What about the energy measured outside of this diameter? This is called scatter, and the infrared thermometer is measuring it as well. Most infrared thermometers come with a diagram, or a specification of distance to size ratio (D:S). The diameter specified by this ratio only contains a certain percentage of the radiation received by the infrared thermometer. For a measurement, it is best to have at least two times this ratio in diameter [1] as is shown in Figure 2. For calibration, the diameter of the source should be at least three times this diameter [4]. For this reason, a flat-plate is often used as a thermal radiation source instead of a cavity. At a minimum, the measuring distance and diameter of the source should be stated on the calibration certificate.

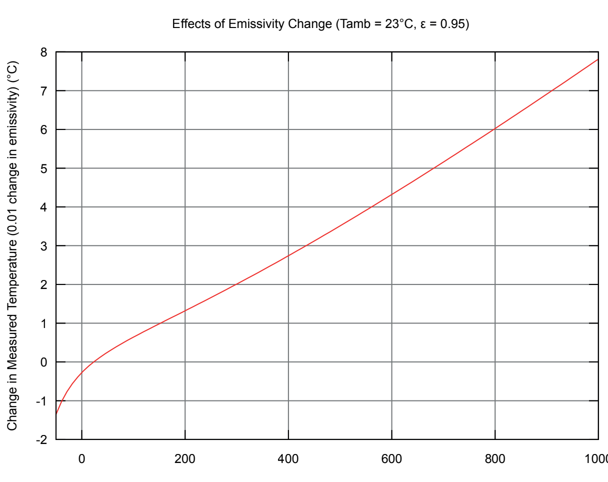

Figure 1. Effect of emissivity error.

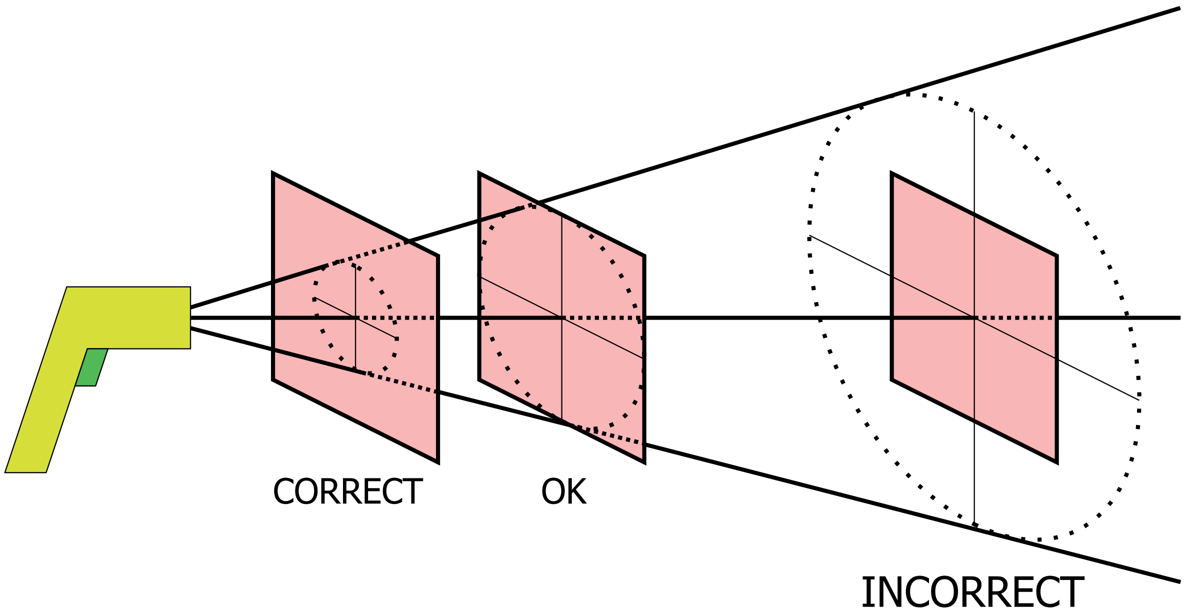

Figure 2. Proper measurement size-of-source.

Equipment Needed for Calibration

Table 1 provides a list of equipment for infrared thermometer calibration [5].

Mandatory Equipment	
Thermal Radiation Source	Two Types: • Cavity (preferred) • Flat-plate (large size-of-source)
Transfer Standard	Two Types: • Contact thermometer • Radiation thermometer
Ambient Temperature Thermometer	Monitors laboratory temperature.
Mounting Device	Tripod, fixture, or technician's hand.
Distance Measuring Device	Can be a by ruler, tape measure, or fixturing.
Optional Equipment	
Aperture	Needed only if requested by user or required by manufacturer.
Purge Device	• Cold Temperatures: Prevents ice or dew build-up • High Temperatures: Prevents oxidation • May also improve temperature gradients

Table 1. Mandatory and optional calibration equipment.

