Basics of IR thermography

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Key Concepts

- Incandescent objects emit visible and invisible radiation.
- Infrared instruments can be spot, line scanners, or imagers.
- IR transmission losses can be caused by anything in the sight path.

All matter above absolute zero continuously emits energy in the form of infrared (IR) radiation. This emitted energy is detectable and quantified as an object's temperature through the technique of infrared thermography. The human eye can see in a very narrow range of the electromagnetic spectrum, in wavelengths from 0.4 to 0.7 microns. The infrared portion of the spectrum ranges from 1 to 100 microns (Fig. 1).

A sufficiently hot object will emit light or visible radiation, a phenomenon called incandescence. A light bulb filament, smoldering ember, and a billet of red-hot steel are examples of this phenomenon. The hotter the object, the brighter and whiter its color. It is possible to estimate the temperature of an object this way. Experienced steelworkers do this regularly.

Not as widely recognized is the fact that incandescent objects emit a tremendous amount of invisible infrared radiation. For example, the radiance of a steel billet at 1500 F is 100,000 times greater in the infrared spectrum than in the visible spectrum.

Infrared energy is part of the electromagnetic spectrum and behaves similarly to visible light. It travels through space at the speed of light and can be reflected, refracted, absorbed, and emitted. The wavelength of IR energy is about an order of magnitude longer than visible light. Other common forms of electromagnetic radiation include radio, ultraviolet, and x-rays.

Infrared thermometer elements

A simple analysis of the eye, one form of a radiation thermometer, reveals the basic components used in an infrared thermometer. The eye contains a lens, which focuses the photon flux from the emitter onto the retina or radiation detector of the human system.

The retina is stimulated by the incident radiation and produces a signal that is transmitted to the brain. The brain serves as an indicator or recorder, which measures the radiance of the emitter and, if properly calibrated by experience, relates this radiance to temperature.

The same basic elements comprise an industrial infrared thermometer. These include collecting optics, a radiation detector, and some form of indicator. It is the capabilities of available detectors that result in the effectiveness of present day infrared thermometers.

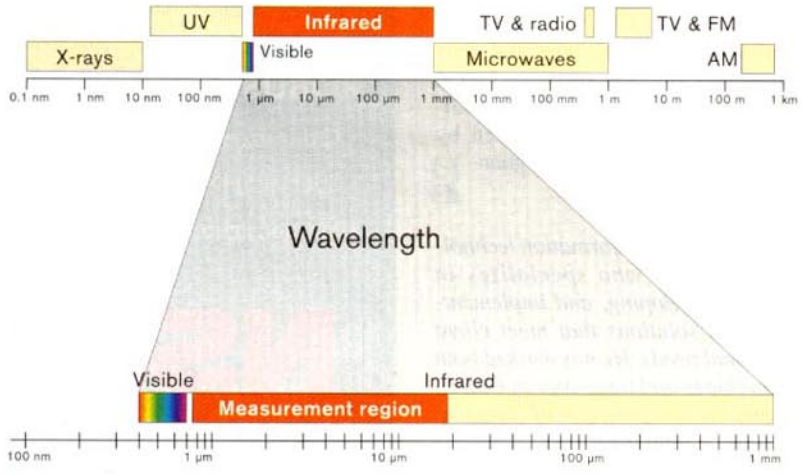

Fig. 1. Only the 0.7 to 18-micron band is used for infrared temperature measurement.

Temperature instruments

Spot instruments are the oldest form of IR thermometer. They are noncontact thermometers that measures a spot on a target (Fig. 2). These instruments are used for controlling ovens, furnaces, and heaters. They can measure as low as -50 F and as high as 6500 F and measure spots as small as 0.017 in. in diameter at speeds as fast as 25 milliseconds.

Units are available in single and dual wavelength models. Lenses can be fixed or focusable, or fiber optics may be used to transmit energy from the target to the sensor. Spot instruments are useful for moving targets because they do not interfere with the process. A disadvantage is they only measure one spot on the target.

Line scanners were developed to measure the temperature of hot webs of moving material, such as steel and glass. A single detector with a 45-deg angle mirror creates a 90-deg scan angle across the target as it is moving to develop a two-dimensional (2D) thermal image.

