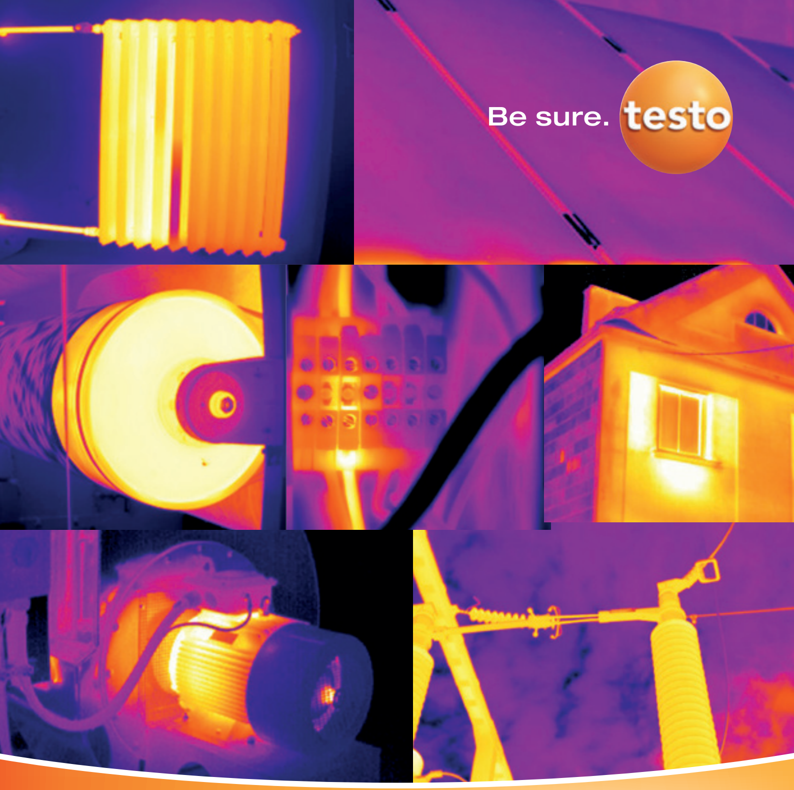


Thermography Pocket Guide

Theory – Practice – Tips & Tricks

Testo SE & Co. KGaA, in December 2017

Foreword

Dear Testo Customer

“A picture says more than a thousand words”.

In times of increasing energy prices and high costs for machine downtimes, non-contact temperature measurement has established itself both for the assessment of building efficiency and for industrial maintenance. However, not all thermography is the same, and there are a few basic ground rules to be followed in non-contact temperature measurement.

The “Thermography Pocket Guide” handbook was created by summarizing the questions raised by our customers on a day-to-day basis. This Pocket Guide is full of lots of interesting information, as well as tips and tricks from practical measurement applications, and is designed to offer you useful, practical help and support you in your daily work.

Have fun reading through it!

Prof. Burkart Knospe, CEO

Content

1 Theory of thermography

Every object with a temperature above absolute zero (0 Kelvin = -273.15 °C) emits infrared radiation. This infrared radiation is invisible to the human eye.

As the physicists Josef Stefan and Ludwig Boltzmann proved as far back as 1884, there is a correlation between the temperature of a body and the intensity of the infrared radiation it emits. A thermal imager measures the long-wave infrared radiation received within its field of view. From this it calculates the temperature of the object being measured. The calculation factors in the emissivity (ε) of the surface of the measuring object and the reflected temperature compensation (RTC), with both variables being able to be set manually in the thermal imager. Each pixel of the detector represents a temperature point that is shown on the display as a false colour image (cf. “1.2 Measurement spot and measuring distance”, p. 13).

Thermography (temperature measurement with a thermal imager) is a passive, non-contact measurement method. It involves the thermal image showing the temperature distribution on the surface of an object. This means you cannot look into or even through objects with a thermal imager.

1.1 Emission, reflection, transmission

The radiation recorded by the thermal imager consists of the emitted, reflected and transmitted long-wave infrared radiation emerging from the objects within the field of view of the thermal imager.

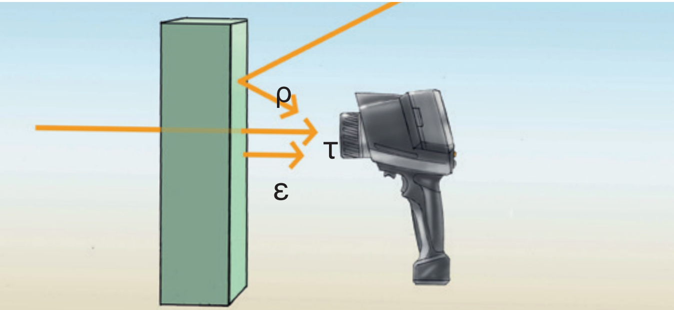
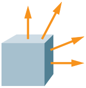


Figure 1.1: Emission, reflection and transmission



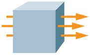
Emissivity (ε)
Emissivity (ε) is a measure of the ability of a material to emit (give off) infrared radiation.

- ε varies according to the surface properties, the material and, for some materials, also the temperature of the measuring object, as well as according to the spectral range of the thermal imager being used.
- Maximum emissivity: ε = 1 (≙ 100%) (cf. “Black body radiator”, p. 39). ε = 1 never occurs in reality.

- Real bodies: ε < 1, because real bodies also reflect and possibly transmit radiation.
- Many non-metallic materials (e.g. PVC, concrete, organic substances) have high emissivity (ε ≈ 0.8 – 0.95) in the long-wave infrared range that is not dependent on the temperature.
- Metals, particularly those with a shiny surface, have low emissivity that fluctuates with the temperature.
- ε can be set manually in the thermal imager.

Reflectance (ρ)
Reflectance (ρ) is a measure of the ability of a material to reflect infrared radiation.

