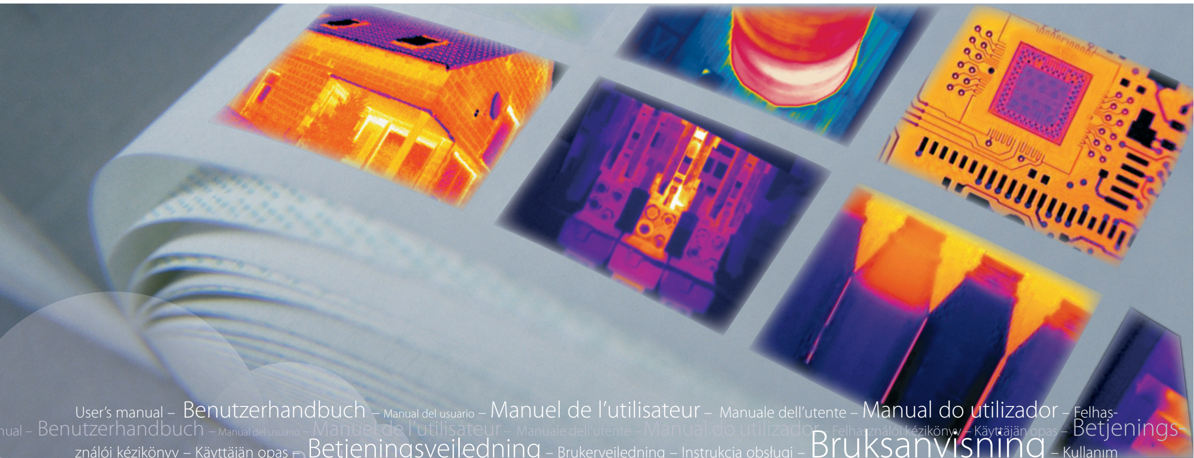
ThermaCAM™ E25



User's manual

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ThermaCAM™ E25

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Publ. No. 1558014 Rev. a155 – ENGLISH (EN) – February 6, 2006

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All products not manufactured by FLIR Systems included in systems delivered by FLIR Systems to the original purchaser carry the warranty, if any, of the particular supplier only and FLIR Systems has no responsibility whatsoever for such products.

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Quality assurance

The Quality Management System under which these products are developed and manufactured has been certified in accordance with the ISO 9001 standard.

FLIR Systems is committed to a policy of continuous development; therefore we reserve the right to make changes and improvements on any of the products described in this manual without prior notice.

Patents

This product is protected by patents, design patents, patents pending, or design patents pending.

One or several of the following patents, design patents, patents pending, or design patents pending apply to the products and/or features described in this manual:

Designation	Status	Reg. No.
China	Application	00809178.1
China	Application	01823221.3
China	Application	01823226.4
China	Design Patent	235308
China	Design Patent	ZL02331553.9
China	Design Patent	ZL02331554.7
China	Pending	200530018812.0
EPC	Patent	1188086
EPO	Application	01930377.5
EPO	Application	01934715.2
EPO	Application	27282912
EU	Design Patent	000279476-0001
France	Patent	1188086

Designation	Status	Reg. No.
Germany	Patent	60004227.8
Great Britain	Design Patent	106017
Great Britain	Design Patent	3006596
Great Britain	Design Patent	3006597
Great Britain	Patent	1188086
International	Design Patent	DM/057692
International	Design Patent	DM/061609
Japan	Application	2000-620406
Japan	Application	2002-588123
Japan	Application	2002-588070
Japan	Design Patent	1144833
Japan	Design Patent	1182246
Japan	Design Patent	1182620
Japan	Pending	2005-020460
PCT	Application	PCT/SE01/00983
PCT	Application	PCT/SE01/00984
PCT	Application	PCT/SE02/00857
PCT	Application	PCT/SE03/00307
PCT	Application	PCT/SE/00/00739
Sweden	Application	0302837-0
Sweden	Design Patent	68657
Sweden	Design Patent	75530
Sweden	Patent	518836
Sweden	Patent	522971
Sweden	Patent	524024
U.S.	Application	09/576266
U.S.	Application	10/476,217
U.S.	Application	10/476,760
U.S.	Design Patent	466540
U.S.	Design Patent	483782
U.S.	Design Patent	484155
U.S.	Patent	5,386,117
U.S.	Patent	5,637,871
U.S.	Patent	5,756,999
U.S.	Patent	6,028,309
U.S.	Patent	6,707,044
U.S.	Patent	6,812,465

Designation	Status	Reg. No.
U.S.	Pending	29/233,400

Table of contents

1 Warnings & cautions

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- This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.
- An infrared camera is a precision instrument and uses a very sensitive IR detector. Pointing the camera towards highly intensive energy sources – such as devices emitting laser radiation, or reflections from such devices – may affect the accuracy of the camera readings, or even harm – or irreparably damage – the detector. Note that this sensitivity is also present when the camera is switched off and the lens cap is mounted on the lens.
- Each camera from FLIR Systems is calibrated prior to shipping. It is advisable that the camera is sent in for calibration once a year.
- For protective reasons, the LCD (where applicable) will be switched off if the detector temperature exceeds +60 °C (+149 °F) and the camera will be switched off if the detector temperature exceeds +68 °C (+154.4 °F).
- The camera requires a warm-up time of 5 minutes before accurate measurements (where applicable) can be expected.

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2 Important note about this manual

As far as it is practically possible, FLIR Systems configures each manual to reflect each customer's particular camera configuration. However, please note the following exceptions:

- The packing list is subject to specific customer configuration and may contain more or less items
- FLIR Systems reserves the right to discontinue models, parts and accessories, and other items, or change specifications at any time without prior notice
- In some cases, the manual may describe features that are not available in your particular camera configuration

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3 Welcome!

Thank you for choosing the ThermaCAM™ E25 infrared camera!

The ThermaCAM™ E25 IR camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature. The camera system also features a laser pointer, a 2.5" color LCD, an IR lens, a removable battery and a range of accessories.

The camera is very easy to use. It is operated by using a few buttons which are conveniently placed on the camera, allowing fingertip control of major functions. A built-in menu system also gives easy access to an advanced, simple-to-use camera software for increased functionality.

To document the object under inspection it is possible to capture and store images to the camera's internal memory. The images can be analyzed either in the field by using the real-time measurement functions built into the camera, or in a PC using FLIR Systems ThermaCAM Reporter software by downloading the images from the camera using ThermaCAM™ QuickView.

3.1 About FLIR Systems

With over 40 years experience in IR systems and applications development, and over 30 000 infrared cameras in use worldwide, FLIR Systems is the undisputed global commercial IR industry leader.

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Figure 3.1 FLIR Systems, Boston, USA, FLIR Systems, Danderyd, Sweden, and FLIR Systems, Portland, USA.

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Figure 3.2 Indigo Operations, Niceville, USA, and Indigo Operations, Santa Barbara, USA. Indigo Operations is a division of FLIR Systems.

As pioneers in the IR industry, FLIR Systems has a long list of ‘firsts’ the world of infrared thermography:

- 1965: 1st thermal imaging system for predictive maintenance (Model 650).
- 1973: 1st battery-operated portable IR scanner for industrial applications predictive maintenance (Model 750).
- 1975: 1st TV compatible system (Model 525).
- 1978: 1st dual-wavelength scanning system capable of real-time analog recording of thermal events (Model 780). Instrumental in R & D market development.
- 1983: 1st thermal imaging and measurement system with on-screen temperature measurement.
- 1986: 1st TE (thermo-electrically) cooled system.
- 1989: 1st single-piece infrared camera system for PM (predictive maintenance) and R & D (research & development) with on-board digital storage.
- 1991: 1st Windows-based thermographic analysis and reporting system.
- 1993: 1st Focal Plane Array (FPA) system for PM and R & D applications.
- 1995: 1st full-featured camcorder style FPA infrared system (ThermaCAM).
- 1997: 1st: uncooled microbolometer-based PM/R & D system.

- 2000: 1st thermography system with both thermal and visual imaging.
- 2000: 1st thermography system to incorporate thermal/visual/voice and text data logging.
- 2002: 1st automated thermography system (model P60) to feature detachable remotely controllable LCD, JPEG image storage, enhanced connectivity including USB and IrDA wireless, thermal/visual/voice and text data logging.
- 2002: 1st low-cost ultra-compact hand-held thermography camera (E series). Revolutionary, ergonomic design, lightest IR measurement camera available.
- 2003: 1st low-cost, ultra-compact infrared camera for fixed installation intended for automation and security applications. Exceptionally user-friendly due to standard interfaces and extensive built-in functionality.
- 2004: 1st camera models specially designed for building thermography (B1, B2 and B20)

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Figure 3.3 LEFT: FLIR Systems Thermovision® Model 661. The photo is taken on May 30th, 1969 at the distribution plant near Beckomberga, in Stockholm, Sweden. The camera weighed approx. 25 kg (55 lb), the oscilloscope 20 kg (44 lb), the tripod 15 kg (33 lb). The operator also needed a 220 VAC generator set, and a 10 L (2.6 US gallon) jar with liquid nitrogen. To the left of the oscilloscope the Polaroid attachment (6 kg/13 lb) can be seen. **RIGHT:** FLIR Systems ThermaCAM Model E2 from 2002 – weight: 0.7 kg (1.54 lb), including battery.

With this tradition of unparalleled technical excellence and innovative achievements, FLIR Systems continues to develop new infrared products, educational venues and applications expertise to meet the diverse demands of thermographers worldwide.

3.1.1 A few images from our facilities

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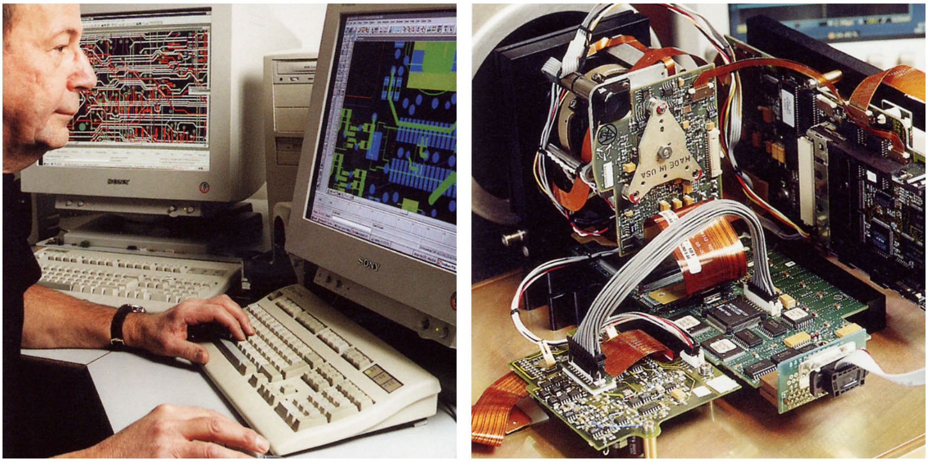

Figure 3.4 LEFT: Development of system electronics; **RIGHT:** Testing of an FPA detector

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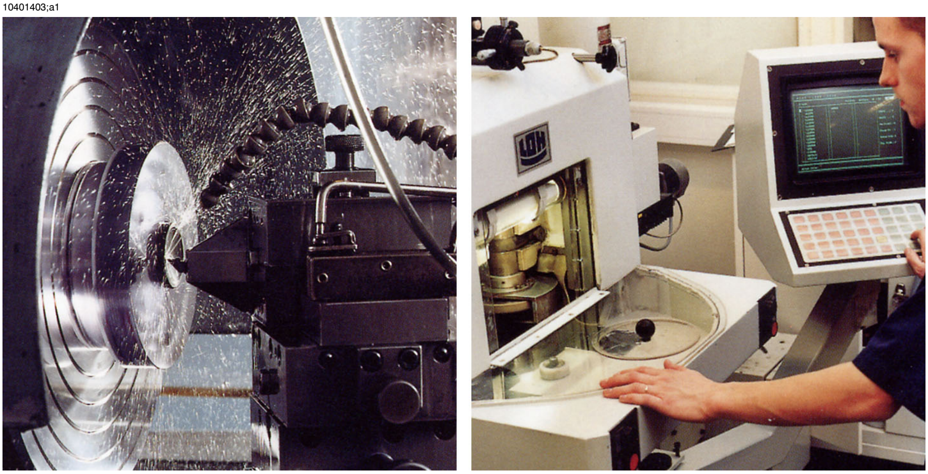

Figure 3.5 LEFT: Diamond turning machine; **RIGHT:** Lens polishing

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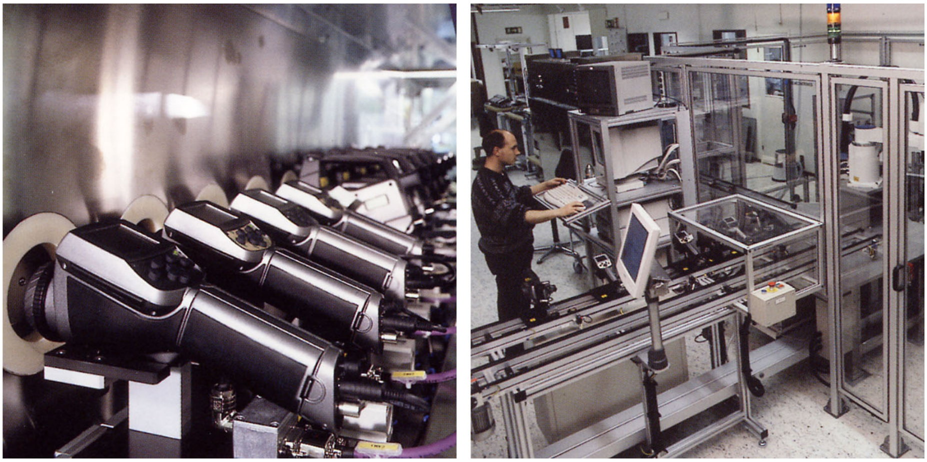

Figure 3.6 LEFT: Testing of IR cameras in the climatic chamber; **RIGHT:** Robot for camera testing and calibration

3.2 Comments & questions

FLIR Systems is committed to a policy of continuous development, and although we have tested and verified the information in this manual to the best of our ability, you may find that features and specifications have changed since the time of printing. Please let us know about any errors you find, as well as your suggestions for future editions, by sending an e-mail to:

documentation@flir.se

➲ Do not use this e-mail address for technical support questions. Technical support is handled by FLIR Systems local sales offices.

4 Packing list

The ThermaCAM™ E25 and its accessories are delivered in a hard transport case which typically contains the items below. On receipt of the transport case, inspect all items and check them against the delivery note. Any damaged items must be reported to the local FLIR Systems representative immediately.

Description	Part Number	Qty.
Battery	1 195 106	1
Hand strap	1 195 221	1
Lens cap for camera body	1 120 987	1
Operator's manual	1558014	1
Power supply	1 909 528	1
ThermaCAM™ E25 infrared camera with lens	Configuration-dependent	1
TrainIR CD	1 195 494	1
USB cable	1 195 128	1
Video cable	1 909 775	1

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5 System overview

This system overview shows all accessories that are possible to order for a ThermaCAM™ E25.

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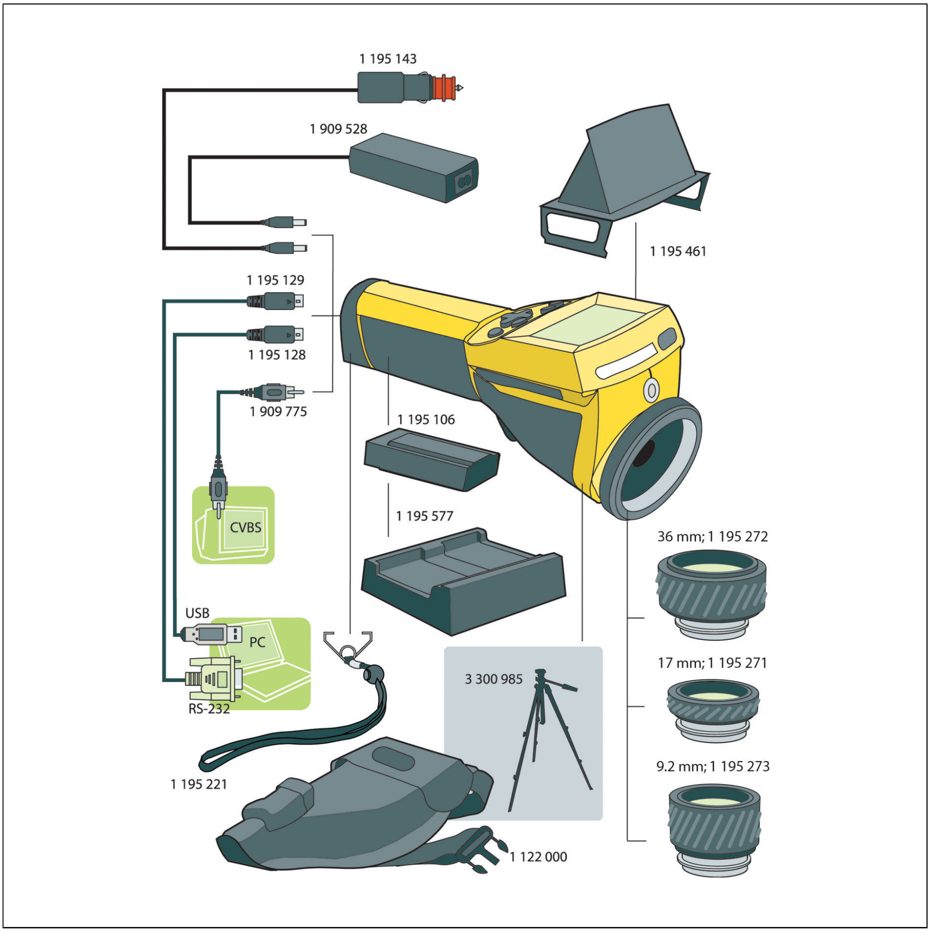

Figure 5.1 System overview

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6 Connecting system components

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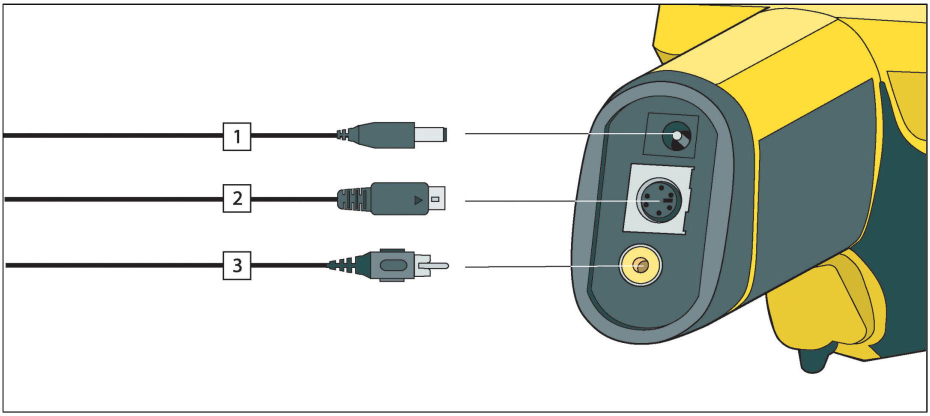

Figure 6.1 How to connect system components

Figure 6.2 Explanations of callouts

Callout	Explanation
1	Power supply cable (11–16 VDC)
2	USB / RS-232 cable
3	Video cable (CVBS, i.e. composite video)

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7 Introduction to thermographic inspections of electrical installations

7.1 Important note

All camera functions and features that are described in this section may not be supported by your particular camera configuration.

Electrical regulations differ from country to country. For that reason, the electrical procedures described in this section may not be the standard of procedure in your particular country. Also, in many countries carrying out electrical inspections requires formal qualification. Always consult national or regional electrical regulations.

7.2 General information

7.2.1 Introduction

Today, thermography is a well-established technique for the inspection of electrical installations. This was the first and still is the largest. the largest application of thermography. The infrared camera itself has gone through an explosive development and we can say that today, the 8th generation of thermographic systems is available. It all began in 1964, more than 40 years ago. The technique is now established throughout the whole world. Industrialized countries as well as developing countries have adopted this technique.

Thermography, in conjunction with vibration analysis, has over the latest decades been the main method for fault diagnostics in the industry as a part of the preventive maintenance program. The great advantage with these methods is that it is not only possible to carry out the inspection on installations in operation; normal working condition is in fact a prerequisite for a correct measurement result, so the ongoing production process is not disturbed. Thermographic inspection of electrical installations are used in three main areas:

- Power generation
- Power transmission
- Power distribution, that is, industrial use of electrical energy.

The fact that these controls are carried out under normal operation conditions has created a natural division between these groups. The power generation companies measure during the periods of high load. These periods vary from country to country and for the climatic zones. The measurement periods may also differ depending on the type of plant to be inspected, whether they are hydroelectric, nuclear, coal-based or oil-based plants.

In the industry the inspections are—at least in Nordic countries with clear seasonal differences—carried out during spring or autumn or before longer stops in the operation. Thus, repairs are made when the operation is stopped anyway. However, this seems to be the rule less and less, which has led to inspections of the plants under varying load and operating conditions.

7.2.2 General equipment data

The equipment to be inspected has a certain temperature behavior that should be known to the thermographer before the inspection takes place. In the case of electrical equipment, the physical principle of why faults show a different temperature pattern because of increased resistance or increased electrical current is well known.

However, it is useful to remember that, in some cases, for example solenoids, 'overheating' is natural and does not correspond to a developing defect. In other cases, like the connections in electrical motors, the overheating might depend on the fact that the healthy part is taking the entire load and therefore becomes overheated. A similar example is shown in section 7.5.7 – Overheating in one part as a result of a fault in another on page 33.

Defective parts of electrical equipment can therefore both indicate overheating and be cooler than the normal 'healthy' components. It is necessary to be aware of what to expect by getting as much information as possible about the equipment before it is inspected.

The general rule is, however, that a hot spot is caused by a probable defect. The temperature and the load of that specific component at the moment of inspection will give an indication of how serious the fault is and can become in other conditions.

Correct assessment in each specific case demands detailed information about the thermal behavior of the components, that is, we need to know the maximum allowed temperature of the materials involved and the role the component plays in the system.

Cable insulations, for example, lose their insulation properties above a certain temperature, which increases the risk of fire.

In the case of breakers, where the temperature is too high, parts can melt and make it impossible to open the breaker, thereby destroying its functionality.

The more the IR camera operator knows about the equipment that he or she is about to inspect, the higher the quality of the inspection. But it is virtually impossible for an IR thermographer to have detailed knowledge about all the different types of equipment that can be controlled. It is therefore common practice that a person responsible for the equipment is present during the inspection.

7.2.3 Inspection

The preparation of the inspection should include the choice of the right type of report. It is often necessary to use complementary equipment such as ampere meters in order to measure the current in the circuits where defects were found. An anemometer is necessary if you want to measure the wind speed at inspection of outdoor equipment.

Automatic functions help the IR operator to visualize an IR image of the components with the right contrast to allow easy identification of a fault or a hot spot. It is almost impossible to miss a hot spot on a scanned component. A measurement function will also automatically display the hottest spot within an area in the image or the difference between the maximum temperature in the chosen area and a reference, which can be chosen by the operator, for example the ambient temperature.

