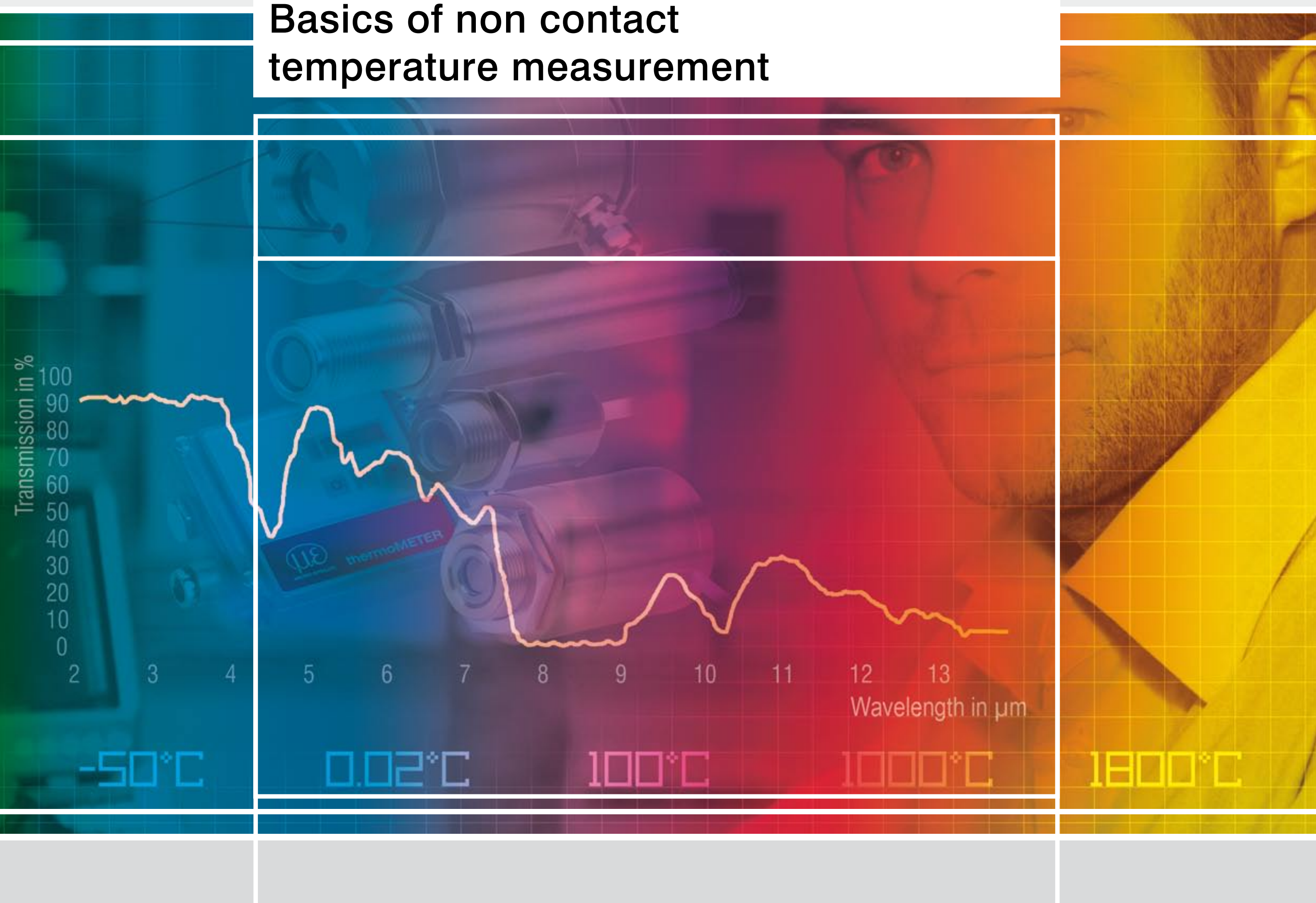
MICRO-EPSILON

More Precision.

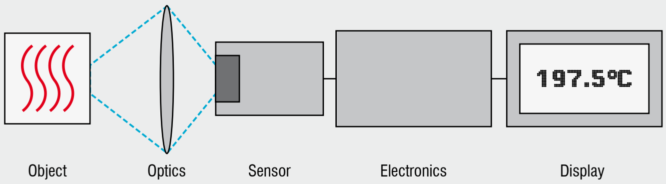
Basics of non contact temperature measurement



With our eyes we see the world in visible light. Whereas visible light fills only a small part of the radiation spectrum, the invisible light covers most of the remaining spectral range. The radiation of invisible light carries much more additional information.

The Infrared Temperature Measurement System

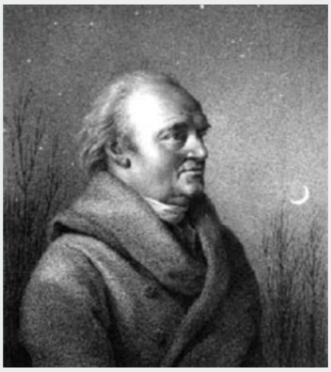
Each body with a temperature above the absolute zero (-273.15°C = 0 Kelvin) emits an electromagnetic radiation from its surface, which is proportional to its intrinsic temperature. A part of this so-called intrinsic radiation is infrared radiation, which can be used to measure a body's temperature. This radiation penetrates the atmosphere. With the help of a lens (input optics) the beams are focused on a detector element, which generates an electrical signal proportional to the radiation. The signal is amplified and, using successive digital signal processing, is transformed into an output signal proportional to the object temperature. The measuring value may be shown in a display or released as analog output signal, which supports an easy connection to control systems of the process management.



Infrared System

The advantages of non-contact temperature measurement are clear - it supports:

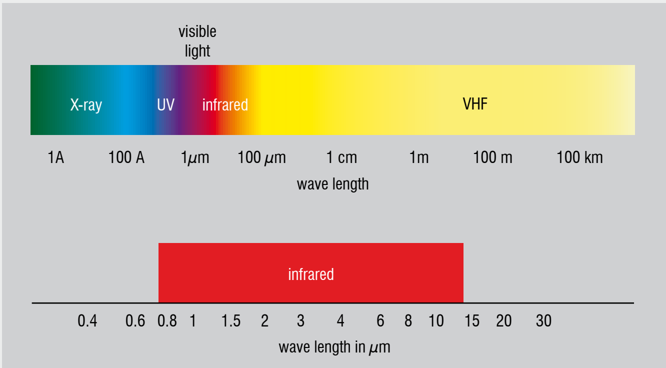
- Temperature measurements of moving or overheated objects and of objects in hazardous surroundings
- Very fast response and exposure times
- Measurement without interreaction, no influence on the measuring object
- Non-destructive measurement
- Long lasting measurement, no mechanical wear




William Herschel (1738 - 1822)

Discovery of the Infrared Radiation

Searching for new optical material William Herschel by chance found the infrared radiation in 1800. He blackened the peak of a sensitive mercury thermometer. This thermometer, a glass prism that led sun rays onto a table made his measuring arrangement. With this, he tested the heating of different colors of the spectrum. Slowly moving the peak of the blackened thermometer through the colors of the spectrum, he noticed the increasing temperature from violet to red. The temperature rose even more in the area behind the red end of the spectrum. Finally he found the maximum temperature far behind the red area. Nowadays this area is called "infrared wavelength area".



The electromagnetic system with the infrared area used by pyrometers

The Electromagnetic Radiation Spectrum

A spectrum in the physical sense is the intensity of a mixture of electromagnetic waves as the function of the wavelength or frequency. The electromagnetic radiation spectrum covers a wavelength area of about 23 decimal powers and varies from sector to sector in origin, creation and application of the radiation. All types of electromagnetic radiation follow similar principles of diffraction, refraction, reflection and polarisation. Their expansion speed corresponds to the light speed under normal conditions: The result of multiplying wavelength with frequency is constant:

$$\gamma \cdot f = c$$

The infrared radiation covers a very limited part in the whole range of the electromagnetic spectrum: It starts at the visible range of about 0.78 μm and ends at wavelengths of approximately 1000 μm.

Wavelengths ranging from 0.7 to 14 μm are important for infrared temperature measurement. Above these wavelengths the energy level is so low, that detectors are not sensitive enough to detect them.

Physical Basics

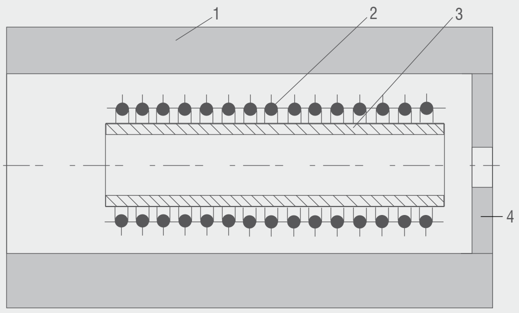
In about 1900 Planck, Stefan, Boltzmann, Wien and Kirchhoff precisely defined the electromagnetic spectrum and established qualitative and quantitative correlations for describing the infrared energy.

The Black Body

A black body is a radiator, which absorbs all incoming radiation. It shows neither reflection nor transmissivity.

$$\alpha = \varepsilon = 1 \text{ (}\alpha\text{ Absorption, }\varepsilon\text{ Emissivity)}$$

A black body radiates the maximum energy possible at each wavelength. The concentration of the radiation does not depend on angles. The black body is the basis for understanding the physical fundaments of non-contact temperature measurement and for calibrating the infrared thermometers.



Drawing of a black body:
1 ceramic conduit, 2 heating, 3 conduit made from Al2O3, 4 aperture

The construction of a black body is simple. A thermal hollow body has a small hole at one end. If the body is heated and reaches a certain temperature, inside the hollow room a balanced temperature spreads. The hole emits ideal black radiation of this temperature. For each temperature range and application purpose the construction of these black bodies depends on material and the geometric structure. If the hole is very small compared to the surface as a whole, the interference of the ideal state is very small. If you point the measuring device on this hole, you can declare the temperature emitting from inside as black radiation which you can use for calibrating your measuring device. In reality simple arrangements use surfaces, which are covered with pigmented paint and show absorption and emissivity values of 99% within the required wavelength range. Usually this is sufficient for calibrations of real measurements.

