Infrared (IR) technology has been successfully employed for years in manufacturing industries for ongoing temperature measurement and control. Even though this technology offers many proven advantages for end users, instrumentation suppliers continue to develop new solutions further improving the accuracy, reliability and ease-of-use of IR systems in demanding production environments.

In this article, we will discuss how the latest advancements in IR sensors not only help users optimize their manufacturing processes and business results, but also enable them to meet industry standards defining guidelines for final product quality and reliability.

**Understanding Infrared Principles**

For manufacturers, temperature plays a critical role as an indicator of the condition of a process, product, or piece of machinery. Accurate temperature monitoring improves product quality and increases productivity. Downtimes are also decreased, since production processes can proceed without interruption—and under optimal conditions.

Plants, factories and other industrial facilities use IR thermometers to obtain precise temperature measurements in a wide range of automation applications. IR instruments can measure temperature without coming into physical contact with a product or other target. This ability is based on Planck’s Law of black body radiation that states every object emits radiant energy, and the intensity of this radiation is a function of the object’s temperature. The sensor simply measures the intensity of radiation, thereby measuring an object’s temperature (See Fig. 1).

Infrared technology is not a new phenomenon, but recent innovations have reduced costs, increased reliability, and enabled smaller units of temperature measurement. All of these factors have led infrared measurement to become an area of interest for new applications and users.

What are the advantages offered by infrared technology?

- It is fast, allowing for more measurements and accumulation of data,
- It facilitates measurement of moving targets,
- Measurements can be taken of hazardous or physically inaccessible objects,
- Measurements can be taken in high-temperature environments,
- There is no interference—thus, no energy is lost from the target,
- There is no risk of contamination and no mechanical effect on the surface of the object.

**Common Application Considerations**

Although noncontact infrared temperature measurement offers many benefits for industrial operations, users must understand the inherent characteristics of the technology when it is employed in a “real-world” environment. For example, IR measurement targets must be optically (infrared-optically) visible to the sensor. Concrete obstacles, such as a closed metallic reaction vessel, allow for only topical measurement—the inside of the container cannot be measured. Plus, the optics of an IR sensor must be protected from particulates and condensing liquids.

Users should consider several important factors when implementing an IR temperature measurement solution. These include:

**Optical resolution**

The optical system of an IR thermometer focuses the emitted infrared energy from a circular measurement spot on to a detector. The target must completely fill this spot, otherwise the instrument will "see" other temperature radiation from the background—making the measured value inaccurate.

Optical resolution with IR thermometers is specified by the D:S ratio, which is determined by comparing the distance from the object to the sensor (D) with the size (i.e., diameter) of the spot being measured (S). The larger the ratio number, the better the instrument's resolution and the smaller the spot size that can be measured from greater distance. For instance, a one-inch spot on a target being measured at a distance of 10 inches has a D:S ratio of 10:1 (See Fig. 2).

Infrared sensors on the market today have D:S ratios ranging from 2:1 (low optical resolution) to more than 300:1 (high optical resolution). The higher the optical resolution, the more expensive the instrument optics tends to be.

At some industrial sites, steam, dust, smoke, etc., can prevent accurate infrared measurement by obstructing the unit's optics. Noise, electromagnetic fields, or vibration can also have an adverse effect on instrument performance.

**Target sighting**
A variety of optical aiming techniques are used with noncontact IR temperature sensors. The simplest thermometers have no sighting mechanism, since they are intended for close-in targets only. As you move farther from the target, you need a sighting guide.

Target sighting options for IR sensors range from simple bead-and-groove gun sights (purely mechanical sights intended for short to intermediate distances), to integrated or detachable optical viewfinders, through-the-lens sighting, and integrated or detachable light beam markers.

Laser sighting provides a single beam that accurately indicates the center of the target area, or draws a “circle” around the target, removing any doubt about the measurement area. In bright or outdoor light, or over long working distances, the laser may not be visible.

Through-the-lens sighting is similar to a camera; the operator looks through the actual lens to view the target spot. This approach is effective in any light, but generally more expensive than comparable laser sighting.

