# INTERNATIONAL STANDARD

# ISO 18434-1

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## Condition monitoring and diagnostics of machines — Thermography —

## Part 1:
## General procedures

*Surveillance et diagnostic de l'état des machines — Thermographie —*

*Partie 1: Procédures générales*



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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 18434-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.



ISO 18434 consists of the following parts, under the general title *Condition monitoring and diagnostics of machines — Thermography*:

— *Part 1: General procedures*



Image interpretation and diagnostics is to form the subject of a future Part 2.

## Introduction

This part of ISO 18434 provides guidance on the use of infrared thermography (IRT) as part of a programme for condition monitoring and diagnostics of machines. IRT can be used to identify and document anomalies for the purposes of condition monitoring of machines. These anomalies are usually caused by such mechanisms as operation, improper lubrication, misalignment, worn components or mechanical loading anomalies.

IRT is based on measuring the distribution of radiant thermal energy (heat) emitted from a target surface, and converting this to a map of radiation intensity differences (surface temperature map) or *thermogram*. The thermographer therefore requires an understanding of heat, temperature and the various types of heat transfer as essential prerequisites when undertaking an IR programme. Thermal energy is present with the operation of all machines. It can be in the form of friction or energy losses, as a property of the process media, produced by the actual process itself or any combination thereof. As a result, temperature can be a key parameter for monitoring the performance of machines, the condition of machines, and the diagnostics of machine problems. IRT is an ideal technology to do this temperature monitoring because it provides complete thermal images of a machine, or a machine component, with no physical attachments (non-intrusive), requires little set-up, and provides the results in a very short period of time.

An important advantage of radiation thermometers over contact thermometers is their speed of response. The measured energy travels from the target to the sensor at the speed of light. The response of the instrument can then be in milliseconds or even microseconds. Another advantage is the sensitivity of the instruments in that they can detect and display a thermal "picture" composed of the very subtle temperature differences of the target.



Although extremely useful, IRT has a limitation in that radiometric sensing is susceptible to unacceptable error when used on most low emissivity surfaces.

# Condition monitoring and diagnostics of machines — Thermography —

# Part 1:
# General procedures

## 1 Scope

This part of ISO 18434 provides an introduction to the application of infrared thermography (IRT) to machinery condition monitoring and diagnostics, where "machinery" includes machine auxiliaries such as valves, fluid and electrically powered machines, and machinery related heat exchanger equipment. In addition, IR applications pertaining to machinery performance assessment are addressed.

This part of ISO 18434:

— introduces the terminology of IRT as it pertains to condition monitoring and diagnostics of machines;



— describes the types of IRT procedures and their merits;



— provides guidance on establishing severity assessment criteria for anomalies identified by IRT;



— outlines methods and requirements for carrying out IRT of machines, including safety recommendations;



— provides information on data interpretation, and assessment criteria and reporting requirements;

— provides procedures for determining and compensating for reflected apparent temperature, emissivity and attenuating media.

This part of ISO 18434 also encompasses the testing procedures for determining and compensating for reflected apparent temperature, emissivity and attenuating media when measuring the surface temperature of a target with a quantitative IRT camera.

NOTE It is intended that future parts will address application-specific analysis guidelines.

## 2 Normative references

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

ISO 13372, *Condition monitoring and diagnostics of machines — Vocabulary*

ISO 13379, *Condition monitoring and diagnostics of machines — General guidelines on data interpretation and diagnostics techniques*

ISO 13381-1, *Condition monitoring and diagnostics of machines — Prognostics — Part 1: General guidelines*

ISO 17359, *Condition monitoring and diagnostics of machines — General guidelines*

 

ISO 18436-7, *Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 7: Thermography*

ASTM E1897, *Standard test methods for measuring and compensating for transmittance of an attenuating medium using infrared imaging radiometers*

## 3 Terms and definitions

For the purposes of this document the terms and definitions given in ISO 13372 and the following apply.

**3.1**
**apparent temperature**
uncompensated reading from an infrared thermography camera containing all radiation incident on the detector, regardless of its source

**3.2**
**attenuating media**
windows, filters, atmospheres, external optics, materials or other media that attenuate the infrared radiation emitted from a source

**3.3**
**black body**
ideal perfect emitter and absorber of thermal radiation at all wavelengths

NOTE This is described by Planck's law.



**3.4**
**emissivity**
$\varepsilon$
ratio of a target surface's radiance to that of a black body at the same temperature and over the same spectral interval



**3.5**
**infrared thermography camera**
**IRT camera**
instrument that collects the infrared radiant energy from a target surface and produces an image in monochrome (black and white) or colour, where the grey shades or colour hues are related to target surface apparent temperature distribution

NOTE Such images are sometimes called *infrared thermograms*.

**3.6**
**image processing**
converting an image to digital form and further enhancing the image to prepare it for computer or visual analysis

NOTE In the case of an infrared image or thermogram this could include temperature scaling, spot temperature measurements, thermal profiles, image manipulation, subtraction and storage.

