Technical Solutions – *TS103*

Instrument Errors in Infrared Brightness Thermometers

No measurement device produces perfect measurements because no real system is absolutely perfect. Manufacturers of infrared brightness thermometers, however, establish limits to the doubt involved in any given measurement. The measurement uncertainty specified by the manufacturer represents the worst case combination of the various unavoidable built-in error sources.

In this article we will look briefly at some of the more significant instrument error sources. We will also give some guidelines for you, the user, to follow so you won't exceed the specified uncertainty range of your instrument.

In this article of the Temperature Error Series, we will see how characteristics of the instrument, rather than of the detected radiation, can affect temperature measurements. Although most instrument errors cannot be completely eliminated, they can be minimized through good design, manufacturing and operating practices.

INSTRUMENT ERROR SOURCES

Calibration

The calibration of an infrared brightness thermometer involves adjusting the thermometer reading to match the temperature of a known "blackbody" standard source. There is an uncertainty associated with the operator's ability to make this adjustment. The limitation here is imposed by the accuracy of the thermometer's temperature indications. For example, if the unit being calibrated had a meter scale like the one shown in Figure 1, it would not be possible to ensure that the thermometer matched the blackbody temperature any more closely than ±1° or so.

There is also a calibration uncertainty associated with the blackbody standard's value. This has to do, in part, with how closely the standard approximates blackbody characteristics. Although a blackbody, by definition, radiates the ideal, maximum amount of energy possible at each temperature, no real object truly radiates ideally. It is possible, though, to make very good blackbody simulators (with emissivities very close to 1) using real materials shaped in the form of a cavity. Yet a margin of uncertainty remains, and its magnitude is determined by the design and construction of the blackbody used.

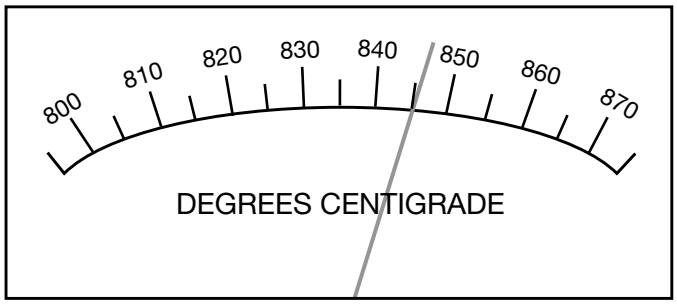

Figure 1—Temperature values on this meter scale cannot be read with much less uncertainty than plus or minus one degree.

Not only is there some uncertainty about how much radiation the "blackbody" source is emitting at each temperature, there is also some question as to what the temperature actually is. To know the blackbody standard's temperature, we must have some other means of monitoring it. No matter what method is used, there is some degree of uncertainty associated with this measurement as well.

Component Temperature

Another uncertainty exists because the temperature of the infrared thermometer components can affect their operation. Component temperature can alter not only the action of the sensor and the circuitry, but even the properties of filters and other optical components. These effects are especially important when the instrument is subjected to a wide range of temperatures. A unit that was calibrated with its outer case at room temperature will not produce the exact same measurements when positioned near a high temperature furnace.

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Electronics

The electronics in infrared thermometers are used to process the voltages generated by the radiant energy striking the detector. Because brightness thermometers measure this voltage quantitatively to determine a target's temperature, the voltage levels cannot be allowed to drift or fluctuate arbitrarily. Any situation which allows this to occur produces an error.

Electrical noise, for instance, can produce significant fluctuations, especially if the signal is small. Either very short response times or very low target temperatures can degrade the "signal to noise ratio." Also, as electrical components age and are subjected to different environmental conditions, their circuit voltages have a tendency to drift. Ircon instruments are burnt in using an environmental chamber to minimize this problem.

Optical System

The optical system is used to focus radiation from the target on the detector. Because it can be made with high precision, errors introduced in the optical system generally are quite small. Of these small optical errors, the most significant one is usually related to the instrument's ability to reject radiation from outside its field of view—or its sensitivity to stray radiation.

We usually assume that the optical system collects only the radiation coming from the area on the target's surface which intersects the instrument's specified cone of vision. However, it is physically impossible to make an optical system which has an absolutely distinct cutoff to the area it measures. As a result, there is a relatively small percentage contribution from sources outside the specified cone of vision. The contribution diminishes as the angle out from the cone of vision increases, as represented in Figure 2.

This usually presents very little problem because the target is much larger than the measuring area in most applications. When this is true, most of the detected radiation from outside the specified cone of vision is also entitled by the target object, as in Figure 2. In this case, any error due to the instrument's sensitivity to stray radiation is negligible; the target itself is the source of most of the "stray" radiation.

On the hand, if the spot size is about the same size as the target, much of this contribution comes from the background. If we assumed that 5% of the detected radiation came from outside the specified cone of vision as much as 5% of the detected radiation could have come from the background. Yet if the target diameter is twice the specified comes from background sources. As discussed in the Error Series article (TS103) on background errors, reducing the contribution from background sources reduces any resulting measurement error.

USER GUIDELINES

If an instrument is used properly, it will operate with an accuracy within its specified uncertainty. Note, though, that some instrument errors can worsen with time. Periodic maintenance checks are a vital means of verifying that the instrument is operating according to its specifications. We will now look at some other considerations which can be important in keeping the effects of some of the instrument error sources to a minimum.