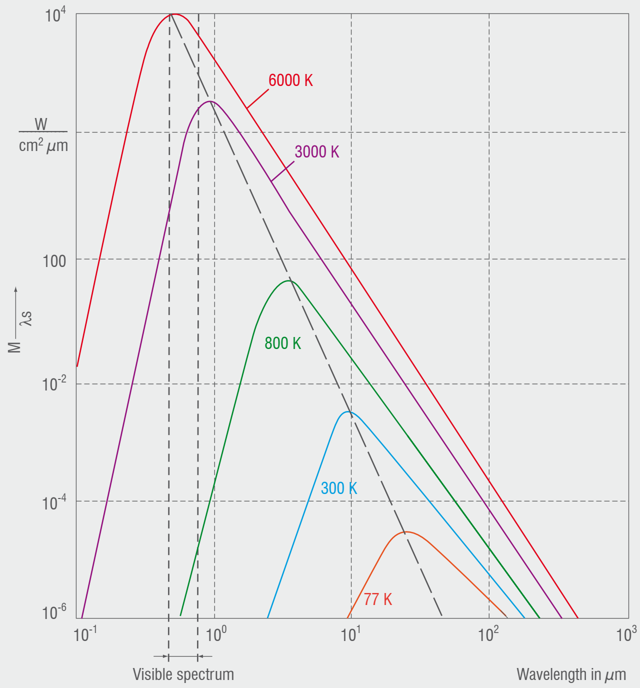
Radiation Principles of a Black Body

The radiation law by Planck shows the basic correlation for non-contact temperature measurements: It describes the spectral specific radiation $M_{\gamma s}$ of the black body into the half space depending on its temperature T and the wavelength γ.

$$\frac{2\pi h c^2}{\lambda^5}\,\frac{1}{e^{hc/\lambda kT}-1} = \frac{C_1}{\lambda^5}\,\frac{1}{e^{c_2/\lambda T}-1}$$

C = light speed
$C_1 = 3.74 \cdot 10^{-16}$ W m²
$C_2 = 1.44 \cdot 10^{-2}$ K m
h = Planck's constant

The following illustration shows the graphic description of the formula depending on λ with different temperatures as parameters.



Spectral specific radiation $M_{\lambda s}$ of the black body depending on the wavelength

With rising temperatures the maximum of the spectral specific radiation shifts to shorter wavelengths. As the formula is very abstract it cannot be used for many practical applications. But, you may derive various correlations from it. By integrating the spectral radiation intensity for all wavelengths from 0 to infinite you can obtain the emitted radiation value of the body as a whole. This correlation is called Stefan-Boltzmann-Law.

$$M_{\lambda s} = \sigma \cdot T^4 \text{ [Watt m}^2\text{]} \qquad \sigma = 5.67 \cdot 10^{-8} \text{ W M}^{-2} \text{ K}^{-4}$$

The entire emitted radiation of a black body within the overall wavelength range increases proportional to the fourth power of its absolute temperature. The graphic illustration of Planck's law also shows, that the wavelength, which is used to generate the maximum of the emitted radiation of a black body, shifts when temperatures change. Wien's displacement law can be derived from Planck's formula by differentiation.

$$\lambda_{max} \cdot T = 2898\ \mu\text{m} \cdot \text{K}$$

The wavelength, showing the maximum of radiation, shifts with increasing temperature towards the range of short wavelengths.

The Grey Body

Only few bodies meet the ideal of the black body. Many bodies emit far less radiation at the same temperature. The emissivity ε defines the relation of the radiation value in real and of the black body. It is between zero and one. The infrared sensor receives the emitted radiation from the object surface, but also reflected radiation from the surroundings and perhaps penetrated infrared radiation from the measuring object:

$$\varepsilon + \varphi + \tau = 1$$

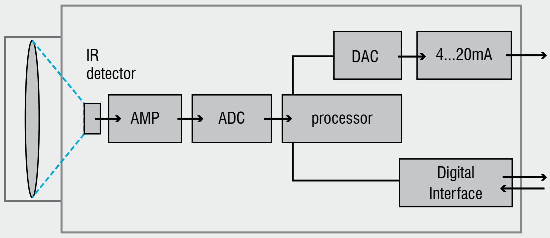
ε emissivity
φ reflection
τ transmissivity

Most bodies do not show transmissivity in infrared, therefore the following applies:

$$\varepsilon + \varphi = 1$$

This fact is very helpful as it is much easier to measure the reflection than to measure the emissivity.

Construction and Operation of Infrared Thermometers



Block diagram of an infrared thermometer

The illustration shows the general construction of an infrared thermometer. With the help of input optics the emitted object radiation is focused onto an infrared detector. The detector generates a corresponding electrical signal which then is amplified and may be used for further processing. Digital signal processing transforms the signal into an output value proportional to the object temperature. The temperature result is either shown on a display or may be used as analog signal for further processing. In order to compensate influences from the surroundings a second detector catches the temperature of the measuring device and of his optical channel, respectively. Consequently, the temperature of the measuring object is mainly generated in three steps:

1. Transformation of the received infrared radiation into an electrical signal
2. Compensation of background radiation from thermometer and object
3. Linearization and output of temperature information.

Besides the displayed temperature value, the thermometers also support linear outputs such as 0/4-20 mA, 0-10 V and thermocouple elements, which allow an easy connection to control systems of the process management. Furthermore, the most of the presently used infrared thermometers offer digital interfaces (USB, RS232, RS485) for further digital signal processing and in order to be able to have access to the device parameters.

Infrared Detectors

The most important element in each infrared thermometer is the radiation receiver, also called detector.

There are 2 main groups of infrared detectors.

Infrared Detectors

Thermal Detectors
Thermopile detector
Pyroelectrical detector
Bolometer FPA (for IR cameras)

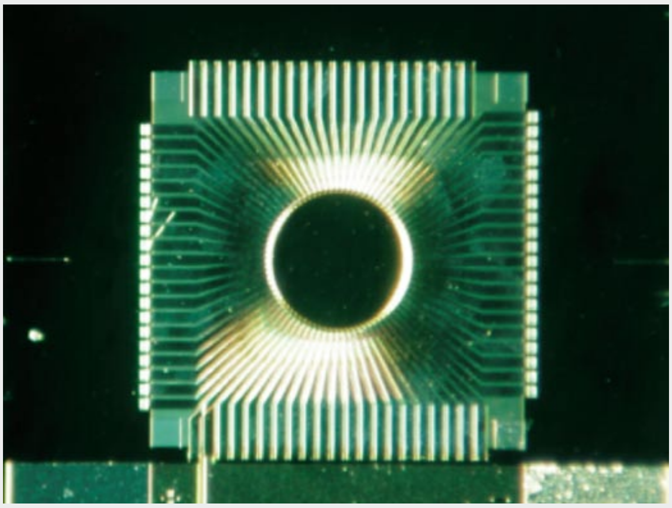
Quantum Detectors

Thermal Detectors

In these detectors the temperature of the sensitive element varies because of the absorption of electromagnetic radiation. This leads to a modified property of the detector, which depends on temperature. This change of the property will be electrically analysed and used as a standard for the absorbed energy.

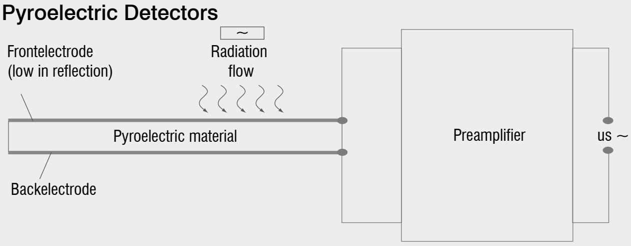
Radiation Thermocouple Elements (Thermopiles)

If the joint between two wires of different metallic material heats up, the thermoelectrical effect results in an electrical voltage. The contact temperature measurement has been using this effect for a long time with the help of thermocouple elements. If the connection is warm because of absorbed radiation, this component is called radiation thermocouple. The illustration shows thermocouples made of bismuth/antimony which are arranged on a chip round an absorbing element. In case the temperature of the detector increases, this results in a proportional voltage, which can be caught at the end of the bond isles.



Thermopile TS80

Pyroelectric Detectors



Construction of a pyroelectric detector

The illustration shows the common construction of a pyroelectric detector. This sensitive element consists of pyroelectric material with two electrodes. The absorbed infrared radiation results in a changed temperature of the sensitive element which leads to a changed surface loading due to the pyroelectric effect. The so created electric output signal is processed by a preamplifier. Due to the nature of how the loading is generated in the pyroelectric element the radiation flow has to be continuously and alternately interrupted. The advantage of the frequence selective preamplifying is a better signal to noise ratio.

Bolometers

Bolometers use the temperature dependency of the electric resistance. The sensitive element consists of a resistor, which changes when it absorbs heat. The change in resistance leads to a changed signal voltage. The material should have a high temperature factor of the electrical resistance in order to work with high sensitivity and high specific detectivity.
Bolometers which work at room temperature use the temperature coefficient of metallic resistors (e.g. black layer and thin layer bolometer) as well as of semiconductor resistors (e.g. thermistor bolometers). Nowadays infrared imagers are based on the following technological developments:
The semiconductor technology replaces mechanical scanners. FPA's (Focal Plane Arrays) are produced on the basis of thin layer bolometers. For that purpose VOX (Vanadium oxide) or amorphous silicon are used as alternative technologies. These technologies significantly improve the price-performance ratio. The latest standard includes 160 x 120 and 320 x 240 element arrays.

Quantum Detectors

The decisive difference between quantum detectors and thermal detectors is their faster reaction on absorbed radiation. The mode of operation of quantum detectors is based on the photo effect. The striking photons of the infrared radiation lead to an increase of the electrons into a higher energy level inside the semiconductor material. When the electrons fall back an electric signal (voltage or power) is generated. Also a change of the electric resistance is possible. These signals can be analysed in an exact way. Quantum detectors are very fast (ns to µs).
The temperature of the sensitive element of a thermal detector changes relatively slowly. Time constants of thermal detectors are usually bigger than time constants of quantum detectors. Roughly approximated one can say that time constants of thermal detectors can be measured in Milliseconds whereas time constants of quantum detectors can be measured in Nanoseconds or even Microseconds. Despite of the fast development on the field of quantum detectors there are lots of applications, where thermal detectors are preferably used. That is why they are equally positioned with the quantum detectors.

Transformation of Infrared Radiation into an Electrical Signal and Calculation of the Object Temperature

As per the Stefan-Boltzmann law the electric signal of the detector is as follows:

$$U \sim \varepsilon T_{obj}^{4}$$

As the reflected ambient radiation and the self radiation of the infrared thermometer is to be considered as well, the formula is as follows:

$$U = C\,(\varepsilon T_{obj}^{4} + (1-\varepsilon)T_{amb}^{4} - T_{pyr}^{4})$$

U	detector signal
T_{obj}	object temperature
T_{amb}	temperature of background radiation
T_{pyr}	temperature of the device
C	device specific constant

$$\rho = 1-\varepsilon \quad \text{reflection of the object}$$

As infrared thermometers do not cover the wavelength range as a whole, the exponent n depends on the wavelength λ. At wavelengths ranging from 1 to 14 µm n is between 17 and 2 (at long wavelengths between 2 and 3 and at short wavelengths between 15 and 17).

$$U = C \cdot (\varepsilon T_{obj}^{n} + (1-\varepsilon) \cdot T_{amb}^{n} - T_{pyr}^{n})$$

Thus the object temperature is determined as follows:

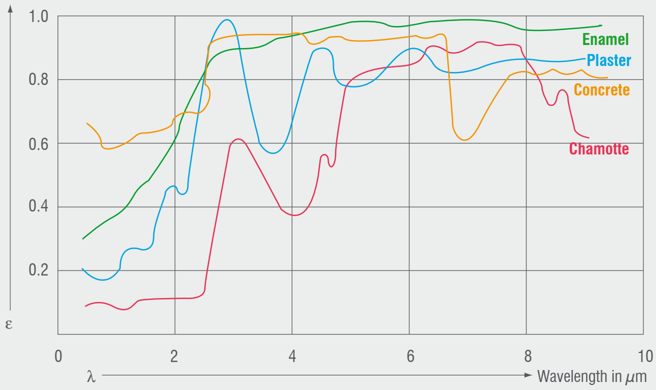
$$T_{obj} = \sqrt[n]{\frac{U - C \cdot T_{amb}^{n} + C\,\varepsilon\,T_{amb}^{n} + C \cdot T_{pyr}^{n}}{C\,\varepsilon}}$$

The results of these calculations for all temperatures are stored as curve band in the EEPROM of the infrared thermometer. Thus a quick access to the data as well as a fast calculation of the temperature are guaranteed.