With software, the target can be divided into spots for online and offline analysis and data storage. These instruments measure temperatures from 50 to 4000 F at speeds of 100 Hz.

Thermal imagers are the ideal IR thermometer for static targets. They provide a thermal image of the entire product (Fig. 3). They can measure from –40 to 4500 F and can see small targets. They are available in almost every wavelength that is provided by spot instruments.

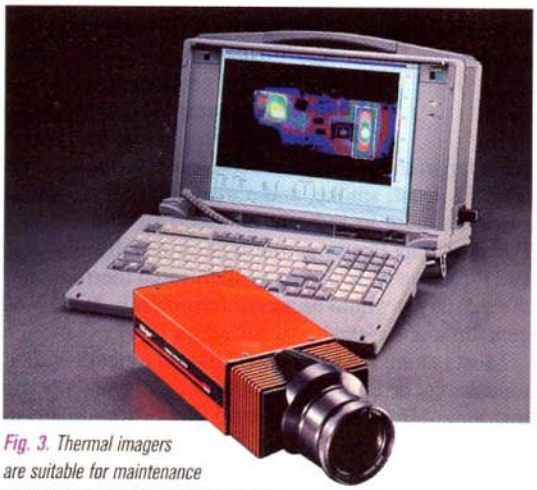

Fig. 3. Thermal imagers are suitable for maintenance projects and use software to manipulate the image and generate reports.

The detector for this instrument is a focal plane array. Each pixel acts as an individual infrared thermometer. The detector is radiometric. This means that the signal from each pixel is changed to a temperature indicator.

Causes of temperature error

Several factors must be considered when installing and operating an infrared thermometer. Errors caused by these factors can be sizeable but are avoidable, so the instrument will provide the correct subject temperature.

Emissivity. All infrared thermometers are calibrated to a device called a black body. A black body is considered the perfect emitter. This means it is the only target that emits maximum infrared energy at any temperature and wavelength.

Every other target emits less than the maximum and has an emissivity error. For example, oxidized steel has an emissivity of 0.8 at almost all wavelengths, which means it emits 80% of its infrared energy compared to a black body. As a result, when an instrument that operates at 1 micron sees this target at 1600 F it would indicate a temperature of 1563 F, an error of 37 deg F.

Fig. 2. Spot instrument temperature measurements can be taken on moving objects.

To correct for this error almost all infrared thermometers have an emittance control. When it is set at 0.8, a 20% gain is added to the infrared signal to allow the thermometer to indicate the true temperature. Values for emissivity vary with the subject and the instrument wavelength but can be obtained from published tables.

Reflections. Many applications for infrared thermometers require measuring the temperature of a subject inside an oven. The problem is, the oven is hotter than the subject, and every target has a factor called reflectivity.

For example, steel with an emissivity of 0.8 is a 20% reflector. When looking at steel inside a reheat furnace, the instrument measures the radiant energy from the steel and 20% of the reflected energy from the furnace walls. The final temperature reading would be as much as 200 deg F too high.

The basic solution to eliminating reflections is to measure the temperature of the subject as it exits the oven where the background is cooler than the target and reflection is not a problem (Fig. 4).

Transmission. For transparent materials, such as glass, plastic, and some semiconductor products, there is a factor to consider that is called transmission. If the instrument is looking at a target that is being heated from the other side, the instrument could measure the heater rather than the

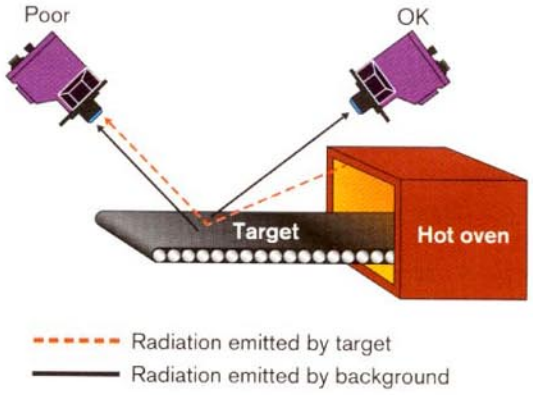

Fig. 4. Proper positioning of the sensing head can prevent significant background errors.

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