NON-CONTACT TEMPERATURE MEASUREMENT – PART 1

Using an IR pyrometer for temperature measurement is becoming increasingly common. However, to avoid the risk of large and unnecessary measurement errors, knowledge is required about the radiation pyrometer's function and properties.

In this first of two articles about non-contact temperature measurement with IR pyrometers, we will review some underlying concepts. In the next article, which you can read in the upcoming issue of *Pentronic News*, we will also look at some special measurement solutions for pyrometers and what sort of things are important to keep in mind.

THE IR PYROMETER IS BEST AT COMPARATIVE MEASURING

To start with, it is important to understand that a radiation pyrometer is seldom suitable for measuring a single, absolute temperature. The strengths of IR pyrometers are to be found in processes with continual and comparative measurements. An example is a fixed installation where influencing factors such as the material, temperature level, wavelength, surface properties, and angle of incidence are very similar on each measurement occasion. Even if the absolute level of the temperature deviates from the actual one, you will get repetitive values, which can be used to steer the process. Handheld pyrometers for low temperature use can be utilised in a similar way, for example to discover inadequate pipe or wall insulation, overheated cabling and similar situations.

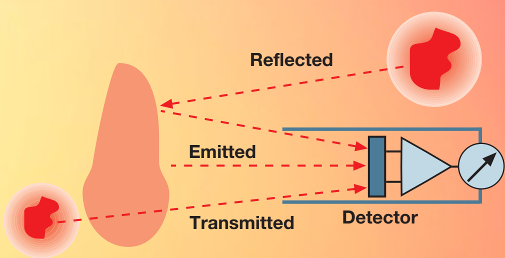
FUNDAMENTAL TECHNOLOGY

A radiation pyrometer measures the thermal energy which all bodies with a temperature above absolute zero radiate within the infrared (IR) wavelength range, normally within the interval 0.7 – 20 µm. Industrial instruments are built for the measuring ranges between approx. -50 and 3000 °C but no single instrument exists for the entire measuring range.

In principle, a pyrometer consists of a detector which measures the incoming thermal radiation. Unfortunately, not all incoming radiation stems from the object's surface temperature. In addition to the radiation emitted from the surface, there is reflected radiation from heat sources in the surroundings, and in some cases also transmitted radiation through the object, such as when you measure plastic film. The detector senses the total radiation within the wavelength range.

THE ε FACTOR

The emission factor (ε) is the relationship between the object's stated temperature radiation and the given thermal radiation of a non-reflecting body (called a black body) at the same temperature. A black body emits only its own thermal energy. In contrast, most shiny metals have a low self-radiation and also reflect the temperature radiation of their



The pyrometer senses the sum of the emitted, reflected and transmitted radiation. For measuring purposes, only the emitted radiation is of interest. Shielding and the choice of wavelength can reduce reflection and transmission.

surroundings. The factors influencing the emission factor of a surface are: material, temperature, wavelength, surface properties, and angle of incidence.

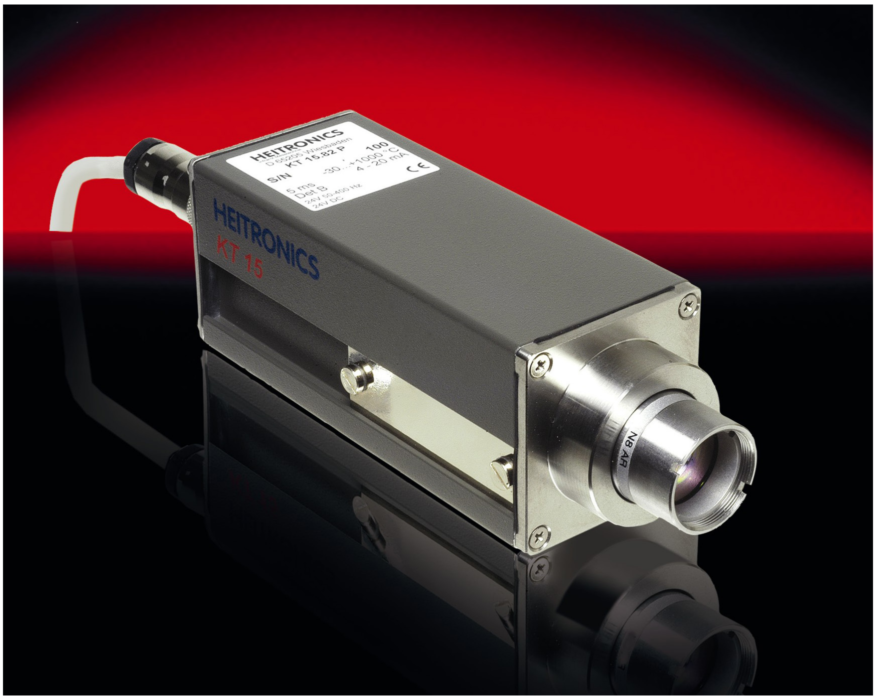
The most common situation is that the pyrometer is used to measure surfaces that are not black bodies, that is, they have the emission factor $\varepsilon < 1$.

