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Non-destructive testing - Thermographic testing - Part 2: Equipment

Zerstörungsfreie Prüfung - Thermografische Prüfung - Teil 2: Geräte

Essais non destructifs - Essais thermographiques - Partie 2: Equipement

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Non-destructive testing - Thermographic testing - Part 2: Equipment

Essais non destructifs - Analyses thermographiques - Partie 2: Equipement

Zerstörungsfreie Prüfung - Thermografische Prüfung - Teil 2: Geräte

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European foreword

This document (EN 16714-2:2016) has been prepared by Technical Committee CEN/TC 138 “Non-destructive testing”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2017, and conflicting national standards shall be withdrawn at the latest by February 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

EN 16714, *Non-destructive testing — Infrared thermographic testing* consists of the following parts:

— *Part 1*: *General principles*

— *Part 2*: *Equipment*

— *Part 3*: *Terms and definitions*

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard describes properties and requirements of infrared cameras used for thermographic testing for non-destructive testing.

This document gives also examples of excitation sources, the properties and requirements are described in application standards for active thermography.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16714-3, *Non-destructive testing — Infrared thermographic testing — Part 3: Terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 16714-3 apply.

4 Equipment

4.1 Selection of infrared camera

The infrared camera (IR camera) has to be selected according to the application and the temperature of the inspected object.

IR camera relevant parameters are:

— spectral sensitivity;

— temperature range;

— thermal resolution;

— spatial resolution;

— frame rate;

— temporal resolution.

These parameters shall be provided by the manufacturer.

4.2 Classification of IR cameras

4.2.1 General

IR cameras are classified according to detector arrangement and working principle.

The classification according to the detector arrangement is:

— single element detector with two-dimensional opto-mechanical scanning;

— line scanner with one-dimensional opto-mechanical scanning or linear array;

— two-dimensional detector matrix without mechanical scanning (Focal Plane Array, FPA).

Mechanical scanning is achieved by moving mirrors and/or prisms. However, the frame rate is limited due to the scanning. They are therefore less applicable to capture fast processes than FPA-cameras.

The classification according to the detector working principle is:

— thermal detectors;

— quantum detectors.

Thermal detectors, e.g. microbolometers or pyroelectric detectors, work at room temperature. Quantum detectors have to be cooled down to very low temperatures. Cooling is accomplished with multi-stage Peltier elements (thermo-electric), liquid nitrogen, expansion devices or refrigeration machines (Stirling engine). Quantum detectors have a higher sensitivity (specific detectivity D*) and can achieve higher frame rates than thermal detectors.

IR cameras can be just imagers or radiometric calibrated devices. IR-imagers are sufficient for qualitative tasks like hot spot detection or analysis of radiation distributions. Radiometric calibrated IR-cameras allow for the measurements of radiance, temperature differences or absolute temperatures provided that object parameters, such as (but not limited to) emissivity and reflected apparent temperature are known.

IR cameras are adapted to the transmission properties of the atmosphere for infrared radiation (atmospheric windows):

— short Wave, SW: wavelength between approx. 0,8 µm and 2,0 µm;

— mid Wave, MW: wavelength between approx. 2,0 µm and 5,0 µm;

— long Wave, LW: wavelength between approx. 8,0 µm and 14,0 µm.

4.2.2 Temperature range

The temperature range is the interval between lowest and highest measurable temperature. The range should be specified for black-body temperatures (emissivity = 1).

NOTE 1 Temperature range means the total temperature range, which can consist of several partial measurement ranges that can be adjusted separately at the device.

NOTE 2 The use of optical components like spectral filters can alter the measurable temperature range.

4.2.3 Thermal resolution

The thermal resolution describes the ability of an IR camera to resolve small temperature differences. The thermal resolution is commonly described by the noise equivalent temperature difference (NETD, see A.5).

The thermal resolution depends among others on:

— the object temperature;

— the integration time or response time;

— the temperature range.

Therefore, it shall be specified at least with indication of these values.

The required thermal resolution depends strongly on the application.

NOTE Typical values for the thermal resolution for object temperatures around 300 K are 0,05 K for uncooled thermal detectors and 0,02 K for cooled quantum detectors.

4.2.4 Spatial resolution and lenses

The spatial resolution describes the ability of an IR camera to resolve small objects or details. The spatial resolution is commonly quantified with the *slit response function* (SRF, see A.3), *hole response function* (HRF, see A.4) or the *instantaneous field of view* (IFOV, see A.1) which is field of view for a single detector element.

These specifications are needed to calculate the spot size diameter. They depend not only on the camera itself but also on the field of view of the lens. The spot size diameter also depends on the distance between the camera and the object.

The required spatial resolution of the combination IR camera / lens depends strongly on the size of the investigated object or object detail.