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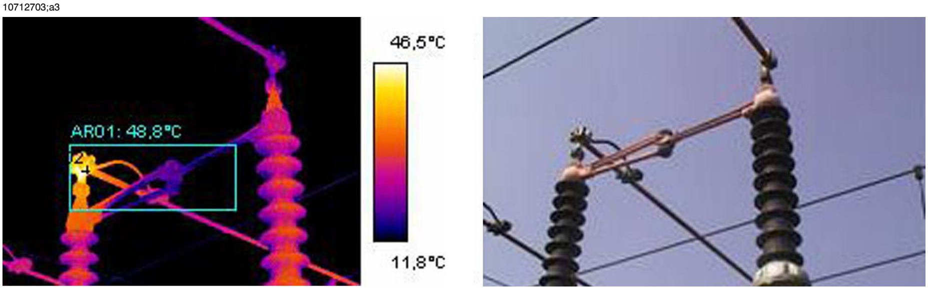

Figure 7.1 An infrared and a visual image of a power line isolator

When the fault is clearly identified and the IR thermographer has made sure that it is not a reflection or a naturally occurring hot spot, the collection of the data starts, which will allow the correct reporting of the fault. The emissivity, the identification of the component, and the actual working conditions, together with the measured temperature, will be used in the report. In order to make it easy to identify the component a visual photo of the defect is often taken.

7.2.4 Classification & reporting

Reporting has traditionally been the most time-consuming part of the IR survey. A one-day inspection could result in one or two days' work to report and classify the found defects. This is still the case for many thermographers, who have chosen not to use the advantages that computers and modern reporting software have brought to IR condition monitoring.

The classification of the defects gives a more detailed meaning that not only takes into account the situation at the time of inspection (which is certainly of great importance), but also the possibility to normalize the over-temperature to standard load and ambient temperature conditions.

An over-temperature of +30°C (+86°F) is certainly a significant fault. But if that over-temperature is valid for one component working at 100% load and for another at 50% load, it is obvious that the latter will reach a much higher temperature should its load increase from 50% to 100%. Such a standard can be chosen by the plant's circumstances. Very often, however, temperatures are predicted for 100% load. A standard makes it easier to compare the faults over time and thus to make a more complete classification.

7.2.5 Priority

Based on the classification of the defects, the maintenance manager gives the defects a repair priority. Very often, the information gathered during the infrared survey is put together with complementary information on the equipment collected by other means such as vibration monitoring, ultrasound or the preventive maintenance scheduled.

Even if the IR inspection is quickly becoming the most used method of collecting information about electrical components safely with the equipment under normal operating conditions, there are many other sources of information the maintenance or the production manager has to consider.

The priority of repair should therefore not be a task for the IR camera operator in the normal case. If a critical situation is detected during the inspection or during the classification of the defects, the attention of the maintenance manager should of course be drawn to it, but the responsibility for determining the urgency of the repair should be his.

7.2.6 Repair

To repair the known defects is the most important function of preventive maintenance. However, to assure production at the right time or at the right cost can also be important goals for a maintenance group. The information provided by the infrared survey can be used to improve the repair efficiency as well as to reach the other goals with a calculated risk.

To monitor the temperature of a known defect that can not be repaired immediately for instance because spare parts are not available, can often pay for the cost of inspection a thousandfold and sometimes even for the IR camera. To decide not to repair known defects to save on maintenance costs and avoid unnecessary downtime is also another way of using the information from the IR survey in a productive way.

However, the most common result of the identification and classification of the detected faults is a recommendation to repair immediately or as soon as it is practically possible. It is important that the repair crew is aware of the physical principles for the identification of defects. If a defect shows a high temperature and is in a critical situation, it is very common that the repair personnel expect to find a highly corroded component. It should also come as no surprise to the repair crew that a connection, which is usually healthy, can give the same high temperatures as a corroded one if it has come loose. These misinterpretations are quite common and risk putting in doubt the reliability of the infrared survey.

7.2.7 Control

A repaired component should be controlled as soon as possible after the repair. It is not efficient to wait for the next scheduled IR survey in order to combine a new inspection with the control of the repaired defects. The statistics on the effect of the repair show that up to a third of the repaired defects still show overheating. That is the same as saying that those defects present a potential risk of failure.

To wait until the next scheduled IR survey represents an unnecessary risk for the plant.

Besides increasing the efficiency of the maintenance cycle (measured in terms of lower risk for the plant) the immediate control of the repair work brings other advantages to the performance of the repair crew itself.

When a defect still shows overheating after the repair, the determination of the cause of overheating improves the repair procedure, helps choose the best component suppliers and detect design shortcomings on the electrical installation. The crew rapidly sees the effect of the work and can learn quickly both from successful repairs and from mistakes.

Another reason to provide the repair crew with an IR instrument is that many of the defects detected during the IR survey are of low gravity. Instead of repairing them, which consumes maintenance and production time, it can be decided to keep these defects under control. Therefore the maintenance personnel should have access to their own IR equipment.

It is common to note on the report form the type of fault observed during the repair as well as the action taken. These observations make an important source of experience that can be used to reduce stock, choose the best suppliers or to train new maintenance personnel.

7.3 Measurement technique for thermographic inspection of electrical installations

7.3.1 How to correctly set the equipment

A thermal image may show high temperature variations:

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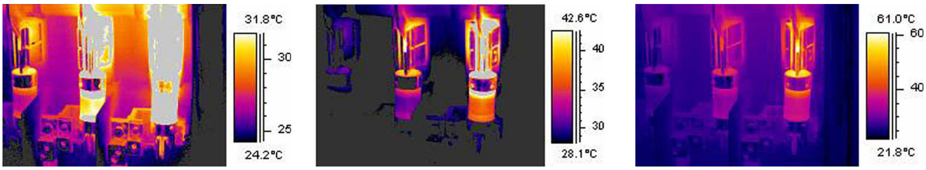

Figure 7.2 Temperature variations in a fusebox

In the images above, the fuse to the right has a maximum temperature of +61°C (+142°F), whereas the one to the left is maximum +32°C (+90°F) and the one in the middle somewhere in between. The three images are different inasmuch as the temperature scale enhances only one fuse in each image. However, it is the same image and all the information about all three fuses is there. It is only a matter of setting the temperature scale values.

7.3.2 Temperature measurement

Some cameras today can automatically find the highest temperature in the image. The image below shows how it looks to the operator.

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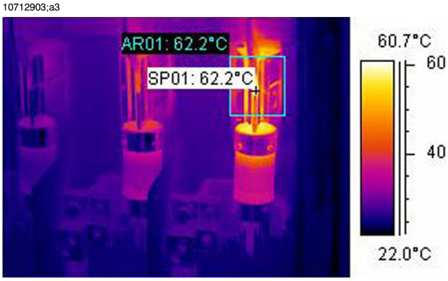

Figure 7.3 An infrared image of a fusebox where the maximum temperature is displayed

The maximum temperature in the area is +62.2°C (+144.0°F). The spot meter shows the exact location of the hot spot. The image can easily be stored in the camera memory.

The correct temperature measurement depends, however, not only on the function of the evaluation software or the camera. It may happen that the actual fault is, for example, a connection, which is hidden from the camera in the position it happens to be in for the moment. It might be so that you measure heat, which has been conducted over some distance, whereas the 'real' hot spot is hidden from you. An example is shown in the image below.

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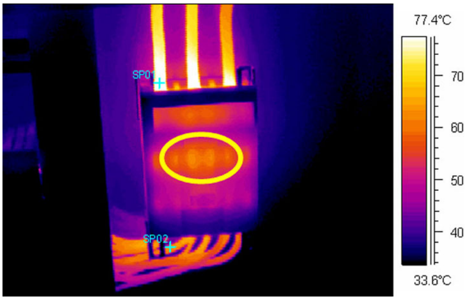

Figure 7.4 A hidden hot spot inside a box

Try to choose different angles and make sure that the hot area is seen in its full size, that is, that it is not disappearing behind something that might hide the hottest spot. In this image, the hottest spot of what the camera can 'see', is +83°C (+181°F), where the operating temperature on the cables below the box is +60°C (+140°F). However, the real hot spot is most probably hidden inside the box, see the in yellow encircled area. This fault is reported as a +23.0°C (+41.4°F) excess temperature, but the real problem is probably essentially hotter.

Another reason for underestimating the temperature of an object is bad focusing. It is very important that the hot spot found is in focus. See the example below.

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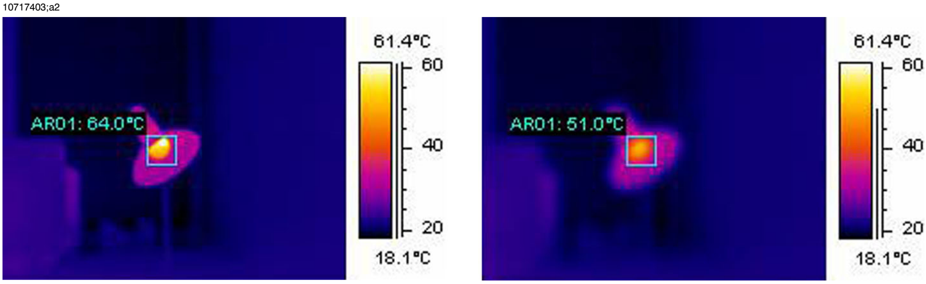

Figure 7.5 **LEFT:** A hot spot in focus; **RIGHT:** A hot spot out of focus

In the left image, the lamp is in focus. Its average temperature is +64°C (+147°F). In the right image, the lamp is out of focus, which will result in only +51°C (+124°F) as the maximum temperature.

7.3.3 Comparative measurement

For thermographic inspections of electrical installations a special method is used, which is based on comparison of different objects, so-called *measurement with a reference*. This simply means that you compare the three phases with each other. This method needs systematic scanning of the three phases in parallel in order to assess whether a point differs from the normal temperature pattern.

A normal temperature pattern means that current carrying components have a given operation temperature shown in a certain color (or gray tone) on the display, which is usually identical for all three phases under symmetrical load. Minor differences in the color might occur in the current path, for example, at the junction of two different materials, at increasing or decreasing conductor areas or on circuit breakers where the current path is encapsulated.

The image below shows three fuses, the temperatures of which are very close to each other. The inserted isotherm actually shows less than +2°C (+3.6°F) temperature difference between the phases.

Different colors are usually the result if the phases are carrying an unsymmetrical load. This difference in colors does not represent any overheating since this does not occur locally but is spread along the whole phase.

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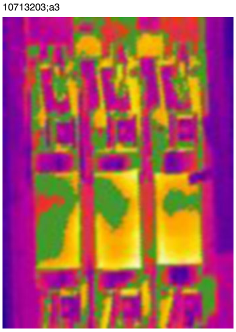

Figure 7.6 An isotherm in an infrared image of a fusebox

A 'real' hot spot, on the other hand, shows a rising temperature as you look closer to the source of the heat. See the image below, where the profile (line) shows a steadily increasing temperature up to about +93°C (+199°F) at the hot spot.

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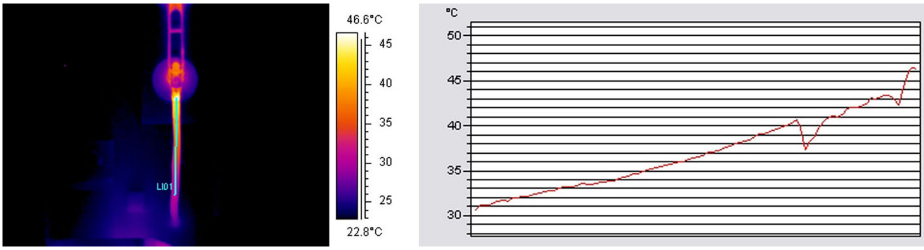

Figure 7.7 A profile (line) in an infrared image and a graph displaying the increasing temperature

7.3.4 Normal operating temperature

Temperature measurement with thermography usually gives the absolute temperature of the object. In order to correctly assess whether the component is too hot, it is necessary to know its operating temperature, that is, its normal temperature if we consider the load and the temperature of its environment.

As the direct measurement will give the absolute temperature—which must be considered as well (as most components have an upper limit to their absolute temperatures)—it is necessary to calculate the expected operating temperature given the load and the ambient temperature. Consider the following definitions:

- Operating temperature: the absolute temperature of the component. It depends on the current load and the ambient temperature. It is always higher than the ambient temperature.
- Excess temperature (overheating): the temperature difference between a properly working component and a faulty one.

The excess temperature is found as the difference between the temperature of a ‘normal’ component and the temperature of its neighbor. It is important to compare the same points on the different phases with each other.

As an example, see the following images taken from indoor equipment:

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Figure 7.8 An infrared image of indoor electrical equipment (1)

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10713503;a4

Figure 7.9 An infrared image of indoor electrical equipment (2)

The two left phases are considered as normal, whereas the right phase shows a very clear excess temperature. Actually, the operating temperature of the left phase is +68°C (+154°F), that is, quite a substantial temperature, whereas the faulty phase to the right shows a temperature of +86°C (+187°F). This means an excess temperature of +18°C (+33°F), that is, a fault that has to be attended to quickly.

7

For practical reasons, the (normal, expected) operating temperature of a component is taken as the temperature of the components in at least two out of three phases, provided that you consider them to be working normally.. The 'most normal' case is of course that all three phases have the same or at least almost the same temperature. The operating temperature of outdoor components in substations or power lines is usually only 1°C or 2°C above the air temperature (1.8°F or 3.6°F). In indoor substations, the operating temperatures vary a lot more.

This fact is clearly shown by the bottom image as well. Here the left phase is the one, which shows an excess temperature. The operating temperature, taken from the two 'cold' phases, is +66°C (+151°F). The faulty phase shows a temperature of +127°C (+261°F), which has to be attended to without delay.

7.3.5 Classification of faults

Once a faulty connection is detected, corrective measures may be necessary—or may not be necessary for the time being. In order to recommend the most appropriate action the following criteria should be evaluated:

- Load during the measurement
- Even or varying load
- Position of the faulty part in the electrical installation
- Expected future load situation
- Is the excess temperature measured directly on the faulty spot or indirectly through conducted heat caused by some fault inside the apparatus?

Excess temperatures measured directly on the faulty part are usually divided into three categories relating to 100% of the maximum load.

I	< 5°C (9°F)	The start of the overheat condition. This must be carefully monitored.
II	5–30°C (9–54°F)	Developed overheating. It must be repaired as soon as possible (but think about the load situation before a decision is made).
III	>30°C (54°F)	Acute overheating. Must be repaired immediately (but think about the load situation before a decision is made).

7.4 Reporting

Nowadays, thermographic inspections of electrical installations are probably, without exception, documented and reported by the use of a report program. These programs, which differ from one manufacturer to another, are usually directly adapted to the cameras and will thus make reporting very quick and easy.

The program, which has been used for creating the report page shown below, is called ThermaCAM™ Reporter. It is adapted to several types of infrared cameras from FLIR Systems.

A professional report is often divided into two sections:

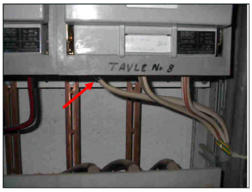
- Front pages, with facts about the inspection, such as:
  - Who the client is, for example, customer's company name and contact person
  - Location of the inspection: site address, city, and so on
  - Date of inspection
  - Date of report
  - Name of thermographer
  - Signature of thermographer
  - Summary or table of contents

- Inspection pages containing IR images to document and analyze thermal properties or anomalies.
  - Identification of the inspected object:
    - What is the object: designation, name, number, and so on
    - Photo
  - IR image. When collecting IR images there are some details to consider:
    - Optical focus
    - Thermal adjustment of the scene or the problem (level & span)
    - Composition: proper observation distance and viewing angle.
  - Comment
    - Is there an anomaly or not?
    - Is there a reflection or not?
    - Use a measurement tool—spot, area or isotherm—to quantify the problem. Use the simplest tool possible; a profile graph is almost never needed in electrical reports.

10713603;a3

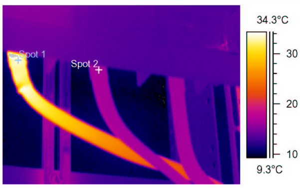
FLIR SYSTEMS	**THERMOGRAPHY INSPECTION** **for** **FLIR Systems AB**	Date: 2005-10-10 Sign. ___________ Contract. : 1708

Photograph



Place	Building 1
Localization	Right panel, group 2
Equipment	Fuse
Model / type	BBC LHBN 250
Phase / ID	Supply for Panel 8
Room temperature °C	15
Status	**Over heated**

Thermogram



Temp. Spot 1	34 °C
Temp. Spot 2	17 °C
TEMPERATURE DIFF	**17 °C**

Phase	L1	L2	L3
Load (A)	45	47	47

Rated load	250
Fault class	**2**

Comment

Disconnect cable, clean contact surfaces. Check for connectivity between cable shoe and lead. Replace any defective component. Assemble according to directions with correct torque.

Note that load is only 18%. Calculated temperature rise at 50% load would be approximately 104°C. [T50=(T1-T2)*(125/45)^1.6+T2]

Corrected

Measure taken:___________________________	Date:_________
Sign:___________________________	Sign.:_________

Side 1

Figure 7.10 A report example

7.5 Different types of hot spots in electrical installations

7.5.1 Reflections

The thermographic camera sees any radiation that enters the lens, not only originating from the object that you are looking at, but also radiation that comes from other sources and has been reflected by the target. Most of the time, electrical components are like mirrors to the infrared radiation, even if it is not obvious to the eye. Bare metal parts are particularly shiny, whereas painted, plastic or rubber insulated parts are mostly not. In the image below, you can clearly see a reflection from the thermographer. This is of course not a hot spot on the object. A good way to find out if what you see is a reflection or not, is for you to move. Look at the target from a different angle and watch the 'hot spot.' If it moves when you do, it is a reflection.

Measuring temperature of mirror like details is not possible. The object in the images below has painted areas which are well suited for temperature measurement. The material is copper, which is a very good heat conductor. This means that temperature variation over the surface is small.

10717503;a2

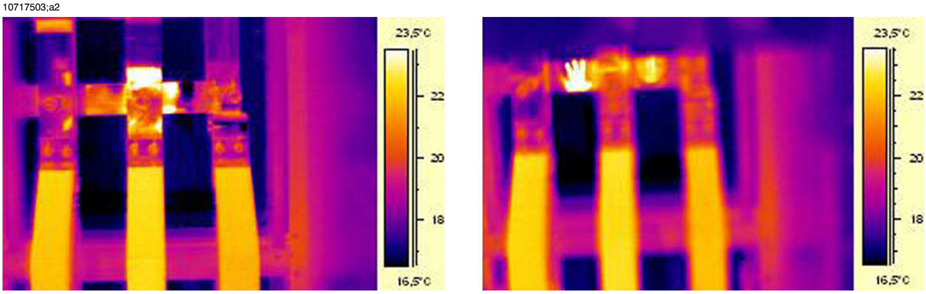


Figure 7.11 Reflections in an object

7.5.2 Solar heating

The surface of a component with a high emissivity, for example, a breaker, can on a hot summer day be heated up to quite considerable temperatures by irradiation from the sun. The image shows a circuit breaker, which has been heated by the sun.

10713803;a3

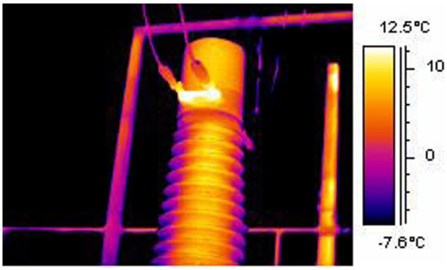


Figure 7.12 An infrared image of a circuit breaker

7.5.3 Inductive heating

10713903;a3

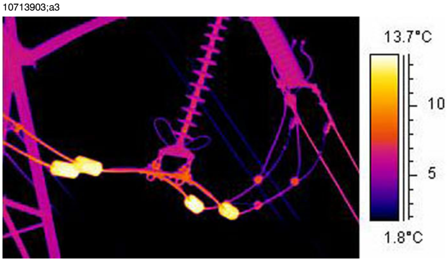


Figure 7.13 An infrared image of hot stabilizing weights

Eddy currents can cause a hot spot in the current path. In cases of very high currents and close proximity of other metals, this has in some cases caused serious fires. This type of heating occurs in magnetic material around the current path, such as metallic bottom plates for bushing insulators. In the image above, there are stabilizing weights, through which a high current is running. These metal weights, which are made of a slightly magnetic material, will not conduct any current but are exposed to the alternating magnetic fields, which will eventually heat up the weight. The overheating in the image is less than +5°C (+9°F). This, however, need not necessarily always be the case.

7.5.4 Load variations

3-phase systems are the norm in electric utilities. When looking for overheated places, it is easy to compare the three phases directly with each other, for example, cables, breakers, insulators. An even load per phase should result in a uniform temperature pattern for all three phases. A fault may be suspected in cases where the temperature of one phase differs considerably from the remaining two. However, you should always make sure that the load is indeed evenly distributed. Looking at fixed ampere meters or using a clip-on ampere meter (up to 600 A) will tell you.

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10714003;a3

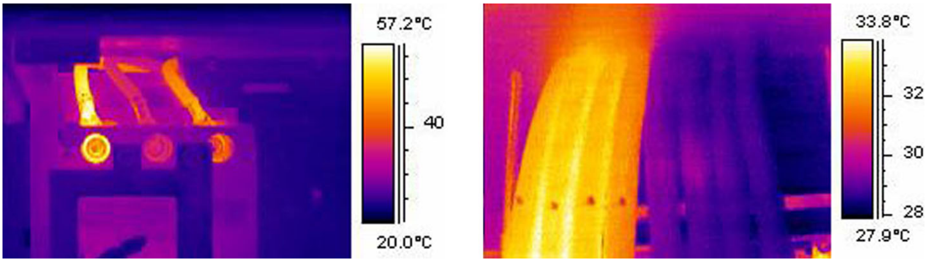

Figure 7.14 Examples of infrared images of load variations

The image to the left shows three cables next to each other. They are so far apart that they can be regarded as thermally insulated from each other. The one in the middle is colder than the others. Unless two phases are faulty and overheated, this is a typical example of a very unsymmetrical load. The temperature spreads evenly along the cables, which indicates a load-dependent temperature increase rather than a faulty connection.

7

The image to the right shows two bundles with very different loads. In fact, the bundle to the right carries next to no load. Those which carry a considerable current load, are about 5°C (9°F) hotter than those which do not. No fault to be reported in these examples.

7.5.5 Varying cooling conditions

10714103;a3

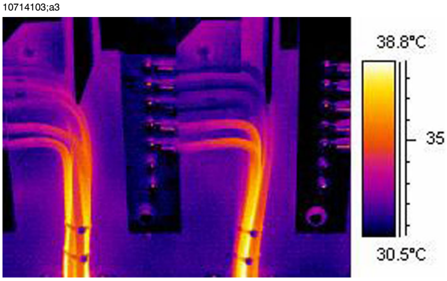

Figure 7.15 An infrared image of bundled cables

When, for example, a number of cables are bundled together it can happen that the resulting poor cooling of the cables in the middle can lead to them reaching very high temperatures. See the image above.

The cables to the right in the image do not show any overheating close to the bolts. In the vertical part of the bundle, however, the cables are held together very tightly, the cooling of the cables is poor, the convection can not take the heat away, and the cables are notably hotter, actually about 5°C (9°F) above the temperature of the better cooled part of the cables.

7.5.6 Resistance variations

Overheating can have many origins. Some common reasons are described below.

Low contact pressure can occur when mounting a joint, or through wear of the material, for example, decreasing spring tension, worn threads in nuts and bolts, even too much force applied at mounting. With increasing loads and temperatures, the yield point of the material is exceeded and the tension weakens.

The image to the left below shows a bad contact due to a loose bolt. Since the bad contact is of very limited dimensions, it causes overheating only in a very small spot from which the heat is spread evenly along the connecting cable. Note the lower emissivity of the screw itself, which makes it look slightly colder than the insulated—and thereby it has a high emissivity—cable insulation.