When we measure materials with low emissivity, our measurements are very sensitive. If a surface has $\varepsilon = 0.12$ and the pyrometer is set at $\varepsilon = 0.1$, you will get a measurement error of tens of degrees depending on the object's temperature. The relative difference is a full 20%. In addition, situations of low emissivity are highly sensitive to reflected radiation. For example, if you try to measure the temperature in a refrigerated room and aim the pyrometer at the stainless steel wall opposite you, the pyrometer will mostly detect the reflected radiation from your body and will display too high a temperature.

In the next issue of *Pentronic News* we will examine solutions and adaptations that can be done for measuring materials with a low or varying emission factor.

WAVELENGTH RANGES

The IR radiation from an object to the pyrometer normally passes through air containing a greater or lesser proportion of water vapour.



There are a number of wavelength bands between 0.7 and 20 µm in which the radiation is minimally dampened in the water vapour. Depending on what type of material you want to measure, and on the pyrometer's intended temperature range, you can improve your measuring processes by selecting a suitable wavelength range.

From this it is clear that any one individual pyrometer cannot handle all measuring tasks. Handheld universal pyrometers for temperatures under 500 °C often use the wavelength range 8 – 14 µm whereas for higher temperatures narrower ranges are normally used with shorter wavelengths. By selecting a wavelength range you can optimise the IR pyrometer for the application. The table to the right gives some general guidelines for common applications.

You are welcome to contact Pentronic's sales team for advice on suitable products and solutions.

Wavelength (µm)	T_{min} ...T_{max} (°C)	Material
0.85 - 1.7	125...2500	Metal, semiconductor, ceramic
2.0 - 2.7	250...2500	Metal, glass, ceramic
2.0 - 4.5	100...1200	Metals
3.43 ± 0.15	80...350	Plastic film
5.7 ± 0.1	40...400	Plastic film
6.8 ± 0.1	50...400	Plastic film (PE etc)
7.93 ± 0.15	0...400	Plastic film (polyester, PVC etc)
8.05 ± 0.15	0...400	Plastic film and ceramic
3.9 ± 0.1	200...2500	Glass, measuring through gases
4.9 - 5.5	100...2500	Glass
7.5 - 8.2	0...2500	Glass and ceramic
4.26 ± 0.13	300...2500	CO_2 gas
4.5 ± 0.1	300...2500	CO and CO_2 gas
4.66 ± 0.1	300...2500	CO gas
5.3 ± 0.1	300...2500	NO gas
8 - 10	0...1000	Thick film, ceramic
8 -14	-50...1000	General measuring
8 - 20	-50...1000	Low temperature high resolution
9.6 - 11.5	-50...200	Through the atmosphere at a far distance

The table gives examples of the optimal wavelength ranges for various materials. Reliable measuring is best done with instruments chosen and installed for the right application.

NON-CONTACT TEMPERATURE MEASUREMENT – PART 2

This is the continuation of Pentronic News' series on IR pyrometry. In the previous issue we described the fundamental concepts and technology underlying the measuring process. In this issue we will describe some examples of applications where adaptations and special products can enable more stable and more reliable measurements in various processes.

SUMMARY OF PART 1

In Part 1 we read about the importance of the emission factor (ε). The emission factor describes the radiation properties of the object you want to measure. A low, or in the worst case an unknown emission factor, can cause major problems with your measuring process. We also noted that for IR pyrometry there is not one single "camera" for all applications. Instead, you need to select the correct instrument based on the material you want to measure, the temperature range and the environment.

The Heitronics CT13 is a rugged and accurate IR pyrometer which is also available in the "CT13 Chemistry" version for use in extremely demanding environments.

WHEN DO WE USE AN IR PYROMETER?