Component Temperature

For applications where exact temperature measurements are critical, it is helpful, for instance, to keep the sensing head's outer case temperature as close as possible to what it was during the instrument calibration.

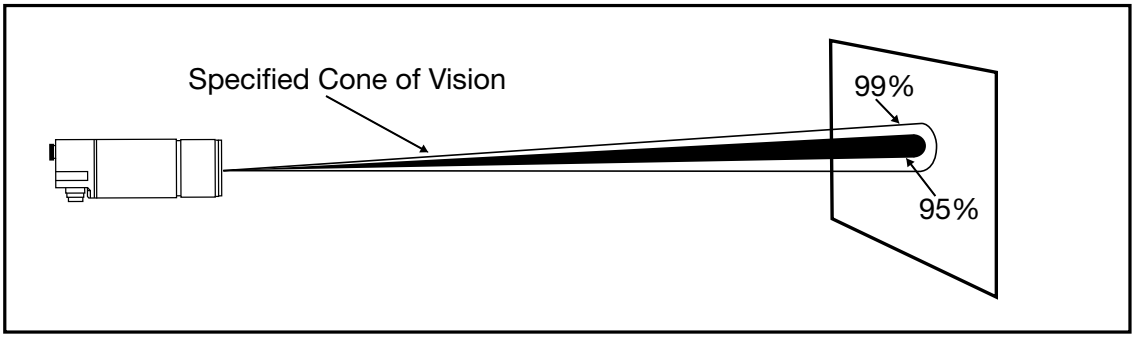

Figure 2—The optical system collects a small percentage of the detected radiation from outside of the cone of vision. The instrument's sensitivity to stray radiation decreases with angle outward from the cone of vision.

Also, be careful about relying on uncertainty specifications if the unit has not recently undergone a routine maintenance check. There is a change that such a unit may be operating out of spec if its case temperature is far from the center of the allowable case temperature range. An instrument operates least reliable when subjected to temperatures extremes.

Optical System

If you are going to calibrate your own instrument, it is particularly important to be aware of the possible influence of stray radiation. Suppose the blackbody target used for calibration is exactly the same size as the reticle in the sighting telescope. Then any radiation detected from outside the specified field of view comes from the background.

Since the blackbody sources used in calibration usually are hotter than room temperature, the contribution from the background represents a much lower temperature than the blackbody temperature. Thus the average amount of detected radiation is lower than it should be, and an energy that is too low is associated with the blackbody temperature. This throws off the calibration and introduces an error into all subsequent measurements.

Clearly the error would be reduced if the blackbody target were larger than the reticle. It is considered good practice to calibrate an instrument using a blackbody target which is at least 2 times the reticle diameter. If this guideline is also followed for subsequent targets, sensitivity to stray radiation will not present a problem.

Electronics

You can prevent electrical problems which result from poor installation techniques. Because leads from the sensing head or to a controller can pick up noise from electromagnetic interferences, it is very important to follow the wiring guidelines presented in Ircon operations manuals. For instance:

- Always use shielded cables.
- Shield al low level outputs.
- Use a “clean” power line. Avoid power lines driving brush motors; loads driven by SCR’s and contractors; and other intermittent, high-inrush loads which distort the power line waveform.
- Before connecting any device to an output, verify that the impedance values of the output and the input are compatible.
- Avoid ground loops between the sensing head, the signal processing unit, and remote indicator units.

MINIMIZING INSTRUMENT ERRORS

In this article we have not discussed the magnitudes of the instrument errors we have examined. This is because the magnitude of each error is highly dependent on the specifics of the application. However, most instrument errors are subject to the same trends as emissivity and transmission errors.

For instance suppose the ambient temperature conditions cause a 5% increase in the instrument’s signal voltage. This problem will cause more significant errors in units which detect longer wavelengths than in those which detect shorter wavelengths. Similarly, the temperature error increases as the target temperature increases. Thus it is beneficial to choose the unit which measures the shortest wavelength possible for the temperature range of interest.

Yet it is nearly always the case that instrument errors represent the least significant of all the possible kinds of errors. Uncertainty about a target’s emissivity value, for example, usually far outweighs any problems which occur due to linearization. Nevertheless, it makes sense to try to minimize all sources of error. As we have seen, the most practical ways to minimize instrument errors are:

- Install the instrument with care and always follow recommendations given in the operations manual.
- View target where it is at least twice the instrument spot size.
- Avoid extreme instrument case temperatures.
- Use a clean power line.
- Shield all signal wiring.
- Institute a routine maintenance schedule to guarantee continued reliability.

Remember, the best way to minimize all temperature measurement errors is by choosing the right instrument for your application!

Fluke Process Instruments

Americas
Santa Cruz, CA USA
Tel: +1 800 227 8074 (USA and Canada, only)
+1 831 458 3900
solutions@flukeprocessinstruments.com

EMEA
Berlin, Germany
Tel: +49 30 4 78 00 80
info@flukeprocessinstruments.de

China
Beijing, China
Tel: +8610 6438 4691
info@flukeprocessinstruments.cn

Japan
Tokyo, Japan
Tel: +81 03 6714 3114
info@flukeprocessinstruments.jp

Asia East and South
India Tel: ++91 22 2920 7691
Singapore Tel: +65 6799 5578
sales.asia@flukeprocessinstruments.com

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