The image to the right shows another overheating situation, this time again due to a loose connection. It is an outdoor connection, hence it is exposed to the cooling effect of the wind and it is likely that the overheating would have shown a higher temperature, if mounted indoors.

10714203;a3

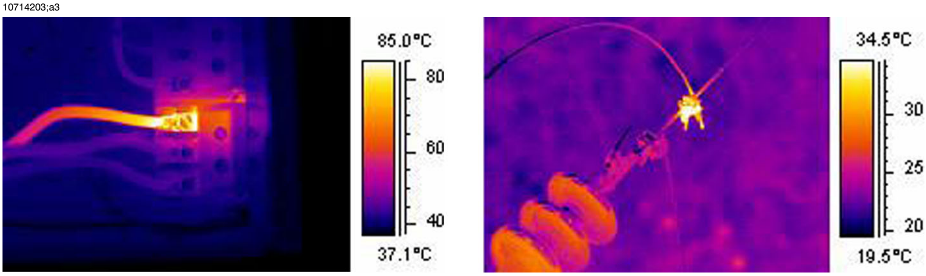

Figure 7.16 **LEFT:** An infrared image showing bad contact due to a loose bolt; **RIGHT:** A loose outdoor connection, exposed to the wind cooling effect.

7.5.7 Overheating in one part as a result of a fault in another

Sometimes, overheating can appear in a component although that component is OK. The reason is that two conductors share the load. One of the conductors has an increased resistance, but the other is OK. Thus, the faulty component carries a lower load, whereas the fresh one has to take a higher load, which may be too high and which causes the increased temperature. See the image.

10714303;a3

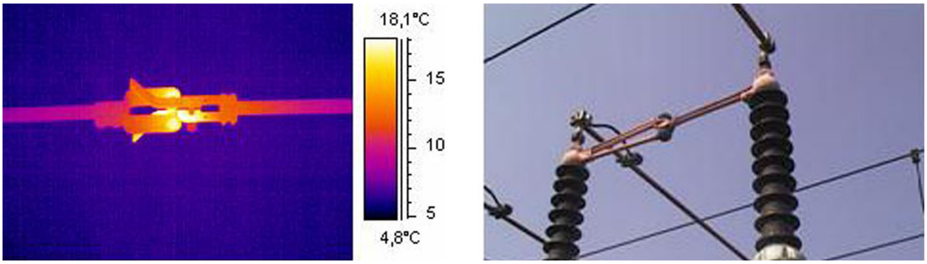

Figure 7.17 Overheating in a circuit breaker

The overheating of this circuit breaker is most probably caused by bad contact in the near finger of the contactor. Thus, the far finger carries more current and gets hotter. The component in the infrared image and in the photo is not the same, however, it is similar).

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7.6 Disturbance factors at thermographic inspection of electrical installations

During thermographic inspections of different types of electrical installations, disturbance factors such as wind, distance to object, rain or snow often influence the measurement result.

7.6.1 Wind

During outdoor inspection, the cooling effect of the wind should be taken into account. An overheating measured at a wind velocity of 5 m/s (10 knots) will be approximately twice as high at 1 m/s (2 knots). An excess temperature measured at 8 m/s (16 knots) will be 2.5 times as high at 1 m/s (2 knots). This correction factor, which is based on empirical measurements, is usually applicable up to 8 m/s (16 knots).

There are, however, cases when you have to inspect even if the wind is stronger than 8 m/s (16 knots). There are many windy places in the world, islands, mountains, and so on but it is important to know that overheated components found would have shown a considerably higher temperature at a lower wind speed. The empirical correction factor can be listed.

Wind speed (m/s)	Wind speed (knots)	Correction factor
1	2	1
2	4	1.36
3	6	1.64
4	8	1.86
5	10	2.06
6	12	2.23
7	14	2.40
8	16	2.54

The measured overheating multiplied by the correction factor gives the excess temperature with no wind, that is, at 1 m/s (2 knots).

7.6.2 Rain and snow

Rain and snow also have a cooling effect on electrical equipment. Thermographic measurement can still be conducted with satisfactory results during light snowfall with dry snow and light drizzle, respectively. The image quality will deteriorate in heavy snow or rain and reliable measurement is no longer possible. This is mainly because a heavy snowfall as well as heavy rain is impenetrable to infrared radiation and it is rather the temperature of the snowflakes or raindrops that will be measured.

7.6.3 Distance to object

This image is taken from a helicopter 20 meters (66 ft.) away from this faulty connection. The distance was incorrectly set to 1 meter (3 ft.) and the temperature was measured to +37.9°C (+100.2°F). The measurement value after changing the distance to 20 meters (66 ft.), which was done afterwards, is shown in the image to the right, where the corrected temperature is +38.8°C (+101.8°F). The difference is not too crucial, but may take the fault into a higher class of seriousness. So the distance setting must definitely not be neglected.

10714403;a3

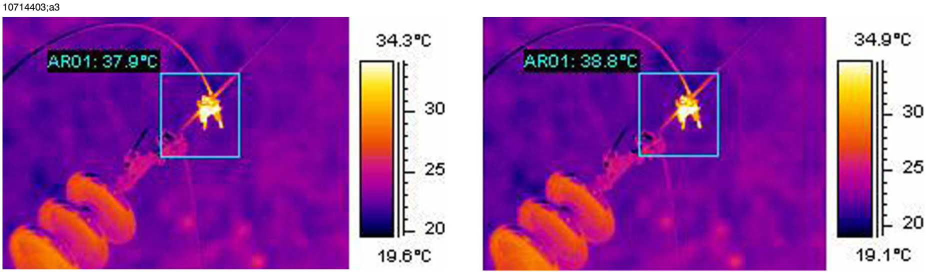

Figure 7.18 **LEFT:** Incorrect distance setting; **RIGHT:** Correct distance setting

The images below show the temperature readings from a blackbody at +85°C (+185°F) at increasing distances.

10714503;a3

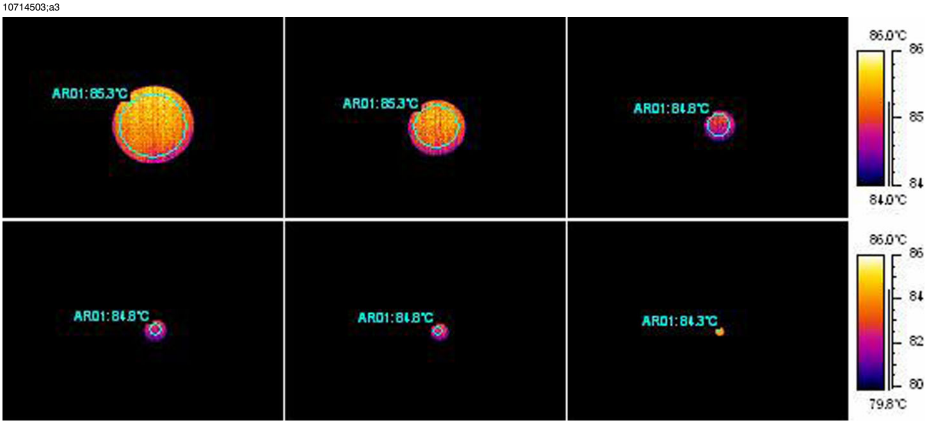

Figure 7.19 Temperature readings from a blackbody at +85°C (+185°F) at increasing distances

The measured average temperatures are, from left to right, +85.3°C (+185.5°F),+85.3°C (+185.5°F), +84.8°C (+184.6°F), +84.8°C (+184.6°F), +84.8°C (+184.6°F) and +84.3°C (+183.7°F) from a blackbody at +85°C (+185°F). The thermograms are taken with a 12° lens. The distances are 1, 2, 3, 4, 5 and 10 meters (3, 7, 10, 13, 16 and 33 ft.). The correction for the distance has been meticulously set and works, because the object is big enough for correct measurement.

7.6.4 Object size

The second series of images below shows the same but with the normal 24° lens. Here, the measured average temperatures of the blackbody at +85°C (+185°F) are: +84.2°C (+183.6°F), +83.7°C (+182.7°F), +83.3°C (+181.9°F), +83.3°C (+181.9°F), +83.4°C (+181.1°F) and +78.4°C (+173.1°F).

The last value, (+78.4°C (+173.1°F)), is the maximum temperature as it was not possible to place a circle inside the now very small blackbody image. Obviously, it is not possible to measure correct values if the object is too small. Distance was properly set to 10 meters (33 ft.).

10714603;a3

Figure 7.20 Temperature readings from a blackbody at +85°C (+185°F) at increasing distances (24° lens)

The reason for this effect is that there is a smallest object size, which gives correct temperature measurement. This smallest size is indicated to the user in all FLIR Systems cameras. The image below shows what you see in the viewfinder of camera model 695. The spot meter has an opening in its middle, more easily seen in the detail to the right. The size of the object has to be bigger than that opening or some radiation from its closest neighbors, which are much colder, will come into the measurement as well, strongly lowering the reading. In the above case, where we have a point-shaped object, which is much hotter than the surroundings, the temperature reading will be too low.

10714703;a3

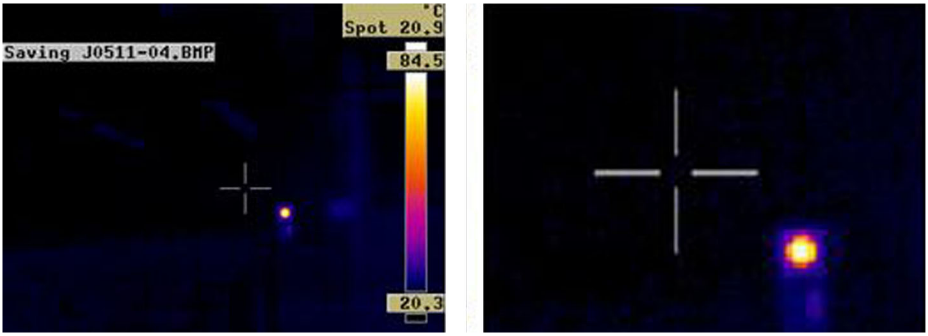

Figure 7.21 Image from the viewfinder of a ThermaCAM 695

This effect is due to imperfections in the optics and to the size of the detector elements. It is typical for all infrared cameras and can not be avoided.

7.7 Practical advice for the thermographer

Working in a practical way with a camera, you will discover small things that make your job easier. Here are ten of them to start with.

7.7.1 From cold to hot

You have been out with the camera at +5°C (+41°F). To continue your work, you now have to perform the inspection indoors. If you wear glasses, you are used to having to wipe off condensed water, or you will not be able to see anything. The same thing happens with the camera. To measure correctly, you should wait until the camera has become warm enough for the condensation to evaporate. This will also allow for the internal temperature compensation system to adjust to the changed condition.

7.7.2 Rain showers

If it starts raining you should not perform the inspection because the water will drastically change the surface temperature of the object that you are measuring. Nevertheless, sometimes you need to use the camera even under rain showers or splashes. Protect your camera with a simple transparent polyethylene plastic bag. Correction for the attenuation which is caused by the plastic bag can be made by adjusting the object distance until the temperature reading is the same as without the plastic cover. Some camera models have a separate **External optics transmission** entry.

7.7.3 Emissivity

You have to determine the emissivity for the material, which you are measuring. Mostly, you will not find the value in tables. Use optical black paint, that is, Nextel Black Velvet. Paint a small piece of the material you are working with. The emissivity of the optical paint is normally 0.94. Remember that the object has to have a temperature, which is different—usually higher—than the ambient temperature. The larger the difference the better the accuracy in the emissivity calculation. The difference should be at least 20°C (36°F). Remember that there are other paints that support very high temperatures up to +800°C (+1472°F). The emissivity may, however, be lower than that of optical black.

Sometimes you can not paint the object that you are measuring. In this case you can use a tape. A thin tape for which you have previously determined the emissivity will work in most cases and you can remove it afterwards without damaging the object of your study. Pay attention to the fact that some tapes are semi-transparent and thus are not very good for this purpose. One of the best tapes for this purpose is Scotch electrical tape for outdoor and sub-zero conditions.

7.7.4 Reflected apparent temperature

You are in a measurement situation where there are several hot sources that influence your measurement. You need to have the right value for the reflected apparent temperature to input into the camera and thus get the best possible correction. Do it in this way: set the emissivity to 1.0. Adjust the camera lens to near focus and, looking in the opposite direction away from the object, save one image. With the area or the isotherm, determine the most probable value of the average of the image and use that value for your input of reflected apparent temperature.

7.7.5 Object too far away

Are you in doubt that the camera you have is measuring correctly at the actual distance? A rule of thumb for your lens is to multiply the IFOV by 3. (IFOV is the detail of the object seen by one single element of the detector). Example: 25 degrees correspond to about 437 mrad. If your camera has a 120 × 120 pixel image, IFOV becomes 437/120 = 3.6 mrad (3.6 mm/m) and your spot size ratio is about 1000/(3 × 3.6)=92:1. This means that at a distance of 9.2 meters (30.2 ft.), your target has to be at least about 0.1 meter or 100 mm wide (3.9"). Try to work on the safe side by coming closer than 9 meters (30 ft.). At 7–8 meters (23–26 ft.), your measurement should be correct.

8 Tutorials

8.1 *Switching on & switching off the camera*

8.1.1 Switching on the camera

Step	Action
1	Insert the battery into the battery compartment.
2	Press PWR/NO to switch on the camera.

8.1.2 Switching off the camera

Step	Action
1	To switch off the camera, press and hold down PWR/NO until the message **Shutting down...** appears. Briefly pressing PWR/NO when the camera is in menu mode will cancel menu selections.

8.2 *Working with images*

8.2.1 Acquiring an image

Step	Action
1	Point the camera at a warm object, like a face or a hand.
2	Adjust the focus by turning the focus ring at the front of the lens. ➲ Please note what is the locking ring and what is the focus ring in the figure on page 48. Trying to adjust the focus by rotating the locking ring will remove the lens.
3	If the camera is in manual adjust mode, press and hold down SEL for more than one second to autoadjust the camera.

8.2.2 Freezing an image

Step	Action
1	Adjust focus by turning the focus ring at the front of the lens. ➲ Please note what is the locking ring and what is the focus ring in the figure on page 48. Trying to adjust the focus by rotating the locking ring will remove the lens.
2	If the camera is in manual adjust mode, press and hold down SEL for more than one second to autoadjust the camera.
3	Briefly pressing SAVE/FRZ will display a confirmation box. ▪ To save the image, press YES ▪ To leave the confirmation box without saving the image, press NO

8.2.3 Saving an image

Step	Action
1	Adjust the focus by turning the focus ring at the front of the lens. ➲ Please note what is the locking ring and what is the focus ring in the figure on page 48. Trying to adjust the focus by rotating the locking ring will remove the lens.
2	If the camera is in manual adjust mode, press and hold down SEL for more than one second to autoadjust the camera.
3	Briefly press SAVE/FRZ to freeze the image. This will display a confirmation box where you will be prompted to accept or cancel the image. Accepting the image will save it to the internal memory.
4	To save an image directly (without freezing the image first), press SAVE/FRZ for more than 1 second.

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8.2.4 Deleting one or several images

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **File** on the vertical menu bar and press the MENU/YES.
3	Point to **Delete image** or **Delete all images** and press MENU/YES to delete one or several images.

8.2.5 Opening an image

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **File** on the vertical menu bar and press the MENU/YES.
3	Point to **Open** and press MENU/YES to open the most recently saved or viewed image. To view another image, use the navigation pad to select the image.

8.3 Working with measurements

8.3.1 Laying out a spot

➲ The camera requires a warm-up time of 5 minutes before accurate measurements can be expected.

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Meas. mode** on the vertical menu bar and press MENU/YES.
3	Select **Spot** in the **Meas. mode** dialog box and press MENU/YES.
4	The temperature will be displayed in the top right corner of the LCD.

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8.4 Changing level & span

8.4.1 Changing level

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Manual adjust** on the vertical menu bar and press MENU/YES.
3	Press the navigation pad up/down to change the level. An arrow pointing upwards or downwards will be displayed.

For more information about level, see section 10.4.3 – Manual adjust/Automatic adjust on page 64.

8.4.2 Changing span

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Manual adjust** on the vertical menu bar and press MENU/YES.
3	Press the navigation pad left/right to change the span. Two arrows pointing away from each other or towards each other will be displayed.

For more information about span, see section 10.4.3 – Manual adjust/Automatic adjust on page 64.

8.5 Changing system settings

8.5.1 Changing language

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Local Settings** on the **Setup** menu and press MENU/YES.
3	Press the navigation pad up/down to select **Language**.
4	Press the navigation pad left/right to change the language.
5	Press MENU/YES to confirm your changes and leave the dialog box.

8.5.2 Changing temperature unit

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Local Settings** on the **Setup** menu and press MENU/YES.
3	Press the navigation pad up/down to select **Temp unit**.
4	Press the navigation pad left/right to change the temperature unit.
5	Press MENU/YES to confirm your changes and leave the dialog box.

8.5.3 Changing date format

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Local Settings** on the **Setup** menu and press MENU/YES.
3	Press the navigation pad up/down to select **Date format**.
4	Press the navigation pad left/right to change the date format.
5	Press MENU/YES to confirm your changes and leave the dialog box.

8.5.4 Changing time format

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Local Settings** on the **Setup** menu and press MENU/YES.
3	Press the navigation pad up/down to select **Time format**.
4	Press the navigation pad left/right to change the time format.

Step	Action
5	Press MENU/YES to confirm your changes and leave the dialog box.

8.5.5 Changing date & time

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Date/time** on the **Setup** menu and press MENU/YES.
3	Press the navigation pad up/down to select year, month, day, hour, minute and second.
4	Press the navigation pad left/right to change each parameter.
5	Press MENU/YES to confirm your changes and leave the dialog box.

8.6 Working with the camera

8.6.1 Removing the lens

➲ Please note the following:

- Before trying to remove fingerprints or other marks on the lens elements, see section 12.2 – Lenses on page 77.
- Removing an IR lens will expose very sensitive camera parts. Do not touch any exposed parts.
- Please note what is the locking ring and what is the focus ring in the figure below. Trying to remove the lens by rotating the focus ring may damage the lens.

10374803;a4

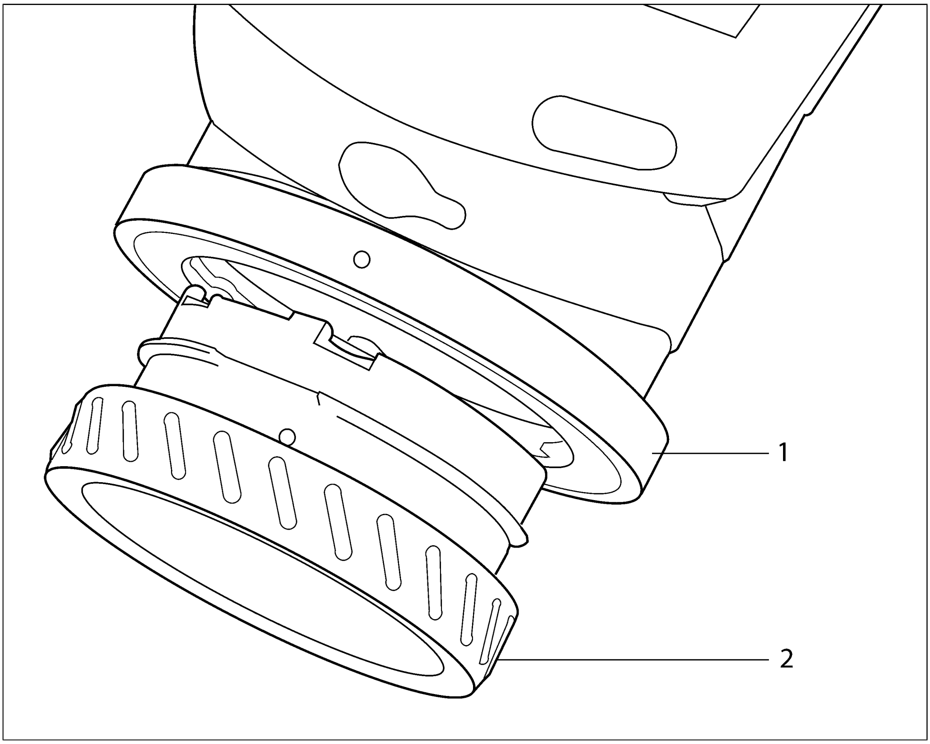

Figure 8.1 Removing a lens. **1:** Locking ring; **2:** Focus ring

8

10396303;a3

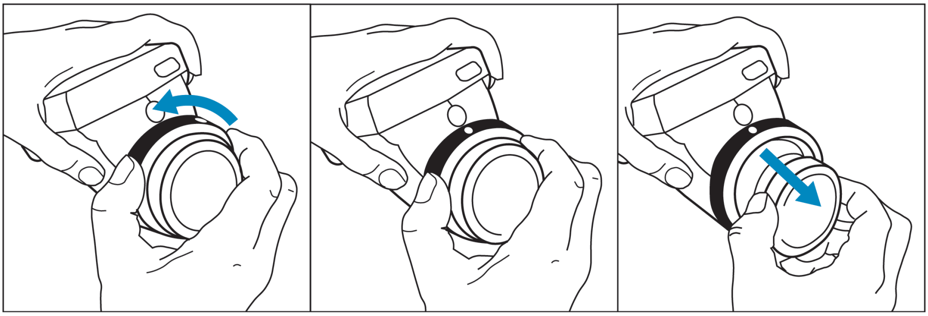

Figure 8.2 Removing a lens

Step	Action
1	Rotate the locking ring on the camera 30° counter-clock-wise until the index mark is lined up with the laser window.
2	Carefully pull out the lens. Do not use excessive force.

8.6.2 Adjusting the focus

➲ Please note what is the locking ring and what is the focus ring in figure 8.1 on page 48. Trying to adjust the focus by rotating the locking ring will remove the lens.

Step	Action
1	To adjust the focus, rotate the focus ring clock-wise or counter-clock-wise.

8.6.3 Inserting & removing the battery

➲ The camera is shipped with charged batteries. To increase the battery life, the battery should be fully discharged and charged a couple of times. You can do this by using the camera until the battery is fully depleted.

8

8.6.3.1 Inserting the battery

10396403;a2

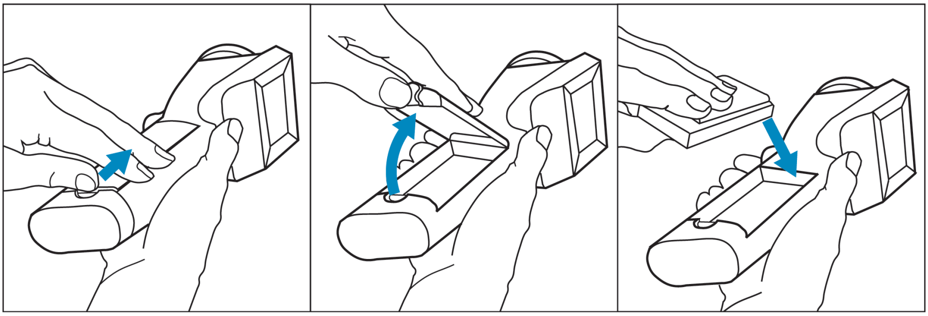

Figure 8.3 Inserting the battery

Step	Action
1	Remove lid of the battery compartment by pressing the locking mechanism.
2	Insert the battery with the connectors facing the rear end of the camera and the arrow symbol facing the front end of the camera.
3	Replace the lid of the battery compartment.