Emissivity

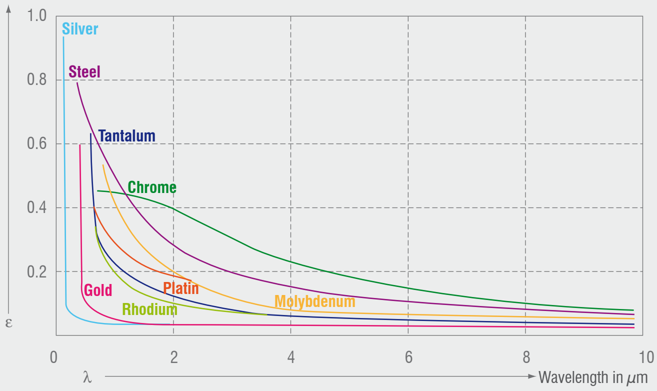
The formula show that the emissivity ε is of central significance, if you want to determine the temperature with radiation measurement. The emissivity stands for the relation of thermal radiations, which are generated by a grey and a black body at the same temperature. The maximum emissivity for the black body is 1. A grey body is an object, which has the same emissivity at all wavelengths and emits less infrared radiation than a black radiator ($\varepsilon < 1$). Bodies with emissivities, which depend on the temperature as well as on the wavelength, are called non grey or selective bodies (e.g. metals).

The emissivity depends on the material, its surface, temperature, wavelength and sometimes on the measuring arrangement. Many objects consisting of nonmetallic material show a high and relatively constant emissivity independent from their surface consistency, at least in longwave ranges.



Spectral emissivity of some materials

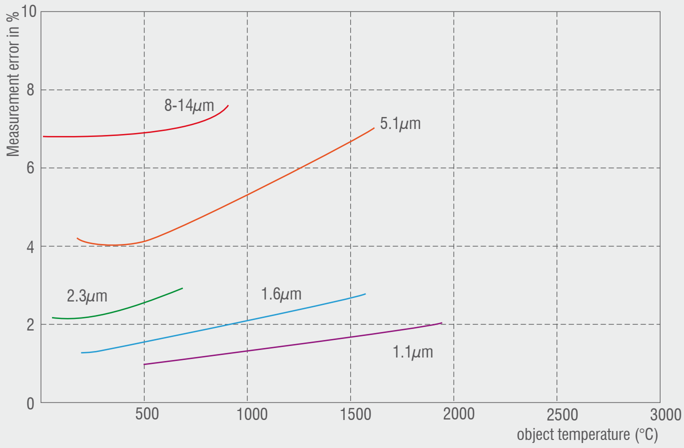
Generally metallic materials show a low emissivity, which strongly depends on the surface consistency and which drop in higher wavelengths.



Spectral emissivity of metallic materials

Temperature Measurement of Metallic Materials

This may result in varying measuring results. Consequently, already the choice of the infrared thermometer depends on the wavelength and temperature range, in which metallic materials show a relatively high emissivity. For metallic materials the shortest possible wavelength should be used, as the measuring error increases in correlation to the wavelength.



Measurement error of 10 % as result of wrongly adjusted emissivity and in dependence on wavelength and object temperature.

The optimal wavelength for metals ranges with 0.8 to 1.0 µm for high temperatures at the limit of the visible area. Additionally, wavelengths of 1.6 µm, 2.2 µm and 3.9 µm are possible.

Temperature Measurement of Plastics

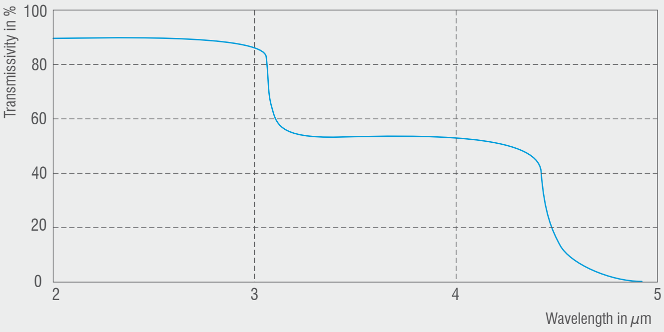
Transmissivities of plastics vary with the wavelength. They react inversely proportional to the thickness, whereas thin materials are more transmissive than thick plastics. Optimal measurements can be carried out with wavelengths, where transmissivity is almost zero independent from the thickness. Polyethylene, polypropylen, nylon and polystyrene are non-transmissive at 3.43 µm, polyester, polyurethane, teflon, FEP and polyamide are non-transmissive at 7.9 µm. For thicker and pigmented films wavelengths between 8 and 14 µm will do. The manufacturer of infrared thermometers can determine the optimal spectral range for the temperature measurement by testing the plastics material. The reflection is between 5 and 10 % for almost all plastics.

Spectral permeability of plastics made from polethylene.

Spectral transmissivity of plastic layers made of polyester

Temperature Measurement of Glass

If you measure temperatures of glass it implies that you take care of reflection and transmissivity. A careful selection of the wavelength facilitates measurements of the glass surface as well as of the deeper layers of the glass. Wavelengths of 1.0 µm, 2.2 µm or 3.9 µm are appropriate for measuring deeper layers whereas 5 µm are recommended for surface measurements. If temperatures are low, you should use wavelengths between 8 and 14 µm in combination with an emissivity of 0.85 in order to compensate reflection. For this purpose a thermometer with short response time should be used as glass is a bad heat conductor and can change its surface temperature quickly.



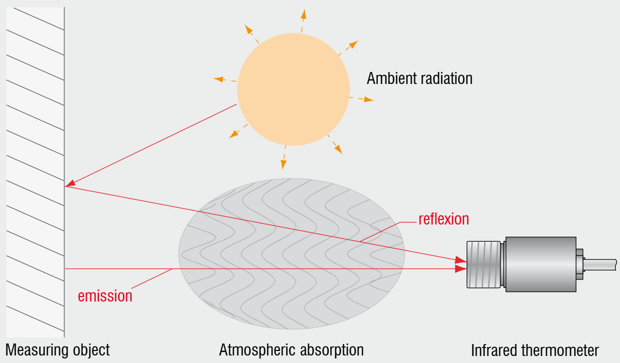
Spectral transmissivity of glass

Influence from the Surroundings

The illustration shows that the transmissivity of air strongly depends on the wavelength. Strong flattening alternates with areas of high transmissivity - the so-called “atmospheric windows”. The transmissivity in the longwave atmospheric window (8 - 14 µm) is constantly high whereas there are measurable alleviations by the atmosphere in the shortwave area, which may lead to false results. Typical measuring windows are 1.1 … 1.7 µm, 2 … 2.5 µm and 3 … 5 µm.

Spectral transmissivity of air (1 m, 32°C, 75 % r. F.)

Additional influences can arise from heat sources in the environment of the measuring object. To prevent wrong measuring results due to increased ambient temperatures, the infrared thermometer compensates the influence of ambient temperatures beforehand (as e.g. when measuring temperatures of metals in industrial ovens, where the oven walls are hotter than the measuring object). A second temperature sensing head helps to generate accurate measuring results by automatically compensating the ambient temperatures and a correctly adjusted emissivity.



Compensating ambient influences

Dust, smoke and suspended matter in the atmosphere can pollute the optics and result in false measuring data. Here air purge collars (which are installed in front of the optics with compressed air) help to prevent deposition of suspended matter in front of the optics. Accessories for air and water cooling support the use of infrared thermometers even in hazardous surroundings.

Experimental Determination of Emissivities

In the addendum you will find emissivity dates for various materials from technical literature and measurement results. There are different ways to determine the emissivity.

Method 1: With the help of a thermocouple

With the help of a contact probe (thermocouple) an additional simultaneous measurement shows the real temperature of an object surface. Now the emissivity on the infrared thermometer will be adapted so that the temperature displayed corresponds to the value shown with the contact measurement. The contact probe should have good temperature contact and only a low heat dissipation.

Method 2: Creating a black body with a test object from the measuring material

A drilled hole (drilling depth <=1/3) in thermal conducting material reacts similar to a black body with an emissivity near 1. It is necessary to aim at the ground of the drilled hole because of the optical features of the infrared device and the measuring distance. Then the emissivity can be determined.

Method 3: With a reference emissivity

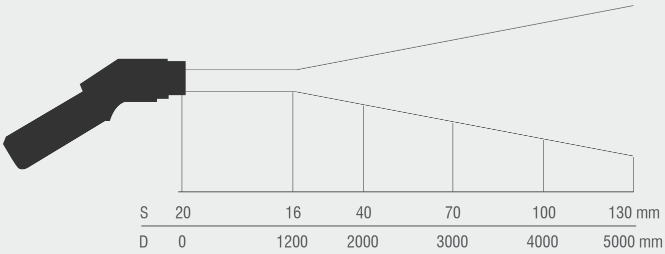
A plaster or band or paint with a known emissivity, which is put onto the object surface, helps to take a reference measurement. With an emissivity thus adjusted on the infrared thermometer the temperature of the plaster, band or paint can be taken. Afterwards the temperature next to this surface spot will be taken, while simultaneously the emissivity will have to be adjusted until the same temperature is displayed as is measured beforehand on the plaster, band or paint. Now the emissivity is displayed on the device.

Construction of the Infrared Thermometers

Infrared thermometers have various configurations and designs, which differ in optics, electronics, technology, size and housing. Nevertheless, the way of how the signals are processed is the same: It always starts with an infrared signal and ends with an electronic temperature output signal.

