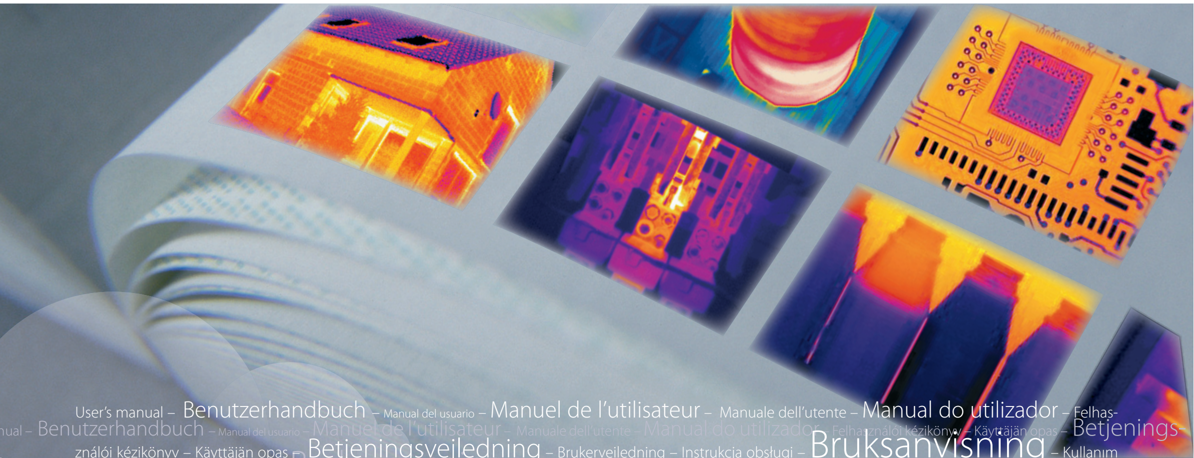
ThermaCAM™ BX320



User's manual

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

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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
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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
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Japan	Application	2000-620406
Japan	Application	2002-588123
Japan	Application	2002-588070
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Japan	Design Patent	1182246
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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

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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™ BX320 infrared camera – the industry-standard tool for carrying out building thermography inspections!

The ThermaCAM™ BX320 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.

10380703;a2

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

10570303;a2

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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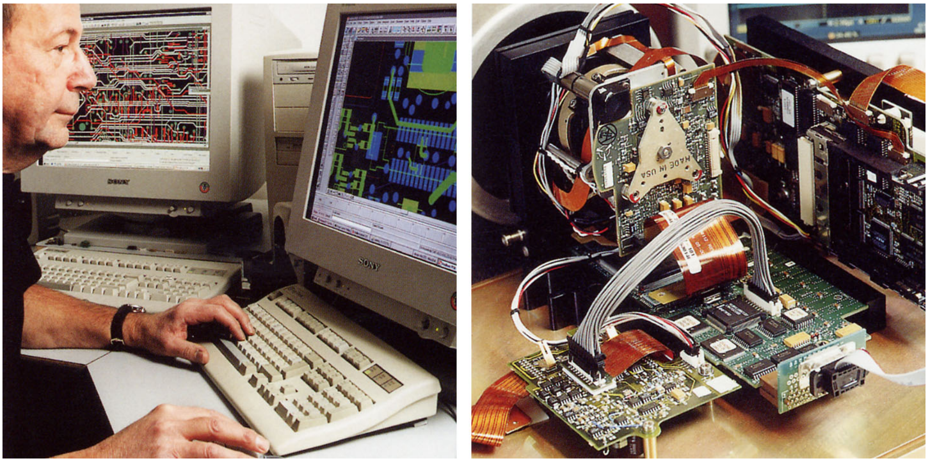

Figure 3.4 **LEFT:** Development of system electronics; **RIGHT:** Testing of an FPA detector

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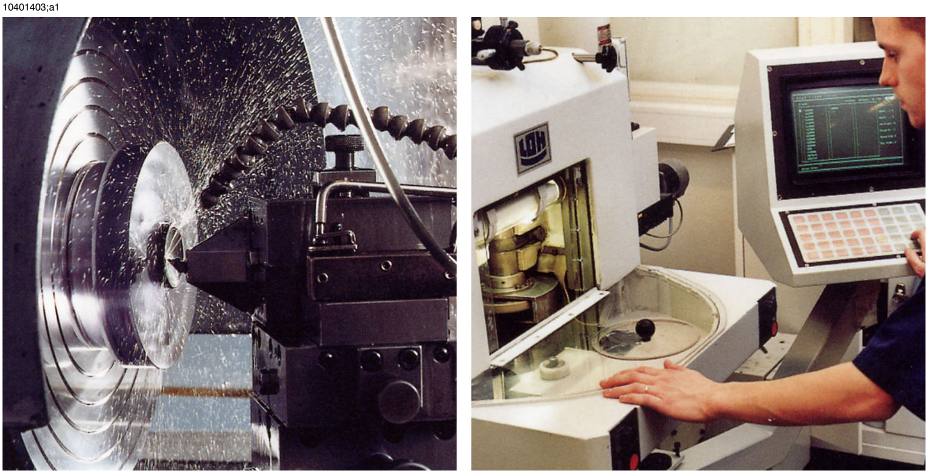

Figure 3.5 **LEFT:** Diamond turning machine; **RIGHT:** Lens polishing

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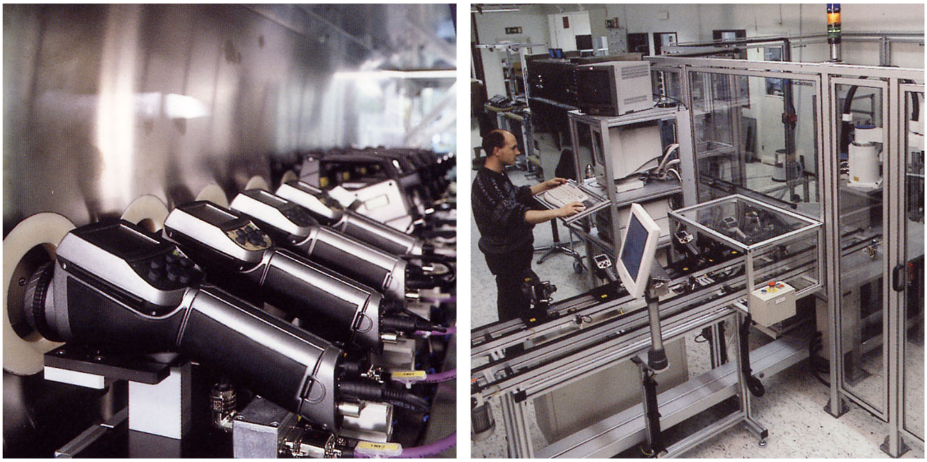

Figure 3.6 LEFT: Testing of IR cameras in the climatic chamber; **RIGHT:** Robot for camera testing and calibration

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™ BX320 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	2
Battery charger	1 195 102	1
Hand strap	1 195 221	1
Lens cap for camera body	1 120 987	1
Operator's manual	1558440	1
Power supply	1 909 528	1
ThermaCAM™ BX320 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™ BX320.

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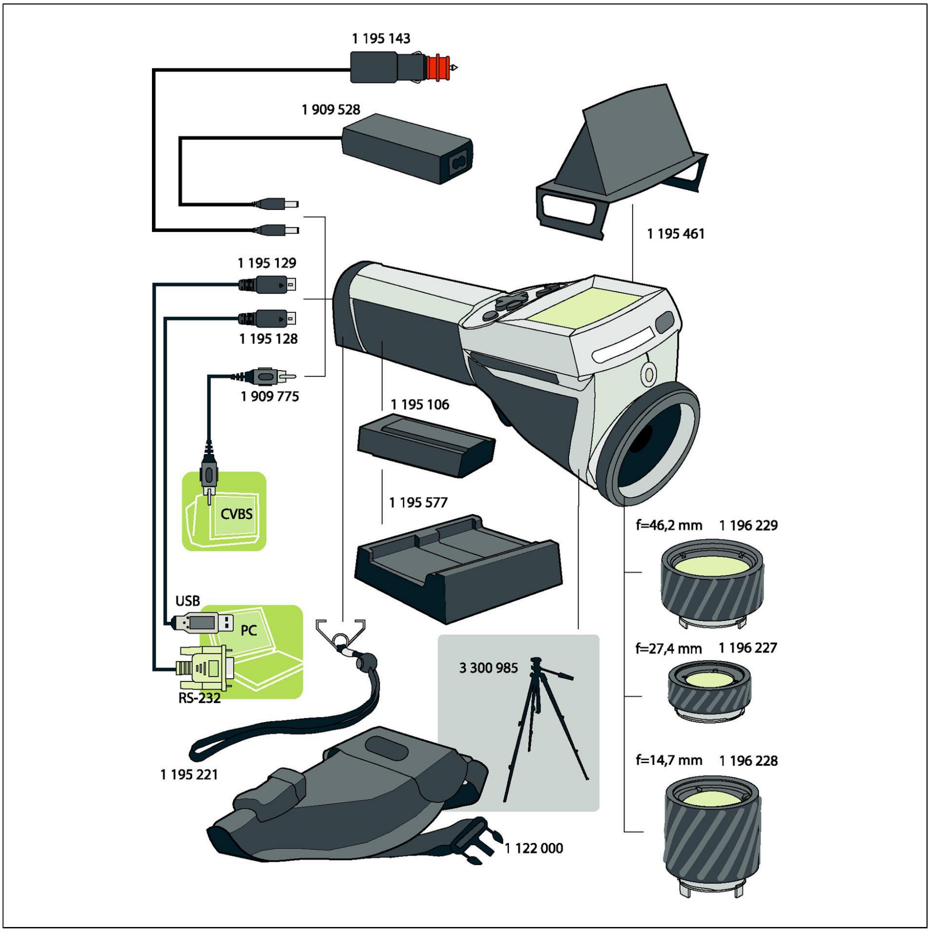

Figure 5.1 System overview

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6 Connecting system components

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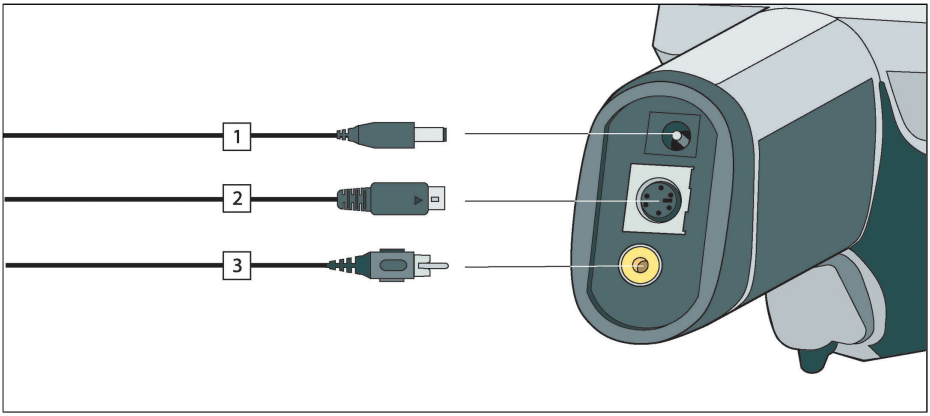

Figure 6.1 How to connect system components

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 building thermography

7.1 *Important note*

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

7.2 *Typical field investigations*

7.2.1 Guidelines

As will be noted in subsequent sections there are a number of general guidelines the user should take heed of when carrying out building thermography inspection. This section gives a summary of these guidelines.

7.2.1.1 *General guidelines*

- The emissivity of the majority of building materials fall between 0.85 and 0.95. Setting the emissivity value in the camera to 0.90 can be regarded as a good starting point.
- An infrared inspection alone should never be used as a decision point for further actions. Always verify suspicions and findings using other methods, such as construction drawings, moisture meters, humidity & temperature datalogging, tracer gas testing etc.
- Change level and span to thermally tune the infrared image and reveal more details. The figure below shows the difference between a thermally untuned and a thermally tuned infrared image.

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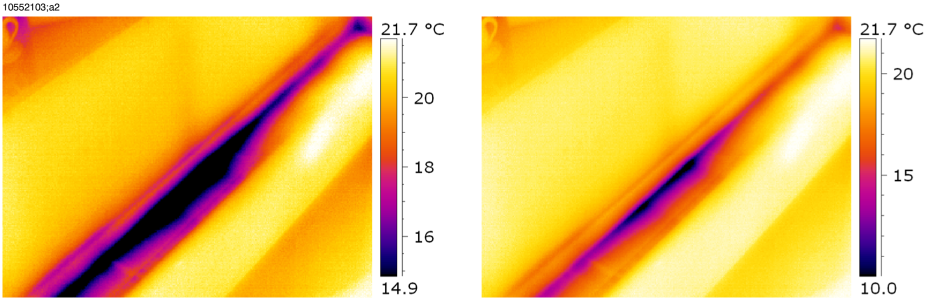

Figure 7.1 LEFT: A thermally untuned infrared image; **RIGHT:** A thermally tuned infrared image, after having changed level and span.

7.2.1.2 Guidelines for moisture detection, mold detection & detection of water damages

- Building defects related to moisture and water damages may only show up when heat has been applied to the surface, e.g. from the sun.
- The presence of water changes the thermal conductivity and the thermal mass of the building material. It may also change the surface temperature of building material due to evaporative cooling. Thermal conductivity is a material's ability to conduct heat, while thermal mass is its ability to store heat.
- Infrared inspection does not directly detect the presence of mold, rather it may be used to find moisture where mold may develop or has already developed. Mold requires temperatures between +4°C to +38°C (+40°F to +100°F), nutrients and moisture to grow. Humidity levels above 50% can provide sufficient moisture to enable mold to grow.

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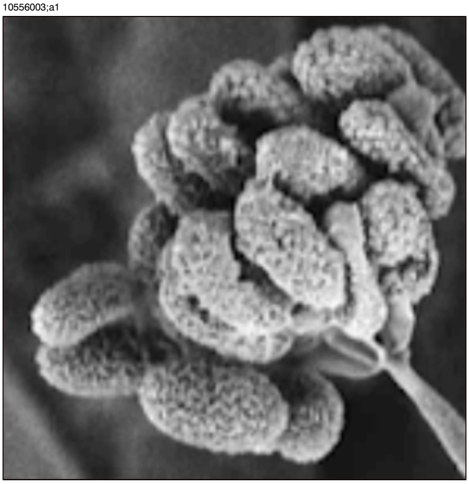


Figure 7.2 Microscopic view of mold spore

7.2.1.3 Guidelines for detection of air infiltration & insulation deficiencies

- For very accurate camera measurements, take measurements of the temperature and enter this value in the camera.
- It is recommended that there is a difference in pressure between the outside and the inside of the building structure. This facilitates the analysis of the infrared images and reveals deficiencies that would not be visible otherwise. Although a negative pressure of between 10 and 50 Pa is recommended, carrying out the inspection at a lower negative pressure may be acceptable. To do this, close all windows, doors and ventilation ducts and then run the kitchen exhaust fan for some time to reach a negative pressure of 5–10 Pa (applies to residential houses only).

- A difference in temperature between the inside and the outside of 10–15°C (18–27°F) is recommended. Inspections can be carried out at a lower temperature difference, but will make the analysis of the infrared images somewhat more difficult.
- Avoid direct sunlight on a part of a building structure—e.g. a façade—that is to be inspected from the inside. The sunlight will heat the façade which will equalize the temperature differences on the inside and mask deficiencies in the building structure. Spring seasons with low nighttime temperatures (±0°C (+32°F)) and high daytime temperatures (+14°C (+57°F)) are especially risky.

7.2.2 About moisture detection

Moisture in a building structure can originate from several different sources, e.g.:

- External leaks, such as floods, leaking fire hydrants etc.
- Internal leaks, such as freshwater piping, waste water piping etc.
- Condensation, which is humidity in the air falling out as liquid water due to condensation on cold surfaces.
- Building moisture, which is any moisture in the building material prior to erecting the building structure.
- Water remaining from firefighting.

As a non-destructive detection method, using an infrared camera has a number of advantages over other methods, and a few disadvantages:

Advantage	**Disadvantage**
▪ The method is quick. ▪ The method is a non-intrusive means of investigation. ▪ The method does not require relocation of the occupants. ▪ The method features an illustrative visual presentation of findings. ▪ The method confirms failure points and moisture migration paths.	▪ The method only detects surface temperature differentials and can not see through walls. ▪ The method can not detect subsurface damage, i.e. mold or structural damage.

7.2.3 Moisture detection (1): Low-slope commercial roofs

7.2.3.1 General information

Low-slope commercial roofing is one of the most common roof types for industrial building, such as warehouses, industrial plants, machinery shops etc. Its major advantages over a pitched roof is the lower cost in material and building. However, due to its design where snow and ice will not fall off by itself—as is the case for the majority of pitched roofs—it must be strongly built to support the accumulated weight of both roof structure and any snow, ice and rain.

Although a basic understanding of the construction of low-slope commercial roofs is desirable when carrying out a roof thermography inspection, expert knowledge is not necessary. There is a large number of different design principles for low-slope commercial roofs—both when it comes to material and design—and it would be impossible for the infrared inspection person to know them all. If additional information about a certain roof is needed, the architect or contractor of the building can usually supply the relevant information.

Common causes of roof failure are outlined in the table below (from SPIE Thermosense Proceedings Vol. 371 (1982), p. 177).

