CONTROL
For the Process Industries

Taking the Mystery Out of Infrared Sensors

Applications for Non-Contact Temperature Instrumentation Are Proliferating as They Become Less Expensive, More Accurate, and Easier to Use. Here's What You Need to Know to Understand These Versatile Devices.

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Today's temperature measurement applications can be divided into two types: contact and non-contact. Conventional contact temperature measurement methods include thermocouples, resistance temperature detectors (RTDs), and thermistors. Ordinary mercury-in-glass thermometers also fall into this category.

Infrared is a method of non-contact measurement, so called because the measuring device does not have to touch the fluid or product being measured. Infrared thermometers are the fastest-growing segment of the temperature sensor market.

Why Infrared?

Contact temperature sensors must equilibrate with the temperature of the target material. For example, the mercury in a thermometer takes on the temperature of the air and expands or contracts accordingly. When a contact sensor is exposed to a different temperature, it may take some time for it to equilibrate. This is known as the response time of the sensor.

In some applications, it is not practical or possible to use contact sensors. Because infrared sensors can measure temperature at a distance with very small response times, they are suited for use in these cases:

* Moving objects (e.g., web products, moving machinery, or rollers),
* Where there is danger of contamination or a safety hazard (e.g., high voltage),
* When distances are too great for contact measurement, and/or
* Temperatures are too high to use thermocouples or RTDs.

Infrared Detectors

While designs for infrared sensors have been around since the 19th Century (see following article, "What Is Infrared Radiation?") the technology to create practical measuring instruments from these designs was not available until the 1930s. Since that time, many advances have been made in the use of infrared thermometers, and they have gained wide usage in research and industry.

Infrared sensors, usually called infrared or radiation detectors, produce an output signal that corresponds to the amount of infrared radiation that strikes the detector. Infrared detectors are sometimes classified into two categories: thermal and photon-type detectors. Thermal detectors respond more slowly than photon-type detectors.

Thermal infrared detectors convert incoming radiation into heat, raising the temperature of the thermal detector. This change in the temperature is then converted into an electrical signal, which can be displayed and amplified. There are three main types of thermal infrared detectors:

* Bolometer: Resistance varies with received radiation.
* Pyroelectric: Surface charge varies in response to received radiation.
* Thermopile: Consists of multiple thermocouples in series whose voltage output varies with received radiation.
* Photon-type detectors react to the photons emitted by the object. The infrared radiation causes changes in the electrical properties of photon-type detectors. These changes can be monitored as an output signal. There are two main types of photon infrared detectors:
* Photoconductive: Exhibit increased conductivity with received radiation.
* Photovoltaic: Convert received radiation into electric current

Infrared detectors are used in a variety of products for industrial and process applications. They fall into the four main types:

* Infrared thermocouples,
* Infrared thermometers,
* Infrared linescanners, and
* Infrared thermal imagers, or thermal imaging systems.

Infrared Thermocouples

Infrared thermocouples, despite their name, are not actually thermocouples. Instead, they have infrared detectors and emulate a thermocouple output. For example, if someone wishes to replace a type K thermocouple with a noncontact form of measurement, an infrared thermocouple is available for that thermocouple type. By emulating their outputs, infrared thermocouples can replace contact thermocouples and provide the input that a loop controller, programmable logic controller (PLC), transmitter, or recorder is expecting.

Infrared thermocouples are often used in situations when temperature swings are not great, and high accuracy and repeatability are required. Different infrared thermocouple models are available for various temperature ranges.

Infrared Thermometers

An infrared thermometer detects the infrared energy emitted by materials at temperatures above absolute zero, and uses this value to measure temperature. One basic design includes a lens that focuses infrared energy onto an infrared detector. This energy is then converted to an electrical signal that can be displayed in temperature units. Ambient temperature variations must be compensated to give an accurate reading. Using this arrangement, it is possible to determine the temperature of an object without making physical contact.