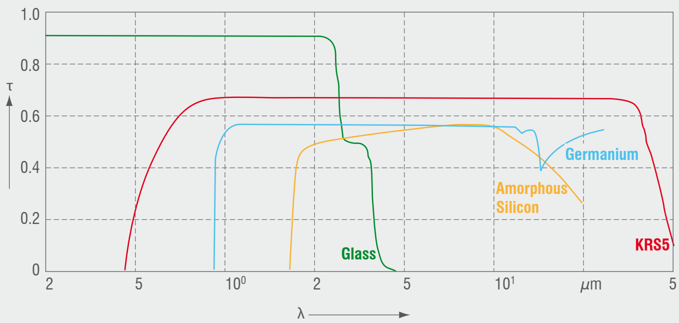
Optics and Window

An optical system - mostly consisting of lens optics - forms the beginning of the measuring chain. The lens receives the emitted infrared energy from a measuring object and focuses it onto a detector. Measurements based on this technology can only be correct, if the measuring object is bigger in size than the detector spot. The distance ratio describes the size of the measuring spot at a certain distance. It is defined as D:S-ratio: relation of measuring distance to spot diameter. The optical resolution improves with increasing values of the D:S ratio.



Optical Diagram of an infrared sensor

Because of their material infrared optics can be used for a certain range of wavelengths, only. The following illustration shows typical lenses and window materials with their corresponding wavelength for infrared thermometers.



Transmissivity of typical infrared materials (1 mm thick)

Some measurements make it necessary to take the temperature through an appropriate measuring window, as in closed reaction containers, ovens or vacuum chambers. The transmissivity of the measuring window should match the spectral sensitivity of the sensor. Quartz crystal fits for high measuring temperatures. Special material like Germanium, AMTIR or Zinkselenid should be used for low temperatures in the spectral range between 8 - 14 µm. Also diameter of the window, temperature conditions and maximum compression balance are important features for the selection of a qualified window material. A window of 25 mm in diameter, which has to resist a compression balance of 1 atmosphere, should be 1.7 mm thick. Window material, which is transparent also in the visible range, might help in order to appropriately adjust the sensor onto the measuring object (e.g. inside the vacuum container).

The table shows various window materials in a survey

Window material/features	Al2O3	SiO2	CaF2	BaF2	AMTIR	ZnS
Recommended infrared wavelength in µm	1…4	1…2.5	2…8	2…8	3…14	2…14
Max. window temperature in °C	1800	900	600	500	300	250
Transmissivity in visible area	yes	yes	yes	yes	no	yes
Resistiveness against humidity, acids, ammoniac combinations	very good	very good	few	few	good	good

Windows with anti reflection coating have a significantly higher transmissivity (up to 95%). The transmissivity loss can be corrected with the transmissivity setup, in case the manufacturer specified the corresponding wavelength area. If not, it has to be identified with an infrared thermometer and a reference source.

Latest Trends in Sighting Techniques

New principles of measurement and sighting techniques facilitate an improved and precise use of infrared thermometers. Developments in the field of solid state lasers are adapted for multiple laser arrangements to mark the spot sizes. Thus, the real spot sizes inside the object field are denoted with the help of laser crosshairs techniques. Different products use video camera chips instead of optical sighting systems.

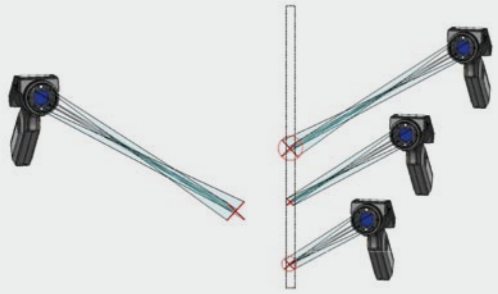
Development of High-Performance Optics combined with Laser Crosshairs Techniques

Simple, cost-effective portable infrared thermometers use single point laser aimers in order to distinguish the centre of the spot with a parallax default. With that technique the user has to estimate the spot size with the help of the spot size diagram and the likewise estimated measuring distance. If the measuring object takes only a part of the measuring spot, temperature rises are only displayed as average value of hot area and ambient cold area. A higher resistance of an electric connection due to a corroded contact results in an unduly heating. Due to small objects and inappropriate big spot sizes, this rise will be shown as a minor heating, only: Thus, potentially dangerous heatings may not be recognized in time. In order to display spots in their real size, optical sighting systems with a size marking were developed. They allow an exact targeting. As laser pyrometers are significantly easier and safer than contact thermometers, engineers have tried to mark the spot size with laser sighting techniques independently from the distance - according to the distance-spot-size-ratio in the diagram.

Two warped laser beams approximately show the narrowing of the measuring beam and its broadening in longer distances. The diameter of the spot size is indicated by two spots on the outer circumference. Due to the design the angle position of these laser points on the circuit alternates which makes an aiming difficult.

The Principle of the Crosshairs

New laser sighting techniques support denoting measuring spots of infrared thermometers as real size crosshairs, exactly matching the measuring spot in their dimension.



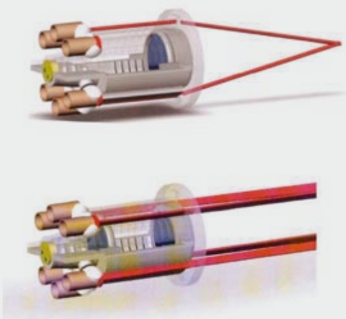
Infrared thermometer with laser crosshairs for exact spot size marking

Four laser diodes are arranged in symmetrical order around the infrared optical measuring channel. They are connected to line generators, which create a line of defined length inside the focus distance. The line generators, arranged in pairs, face each other. They overlap the projected laser lines at the focus. That way crosshairs are generated, which exactly display the diameter of the measuring spot. At longer or shorter distances the overlapping is only partly. Thus the user has a changed line length and with this changed measuring crosshairs. With the help of this technology the precise dimensions of a measuring spot can be denoted for the first time. This development improves the practical use of products with good optical performance.

Switching to Close Focus Mode

Common applications in electrical maintenance and industrial quality control imply optimal measuring distances of about 0.75 to 2.5 metres. Additionally, it is often necessary to measure distinctly smaller objects at shorter distances. Because of that engineers designed products, which allow focusing within certain limits. Still, they had not succeeded in creating spot sizes smaller than 1 mm.

New products apply a technology which uses two-lens optics: Similar to digital cameras, the inner lens position can be switched digitally into focusing onto very small spot sizes. The result is a very small spot size, but only at a constant distance. If the distance grows smaller or longer between measuring spot and infrared thermometer, the measuring spot increases in size. Two laser beams crossing each other create a laser point diameter of 1 mm at the smallest spot size position. They help to show optimal distance as well as spot size. The illustration shows the optical system of a modern infrared thermometer: The lens position is selectable and simultaneously various laser sighting systems support a real size display of the measuring spot.



Optomechanical construction of a modern infrared thermometer

Electronics: Displays, Outputs and Interfaces

The electronics of the infrared thermometer linearise the output signal of the detector in order to generate a linear power signal 0/4 - 20 mA or voltage signal 0 - 10 V. The portable thermometers show this signal as a temperature result on the LCD displays. Additionally some of the portable units as well as online sensors offer various outputs and interfaces for further signal processing.

Outputs and Interfaces

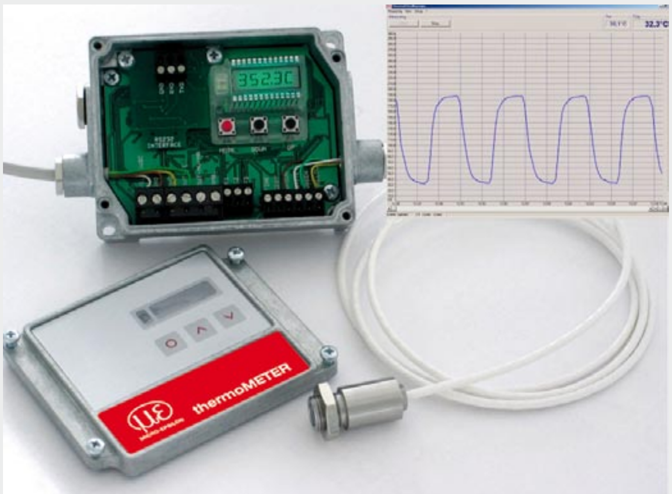
Analog Outputs

Current output
0-20/4-20mA
0-5/0-10V
Thermocouple

Digital Outputs
uni/bidirectional

RS232/RS422
RS485
Fieldbus
(CAN,Profibus...)
Ethernet

Examples for Outputs and Interfaces of Infrared Thermometers



The output interfaces of infrared thermometers may be directly connected with PC, laptop, measuring data printer. PC software allows customer oriented graphics and tables.

The importance of industrial field bus systems increases more and more. They allow more flexibility and less cabling and wiring efforts. If the manufacturer plans a change in products, the sensor parameters (emissivity, measuring range or limiting value) can be adjusted remotely. Consequently, a continuous process control and management is guaranteed even in hazardous surroundings and with a minimum of labor. If a failure occurs, e.g. cable interruptions, drop out of components, automatically an error message appears. A further advantage of infrared thermometers with digital interface is the possibility to carry out field calibrations with calibration software of the manufacturer.

Applications of Infrared Thermometers

Noncontact temperature measurement with infrared thermometers is a qualified method of controlling, monitoring and managing process temperatures and of preventive maintenance of machines and facilities. Portable infrared thermometers or infrared online sensors, additionally split into point and image measuring products, can be selected depending on the application.

Portable Infrared Thermometers

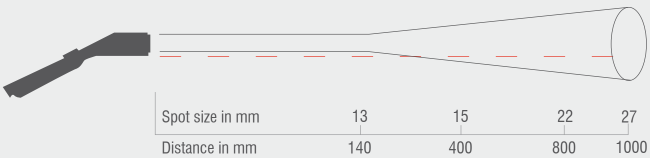
Generally portable infrared thermometers are used for preventive maintenance and inspection of electrical facilities, rotating machines as well as a tool for diagnosis for heating, ventilation and air conditioning systems and for the quick analysis of cars.

Easy and precise - fast inspection with portable infrared thermometers.

The infrared thermometers are also designed for applications under difficult industrial conditions. They might be used inside and outside, in sun and rain, in unsteady temperature conditions. The MS - although lightweight and with the latest design - is rugged and easy to handle. No matter whether you carry it in your shirt pocket, at the belt or you put it into the toolbox, it should always be with you for fast inspections.

Portable infrared thermometers

Within only 0.3 seconds you can take temperatures from -32 to 530°C with an accuracy of ± 1 % and ± 1°C. The installed laser helps you to aim at the measuring object, with only one click the temperature is shown on the display with a resolution of 0.1°C. An alarm signal for maximum and minimum values supports a systematic scanning of the measuring object and a quick detection of the hot spot. The new precision optics allow to measure very small objects. If you can approach the measuring object up to 14 cm, you will have a spot size of only 13 mm. The spot size increases with growing distance. At a distance (D) of 1 meter you can take the temperature of a surface 50 mm in size (S) - consequently, the optical resolution D:S is 20:1.