- ρ depends on the surface properties, the temperature and the type of material.
- In general, smooth, polished surfaces reflect more strongly than rough, matt surfaces made of the same material.
- The temperature of the reflected radiation can be set manually in the thermal imager (RTC).
- RTC corresponds to the ambient temperature in many measurement applications (mainly with indoor thermography). In most cases you can measure this using the testo 810 air thermometer, for example.
- RTC can be determined using a Lambert radiator (cf. “Measurement of reflected temperature using an (improvised) Lambert radiator”, p. 27).
- The angle of reflection of the reflected infrared radiation is always the same as the angle of incidence (cf. “Specular reflection”, p. 31).



Transmittance (τ)
Transmittance (τ) is a measure of the ability of a material to transmit (allow through) infrared radiation.

- τ depends on the type and thickness of the material.
- Most materials are not transmissive, that is permeable, to long-wave infrared radiation.

Conservation of energy principle for radiation according to Kirchhoff's rules

The infrared radiation recorded by the thermal imager consists of:

- the radiation emitted by the measuring object,
- the reflection of ambient radiation and
- the transmission of radiation through the measuring object. (cf. Fig. 1.1, p. 36)

The sum of these parts is always taken to be 1 (≙ 100 %):

$$\varepsilon + \rho + \tau = 1$$

As transmission rarely plays a role in practice, the transmission τ is omitted and the formula

$$\varepsilon + \rho + \tau = 1$$

is simplified to

$$\varepsilon + \rho = 1.$$

For thermography this means:
the lower the emissivity,

- the higher the proportion of reflected infrared radiation is,
- the harder it is to take an accurate temperature measurement and
- the more important it is that the reflected temperature compensation (RTC) is set correctly.

Correlation between emission and reflection

1. Measuring objects with high emissivity ($\varepsilon \geq 0.8$):
    - have low reflectance (ρ): $\rho = 1 - \varepsilon$
    - their temperature can be very accurately measured with a thermal imager

2. Measuring objects with medium emissivity ($0.6 < \varepsilon < 0.8$):
    - have medium reflectance (ρ): $\rho = 1 - \varepsilon$
    - their temperature can be accurately measured with a thermal imager

3. Measuring objects with low emissivity ($\varepsilon \leq 0.6$):
    - have high reflectance (ρ): $\rho = 1 - \varepsilon$
    - temperature measurement with the thermal imager is possible, however you should critically scrutinize the results
    - correct setting of the reflected temperature compensation is indispensable, as it makes a major contribution to the temperature calculation

Ensuring the emissivity setting is correct is particularly crucial where there are large differences in temperature between the measuring object and the measuring environment.

1. Where the temperatures of the measuring object are higher than the ambient temperature (cf. heater in Fig. 1.2, 11):
    - excessively high emissivity settings result in excessively low temperature readings (cf. camera 2)
    - excessively low emissivity settings result in excessively high temperature readings (cf. camera 1)

2. Where the temperatures of the measuring object are lower than the ambient temperature (cf. doors in Fig. 1.2, p.11):
    - excessively high emissivity settings result in excessively high temperature readings (cf. camera 2)
    - excessively low emissivity settings result in excessively low temperature readings (cf. camera 1)

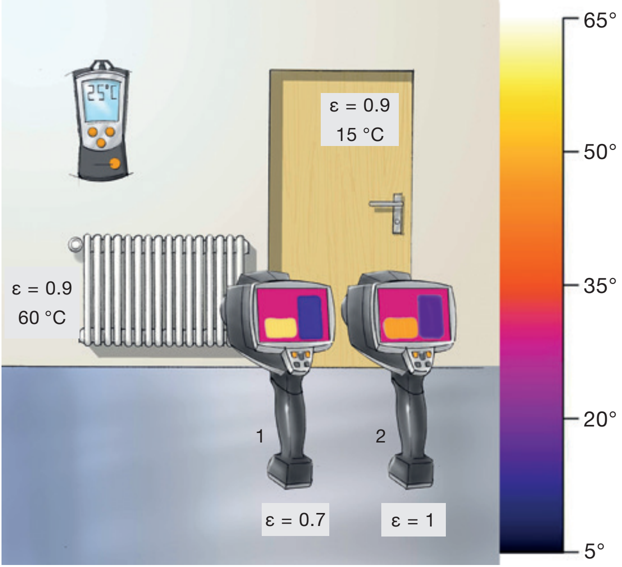


Figure 1.2: Effects of an incorrect emissivity setting on the temperature measurement

Please note:
The greater the difference between the temperature of the measuring object and ambient temperature and the lower emissivities are, the greater the measurement errors are. These errors increase if the emissivity setting is incorrect.

Please note:

- You can only ever measure the temperatures of the surfaces with a thermal imager; you cannot look into something or through something.
- Many materials which are transparent for the human eye, such as glass, are not transmissive (permeable) to long-wave infrared radiation (cf. “Measurements on glass”, p. 30).
- If necessary remove any covering from the measuring object, otherwise the thermal imager will measure only the surface temperature of the covering.

Caution: Always observe the operating instructions for the measuring object!

- The small number of transmissive materials include, for example, thin plastic sheets and Germanium, the material from which the lens and the protective glass of a Testo thermal imager are made.
- If elements which lie under the surface influence the temperature distribution of the measuring object's surface through conduction, structures of the interior of the measuring object can often be identified in the thermal image. Nevertheless, the thermal imager only ever measures the surface temperature. An exact statement about the temperature values of elements within the measuring object is not possible.

Would you also like to download the remaining pages of our pocket guide on thermography, and learn more about theory, practice, tips and tricks?

Then please register here.

After you have registered, you will receive an e-mail with a link which you can use to download the full version of the pocket guide.