8.6.3.2 Removing the battery

10396503;a2

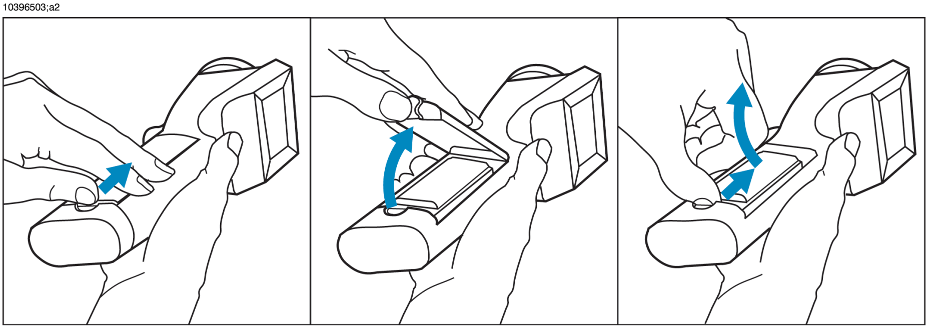

Figure 8.4 Removing the battery

Step	Action
1	Remove the lid of the battery compartment by pressing the locking mechanism.
2	Remove the battery by firmly grabbing its rear end and carefully lifting it out from the battery compartment.
3	Replace the lid of the battery compartment.

For more information about the battery system, see section 11 – Electrical power system on page 71.

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9 Camera overview

9.1 Camera parts

10308903;a5

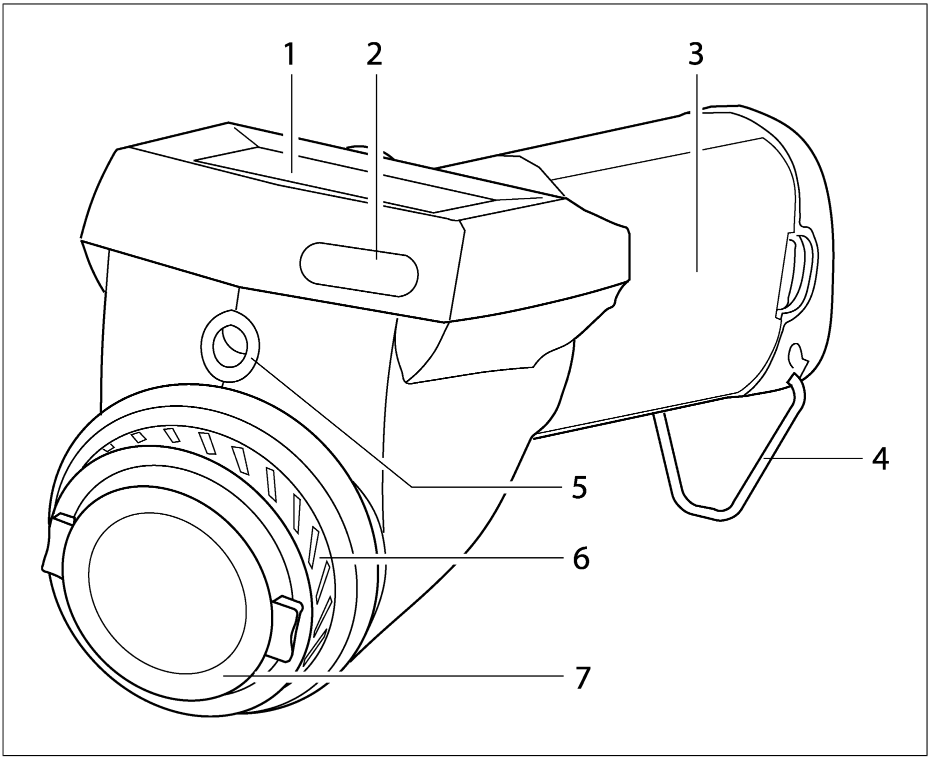

Figure 9.1 Camera parts – front view

Callout	Description of part
1	LCD
2	–
3	Lid of the battery compartment
4	Ring for hand strap

Callout	Description of part
5	Laser LocatIR with lens cap ➲ Please note the following: ■ A laser icon appears on the screen when the Laser LocatIR is switched on. ■ Since the distance between the laser beam and the image center will vary by the target distance, Laser LocatIR should only be used as an aiming aid. Always check the LCD to make sure the camera captures the desired target. ■ Do not look directly into the laser beam. ■ When not in use, the Laser LocatIR should always be protected by the lens cap.
6	Focus ring
7	Lens cap

10315803;a4

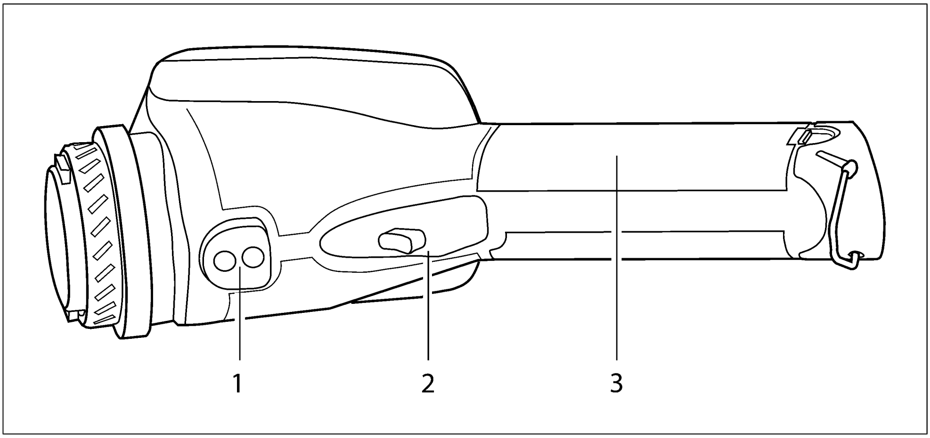

Figure 9.2 Camera parts – view from below

Callout	Description of part
1	Tripod mount
2	Trigger
3	Lid of the battery compartment

9

10310603;a5

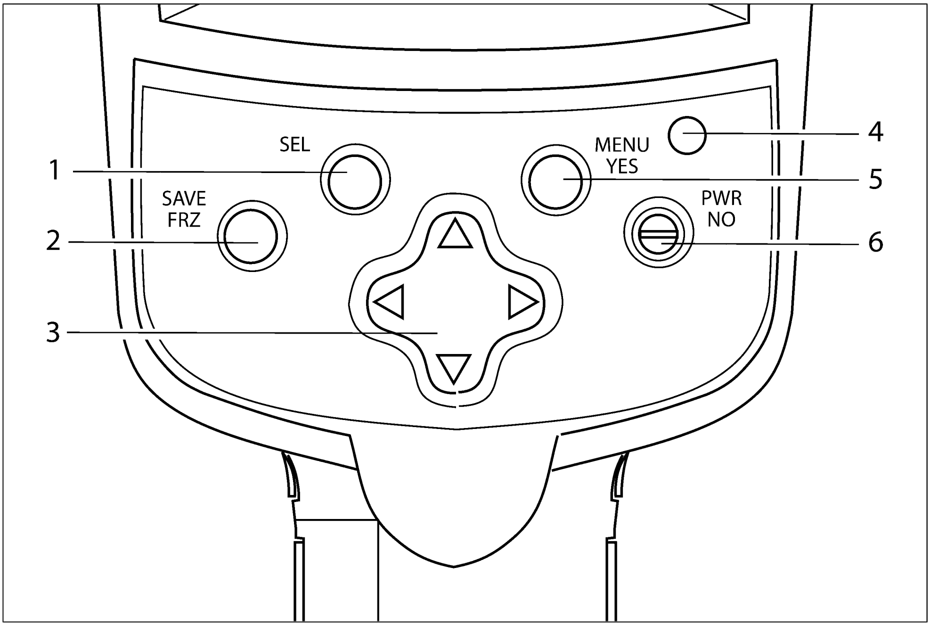

Figure 9.3 Camera parts – view from above

Callout	Description of part
1	SEL button For more information about the functionality of this button, see section 9.2 – Keypad buttons & functions on page 57
2	SAVE/FRZ button For more information about the functionality of this button, see section 9.2 – Keypad buttons & functions on page 57
3	Navigation pad For more information about the functionality of the navigation pad, see section 9.2 – Keypad buttons & functions on page 57
4	LED indicator
5	MENU/YES button For more information about the functionality of this button, see section 9.2 – Keypad buttons & functions on page 57
6	PWR/NO button For more information about the functionality of this button, see section 9.2 – Keypad buttons & functions on page 57

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9.2 Keypad buttons & functions

Button	Comments
SAVE/FRZ button	▪ Briefly press SAVE/FRZ to freeze the current image and display a dialog box where you can choose to save or cancel the image ▪ Press and hold down SAVE/FRZ for more than one second to save the current image without previewing ➲ The image will be saved according to the syntax *IRnnnn.jpg* where *nnnn* is a unique counter. The counter can be reset by pointing to **Factory default** on the **Setup** menu. ➲ Approx. 100 JPG images can be saved.
SEL button	▪ Press and hold down SEL for more than one second to autoadjust the camera ▪ Briefly press SEL to show current navigation pad focus, i.e. which screen object you can change or move by using the navigation pad. ▪ Press SEL repeatedly to switch between different screen objects
MENU/YES button	▪ Press MENU/YES to display the vertical menu bar ▪ Press MENU/YES to confirm selections in dialog boxes ▪ Press MENU/YES to display the graphics if you have previously selected **Hide graphics** on the vertical menu bar
PWR/NO button	▪ Press PWR/NO when the camera is switched off to switch on the camera ▪ Press PWR/NO to cancel selections in dialog boxes ▪ Press and hold down PWR/NO for more than two seconds to switch off the camera ▪ Press PWR/NO to leave freeze and recall mode ▪ Press PWR/NO to display the graphics if you have previously selected **Hide graphics** on the vertical menu bar.
Navigation pad	In menu mode: ▪ Press left/right or up/down to navigate in menus and dialog boxes ▪ Press left/right or up/down to change or move a screen object previously selected by using SEL In manual adjust mode: ▪ Press up/down to change the level (after having selected the scale by pressing SEL) ▪ Press left/right to change the span (after having selected the scale by pressing SEL) For more information about level and span, see section 10.4.3 – Manual adjust/Automatic adjust on page 64

Button	Comments
Trigger	Pull the trigger to do one of the following: ■ Save the image ■ Switch on or switch off the Laser LocatIR ■ Autoadjust the camera The function of the trigger depends on the trigger settings in the **Settings** dialog box. For more information about trigger settings, see section 10.4.9.1 – Settings on page 68

9.3 Laser LocatIR

By pulling the trigger on the bottom side of the camera body, a laser dot appears approx. 40 mm/1.57" above the target.

➲ Please note the following:

- A laser icon appears on the screen when the Laser LocatIR is switched on.
- Since the distance between the laser beam and the image center will vary by the target distance, Laser LocatIR should only be used as an aiming aid. Always check the LCD to make sure the camera captures the desired target.
- Do not look directly into the laser beam.
- When not in use, the Laser LocatIR should always be protected by the lens cap.

For more information about trigger settings, see section 10.4.9.1 – Settings on page 68.

10376403;a2

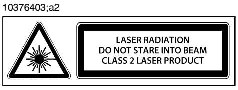


Figure 9.4 Wavelength: 635 nm. Max. output power: 1 mW. This product complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated July 26th, 2001

10311303;a4

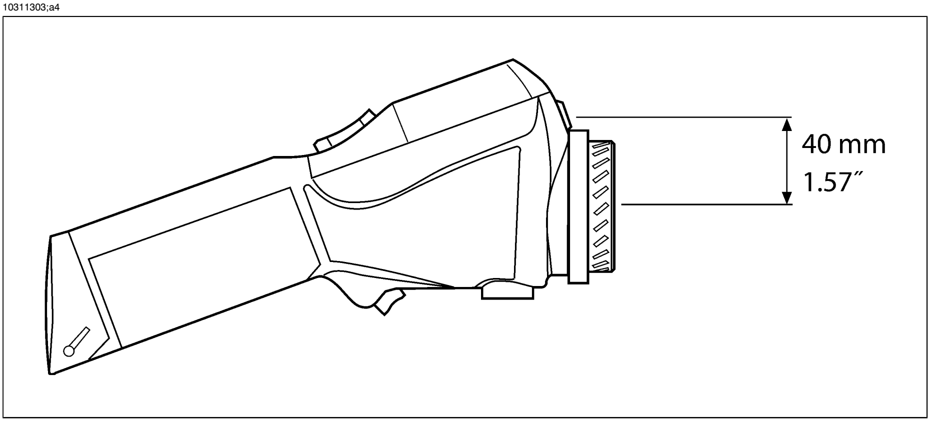


Figure 9.5 Distance between the laser beam and the image center

9.4 LED indicator on keypad

Figure 9.6 Explanations of the LED indicator on the keypad

Indicator mode	**Explanation**
Continuous green light	Powering up or operating.
Flashing green light (0.25 sec. switched on + 0.25 sec. switched off)	Battery charging in standby mode.
Flashing green light (3 sec. switched on + 0.06 sec. switched off)	Battery charging in power-on mode.
No light	The camera is switched off, or the LCD is temporarily switched off.

10 Camera program

10.1 Result table

The results of measurement markers are displayed in a result table in the top right-hand corner of the screen.

Figure 10.1 Explanation of measurement markers appearing in the result table

Icon	**Explanation**
	Spot
✳	The ✳ symbol indicates uncertain result due to an internal updating process after the range has been changed or the camera has been started. The symbol disappears after 15 seconds.

10.2 System messages

10.2.1 Status messages

Status messages are displayed at the bottom of the screen, or in the top left part of the screen. Here you will find information about the current status of the camera.

Figure 10.2 Status messages – a few examples

Message	Explanation
Frozen	Message is displayed when the image is frozen.
Manual	Message is displayed when the camera is currently in manual adjust mode.
Please wait	Message is displayed during operations that take some time.
Restarting	Message is displayed when the software is restarted, *i.e.* after **Factory default**.
Saving as	Message is displayed while an image is being saved.

10.2.2 Warning messages

Warning messages are displayed in the center of the screen. Here you will find important information about battery status, for example.

Figure 10.3 Critical camera information – a few examples

Message	Explanation
Battery low	The battery level is below a critical level.
Shutting down	The camera will be switched off immediately.
Shutting down in 2 seconds	The camera will be switched off in 2 seconds.

10.3 Selecting screen objects

10.3.1 Selecting screen objects

Some screen objects – *e.g.* the scale, the information field, a spot *etc.* – can be selected by pressing SEL repeatedly until the object is either highlighted or surrounded by small brackets. After three seconds the cursor will automatically be hidden. Pressing SEL or the navigation pad will display the cursor again.

When an object is selected you can use the navigation pad to change its value or, where applicable, change its position.

10.3.2 Examples of selected screen objects

10383503;a4

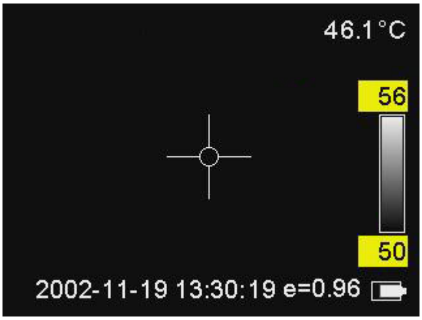


Figure 10.4 A selected temperature scale. Press the navigation pad up/down at this stage to increase/decrease the *level*, and left/right to increase/decrease the *span*.

10383803;a3

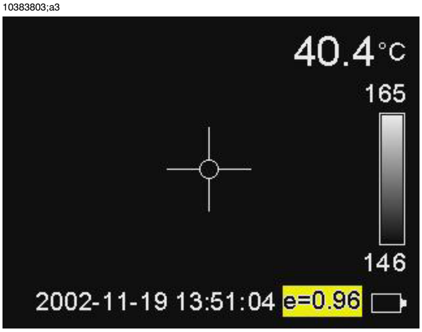


Figure 10.5 A selected emissivity field. Press the navigation pad up/down at this stage to increase/decrease the emissivity.

10.4 Menu system

10.4.1 Navigating the menu system

- Press MENU/YES to display the vertical menu bar
- Press MENU/YES to confirm selections in menus and dialog boxes
- Press PWR/NO to exit the menu system
- Press PWR/NO to cancel selections in menus and dialog boxes
- Press the navigation pad up/down to move up/down in menus, submenus and dialog boxes
- Press the navigation pad right/left to move right/left in menus and submenus, and to change values in dialog boxes

10.4.2 Meas. mode

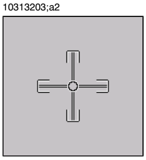
10402203;a2

Figure 10.6 **Meas. mode** dialog box.

Point to **Meas. mode** on the vertical menu bar and press MENU/YES to display the **Meas. mode** dialog box.

- To enable/disable the spot, press the navigation pad left/right.
- To confirm the choice, press MENU/YES.
- To cancel any changes, press PWR/NO

10313203;a2



10

Figure 10.7 A selected measurement function

➲ To ensure correct temperature readings, make sure that the circle in the middle of the crosshair is completely filled by the target.

10.4.3 Manual adjust/Automatic adjust

Point to **Manual adjust** and press MENU/YES to manually select *level* and *span* settings. The level command can be regarded as the *brightness*, while the span command can be regarded as the *contrast*.

- Press the navigation pad up/down to change the level (indicated by an arrow pointing upwards or downwards in the temperature scale)
- Press the navigation pad left/right to change the span (indicated by two arrows pointing away from each other or towards each other)

10392103;a3

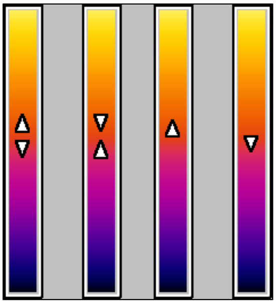


Figure 10.8 Symbols in the temperature scale, indicating (1) increasing span; (2) decreasing span; (3) increasing level, and (4) decreasing level

Point to **Automatic adjust** and press MENU/YES to put the camera in automatic mode, continuously optimizing the image for best level and span.

10.4.4 Emissivity

10382503;a3

Figure 10.9 **Emissivity** dialog box

Point to **Emissivity** on the vertical menu bar and press MENU/YES to display the **Emissivity** dialog box.

- To change the emissivity, press the navigation pad right/left
- To confirm the choice, press MENU/YES
- To cancel any changes, press PWR/NO
- To change **T Refl** (reflected ambient temperature), press the navigation pad right/left
- To confirm the choice, press MENU/YES
- To cancel any changes, press PWR/NO

For more information about emissivity and reflected ambient temperature, see section 16 – Thermographic measurement techniques on page 113 and section 18 – Theory of thermography on page 123

➲ Please note the following:

- When the scale is selected, you can change the emissivity directly by using the navigation pad.
- If you enter an emissivity value less than 0.30 the emissivity box will begin flashing to remind you that this value is unusually low.

10

10.4.5 Palette

10382603;a4

Figure 10.10 **Palette** dialog box

Point to **Palette** on the vertical menu bar and press MENU/YES to display the **Palette** dialog box.

- To select another palette, press the navigation pad left/right
- To confirm the choice, press MENU/YES
- To cancel any changes, press PWR/NO

10.4.6 Range (extra option)

Point to **Range** on the vertical menu bar and press MENU/YES to display the **Range** dialog box.

- To select another temperature range, press the navigation pad left/right
- To confirm the choice, press MENU/YES
- To cancel any changes, press PWR/NO

10.4.7 Hide graphics / Show graphics

Point to **Hide graphics** on the vertical menu bar and press MENU/YES to hide all graphics currently displayed on the screen. To display the graphics again, either:

- Point to **Show graphics** on the menu, *or*
- Briefly press SEL, *or*
- Briefly press MENU/YES, *or*
- Briefly press PWR/NO

➲ The laser icon overrides the **Hide graphics** menu selection. This means that even though **Hide graphics** is selected when the Laser LocatIR is lit, the laser icon will still be displayed on the screen.

10.4.8 File

10382903;a3

Figure 10.11 **File** menu

Figure 10.12 Explanations of the **File** menu

Command	Explanation
Open	Point to **Open** and press MENU/YES to open the most recently saved or viewed image. To view another image, use the navigation pad to select the image.
Delete image	Point to **Delete image** and press MENU/YES to delete a recalled image. This choice will display a confirmation box where you can either confirm or cancel the deletion.
Delete all images	Point to **Delete all images** and press MENU/YES to delete all images. This choice will display a confirmation box where you can either confirm or cancel the deletion.

➲ Approx. 100 radiometric JPG images can be saved.

10.4.9 Setup

10383003;a4

Figure 10.13 Setup menu

10.4.9.1 Settings

10382003;a4

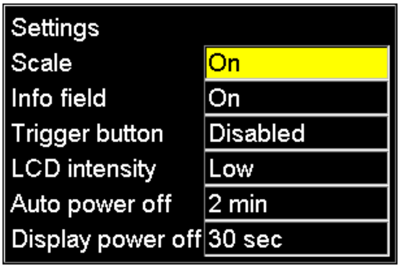


Figure 10.14 **Settings** dialog box

Figure 10.15 Explanations of the **Settings** dialog box

Label	**Value**	**Explanation**
Scale	■ **On** ■ **Off**	■ Select **On** to display the scale on the screen ■ Select **Off** to hide the scale
Info field	■ **On** ■ **Off** ■ **On + TRefl**	■ Select **On** to display the information field at the bottom of the screen ■ Select **Off** to hide the information field ■ Select **On + TRefl** to display the information field and the reflected ambient temperature
Trigger	■ **Laser** ■ **Save** ■ **Disabled** ■ **One-shot autoadjust**	■ Select **Laser** to activate the laser when pulling the trigger ■ Select **Save** to save the current image when pulling the trigger ■ Select **Disabled** to disable the trigger ■ Select **One-shot autoadjust** to autoadjust the camera when pulling the trigger
LCD intensity	■ **Low** intensity of the LCD ■ **Medium** ■ **High**	■ Select **Low** to set the LCD intensity to the lowest level ■ Select **Medium** to set the LCD intensity to medium level ■ Select **High** to set the LCD intensity to the highest level

Label	Value	Explanation
Auto power off	▪ None ▪ 2 min ▪ 5 min ▪ 10 min	If the camera is switched on but currently not used, it will automatically be switched off after a specified time. Set the time by pressing the navigation pad left/right.
Display power off	▪ None ▪ 30 sec. ▪ 60 sec. ▪ 2 min.	If the camera is switched on but currently not used, the display will automatically be switched off after a specified time. Set the time by pressing the navigation pad left/right.

➲ For protective reasons, the LCD will be switched off if the detector temperature exceeds +60 °C (+149 °F) and the camera will be switched off if the detector temperature exceeds +68 °C (+154.4 °F)

10.4.9.2 Date/time

10382103;a3

Figure 10.16 **Date/time** dialog box

Figure 10.17 Explanations of the **Date/time** dialog box

Label	Explanation
Year	1970–2036
Month	1–12
Day	1–31
Hour	▪ 12 a.m.–12 p.m. ▪ 1–24 The format depends on the settings in the **Local Settings** dialog box.
Minute	00–59
Second	00–59

10.4.9.3 Local settings

10567103;a2

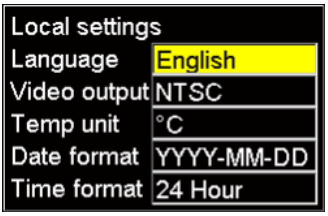


Figure 10.18 **Local settings** dialog box

Figure 10.19 Explanations of the **Local settings** dialog box

Label	**Explanation**
Language	Configuration-dependent
Video output	■ NTSC ■ PAL
Temp unit	■ °C – degrees Celsius *or* ■ °F – degrees Fahrenheit
Date format	■ YYYY-MM-DD ■ YY-MM-DD ■ MM/DD/YY ■ DD/MM/YY
Time format	■ 24 hour ■ AM/PM

10.4.9.4 Camera info

The camera info panel shows information about memory usage, battery status, serial numbers, software revisions, *etc.*

No changes can be made.

