IEC 62693

Edition 1.0 2013-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial electroheating installations – Test methods for infrared electroheating installations

Installations électrothermiques industrielles – Méthodes d'essais relatives aux installations électrothermiques par rayonnement infrarouge

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ELECTROTECHNICAL
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PRICE CODE
CODE PRIX V

ICS 25.180.10 ISBN 978-2-83220-866-3

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INDUSTRIAL ELECTROHEATING INSTALLATIONS – TEST METHODS FOR INFRARED ELECTROHEATING INSTALLATIONS

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International Standard IEC 62693 has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing.

The text of this standard is based on the following documents:

CDV	Report on voting
27/877/CDV	27/902/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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INTRODUCTION

This standard on particular test methods for infrared electroheating installations is one of TC 27 standards that describe test methods for various types of electroheating installations.

Test methods for ovens under the scope of IEC 60397 [3][1] are also covered in this standard when infrared radiation is the intended heat transfer in such equipment – this is assumed to be valid above an actual or processing temperature of 700 °C, independently of the rated temperature of the oven.

This standard is solely concerned with tests for infrared equipment and installations. Tests that focus on the performance of infrared emitters will be covered by IEC 62798 [2] [11]. The rationale for this separation is that infrared installations are usually manufactured by other companies than infrared emitters. Still, infrared emitters are a very important and distinct part of infrared installations and a set of tests that allow for proper comparison of different infrared emitters will be valuable to manufacturers of infrared installations.

The major guiding principle in this standard is to define tests that can be performed with the usual test and measuring equipment available to most kinds of companies, large or small.

The tests focus on the performance and efficiency of installations, as these are of major interest for manufacturers and users of such installations. The tests are intended to enable a fair comparison of installations belonging to a given class. The standard includes considerations and tests concerned with energy efficiency, so that the tests can be used for assessment of energy use and for energetic optimisation of installations as well.

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1 Numbers in square brackets refer to the Bibliography.

2 Under consideration.

INDUSTRIAL ELECTROHEATING INSTALLATIONS – TEST METHODS FOR INFRARED ELECTROHEATING INSTALLATIONS

1 Scope and object

This International Standard specifies test procedures, conditions and methods according to which the main parameters and the main operational characteristics of industrial infrared electroheating installations are established.

A limitation of the scope is that the infrared emitters have a maximum spectral emission at longer wavelengths than 780 nm in air or vacuum, and are emitting wideband continuous spectra such as by thermal radiation or high pressure arcs.

In industrial infrared electroheating installations, infrared radiation is usually generated by infrared emitters and infrared radiation is significantly dominating over heat convection or heat conduction as means of energy transfer to the workload.

IEC 60519-1:2010 defines infrared as optical radiation within the frequency range between about 400 THz and 300 GHz. This corresponds to the wavelength range between 780 nm and 1 mm in vacuum. Industrial infrared heating usually uses infrared sources with rated temperatures between 500 °C and 3 000 °C; the emitted radiation from these sources dominates in the wavelength range between 780 nm and 10 µm.

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Installations under the scope of this standard typically use the Joule effect for the conversion of electric energy inside one or several sources into infrared radiation emitted onto the workload. Such infrared emitters are especially

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- thermal infrared emitters in the form of tubular, plate-like or otherwise shaped ceramics with a resistive element inside;
- infrared quartz glass tube or halogen lamp emitters with a hot filament as a source;
- non insulated elements made from molybdenum disilicide, silicon carbide or comparable materials;
- restive metallic heating elements made e.g. from nickel based alloys or iron-chromium-aluminium alloys;
- wide-spectrum arc lamps.

This standard is not applicable to

- infrared installations with lasers or light-emitting diodes (LEDs) as main sources – they are covered by IEC 62471:2006 [9], IEC 60825-1:2007 [6] and IEC/TR 60825-9:1999 [7];
- appliances for use by the general public;
- appliances for laboratory use – they are covered by IEC 61010-1:2010 [8];
- electroheating installations where resistance heated bare wires, tubes or bars are used as heating elements, and infrared radiation is not a dominant side effect of the intended use, covered by IEC 60519-2:2006 [5];
- infrared heating equipment with a nominal combined electrical power of the infrared emitters of less than 250 W;
- handheld infrared equipment.

The tests are intended to be used to enable a fair comparison of the performance of installations belonging to the same class.

Tests related to safety of the installations are defined in IEC 60519-12:2013. Tests related to the performance of infrared electroheating emitters are specified in IEC 62798:— [11].

Therefore, this standard is applicable to ovens and furnaces with resistive heating elements if they fall under the scope of this standard.

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.

IEC 60519-1:2010, *Safety in electroheating installations – Part 1: General requirements*

IEC 60519-12:2013, *Safety in electroheating installations – Part 12: Particular Requirements for infrared electroheating installations*

3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60519-12:2013 and the following apply.