Regardless of the chosen sight, improper aiming of an IR thermometer during installation can affect its readings and limit the user’s ability to control process temperature set points. This is a common problem in applications where the line of sight to the product is obstructed, or where the atmosphere makes it difficult to view the target.

**Variable emissivity**

Emissivity is the measure of an object’s ability to emit infrared energy. Emitted energy indicates the temperature of the object. Emissivity can have a value from 0 (shiny mirror) to 1.0 (blackbody). Most organic, painted, or oxidized surfaces have emissivity values close to 0.95 (See Fig. 3).

Objects can reflect, transmit and emit energy, but only the emitted energy indicates the temperature of the object. When IR thermometers measure the surface temperature of a target, they sense all three kinds of energy. Therefore, all thermometers have to be configured to read emitted energy only. Measuring errors are often caused by IR energy being reflected by light sources.

The accuracy of process temperature readings depends on the ability of the IR instrument to compensate for target emissivity. Although preset emissivity values can be used for on-line sensors to monitor targets of constant emissivity, measurements on materials with variable emissivity require an accurate and reproducible emissivity adjustment.
Metal targets, by definition, have variable emissivity and reflectivity that can change from part to part, and vary with temperature as well. Thus, everyone working with metal—whether they know it or not—has the potential for emissivity-related problems.

Most current IR sensor designs have adjustable emissivity settings, usually from 0.1 to 1.0. However, these instruments typically use long wavelengths for measuring lower temperatures where a limited amount of infrared energy is available. A problem exists due to long wavelengths being more sensitive to emissivity changes than short wavelengths. Ideally, the temperature measurement solution should use the shortest wavelengths possible to improve accuracy (See Fig. 4).

**Latest Technology Advancements**

Instrumentation companies have pioneered new advancements in infrared thermometers, line scanners and imaging systems addressing a host of application challenges. The new breed of IR sensor technology provides better accuracy, higher reliability, and greater ease of use than ever before.

Today’s noncontact infrared thermometers measure temperatures of dynamic processes quickly and efficiently. Unlike other technologies, they measure the temperature of the product directly, allowing users to quickly adjust process parameters to optimize product quality. These sophisticated instruments also increase production efficiency, and improve yields, by enabling smaller units of measurement and a greater accumulation of temperature data. Temperature measurements can be made of a large area or a small spot.

Specific benefits from IR sensor design improvements include:

**Easier sighting.** To address sighting problems with IR thermometers, instrument companies have developed sensor platforms providing integrated through-the-lens target sighting, plus either laser or video sighting. This combined approach ensures correct aiming and target location under the most adverse conditions.

Thermometers may also incorporate simultaneous real-time video monitoring and automated image recording and storage—thus delivering valuable new process information. Users can quickly and easily take snapshots of the process and include temperature and time/date information in their documentation.

**Higher resolution.** Compact IR thermometers offer twice the optical resolution of earlier, bulky sensor models, extending their performance in demanding process control applications and allowing direct replacement of contact probes. These devices are suited for various uses in thermoforming and drying processes, paper mills, printing, paint booths, food and tobacco processing, etc.
Some new IR sensor designs utilize a miniature sensing head and separate electronics. The sensors can achieve up to 22:1 optical resolution and withstand ambient temperatures approaching 200 degrees C without any cooling. This allows accurate measurement of very small spot sizes in confined spaces and difficult ambient conditions. The sensors are small enough to be installed just about anywhere, and can be housed in a stainless steel enclosure for protection from harsh industrial processes.

Innovations in IR sensor electronics have also improved signal processing capabilities, including emissivity, sample and hold, peak hold, valley hold, and averaging functions. With some systems, these variables can be adjusted from a remote user interface for added convenience (See Figure 5).

**Greater flexibility.** End users can now choose IR thermometers with motorized, remote-controlled variable target focusing. This capability allows fast and accurate adjustment of the focus of measurement targets, either manually at the rear of the instrument or remotely via an RS232/RS485 PC connection, where adjustments can be seen real-time through video (See Figure 6).