10.4.9.5 Factory default

Point to **Factory default** and press MENU/YES to reset all camera settings to factory settings.

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11 Electrical power system

The camera's electrical power system consists of the following parts:

- a removable battery
- a power supply
- an internal battery charger

The camera may powered either by using the battery, or by using the power supply. When using the power supply, the battery will – if it's inserted in the battery compartment – automatically be charged. You can still use the camera during charging.

➲ Please note the following:

- The camera is shipped with charged batteries. To increase the battery life, the battery should be fully discharged and charged a couple of times by using the camera or leaving the camera on, until the camera says **Battery low**.
- The same power supply can be used for both the internal battery charger and the external battery charger.

10306103;a4

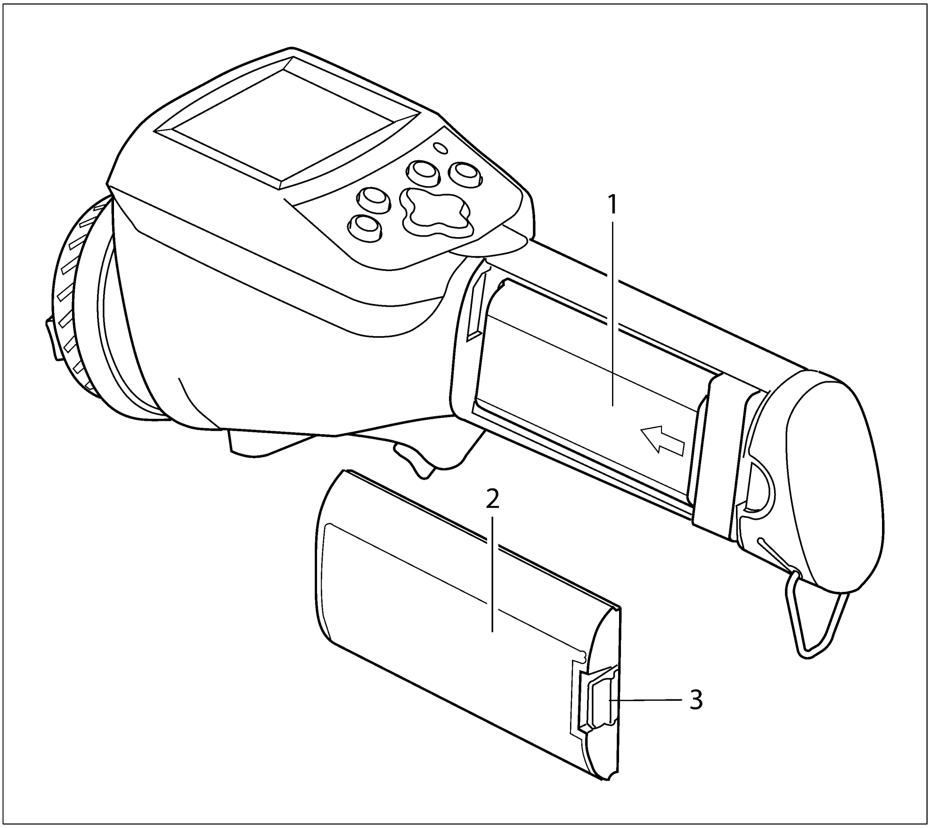

Figure 11.1 Battery and battery compartment

Callout	Description of part
1	Battery
2	Battery cover
3	Release button

The removable battery gives an operation time of approx. 1.5–2 hours. When **Battery low** is displayed on the screen it is time to charge the battery.

➲ The operation time of the camera when run on a battery is substantially shorter in low temperatures.

11.1 Internal battery charging

To charge the battery using the internal battery charger, follow the instructions below:

Step	Action
1	Make sure that the battery is correctly inserted into the camera.
2	Connect the power cable to the camera.
3	While charging, the battery status symbol will pulse until the battery is fully charged. When the battery is fully charged the battery symbol will stop pulsing and be completely filled.

10305803;a2

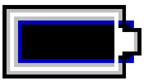

Figure 11.2 **Battery full** symbol

11.2 External battery charging

➲ External battery charger is an extra option.

You can also charge the battery by using the external battery charger. The battery status during charging is indicated by a number of LEDs.

10379603;a4

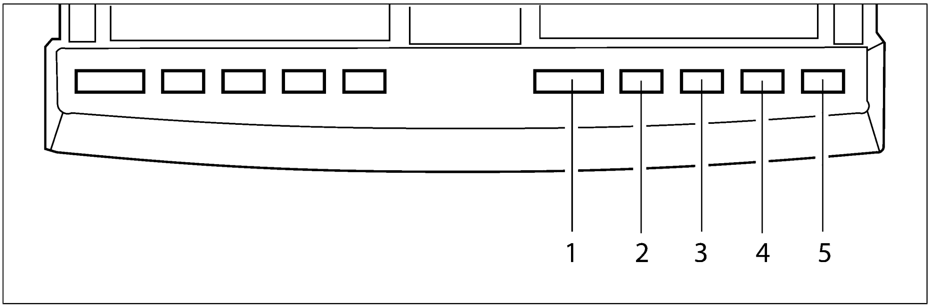

Figure 11.3 LED indicators on the external battery charger

Figure 11.4 LED indicators – explanations of callouts

Situation	LED indicator no.	Color & mode
The charger is under power, but no battery is inserted	**1**	Fixed red light
The charger is under power, and a battery is inserted	**1**	Fixed green light
The battery is too cold or too warm	1	Flashing green light
The battery is out of order	**1**	Flashing red light
The battery is now being charged	**5-2**	Pulsing green light from LED no. 5 to LED no. 2 Each LED represents 25 % battery capacity and will be lit accordingly.

11

11.3 Battery safety warnings

- Do not place the battery in fire or heat the battery.
- Do not install the battery backwards so that the polarity is reversed.
- Do not connect the positive terminal and the negative terminal of the battery to each other with any metal object (such as wire).
- Do not pierce the battery with nails, strike the battery with a hammer, step on the battery, or otherwise subject it to strong impacts or shocks.
- Do not solder directly onto the battery.
- Do not expose the battery to water or salt water, or allow the battery to get wet.
- Do not disassemble or modify the battery. The battery contains safety and protection devices which, if damaged, may cause the battery to generate heat, explode or ignite.
- Do not place the battery on or near fires, stoves, or other high-temperature locations.
- When the battery is worn out, insulate the terminals with adhesive tape or similar materials before disposal.
- Immediately discontinue use of the battery if, while using, charging, or storing the battery, the battery emits an unusual smell, feels hot, changes color, changes shape, or appears abnormal in any other way. Contact your sales location if any of these problems are observed.
- In the event that the battery leaks and the fluid gets into one's eye, do not rub the eye. Rinse well with water and immediately seek medical care. If left untreated the battery fluid could cause damage to the eye.
- When charging the battery, only use a specified battery charger.
- Do not attach the batteries to a power supply plug or directly to a car's cigarette lighter.
- Do not place the batteries in or near fire, or into direct sunlight. When the battery becomes hot, the built-in safety equipment is activated, preventing the battery from charging further, and heating the battery can destroy the safety equipment and can cause additional heating, breaking, or ignition of the battery.
- Do not continue charging the battery if it does not recharge within the specified charging time. Doing so may cause the battery to become hot, explode, or ignite.
- The temperature range over which the battery can be charged is 0–+45 °C (+32–+113 °F). Charging the battery at temperatures outside of this range may cause the battery to become hot or to break. Charging the battery outside of this temperature range may also harm the performance of the battery or reduce the battery's life expectancy.
- Do not discharge the battery using any device except for the specified device. When the battery is used in devices aside from the specified device it may damage the performance of the battery or reduce its life expectancy, and if the device causes an abnormal current to flow, it may cause the battery to become hot, explode, or ignite and cause serious injury.

- The temperature range over which the battery can be discharged is -15–+45 °C (+18.8–+113 °F). Use of the battery outside of this temperature range may damage the performance of the battery or may reduce its life expectancy.

12 Maintenance & cleaning

12.1 Camera body, cables & accessories

The camera body, cables and accessories may be cleaned by wiping with a soft cloth. To remove stains, wipe with a soft cloth moistened with a mild detergent solution and wrung dry, then wipe with a dry soft cloth.

➲ Do not use benzene, thinner, or any other chemical product on the camera, the cables or the accessories, as this may cause deterioration.

12.2 Lenses

All lenses are coated with an anti-reflective coating and care must be taken when cleaning them. Cotton wool soaked in 96 % ethyl alcohol (C_2H_5OH) may be used to clean the lenses. The lenses should be wiped once with the solution, then the cotton wool should be discarded.

If ethyl alcohol is unavailable, DEE (*i.e.* 'ether' = diethylether, $C_4H_{10}O$) may be used for cleaning.

Sometimes drying marks may appear on the lenses. To prevent this, a cleaning solution of 50 % acetone (*i.e.* dimethylketone, $(CH_3)_2CO$)) and 50 % ethyl alcohol (C_2H_5OH) may be used.

➲ Please note the following:

- Excessive cleaning of the lenses may wear down the coating.
- The chemical substances described in this section may be dangerous. Carefully read all warning labels on containers before using the substances, as well as applicable MSDS (Material Safety Data Sheets).

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13 Troubleshooting

Problem	**Possible reason**	**Solution**
The LCD displays no image at all.	The camera may have been switched off automatically due the settings in the **Settings** dialog box.	Press PWR/NO to switch on the camera.
	The LCD may have been switched off automatically due to the settings in the **Settings** dialog box.	Press PWR/NO to switch on the camera.
	There is no battery in the battery compartment.	Insert a fully charged battery.
	There is a battery in the battery compartment, but the battery is depleted.	Charge the battery.
	If you are using the power supply, the connector may not be properly inserted into the power connector on the camera.	Verify that the power supply connector is properly inserted.
	If you are using the power supply, the mains plug may not be properly plugged in into a mains supply.	Verify that the mains plug is properly plugged in.
	If you are using the power supply, the mains cable may not be properly plugged in into the power supply.	Verify that the mains cable is properly plugged in.
The LCD displays an image, but it is of poor quality.	The level needs to be changed.	Change the level.
	The span needs to be changed	Change the span.
	The camera needs to be autoadjusted.	Carry out an autoadjust maneuver.
	The target may be hotter or colder than the temperature range you are currently using.	If your camera features an additional range, change the range.
	A different palette may be more suitable for imaging the target than the one you are currently using.	Change the palette.
The LCD displays an image, but it is blurry.	The target may be out of focus.	Focus the camera by rotating the focus ring on the lens.
The LCD displays an image, but it is of low contrast.	The contrast of the LCD may have accidently been set to too low a value.	Change the contrast of the LCD.

Problem	Possible reason	Solution
The trigger button does not work as expected.	The function of the trigger button may have accidently been changed.	Change the function of the trigger button.
The trigger button does not work at all.	The trigger button may have accidentally been disabled.	Enable the trigger button.
When connecting the infrared camera to an external video monitor, no image appears.	The video cable connector may not be properly inserted into the video connector on the camera.	Verify that the video connector is properly inserted.
	The video cable connector may not be properly inserted into the video connector on the external monitor.	Verify that the video connector is properly inserted.
	The camera may have accidentally been set to PAL video format, while the external video monitor is set to NTSC video format, and vice versa.	Change the video format.
The LCD does not display the correct date & time.	The camera may have accidentally been set to the wrong date & time.	Change the date & time.
It is not possible to store any more images in the camera.	The internal flash memory may be full.	To be able to save more images, download the images to your computer using ThermaCAM™ QuickView.

14 Technical specifications & dimensional drawings

➲ FLIR Systems reserves the right to discontinue models, parts and accessories, and other items, or change specifications at any time without prior notice.

14.1 Imaging performance

Focus	Manual
Start-up time	Approx. 15 seconds
Start-up time from stand-by	< 1 second @ +25 °C (+77 °F)
Detector type	Focal Plane Array (FPA), uncooled microbolometer 160 × 120 pixels
Spectral range	7.5–13 µm

14.2 Image presentation

Display	2.5" color LCD, 16-bit colors
Video output	Composite video CVBS (ITU-R BT.470 PAL/SMPTE 170M NTSC)

14.3 Temperature range

Temperature range	Temperature range is subject to customer configuration, and/or three-digit camera type number. The three-digit camera type number is the three first digits in the camera S/N. Refer to the camera menu system to see available temperature ranges.
Accuracy	± 2 °C / ± 3.6 °F or ± 2 % of reading

14.4 Laser LocatIR

Classification	Class 2
Type	Semiconductor AlGaInP diode laser, 1 mW/635 nm (red)

14.5 Electrical power system

Battery type	Rechargeable Li/Ion battery
Battery operating time	1.5 hours. Display shows battery status
Battery charging	Internal, AC adapter, or 12 VDC car adapter. 2-bay desktop charger.
AC operation	AC adapter, 90–260 VAC, 50/60 Hz, 12 VDC out
Voltage	11–16 VDC
Power management	Automatic shut-down and sleep mode (user-selectable)

14.6 Environmental specifications

Operating temperature range	For camera type 215 & 247: -15–+45 °C (+5–+113 °F) For camera type 243: -15–+50 °C (+5–+122 °F) The three-digit camera type number is the three first digits in the camera S/N.
Storage temperature range	-40–+70 °C (-40–+158 °F)
Humidity	Operating & storage, 10–95 %, non-condensing, IEC 359.
Encapsulation	IP 54
Shock	25 g, IEC 68-2-29
Vibration	2 g, IEC 68-2-6
EMC	The applicable EMC standards depend on the three-digit camera type number. One or more of the following standards apply: EN 61000-6-3:2001 EN 61000-6-2:2001 EN 50081-2 (emission) EN 50082-2 (immunity) FCC 47 CFR Part 15 B The three-digit camera type number is the three first digits in the camera S/N.

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14.7 Physical specifications

Weight	0.7 kg (1.54 lb), including battery and 17 mm lens

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Size (L × W × H)	246 × 80 × 135 mm (9.7 × 3.2 × 5.3") with 17 mm lens
Tripod mount	Standard, 1/4"-20
Housing	Plastics & rubber

14.8 Communications interfaces

USB	Image transfer to PC USB Rev 2.0 (full speed 12 Mbit)
RS-232 (optional)	Image transfer to PC

14.9 Pin configurations

14.9.1 RS-232/USB connector

10384403;a4

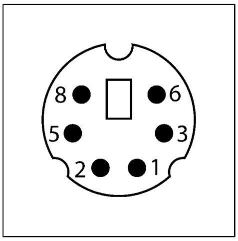

Figure 14.1 Pin configuration – RS-232/USB (on camera – operator's side)

Figure 14.2 Pin configuration

Pin	Signal name
1	USB -
2	RS-232_TX
3	GND
4	N/C
5	USB POWER
6	USB +
7	N/C
8	RS-232_RX

14.9.2 Power connector

10402503;a1

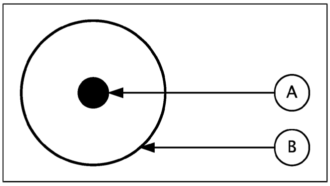

Figure 14.3 Pin configuration for power connector (on camera – operator's side). **A:** Center pin; **B:** Chassis

Connector type:	**2.5 mm DC**	
Signal name	**Type**	**Pin number**
+12V	POWER	CENTER PIN
GND	POWER	CHASSIS

14.9.3 CVBS connector

10402503;a1

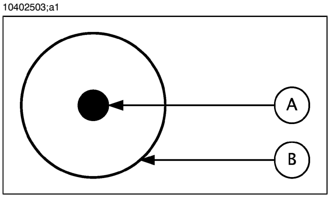

Figure 14.4 Pin configuration for CVBS connector (on camera – operator's side). **A:** Center pin; **B:** Chassis

Connector type:	**RCA/PHONO**	
Signal name	**Type**	**Pin number**
CVBS	VIDEO	CENTER PIN
GND	POWER	CHASSIS

14.10 Relationship between fields of view and distance

10563503;a3

This table only applies to camera type number 215									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 87 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 4.87									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.04	0.09	0.17	0.43	0.85	2.13	4.25	8.51	**m**
VFOV	0.03	0.06	0.13	0.32	0.64	1.59	3.19	6.38	**m**
IFOV	0.27	0.53	1.06	2.66	5.32	13.29	26.58	53.16	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.14	0.28	0.56	1.39	2.79	6.97	13.94	27.89	**ft.**
VFOV	0.10	0.21	0.42	1.05	2.09	5.23	10.46	20.92	**ft.**
IFOV	0.01	0.02	0.04	0.10	0.21	0.52	1.05	2.09	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.5 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 87 mm IR lens. Applies to camera type 215 only.

10564203;a3

This table only applies to camera type number 215									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 54 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 7.83									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.07	0.14	0.27	0.69	1.37	3.43	6.85	13.70	**m**
VFOV	0.05	0.10	0.21	0.51	1.03	2.57	5.14	10.28	**m**
IFOV	0.43	0.86	1.71	4.28	8.56	21.41	42.82	85.65	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.22	0.45	0.90	2.25	4.49	11.23	22.47	44.93	**ft.**
VFOV	0.17	0.34	0.67	1.68	3.37	8.42	16.85	33.70	**ft.**
IFOV	0.02	0.03	0.07	0.17	0.34	0.84	1.69	3.37	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.6 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 54 mm IR lens. Applies to camera type 215 only.

10564503;a3

This table only applies to camera type number 215									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 36 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 11.7									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.10	0.21	0.41	1.03	2.06	5.14	10.28	20.56	**m**
VFOV	0.08	0.15	0.31	0.77	1.54	3.85	7.71	15.42	**m**
IFOV	0.64	1.28	2.57	6.42	12.85	32.12	64.24	128.47	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.34	0.67	1.35	3.37	6.74	16.85	33.70	67.40	**ft.**
VFOV	0.25	0.51	1.01	2.53	5.05	12.64	25.27	50.55	**ft.**
IFOV	0.03	0.05	0.10	0.25	0.51	1.26	2.53	5.06	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.7 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 36 mm IR lens. Applies to camera type 215 only.

10564803;a3

This table only applies to camera type number 215									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 17 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 24.5									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.22	0.44	0.87	2.18	4.35	10.88	21.76	43.53	**m**
VFOV	0.16	0.33	0.65	1.63	3.26	8.16	16.32	32.65	**m**
IFOV	1.36	2.72	5.44	13.60	27.21	68.01	136.03	272.06	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.71	1.43	2.85	7.14	14.27	35.68	71.36	142.72	**ft.**
VFOV	0.54	1.07	2.14	5.35	10.70	26.76	53.52	107.04	**ft.**
IFOV	0.05	0.11	0.21	0.54	1.07	2.68	5.36	10.71	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.8 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 17 mm IR lens. Applies to camera type 215 only.

10565103;a3

This table only applies to camera type number 215									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 9.2 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 43.8									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.40	0.80	1.61	4.02	8.04	20.11	40.22	80.43	**m**
VFOV	0.30	0.60	1.21	3.02	6.03	15.08	30.16	60.33	**m**
IFOV	2.51	5.03	10.05	25.14	50.27	125.68	251.36	502.72	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	1.32	2.64	5.27	13.19	26.37	65.93	131.86	263.72	**ft.**
VFOV	0.99	1.98	3.96	9.89	19.78	49.45	98.90	197.79	**ft.**
IFOV	0.10	0.20	0.40	0.99	1.98	4.95	9.90	19.79	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.9 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 9.2 mm IR lens. Applies to camera type 215 only.

10563703;a3

This table only applies to camera type number 215									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 4.5 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 78.8									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.82	1.64	3.29	8.22	16.44	41.11	82.22	164.44	**m**
VFOV	0.62	1.23	2.47	6.17	12.33	30.83	61.67	123.33	**m**
IFOV	5.14	10.28	20.56	51.39	102.78	256.94	513.89	1 027.78	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	2.70	5.39	10.78	26.96	53.92	134.79	269.58	539.16	**ft.**
VFOV	2.02	4.04	8.09	20.22	40.44	101.09	202.19	404.37	**ft.**
IFOV	0.20	0.40	0.81	2.02	4.05	10.12	20.23	40.46	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.10 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 4.5 mm IR lens. Applies to camera type 215 only.

10564003;a3

This table only applies to camera type number 243									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 87 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 3.68									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.03	0.06	0.13	0.32	0.64	1.61	3.22	6.44	**m**
VFOV	0.02	0.05	0.10	0.24	0.48	1.21	2.41	4.83	**m**
IFOV	0.20	0.40	0.80	2.01	4.02	10.06	20.11	40.23	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.11	0.21	0.42	1.06	2.11	5.28	10.55	21.10	**ft.**
VFOV	0.08	0.16	0.32	0.79	1.58	3.96	7.91	15.83	**ft.**
IFOV	0.01	0.02	0.03	0.08	0.16	0.40	0.79	1.58	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.11 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 87 mm IR lens. Applies to camera type 243 only.

14

10564303;a3

This table only applies to camera type number 243									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 54 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 5.93									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.05	0.10	0.21	0.52	1.04	2.59	5.19	10.37	**m**
VFOV	0.04	0.08	0.16	0.39	0.78	1.94	3.89	7.78	**m**
IFOV	0.32	0.65	1.30	3.24	6.48	16.20	32.41	64.81	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.17	0.34	0.68	1.70	3.40	8.50	17.00	34.00	**ft.**
VFOV	0.13	0.26	0.51	1.28	2.55	6.38	12.75	25.50	**ft.**
IFOV	0.01	0.03	0.05	0.13	0.26	0.64	1.28	2.55	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.12 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 54 mm IR lens. Applies to camera type 243 only.

10564603;a3

This table only applies to camera type number 243									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 36 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 8.89									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.08	0.16	0.31	0.78	1.56	3.89	7.78	15.56	**m**
VFOV	0.06	0.12	0.23	0.58	1.17	2.92	5.83	11.67	**m**
IFOV	0.49	0.97	1.94	4.86	9.72	24.31	48.61	97.22	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.26	0.51	1.02	2.55	5.10	12.75	25.50	51.00	**ft.**
VFOV	0.19	0.38	0.77	1.91	3.83	9.56	19.13	38.25	**ft.**
IFOV	0.02	0.04	0.08	0.19	0.38	0.96	1.91	3.83	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.13 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 36 mm IR lens. Applies to camera type 243 only.

10564903;a3

This table only applies to camera type number 243									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 17 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 18.7									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.16	0.33	0.66	1.65	3.29	8.24	16.47	32.94	**m**
VFOV	0.12	0.25	0.49	1.24	2.47	6.18	12.35	24.71	**m**
IFOV	1.03	2.06	4.12	10.29	20.59	51.47	102.94	205.88	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.54	1.08	2.16	5.40	10.80	27.00	54.00	108.00	**ft.**
VFOV	0.41	0.81	1.62	4.05	8.10	20.25	40.50	81.00	**ft.**
IFOV	0.04	0.08	0.16	0.41	0.81	2.03	4.05	8.11	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.14 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 17 mm IR lens. Applies to camera type 243 only.