Cause	**%**
Poor workmanship	47.6
Roof traffic	2.6
Poor design	16.7
Trapped moisture	7.8
Materials	8.0
Age & weathering	8.4

Potential leak locations include the following:

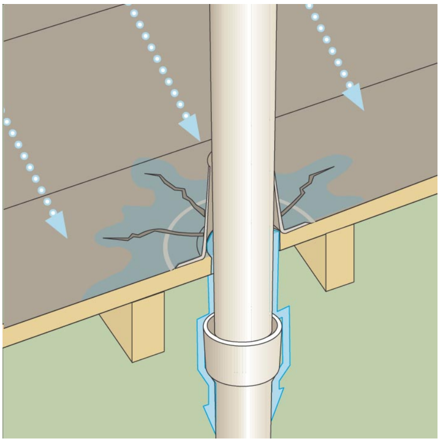
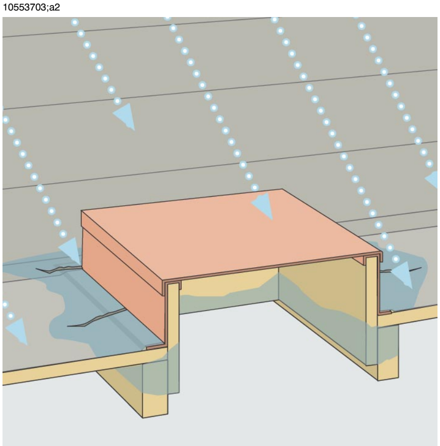
- Flashing
- Drains
- Penetrations
- Seams
- Blisters

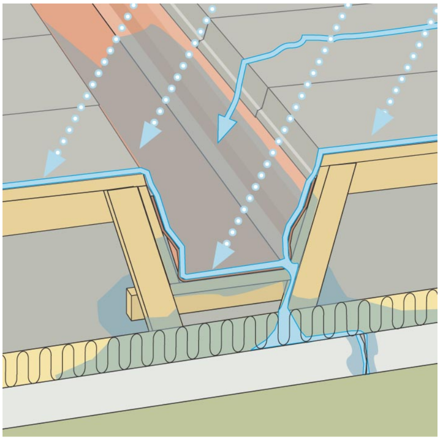
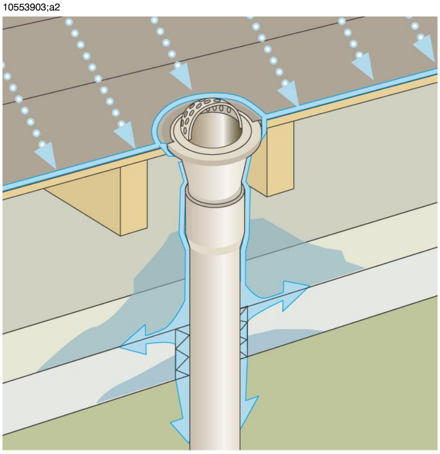
7.2.3.2 Safety precautions

- Recommend a minimum of two people on a roof, preferably three or more.
- Inspect the underside of the roof for structural integrity prior to walking on it.
- Avoid stepping on blisters that are common on built up bitumen and gravel roofs.
- Have a cell phone or radio available in case of emergency.
- Inform local police and plant security prior to doing nighttime roof survey.

7.2.3.3 *Commented building structures*

This section includes a few typical examples of moisture problems on low-slope commercial roofs.

Structural drawing	Comment
10553603;a2 	Inadequate sealing of roof membrane around conduit and ventilation ducts leading to local leakage around the conduit or duct.
10553703;a2 	Roof membrane inadequately sealed around roof access hatch.

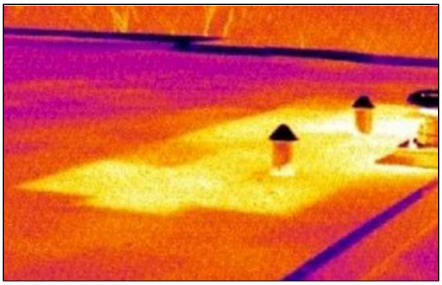
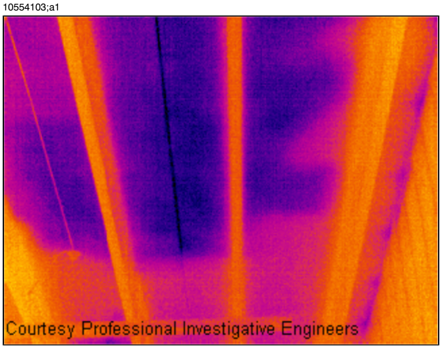
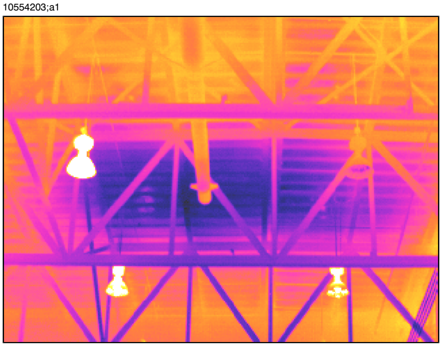
Structural drawing	Comment
10553803;a2 	Drainage channels located too high and with too low an inclination. Some water will remain in the drainage channel after rain, which may lead to local leakage around the channel.
10553903;a2 	Inadequate sealing between roof membrane and roof outlet leading to local leakage around the roof outlet.

7.2.3.4 *Commented infrared images*

How do you find wet insulation below the surface of the roof? When the surface itself is dry, including any gravel or ballast, a sunny day will warm the entire roof. Early in the evening, if the sky is clear, the roof will begin to cool down by radiation. Because of its higher thermal capacity the wet insulation will stay warmer longer than the dry and will be visible in the infrared imager (see photos below). The technique is particularly effective on roofs having absorbent insulation—such as wood fiber, fiberglass, and perlite—where thermal patterns correlate almost perfectly with moisture.

Infrared inspections of roofs with nonabsorbent insulations, common in many single-ply systems, are more difficult to diagnose because patterns are more diffuse.

This section includes a few typical infrared images of moisture problems on low-slope commercial roofs:

Infrared image	Comment
10554003;a1 	Moisture detection on a roof, recorded during the evening. Since the building material affected by moisture has a higher thermal mass, its temperature decreases slower than surrounding areas.
10554103;a1 	Water-damaged roofing components and insulation identified from infrared scan from the underside of the built-up roof on a structural concrete tee deck. Affected areas are cooler than the surrounding sound areas, due to conductive and/or thermal capacitive effect.
10554203;a1 	Daytime survey of built-up low-slope commercial roof. Affected areas are cooler than the surrounding dry areas, due to conductive and/or thermal capacitive effect.

7.2.4 Moisture detection (2): Commercial & residential façades

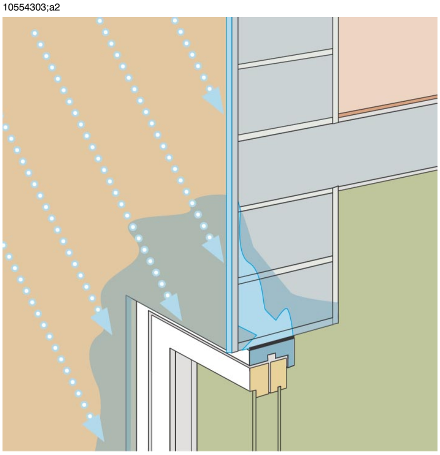
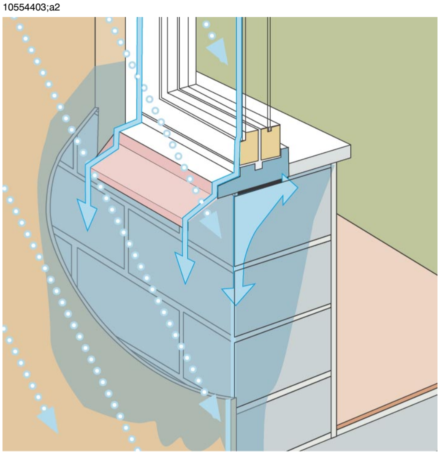
7.2.4.1 General information

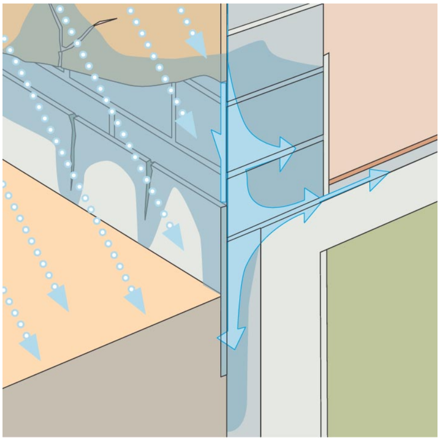
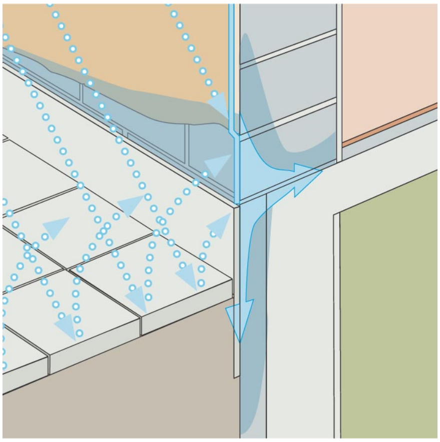
Thermography has proven to be invaluable in the assessment of moisture infiltration into commercial and residential façades. Being able to provide a physical illustration of the moisture migration paths is more conclusive than extrapolating moisture meter probe locations and more cost-effective than large intrusive test cuts.

7.2.4.2 Commented building structures

This section includes a few typical examples of moisture problems on commercial and residential façades.

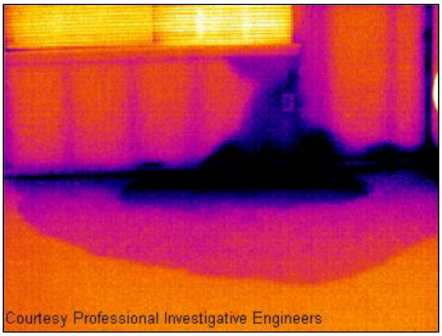
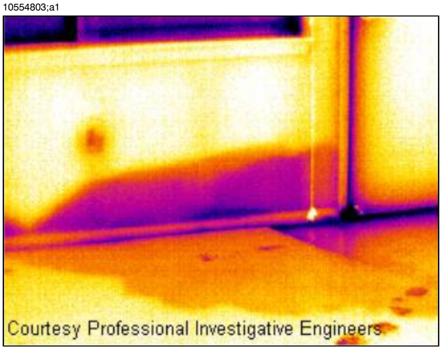
7

Structural drawing	**Comment**
10554303;a2 	Pelting rain penetrates the façade due to badly executed bed joints. Moisture builds up in the masonry above the window.
10554403;a2 	Pelting rain hits the window at an angle. Most of the rain runs off the window edge flashing but some finds its way into the masonry where the plaster meets the underside of the flashing.

<table>
<tr><th>Structural drawing</th><th>Comment</th></tr>
<tr><td>10554503;a2
</td><td>Rain hits the façade at an angle and penetrates the plaster through cracks. The water then follows the inside of the plaster and leads to frost erosion.</td></tr>
<tr><td>10554603;a2
</td><td>Rain splashes on the façade and penetrates the plaster and masonry by absorption, which eventually leads to frost erosion.</td></tr>
</table>

7.2.4.3 Commented infrared images

This section includes a few typical infrared images of moisture problems on commercial & residential façades.

Infrared image	**Comment**
10554703;a1 	Improperly terminated and sealed stone veneer to window frame and missing flashings has resulted in moisture infiltration into the wall cavity and interior living space.
10554803;a1 	Moisture migration into drywall from capillary drive and interior finish components from inadequate clearance and slope of grade from vinyl siding façade on an apartment complex.

7.2.5 Moisture detection (3): Decks & balconies

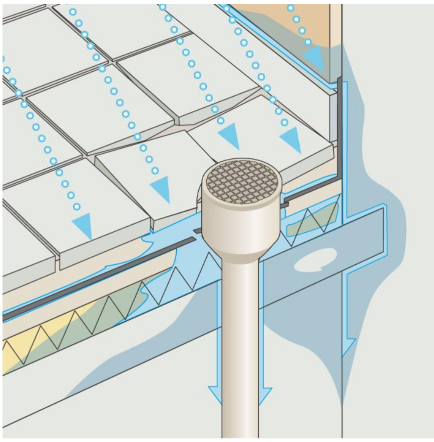
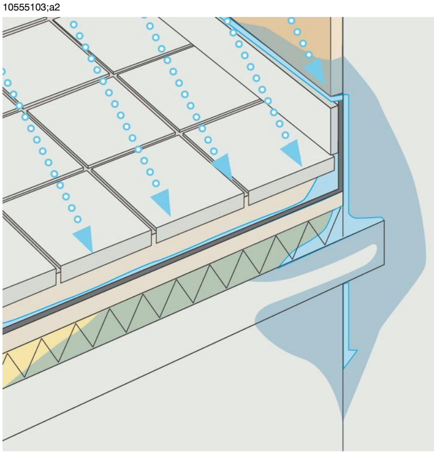
7.2.5.1 General information

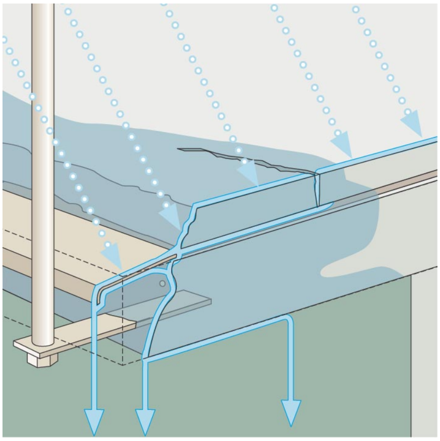
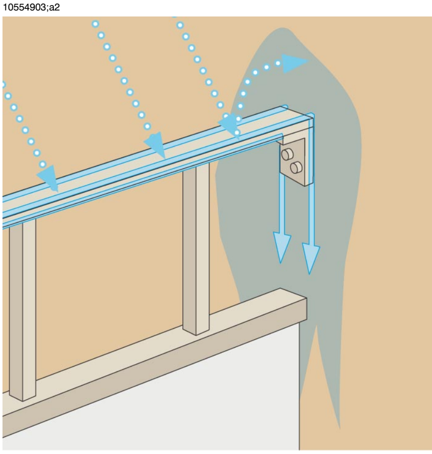
Although there are differences in design, materials and construction, decks—plaza decks, courtyard decks etc—suffer from the same moisture and leaking problems as low-slope commercial roofs. Improper flashing, inadequately sealed membranes, and insufficient drainage may lead to substantial damage in the building structures below.

Balconies, although smaller in size, require the same care in design, choice of material, and workmanship as any other building structure. Since balconies are usually supported on one side only, moisture leading to corrosion of struts and concrete reinforcement can cause problems and lead to hazardous situations.

7.2.5.2 *Commented building structures*

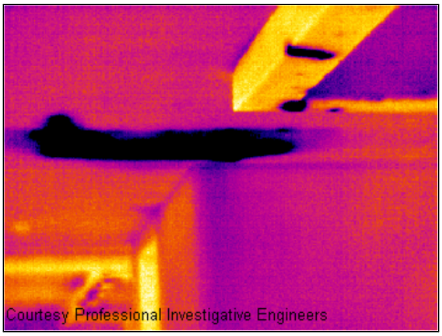
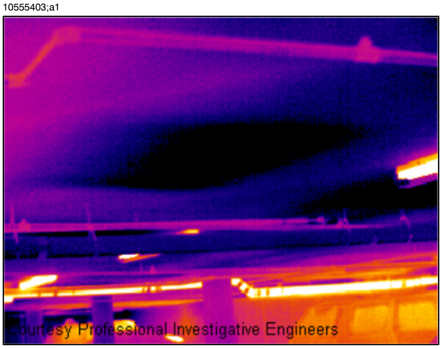
This section includes a few typical examples of moisture problems on decks and balconies.

Structural drawing	Comment
10555203;a2 	Improper sealing of paving and membrane to roof outlet, leading to leakage during rain.
10555103;a2 	No flashing at deck-to-wall connection, leading to rain penetrating the concrete and insulation.

Structural drawing	Comment
10555003;a2 	Water has penetrated the concrete due to inadequately sized drop apron and has led to concrete disintegration and corrosion of reinforcement. SECURITY RISK!
10554903;a2 	Water has penetrated the plaster and underlying masonry at the point where the handrail is fastened to the wall. SECURITY RISK!

7.2.5.3 *Commented infrared images*

This section includes a few typical infrared images of moisture problems on decks and balconies.

Infrared image	**Comment**
10555303;a1 	Improper flashing at balcony-to-wall connections and missing perimeter drainage system resulted in moisture intrusion into the wood framing support structure of the exterior walkway balcony of a loft complex.
10555403;a1 	A missing composite drainage plane or medium on a below-grade parking garage plaza deck structure resulted in standing water between the structural concrete deck and the plaza wearing surface.