Distance-to-spot-ratio (D:S) 20:1

Typical Applications in Maintenance and Service

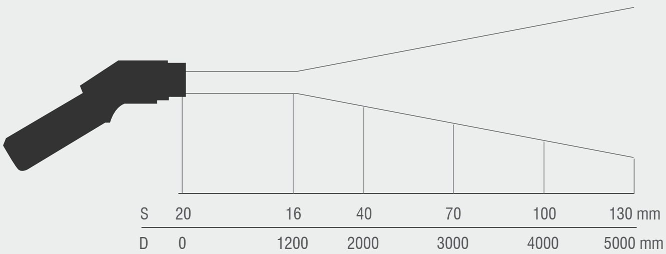
The LS allows very fast inspections: Within 150 ms you can take temperatures ranging from -32 to 900°C. The installed laser crosshairs help to exactly aim at the measuring object and mark the real measuring spot size. Just one click later the temperature result is shown on the display with a temperature resolution of 0.1°C. A visual and optical alarm signalizes that values either exceeded or dropped below the set limits (MAX/MIN-function). That way a systematic scanning of the object and a fast detection of the source of trouble is possible. The new two-lens precision optics of the LS also facilitates to measure very small objects. Switching into the close focus mode supports the user to exactly measure objects with the size of 1 mm. Two lasers, which cross each other directly at the close focus point at the distance of 62 mm, help to aim at the small spot. Up to now thermometers have been constructed to either measure at long distances or to exclusively measure small objects. Thus it was necessary to buy several tools or exchangeable lenses. The LS is an “all in one”-tool, which enables to focus on close distances by switching into the close focus mode.

Detailed infrared temperature measurement of an electric control with the help of the installed close focus optics for 1 mm ranges of the LS

A special sophisticated solution is the smart Flip display of the LS. An integrated position sensor automatically turns the LCD display into the most convenient viewing position for vertical or horizontal measurements. Common infrared thermometers have made it difficult to read the display in vertical or upright down positions. The illustration shows such a typically vertical measuring position during the control of electronic components. Please note the well visible and automatically into the best position turned display. Hand held infrared thermometers like these with very small measuring spot geometries of 1 mm are an alternative to buying an infrared thermal imager. Under common conditions - due to high production quantities and a high number of testing places - the use of several infrared thermal imagers at different stations can be too expensive.

Highly accurate infrared temperature measurement with the LS of 1 mm small SMD components during a printed circuit board testing

Defective switchgears, fuses, engines and electrical connections are barely visible with the naked eye. But it is common knowledge, that most production facilities, which consume electricity or transfer mechanical power, heat up in case of a malfunction. Non-contact temperature measurement is an important instrument in preventive maintenance in order to guarantee the safeness of facilities. The LS portable thermometers offer a spot size of 1 mm, only. Combined with the laser sighting technique they are the ideal tools for fast everyday temperature measurements of a vast number of measuring objects in a company.



Optical diagram of close focus optics

- Temperature measurements of moving machines and facilities, electrical connections of engines and of objects in hazardous surroundings
- Detection of loose connection joints
- Localization of hidden failures in cable channels
- Inspection of fuses and circuit breakers
- Monitoring the low and medium voltage facilities
- Detection of one-sided overload and unbalanced energy distribution
- Checking transformers and small components

Temperature Measurement of Contacts

During the transfer of high electrical performance bus contacts often show unbalanced load distribution and overheating, which might be a safety risk. Mechanical movement of material may result in loose contacts, which - due to cyclic heating and cooling - increase their electrical resistance, which leads to a higher power consumption and generates more heat. Also dust and corrosion may be reasons for higher resistance. The temperature difference compared to the evenly charged contacts as well as the ambient temperature lead to conclusions on the operating condition. 10 K difference indicate a bad connection, 30 K imply a critical state.

Checking the Transformers

Transformers have a maximum operating temperature. Unduly heating of wirings of the air transformer indicates a malfunction. A reason for that can either be the wiring or an unsteady charging of the phases.

Localization of Defective Cables

“Hidden” defects in cables may be localized by a fast scanning with infrared thermometers. Increased temperatures signalize an increased power consumption. At these points the cables can be checked for splits, corrosion and aging.

Typical Applications in Heating, Ventilation and Air Conditioning Systems

Drafty rooms or bad climate are often the result of defective or unsteady working heating, ventilation and air conditioning systems. The HVAC engineer is asked to locate the source of trouble in the shortest possible time and to prevent unscheduled shutoffs. This has been a very time-consuming and troublesome work depending on the method. Often the engineer had to drill holes into channels in order to trace leakages in channels, jammed filters or iced refrigerating coils. The then inserted thermometers took some time to stabilise and to correctly take the air temperature of the conduit. The use of infrared thermometers makes this work considerably easier and saves valuable working time. Surface temperatures of components can now be taken from a safe distance in a fast and comfortable way. There is no more need for ladders. HVAC engineers need measuring tools, which work efficiently and reliably, which have a rugged design and are easy to handle.

The LS supports:
- to detect defective isolations
- to find leakages in floor heating systems
- to check burners of oil heaters and gas boilers
- to control heat exchangers, heating circles as well as heating distributors
- to locate leakages in conduits
- to control air outlets and safety valves
- to regulate thermostats or to condition the air of a room

Typical Applications of Car Analysis

The important factor is to locate and mend sources of trouble as quickly as possible. Please find here some examples of how to use non-contact temperature measurement in order to prevent repetitive exchange of expensive components:

Analysis of
- malfunction in engines
- overheating of catalytic converters
- engine management system
- air conditioning system
- cooling system or
- braking system.

Advantages of Infrared Thermometers:

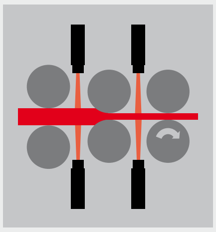
- Easy to handle
- Work non-contact and deliver precise measurement results within seconds
- Carry out safe inspections on hot components or objects in hazardous surroundings
- Locate sources of problem without exchanging components
- Detect weak points before they become a problem
- Save valuable time and money

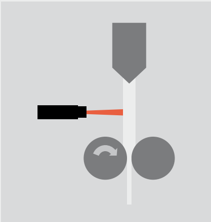
Online Infrared Thermometers

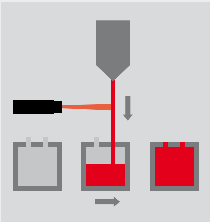
Online infrared temperature sensors are applicable for quality management purposes in production lines. In addition to the non-contact temperature measurement and the display of the results the user is able to control and manage the process temperatures. The wide range of possibilities to adjust infrared sensors to the measuring task allows an easy upgrade in existing production facilities as well as in the long-term planned equipment in cooperation with OEM customers in the machine construction industry.

Manifold applications are:

- Plastics processing
- Glass processing
- Paper processing
- In printing plants
- In laser welding and cutting processes
- Measurements of electronic components



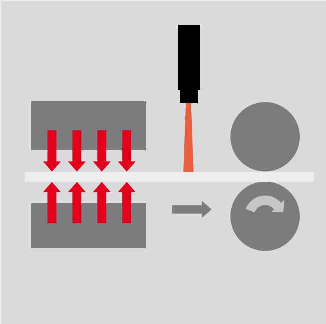




Typical Applications for Online Infrared Thermometers

Online infrared thermometers are used to control the temperature of paper web and the application of glue during the manuacturing of corrugated paper.

The high production speed of running paper web in modern laminating facilities require a precise and fast control of the paper temperature, of the glue and of the basic product, which needs to be concealed. An accurate laminating is only possible, if the necessary temperature balance for this process is taken care of at all times.



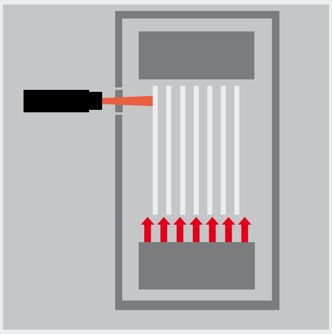
Infrared temperature measurement in paper and cardboard processing

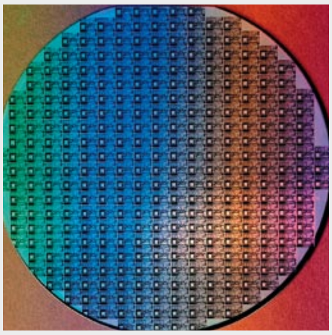
Temperature monitoring and managing of temperatures of printing machines with miniaturized infrared temperature sensors

The use of miniaturized infrared temperature sensors along the paper web of the press on roller and along the machine applying the glue in order to monitor and manage the temperatures support a steady laminating process. Air purging and cleaning processes on the optical channels of the infrared sensors support a maintenance-free measurement. The intelligent signal processing of the infrared sensors right along the track facilitate a geometrical correction of the glue application process.

Controlling the Temperature of Electronic Components during Function Tests

Increasingly more manufacturers of electronic components and PCB's use non-contact temperature measurement in order to monitor and check the thermal behavior of their products.



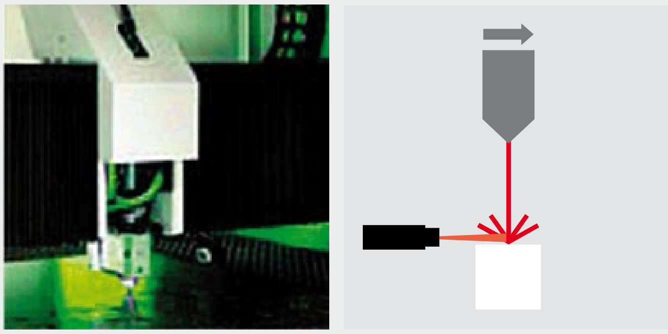


Infrared temperature measurement of wafers and electronic components

Infrared cameras support a detailed real-time analysis of the thermal reaction of circuit boards in research and development as well as in serial production. Under certain circumstances high production numbers and the increasing number of test and calibration stations make the use of infrared thermal cameras too expensive. The miniaturized infrared temperature sensors CT can be applied for serial monitoring of critical components in production facilities. The result is at once communicated to the test desk for further decision making. That way smallest spot sizes of only 0,6 mm can be monitored with an CT and an installed focus lens.

Monitoring the Product Temperature in Laser Welding and Laser Cutting Processes

To join and cut with the help of lasers appears to be a very sophisticated, cost- and time-effective technology. These processes use the precision of lasers and a high energy concentration. More accuracy on the cutting edge and shorter retention times combined with a higher temperature require a high quality product handling and compensation routine. Expansion in length according to temperature changes is one result for a deterioration in accuracy.



Infrared temperature measurement in laser welding processes

The miniaturized infrared temperature sensors CT measure the product temperature at the cutting or joining edge very quickly and react with corresponding correction signals. The CT and an installed focus lens can measure small spots of 0.6 mm. Thus production engineers have a measurement and control system, which works continuously and monitors the temperature reaction of the products in order to:

- quickly adjust and start facilities during batch changes, reducing idle times and test material
- monitor and record batch production
- guarantee a high and constant process quality

Thermal Imagers

The use of thermal imagers is increasingly important for preventive maintenance. As anomalies and malfunction on sensitive and important facility components often show with a heat radiation, the consequent and directed use of this technology helps to prevent high consequential costs, which might be the result of machine failure and production stops.