NOTE A typical value for the horizontal viewing angle of a single detector element is 1 mrad (for a lens with a 20° field of view and a detector matrix of 320 horizontal detector elements).

The minimum resolvable temperature difference (MRTD, see A.6) considers thermal as well as spatial resolution of IR cameras including the observer. The MRTD characterizes the ability of the combined system IR camera and human observer to resolve small temperature differences at small structures in relation with the whole FOV (see A.2).

4.2.5 Frame rate and temporal resolution

The frame rate is the number of frames which are read out from the detector per time unit.

NOTE 1 If windowed frames are selected the frame rate can be higher.

The maximum frame rate is limited by the read out circuit. Other parameters such as (but not limited to) integration time, read out mode (integrate then read, integrate while read) and response time may also impact the maximum frame rate. Temporal and thermal resolution are closely connected.

For quantum detectors, for defined object conditions highest thermal resolution is achieved with long integration times, which in turn limits the maximum frame rate.

The temporal resolution of IR cameras is important for capturing moving objects (or for moving cameras) as well as fast temperature changes.

NOTE 2 Typical values for frame rates are for scanning cameras with a single detector element around 30 s^{-1}, for FPA cameras with uncooled thermal detectors around 60 s^{-1} and for FPA cameras with cooled quantum detectors up to 300 s^{-1} for full frames and up to 70 000 s^{-1} for windowed frames.

4.2.6 Operating temperature range

The operating temperature range is the intended ambient temperature range for operating the camera. The operating temperature range is provided by the manufacturer of the camera.

4.2.7 Storage temperature range

The storage temperature range is the intended ambient temperature for storing the camera. The storage temperature range is provided by the manufacturer of the camera.

4.2.8 Spectral filter

Spectral filters limit the spectral sensitivity range of IR cameras. They are used to adapt the camera to material specific emission or absorption properties and/or adjust the temperature measurement range.

In many cases MW cameras are used for analysing material properties because many absorption and transmission bands lay within the wavelength range between 2 µm and 5 µm. Examples are measurements through/on glass, plastics, flames, gases, etc. The absorption and transmission bands should be known beforehand so that the right filters can be chosen.

4.3 Accessories

4.3.1 Interchangeable lenses

Interchangeable lenses are used to adapt the camera system to specific spatial requirements of measurement tasks (image area, required minimal spatial resolution, working distance).

There are standard lenses, e.g. wide angle and telephoto lenses as well as accessory lenses for the measurement of small objects. For calibrated cameras the calibration process shall include each lens together with the camera.

4.3.2 IR mirrors

IR mirrors are flat highly polished metal surfaces that reflect infrared radiation. They are usually used for imaging of inaccessible objects or object parts.

4.3.3 IR protective windows

IR protective windows consist of materials with good transmission properties for infrared radiation. They are used to protect the lens from mechanical and/or chemical damage or high environmental temperatures.

4.3.4 IR camera protective housing

Protective housings protect IR cameras against extreme environmental conditions like:

— heat;

— dust;

— water;

— aggressive chemical substances;

— strong magnetic and electric fields;

— mechanical damage;

— explosive atmospheres.

4.3.5 Examples of excitation sources for active thermography

4.3.5.1 Flash lamps

Flash lamps heat up the surface of the investigated object with very short light pulses (pulse thermography).

4.3.5.2 Lamps, LED and laser

Lamps, LED and laser are used for modulated or pulsed excitation of the investigated object.

4.3.5.3 Hot or cold air

Hot or cold air is used for convective heating or cooling of the investigated object.

4.3.5.4 Induction coils

Induction coils are used for contactless heating of electrically conductive objects.

4.3.5.5 Mechanical excitation

Objects can also be excited by mechanical excitation (e.g. by ultrasound or vibration sources). Certain object areas are selectively heated up because of mechanical losses (e.g. hysteresis, Coulomb friction).

5 Function check and traceability

5.1 General remarks

The functioning of all devices has to be checked regularly. This includes checking of mechanical, optical, and electronic properties, as well as the correct functioning of the software.

5.2 Checks by the user

The following items shall be checked before starting a test:

— the starting procedure and general function check (live image, reaction on pushing buttons);

— image quality (focusing, thermal resolution, non-uniformity correction (NUC));

— data storage (store and open IR images);

— temperature calibration (e.g. with black-body): cameras that are used for quantitative measurements of temperatures or temperature differences shall be calibrated with sufficient accuracy according to the international temperature scale.

5.3 Additional checks by the camera supplier

Check of accuracy of temperature measurement according to traceable standards (new calibration if necessary).

5.4 Frequency of function checks

a) by the user: before every use and after any malfunction of the device;

b) by the camera supplier: according to the recommended service and calibration intervals.