7.2.6 Moisture detection (4): Plumbing breaks & leaks

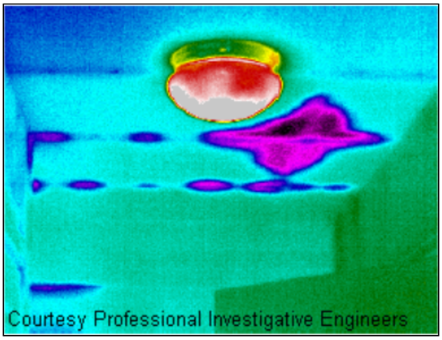
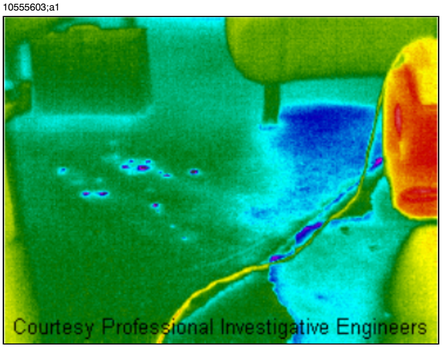
7.2.6.1 *General information*

Water from plumbing leaks can often lead to severe damage on a building structure. Small leaks may be difficult to detect, but can—over the years—penetrate structural walls and foundations to a degree where the building structure is beyond repair.

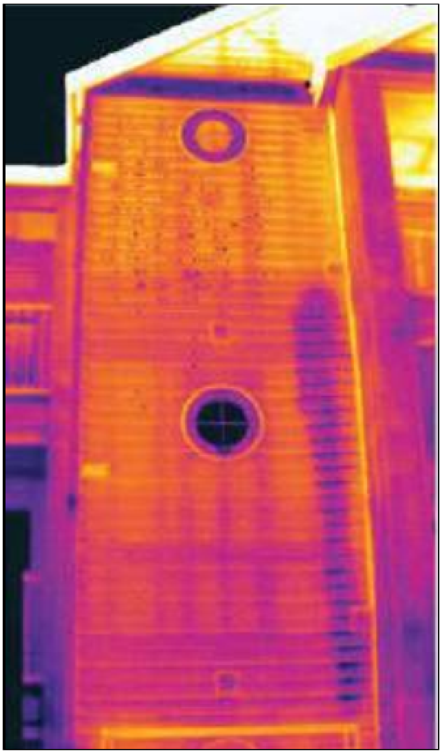
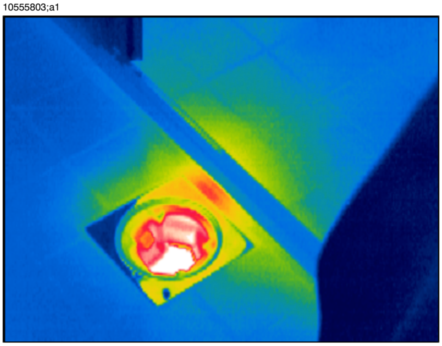
Using building thermography at an early stage when plumbing breaks and leaks are suspected can lead to substantials savings on material and labor.

7.2.6.2 Commented infrared images

This section includes a few typical infrared images of plumbing breaks & leaks.

Infrared image	Comment
10555503;a1 	Moisture migration tracking along steel joist channels inside ceiling of a single family home where a plumbing line had ruptured.
10555603;a1 	Water from plumbing leak was found to have migrated farther than originally anticipated by the contractor during remediation techniques of cutting back carpet and installing dehumidifiers.

7

Infrared image	Comment
10555703;a1 	The infrared image of this vinyl-sided 3-floor apartment house clearly shows the path of a serious leak from a washing machine on the third floor, which is completely hidden within the wall.
10555803;a1 	Water leak due to improper sealing between floor drain and tiles.

7.2.7 Air infiltration

7.2.7.1 General information

Due to the wind pressure on a building, temperature differences between the inside and the outside of the building, and the fact that most buildings use exhaust air terminal devices to extract used air from the building, a negative pressure of 2–5 Pa can be expected. When this negative pressure leads to cold air entering the building structure due to deficiencies in building insulation and/or building sealing, we have what is called *air infiltration*. Air infiltration can be expected at joints and seams in the building structure.

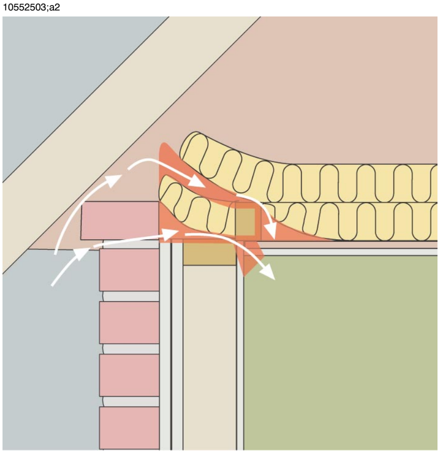
Due to the fact that air infiltration creates an air flow of cool air into e.g. a room, it can lead to substantial deterioration of the indoor climate. Air flows as small as 0.15 m/s (0.49 ft./s) are usually noticed by inhabitants, although these air flows may be difficult to detect using ordinary measurement devices.

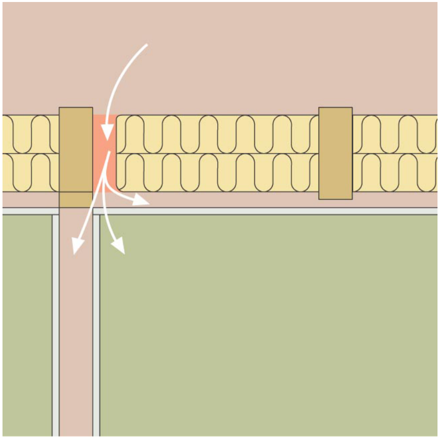
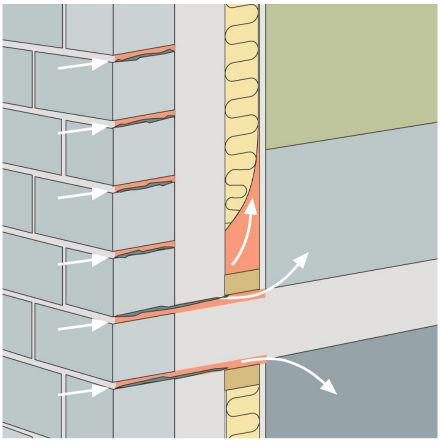
On an infrared image air infiltration can be identified by its typical ray pattern, which emanates from the point of exit in the building structure—e.g. from behind a skirting strip. Furthermore, areas of air infiltration typically have a lower detected temperature than areas where there is only an insulation deficiency. This is due to the chill factor of the air flow.

7

7.2.7.2 Commented building structures

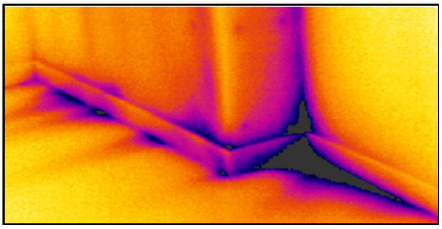
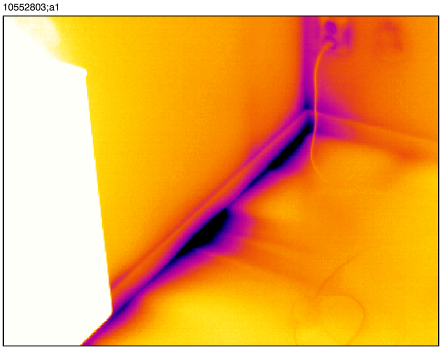
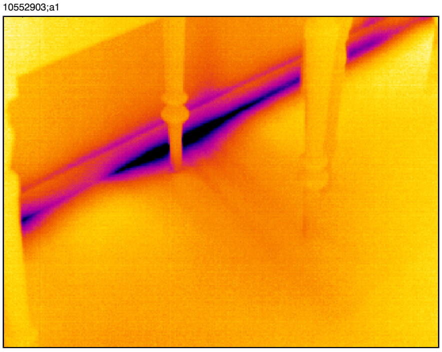
This section includes a few typical examples of details of building structures where air infiltration may occur.

Structural drawing	Comment
10552503;a2 	Insulation deficiencies at the eaves of a brickwall house due to improperly installed fiberglass insulation batts. The air infiltration enters the room from behind the cornice.

Structural drawing	Comment
10552303;a2 	Insulation deficiencies in an intermediate floow due to improperly installed fiberglass insulation batts. The air infiltration enters the room from behind the cornice.
10552603;a2 	Air infiltration in a concrete floor-over-crawl-space due to cracks in the brick wall façade. The air infiltration enters the room beneath the skirting strip.

7.2.7.3 *Commented infrared images*

This section includes a few typical infrared images of details of building structures where air infiltration has occurred.

Infrared image	Comment
10552703;a1 	Air infiltration from behind a skirting strip. Note the typical ray pattern.
10552803;a1 	Air infiltration from behind a skirting strip. Note the typical ray pattern. The white area to the left is a radiator.
10552903;a1 	Air infiltration from behind a skirting strip. Note the typical ray pattern.

7.2.8 Insulation deficiencies

7.2.8.1 General information

Insulation deficiencies do not necessarily lead to air infiltration. If fiberglass insulation batts are improperly installed air pockets will form in the building structure. Since these air pockets have a different thermal conductivity than areas where the insulation batts are properly installed, the air pockets can be detected during a building thermography inspection.

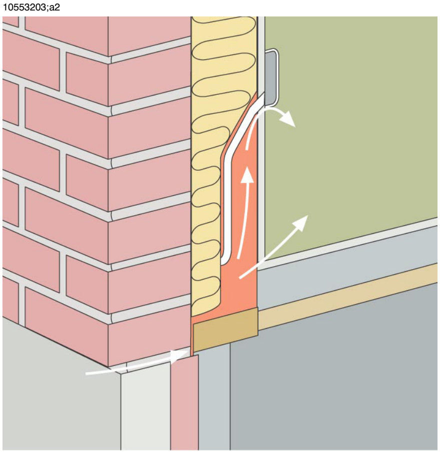
As a rule of thumb, areas with insulation deficiencies typically have higher temperatures than where there is only an air infiltration.

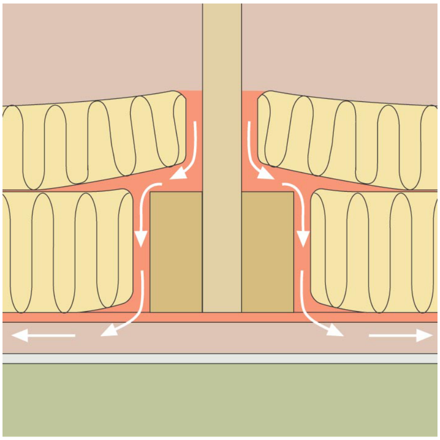
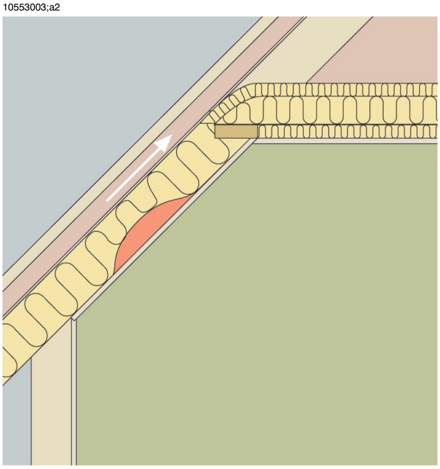
When carrying out building thermography inspections aimed at detecting insulation deficiencies, be aware of the following parts in a building structure, which may look like insulation deficiencies on the infrared image:

- Wooden joists, studs, rafter, beams
- Steel girders and steel beams
- Water piping inside walls, ceilings, floors
- Electrical installations inside walls, ceilings, floors—such as trunking, piping etc.
- Concrete columns inside timber framed walls
- Ventilation ducts & air ducts

7.2.8.2 Commented building structures

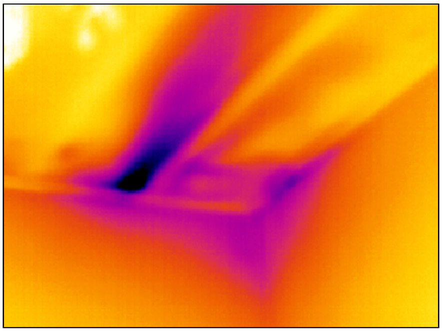
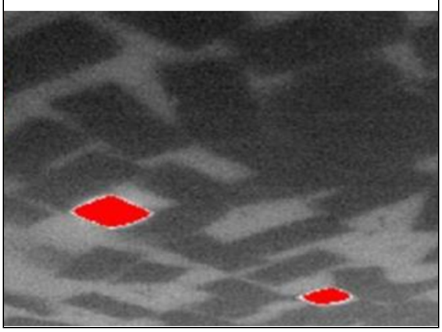
This section includes a few typical examples of details of building structures with insulation deficiencies:

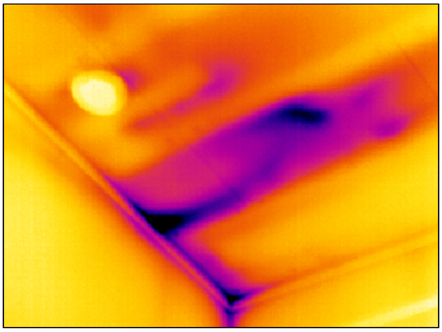
Structural drawing	Comment
10553203;a2 	Insulation deficiencies (and air infiltration) due to improper installation of insulation batts around an electrical mains supply. This kind of insulation deficiency will show up as dark areas on an infrared image.

Structural drawing	Comment
10553103;a2 	Insulation deficiencies due to improper installation of insulation batts around an attic floor beam. Cool air infiltrates the structure and cools down the inside of the ceiling. This kind of insulation deficiency will show up as dark areas on an infrared image.
10553003;a2 	Insulation deficiencies due to improper installation of insulation batts creating an air pocket on the outside of an inclined ceiling. This kind of insulation deficiency will show up as dark areas on an infrared image.

7.2.8.3 *Commented infrared images*

This section includes a few typical infrared images of insulation deficiencies.

Infrared image	Comment
10553303;a1 	Insulation deficiencies in an intermediate floor structure. The deficiency may be due to either missing insulation batts or improperly installed insulations batts (air pockets).
10553403;a1  	Improperly installed fiberglass batts in a suspended ceiling.

Infrared image	Comment
10553503;a1 	Insulation deficiencies in an intermediate floor structure. The deficiency may be due to either missing insulation batts or improperly installed insulations batts (air pockets).

7.3 Theory of building science

7.3.1 General information

The demand for energy-efficient constructions has increased significantly in recent times. Developments in the field of energy, together with the demand for pleasant indoor environments, have resulted in ever-greater significance having to be attached to both the function of a building's thermal insulation and airtightness and the efficiency of its heating and ventilation systems.

Defective insulation and tightness in highly insulated and airtight structures can have a great impact on energy losses. Defects in a building's thermal insulation and airtightness do not merely entail risk of excessive heating and maintenance costs, they also create the conditions for a poor indoor climate.

A building's degree of insulation is often stated in the form of a thermal resistance or a coefficient of thermal transmittance (U value) for the various parts of the building. However, the stated thermal resistance values rarely provide a measure of the actual energy losses in a building. Air leakage from joints and connections that are not airtight and insufficiently filled with insulation often gives rise to considerable deviations from the designed and expected values.

Verification that individual materials and building elements have the promised properties is provided by means of laboratory tests. Completed buildings have to be checked and inspected in order to ensure that their intended insulation and airtightness functions are actually achieved.

In its structural engineering application, thermography is used to study temperature variations over the surfaces of a structure. Variations in the structure's thermal resistance can, under certain conditions, produce temperature variations on its surfaces. Leakage of cold (or warm) air through the structure also affects the variation in surface temperature. This means that insulation defects, thermal bridges and air leaks in a building's enclosing structural components can be located and surveyed.

Thermography itself does not directly show the structure's thermal resistance or airtightness. Where quantification of thermal resistance or airtightness is required, additional measurements have also to be taken. Thermographic analysis of buildings relies on certain prerequisites in terms of temperature and pressure conditions across the structure.

Details, shapes and contrasts in the thermal image can vary quite clearly with changes in any of these parameters. The in-depth analysis and interpretation of thermal images therefore requires thorough knowledge of such aspects as material and structural properties, the effects of climate and the latest measuring techniques. For assessing the results of measurements, there are special requirements in terms of the skills and experience of those taking the measurements, e.g. by means of authorization by a national or regional standardization body.

7.3.2 The effects of testing and checking

It can be difficult to anticipate how well the thermal insulation and airtightness of a completed building will work. There are certain factors involved in assembling the various components and building elements that can have a considerable impact on the final result. The effects of transport, handling and storage at the site and the way the work is done cannot be calculated in advance. To ensure that the intended function is actually achieved, verification by testing and checking the completed building is required.

Modern insulation technology has reduced the theoretical heat requirement. This does mean, however, that defects that are relatively minor, but at important locations, e.g. leaking joints or incorrectly installed insulation, can have considerable consequences in terms both of heat and comfort. Verification tests, e.g. by means of thermography, have proved their value, from the point of view both of the designer and the contractor and of the developer, the property manager and the user.

- For the designer, the important thing is to find out about the function of various types of structures, so that they can be designed to take into account both working methods and functional requirements. The designer must also know how different materials and combinations of materials function in practice. Effective testing and checking, as well as experiential feedback, can be used to achieve the required development in this area.
- The contractor is keen on more testing and inspection in order to ensure that the structures keep to an expected function that corresponds to established requirements in the regulations issued by authorities and in contractual documents. The contractor wants to know at an early stage of construction about any changes that may be necessary so that systematic defects can be prevented. During construction, a check should therefore be carried out on the first apartments completed in a mass production project. Similar checking then follows as production continues. In this way systematic defects can be prevented and unnecessary costs and future problems can be avoided. This check is of benefit both to manufacturers and to users.
- For the developer and the property manager it is essential that buildings are checked with reference to heat economy, maintenance (damage from moisture or moisture infiltration) and comfort for the occupants (e.g. cooled surfaces and air movements in occupied zones).