IR sensors with remote controlled variable target focusing can be configured according to each application requirement, reducing the chance for incorrect installation. Engineers can fine-tune the sensor’s measurement target focus from the safety of their own office, and continuously observe and record temperature variations in their process in order to take immediate corrective action. This solution is particularly useful for large, multiple sensor installations, where sensors are periodically replaced or the distance to the measurement object changes.

Suppliers are further improving the versatility of infrared temperature measurement by supplying systems with field calibration software, allowing users to calibrate sensors on site. Plus, new IR systems offer different means for physical connection, including quick disconnect connectors and terminal connections; different wavelengths for high- and low-temperature measurement; and a choice of milliamp, millivolt and thermocouple signals.

**Increased accuracy.** Instrumentation designers have responded to emissivity issues associated with IR sensors by developing short wavelength units that minimize errors due to the uncertainty of emissivity in low-temperature applications like annealing. These devices are not as sensitive to changes in emissivity on the target material as conventional, high-temperature sensors. As such, they provide more accurate readings across varying targets at varying temperatures.

IR temperature measurement systems with automatic emissivity correction mode enable manufacturers to set-up predefined recipes to accommodate frequent product changes. By quickly identifying thermal irregularities within the measurement target, they allow the user to improve product quality and uniformity,
reduce scrap, and improve operating efficiency. If a fault or defect occurs, the system can trigger an alarm to allow for corrective action.

For example, manufacturers of low-emissivity (“Low-E”) glass can automatically adjust emissivity value when changing glass types or coatings during the tempering process, and replace manual corrections (e.g., with regards to alarm thresholds) with automatic control.

In this application, an infrared line scanner monitors the temperature distribution on the coated topside of the heated glass sheets, and produces a thermal image snapshot activated by a temperature value or an external trigger. A point sensor mounted under the process line measures the uncoated surface and, therefore, the “true” temperature of the glass. Using inputs from both the line scanner and the point sensor, system software creates an accurate thermal image of the glass sheet.

**Greater efficiency.** Industrial manufacturers are finding that enhanced infrared sensing technology can help streamline production processes. When using an IR temperature measurement system for induction heating, operators can pick a part number from an existing temperature set point list, and automatically record each peak temperature value. This solution eliminates sorting and increases cycle times. It also optimizes control of heating zones and increases productivity.

In thermoforming, IR sensor technology can optimize thermoplastic de-molding processes. Thermoformers sometimes run their ovens too hot, or leave parts in the mold too long. By using a thermoforming system with an infrared scope, they can maintain consistent cooling temperatures across molds—increasing production throughput and allowing parts to be removed without significant losses due to sticking or deformation.

**Conclusion**

Today’s infrared temperature measurement technology can help improve the reliability and efficiency of the most demanding industrial operations. End users save thousands of dollars, and hundreds of man-hours, by implementing noncontact IR temperature measurement systems.

**About the Author**

Bill Kolbeck serves as Business Unit Director, Automation Products, for Raytek Corporation in Santa Cruz, California. Bill can be reached at 831-458-3920 or at bill.kolbeck@raytek.com. Visit the Raytek website at www.raytek.com.
Figures

Figure 1

Spectral Characteristics of Blackbody Radiation

Unique Relationship between Temperature and Energy

Relative blackbody radiant emittance

Figure 2

Optical Resolution

\[ \frac{\text{Distance from sensor to object}}{\text{Size of spot}} = D:S \]
**Figure 3**

**Emissivity vs. Wavelength**

Spectral Distribution of Different Emissivities

- $\varepsilon = 1.0$ (blackbody)
- $\varepsilon = 0.9$ (graybody)
- $\varepsilon$ varies with wavelength (non-graybody)

**Figure 4**

**Temperature Errors Due to Emissivity Uncertainty**

- Solution: Use shortest measurement wavelength

*Emissivity error assumed to be 10%
Signal Processing

- Hot Objects Moving on Production Line
- Standard Output Signal
- Peak Hold Output Signal
- Valley Hold Output Signal
- Average Output Signal

Figure 5

Figure 6

846.7°F