Thermal imager

The latest thermal imagers are small, lightweight, are easy to use and have good ergonomics. Connected to a notebook data analysis on site is supported in order to decide on appropriate maintenance methods at once and to carry out repairs. According to the environmental rating IP67 the systems are safe against environmental influence such as dust and splattering water and therefore are best equipped for the industrial use. The thermal imagers take temperatures ranging from -20 and 900°C. The systems accuracy is ± 2 % or ± 2°C of the reading. A logically built menu supports the easy adjustment of basic features such as choosing the colors, measuring spots, alarm values, emissivity. It also helps to organize the stored thermal images and videos.

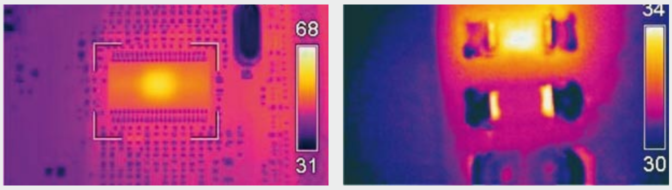
The Infrared Detector

The high quality Vanadium oxide detectors are safe against high radiation, dazzling sunlight and hot objects, which are accidentally included in the image. Consequently, measurements can be safely carried out outside and with direct light. The image rating of 120 Hz combined with a high thermal resolution of < 0.08 K help to catch even small temperature discrepancies in real time, even if objects are moving or different objects are aimed at in fast sequence.

Due to the high thermal sensitivity the detector shows the surroundings of the measuring objects in high contrast. This helps to better orientate in the thermal image.

Smart Camera

The temperature result is shown on the display with a resolution of 0.1°C. Furthermore, crosshairs mark the measuring point in the display. Thus, the user may in a first step obtain an overview of the electric switch box. In a second step he can control single components such as electrical connections, contacts or contactors and record them. Very small objects, as for instance circuits or SMD components on printed circuit boards, are better controlled with an infrared camera, as the aiming at such small objects requires either a tripod or much patience. Infrared cameras can be switched into a mode, which helps to find the maximum temperature: Inside a defined square image cutout all pixels are itemised and their temperatures are shown on the display. This very helpful function allows to determine the temperature of tiny objects. Optional to the maximum result, the display also shows minimum or average result.



Temperature control on a circuit with maximum function

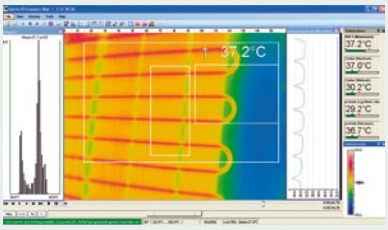
The camera stores the infrared images in JPG format including all radiometric data of each single pixel for further processing or documentation purposes. An integrated USB interface supports the transfer of the data to PC or laptop. The provided software allows the analysis of the results.

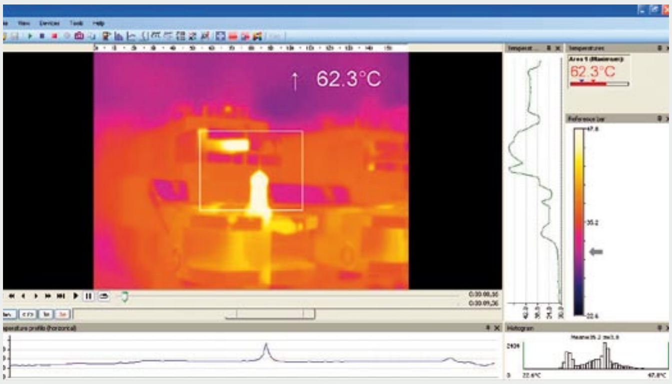
Exchangeable Lenses for Manifold Applications

Three different exchangeable lenses are available for various measuring distances between camera and object. Thus, the user can choose the optimal adjustment for his application. The standard lens for medium distances is a 25°-lens. With its optimized field of view it can be used for all standard everyday measurements, as there are the control of mechanical systems like bearings, waves and drive units, the inspection of conduits and isolations as well as classical building thermography.
The 6°-tele lens is appropriate for measuring objects at a longer distance with a high detailed resolution of single components (e.g. controlling switches and insulators in high voltage facilities). The 23° and 48° wide-angle lenses complete the supply and provides the monitoring of medium-sized electric switch boards “at one glance” in narrow circumstances as they often are in manufacturing facilities. Thus, the camera still covers an area of 1.50 m x 1.40 m even at a distance of only 2 m between measuring object and lens.
A further important application is the measurement of very small SMD components on printed circuit boards. For that purpose the 23° and 48° lens can be focused on very short distances of less than 50 mm. The so achieved resolution enables the user to determine temperatures of objects of only 0.5 mm diameter.

Software of Thermal Imagers and Thermographic Solutions

Thermographic solutions are completed with software for the online video display and recording of fast thermodynamic processes with manifold tools for picture analysis. Comfortable transfer and management of data from the infrared camera as well as subsequent analysis of the radiometric data of the infrared images support the processing of the temperature results. Temperature information can be displayed for each single image pixel. Subsequent adjustment of colors as well as setup of the color palette help to customize the data to the requirements of the analysis.





Recommended Literature:

1 VDI/VDE Richtlinie, Technische Temperaturmessungen - Spezifikation von Strahlungsthermometern, Juni 2001, VDI 3511 Blatt 4.1

2 Stahl, Miosga: Grundlagen Infrarottechnik, 1980, Dr. Alfred Hütthig Verlag Heidelberg

3 Walther, Herrmann: Wissensspeicher Infrarotmesstechnik, 1990, Fachbuchverlag Leipzig

4 Walther, L., Gerber, D:. Infrarotmesstechnik, 1983, Verlag Technik Berlin

5 De Witt, Nutter: Theory and Practice of Radiation Thermometry, 1988, John Wiley & Son, New York, ISBN 0-471-61018-6

6 Wolfe, Zissis: The Infrared Handbook, 1978, Office of Naval Research, Department of the Navy, Washington DC.

Emissivity Tables

Literature
Emissivity
Spectrum
T: total spectrum
SW: 2 - 5μm,
LW: 8 - 14μm
LLW: 6.5 - 20μm
Material
Specification
Temperature in °C

Material	Specification	°C	Spec.	Emissivity	Lit.
Aluminumbrass		20	T	0.6	1
Aluminum	Plate, 4 samples differently scratched	70	LW	0.03 - 0.06	9
Aluminum	Plate, 4 samples differently scratched	70	SW	0.05 - 0.08	9
Aluminum	anodized, light grey, dull	70	LW	0.97	9
Aluminum	anodized, light grey, dull	70	SW	0.61	9
Aluminum	anodized, light grey, dull	70	LW	0.95	9
Aluminum	anodized, light grey, dull	70	SW	0.67	9
Aluminum	anodized plate	100	T	0.55	2
Aluminum	film	27	3μm	0.09	3
Aluminum	film	27	10μm	0.04	3
Aluminum	harshened	27	3μm	0.28	3
Aluminum	harshened	27	10μm	0.18	3
Aluminum	Cast, sandblasted	70	LW	0.46	9
Aluminum	Cast, sandblasted	70	SW	0.47	9
Aluminum	dipped in HNO3, plate	100	T	0.05	4
Aluminum	polished	50 - 100	T	0.04 - 0.06	1
Aluminum	polished, plate	100	T	0.05	2
Aluminum	polished plate	100	T	0.05	4
Aluminum	harshened surface	20 - 50	T	0.06 - 0.07	1
Aluminum	deeply oxidized	50 - 500	T	0.2 - 0.3	1
Aluminum	deeply weather beaten	17	SW	0.83 - 0.94	5
Aluminum	unchanged, plate	100	T	0.09	2
Aluminum	unchanged, plate	100	T	0.09	4
Aluminum	vacuumcoated	20	T	0.04	2
Aluminumoxide	activated, powder		T	0.46	1
Aluminumhydroxide	powder		T	0.28	1
Aluminumoxide	clean, powder (aluminumoxide)		T	0.16	1
Asbestos	Floor tiles	35	SW	0.94	7
Asbestos	Boards	20	T	0.96	1
Asbestos	Tissue		T	0.78	1
Asbestos	Paper	40 - 400	T	0.93 - 0.95	1
Asbestos	Powder		T	0.40 - 0.60	1
Asbestos	brick	20	T	0.96	1
Asphalt road surface		4	LLW	0.967	8
Brass	treated with 80-sandpaper	20	T	0.2	2
Brass	plate, milled	20	T	0.06	1
Brass	plate, treated with sandpaper	20	T	0.2	1
Brass	stronlgy polished	100	T	0.03	2
Brass	oxidized	70	SW	0.04 - 0.09	9
Brass	oxidized	70	LW	0.03 - 0.07	9
Brass	oxidized	100	T	0.61	2
Brass	oxidized at 600°C	200 - 600	T	0.59 - 0.61	1
Brass	polished	200	T	0.03	1
Brass	blunt, patchy	20 - 350	T	0.22	1
Brick	Aluminumoxide	17	SW	0.68	5
Brick	Dinas-Siliziumoxide, fireproof	1000	T	0.66	1
Brick	Dinas-Siliziumoxid, glazed, harshened	1100	T	0.85	1
Brick	Dinas-Siliziumoxid, unglazed, harshened	1000	T	0.8	1
Brick	fireproof product, corundom	1000	T	0.46	1
Brick	fireproof product, magnesit	1000 - 1300	T	0.38	1
Brick	fireproof product, mildly beaming	500 - 1000	T	0.65 - 0.75	1
Brick	fireproof product, strongly beaming	500 - 1000	T	0.8 - 0.9	1
Brick	fire brick	17	SW	0.68	5
Brick	glazed	17	SW	0.94	5
Brick	brickwork	35	SW	0.94	7
Brick	brickwork, plastered	20	T	0.94	1
Brick	normal	17	SW	0.86 - 0.81	5
Brick	red, normal	20	T	0.93	2
Brick	red, grey	20	T	0.88 - 0.93	1
Brick	chamotte	20	T	0.85	1
Brick	chamotte	1000	T	0.75	1
Brick	chamotte	1200	T	0.59	1
Brick	amorphous silicon 95% SiO_2	1230	T	0.66	1
Brick	Sillimanit, 33% SiO_2, 64% Al_2O_3	1500	T	0.29	1
Bronze	Phosphorbronze	70	LW	0.06	9
Bronze	Phosphorbronze	70	SW	0.08	1
Bronze	polished	50	T	0.1	1
Bronze	Porous, harshened	50 - 100	T	0.55	1
Bronze	powder		T	0.76 - 0.80	1
Carbon	fluent	20	T	0.98	2
Carbon	plumbago powder		T	0.97	1
Carbon	charcoal powder		T	0.96	1
Carbon	candle soot	20	T	0.95	2
Carbon	lamp soot	20 - 400	T	0.95 - 0.97	1
Cast Iron	treated	800 - 1000	T	0.60 - 0.70	1
Cast Iron	fluent	1300	T	0.28	1
Cast Iron	cast	50	T	0.81	1
Cast Iron	blocks made of cast iron	1000	T	0.95	1
Cast Iron	oxidized	38	T	0.63	4
Cast Iron	oxidized	100	T	0.64	2
Cast Iron	oxidized	260	T	0.66	4
Cast Iron	oxidized	538	T	0.76	4
Cast Iron	oxidized at 600°C	200 - 600	T	0.64 - 0.78	1
Cast Iron	polished	38	T	0.21	4
Cast Iron	polished	40	T	0.21	2
Cast Iron	polished	200	T	0.21	1
Cast Iron	untreated	900 - 1100	T	0.87 - 0.95	1
Chipboard	untreated	20	SW	0.9	6
Chrome	polished	50	T	0.1	1
Chrome	polished	500 - 1000	T	0.28 - 0.38	1
Clay	burnt	70	T	0.91	1
Cloth	black	20	T	0.98	1
Concrete		20	T	0.92	2
Concrete	pavement	5	LLW	0.974	8
Concrete	harshened	17	SW	0.97	5
Concrete	dry	36	SW	0.95	7
Copper	electrolytic, brightly polished	80	T	0.018	1
Copper	electrolytic, polished	-34	T	0.006	4
Copper	scraped	27	T	0.07	4
Copper	molten	1100 - 1300	T	0.13 - 0.15	1
Copper	commercial, shiny	20	T	0.07	1
Copper	oxidized	50	T	0.6 - 0.7	1
Copper	oxidized, dark	27	T	0.78	4
Copper	oxidized, deeply	20	T	0.78	2
Copper	oxidized, black		T	0.88	1
Copper	polished	50 - 100	T	0.02	1
Copper	pollished	100	T	0.03	2
Copper	polished, commercial	27	T	0.03	4
Copper	polished, mechanical	22	T	0.015	4
Copper	clean, thoroughly prepared surface	22	T	0.008	4
Copper-dioxide	powder		T	0.84	1
Copper-dioxide	red, powder		T	0.7	1
Earth	saturated with water	20	T	0.95	2
Earth	dry	20	T	0.92	2
Enamel		20	T	0.9	1
Enamel	paint	20	T	0.85 - 0.95	1
Fiberboard	hard, untreated	20	SW	0.85	6
Fiberboard	Ottrelith	70	LW	0.88	9