- For the user the important thing is that the finished product fulfills the promised requirements in terms of the building's thermal insulation and airtightness. For the individual, buying a house involves a considerable financial commitment, and the purchaser therefore wants to know that any defects in the construction will not involve serious financial consequences or hygiene problems.

The effects of testing and checking a building's insulation and airtightness are partly physiological and partly financial.

The physiological experience of an indoor climatic environment is very subjective, varying according to the particular human body's heat balance and the way the individual experiences temperature. The experience of climate depends on both the indoor air temperature and that of the surrounding surfaces. The speed of movement and moisture content of indoor air are also of some significance. Physiologically, a draft produces the sensation of local cooling of the body's surface caused by

- excessive air movements in the occupied zone with normal air temperature;
- normal air movements in the occupied zone but a room temperature that is too low;
- substantial radiated heat exchange with a cold surface.

It is difficult to assess the quantitative effects of testing and checking a building's thermal insulation.

Investigations have shown that defects found in the thermal insulation and airtightness of buildings cause heat losses that are about 20–30% more than was expected. Monitoring energy consumption before and after remedial measures in relatively large complexes of small houses and in multi-dwelling blocks has also demonstrated this. The figures quoted are probably not representative of buildings in general, since the investigation data cannot be said to be significant for the entire building stock. A cautious assessment however would be that effectively testing and checking a building's thermal insulation and airtightness can result in a reduction in energy consumption of about 10%.

Research has also shown that increased energy consumption associated with defects is often caused by occupants increasing the indoor temperature by one or a few degrees above normal to compensate for the effect of annoying thermal radiation towards cooled surfaces or a sensation of disturbing air movements in a room.

7.3.3 Sources of disruption in thermography

During thermography, the risk of confusing temperature variations caused by insulation defects with those associated with the natural variation in U values along warm surfaces of a structure is considered slight under normal conditions.

The temperature changes associated with variations in the U value are generally gradual and symmetrically distributed across the surface. Variations of this kind do of course occur at the angles formed by roofs and floors and at the corners of walls.

Temperature changes associated with air leaks or insulation defects are in most cases more evident with characteristically shaped sharp contours. The temperature pattern is usually asymmetrical.

During thermography and when interpreting an infrared image, comparison infrared images can provide valuable information for assessment.

The sources of disruption in thermography that occur most commonly in practice are

- the effect of the sun on the surface being thermographed (sunlight shining in through a window);
- hot radiators with pipes;
- lights directed at, or placed near, the surface being measured;
- air flows (e.g. from air intakes) directed at the surface;
- the effect of moisture deposits on the surface.

Surfaces on which the sun is shining should not be subjected to thermography. If there is a risk of an effect by sunlight, windows should be covered up (closing Venetian blinds). However, be aware that there are building defects or problems (typically moisture problems) that only show up when heat has been applied to the surface, e.g. from the sun.

For more information about moisture detection, see section 7.2.2 – About moisture detection on page 19.

A hot radiator appears as a bright light surface in an infrared image. The surface temperature of a wall next to a radiator is raised, which may conceal any defects present.

For maximum prevention of disruptive effects from hot radiators, these may be shut off a short while before the measurement is taken. However, depending on the construction of the building (low or high mass), these may need to be shut off several hours before a thermographic survey. The room air temperature must not fall so much as to affect the surface temperature distribution on the structure's surfaces. There is little timelag with electric radiators, so they cool down relatively quickly once they have been switched off (20–30 minutes).

Lights placed against walls should be switched off when the infrared image is taken.

During thermography there should not be any disruptive air flows (e.g. open windows, open valves, fans directed at the surface being measured) that could affect the surfaces being thermographed.

Any wet surfaces, e.g. as a result of surface condensation, have a definite effect on heat transfer at the surface and the surface temperature. Where there is moisture on a surface, there is usually some evaporation which draws off heat, thus lowering the temperature of the surface by several degrees. There is risk of surface condensation at major thermal bridges and insulation defects.

Significant disruptions of the kind described here can normally be detected and eliminated before measuring.

If during thermography it is not possible to shield surfaces being measured from disruptive factors, these must be taken into account when interpreting and evaluating the results. The conditions in which the thermography was carried out should be recorded in detail when each measurement is taken.

7.3.4 Surface temperature and air leaks

Defects in building airtightness due to small gaps in the structure can be detected by measuring the surface temperature. If there is a negative pressure in the building under investigation, air flows into the space through leaks in the building. Cold air flowing in through small gaps in a wall usually lowers the temperature in adjacent areas of the wall. The result is that a cooled surface area with a characteristic shape develops on the inside surface of the wall. Thermography can be used to detect cooled surface areas. Air movements at the wall surface can be measured using an air velocity indicator. If there is a positive pressure inside the building being investigated, warm room air will leak out through gaps in the wall, resulting in locally warm surface areas around the locations of the leaks.

The amount of leakage depends partly on gaps and partly on the differential pressure across the structure.

7.3.4.1 Pressure conditions in a building

The most important causes of differential pressure across a structural element in a building are

- wind conditions around the building;
- the effects of the ventilation system;
- temperature differences between air inside and outside (thermal differential pressure).

The actual pressure conditions inside a building are usually caused by a combination of these factors.

The resultant pressure gradient across the various structural elements can be illustrated by the figure on page 45. The irregular effects of wind on a building means that in practice the pressure conditions may be relatively variable and complicated.

In a steady wind flow, Bernoulli's Law applies:

$$\frac{\rho v^2}{2} + p = \text{constant}$$

where:

ρ	Air density in kg/m³
v	Wind velocity in m/s
p	Static pressure in Pa

and where:

$$\frac{\rho v^2}{2} + p$$

denotes the dynamic pressure and p the static pressure. The total of these pressures gives the total pressure.

7

Wind load against a surface makes the dynamic pressure become a static pressure against the surface. The magnitude of this static pressure is determined by, amongst other things, the shape of the surface and its angle to the wind direction.

The portion of the dynamic pressure that becomes a static pressure on the surface (p_{stat}) is determined by what is known as a stress concentration factor:

$$C = \frac{p_{stat}}{\frac{\rho v^2}{2}}$$

If ρ is 1.23 kg/m³ (density of air at +15°C (+59°F)), this gives the following local pressures in the wind flow:

$$p_{stat} = C \times \frac{\rho v^2}{2} = C \times \frac{v^2}{1.63} \ \text{Pa}$$

10551803;a1

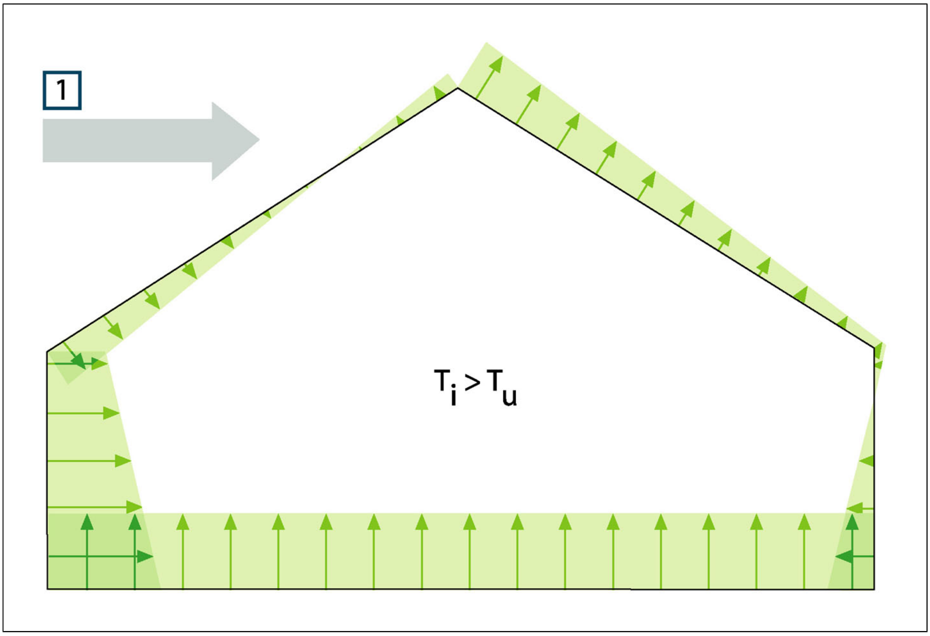


Figure 7.3 Distribution of resultant pressures on a building's enclosing surfaces depending on wind effects, ventilation and internal/external temperature difference. **1**: Wind direction; T_u: Thermodynamic air temperature outdoors in K; T_i: Thermodynamic air temperature indoors in K.

If the whole of the dynamic pressure becomes static pressure, then C = 1. Examples of stress concentration factor distributions for a building with various wind directions are shown in the figure on page 46.

The wind therefore causes an internal negative pressure on the windward side and an internal positive pressure on the leeward side. The air pressure indoors depends on the wind conditions, leaks in the building and how these are distributed in relation to the wind direction. If the leaks in the building are evenly distributed, the internal pressure may vary by ±0.2 p_{stat}. If most of the leaks are on the windward side, the internal pressure increases somewhat. In the opposite case, with most of the leaks on the leeward side, the internal pressure falls.

10551903;a1

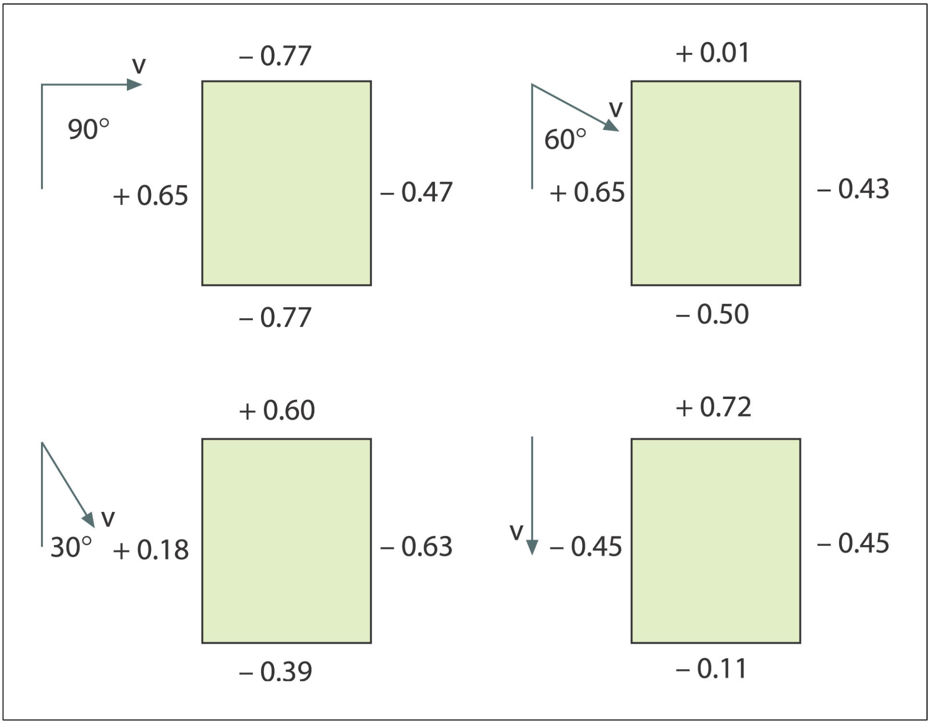


Figure 7.4 Stress concentration factor (C) distributions for various wind directions and wind velocities (v) relative to a building.

Wind conditions can vary substantially over time and between relatively closely situated locations. In thermography, such variations can have a clear effect on the measurement results.

It has been demonstrated experimentally that the differential pressure on a façade exposed to an average wind force of about 5 m/s (16.3 ft/s) will be about 10 Pa.

Mechanical ventilation results in a constant internal negative or positive pressure (depending on the direction of the ventilation). Research has showed that the negative pressure caused by mechanical extraction (kitchen fans) in small houses is usually between 5 and 10 Pa. Where there is mechanical extraction of ventilation air, e.g. in multi-dwelling blocks, the negative pressure is somewhat greater, 10–50 Pa. Where there is so-called balanced ventilation (mechanically controlled supply and extract air), this is normally adjusted to produce a slight negative pressure inside (3–5 Pa).

The differential pressure caused by temperature differences, the so-called chimney effect (airtightness differences of air at different temperatures) means that there is a negative pressure in the building's lower part and a positive pressure in the upper part. At a certain height there is a neutral zone where the pressures on the inside and outside are the same, see the figure on page 48. This differential pressure may be described by the relationship:

$$\Delta p = g \times \rho_u \times h \left(1 - \frac{T_u}{T_i}\right) \text{ Pa}$$

Δp	Air pressure differential within the structure in Pa
g	9.81 m/s^2
ρ_u	Air density in kg/m^3
T_u	Thermodynamic air temperature outdoors in K
T_i	Thermodynamic air temperature indoors in K
h	Distance from the neutral zone in meters

If ρ_u = 1.29 kg/m^3 (density of air at a temperature of 273 K and ≈100 kPa), this produces:

$$\Delta p \approx 13 \times h \left(1 - \frac{T_u}{T_i}\right)$$

With a difference of +25°C (+77°F) between the ambient internal and external temperatures, the result is a differential pressure difference within the structure of about 1 Pa/m difference in height (= 3.28 Pa/ft.).

10552003;a1

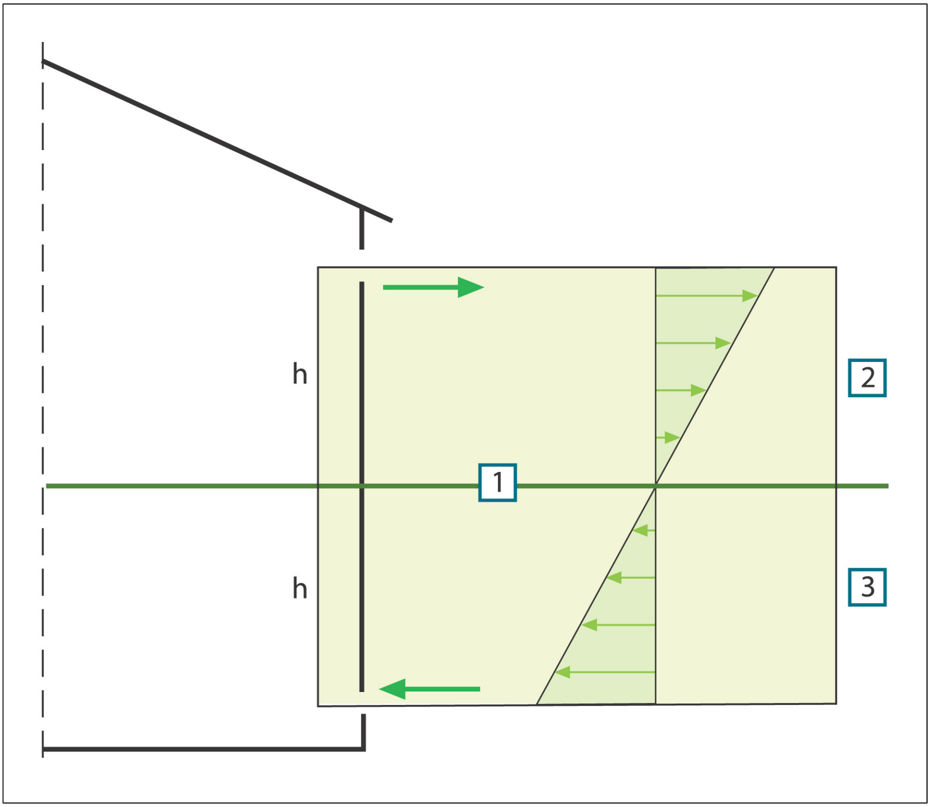


Figure 7.5 Distribution of pressures on a building with two openings and where the external temperature is lower than the internal temperature. **1**: Neutral zone; **2**: Positive pressure; **3**: Negative pressure; **h**: Distance from the neutral zone in meters.

The position of the neutral zone may vary, depending on any leaks in the building. If the leaks are evenly distributed vertically, this zone will be about halfway up the building. If more of the leaks are in the lower part of the building, the neutral zone will move downwards. If more of the leaks are in the upper part, it will move upwards. Where a chimney opens above the roof, this has a considerable effect on the position of the neutral zone, and the result may be a negative pressure throughout the building. This situation most commonly occurs in small buildings.

In a larger building, such as a tall industrial building, with leaks at doors and any windows in the lower part of the building, the neutral zone is about one-third of the way up the building.

7.3.5 Measuring conditions & measuring season

The foregoing may be summarized as follows as to the requirements with regard to measuring conditions when carrying out thermographic imaging of buildings.

Thermographic imaging is done in such a way that the disruptive influence from external climatic factors is as slight as possible. The imaging process is therefore carried out indoors, i.e. where a building is heated, the structure's warm surfaces are examined.

Outdoor thermography is only used to obtain reference measurements of larger façade surfaces. In certain cases, e.g. where the thermal insulation is very bad or where there is an internal positive pressure, outdoor measurements may be useful. Even when investigating the effects of installations located within the building's climatic envelope, there may be justification for thermographic imaging from outside the building.