**3.7**
**infrared**
**IR**
that portion of the electromagnetic continuum extending from the red visible wavelength, 0,75 µm, to 1 000 µm

NOTE Because of instrument design considerations and the infrared transmission characteristics of the atmosphere, most infrared measurements are made between 0,75 µm and 15 µm wavelengths.

 

**3.8**
**isotherm**
enhancement feature applied to an image, which marks an interval of equal apparent temperatures

**3.9**
**infrared thermography**
**IRT**
acquisition and analysis of thermal information from non-contact thermal imaging devices

**3.10**
**radiation, thermal**
mode of heat flow that occurs by emission and absorption of electromagnetic radiation, propagating at the speed of light

NOTE Unlike conductive and convective heat flow, it is capable of propagating across a vacuum. A form of heat transfer which allows IRT to work since infrared energy travels from the target to the detector by radiation.

**3.11**
**reflectivity**
$\rho$
ratio of the total reflected energy from a surface to total incident energy on that surface

NOTE 1 $\rho = 1 - \varepsilon - \tau$; for a mirror, reflectivity approaches 1,0; for a black body, $\rho = 0$.

NOTE 2 Technically, reflectivity is the ratio of the intensity of the reflected radiation to the total radiation; reflectance is the ratio of the reflected flux to the incident flux. In IRT, the two terms are often used interchangeably.



**3.12**
**reflected apparent temperature**
$T_{\text{refl}}$
apparent temperature of other objects that are reflected by the target into the infrared thermography camera



**3.13**
**repeatability**
⟨infrared thermography⟩ capability of an instrument to repeat exactly a reading on a fixed target over a short- or long-term interval

NOTE Repeatability is expressed in ± degrees or a percentage of full scale.

**3.14**
**signal processing**
manipulation of a temperature signal or image data for the purposes of enhancing or controlling a process

EXAMPLE 1 For infrared radiation thermometers: peak hold, valley hold, sample hold and averaging.

EXAMPLE 2 For scanners, cameras and imagers: isotherm enhancement, image averaging, alignment, image subtraction and image filtering.

**3.15**
**spatial measurement resolution**
measurement-spot size in terms of working distance

NOTE In an infrared radiation thermometer this is expressed in milliradians or as a ratio of the target-spot size (containing 95 % of the radiant energy, according to common usage) to the working distance. In scanners, cameras and imagers it is most often expressed in milliradians.

**3.16**
**target**
object surface to be measured

**3.17**
**thermogram**
thermal map or image of a target where the grey tones or colour hues represent the distribution of infrared thermal radiant energy over the surface of the target

**3.18**
**transmissivity**
**transmittance**
$\tau$
proportion of infrared radiant energy impinging on an object surface, for any given spectral interval, that is transmitted through the object

NOTE 1 $\tau = 1 - \varepsilon - \rho$

where

$\tau$ is transmissivity;

$\varepsilon$ is emissivity;

$\rho$ is reflectivity.

NOTE 2 For a black body, $\tau = 0$. Transmissivity is that fraction of incident radiation transmitted by matter.

**3.19**
**working distance**
distance from the target to the instrument, usually to the primary optic



## 4 Thermography techniques

There are several recognized IRT techniques in use throughout industry. *Comparative thermography* is the most common technique and it is normally used to provide the best available data in lieu of ideal, or absolute, thermal measurements. When encountering changing machinery operating conditions, the ability to perform rough emissivity estimates, and the ability to differentiate emissivity differences on machinery equipment, provides useful information for the condition monitoring and diagnostics of the machine under the less-than-ideal circumstances frequently encountered in the field. The confidence level of the information obtained depends on the IRT equipment used, the training and experience of the thermographer, and the detection method applied.

*Non-contact thermometry* using infrared thermal cameras is used when it is essential to know as precisely as possible the true temperature of a target. However, this technique is not normally used for condition monitoring and diagnostics.

Comparative thermography is normally used as part of a condition-monitoring process when such a process is implemented in accordance with ISO 17359. IRT can also be used as a primary or secondary technique for diagnosis and prognosis when these processes are carried out in accordance with ISO 13379 and ISO 13381-1 respectively.

## 5 Comparative thermography

### 5.1 Types of comparative thermography

Comparative thermography can be either *quantitative* or *qualitative*. The *quantitative* technique requires the determination of a temperature value to distinguish the severity of a component's condition. This value is determined by comparing the target's temperature to that of similar service equipment or baseline data. For high emissivity surfaces both temperature, $T$, and temperature difference, $\Delta T$, values are typically reliable provided good measurement techniques are followed. $T$ and $\Delta T$ values of low emissivity surfaces are often unreliable due to surface and environmental variations. In addition, many applications also require assigning values to observed thermal patterns for the purposes of analysis, trending, designating severity levels and assigning priorities.

However, there are many applications where quantitative data are not required to monitor the condition of machinery, or to diagnose a problem and recommend the appropriate corrective action. In these cases, *qualitative* techniques may be more than adequate.