Material	Specification	°C	Spec.	Emissivity	Lit.
Fiberboard	Ottrelith	70	SW	0.75	9
Fiberboard	particle plate	70	LW	0.89	9
Fiberboard	particle plate	70	SW	0.77	9
Fiberboard	porous, untreated	20	SW	0.85	6
Glazing Rebates	8 different colors and qualities	70	LW	0.92 - 0.94	9
Glazing Rebates	8 different colors and qualities	70	SW	0.88 - 0.96	9
Glazing Rebates	aluminum, different age	50 - 100	T	0.27 - 0.67	1
Glazing Rebates	on oily basis, average of 16 colors	100	T	0.94	2
Glazing Rebates	chrome green		T	0.65 - 0.70	1
Glazing Rebates	cadmium yellow		T	0.28 - 0.33	1
Glazing Rebates	cobalt blue		T	0.7 - 0.8	1
Glazing Rebates	plastics, black	20	SW	0.95	6
Glazing Rebates	plastics, white	20	SW	0.84	6
Glazing Rebates	oil	17	SW	0.87	5
Glazing Rebates	oil, different colors	100	T	0.92 - 0.96	1
Glazing Rebates	oil, shiny grey	20	SW	0.96	6
Glazing Rebates	oil, grey, matt	20	SW	0.97	6
Glazing Rebates	oil, black, matt	20	SW	0.94	6
Glazing Rebates	oil, black, shiny	20	SW	0.92	6
Gold	brightly polished	200 - 600	T	0.02 - 0.03	1
Gold	strongly polished	100	T	0.02	2
Gold	polished	130	T	0.018	1
Granite	polished	20	LLW	0.849	8
Granite	harshened	21	LLW	0.879	8
Granite	harshened, 4 different samples	70	LW	0.77 - 0.87	9
Granite	harshened, 4 different samples	70	SW	0.95 - 0.97	9
Gypsum		20	T	0.8 - 0.9	1
Gypsum, applied		17	SW	0.86	5
Gypsum, applied	gypsum plate, untreated	20	SW	0.9	6
Gypsum, applied	harshened surface	20	T	0.91	2
Ice: see Water					
Iron and Steel	electrolytic	22	T	0.05	4
Iron and Steel	electrolytic	100	T	0.05	4
Iron and Steel	electrolytic	260	T	0.07	4
Iron and Steel	electrolytic, brightly polished	175 - 225	T	0.05 - 0.06	1
Iron and Steel	freshly milled	20	T	0.24	1
Iron and Steel	freshly processed with sandpaper	20	T	0.24	1
Iron and Steel	smoothed plate	950 - 1100	T	0.55 - 0.61	1
Iron and Steel	forged, brightly polished	40 - 250	T	0.28	1
Iron and Steel	milled plate	50	T	0.56	1
Iron and Steel	shiny, etched	150	T	0.16	1
Iron and Steel	shiny oxide layer, plate	20	T	0.82	1
Iron and Steel	hotly milled	20	T	0.77	1
Iron and Steel	hotly milled	130	T	0.6	1
Iron and Steel	coldly milled	70	LW	0.09	9
Iron and Steel	coldly milled	70	SW	0.2	9
Iron and Steel	covered with red rust	20	T	0.61 - 0.85	1
Iron and Steel	oxidized	100	T	0.74	1
Iron and Steel	oxidized	100	T	0.74	4
Iron and Steel	oxidized	125 - 525	T	0.78 - 0.82	1
Iron and Steel	oxidized	200	T	0.79	2
Iron and Steel	oxidized	200 - 600	T	0.8	1
Iron and Steel	oxidized	1227	T	0.89	4
Iron and Steel	polished	100	T	0.07	2
Iron and Steel	polished	400 - 1000	T	0.14 - 0.38	1
Iron and Steel	polished plate	750 - 1050	T	0.52 - 0.56	1
Iron and Steel	harshened, even surface	50	T	0.95 - 0.98	1
Iron and Steel	rusty, red	20	T	0.69	1
Iron and Steel	rusty red, plate	22	T	0.69	4
Iron and Steel	deeply oxidized	50	T	0.88	1
Iron and Steel	deeply oxidized	500	T	0.98	1
Iron and Steel	deeply rusted	17	SW	0.96	5
Iron and Steel	deeply rusted plate	20	T	0.69	2

Material	Specification	°C	Spec.	Emissivity	Lit.
Iron galvanized	plate	92	T	0.07	4
Iron galvanized	plate, oxidized	20	T	0.28	1
Iron galvanized	plate, oxidized	30	T	0.23	1
Iron galvanized	deeply oxidized	70	LW	0.85	9
Iron galvanized	deeply oxidized	70	SW	0.64	9
Iron tinned	plate	24	T	0.064	4
Leather	tanned fur		T	0.75 - 0.80	1
Limestone			T	0.3 - 0.4	1
Magnesium		22	T	0.07	4
Magnesium		260	T	0.13	4
Magnesium		538	T	0.18	4
Magnesium	polished	20	T	0.07	2
Magnesiumpowder			T	0.86	1
Molybdenum		600 - 1000	T	0.08 - 0.13	1
Molybdenum		1500 - 2200	T	0.19 - 0.26	1
Molybdenum	twine	700 - 2500	T	0.1 - 0.3	1
Mortar		17	SW	0.87	5
Mortar	dry	36	SW	0.94	7
Nickel	wire	200 - 1000	T	0.1 - 0.2	1
Nickel	electrolytic	22	T	0.04	4
Nickel	electrolytic	38	T	0.06	4
Nickel	electrolytic	260	T	0.07	4
Nickel	electrolytic	538	T	0.1	4
Nickel	galvanized, polished	20	T	0.05	2
Nickel	galvanized on iron, not polished	20	T	0.11 - 0.40	1
Nickel	galvanized on iron, non polished	22	T	0.11	4
Nickel	galvanized on iron, non polished	22	T	0.045	4
Nickel	lightly matt	122	T	0.041	4
Nickel	oxidized	200	T	0.37	2
Nickel	oxidized	227	T	0.37	4
Nickel	oxidized	1227	T	0.85	4
Nickel	oxidized at 600°C	200 - 600	T	0.37 - 0.48	1
Nickel	polished	122	T	0.045	4
Nickel	clean, polished	100	T	0.045	1
Nickel	clean, polished	200 - 400	T	0.07 - 0.09	1
Nickel-chrome	wire, bare	50	T	0.65	1
Nickel-chrome	wire, bare	500 - 1000	T	0.71 - 0.79	1
Nickel-chrome	wire, oxidized	50 - 500	T	0.95 - 0.98	1
Nickel-chrome	milled	700	T	0.25	1
Nickel-chrome	sandblasted	700	T	0.7	1
Nickeloxide		500 - 650	T	0.52 - 0.59	1
Nickeloxide		1000 - 1250	T	0.75 - 0.86	1
Oil, Lubricating Oil	0.025-mm-layer	20	T	0.27	2
Oil, Lubricating Oil	0.05-mm-layer	20	T	0.46	2
Oil, Lubricating Oil	0.125-mm-layer	20	T	0.72	2
Oil, Lubricating Oil	thick layer	20	T	0.82	2
Oil, Lubricating Oil	layer on Ni-basis: only Ni-Basis	20	T	0.05	2
Paint	3 colors, sprayed on aluminum	70	LW	0.92 - 0.94	9
Paint	3 colors, sprayed on aluminum	70	SW	0.50 - 0.53	9
Paint	aluminum on harshened surface	20	T	0.4	1
Paint	bakelite	80	T	0.83	1
Paint	heat-proof	100	T	0.92	1
Paint	black, shiny, sprayed on iron	20	T	0.87	1
Paint	black, matt	100	T	0.97	2
Paint	black, blunt	40 - 100	T	0.96 - 0.98	1
Paint	white	40 - 100	T	0.8 - 0.95	1
Paint	white	100	T	0.92	2
Paper	4 different colors	70	LW	0.92 - 0.94	9
Paper	4 different colors	70	SW	0.68 - 0.74	9
Paper	coated with black paint		T	0.93	1
Paper	dark blue		T	0.84	1
Paper	yellow		T	0.72	1
Paper	green		T	0.85	1