10565203;a3

This table only applies to camera type number 243									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 9.2 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 33.8									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV		0.30	0.61	1.22	3.04	6.09	15.22	30.43	60.87	**m**
VFOV		0.23	0.46	0.91	2.28	4.57	11.41	22.83	45.65	**m**
IFOV		1.90	3.80	7.61	19.02	38.04	95.11	190.22	380.43	**mm**
D --->		**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV		1.00	2.00	3.99	9.98	19.96	49.89	99.79	199.57	**ft.**
VFOV		0.75	1.50	2.99	7.48	14.97	37.42	74.84	149.68	**ft.**
IFOV		0.07	0.15	0.30	0.75	1.50	3.74	7.49	14.98	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.15 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 9.2 mm IR lens. Applies to camera type 243 only.

10563803;a3

This table only applies to camera type number 243									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 4.5 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 63.7									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.62	1.24	2.49	6.22	12.44	31.11	62.22	124.44	**m**
VFOV	0.47	0.93	1.87	4.67	9.33	23.33	46.67	93.33	**m**
IFOV	3.89	7.78	15.56	38.89	77.78	194.44	388.89	777.78	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	2.04	4.08	8.16	20.40	40.80	102.00	204.01	408.01	**ft.**
VFOV	1.53	3.06	6.12	15.30	30.60	76.50	153.01	306.01	**ft.**
IFOV	0.15	0.31	0.61	1.53	3.06	7.66	15.31	30.62	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.16 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 4.5 mm IR lens. Applies to camera type 243 only.

10564103;a3

This table only applies to camera type number 247									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 87 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 4.00									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.03	0.07	0.14	0.35	0.70	1.75	3.49	6.99	**m**
VFOV	0.03	0.05	0.10	0.26	0.52	1.31	2.62	5.24	**m**
IFOV	0.22	0.44	0.87	2.18	4.37	10.92	21.84	43.68	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.11	0.23	0.46	1.15	2.29	5.73	11.46	22.91	**ft.**
VFOV	0.09	0.17	0.34	0.86	1.72	4.30	8.59	17.18	**ft.**
IFOV	0.01	0.02	0.03	0.09	0.17	0.43	0.86	1.72	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.17 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 87 mm IR lens. Applies to camera type 247 only.

10564403;a3

This table only applies to camera type number 247									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 54 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 6.44									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.06	0.11	0.23	0.56	1.13	2.81	5.63	11.26	**m**
VFOV	0.04	0.08	0.17	0.42	0.84	2.11	4.22	8.44	**m**
IFOV	0.35	0.70	1.41	3.52	7.04	17.59	35.19	70.37	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.18	0.37	0.74	1.85	3.69	9.23	18.46	36.92	**ft.**
VFOV	0.14	0.28	0.55	1.38	2.77	6.92	13.84	27.69	**ft.**
IFOV	0.01	0.03	0.06	0.14	0.28	0.69	1.39	2.77	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.18 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 54 mm IR lens. Applies to camera type 247 only.

10564703;a3

This table only applies to camera type number 247									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 36 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 9.65									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.08	0.17	0.34	0.84	1.69	4.22	8.44	16.89	**m**
VFOV	0.06	0.13	0.25	0.63	1.27	3.17	6.33	12.67	**m**
IFOV	0.53	1.06	2.11	5.28	10.56	26.39	52.78	105.56	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.28	0.55	1.11	2.77	5.54	13.84	27.69	55.37	**ft.**
VFOV	0.21	0.42	0.83	2.08	4.15	10.38	20.77	41.53	**ft.**
IFOV	0.02	0.04	0.08	0.21	0.42	1.04	2.08	4.16	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.19 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 36 mm IR lens. Applies to camera type 247 only.

14

10565003;a3

This table only applies to camera type number 247									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 17 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 20.2									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.18	0.36	0.72	1.79	3.58	8.94	17.88	35.76	**m**
VFOV	0.13	0.27	0.54	1.34	2.68	6.71	13.41	26.82	**m**
IFOV	1.12	2.24	4.47	11.18	22.35	55.88	111.76	223.53	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.59	1.17	2.35	5.86	11.73	29.32	58.63	117.26	**ft.**
VFOV	0.44	0.88	1.76	4.40	8.79	21.99	43.97	87.95	**ft.**
IFOV	0.04	0.09	0.18	0.44	0.88	2.20	4.40	8.80	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.20 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 17 mm IR lens. Applies to camera type 247 only.

10563603;a3

This table only applies to camera type number 247									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 9.2 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 36.5									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.33	0.66	1.32	3.30	6.61	16.52	33.04	66.09	**m**
VFOV	0.25	0.50	0.99	2.48	4.96	12.39	24.78	49.57	**m**
IFOV	2.07	4.13	8.26	20.65	41.30	103.26	206.52	413.04	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	1.08	2.17	4.33	10.83	21.67	54.17	108.34	216.68	**ft.**
VFOV	0.81	1.63	3.25	8.13	16.25	40.63	81.25	162.51	**ft.**
IFOV	0.08	0.16	0.33	0.81	1.63	4.07	8.13	16.26	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.21 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 9.2 mm IR lens. Applies to camera type 247 only.

10563903;a3

This table only applies to camera type number 247									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 4.5 mm									
Resolution: 160 x 120 pixels									
Field of view in degrees: 68.0									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.68	1.35	2.70	6.76	13.51	33.78	67.56	135.11	**m**
VFOV	0.51	1.01	2.03	5.07	10.13	25.33	50.67	101.33	**m**
IFOV	4.22	8.44	16.89	42.22	84.44	211.11	422.22	844.44	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	2.21	4.43	8.86	22.15	44.30	110.75	221.49	442.99	**ft.**
VFOV	1.66	3.32	6.64	16.61	33.22	83.06	166.12	332.24	**ft.**
IFOV	0.17	0.33	0.66	1.66	3.32	8.31	16.62	33.25	**in.**
Legend:									
D = Distance to target in meters & feet									
HFOV = Horizontal field of view in meters & feet									
VFOV = Vertical field of view in meters & feet									
IFOV = Instantaneous field of view (size of one detector element) in millimeters & inches									

Figure 14.22 Horizontal, vertical and instantaneous fields of view for certain distances to targets. **D** = distance to target. 4.5 mm IR lens. Applies to camera type 247 only.

Figure 14.23 F-number and close focus limits for various lenses

IR lens →	**36 mm**	**17 mm**	**9.2 mm**
Close focus limit (m)	0.70	0.30	0.01
Close focus limit (ft.)	2.30	0.98	0.03
f-number	1.2	1.2	1.2

14

14.11 Camera – dimensional drawings

10384503;a4

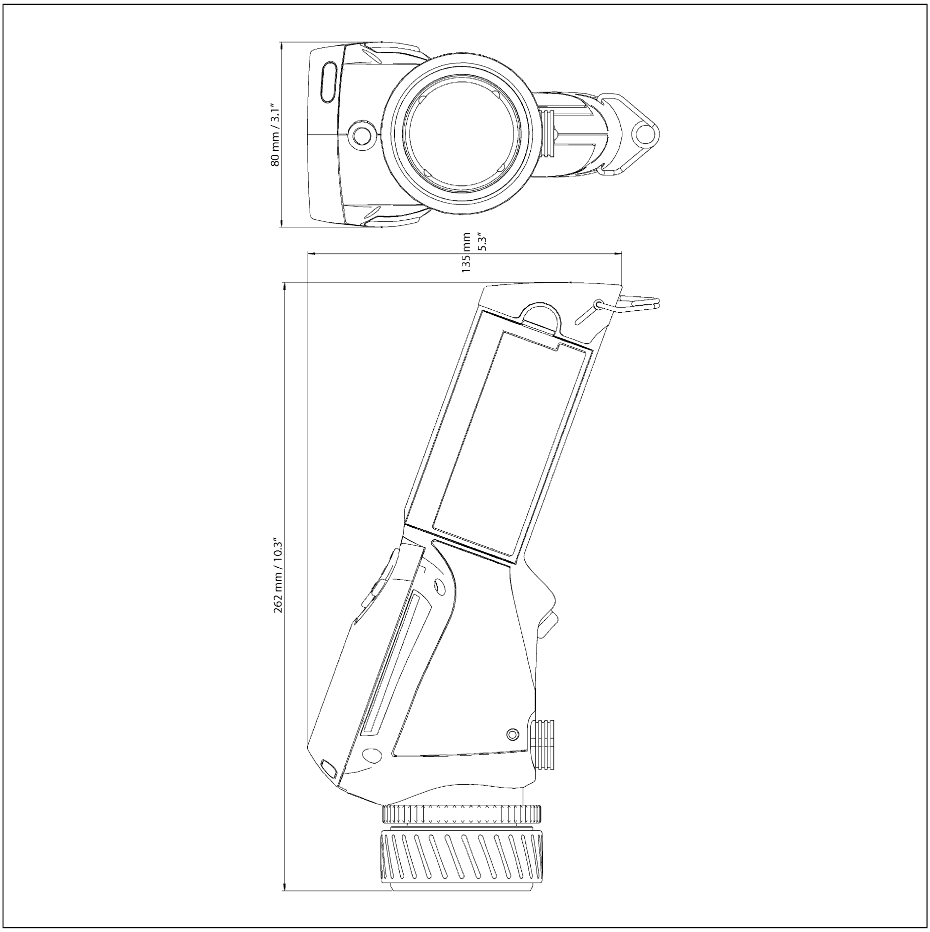

Figure 14.24 Overall dimensions of the camera with a 36 mm IR lens.

10384603;a4

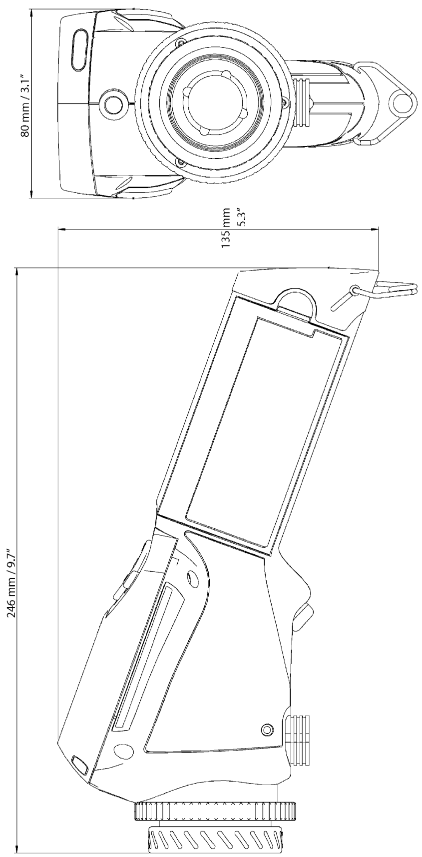

Figure 14.25 Overall dimensions of the camera with a 17 mm IR lens.

10384703;a4

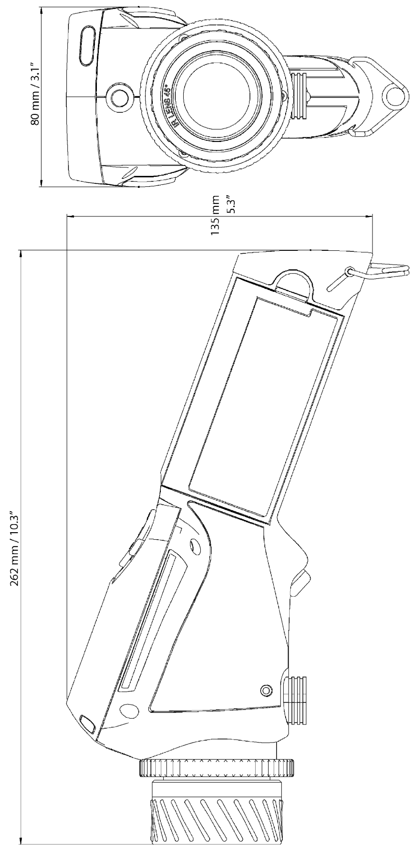

Figure 14.26 Overall dimensions of the camera with a 9.2 mm IR lens.

14.12 Battery charger – dimensional drawing

➲ External battery charger is an extra option.

10387403;a4

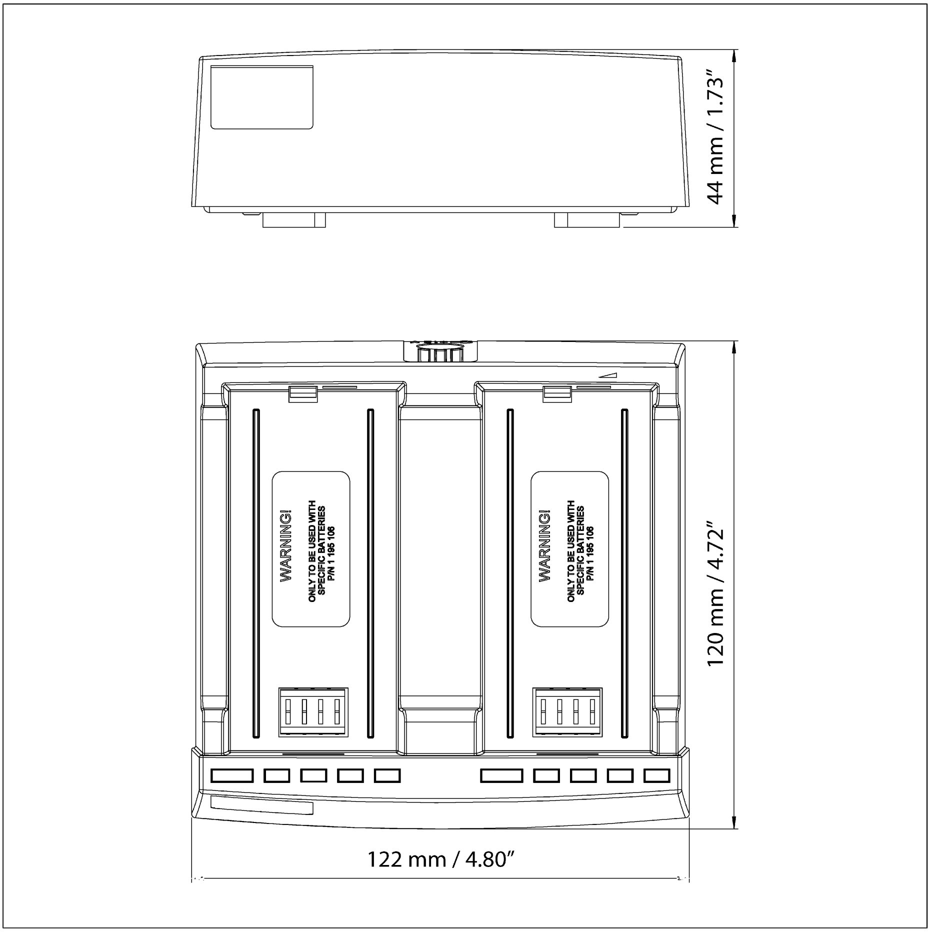

Figure 14.27 Overall dimensions of the battery charger

14.13 Battery – dimensional drawing

10387503;a4

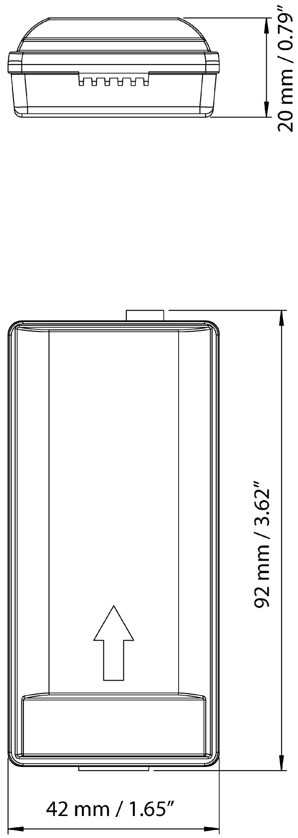

Figure 14.28 Overall dimensions of the battery

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15 Glossary

Term or expression	Explanation
absorption (absorption factor)	The amount of radiation absorbed by an object relative to the received radiation. A number between 0 and 1.
ambient	Objects and gases that emit radiation towards the object being measured.
atmosphere	The gases between the object being measured and the camera, normally air.
autoadjust	A function making a camera perform an internal image correction.
autopalette	The IR image is shown with an uneven spread of colors, displaying cold objects as well as hot ones at the same time.
blackbody	Totally non-reflective object. All its radiation is due to its own temperature.
blackbody radiator	An IR radiating equipment with blackbody properties used to calibrate IR cameras.
calculated atmospheric transmission	A transmission value computed from the temperature, the relative humidity of air and the distance to the object.
cavity radiator	A bottle shaped radiator with an absorbing inside, viewed through the bottleneck.
color temperature	The temperature for which the color of a blackbody matches a specific color.
conduction	The process that makes heat spread into a material.
continuous adjust	A function that adjusts the image. The function works all the time, continuously adjusting brightness and contrast according to the image content.
convection	The process that makes hot air or liquid rise.
difference temperature	A value which is the result of a subtraction between two temperature values.
dual isotherm	An isotherm with two color bands, instead of one.

Term or expression	Explanation
emissivity (emissivity factor)	The amount of radiation coming from an object, compared to that of a blackbody. A number between 0 and 1.
emittance	Amount of energy emitted from an object per unit of time and area (W/m^2)
estimated atmospheric transmission	A transmission value, supplied by a user, replacing a calculated one
external optics	Extra lenses, filters, heat shields etc. that can be put between the camera and the object being measured.
filter	A material transparent only to some of the infrared wavelengths.
FOV	Field of view: The horizontal angle that can be viewed through an IR lens.
FPA	Focal plane array: A type of IR detector.
graybody	An object that emits a fixed fraction of the amount of energy of a blackbody for each wavelength.
IFOV	Instantaneous field of view: A measure of the geometrical resolution of an IR camera.
image correction (internal or external)	A way of compensating for sensitivity differences in various parts of live images and also of stabilizing the camera.
infrared	Non-visible radiation, having a wavelength from about 2–13 μm.
IR	infrared
isotherm	A function highlighting those parts of an image that fall above, below or between one or more temperature intervals.
isothermal cavity	A bottle-shaped radiator with a uniform temperature viewed through the bottleneck.
Laser LocatIR	An electrically powered light source on the camera that emits laser radiation in a thin, concentrated beam to point at certain parts of the object in front of the camera.
laser pointer	An electrically powered light source on the camera that emits laser radiation in a thin, concentrated beam to point at certain parts of the object in front of the camera.

Term or expression	Explanation
level	The center value of the temperature scale, usually expressed as a signal value.
manual adjust	A way to adjust the image by manually changing certain parameters.
NETD	Noise equivalent temperature difference. A measure of the image noise level of an IR camera.
noise	Undesired small disturbance in the infrared image
object parameters	A set of values describing the circumstances under which the measurement of an object was made, and the object itself. (such as emissivity, ambient temperature, distance etc.)
object signal	A non-calibrated value related to the amount of radiation received by the camera from the object.
palette	The set of colors used to display an IR image.
pixel	Stands for *picture element*. One single spot in an image.
radiance	Amount of energy emitted from an object per unit of time, area and angle ($W/m^2/sr$)
radiant power	Amount of energy emitted from an object per unit of time (W)
radiation	The process by which electromagnetic energy is emitted by an object or a gas.
radiator	A piece of IR radiating equipment.
range	The current overall temperature measurement limitation of an IR camera. Cameras can have several ranges. Expressed as two blackbody temperatures that limit the current calibration.
reference temperature	A temperature which the ordinary measured values can be compared with.
reflection	The amount of radiation reflected by an object relative to the received radiation. A number between 0 and 1.
relative humidity	Percentage of water in the air, relative to what is physically possible. Air temperature dependent.

Term or expression	Explanation
saturation color	The areas that contain temperatures outside the present level/span settings are colored with the saturation colors. The saturation colors contain an ‘overflow’ color and an ‘underflow’ color. There is also a third red saturation color that marks everything saturated by the detector indicating that the range should probably be changed.
span	The interval of the temperature scale, usually expressed as a signal value.
spectral (radiant) emittance	Amount of energy emitted from an object per unit of time, area and wavelength ($W/m^2/\mu m$)
temperature range	The current overall temperature measurement limitation of an IR camera. Cameras can have several ranges. Expressed as two blackbody temperatures that limit the current calibration.
temperature scale	The way in which an IR image currently is displayed. Expressed as two temperature values limiting the colors.
thermogram	infrared image
transmission (or transmittance) (factor)	Gases and materials can be more or less transparent. Transmission is the amount of IR radiation passing through them. A number between 0 and 1.
transparent isotherm	An isotherm showing a linear spread of colors, instead of covering the highlighted parts of the image.

16 Thermographic measurement techniques

16.1 Introduction

An infrared camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature.

However, the radiation measured by the camera does not only depend on the temperature of the object but is also a function of the emissivity. Radiation also originates from the surroundings and is reflected in the object. The radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere.

To measure temperature accurately, it is therefore necessary to compensate for the effects of a number of different radiation sources. This is done on-line automatically by the camera. The following object parameters must, however, be supplied for the camera:

- The emissivity of the object
- The reflected apparent temperature
- The distance between the object and the camera
- The relative humidity
- Temperature of the atmosphere

16.2 Emissivity

The most important object parameter to set correctly is the emissivity which, in short, is a measure of how much radiation is emitted from the object, compared to that from a perfect blackbody of the same temperature.

Normally, object materials and surface treatments exhibit emissivity ranging from approximately 0.1 to 0.95. A highly polished (mirror) surface falls below 0.1, while an oxidized or painted surface has a higher emissivity. Oil-based paint, regardless of color in the visible spectrum, has an emissivity over 0.9 in the infrared. Human skin exhibits an emissivity 0.97 to 0.98.

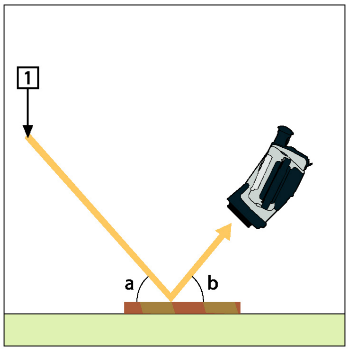
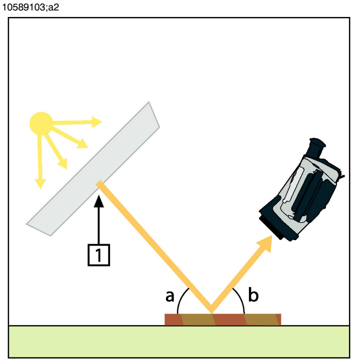
Non-oxidized metals represent an extreme case of perfect opacity and high reflexivity, which does not vary greatly with wavelength. Consequently, the emissivity of metals is low – only increasing with temperature. For non-metals, emissivity tends to be high, and decreases with temperature.

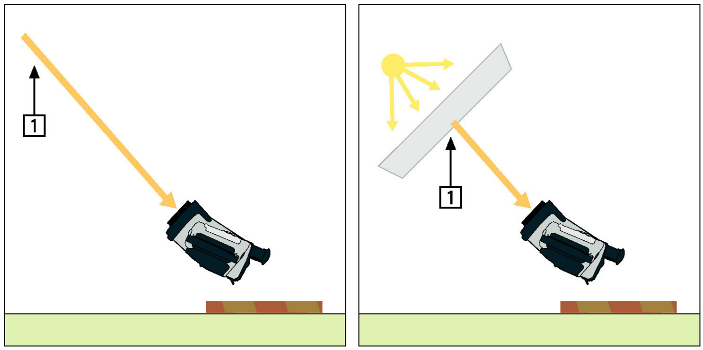
16.2.1 Finding the emissivity of a sample

16.2.1.1 *Step 1: Determining reflected apparent temperature*

Use one of the following two methods to determine reflected apparent temperature:

16.2.1.1.1 *Method 1: Direct method*

Step	Action
1	Look for possible reflection sources, considering that the incident angle = reflection angle (a = b). 10588903;a1  **Figure 16.1** 1 = Reflection source
2	If the reflection source is a spot source, modify the source by obstructing it using a piece if cardboard. 10589103;a2  **Figure 16.2** 1 = Reflection source

Step	Action
3	Measure the radiation intensity (= apparent temperature) from the reflecting source using the following settings: ■ Emissivity: 1.0 ■ D_{obj}: 0 You can measure the radiation intensity using one of the following two methods: 10589003;a2  **Figure 16.3** 1 = Reflection source

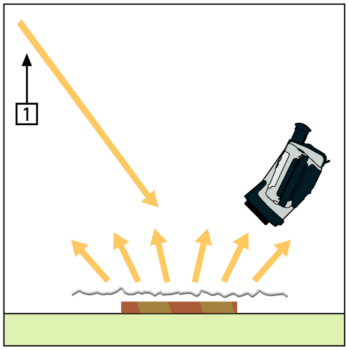
➲ Please note the following:

Using a thermocouple to measure reflecting temperature is not recommended for two important reasons:

- A thermocouple does not measure radiation intensity
- A thermocouple requires a very good thermal contact to the surface, usually by gluing and covering the sensor by a thermal isolator.