The following conditions are recommended:

- The air temperature difference within the relevant part of the building must be at least +10°C (+18°F) for a number of hours before thermographic imaging and for as long as the procedure takes. For the same period, the ambient temperature difference must not vary by more than ±30% of the difference when the thermographic imaging starts. During the thermographic imaging, the indoor ambient temperature should not change by more than ±2°C (±3.6°F).
- For a number of hours prior before thermographic imaging and as long as it continues, no influencing sunlight may fall upon the relevant part of the building.
- Negative pressure within the structure ≈ 10–50 Pa.
- When conducting thermographic imaging in order to locate only air leaks in the building's enclosing sections, the requirements in terms of measuring conditions may be lower. A difference of 5°C (9°F) between the inside and outside ambient temperatures ought to be sufficient for detecting such defects. To be able to detect air leaks, certain requirements must however be made with regard to the differential pressure; about 10 Pa should be sufficient.

7.3.6 Interpretation of infrared images

The main purpose of thermography is to locate faults and defects in thermal insulation in exterior walls and floor structures and to determine their nature and extent. The measuring task can also be formulated in such a way that the aim of the thermography is to confirm whether or not the wall examined has the promised insulation and airtightness characteristics. The 'promised thermal insulation characteristics' for the wall according to the design can be converted into an expected surface temperature distribution for the surface under investigation if the measuring conditions at the time when the measurements are taken are known.

In practice the method involves the following:

Laboratory or field tests are used to produce an expected temperature distribution in the form of typical or comparative infrared images for common wall structures, comprising both defect-free structures and structures with in-built defects. Examples of typical infrared images are shown in section 7.2 – Typical field investigations beginning on page 17.

If infrared images of structural sections taken during field measurements are intended for use as comparison infrared images, then the structure's composition, the way it was built, and the measurement conditions at the time the infrared image was taken must be known in detail and documented.

In order, during thermography, to be able to comment on the causes of deviations from the expected results, the physical, metrological and structural engineering prerequisites must be known.

The interpretation of infrared images taken during field measurements may be described in brief as follows:

A comparison infrared image for a defect-free structure is selected on the basis of the wall structure under investigation and the conditions under which the field measurement was taken. An infrared image of the building element under investigation is then compared with the selected infrared image. Any deviation that cannot be explained by the design of the structure or the measurement conditions is noted as a suspected insulation defect. The nature and extent of the defect is normally determined using comparison infrared images showing various defects.

If no suitable comparison infrared image is available, evaluation and assessment are done on the basis of experience. This requires more precise reasoning during the analysis.

When assessing an infrared image, the following should be looked at:

- Uniformity of brightness in infrared images of surface areas where there are no thermal bridges
- Regularity and occurrence of cooled surface areas, e.g. at studding and corners
- Contours and characteristic shapes in the cooled surface area
- Measured temperature differences between the structure's normal surface temperature and the selected cooled surface area
- Continuity and uniformity of the isotherm curve on the surface of the structure. In the camera software the isotherm function is called **Isotherm** or **Color alarm**, depending on camera model.

Deviations and irregularities in the appearance of the infrared image often indicate insulation defects. There may obviously be considerable variations in the appearance of infrared images of structures with insulation defects. Certain types of insulation defects have a characteristic shape on the infrared image. Section 7.2 – Typical field investigations beginning on page 17 shows examples of interpretations of infrared images.

When taking infrared images of the same building, the infrared images from different areas should be taken with the same settings on the infrared camera, as this makes comparison of the various surface areas easier.

7.3.7 Humidity & dew point

7.3.7.1 Relative & absolute humidity

Humidity can be expressed in two different ways—either as *relative humidity* or as *absolute humidity*. Relative humidity is expressed in percent of how much water a certain volume of air can hold at a certain temperature, while absolute humidity is expressed in percent water by weight of material. The latter way to express humidity is common when measuring humidity in wood and other building materials.

The higher the temperature of air, the larger the amount of water this certain volume of air can hold. The following table specifies the maximum amounts of water in air at different temperatures.

Figure 7.6 **A:** Temperature in degrees Celsius; **B:** Maximum amount of water expressed in g/m^3 (at sea level)

A	B	A	B	A	B	A	B
30.0	30.44	20.0	17.33	10.0	9.42	0.0	4.86
29.0	28.83	19.0	16.34	9.0	8.84	-1.0	4.49
28.0	27.29	18.0	15.40	8.0	8.29	-2.0	4.15
27.0	25.83	17.0	14.51	7.0	7.77	-3.0	3.83
26.0	24.43	16.0	13.66	6.0	7.28	-4.0	3.53
25.0	23.10	15.0	12.86	5.0	6.81	-5.0	3.26
24.0	21.83	14.0	12.09	4.0	6.38	-6.0	3.00
23.0	20.62	13.0	11.37	3.0	5.96	-7.0	2.76
22.0	19.47	12.0	10.69	2.0	5.57	-8.0	2.54
21.0	18.38	11.0	10.04	1.0	5.21	-9.0	2.34

Figure 7.7 **A:** Temperature in degrees Fahrenheit; **B:** Maximum amount of water in gr/ft³ (at sea level)

A	B	A	B	A	B	A	B
86.0	13.30	68.0	7.58	50.0	4.12	32.0	2.12
84.2	12.60	66.2	7.14	48.2	3.86	30.2	1.96
82.4	11.93	64.4	6.73	46.4	3.62	28.4	1.81
80.6	11.29	62.6	6.34	44.6	3.40	26.6	1.67
78.8	10.68	60.8	5.97	42.8	3.18	24.8	1.54
77.0	10.10	59.0	5.62	41.0	2.98	23.0.	1.42
75.2	9.54	57.2	5.29	39.2	2.79	21.2	1.31
73.4	9.01	55.4	4.97	37.4	2.61	19.4	1.21
71.6	8.51	53.6	4.67	35.6	2.44	17.6	1.11
69.8	8.03	51.8	4.39	33.8	2.28	15.8	1.02

7

Example:

The relative humidity of a certain volume of air at a temperature of +30°C (+86°F) is 40 % RH. Amount of water in 1 m³ (35.31 ft³) of air at +30°C = 30.44 × Rel Humidity = 30.44 × 0.40 = 12.18 g (187.96 gr).

7.3.7.2 Definition of dew point

Dew point can be regarded as the temperature at which the humidity in a certain volume of air will condense as liquid water.

Example:

The relative humidity of a certain volume of air at a temperature of +30°C (+86°F) is 40 % RH. Amount of water in 1 m³ (35.31 ft³) of air at +30°C = 30.44 × Rel Humidity = 30.44 × 0.40 = 12.18 g (187.96 gr). In the table above, look up the temperature for which the amount of water in air is closest to 12.18 g. This would be +14.0°C (+57.2°F), which is the approximate dew point.

7.4 Disclaimer

7.4.1 Copyright notice

Some sections and/or images appearing in this chapter are copyrighted to the following organizations and companies:

- FORMAS—The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Stockholm, Sweden
- ITC—Infrared Training Center, Boston, MA, United States
- Stockton Infrared Thermographic Services, Inc., Randleman, NC, United States
- Professional Investigative Engineers, Westminster, CO, United States

7.4.2 Training & certification

Carrying out building thermography inspections requires substantial training and experience, and may require certification from a national or regional standardization body. This section is provided only as an introduction to building thermography. The user is strongly recommended to attend relevant training courses.

For more information about infrared training, visit the following website:

http://www.infraredtraining.com

7.4.3 National or regional building codes

The commented building structures in this chapter may differ in construction from country to country. For more information about construction details and standards of procedure, always consult national or regional building codes.

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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 66. 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 66. 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 66. 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 MENU/YES.
3	Point to **Images** to display thumbnails of the most recently saved images.
4	To open an image, select the image by pressing the navigation pad left/right or up/down and then press MENU/YES.

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	Press SEL until small brackets appear around the spot. You can now move the spot by pressing the navigation pad left/right or up/down. To add additional spots, repeat step 1–4. A maximum number of three spots can be added.
5	The temperature will be displayed in the top right corner of the LCD.

8.3.2 Laying out a measurement area

➲ The camera needs 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 **Area max**, **Area min** or **Area avg** in the **Meas. mode** dialog box and press MENU/YES.
4	The temperature will be displayed in the top right corner of the LCD.

8.4 Working with alarms

You can choose between the following alarm outputs:

- a color alarm, which will assign a color to all pixels above or below a preset temperature level
- a silent alarm, which, compared to the color alarm, will make the font of the temperature result increase in size and its background turn red
- an audible alarm, which, compared to the visual alarm, also triggers a 'beep'.

A settings can also be made in the camera so that an alarm output takes into account the reference temperature. A typical application when you would want to use an alarm that takes into account the reference temperature is screening of people for face temperature detection.

Firstly, the reference temperature is set by screening 10 persons with normal face temperature. The camera puts each of these 10 results in an internal camera buffer and calculates the average temperature value after having discarded the two highest and two lowest values in the event of erroneous samples. Every time a new sample is saved to the internal buffer, the oldest sample will be discarded and a new reference temperature will be calculated 'on the fly'.

Using an alarm that takes into account the reference temperature means that an alarm output will only be triggered if the temperature value exceeds the sum of the average temperature value in the buffer + the user-defined delta alarm offset value.

8.4.1 Setting the reference temperature

Step	Action
1	Press YES to display the vertical menu bar.
2	Point to **Settings** on the **Setup** menu and press YES.
3	In the **Settings** dialog box, press the navigation pad up/down to go to **Trigger button**.
4	Press the navigation pad left/right to select **Update ref temp**.
5	Press the navigation pad up/down to go to **Shutter period**.
6	Press the navigation pad left/right to select shutter period. Although the shutter period works independently of other functions described in this document, FLIR Systems recommends that **Short** is selected when using the camera for detection of face temperature. ➲ Selecting **Normal** will calibrate the camera at least every 15th minute, while selecting **Short** will calibrate the camera at least every 3rd minute.

Step	Action
7	Pointing the camera to the first person with a normal face temperature and pulling the trigger will display the message **Sampled nn.n °C**.
8	After having carried out the same procedure on the following 9 persons, you can do one of the following: ■ Actively continue to sample every new person by pulling the trigger button, and let camera update the reference temperature ■ Stop sampling and let the camera trigger an alarm as soon as the alarm conditions are met (> reference temperature + delta alarm value)

8.4.2 Setting up a color alarm

8.4.2.1 Setting up a color alarm using the menu system

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Meas. mode** and press YES to display the **Meas. mode** dialog box.
3	Select **Meas. mode** by pressing the navigation pad left/right. The alarm function is typically used together with **Area max**.
4	For **Alarm**, select one of the following by pressing the navigation pad left/right: ■ **Above** ■ **Below**
5	For **Alarm output**, select **Color only** by pressing the navigation pad left/right.
6	Specify the **Alarm temp** by pressing the navigation pad left/right. You can also change the color alarm without using the menu system by pressing the navigation pad up/down after having selected the temperature result by pressing SEL. A selected temperature result is highlighted in yellow. ➲ **Alarm temp** will only be available if **Update ref temp** has been previously selected in the **Settings** dialog box.
7	Specify **Delta alarm** by pressing the navigation pad left/right. ➲ **Delta alarm** will only be available if **Update ref temp** has been previously selected in the **Settings** dialog box.

8.4.2.2 Setting up a color alarm without using the menu system

Step	Action
1	Press SEL until the color alarm symbol and the color alarm temperature in the top right hand corner of the screen is selected. The color alarm symbol is an arrow pointing upwards or downwards.
2	Press the navigation pad up/down to change the color alarm temperature.

8.4.3 Setting up a silent alarm (*i.e.* a visual alarm)

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Meas. mode** and press YES to display the **Meas. mode** dialog box.
3	Select **Meas. mode** by pressing the navigation pad left/right. The alarm function is typically used together with **Area max**.
4	For **Alarm**, select one of the following by pressing the navigation pad left/right: ■ **Above** ■ **Below**
5	For **Alarm output**, select **Silent** by pressing the navigation pad left/right.
6	Specify the **Alarm temp** by pressing the navigation pad left/right. ➲ **Alarm temp** will only be available if **Update ref temp** has been previously selected in the **Settings** dialog box.
7	Specify **Delta alarm** by pressing the navigation pad left/right. ➲ **Delta alarm** will only be available if **Update ref temp** has been previously selected in the **Settings** dialog box.

8.4.4 Setting up an audible alarm

Step	Action
1	Press MENU/YES to display the vertical menu bar.
2	Point to **Meas. mod**e and press YES to display the **Meas. mode** dialog box.
3	Select **Meas. mode** by pressing the navigation pad left/right. The alarm function is typically used together with **Area max**.
4	For **Alarm**, select one of the following by pressing the navigation pad left/right: ■ **Above** ■ **Below**
5	For **Alarm output**, select **Beep** by pressing the navigation pad left/right.
6	Specify the **Alarm temp** by pressing the navigation pad left/right. ➲ **Alarm temp** will only be be available if **Update ref temp** has been previously selected in the **Settings** dialog box.
7	Specify **Delta alarm** by pressing the navigation pad left/right. ➲ **Delta alarm** will only be available if **Update ref temp** has been previously selected in the **Settings** dialog box.

8.5 Creating files for image descriptions

Follow this procedure to create a text file where any value of the first label will be used as an image description:

Step	Action
1	Using any ASCII text editor (Notepad, Wordpad etc), type the first label within brackets: `<Recommendation>`

2	On the next lines, type the values you want to use, but this time without brackets:
	`Check connections`
	`Check cables`
	`Check gaskets`
	`Check mountings`

3	The final result should look like this:
	`<Recommendation>`
	`Check connections`
	`Check cables`
	`Check gaskets`
	`Check mountings`

4	Save the file to Desktop, using any file name you want.
	Rename the file name extension to .tcf.
5	Connect the camera to your computer using ThermaCAM™ QuickView. This makes your camera appear as a hard disk drive in Windows® Explorer.
6	Move the file from Desktop to your camera using a drag-and-drop operation.

➲ For information about how to connect the camera to your computer, see the ThermaCAM™ QuickView user's manual.

8

8.6 Changing level & span

8.6.1 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 84.

8.6.2 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 84.

8.7 *Changing system settings*

8.7.1 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.

8.7.2 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.

8.7.3 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.

8.7.4 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.

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

8.7.5 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.

8.8 Working with the camera

8.8.1 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 99.
- 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.

10582103;a1

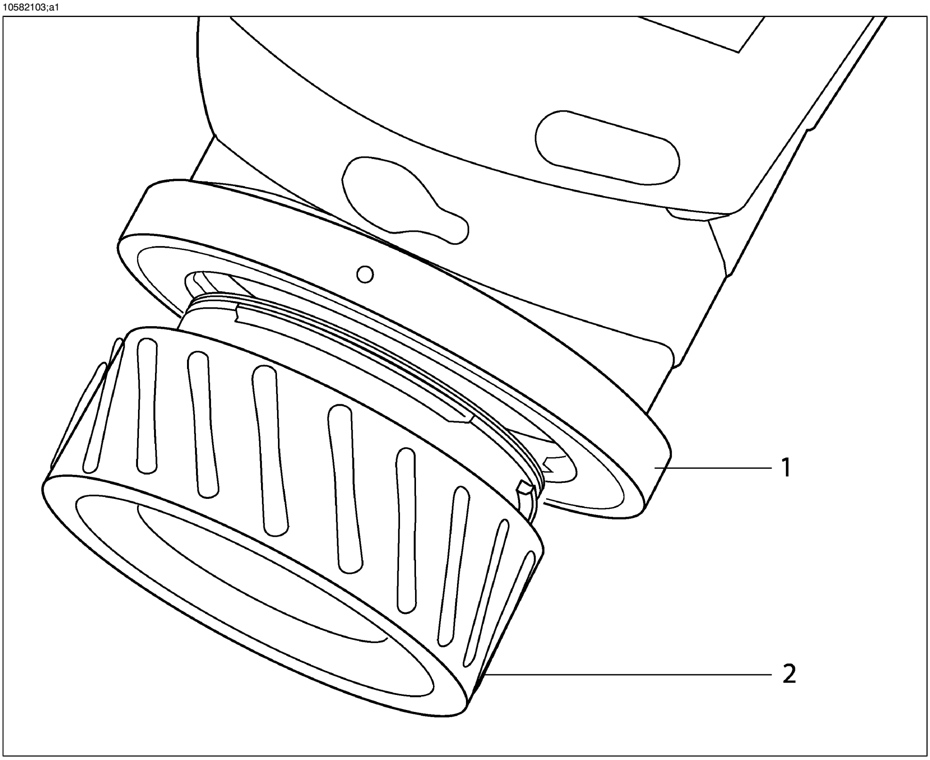

Figure 8.1 Removing a lens. **1:** Locking ring; **2:** Focus ring

10396303;a3

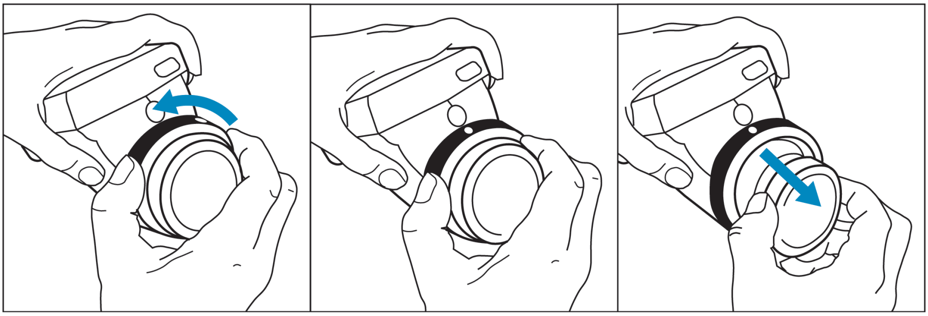

Figure 8.2 Removing a lens

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.