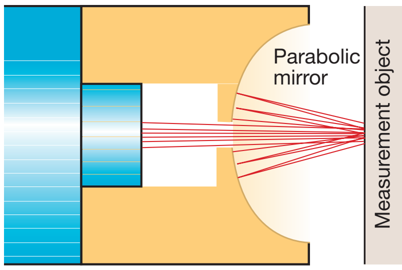
As explained in Part 1, an IR pyrometer is not the most accurate instrument for measuring temperature. However, many applications make it impossible to measure using a fixed contact sensor such as a thermocouple or a resistance type sensor. Here is a list of some common factors that can lead to a recommendation to use an IR pyrometer:

- Mobile measurement objects
- Electrically disruptive environments e.g. induction heating
- The requirement of a short response time (at the millisecond level)
- The requirement of a thermally unloaded measurement object
- Aggressive environments where contact sensors quickly deteriorate
- Very high temperatures

MEASURING SHINY METALS

For understandable reasons, processes involving shiny, rotating steel rollers often require non-contact signal transmission.
The reflective surface causes a radiation pyrometer to perceive more reflected radiation from the surroundings than that emitted by the roller itself; the emission factor ε goes towards 0. The measurement error becomes very large and can also vary over time. One elegant way to get rid of the reflections from a shiny surface is to exploit the principle of a black body, which has ε = 1 for varying temperatures and wavelengths (see figure). By imitating the black body's function, we can create an emissivity amplifier. The dish-shaped reflector section with a gold-coated inside surface is placed out to stand by itself a few millimetres from the roller's surface. The parabolic reflector focuses the roller's radiation back to the measurement surface through multiple reflections, while the disruptive external radiation beams are not focused and will therefore only make up a fraction of the total radiation that reaches the lens.

IR pyrometer with lens (blue)



The emissivity amplifier is a parabolic mirror which focuses the measurement object's heat radiation back to the measurement surface. The proportion of emitted radiation apparently increases and external radiation is suppressed.

The Heitronics LT13EB is a practical example of an IR pyrometer with emissivity amplifier (gold coloured).

SEVERAL WAVELENGTH RANGES

Sometimes a two-colour or quotient pyrometer is recommended as the solution to tricky measuring situations. The quotient pyrometer determines the temperature by measuring the radiation at two or more closely adjacent wavelengths and the temperature is calculated from the quotient. The advantage is that we can actually ideally disregard the emission factor (although this assumes that the emission factor is the same for the various wavelength ranges). The quotient pyrometer is also preferred in environments where the pyrometer's sightline is partly obscured – such as in smoke-filled environments or where there is a large risk that the view glass will get dirty.

Using a quotient pyrometer requires the following:

- Emissivity is the same at all wavelengths.
- Transmission through the atmosphere and any view glass is the same for all wavelengths.

In practice this means that a quotient pyrometer is used for metallic materials and high temperatures. However, it is worth noting that quotient pyrometers now exist for many varieties of applications and are even available as hand-held pyrometers.

GAS TEMPERATURES AND TRANSPARENT MATERIALS

Normally IR is used to measure solid materials or the surfaces of liquids. However, it is also possible to measure gas temperatures and materials that appear totally transparent. Doing so relies on the previously discussed knowledge about emittance at different wavelengths.

Hot gases and flames, for instance inside furnaces, are detected via the presence of such substances as CO and CO_2, which emit in known wavelengths in narrow bands, e.g. around 4.66 and 4.26 micrometres respectively. Measuring CO_2 and CO can be done well at temperatures between 300 and 2,500 °C. A minimum volume of the gases to be measured is required, but industrial incinerators, for example, are often large enough.

The same principle can be exploited for such materials as plastic films if you know the material's specific properties.

KNOWLEDGE IS NECESSARY

Factors fundamental to all pyrometry (except for quotient pyrometers) include: that the measurement object is larger than the measurement spot, that no extraneous radiation is reflected together with the desired radiation, and that the view glass and lens have consistent properties for the wavelength in question.

If you as the customer tell us the temperature range, the measurement surface's size and distance, the required response time, and the measurement object's properties plus the surrounding environment, we will help to specify a pyrometer system that gives you reliable and repeatable temperature measurements with sufficient accuracy.

Knowledge is everything in measurement technology, and this applies to IR pyrometry just as much as to thermocouples and Pt100 sensors.

The Capella C3 from SensorTherm is an example of a quotient pyrometer.

The Heitronics TRT, the world's most accurate IR pyrometer.