Emissivity Tables

Material	Specification	°C	Spec.	Emissivity	Lit.
Paper	red		T	0.76	1
Paper	black		T	0.9	1
Paper	black, blunt		T	0.94	1
Paper	black, blunt	70	LW	0.89	9
Paper	black, blunt	70	SW	0.86	9
Paper	white	20	T	0.7 - 0.9	1
Paper	white, 3 different shiny coatings	70	LW	0.88 - 0.90	9
Paper	white, 3 different shiny coatings	70	SW	0.76 - 0.78	9
Paper	white, bonded	20	T	0.93	2
Plastics	fiber optics laminate (printed circuit board)	70	LW	0.91	9
Plastics	fiber optics laminate (printed circuit board)	70	SW	0.94	9
Plastics	polyurethane-insulating plate	70	LW	0.55	9
Plastics	polyurethane-insulating plate	70	SW	0.29	9
Plastics	PVC, plastic floor, blunt, structured	70	LW	0.93	9
Plastics	PVC, plastic floor, blunt, structured	70	SW	0.94	9
Plate	shiny	20 - 50	T	0.04 - 0.06	1
Plate	white plate	100	T	0.07	2
Platinum		17	T	0.016	4
Platinum		22	T	0.05	4
Platinum		260	T	0.06	4
Platinum		538	T	0.1	4
Platinum		1000 - 1500	T	0.14 - 0.18	1
Platinum		1094	T	0.18	4
Platinum	band	900 - 1100	T	0.12 - 0.17	1
Platinum	wire	50 - 200	T	0.06 - 0.07	1
Platinum	wire	500 - 1000	T	0.10 - 0.16	1
Platinum	wire	1400	T	0.18	1
Platinum	clean, polished	200 - 600	T	0.05 - 0.10	1
Plumb	shiny	250	T	0.08	1
Plumb	non oxidized, polished	100	T	0.05	4
Plumb	oxidized, grey	20	T	0.28	1
Plumb	oxidized, grey	22	T	0.28	4
Plumb	oxidized at 200°C	200	T	0.63	1
Plumb rot		100	T	0.93	4
Plumb rot, Powder		100	T	0.93	1
Polystyrene	heat insulation	37	SW	0.6	7
Porcelain	glazed	20	T	0.92	1
Porcelain	white, glowing		T	0.70 - 0.75	1
Rubber	hard	20	T	0.95	1
Rubber	soft, grey, harshened	20	T	0.95	1
Sand			T	0.6	1
Sand		20	T	0.9	2
Sandpaper	coarse	80	T	0.85	1
Sandstone	polished	19	LLW	0.909	8
Sandstone	harshened	19	LLW	0.935	8
Silver	polished	100	T	0.03	2
Silver	clean, polished	200 - 600	T	0.02 - 0.03	1
Skin	Human Being	32	T	0.98	2
Slag	basin	0 - 100	T	0.97 - 0.93	1
Slag	basin	200 - 500	T	0.89 - 0.78	1
Slag	basin	600 - 1200	T	0.76 - 0.70	1
Slag	basin	1400 - 1800	T	0.69 - 0.67	1
Snow: see Water					
Stainless Steel	plate, polished	70	LW	0.14	9
Stainless Steel	plate, polished		SW	0.18	9
Stainless Steel	plate, not treated, scratched	70	LW	0.28	9
Stainless Steel	plate, not treated, scratched	70	SW	0.3	9
Stainless Steel	milled	700	T	0.45	1
Stainless Steel	alloy, 8% Ni, 18% Cr	500	T	0.35	1
Stainless Steel	sandblasted	700	T	0.7	1
Stainless Steel	type 18-8, shiny	20	T	0.16	2
Stainless Steel	type 18-8, oxidized at 800°C	60	T	0.85	2

Material	Specification	°C	Spec.	Emissivity	Lit.
Tar			T	0.79 - 0.84	1
Tar	paper	20	T	0.91 - 0.93	1
Titanium	oxidized at 540°C	200	T	0.4	1
Titanium	oxidized at 540°C	500	T	0.5	1
Titanium	oxidized at 540°C	1000	T	0.6	1
Titanium	polished	200	T	0.15	1
Titanium	polished	500	T	0.2	1
Titanium	polished	1000	T	0.36	1
Tungsten		200	T	0.05	1
Tungsten		600 - 1000	T	0.1 - 0.16	1
Tungsten		1500 - 2200	T	0.24 - 0.31	1
Tungsten	twine	3300	T	0.39	1
Varnish	on parquet flooring made of oak	70	LW	0.90 - 0.93	9
Varnish	on parquet flooring made of oak	70	SW	0.9	9
Varnish	matt	20	SW	0.93	6
Vulcanite			T	0.89	1
Wall Paper	slightly patterned, light grey	20	SW	0.85	6
Wall Paper	slightly patterned, red	20	SW	0.9	6
Water	distilled	20	T	0.96	2
Water	ice, strongly covered with frost	0	T	0.98	1
Water	ice, slippery	-10	T	0.96	2
Water	ice, slippery	0	T	0.97	1
Water	frost crystals	-10	T	0.98	2
Water	coated >0.1 mm thick	0 - 100	T	0.95 - 0.98	1
Water	snow		T	0.8	1
Water	snow	-10	T	0.85	2
Wood		17	SW	0.98	5
Wood		19	LLW	0.962	8
Wood	planed	20	T	0.8 - 0.9	1
Wood	planed oak	20	T	0.9	2
Wood	planed oak	70	LW	0.88	9
Wood	planed oak	70	SW	0.77	9
Wood	treated with sandpaper		T	0.5 - 0.7	1
Wood	pine, 4 different samples	70	LW	0.81 - 0.89	9
Wood	pine, 4 different samples	70	SW	0.67 - 0.75	9
Wood	plywood, even, dry	36	SW	0.82	7
Wood	plywood, untreated	20	SW	0.83	6
Wood	white, damp	20	T	0.7 - 0.8	1
Zinc	plate	50	T	0.2	1
Zinc	oxidized at 400°C	400	T	0.11	1
Zinc	oxidized surface	1000 - 1200	T	0.50 - 0.60	1
Zinc	polished	200 - 300	T	0.04 - 0.05	1

References

1 Mikaél A. Bramson: Infrared Radiation, A Handbook for Applications, Plenum Press, N.Y.

2 William L. Wolfe, George J. Zissis: The Infrared Handbook, Office of Naval Research, Department of Navy, Washington, D.C.

3 Madding, R.P.: Thermographic Instruments and Systems. Madison, Wisconsin: University of Wisconsin - Extension, Department of Engineering and Applied Science

4 William L. Wolfe: Handbook of Military Infrared Technology, Office of Naval Research, Department of Navy, Wahsington, D.C.

5 Jones, Smith, Probert: External thermography of buildings …, Proc. Of the Society of Phot-Optical Instrumentation Engineers, vol. 110, Industrial and Civil Applications of Infrared Technology, Juni 1977 London

6 Paljak, Pettersson: Thermography of Buildings, Swedish Building Research Institute, Stockholm 1972

7 Vlcek, J.: Determination of emissivity with imaging radiometers and some emissivities at $\lambda = 5\,\mu m$. Photogrammetric Engineering and Remote Sensing.

8 Kern: Evaluation of infrared emission of clouds and ground as measured by weather satellites, Defence Documentation Center, AD 617 417.

9 Öhman, Claes: Emittansmätningar med AGEMA E-Box. Teknisk rapport, AGEMA 1999. (Emissivity measurements with AGEMA E-Box. Technical report, AGEMA 1999.)

A wide selection of infrared thermometers is available for non-contact temperature measurement. The following criteria will help to find the optimal measuring device for your application.
- Temperature range
- Environmental conditions
- Spot size
- Material and surface of the measuring object
- Response time of the infrared thermometer
- Interface

Temperature Range
Choose the temperature range of the sensor as optimal as possible in order to reach a high resolution of the object temperature. The measuring ranges can be adjusted to the measuring task manually or via digital interface.

Environmental Conditions
The maximum acceptable ambient temperature of the sensors is very important. The CT line operates in up to 180°C without any cooling. By using water and air cooling the measuring devices work in even higher ambient temperatures. Air purge systems help to keep the optics clean from additional dust in the atmosphere.

Spot Size
The size of the measuring object has to be equal to or bigger than the viewing field of the sensor in order to reach accurate results. The spot diameter (S) changes accordingly to the distance of the sensor (D). The brochures specify the D:S relation for the different optics.

Material and Surface of the Measuring Object
The emissivity depends on material, surface and other factors. The common rule reads as follows: The higher the emissivity, the easier the measurement generates a precise result. Many infrared thermometers offer the adjustment of the emissivity. The appropriate values can be taken from the tables in the addendum.

Response Time of Infrared Thermometers
The response time of infrared thermometers is very small compared to contact thermometers. They range between 1 ms to 250 ms, strongly depending on the detector of the device. Because of the detector the response time is limited in the lower range. The electronics help to correct and adjust the response time according to the application (e.g. averaging or maximum hold).

Interfaces for the Signal Output
The interface supports the analysis of the measuring results. The following interfaces are available:
- Analog outputs 0/4 - 20 mA and 0 - 1/10 V
- Bus, CAN and DP interfaces
- RS232, RS485, USB
- Ethernet

Glossary

Absorption	Ratio of absorbed radiation by an object to incoming radiation. A number between 0 and 1.
Emissivity	Emitted radiation of an object compared to the radiation from a black bodysource. A number between 0 and 1.
Filter	Material, permeable for certain infrared wavelengths only
FOV	Field of view: Horizontal field of view of an infrared lens.
FPA	Focal Plane Array: type of an infrared detector.
Grey Body Source	An object, which emits a certain part of the energy which a black body source emits at every wavelength.
IFOV	Instantaneous field of view: A value for the geometric resolution of a thermal imager.
NETD	Noise equivalent temperature difference. A value for the noise (in the image) of a thermal imager.
Object parameter	Values, with which measurement conditions and measuring object are described (e.g. emissivity, ambient temperature, distance a.s.o.)
Object signal	A noncalibrated value, which refers to the radiation the thermal imager receives from the measuring object.
Palette	Colors of the infrared image
Pixel	Synonym for picture element. A single picture point in an image.
Reference temperature	Temperature value to compare regular measuring data with.
Reflection	Ratio of radiation reflected by the object and incoming radiation. A number between 0 and 1.
Black body source	Object with a reflection of 0. Any radiation is to be traced back to its temperature.
Spectral specific radiation	Energy emitted by an object related to time, area and wavelength (W/m²/µm).
Specific radiation	Energy emitted from an object related to units of time and area (W/m²).
Radiation	Energy emitted by an object related to time, area and solid angle (W/m²/sr).
Radiation flow	Energy emitted by an object related to the unit of time (W)
Temperature difference	A value, which is determined by subtraction of two temperature values.
Temperature range	Current temperature measuring range of a thermal imager. Imagers can have several temperature ranges. They are described with the help of two black body source values, which serve as threshold values for the current calibration.
Thermogram	Infrared image
Transmissity	Gases and solid states have different transmissivities. Transmissivity describes the level of infrared radiation, which permeates the object. A number between 0 and 1.
Ambient surroundings	Objects and gases, which pass radiation to the measuring object.

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Sensors and systems for non-contact temperature measurement

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MICRO-EPSILON

MICRO-EPSILON
8120 Brownleigh Dr. · Raleigh, NC 27617 / USA
Phone +1/919/787-9707 · Fax +1/919/787-9706
info@micro-epsilon.us · **www.micro-epsilon.com**