Infrared thermometers are available in both portable and fixed models. Portable models use a point-and-shoot method: If you point the thermometer at the material or object whose temperature you want to measure, you can read the temperature of the object on the thermometer display. Some models are available with circular laser sighting. This shows the actual area being measured with a red circular display. Portable models can be used to measure the temperature of many different devices. Examples of applications include measuring the temperature of electrical circuits, automobile engines, tires, concrete, steam traps, furnaces, food transportation, heat treating, and plastics.

Fixed infrared thermometers are also called online thermometers. Online thermometers are used to measure the temperature of materials in a fixed location, such as a process control loop. Fixed thermometers are available in a variety of body formats, operating wavelengths, and output signals. Materials that are extremely hot, moving, or inaccessible are typical candidates for online systems.

Linescanners

Infrared linescanners contain an infrared thermometer, a rotating mirror, and accompanying electronics. As the mirror scans across the target's surface, the thermometer can take a large number of individual temperature measurements. If the target is moving, two-dimensional data can be obtained. Output from the linescanner is transmitted to a personal computer, and a thermal map of the surface of the product is displayed on the computer monitor. Linescanners are used in steel rolling mills and in producing glass fibers for thermal insulation.

Thermal Imaging Systems

Infrared thermal imaging systems, or thermal imagers, work differently from infrared thermometers and linescanners. While infrared thermometers give temperature at a point, and infrared linescanners scan along a line, thermal imagers provide a two-dimensional picture of a complete scene. Portable thermal imagers are operated like a video camera. The operator looks in the viewfinder to see any hot spots in the field of view. The thermal imager can provide the temperature of any hot spots, and the image can be stored internally or downloaded to a video recorder or analyzed on a personal computer. Processing software can display temperature profiles, histograms, historical data, and other information relevant to understanding the temperatures of the viewed objects.

Fixed thermal imagers are used in process control systems in X-ray film production, incinerators, and in the steel and glass industries. Thermal imagers can measure surface temperatures, identify temperature thresholds, and trigger alarms. The rapid temperature feedback they provide is very useful for controlling industrial processes. Thermal imagers are also used for testing heat exchangers and for fire detection in stockyards.

Applications

Because of the specialized nature of infrared measurement, infrared instruments are more widely used in some industries than in others. Three industries where infrared thermometers and thermal imagers are commonly used are in the steel, glass, and plastics industries. They are also widely used for preventive maintenance.

The steel industry uses infrared thermometers because the product is in motion and temperatures are very high. A common steel industry application is temperature at the continuous caster, where molten steel begins its transformation into slabs. Reheating steel to a uniform temperature is critical to preventing deformation, and infrared thermometers are used to measure the temperature inside reheaters. In hot rolling mills, infrared thermometers are used to check that product temperatures are within rolling limits. In cold mills, infrared thermometers monitor the temperature of steel while it is cooling. Both spot thermometers and linescanners are used in steel applications.

In the glass industry, the product is also often in motion, and is heated to very high temperatures. Infrared thermometers are used to measure temperatures in the melt furnace. Portable sensors measure the exterior to detect hot spots, and the temperature of the molten glass is measured to determine proper furnace exit temperature. In flat glass production, sensors measure temperatures at each processing stage. Incorrect temperatures or rapid temperature change can result in uneven expansion and contraction. For bottle and container production, molten glass flows into a forehearth, where it is kept at uniform temperature. Infrared sensors are used to monitor the temperature of glass in the forehearth so it is in proper condition when it reaches the exit. In glass fiber production, infrared sensors are used to monitor the temperature of the glass in the forehearth, and also in the curing oven. Another application for infrared sensors in the glass industry is in windshield production.

In the plastics industries, infrared thermometers are used to avoid contamination of the product, to measure moving objects, and to measure plastic at high temperatures. In the blown film extrusion process, temperature measurements to adjust heating and cooling help maintain the plastic's tensile integrity and thickness. In the cast film extrusion process, sensors help control temperatures to maintain proper product thickness and finish uniformity. In sheet extrusion, sensors allow the operator to adjust the die heater and roll cooling to maintain product quality. In laminating and embossing, linescanners monitor cross-web temperatures to control the adjustments to heating elements. Linescanners also monitor cooling efficiency in the cooling tunnel.