Calibration of the Thermal Radiation Source

There are two methods to calibrate the radiation source. One is using a contact transfer and the other a radiometric transfer. The contact calibration has the advantage in that it is not wavelength dependant. The contact transfer does not account for the 'heat exchange' error [6]. When a flat-plate source is used, it also may result in a large uncertainty for emissivity [5]. The radiometric transfer has the advantage in that it accounts for the errors caused by heat exchange (between the reference probe and the radiation source's surface) and for not well defined emissivity. The radiometric transfer standard must be of the same wavelength as the infrared thermometer's calibrated using the thermal radiation source [5].

Basic Infrared Thermometer Calibration Procedure

Before calibrating an infrared thermometer, the infrared thermometer should be allowed to reach room temperature. This is especially important when moving an infrared thermometer from one environment to another. Typically, 30 minutes is sufficient.

The basic infrared thermometer procedure for a calibration point should include the following steps [5]:

1. If a purge device is used, set up the purge.
2. Allow the thermal radiation source to stabilize at its set-point.

3. If available, set the infrared thermometer's reflected temperature setting to the reflected temperature.
4. Set the infrared thermometer's emissivity to the emissivity of the thermal radiation source.
5. Set the measuring distance of the infrared thermometer.
6. Align the infrared thermometer so that it is centered on the thermal radiation source.
7. Perform the measurement.
8. Repeat these steps for repeatability if needed.

There are a few notes and exceptions to consider when performing these steps. First, most infrared thermometers do not have a reflected temperature setting. Instead, the reflected temperature is detected within the instrument. Second, some infrared thermometers do not have an adjustable emissivity setting. In these cases, if the emissivity setting of the infrared thermometer does not match the emissivity of the thermal radiation source, mathematical corrections may be made.

When using a handheld infrared thermometer, it is typical to initiate a measurement by pulling a trigger. The trigger should be held a significant amount of time longer than the infrared thermometer's specified response time. Finally, the number of set points measured should be driven by the customer. If the infrared thermometer is only used over a narrow temperature range, one or two points may be sufficient. If the infrared thermometer is used over a wide range, three or more points may be necessary. This should be driven by the customer. However, the calibration laboratory should be ready to offer advice.

Where to go for more information?

Reading

- *Radiometric Temperature Measurements, Vol. 1: Fundamentals*, eds. Z. Zhang, B. Tsai, G. Machin (2009, Academic Press)
- *Theory and Practice of Radiation Thermometry* by D.P. DeWitt and Gene D. Nutter (John Wiley & Sons)
- R*adiation Thermometry: Fundamentals and Application in the Petrochemical Industry* by Peter Saunders (SPIE)

Courses

- Radiation Thermometry Short Course (NIST) – Held once a year in Gaithersburg, MD
- Snell Thermography Courses – Held at various locations in the US and Canada
- Fluke Infrared Thermometry Metrology Seminar – Held once a year in American Fork, UT

Standards Organizations

- ASTM: http://www.astm.org/; http://irthermometry.blogspot.com/
- BIPM CCT-WG5: http://www.bipm.org/wg/CCT/CCT-WG5/Allowed/Miscellaneous/Low_T_Uncertainty_Paper_Version_1.71.pdf
- MSL TG22: http://www.msl.irl.cri.nz/sites/all/files/training-manuals/tg22-july-2009v2.pdf

References

[1] *ASTM E2758 - 10 Standard Guide for Selection and Use of Wideband, Low Temperature Infrared Thermometers*, ASTM, West Conshohocken, PA, 2010.

[2] F. Liebmann, "Quality Control for Emissive Surfaces," Proceedings of the National Conference of Standards Laboratories International, 2009.

[3] *IEC/TS 62492-1 Ed. 1.0 Industrial Process Control Devices - Radiation Thermometers - Part 1: Technical data for radiation thermometers*, IEC, Geneva, 2008.

[4] F. Liebmann, "Determining Size of Source for Handheld Infrared Thermometers – Theory and Practice," Proceedings of the Measurement Science Conference, 2008.

[5] *ASTM WK27665 - New Procedure for Accuracy Verification of Wideband Infrared Thermometers*, ASTM, West Conshohocken, PA, not yet published.

[6] J. Fischer, P. Saunders, M. Sadli, M. Battuello, C. W. Park, Z. Yuan, H. Yoon, W. Li, E. van der Ham, F. Sakuma, Y. Yamada, M. Ballico, G. Machin, N. Fox, J. Hollandt, S. Ugur, M. Matveyev and P. Bloembergen, "Uncertainty budgets for calibration of radiation thermometers below the silver point", CCT-WG5 working document CCT-WG508-03, Sèvres, France, May 2008.

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