8.8.2 Adjusting the focus

➲ Please note what is the locking ring and what is the focus ring in figure 8.1 on page 66. 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.

8.8.3 Changing digital zoom factor

Step	Action
1	To change digital zoom factor, press SEL until the zoom indicator appears in the left bottom corner of the screen. 10583603;a1 
2	Do one of the following: ■ Press the navigation pad up or right to increase the zoom factor (1x → 2x → 4x) ■ Press the navigation pad down or left to decrease the zoom factor (4x → 2x → 1x)

➲ Please note the following:

- The zoom factor when viewing live images will not be saved when you switch off the camera. Default zoom factor when you switch on the camera is 1x.

- When you save an image, the zoom factor will be saved too. When you open such an image in ThermaCAM™ QuickView or ThermaCAM™ Reporter, you can change the zoom factor again.

8.8.4 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.

8.8.4.1 Inserting the battery

10396403;a2

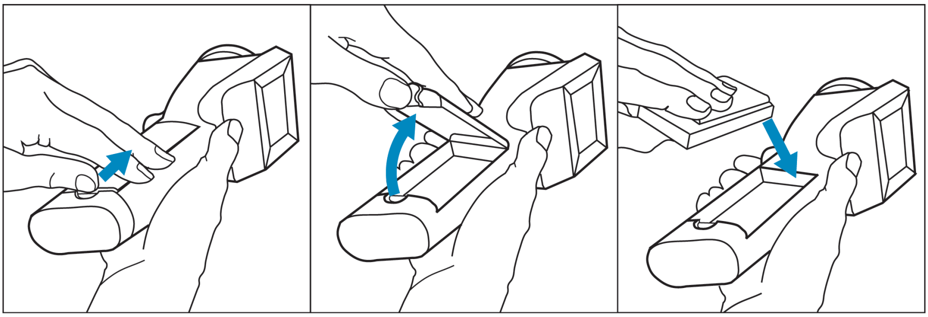

Figure 8.3 Inserting the battery

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.

8.8.4.2 Removing the battery

10396503;a2

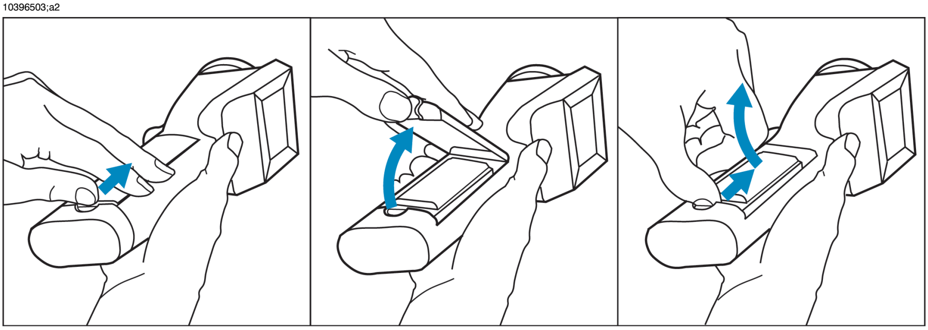

Figure 8.4 Removing the battery

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 93.

8

8

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9 Camera overview

9.1 Camera parts

10581503;a1

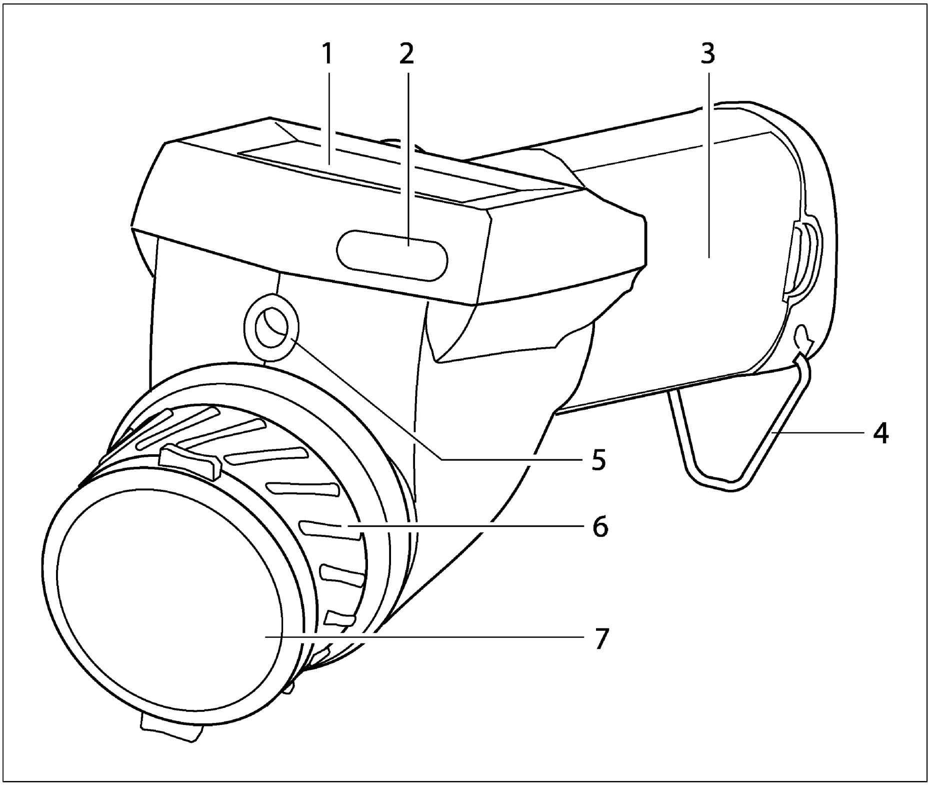

Figure 9.1 Camera parts – front view

Callout	Description of part
1	LCD
2	IrDA infrared communication link
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

10581903;a1

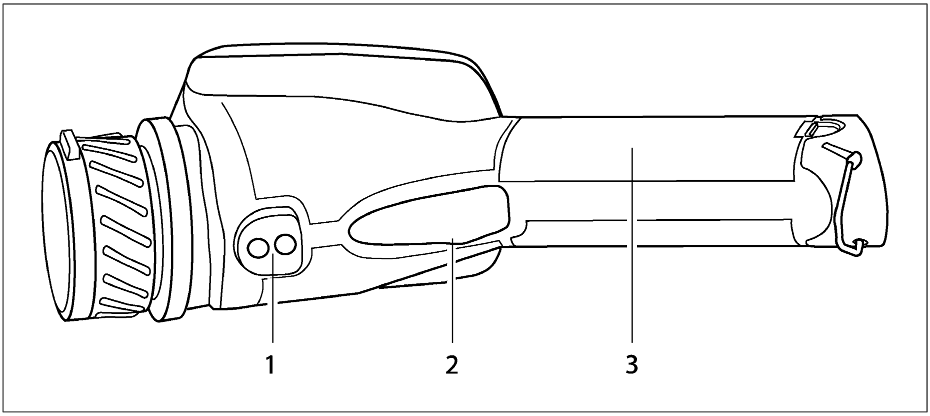

Figure 9.2 Camera parts – view from below

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

10310603;a5

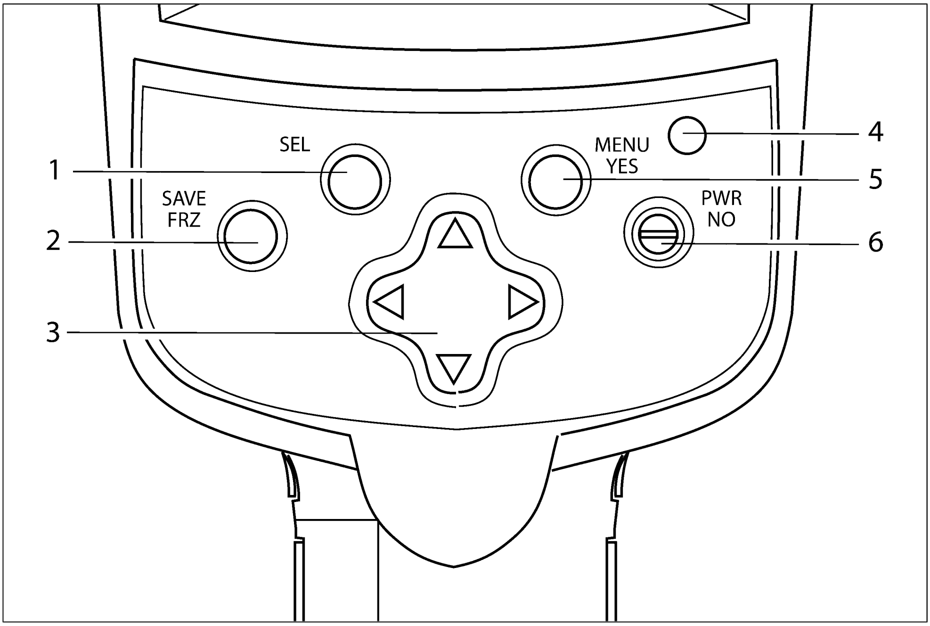

Figure 9.3 Camera parts – view from above

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 75
2	SAVE/FRZ button For more information about the functionality of this button, see section 9.2 – Keypad buttons & functions on page 75
3	Navigation pad For more information about the functionality of the navigation pad, see section 9.2 – Keypad buttons & functions on page 75
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 75
6	PWR/NO button For more information about the functionality of this button, see section 9.2 – Keypad buttons & functions on page 75

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. >80 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 84

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 ▪ Update ref. temp 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 88

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 88.

10376403;a2

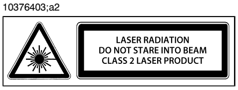

Figure 9.4 Wavelength: 635 nm. Max. output power: 1 mW. This product complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated July 26th, 2001

10581703;a1

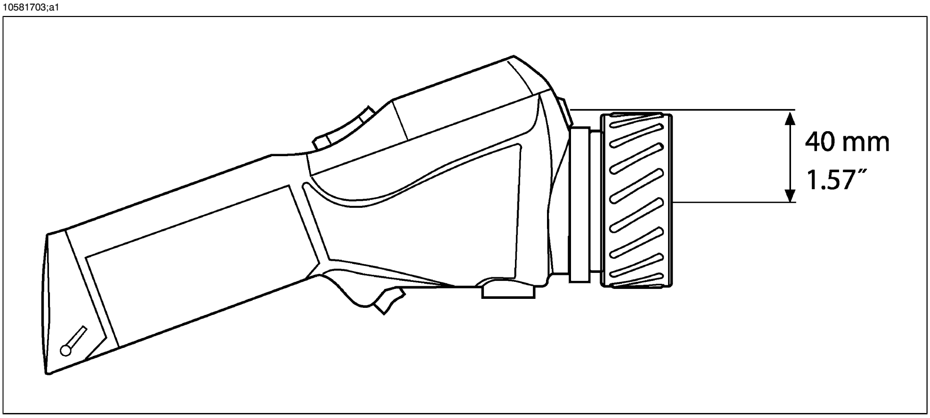

Figure 9.5 Distance between the laser beam and the image center

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
Max	Area, maximum temperature
Min	Area, minimum temperature
	Area, average temperature
	Color alarm above
	Color alarm below
	Difference between spot 1 and spot 2
✳	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.

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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

10383303;a4

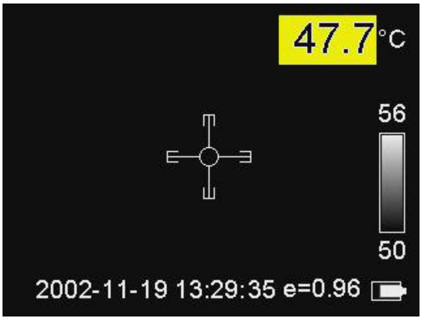

Figure 10.4 A selected measurement marker (spot). Press the navigation pad at this stage to move the spot.

10383503;a4

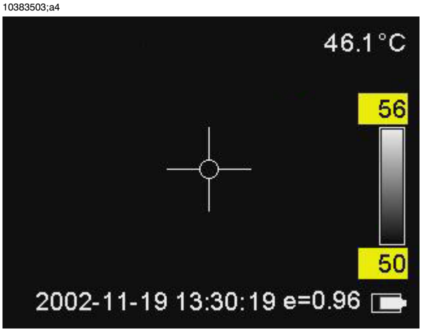

Figure 10.5 A selected temperature scale. Press the navigation pad up/down at this stage to increase/decrease the *level*, and left/right to increase/decrease the *span*.

10383403;a3

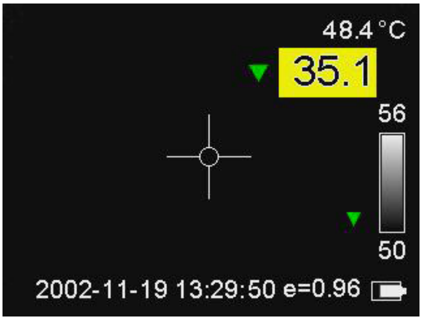

Figure 10.6 A selected color alarm. Press the navigation pad up/down at this stage to increase/decrease the color alarm temperature.

10383803;a3

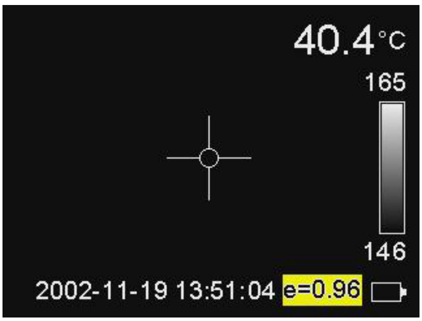

Figure 10.7 A selected emissivity field. Press the navigation pad up/down at this stage to increase/decrease the emissivity.

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

10429603;a2

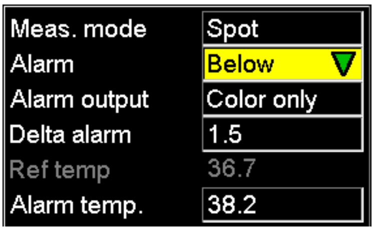

Figure 10.8 **Meas. mode** dialog box

Figure 10.9 Explanations of the **Meas. mode** dialog box

Label	Value	Explanation
Meas. mode	▪ **None** ▪ **Spot** ▪ **Area max** ▪ **Area min** ▪ **Area avg** ▪ **Diff spots**	▪ Select **None** to disable the measurement mode. ▪ Select **Spot** to lay out a spot, where the temperature of the spot will be displayed in the result table. ▪ Select **Area max** to lay out an area on the screen, where the maximum temperature in the area will be displayed in the result table. A measurement marker inside the area will continuously indicate the maximum temperature. ▪ Select **Area min** to lay out an area on the screen, where the minimum temperature in the area will be displayed in the result table. A measurement marker inside the area will continuously indicate the minimum temperature. ▪ Select **Area avg** to lay out an area on the screen, where the average temperature in the area will be displayed in the result table. ▪ Select **Diff spots** to calculate the difference between two spots and display this difference in the result table.

Label	Value	Explanation
Alarm	■ **Off** ■ **Above** ■ **Below**	■ Select **Off** to disable the alarm ■ Select **Above** to assign an alarm color to all pixels above the alarm temperature ■ Select **Below** to assign an alarm color to all pixels below the alarm temperature
Alarm output	■ **Color only** ■ **Silent** ■ **Beep**	■ Select **Color only** to assign only a color to the pixels when an alarm is triggered. ■ Select **Silent** to additionally make the font of the temperature result increase in size and be displayed against a red background (*i.e.* a visual alarm) ■ Select **Beep** to additionally make the camera trigger a beep when an alarm is triggered.
Delta alarm	N/A	Enter an delta alarm value by pressing the navigation pad left/right. ➲ This label is only available if **Update ref temp** has been previously selected in the **Settings** dialog box.
Ref temp	User-defined	For information purposes only. The reference temperature is calculated and updated 'on the fly'. ➲ This label is only available if **Update ref temp** has been previously selected in the **Settings** dialog box.
Alarm temp	User-defined	Enter a temperature value by pressing the navigation pad left/right.

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

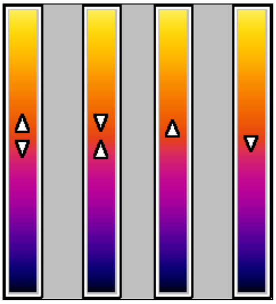

Figure 10.10 Symbols in the temperature scale, indicating (1) increasing span; (2) decreasing span; (3) increasing level, and (4) decreasing level

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

10438903;a2

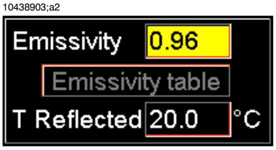

Figure 10.11 **Emissivity** dialog box

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 display an emissivity table and select a value from the table, press **Emissivity table**
- 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 123 and section 18 – Theory of thermography on page 133

➲ 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.

10.4.5 Palette

10382603;a4

Figure 10.12 **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.

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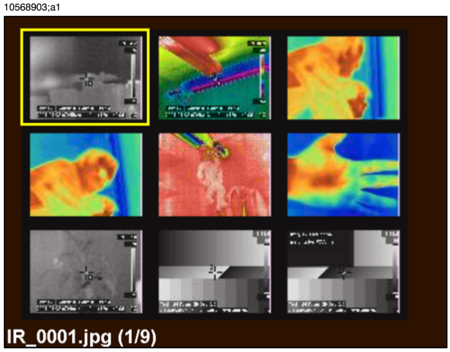
10.4.8 File

10567703;a2

Figure 10.13 File menu

Figure 10.14 Explanations of the **File** menu

Command	Explanation
Images	Point to **Images** and press the joystick to display a thumbnail view of the images in the internal camera memory. Open an image by selecting the image using the joystick, then pressing MENU/YES. 10568903;a1 
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.