16.2.1.1.2 Method 2: Reflector method

Step	Action
1	Crumble up a large piece of aluminum foil.
2	Uncrumble the aluminum foil and attach it to a piece of cardboard of the same size.
3	Put the piece of cardboard in front of the object you want to measure. Make sure that the side with aluminum foil points to the camera.
4	Set the emissivity to 1.0.

Step	Action
5	Measure the apparent temperature of the aluminum foil and write it down. 10727003;a2  **Figure 16.4** Measuring the apparent temperature of the aluminum foil

16.2.1.2 *Step 2: Determining the emissivity*

Step	Action
1	Select a place to put the sample.
2	Determine and set reflected apparent temperature according to the previous procedure.
3	Put a piece of electrical tape with known high emissivity on the sample.
4	Heat the sample at least 20 K above room temperature. Heating must be reasonably even.
5	Focus and auto-adjust the camera, and freeze the image.
6	Adjust **Level** and **Span** for best image brightness and contrast.
7	Set emissivity to that of the tape (usually 0.97).
8	Measure the temperature of the tape using one of the following measurement functions: ■ **Isotherm** (helps you to determine both the temperature and how evenly you have heated the sample) ■ **Spot** (simpler) ■ **Box Avg** (good for surfaces with varying emissivity).
9	Write down the temperature.
10	Move your measurement function to the sample surface.
11	Change the emissivity setting until you read the same temperature as your previous measurement.

Step	Action
12	Write down the emissivity.

➲ Please note the following:

- Avoid forced convection
- Look for a thermally stable surrounding that will not generate spot reflections
- Use high quality tape that you know is not transparent, and has a high emissivity you are certain of
- This method assumes that the temperature of your tape and the sample surface are the same. If they are not, your emissivity measurement will be wrong.

16.3 Reflected apparent temperature

This parameter is used to compensate for the radiation reflected in the object. If the emissivity is low and the object temperature relatively far from that of the reflected it will be important to set and compensate for the reflected apparent temperature correctly.

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17 History of infrared technology

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Less than 200 years ago the existence of the infrared portion of the electromagnetic spectrum wasn't even suspected. The original significance of the infrared spectrum, or simply 'the infrared' as it is often called, as a form of heat radiation is perhaps less obvious today than it was at the time of its discovery by Herschel in 1800.

10398703;a1

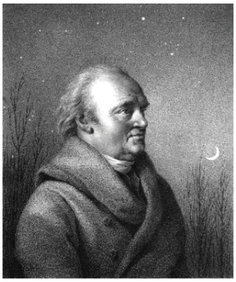

Figure 17.1 Sir William Herschel (1738–1822)

The discovery was made accidentally during the search for a new optical material. Sir William Herschel—Royal Astronomer to King George III of England, and already famous for his discovery of the planet Uranus—was searching for an optical filter material to reduce the brightness of the sun's image in telescopes during solar observations. While testing different samples of colored glass which gave similar reductions in brightness he was intrigued to find that some of the samples passed very little of the sun's heat, while others passed so much heat that he risked eye damage after only a few seconds' observation.

Herschel was soon convinced of the necessity of setting up a systematic experiment, with the objective of finding a single material that would give the desired reduction in brightness as well as the maximum reduction in heat. He began the experiment by actually repeating Newton's prism experiment, but looking for the heating effect rather than the visual distribution of intensity in the spectrum. He first blackened the bulb of a sensitive mercury-in-glass thermometer with ink, and with this as his radiation detector he proceeded to test the heating effect of the various colors of the spectrum formed on the top of a table by passing sunlight through a glass prism. Other thermometers, placed outside the sun's rays, served as controls.

As the blackened thermometer was moved slowly along the colors of the spectrum, the temperature readings showed a steady increase from the violet end to the red end. This was not entirely unexpected, since the Italian researcher, Landriani, in a similar experiment in 1777 had observed much the same effect. It was Herschel, however, who was the first to recognize that there must be a point where the heating effect reaches a maximum, and that measurements confined to the visible portion of the spectrum failed to locate this point.

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Figure 17.2 Marsilio Landriani (1746–1815)

Moving the thermometer into the dark region beyond the red end of the spectrum, Herschel confirmed that the heating continued to increase. The maximum point, when he found it, lay well beyond the red end—in what is known today as the 'infrared wavelengths.'

When Herschel revealed his discovery, he referred to this new portion of the electromagnetic spectrum as the 'thermometrical spectrum.' The radiation itself he sometimes referred to as 'dark heat,' or simply 'the invisible rays,' Ironically, and contrary to popular opinion, it wasn't Herschel who originated the term 'infrared.' The word only began to appear in print around 75 years later, and it is still unclear who should receive credit as the originator.

Herschel's use of glass in the prism of his original experiment led to some early controversies with his contemporaries about the actual existence of the infrared wavelengths. Different investigators, in attempting to confirm his work, used various types of glass indiscriminately, having different transparencies in the infrared. Through his later experiments, Herschel was aware of the limited transparency of glass to the newly-discovered thermal radiation, and he was forced to conclude that optics for the infrared would probably be doomed to the use of reflective elements exclusively (i.e. plane and curved mirrors). Fortunately, this proved to be true only until 1830, when the Italian investigator, Melloni, made his great discovery that naturally occurring rock salt ($NaCl$)—which was available in large enough natural crystals to be made into lenses and prisms—is remarkably transparent to the infrared. The result was that rock salt became the principal infrared optical material, and remained so for the next hundred years, until the art of synthetic crystal growing was mastered in the 1930's.

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Figure 17.3 Macedonio Melloni (1798–1854)

Thermometers, as radiation detectors, remained unchallenged until 1829, the year Nobili invented the thermocouple. (Herschel's own thermometer could be read to 0.2°C (0.036°F), and later models were able to be read to 0.05°C (0.09°F). Then a breakthrough occurred; Melloni connected a number of thermocouples in series to form the first thermopile. The new device was at least 40 times as sensitive as the best thermometer of the day for detecting heat radiation—capable of detecting the heat from a person standing 3 meters away (10 ft.).

The first so-called 'heat-picture' became possible in 1840, the result of work by Sir John Herschel, son of the discoverer of the infrared and a famous astronomer in his own right. Based upon the differential evaporation of a thin film of oil when exposed to a heat pattern focused upon it, the thermal image could be seen by reflected light where the interference effects of the oil film made the image visible to the eye. Sir John also managed to obtain a primitive record of the thermal image on paper, which he called a 'thermograph.'

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Figure 17.4 Samuel P. Langley (1834–1906)

The improvement of infrared-detector sensitivity progressed slowly. Another major breakthrough, made by Langley in 1880, was the invention of the bolometer. This consisted of a thin blackened strip of platinum connected in one arm of a Wheatstone bridge circuit upon which the infrared radiation was focused and to which a sensitive galvanometer responded. This instrument is said to have been able to detect the heat from a cow at a distance of 400 meters (1311 ft.).

An English scientist, Sir James Dewar, first introduced the use of liquefied gases as cooling agents (such as liquid nitrogen with a temperature of −196°C (−320.8°F)) in low temperature research. In 1892 he invented a unique vacuum insulating container in which it is possible to store liquefied gases for entire days. The common 'thermos bottle', used for storing hot and cold drinks, is based upon his invention.

Between the years 1900 and 1920, the inventors of the world 'discovered' the infrared. Many patents were issued for devices to detect personnel, artillery, aircraft, ships—and even icebergs. The first operating systems, in the modern sense, began to be developed during the 1914–18 war, when both sides had research programs devoted to the military exploitation of the infrared. These programs included experimental systems for enemy intrusion/detection, remote temperature sensing, secure communications, and 'flying torpedo' guidance. An infrared search system tested during this period was able to detect an approaching airplane at a distance of 1.5 km (0.94 miles), or a person more than 300 meters (984 ft.) away.

The most sensitive systems up to this time were all based upon variations of the bolometer idea, but the period between the two wars saw the development of two revolutionary new infrared detectors: the image converter and the photon detector. At first, the image converter received the greatest attention by the military, because it enabled an observer for the first time in history to literally 'see in the dark.' However, the sensitivity of the image converter was limited to the near infrared wavelengths, and the most interesting military targets (i.e. enemy soldiers) had to be illuminated by infrared search beams. Since this involved the risk of giving away the observer's position to a similarly-equipped enemy observer, it is understandable that military interest in the image converter eventually faded.

The tactical military disadvantages of so-called 'active' (i.e. search beam-equipped) thermal imaging systems provided impetus following the 1939–45 war for extensive secret military infrared-research programs into the possibilities of developing 'passive' (no search beam) systems around the extremely sensitive photon detector. During this period, military secrecy regulations completely prevented disclosure of the status of infrared-imaging technology. This secrecy only began to be lifted in the middle of the 1950's, and from that time adequate thermal-imaging devices finally began to be available to civilian science and industry.

18 Theory of thermography

18.1 *Introduction*

The subjects of infrared radiation and the related technique of thermography are still new to many who will use an infrared camera. In this section the theory behind thermography will be given.

18.2 *The electromagnetic spectrum*

The electromagnetic spectrum is divided arbitrarily into a number of wavelength regions, called *bands*, distinguished by the methods used to produce and detect the radiation. There is no fundamental difference between radiation in the different bands of the electromagnetic spectrum. They are all governed by the same laws and the only differences are those due to differences in wavelength.

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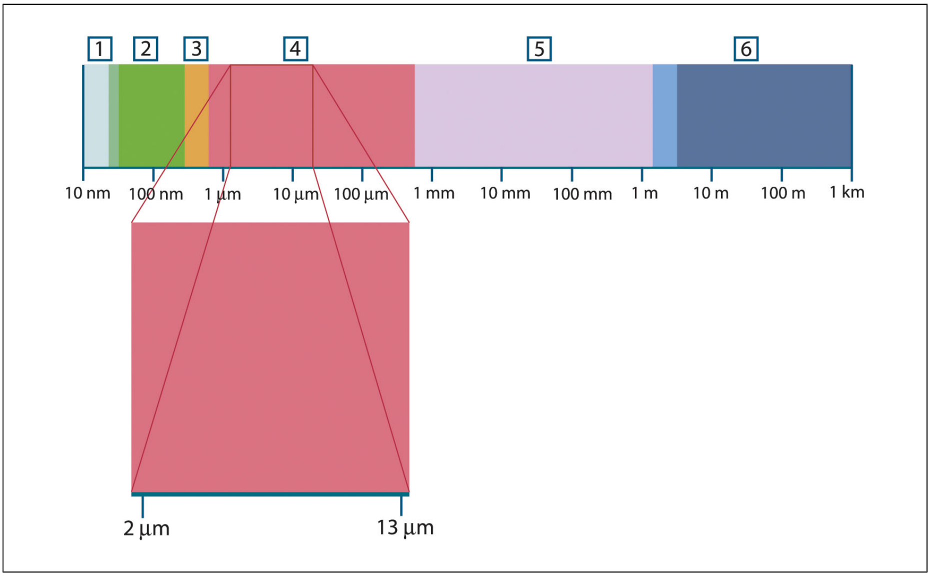

Figure 18.1 The electromagnetic spectrum. **1:** X-ray; **2:** UV; **3:** Visible; **4:** IR; **5:** Microwaves; **6:** Radiowaves.

Thermography makes use of the infrared spectral band. At the short-wavelength end the boundary lies at the limit of visual perception, in the deep red. At the long-wavelength end it merges with the microwave radio wavelengths, in the millimeter range.

The infrared band is often further subdivided into four smaller bands, the boundaries of which are also arbitrarily chosen. They include: the *near infrared* (0.75–3 µm), the *middle infrared* (3–6 µm), the *far infrared* (6–15 µm) and the *extreme infrared* (15–100 µm). Although the wavelengths are given in µm (micrometers), other units are often still used to measure wavelength in this spectral region, *e.g.* nanometer (nm) and Ångström (Å).

The relationships between the different wavelength measurements is:

$$10\ 000\ \text{Å} = 1\ 000\ \text{nm} = 1\ \mu = 1\ \mu\text{m}$$

18.3 Blackbody radiation

A blackbody is defined as an object which absorbs all radiation that impinges on it at any wavelength. The apparent misnomer *black* relating to an object emitting radiation is explained by Kirchhoff's Law (after *Gustav Robert Kirchhoff*, 1824–1887), which states that a body capable of absorbing all radiation at any wavelength is equally capable in the emission of radiation.

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Figure 18.2 Gustav Robert Kirchhoff (1824–1887)

The construction of a blackbody source is, in principle, very simple. The radiation characteristics of an aperture in an isotherm cavity made of an opaque absorbing material represents almost exactly the properties of a blackbody. A practical application of the principle to the construction of a perfect absorber of radiation consists of a box that is light tight except for an aperture in one of the sides. Any radiation which then enters the hole is scattered and absorbed by repeated reflections so only an infinitesimal fraction can possibly escape. The blackness which is obtained at the aperture is nearly equal to a blackbody and almost perfect for all wavelengths.

By providing such an isothermal cavity with a suitable heater it becomes what is termed a *cavity radiator*. An isothermal cavity heated to a uniform temperature generates blackbody radiation, the characteristics of which are determined solely by the temperature of the cavity. Such cavity radiators are commonly used as sources of radiation in temperature reference standards in the laboratory for calibrating thermographic instruments, such as a FLIR Systems camera for example.

If the temperature of blackbody radiation increases to more than 525 °C (977 °F), the source begins to be visible so that it appears to the eye no longer black. This is the incipient red heat temperature of the radiator, which then becomes orange or yellow as the temperature increases further. In fact, the definition of the so-called *color temperature* of an object is the temperature to which a blackbody would have to be heated to have the same appearance.

Now consider three expressions that describe the radiation emitted from a blackbody.

18.3.1 Planck's law

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Figure 18.3 Max Planck (1858–1947)

Max Planck (1858–1947) was able to describe the spectral distribution of the radiation from a blackbody by means of the following formula:

$$W_{\lambda b} = \frac{2\pi hc^3}{\lambda^5 \left(e^{hc/\lambda kT} - 1\right)} \times 10^{-6} \left[Watt/m^2 \mu m\right]$$

where:

$W_{\lambda b}$	Blackbody spectral radiant emittance at wavelength λ.
c	Velocity of light = 3×10^8 m/s
h	Planck's constant = 6.6×10^{-34} Joule sec.
k	Boltzmann's constant = 1.4×10^{-23} Joule/K.
T	Absolute temperature (K) of a blackbody.
λ	Wavelength (μm).

➲ The factor 10^{-6} is used since spectral emittance in the curves is expressed in Watt/m^2m. If the factor is excluded, the dimension will be Watt/m^2μm.

Planck's formula, when plotted graphically for various temperatures, produces a family of curves. Following any particular Planck curve, the spectral emittance is zero at $\lambda = 0$, then increases rapidly to a maximum at a wavelength λ_{max} and after passing it approaches zero again at very long wavelengths. The higher the temperature, the shorter the wavelength at which maximum occurs.

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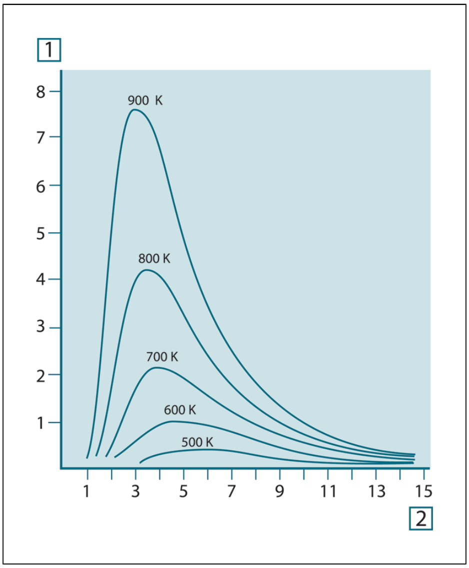

Figure 18.4 Blackbody spectral radiant emittance according to Planck's law, plotted for various absolute temperatures. **1:** Spectral radiant emittance (W/cm^2 × 10^3(μm)); **2:** Wavelength (μm)

18.3.2 Wien's displacement law

By differentiating Planck's formula with respect to λ, and finding the maximum, we have:

$$\lambda_{max} = \frac{2898}{T} [\mu m]$$

This is Wien's formula (after *Wilhelm Wien*, 1864–1928), which expresses mathematically the common observation that colors vary from red to orange or yellow as the temperature of a thermal radiator increases. The wavelength of the color is the same as the wavelength calculated for λ_{max}. A good approximation of the value of λ_{max} for a given blackbody temperature is obtained by applying the rule-of-thumb 3 000/T μm. Thus, a very hot star such as Sirius (11 000 K), emitting bluish-white light, radiates with the peak of spectral radiant emittance occurring within the invisible ultraviolet spectrum, at wavelength 0.27 μm.

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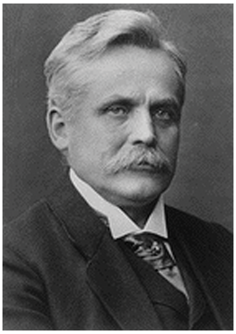

Figure 18.5 Wilhelm Wien (1864–1928)

The sun (approx. 6 000 K) emits yellow light, peaking at about 0.5 µm in the middle of the visible light spectrum.

At room temperature (300 K) the peak of radiant emittance lies at 9.7 µm, in the far infrared, while at the temperature of liquid nitrogen (77 K) the maximum of the almost insignificant amount of radiant emittance occurs at 38 µm, in the extreme infrared wavelengths.

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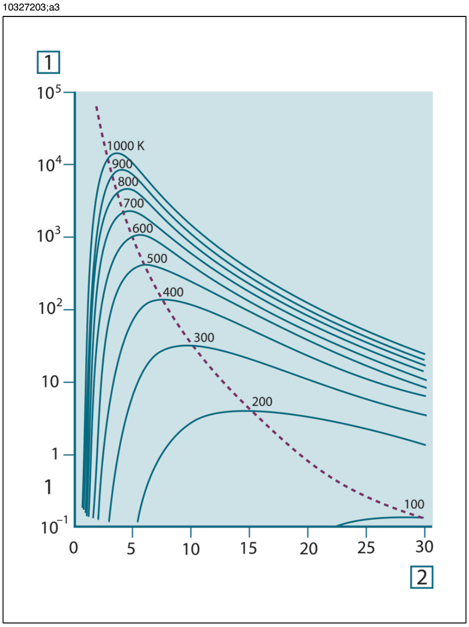

Figure 18.6 Planckian curves plotted on semi-log scales from 100 K to 1000 K. The dotted line represents the locus of maximum radiant emittance at each temperature as described by Wien's displacement law. **1:** Spectral radiant emittance (W/cm² (µm)); **2:** Wavelength (µm).

18.3.3 Stefan-Boltzmann's law

By integrating Planck's formula from λ = 0 to λ = ∞, we obtain the total radiant emittance (W_b) of a blackbody:

$$W_b = \sigma T^4 \ [\mathrm{Watt/m^2}]$$

This is the Stefan-Boltzmann formula (after *Josef Stefan*, 1835–1893, and *Ludwig Boltzmann*, 1844–1906), which states that the total emissive power of a blackbody is proportional to the fourth power of its absolute temperature. Graphically, W_b represents the area below the Planck curve for a particular temperature. It can be shown that the radiant emittance in the interval λ = 0 to λ_{max} is only 25 % of the total, which represents about the amount of the sun's radiation which lies inside the visible light spectrum.

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Figure 18.7 Josef Stefan (1835–1893), and Ludwig Boltzmann (1844–1906)

Using the Stefan-Boltzmann formula to calculate the power radiated by the human body, at a temperature of 300 K and an external surface area of approx. 2 m^2, we obtain 1 kW. This power loss could not be sustained if it were not for the compensating absorption of radiation from surrounding surfaces, at room temperatures which do not vary too drastically from the temperature of the body – or, of course, the addition of clothing.

18.3.4 Non-blackbody emitters

So far, only blackbody radiators and blackbody radiation have been discussed. However, real objects almost never comply with these laws over an extended wavelength region – although they may approach the blackbody behavior in certain spectral intervals. For example, a certain type of white paint may appear perfectly *white* in the visible light spectrum, but becomes distinctly *gray* at about 2 µm, and beyond 3 µm it is almost *black*.

There are three processes which can occur that prevent a real object from acting like a blackbody: a fraction of the incident radiation α may be absorbed, a fraction ρ may be reflected, and a fraction τ may be transmitted. Since all of these factors are more or less wavelength dependent, the subscript λ is used to imply the spectral dependence of their definitions. Thus:

- The spectral absorptance α_λ= the ratio of the spectral radiant power absorbed by an object to that incident upon it.
- The spectral reflectance ρ_λ = the ratio of the spectral radiant power reflected by an object to that incident upon it.
- The spectral transmittance τ_λ = the ratio of the spectral radiant power transmitted through an object to that incident upon it.

The sum of these three factors must always add up to the whole at any wavelength, so we have the relation:

$$\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1$$

For opaque materials $\tau_\lambda = 0$ and the relation simplifies to:

$$\alpha_\lambda + \rho_\lambda = 1$$

Another factor, called the emissivity, is required to describe the fraction ε of the radiant emittance of a blackbody produced by an object at a specific temperature. Thus, we have the definition:

The spectral emissivity ε_λ= the ratio of the spectral radiant power from an object to that from a blackbody at the same temperature and wavelength.

Expressed mathematically, this can be written as the ratio of the spectral emittance of the object to that of a blackbody as follows:

$$\varepsilon_\lambda = \frac{W_{\lambda o}}{W_{\lambda b}}$$

Generally speaking, there are three types of radiation source, distinguished by the ways in which the spectral emittance of each varies with wavelength.

- A blackbody, for which $\varepsilon_\lambda = \varepsilon = 1$
- A graybody, for which $\varepsilon_\lambda = \varepsilon$ = constant less than 1
- A selective radiator, for which ε varies with wavelength

According to Kirchhoff's law, for any material the spectral emissivity and spectral absorptance of a body are equal at any specified temperature and wavelength. That is:

$$\varepsilon_\lambda = \alpha_\lambda$$

From this we obtain, for an opaque material (since $\alpha_\lambda + \rho_\lambda = 1$):

$$\varepsilon_\lambda + \rho_\lambda = 1$$

For highly polished materials ε_λ approaches zero, so that for a perfectly reflecting material (*i.e.* a perfect mirror) we have:

$$\rho_\lambda = 1$$

For a graybody radiator, the Stefan-Boltzmann formula becomes:

$$W = \varepsilon\sigma T^4 \ [\mathrm{Watt/m^2}]$$

This states that the total emissive power of a graybody is the same as a blackbody at the same temperature reduced in proportion to the value of ε from the graybody.