## 5.2 Comparative quantitative thermography

The comparative quantitative thermography method is an accepted and effective method for evaluating the condition of a machine or component by determining approximate temperatures. It is very difficult to determine precisely the actual temperatures of a component using IRT in the field. This is due to a certain extent to the physics of IRT which must take into consideration the multiple parameters that enable a true absolute temperature measurement. These IRT considerations are: emissivity, reflectivity and transmissivity. As a result, estimates of these IRT considerations can be readily made to obtain a component's approximate temperature, which, in most cases, is more than sufficient to determine the severity of an adverse condition.

An example of comparative quantitative thermography would be that, if two or more machines are operating in the same environment and under the same load conditions, and one is experiencing an elevated temperature, this is usually an indication that a deteriorating condition may exist. However, the determination of the temperature difference would then assist in establishing the severity of the condition. In this example, a 5 °C differential would be considered minor, whereas a 100 °C differential may be considered to be critical. Also, knowing the approximate value of the elevated temperature would provide an indication that the temperature limit of a component may be approaching published values. Therefore, while qualitative measurements can also detect deficiencies, it is the quantitative measurements that have the capability of determining severity.



Since it is not always practical to determine the exact temperature, or even emissivities, of each machine surface, the alternative use of comparative thermography becomes more practical. Comparative measurement, unlike qualitative measurement, identifies a thermal deficiency by comparing the temperatures obtained using a consistent emissivity value, $\varepsilon_{default}$, for those surfaces of similar emissivity, i.e. across the surface of a single machine or between the surfaces of similar machines. The temperature *differential* between two or more identical or similar surfaces is measured numerically. Assuming that the environmental conditions and surface properties for both components are similar, the differential temperature for the given piece of equipment is recorded as being the amount above the normal operating temperature of the similar equipment.



The comparative measurement technique uses quick emissivity estimates, reflected apparent temperature and component distance measurements. The emissivity factors of the materials are obtained through experience.

It is possible to check the emissivities of the most commonly encountered materials in a plant to assign default values that can then be used when inspecting components with these materials.

Each plant must develop its own set of default values, as similar components in different plants may have different environments (such as cleanliness), or the equipment may have different surface finishes, and these varying conditions will result in different default values. Once emissivities, distances, and reflected apparent temperatures are estimated, these values are entered into the IRT camera to indicate a temperature value for each component. This type of measurement is effective when surveying many components. It is quick and it provides useful information for determining the severity of a component's condition.

## 5.3 Comparative qualitative thermography

Comparative qualitative measurement compares the thermal pattern or profile of one component to that of an identical or similar component under the same or similar operating conditions. When searching for differing thermal patterns or profiles, an anomaly is identified by the intensity variations between any two or more similar objects, without assigning temperature values to the patterns. This technique is quick and easy to apply, and it does not require any adjustments to the infrared instrument to compensate for atmospheric or environmental conditions, or surface emissivities. Although the result of this type of measurement can identify a deficiency, it does not provide a level of severity.

This IRT technique is used throughout most industries. It is very effective in identifying hot bearings or other abnormally hot machine components, hot spots in electrical equipment, undesirable hot electrical connections, leaking or blocked fluid heat exchange equipment and components (tubes), and fluid leaks from pressure vessels, pipes and valves.

## 6 Non-contact thermometry using infrared thermography cameras

The determination of the corrected temperature of a target using IRT can be difficult because of the many technical and environmental factors involved. As a result, absolute IRT measurements are done only if very precise temperature values, or small temperature differentials, are critical to a process. These determinations are normally attempted only under extremely controlled conditions. This type of measurement using IRT cameras is not normally used for condition monitoring.

## 7 Baseline measurements

For both comparative and absolute techniques, it is strongly recommended that baseline measurements be taken of critical plant equipment for diagnostic and prognostic reference. This is very important when making later IRT surveys of machines or components and comparing them with previous thermograms of the same machines operating under the same load and environmental conditions. This condition monitoring procedure is useful for identifying developing problems early, thus preventing major maintenance operations or catastrophic failures. Some examples of baseline measurements are contained in Annex C.



## 8 Safety

Prior to the commencement of work, minimum safety rules and guidelines shall be established in accordance with applicable local or national standards and regulations and particularly where hazardous environments may exist. An example of minimum safety rules and guidelines is contained in Annex B.

## 9 Calibration

Thermographers shall have IRT cameras calibrated to original equipment manufacturers' guidelines, or established industry practice. Documented calibration checks should be carried out using a traceable black-body reference in accordance with manufacturer's recommendations, client specification or any applicable industry standard. Quick calibration checks are recommended to be performed prior to each inspection or survey.

NOTE A quick check can be made, for example, by using the human face tear duct, boiling water or a melting ice cube, using the correct emissivities under ideal conditions.

## 10 Data collection

Data collection shall be carried out in accordance with the following.

a) Infrared inspections should be performed when environmental and physical conditions such as solar, wind, surface and atmospheric conditions and heat transfer are favourable to gathering accurate data.

b) The operating and environmental conditions under which data are acquired should be repeatable and consistent with normal conditions.

c) The thermographer shall ensure that all emissivity and reflected apparent temperature determinations are carried out in accordance with Annex A.

 