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NOTE General definitions are given in the International Electrotechnical Vocabulary, IEC 60050 [2]. Terms relating to industrial electroheating are defined in IEC 60050-841.

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3.1 General

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3.1.1
installation class
group within a type of installation, using the same principle for processing the workload and the size of this as well as the production capacity

3.1.2
production capacity
measure of the production rate capability of equipment in normal operation

EXAMPLE Flow, mass or volume.

Note 1 to entry: The capacity does not refer to the volume of the working space.

3.1.3
electroheating efficiency, <of an installation>
ratio of the usable enthalpy increase in the workload to the electric energy supplied to it at the location of the equipment, during a cycle of batch operation or stationary operation during a suitable time period for measurements

[SOURCE IEC 60050-841:2004, 841-22-70, modified – The term itself has been modified and details with respect to the kind of operation have been added.]

3.1.4
electric conversion efficiency
quotient between the available electric active power output for the transfer to the workload, and the electric input active power from the supply network, at power settings for normal operation

Note 1 to entry: The concept does not apply to conversion of electric energy to infrared radiation by heated elements.

3.1.5
intended workload quality
product quality
degree to which a set of inherent characteristics of a processed workload fulfils requirements

Note 1 to entry: All workload that does not attain the intended workload quality is regarded as scrap or undergoes rework to reach intended workload quality.

3.2 States and parts

3.2.1
cold start-up
process by which the equipment is energised into hot standby operation, from the cold state, including all other start-up operations which enable the equipment to operate as intended

Note 1 to entry: This mode of operation applies to cases where there is a significant energy consumption needed for obtaining a state of the equipment allowing the actual processing of the workload.

3.2.2
holding power
electric power consumption during which the workload is kept in the treatment chamber at a specified temperature

Note 1 to entry: The temperature is typically maintained during a time intended to equalize the workload temperature.

Note 2 to entry: This mode of operation is not applicable for certain types of electroheating equipment.

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3.2.3
hot standby operation
mode of operation of the installation occurring immediately after normal operation

Note 1 to entry: This mode of operation of the installation is with its hot state remaining, without workload, and with the means of operation ready for prompt normal operation.

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3.2.4
normal operation
range of output settings with the normal workload in allowable working conditions of the installation, as specified in the manufacturer's documentation

3.2.5
shut-down operation
process by which the installation is de-energised safely into the cold state

3.2.6
port
entrance or exit opening in the treatment chamber or enclosure through which the workload moves

3.2.7
means of access
all structural features of the infrared electroheating installation which can be opened or removed without the use of a tool to provide access to the interior of the installation

3.3 Workload

3.3.1
normal workload
object intended to be processed as specified in the manufacturer's documentation

Note 1 to entry: The workload is called "charge" in some electroheating contexts.

Note 2 to entry: The workload includes any container, holder or other device necessary for the processing and which is directly or indirectly subjected to the output power.

3.3.2
dummy workload
artificial workload with known thermal properties, designed for accurate enthalpy increase measurements by absorbing the available output power

3.3.3
infrared dummy workload
IDW
dummy workload intended to mimic the physical behaviour of the workload, especially its radiation absorption behaviour, allowing for the effective measurement of specific parameters of the process

Note 1 to entry: Example for a specific parameter is the homogeneity of processing of the surface of the workload.

Note 2 to entry: This note applies to the French language only.

4 Boundaries of the installation during tests

4.1 Energy considerations

It is necessary to define boundaries or limits of the installation with respect to equipment and energy uses included in or excluded from considerations during tests and calculations. The following definitions of boundaries are intended to enable fair comparisons for both batch and continuous type installations:

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a) Energy of compression or decompression of steam, air or any other gas in the process chamber shall be included in the used and lost energy calculations of the installation.

b) Exo- or endothermic chemical energy involving any reactive gases in the processing of the workload shall be included.

c) Energy used for cooling action by any excess reactive and/or inert gases in the processing of the workload shall be included in the calculation of used and lost energy of the installation.

d) Energy used for cooling of the processed workload to ambient temperature or as preparation for further treatment as part of normal operation shall be included, but stated separately in the calculation of used and lost energy. If a part of this thermal energy is transferred back into the installation or process, this recycling of thermal energy shall be reported separately, to allow comparisons with other installations in the same class but without this feature. Thermal energy used outside the process shall not be included in reporting.

4.2 Batch type installations

Batch type installations are characterised by a discontinuous processing. If there are means of access, these are opened and a workload is placed inside the treatment chamber of the installation and then undergoes normal operation. The means of access are then reopened and the workload is removed from the treatment chamber and the installation either goes into hot standby operation with closed means of access, or the process is restarted with another workload.