Preventive Maintenance

Using a portable thermal imaging system, maintenance personnel can look for potential or actual problem areas. Examples include overheated windings in a motor, plugged cooling fins on a transformer, bad connections on a capacitor bank, and heat buildup on the cylinder heads of a compressor. Any problem that manifests itself with increased heat, or a temperature profile that stands out from its surroundings, can be addressed with a portable thermal imaging system. In many cases, problems can be found in time to correct them, before they require shutting down the process.

In the petrochemical industry, refineries use thermal imaging systems in regularly scheduled preventive maintenance programs. These programs include process furnace inspections and thermocouple validation. In process furnace inspection, infrared imagers are used to inspect heater tubes for carbon scale buildup. This buildup, which is called coking, results in higher furnace firing rates and increased tube temperatures. These higher temperatures can reduce heater tube life. Because coking prevents the product from absorbing the tube's heat uniformly, areas where coking occurs appear warmer than other parts of the tube surface when using an infrared camera. Infrared cameras are also used in petrochemical plants to look for coking near the point of contact for thermocouples, which can cause the thermocouple to provide inaccurate data.

A Look Ahead

While infrared is not a new technology, it remains a new technology to many people. Probably the chief barrier to the wider use of infrared technology is the learning curve required to understand it. Infrared sensors are hard to grasp conceptually, and this makes it more difficult for end users to feel comfortable with the technology.

The popularity of infrared photography may help get some potential customers familiar with infrared technology. Other trends favorable to infrared include substantial price reductions over the past five years and the continued introduction of new products by the suppliers.

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What Is Infrared Radiation?

Infrared thermometers operate by means of infrared radiation. Infrared radiation occupies a portion of the electromagnetic spectrum between visible light and radio waves. The electromagnetic spectrum is a group of different types of radiation. These types include gamma rays, x-rays, ultraviolet light, visible light, infrared radiation, microwaves, and radio waves. Infrared radiation waves are longer than visible light waves. Infrared light waves are not visible to the human eye. The term infrared, which means "below red," reflects the fact that infrared light is found just below red light on the electromagnetic spectrum

Isaac Newton took an important step in our understanding of light in 1666 when he separated the electromagnetic radiation from sunlight by using a prism to break up sunlight into the colors of the rainbow. But infrared radiation was not discovered until 1800 when Sir William Herschel did some experiments, building on Newton's discovery. Herschel directed sunlight through a prism to create the colors of the rainbow. He then placed a thermometer in the path of each color of light. Herschel noticed that the temperatures of the light became higher from the violet to the red portion of the spectrum. He then decided to measure the temperature beyond the red part of the spectrum, in an area that had no sunlight. What Herschel found is that the temperature in this region was the highest of all. This elevated temperature is due to the presence of infrared radiation, and this year marks the 200th anniversary of its discovery.

We are very used to the idea that animals have eyes like ours, which detect visible light. Human beings also like to pride themselves on their superiority to animals. What many people forget is that some animals have senses more sophisticated than our own. The ability of bats and dolphins to "see" with sonar is one example. Another is the pit viper, which uses specialized organs near its eyes to sense the infrared radiation of an approaching warm-blooded animal. These organs sense temperature differences between the snake's own body temperature and the target. The pit viper's organs can sense temperature differences of just .003 C at distances up to 50 cm. Infrared sensors give this snake a unique ability to defend itself against intruders, even in complete darkness.

The infrared portion of the spectrum spans wavelengths from 0.7-1,000 microns. Of this, mainly the portions from 0.7-20 microns are used for temperature measurement, since most infrared detectors are unable to detect the small amounts of energy available at wavelengths above 20 microns.