Command	Explanation
Image description	Point to **Image description** and press MENU/YES to display the **Image description** dialog box. Using this feature, you can add a brief description to an image one of the following ways: ■ By sending a Pocket Word file (*.psw) from a PDA to the camera, using the IrDA infrared communication link ■ By letting the camera read any value of the first label in a standard FLIR Systems *.tcf file (text comment file) located in the camera file system, and use this value as the image description The image description can be read out by other software – e.g. ThermaCAM™ QuickView. ➲ For information about how to create files for image descriptions, see section 8.5 – Creating files for image descriptions on page 62

➲ Approx. >80 radiometric JPG images can be saved.

10.4.9 Setup

10383003;a4

Figure 10.15 **Setup** menu

10.4.9.1 Settings

10567203;a2

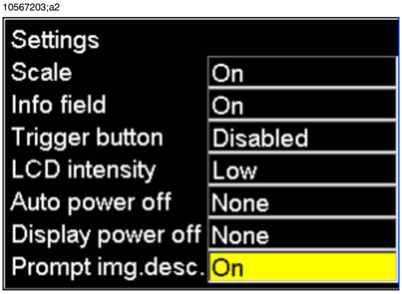


Figure 10.16 **Settings** dialog box

Figure 10.17 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

Label	Value	Explanation
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** ▪ **Update ref. temp.**	▪ 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 ▪ Select **Update ref. temp** to update the reference temperature when pulling the trigger If **Update ref. temp.** is selected: By pulling the trigger for more than 1 second, a dialog displaying the message **Restart ref temp at nn.n °C?** will appear. Do one of the following: ▪ Select **OK** to purge the internal camera buffer and begin a new sampling sequence ▪ Select **Cancel** to leave the dialog box
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
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.
Prompt img. desc.	▪ **On** ▪ **Off**	If you want to be prompted for adding an image description when saving an infrared image, select **On**.

➲ 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 10.18 **Date/time** dialog box

Figure 10.19 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

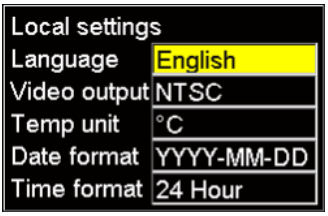


Figure 10.20 **Local settings** dialog box

Figure 10.21 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.

10581303;a1

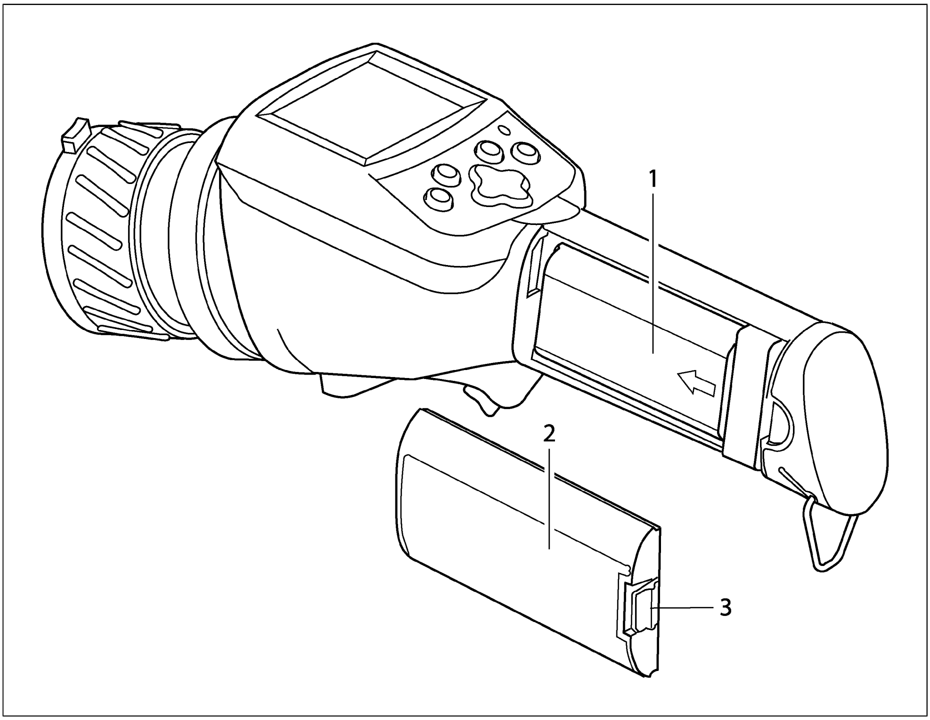

Figure 11.1 Battery and battery compartment

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

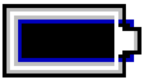

Figure 11.2 **Battery full** symbol

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

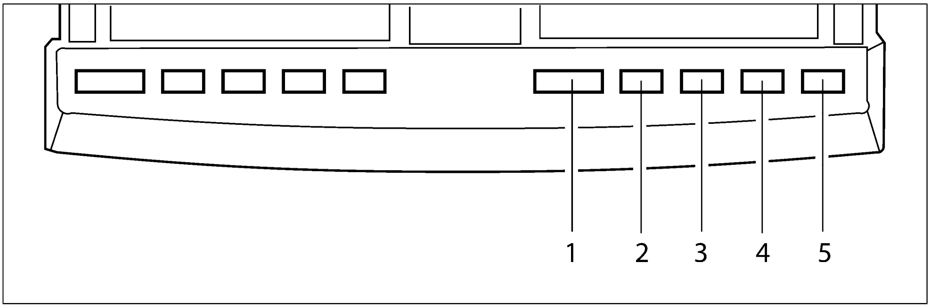

Figure 11.3 LED indicators on the external battery charger

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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Publ. No. 1558440 Rev. a156 – ENGLISH (EN) – February 28, 2006

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 320 × 240 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 252: -15–+45 °C (+5–+113 °F) For camera type 301: -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.

14.7 Physical specifications

Weight	0.8 kg (1.76 lb), including battery and 27.4 mm lens
Size (L × W × H)	259 × 80 × 135 mm (10.2 × 3.2 × 5.3") with 27.4 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

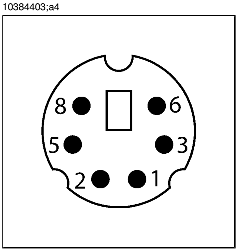

Figure 14.1 Pin configuration – RS-232/USB (on camera – operator's side)

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

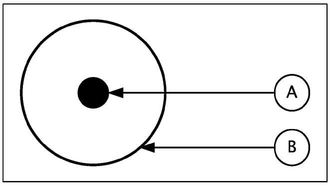

Figure 14.3 Pin configuration for power connector (on camera – operator's side). **A:** Center pin; **B:** Chassis

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

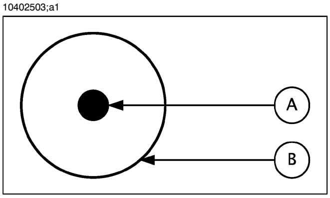

Figure 14.4 Pin configuration for CVBS connector (on camera – operator's side). **A:** Center pin; **B:** Chassis

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

10583303;a4

This table only applies to camera type number 252									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 46.2 mm									
Resolution: 320 x 240 pixels									
Field of view in degrees: 14.9									
D —>	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.13	0.26	0.53	1.32	2.63	6.58	13.16	26.32	**m**
VFOV	0.10	0.20	0.39	0.99	1.97	4.94	9.87	19.74	**m**
IFOV	0.41	0.82	1.65	4.11	8.23	20.56	41.13	82.25	**mm**
D —>	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.43	0.86	1.73	4.31	8.63	21.57	43.15	86.30	**ft.**
VFOV	0.32	0.65	1.29	3.24	6.47	16.18	32.36	64.72	**ft.**
IFOV	0.02	0.03	0.06	0.16	0.32	0.81	1.62	3.24	**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. 46.2 mm lens / camera type 252.

10583403;a4

This table only applies to camera type number 252									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 27.4 mm									
Resolution: 320 x 240 pixels									
Field of view in degrees: 25.0									
D —>	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.22	0.44	0.89	2.22	4.44	11.09	22.19	44.38	**m**
VFOV	0.17	0.33	0.67	1.66	3.33	8.32	16.64	33.28	**m**
IFOV	0.69	1.39	2.77	6.93	13.87	34.67	69.34	138.69	**mm**
D —>	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.73	1.46	2.91	7.28	14.55	36.38	72.75	145.51	**ft.**
VFOV	0.55	1.09	2.18	5.46	10.91	27.28	54.57	109.13	**ft.**
IFOV	0.03	0.05	0.11	0.27	0.55	1.37	2.73	5.46	**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 14.6 Horizontal, vertical and instantaneous fields of view for certain distances to targets. 27.4 mm lens / camera type 252.

10583503;a4

This table only applies to camera type number 252									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 14.7 mm									
Resolution: 320 x 240 pixels									
Field of view in degrees: 44.9									
D —>	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.41	0.83	1.65	4.14	8.27	20.68	41.36	82.72	**m**
VFOV	0.31	0.62	1.24	3.10	6.20	15.51	31.02	62.04	**m**
IFOV	1.29	2.59	5.17	12.93	25.85	64.63	129.25	258.50	**mm**
D —>	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	1.36	2.71	5.42	13.56	27.12	67.80	135.61	271.22	**ft.**
VFOV	1.02	2.03	4.07	10.17	20.34	50.85	101.71	203.41	**ft.**
IFOV	0.05	0.10	0.20	0.51	1.02	2.54	5.09	10.18	**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. 14.7 mm lens / camera type 252.

10726503;a2

This table only applies to camera type number 301									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 46.2 mm									
Resolution: 320 x 240 pixels									
Field of view in degrees: 17.7									
D --->	**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.16	0.31	0.62	1.56	3.12	7.79	15.58	31.17	**m**
VFOV	0.12	0.23	0.47	1.17	2.34	5.84	11.69	23.38	**m**
IFOV	0.49	0.97	1.95	4.87	9.74	24.35	48.70	97.40	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.51	1.02	2.04	5.11	10.22	25.55	51.10	102.19	**ft.**
VFOV	0.38	0.77	1.53	3.83	7.66	19.16	38.32	76.64	**ft.**
IFOV	0.02	0.04	0.08	0.19	0.38	0.96	1.92	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 14.8 Horizontal, vertical and instantaneous fields of view for certain distances to targets. 46.2 mm lens / camera type 301.

10726603;a2

This table only applies to camera type number 301									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 27.4 mm									
Resolution: 320 x 240 pixels									
Field of view in degrees: 29.4									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.26	0.53	1.05	2.63	5.26	13.14	26.28	52.55	**m**
VFOV	0.20	0.39	0.79	1.97	3.94	9.85	19.71	39.42	**m**
IFOV	0.82	1.64	3.28	8.21	16.42	41.06	82.12	164.23	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	0.86	1.72	3.45	8.62	17.23	43.08	86.16	172.31	**ft.**
VFOV	0.65	1.29	2.58	6.46	12.92	32.31	64.62	129.23	**ft.**
IFOV	0.03	0.06	0.13	0.32	0.65	1.62	3.23	6.47	**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. 27.4 mm lens / camera type 301.

10726703;a2

This table only applies to camera type number 301									
The three-digit camera type number is the three first digits in the camera S/N.									
Focal length: 14.7 mm									
Resolution: 320 x 240 pixels									
Field of view in degrees: 52.1									
D --->		**0.50**	**1.00**	**2.00**	**5.00**	**10.00**	**25.00**	**50.00**	**100.00**	**m**
HFOV	0.49	0.98	1.96	4.90	9.80	24.49	48.98	97.96	**m**
VFOV	0.37	0.73	1.47	3.67	7.35	18.37	36.73	73.47	**m**
IFOV	1.53	3.06	6.12	15.31	30.61	76.53	153.06	306.12	**mm**
D --->	**1.64**	**3.28**	**6.56**	**16.39**	**32.79**	**81.97**	**163.93**	**327.87**	**ft.**
HFOV	1.61	3.21	6.42	16.06	32.12	80.29	160.59	321.18	**ft.**
VFOV	1.20	2.41	4.82	12.04	24.09	60.22	120.44	240.88	**ft.**
IFOV	0.06	0.12	0.24	0.60	1.21	3.01	6.03	12.05	**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. 14.7 mm lens / camera type 301.

Figure 14.11 F-number and close focus limits for various lenses

IR lens →	**46.2 mm**	**27.4 mm**	**14.7 mm**
Close focus limit (m)	0.50	0.30	0.20
Close focus limit (ft.)	1.64	0.98	0.66
f-number	1.5	1.5	1.5

14

14.11 Camera – dimensional drawings

10583203;a2

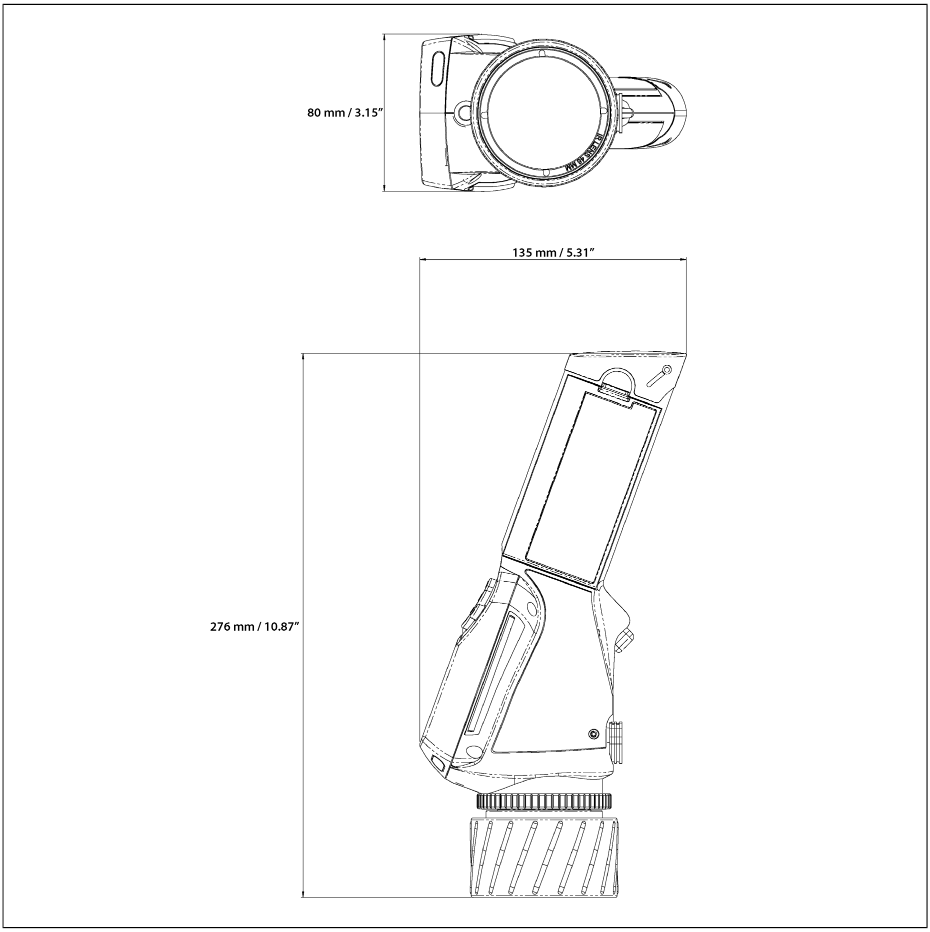

Figure 14.12 Overall dimensions of the camera with a 46.2 mm IR lens.

10583003;a2

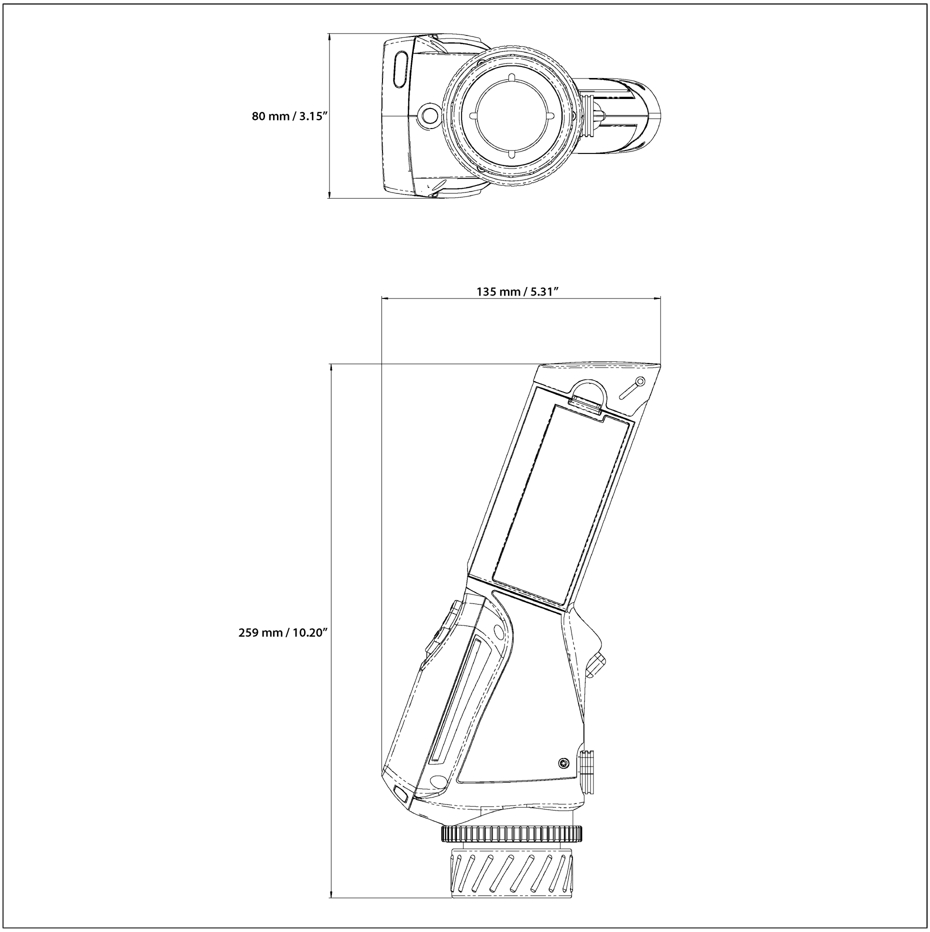

Figure 14.13 Overall dimensions of the camera with a 27.4 mm IR lens.