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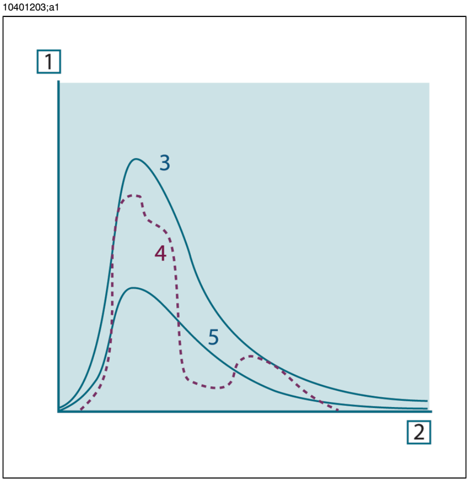

Figure 18.8 Spectral radiant emittance of three types of radiators. **1:** Spectral radiant emittance; **2:** Wavelength; **3:** Blackbody; **4:** Selective radiator; **5:** Graybody.

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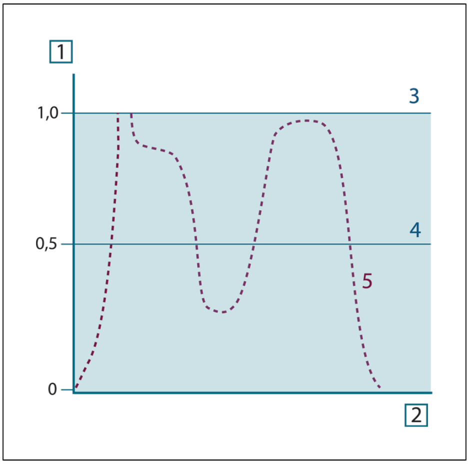

Figure 18.9 Spectral emissivity of three types of radiators. **1:** Spectral emissivity; **2:** Wavelength; **3:** Blackbody; **4:** Graybody; **5:** Selective radiator.

18.4 Infrared semi-transparent materials

Consider now a non-metallic, semi-transparent body – let us say, in the form of a thick flat plate of plastic material. When the plate is heated, radiation generated within its volume must work its way toward the surfaces through the material in which it is partially absorbed. Moreover, when it arrives at the surface, some of it is reflected back into the interior. The back-reflected radiation is again partially absorbed, but some of it arrives at the other surface, through which most of it escapes; part of it is reflected back again. Although the progressive reflections become weaker and weaker they must all be added up when the total emittance of the plate is sought. When the resulting geometrical series is summed, the effective emissivity of a semi-transparent plate is obtained as:

$$\varepsilon_\lambda = \frac{(1-\rho_\lambda)(1-\tau_\lambda)}{1-\rho_\lambda\tau_\lambda}$$

When the plate becomes opaque this formula is reduced to the single formula:

$$\varepsilon_\lambda = 1-\rho_\lambda$$

This last relation is a particularly convenient one, because it is often easier to measure reflectance than to measure emissivity directly.

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19 Emissivity tables

This section presents a compilation of emissivity data from the infrared literature and measurements made by FLIR Systems.

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19.2 Important note about the emissivity tables

The emissivity values in the table below are recorded using a shortwave (SW) camera. The values should be regarded as recommendations only and used by caution.

19.3 Tables

Figure 19.1 **T:** Total spectrum; **SW:** 2–5 µm; **LW:** 8–14 µm, **LLW:** 6.5–20 µm; **1:** Material; **2:** Specification; **3:** Temperature in °C; **4:** Spectrum; **5:** Emissivity: **6:** Reference

1	2	3	4	5	6
Aluminum	anodized, black, dull	70	LW	0.95	9
Aluminum	anodized, black, dull	70	SW	0.67	9

1	2	3	4	5	6
Aluminum	anodized, light gray, dull	70	LW	0.97	9
Aluminum	anodized, light gray, dull	70	SW	0.61	9
Aluminum	anodized sheet	100	T	0.55	2
Aluminum	as received, plate	100	T	0.09	4
Aluminum	as received, sheet	100	T	0.09	2
Aluminum	cast, blast cleaned	70	LW	0.46	9
Aluminum	cast, blast cleaned	70	SW	0.47	9
Aluminum	dipped in HNO_3, plate	100	T	0.05	4
Aluminum	foil	27	3 μm	0.09	3
Aluminum	foil	27	10 μm	0.04	3
Aluminum	oxidized, strongly	50–500	T	0.2–0.3	1
Aluminum	polished	50–100	T	0.04–0.06	1
Aluminum	polished, sheet	100	T	0.05	2
Aluminum	polished plate	100	T	0.05	4
Aluminum	roughened	27	3 μm	0.28	3
Aluminum	roughened	27	10 μm	0.18	3
Aluminum	rough surface	20–50	T	0.06–0.07	1
Aluminum	sheet, 4 samples differently scratched	70	LW	0.03–0.06	9
Aluminum	sheet, 4 samples differently scratched	70	SW	0.05–0.08	9
Aluminum	vacuum deposited	20	T	0.04	2
Aluminum	weathered, heavily	17	SW	0.83–0.94	5
Aluminum bronze		20	T	0.60	1
Aluminum hydroxide	powder		T	0.28	1
Aluminum oxide	activated, powder		T	0.46	1

1	2	3	4	5	6
Aluminum oxide	pure, powder (alumina)		T	0.16	1
Asbestos	board	20	T	0.96	1
Asbestos	fabric		T	0.78	1
Asbestos	floor tile	35	SW	0.94	7
Asbestos	paper	40–400	T	0.93–0.95	1
Asbestos	powder		T	0.40–0.60	1
Asbestos	slate	20	T	0.96	1
Asphalt paving		4	LLW	0.967	8
Brass	dull, tarnished	20–350	T	0.22	1
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	polished, highly	100	T	0.03	2
Brass	rubbed with 80-grit emery	20	T	0.20	2
Brass	sheet, rolled	20	T	0.06	1
Brass	sheet, worked with emery	20	T	0.2	1
Brick	alumina	17	SW	0.68	5
Brick	common	17	SW	0.86–0.81	5
Brick	Dinas silica, glazed, rough	1100	T	0.85	1
Brick	Dinas silica, refractory	1000	T	0.66	1
Brick	Dinas silica, unglazed, rough	1000	T	0.80	1
Brick	firebrick	17	SW	0.68	5
Brick	fireclay	20	T	0.85	1

1	2	3	4	5	6
Brick	fireclay	1000	T	0.75	1
Brick	fireclay	1200	T	0.59	1
Brick	masonry	35	SW	0.94	7
Brick	masonry, plastered	20	T	0.94	1
Brick	red, common	20	T	0.93	2
Brick	red, rough	20	T	0.88–0.93	1
Brick	refractory, corundum	1000	T	0.46	1
Brick	refractory, magnesite	1000–1300	T	0.38	1
Brick	refractory, strongly radiating	500–1000	T	0.8–0.9	1
Brick	refractory, weakly radiating	500–1000	T	0.65–0.75	1
Brick	silica, 95 % SiO_2	1230	T	0.66	1
Brick	sillimanite, 33 % SiO_2, 64 % Al_2O_3	1500	T	0.29	1
Brick	waterproof	17	SW	0.87	5
Bronze	phosphor bronze	70	LW	0.06	9
Bronze	phosphor bronze	70	SW	0.08	9
Bronze	polished	50	T	0.1	1
Bronze	porous, rough	50–150	T	0.55	1
Bronze	powder		T	0.76–0.80	1
Carbon	candle soot	20	T	0.95	2
Carbon	charcoal powder		T	0.96	1
Carbon	graphite, filed surface	20	T	0.98	2
Carbon	graphite powder		T	0.97	1
Carbon	lampblack	20–400	T	0.95–0.97	1
Chipboard	untreated	20	SW	0.90	6

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1	2	3	4	5	6
Chromium	polished	50	T	0.10	1
Chromium	polished	500–1000	T	0.28–0.38	1
Clay	fired	70	T	0.91	1
Cloth	black	20	T	0.98	1
Concrete		20	T	0.92	2
Concrete	dry	36	SW	0.95	7
Concrete	rough	17	SW	0.97	5
Concrete	walkway	5	LLW	0.974	8
Copper	commercial, burnished	20	T	0.07	1
Copper	electrolytic, carefully polished	80	T	0.018	1
Copper	electrolytic, polished	–34	T	0.006	4
Copper	molten	1100–1300	T	0.13–0.15	1
Copper	oxidized	50	T	0.6–0.7	1
Copper	oxidized, black	27	T	0.78	4
Copper	oxidized, heavily	20	T	0.78	2
Copper	oxidized to blackness		T	0.88	1
Copper	polished	50–100	T	0.02	1
Copper	polished	100	T	0.03	2
Copper	polished, commercial	27	T	0.03	4
Copper	polished, mechanical	22	T	0.015	4
Copper	pure, carefully prepared surface	22	T	0.008	4
Copper	scraped	27	T	0.07	4
Copper dioxide	powder		T	0.84	1
Copper oxide	red, powder		T	0.70	1

19

1	2	3	4	5	6
Ebonite			T	0.89	1
Emery	coarse	80	T	0.85	1
Enamel		20	T	0.9	1
Enamel	lacquer	20	T	0.85–0.95	1
Fiber board	hard, untreated	20	SW	0.85	6
Fiber board	masonite	70	LW	0.88	9
Fiber board	masonite	70	SW	0.75	9
Fiber board	particle board	70	LW	0.89	9
Fiber board	particle board	70	SW	0.77	9
Fiber board	porous, untreated	20	SW	0.85	6
Gold	polished	130	T	0.018	1
Gold	polished, carefully	200–600	T	0.02–0.03	1
Gold	polished, highly	100	T	0.02	2
Granite	polished	20	LLW	0.849	8
Granite	rough	21	LLW	0.879	8
Granite	rough, 4 different samples	70	LW	0.77–0.87	9
Granite	rough, 4 different samples	70	SW	0.95–0.97	9
Gypsum		20	T	0.8–0.9	1
Ice: See Water					
Iron, cast	casting	50	T	0.81	1
Iron, cast	ingots	1000	T	0.95	1
Iron, cast	liquid	1300	T	0.28	1
Iron, cast	machined	800–1000	T	0.60–0.70	1
Iron, cast	oxidized	38	T	0.63	4
Iron, cast	oxidized	100	T	0.64	2
Iron, cast	oxidized	260	T	0.66	4
Iron, cast	oxidized	538	T	0.76	4

1	2	3	4	5	6
Iron, cast	oxidized at 600 °C	200–600	T	0.64–0.78	1
Iron, cast	polished	38	T	0.21	4
Iron, cast	polished	40	T	0.21	2
Iron, cast	polished	200	T	0.21	1
Iron, cast	unworked	900–1100	T	0.87–0.95	1
Iron and steel	cold rolled	70	LW	0.09	9
Iron and steel	cold rolled	70	SW	0.20	9
Iron and steel	covered with red rust	20	T	0.61–0.85	1
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, careful-ly polished	175–225	T	0.05–0.06	1
Iron and steel	freshly worked with emery	20	T	0.24	1
Iron and steel	ground sheet	950–1100	T	0.55–0.61	1
Iron and steel	heavily rusted sheet	20	T	0.69	2
Iron and steel	hot rolled	20	T	0.77	1
Iron and steel	hot rolled	130	T	0.60	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	1227	T	0.89	4
Iron and steel	oxidized	200–600	T	0.80	1
Iron and steel	oxidized strongly	50	T	0.88	1
Iron and steel	oxidized strongly	500	T	0.98	1
Iron and steel	polished	100	T	0.07	2

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1	2	3	4	5	6
Iron and steel	polished	400–1000	T	0.14–0.38	1
Iron and steel	polished sheet	750–1050	T	0.52–0.56	1
Iron and steel	rolled, freshly	20	T	0.24	1
Iron and steel	rolled sheet	50	T	0.56	1
Iron and steel	rough, plane surface	50	T	0.95–0.98	1
Iron and steel	rusted, heavily	17	SW	0.96	5
Iron and steel	rusted red, sheet	22	T	0.69	4
Iron and steel	rusty, red	20	T	0.69	1
Iron and steel	shiny, etched	150	T	0.16	1
Iron and steel	shiny oxide layer, sheet,	20	T	0.82	1
Iron and steel	wrought, carefully polished	40–250	T	0.28	1
Iron galvanized	heavily oxidized	70	LW	0.85	9
Iron galvanized	heavily oxidized	70	SW	0.64	9
Iron galvanized	sheet	92	T	0.07	4
Iron galvanized	sheet, burnished	30	T	0.23	1
Iron galvanized	sheet, oxidized	20	T	0.28	1
Iron tinned	sheet	24	T	0.064	4
Lacquer	3 colors sprayed on Aluminum	70	LW	0.92–0.94	9
Lacquer	3 colors sprayed on Aluminum	70	SW	0.50–0.53	9
Lacquer	Aluminum on rough surface	20	T	0.4	1
Lacquer	bakelite	80	T	0.83	1
Lacquer	black, dull	40–100	T	0.96–0.98	1
Lacquer	black, matte	100	T	0.97	2
Lacquer	black, shiny, sprayed on iron	20	T	0.87	1

1	2	3	4	5	6
Lacquer	heat–resistant	100	T	0.92	1
Lacquer	white	40–100	T	0.8–0.95	1
Lacquer	white	100	T	0.92	2
Lead	oxidized, gray	20	T	0.28	1
Lead	oxidized, gray	22	T	0.28	4
Lead	oxidized at 200 °C	200	T	0.63	1
Lead	shiny	250	T	0.08	1
Lead	unoxidized, polished	100	T	0.05	4
Lead red		100	T	0.93	4
Lead red, powder		100	T	0.93	1
Leather	tanned		T	0.75–0.80	1
Lime			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
Magnesium powder			T	0.86	1
Molybdenum		600–1000	T	0.08–0.13	1
Molybdenum		1500–2200	T	0.19–0.26	1
Molybdenum	filament	700–2500	T	0.1–0.3	1
Mortar		17	SW	0.87	5
Mortar	dry	36	SW	0.94	7
Nichrome	rolled	700	T	0.25	1
Nichrome	sandblasted	700	T	0.70	1
Nichrome	wire, clean	50	T	0.65	1
Nichrome	wire, clean	500–1000	T	0.71–0.79	1
Nichrome	wire, oxidized	50–500	T	0.95–0.98	1

1	2	3	4	5	6
Nickel	bright matte	122	T	0.041	4
Nickel	commercially pure, polished	100	T	0.045	1
Nickel	commercially pure, polished	200–400	T	0.07–0.09	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	0.10	4
Nickel	electroplated, polished	20	T	0.05	2
Nickel	electroplated on iron, polished	22	T	0.045	4
Nickel	electroplated on iron, unpolished	20	T	0.11–0.40	1
Nickel	electroplated on iron, unpolished	22	T	0.11	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	wire	200–1000	T	0.1–0.2	1
Nickel oxide		500–650	T	0.52–0.59	1
Nickel oxide		1000–1250	T	0.75–0.86	1
Oil, lubricating	0.025 mm film	20	T	0.27	2
Oil, lubricating	0.050 mm film	20	T	0.46	2
Oil, lubricating	0.125 mm film	20	T	0.72	2
Oil, lubricating	film on Ni base: Ni base only	20	T	0.05	2
Oil, lubricating	thick coating	20	T	0.82	2

1	2	3	4	5	6
Paint	8 different colors and qualities	70	LW	0.92–0.94	9
Paint	8 different colors and qualities	70	SW	0.88–0.96	9
Paint	Aluminum, various ages	50–100	T	0.27–0.67	1
Paint	cadmium yellow		T	0.28–0.33	1
Paint	chrome green		T	0.65–0.70	1
Paint	cobalt blue		T	0.7–0.8	1
Paint	oil	17	SW	0.87	5
Paint	oil, black flat	20	SW	0.94	6
Paint	oil, black gloss	20	SW	0.92	6
Paint	oil, gray flat	20	SW	0.97	6
Paint	oil, gray gloss	20	SW	0.96	6
Paint	oil, various colors	100	T	0.92–0.96	1
Paint	oil based, average of 16 colors	100	T	0.94	2
Paint	plastic, black	20	SW	0.95	6
Paint	plastic, white	20	SW	0.84	6
Paper	4 different colors	70	LW	0.92–0.94	9
Paper	4 different colors	70	SW	0.68–0.74	9
Paper	black		T	0.90	1
Paper	black, dull		T	0.94	1
Paper	black, dull	70	LW	0.89	9
Paper	black, dull	70	SW	0.86	9
Paper	blue, dark		T	0.84	1
Paper	coated with black lacquer		T	0.93	1
Paper	green		T	0.85	1
Paper	red		T	0.76	1
Paper	white	20	T	0.7–0.9	1

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1	2	3	4	5	6
Paper	white, 3 different glosses	70	LW	0.88–0.90	9
Paper	white, 3 different glosses	70	SW	0.76–0.78	9
Paper	white bond	20	T	0.93	2
Paper	yellow		T	0.72	1
Plaster		17	SW	0.86	5
Plaster	plasterboard, untreated	20	SW	0.90	6
Plaster	rough coat	20	T	0.91	2
Plastic	glass fibre laminate (printed circ. board)	70	LW	0.91	9
Plastic	glass fibre laminate (printed circ. board)	70	SW	0.94	9
Plastic	polyurethane isolation board	70	LW	0.55	9
Plastic	polyurethane isolation board	70	SW	0.29	9
Plastic	PVC, plastic floor, dull, structured	70	LW	0.93	9
Plastic	PVC, plastic floor, dull, structured	70	SW	0.94	9
Platinum		17	T	0.016	4
Platinum		22	T	0.03	4
Platinum		100	T	0.05	4
Platinum		260	T	0.06	4
Platinum		538	T	0.10	4
Platinum		1000–1500	T	0.14–0.18	1
Platinum		1094	T	0.18	4
Platinum	pure, polished	200–600	T	0.05–0.10	1
Platinum	ribbon	900–1100	T	0.12–0.17	1

1	2	3	4	5	6
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
Porcelain	glazed	20	T	0.92	1
Porcelain	white, shiny		T	0.70–0.75	1
Rubber	hard	20	T	0.95	1
Rubber	soft, gray, rough	20	T	0.95	1
Sand			T	0.60	1
Sand		20	T	0.90	2
Sandstone	polished	19	LLW	0.909	8
Sandstone	rough	19	LLW	0.935	8
Silver	polished	100	T	0.03	2
Silver	pure, polished	200–600	T	0.02–0.03	1
Skin	human	32	T	0.98	2
Slag	boiler	0–100	T	0.97–0.93	1
Slag	boiler	200–500	T	0.89–0.78	1
Slag	boiler	600–1200	T	0.76–0.70	1
Slag	boiler	1400–1800	T	0.69–0.67	1
Snow: See Water					
Soil	dry	20	T	0.92	2
Soil	saturated with water	20	T	0.95	2
Stainless steel	alloy, 8 % Ni, 18 % Cr	500	T	0.35	1
Stainless steel	rolled	700	T	0.45	1
Stainless steel	sandblasted	700	T	0.70	1
Stainless steel	sheet, polished	70	LW	0.14	9
Stainless steel	sheet, polished	70	SW	0.18	9

1	2	3	4	5	6
Stainless steel	sheet, untreated, somewhat scratched	70	LW	0.28	9
Stainless steel	sheet, untreated, somewhat scratched	70	SW	0.30	9
Stainless steel	type 18-8, buffed	20	T	0.16	2
Stainless steel	type 18-8, oxi-dized at 800 °C	60	T	0.85	2
Stucco	rough, lime	10–90	T	0.91	1
Styrofoam	insulation	37	SW	0.60	7
Tar			T	0.79–0.84	1
Tar	paper	20	T	0.91–0.93	1
Tile	glazed	17	SW	0.94	5
Tin	burnished	20–50	T	0.04–0.06	1
Tin	tin–plated sheet iron	100	T	0.07	2
Titanium	oxidized at 540 °C	200	T	0.40	1
Titanium	oxidized at 540 °C	500	T	0.50	1
Titanium	oxidized at 540 °C	1000	T	0.60	1
Titanium	polished	200	T	0.15	1
Titanium	polished	500	T	0.20	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	filament	3300	T	0.39	1
Varnish	flat	20	SW	0.93	6
Varnish	on oak parquet floor	70	LW	0.90–0.93	9
Varnish	on oak parquet floor	70	SW	0.90	9

1	2	3	4	5	6
Wallpaper	slight pattern, light gray	20	SW	0.85	6
Wallpaper	slight pattern, red	20	SW	0.90	6
Water	distilled	20	T	0.96	2
Water	frost crystals	–10	T	0.98	2
Water	ice, covered with heavy frost	0	T	0.98	1
Water	ice, smooth	–10	T	0.96	2
Water	ice, smooth	0	T	0.97	1
Water	layer >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	ground		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	planed	20	T	0.8–0.9	1
Wood	planed oak	20	T	0.90	2
Wood	planed oak	70	LW	0.88	9
Wood	planed oak	70	SW	0.77	9
Wood	plywood, smooth, dry	36	SW	0.82	7
Wood	plywood, untreat-ed	20	SW	0.83	6
Wood	white, damp	20	T	0.7–0.8	1
Zinc	oxidized at 400 °C	400	T	0.11	1
Zinc	oxidized surface	1000–1200	T	0.50–0.60	1

1	2	3	4	5	6
Zinc	polished	200–300	T	0.04–0.05	1
Zinc	sheet	50	T	0.20	1

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A note on the technical production of this manual

This manual was produced using XML – eXtensible Markup Language. For more information about XML, point your browser to: http://www.w3.org/XML/

Readers interested in the history & theory of markup languages may also want to visit the following sites:

- http://www.gla.ac.uk/staff/strategy/information/socarcpj/
- http://www.renater.fr/Video/2002ATHENS/P/DC/History/plan.htm

A note on the typeface used in this manual

This manual was typeset using Swiss 721, which is Bitstream's pan-European version of Max Miedinger's Helvetica™ typeface. Max Miedinger was born December 24th, 1910 in Zürich, Switzerland and died March 8th, 1980 in Zürich, Switzerland.

10595503;a1

- 1926–30: Trains as a typesetter in Zürich, after which he attends evening classes at the Kunstgewerbeschule in Zürich.
- 1936–46: Typographer for Globus department store's advertising studio in Zürich.
- 1947–56: Customer counselor and typeface sales representative for the Haas'sche Schriftgießerei in Münchenstein near Basel. From 1956 onwards: freelance graphic artist in Zürich.
- 1956: Eduard Hoffmann, the director of the Haas'sche Schriftgießerei, commissions Miedinger to develop a new sans-serif typeface.
- 1957: The Haas-Grotesk face is introduced.
- 1958: Introduction of the roman (or normal) version of Haas-Grotesk.
- 1959: Introduction of a bold Haas-Grotesk.
- 1960: The typeface changes its name from Neue Haas Grotesk to Helvetica™.
- 1983: Linotype publishes its Neue Helvetica™, based on the earlier Helvetica™.

For more information about Max Miedinger, his typeface and its influences, please visit http://www.rit.edu/~rlv5703/imm/project2/index.html

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20234403.xml a32
20234603.xml a20
20234703.xml a34
20234803.xml a21
20234903.xml a11
20235003.xml a34
20235103.xml a17
20235203.xml a18
20235303.xml a13
20236403.xml b9
20236703.xml a32
20236903.xml a10
20237003.xml a8
20237403.xml a11
20237603.xml a22
20248603.xml b12
20254903.xml a25
20255203.xml a4
20273203.xml a8
20273903.xml a2
20275203.xml a3
R0054.rcp a13
config.xml a4

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