10583103;a2

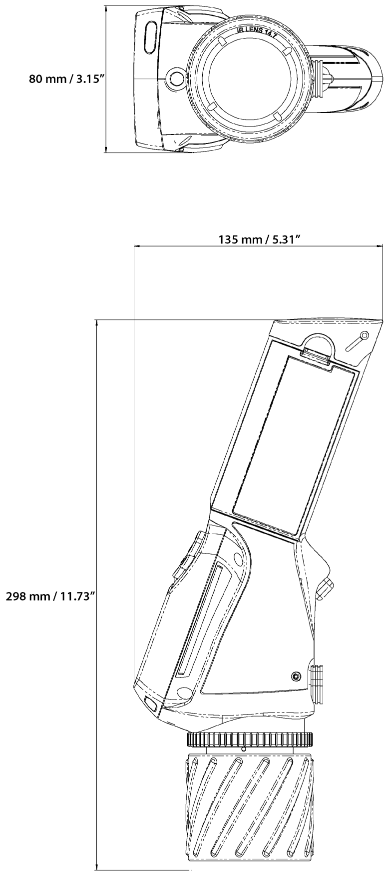

Figure 14.14 Overall dimensions of the camera with a 14.7 mm IR lens.

14.12 Battery charger – dimensional drawing

10387403;a4

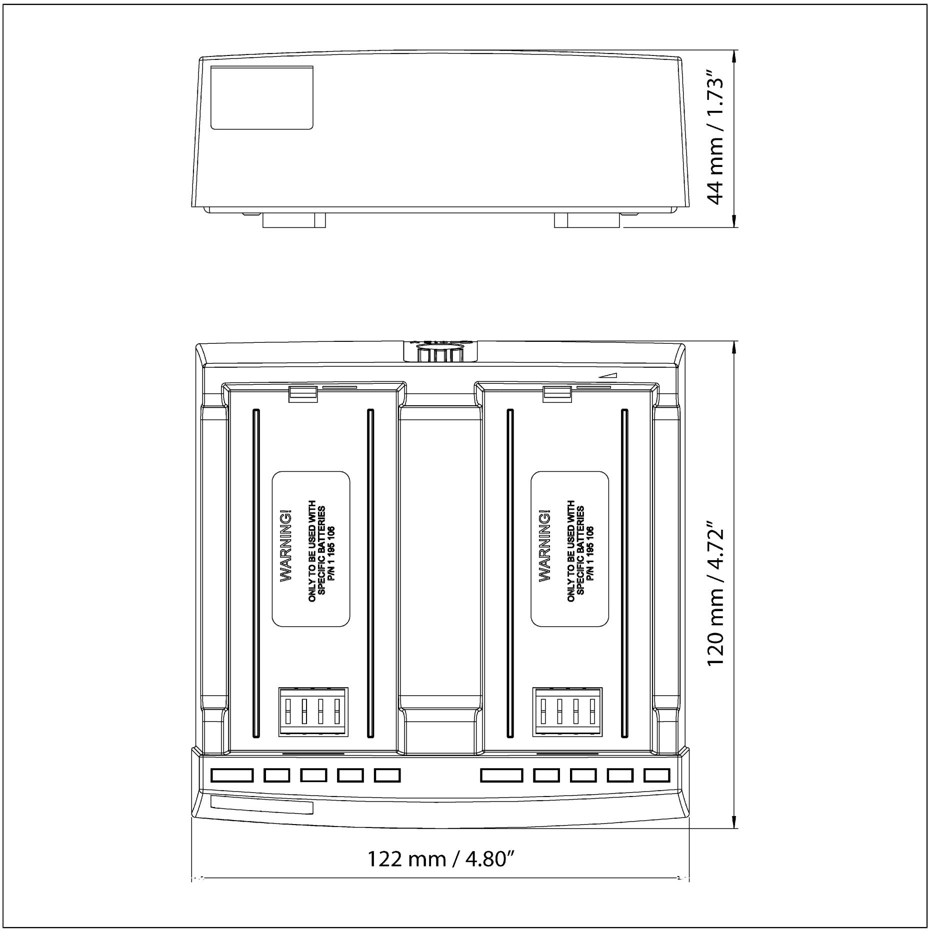

Figure 14.15 Overall dimensions of the battery charger

14.13 Battery – dimensional drawing

10387503;a4

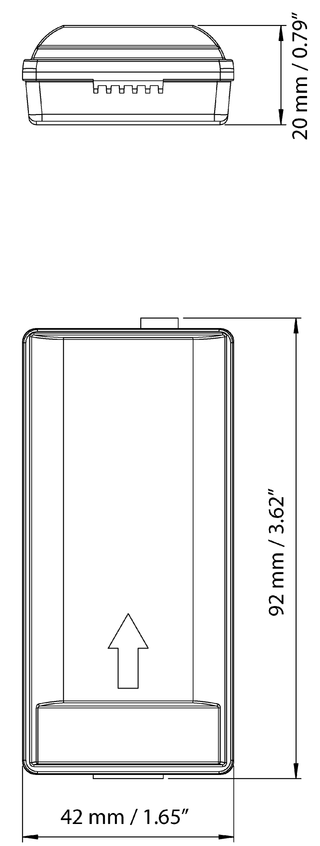

Figure 14.16 Overall dimensions of the battery

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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.

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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

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

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Look for possible reflection sources, considering that the incident angle = reflection angle (a = b).
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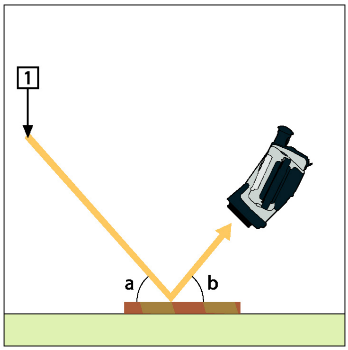


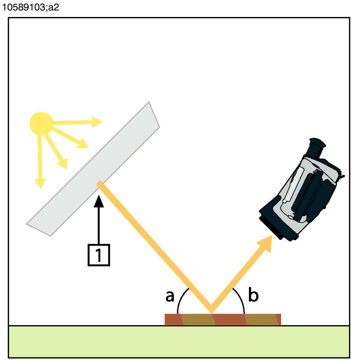
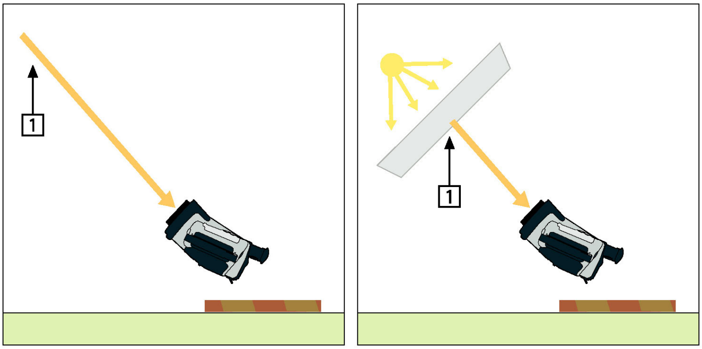
Figure 16.1 1 = Reflection source</td></tr>
<tr><td>2</td><td>If the reflection source is a spot source, modify the source by obstructing it using a piece if cardboard.
10589103;a2


Figure 16.2 1 = Reflection source</td></tr>
</table>

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

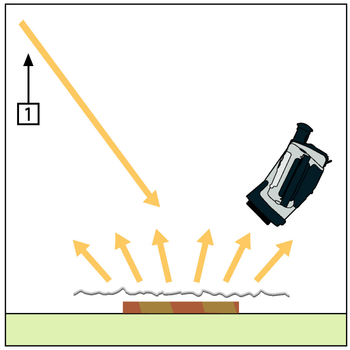
➲ Please note the following:

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

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.

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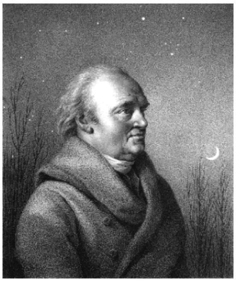

Figure 17.1 Sir William Herschel (1738–1822)

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.

10399103;a1

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.'

10399003;a2

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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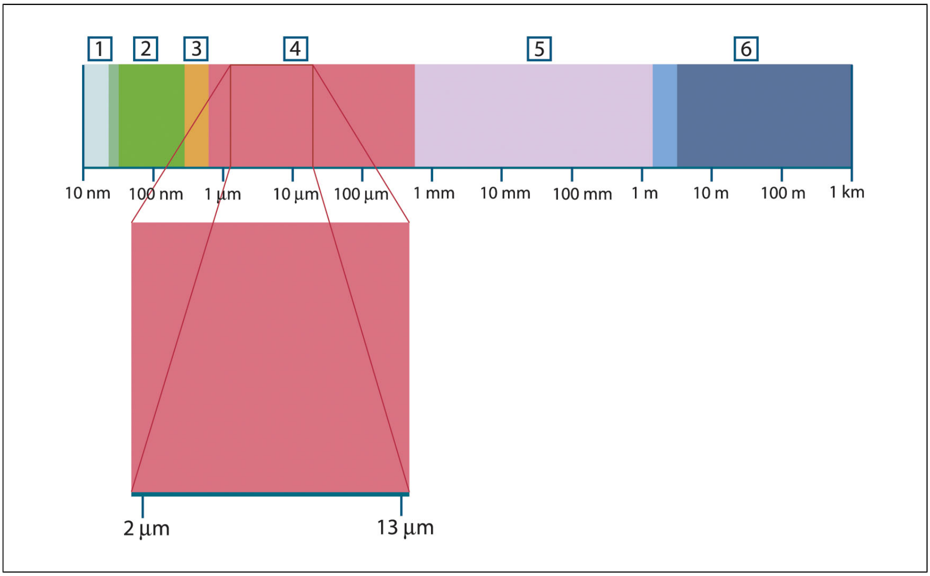

Figure 18.1 The electromagnetic spectrum. **1:** X-ray; **2:** UV; **3:** Visible; **4:** IR; **5:** Microwaves; **6:** Radiowaves.

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

10399203;a1

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:

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

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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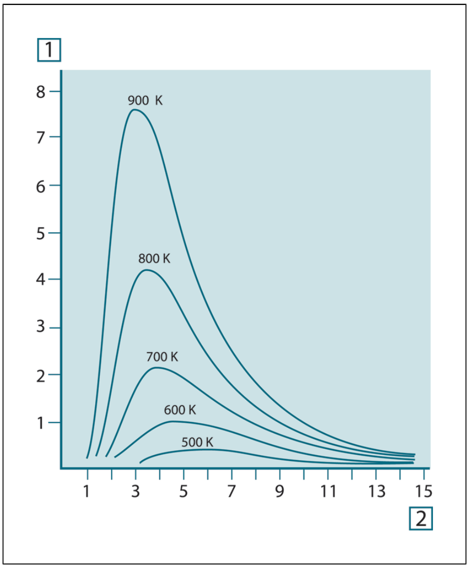

Figure 18.4 Blackbody spectral radiant emittance according to Planck's law, plotted for various absolute temperatures. **1:** Spectral radiant emittance ($W/cm^2 \times 10^3(\mu m)$); **2:** Wavelength (µm)

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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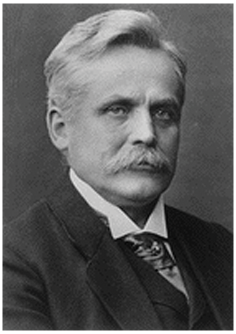

Figure 18.5 Wilhelm Wien (1864–1928)

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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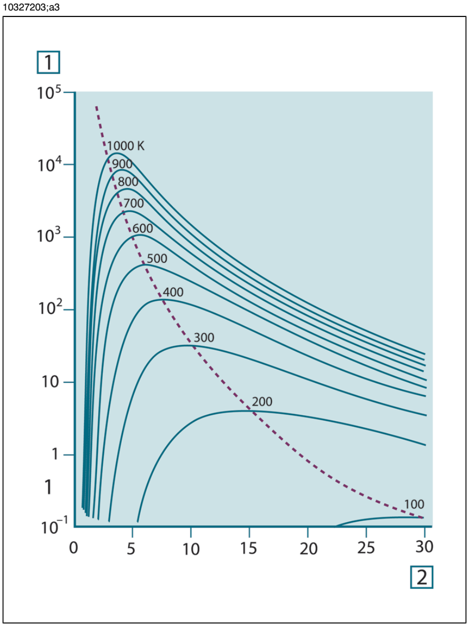

Figure 18.6 Planckian curves plotted on semi-log scales from 100 K to 1000 K. The dotted line represents the locus of maximum radiant emittance at each temperature as described by Wien's displacement law. **1:** Spectral radiant emittance (W/cm² (µm)); **2:** Wavelength (µm).

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.

10399303;a1

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:

$$\rho_\lambda = 1$$

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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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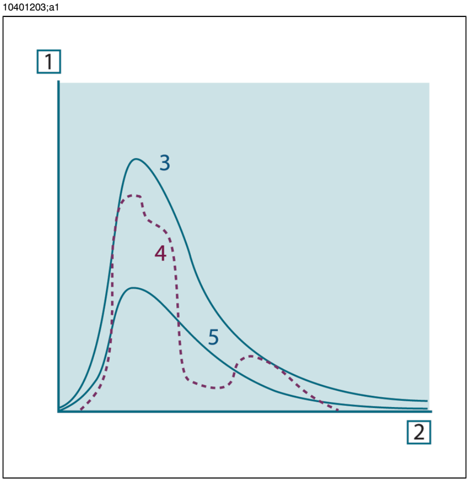

Figure 18.8 Spectral radiant emittance of three types of radiators. **1:** Spectral radiant emittance; **2:** Wavelength; **3:** Blackbody; **4:** Selective radiator; **5:** Graybody.

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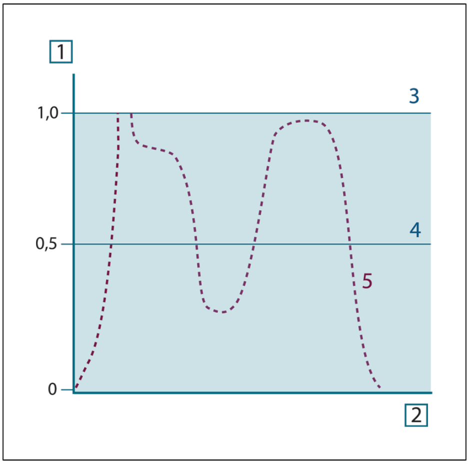

Figure 18.9 Spectral emissivity of three types of radiators. **1:** Spectral emissivity; **2:** Wavelength; **3:** Blackbody; **4:** Graybody; **5:** Selective radiator.

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.

19.1 References

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2	William L. Wolfe, George J. Zissis: *The Infrared Handbook*, Office of Naval Research, Department of Navy, Washington, D.C.
3	Madding, R. P.: *Thermographic Instruments and systems*. Madison, Wisconsin: University of Wisconsin – Extension, Department of Engineering and Applied Science.
4	William L. Wolfe: *Handbook of Military Infrared Technology*, Office of Naval Research, Department of Navy, Washington, D.C.
5	Jones, Smith, Probert: *External thermography of buildings...,* Proc. of the Society of Photo-Optical Instrumentation Engineers, vol.110, Industrial and Civil Applications of Infrared Technology, June 1977 London.
6	Paljak, Pettersson: *Thermography of Buildings*, Swedish Building Research Institute, Stockholm 1972.
7	Vlcek, J: *Determination of emissivity with imaging radiometers and some emissivities at $\lambda = 5\ \mu m$.* Photogrammetric Engineering and Remote Sensing.
8	Kern: *Evaluation of infrared emission of clouds and ground as measured by weather satellites*, Defence Documentation Center, AD 617 417.
9	Öhman, Claes: *Emittansmätningar med AGEMA E-Box*. Teknisk rapport, AGEMA 1999. (Emittance measurements using AGEMA E-Box. Technical report, AGEMA 1999.)

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

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

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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, carefully 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

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

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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

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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, un- treated	20	SW	0.90	6
Plaster	rough coat	20	T	0.91	2
Plastic	glass fibre lami- nate (printed circ. board)	70	LW	0.91	9
Plastic	glass fibre lami- nate (printed circ. board)	70	SW	0.94	9
Plastic	polyurethane isola- tion board	70	LW	0.55	9
Plastic	polyurethane isola- tion 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
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Wood		19	LLW	0.962	8
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Wood	planed	20	T	0.8–0.9	1
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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

The following file identities and file versions were used in the formatting stream output for this manual:

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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
20273903.xml a2
20275203.xml a3
R0095.rcp a1
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