Normal operation always includes heating and can also include one or more of the following sub-processes:

- closing and opening of means of access;
- pressurising of the treatment chamber;
- transport of the workload – this includes for example wobbling movement during operation;

- holding the workload at a specified temperature for a specified time;
- introducing reactive or protective gases into the treatment chamber – including deposition processes;
- free or forced cooling of the workload – for example, if cooling is necessary to avoid damage by exposing the hot workload to ambient atmosphere.

The energy used to perform these sub-processes shall be included. The spatial boundary of the installation with respect to the process is defined by:

a) an entrance port position where the workload is placed prior to normal operation or the equipment which transports the workload into the treatment chamber; this equipment and its energy use is a part of the installation;
b) an exit port position where the workload is placed after normal operation for removal, or the equipment which moves the workload out of the treatment chamber; this equipment and its energy use is part of the installation;
c) all equipment in between, including for example all switchgear, pumps, cooling means necessary to operate the equipment.

NOTE In vacuum equipment, the boundary between the infrared installation and another installation is typically a valve.

The cycle of batch operation relevant for measurement shall begin after hot standby operation.

4.3 Continuous type installations

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Continuous type installations are characterised by a continuous or semi-continuous processing. The workload is conveyed through the treatment chamber of the installation during normal operation. The steps of treatment occur at consecutive positions inside the installation as the workload is transported through it – for example in roll to roll operations or in sheet feed installations. This kind of installation usually goes into hot standby operation when no workload is conveyed.

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The normal operation always includes heating and can include one or more of the following sub-processes which occur at separated spatial positions inside the installation:

- holding the workload at a specified temperature;
- introducing reactive or protective gases – including deposition processes;
- free or forced cooling of the workload – for example if cooling is necessary to avoid damage by exposing the hot workload to ambient atmosphere.

The energy used to perform these processes shall be included. The boundary of the installation is defined by

a) the entrance and exit ports;
b) all equipment in between, including for example all switchgear, pumps, cooling means necessary for operation of the equipment.

The energy consumption of transport or roll handling in stand-alone installations is included in the used energy. It shall be stated separately in the calculations.

5 Types of tests and general test conditions

5.1 General

No tests are defined for installations in the cold state. All such tests are safety related and are not covered by the scope of this standard. Relevant safety related tests are described in IEC 60519-1 and IEC 60519-12.

5.2 List of tests

The following tests shall be conducted in the hot state of the installation during commissioning or when the installation is ready for normal operation as well as at regular intervals as specified by the manufacturer, following maintenance or after modifications:

a) influence of supply voltage on the performance, refer to 7.1;
b) energy consumption during cold start-up operation and time needed, refer to 7.2;
c) power consumption during standby operation, refer to 7.3;
d) power consumption during holding operation, refer to 7.4;
e) energy consumption during shutting down operation and time needed, refer to 7.5;
f) energy consumption during regular maintenance operation, refer to 7.6;
g) energy consumption during normal operation, refer to 7.7;
h) energy consumption during a full operation cycle and peak power consumption, refer to 7.8;
i) production capacity, refer to 7.9;
j) efficiency of energy transfer to workload, refer to Annex A;
k) processing range of the installation to perform the intended operation, refer to 7.11;
l) homogeneity of workload processing, refer to Annex B;
m) infrared radiation distribution inside the installation, refer to Annex C.

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Additional tests may be specified in the commissioning and operation manuals issued by the manufacturer or may be agreed between the manufacturer and user.

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5.3 Test conditions

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5.3.1 Operating conditions during tests

Operating conditions during tests shall be in the range of normal operation conditions and thus reflect the manufacturer's intended use of the installation while excluding extreme usage patterns, deliberate misuse or unauthorized modifications of the installation or its operating parameters.

5.3.2 Environmental conditions during tests

All tests shall be performed

a) under standardised environmental conditions, at ambient temperature in the range between 5 °C and 40 °C and air relative humidity of less than 95 %, or
b) at the point of use of the installation under the available and specified environmental conditions there.

The environmental conditions shall not exceed those defined for the intended purpose of the installation. All environmental conditions affecting measurement results shall be monitored during the tests and be part of the measurement report. This includes

- air temperature and humidity near the installation;
- temperature and humidity of cooling air drawn into the installation;
- exhaust air temperature;
- temperature of the workload when entering the installation;
- moisture content of the workload when entering the installation, if applicable.

5.3.3 Supply voltage

The supply voltage shall not exceed the limits defined for the intended purpose.

NOTE Limits of variation of line voltage are set in IEC 60038 [1].

The supply voltage to the installation shall be monitored during the tests.

All measurements of specific electrical values, such as power consumption or current shall include the data of the supply voltage.

5.4 Infrared dummy workload

The following aspects shall be considered when using an infrared dummy workload (IDW):

- in case of a planar workload, the IDW shall be planar;
- the IDW shall have the same size in batch processes or the same width in continuous processes as the intended workload, if effects covering the full usable size of the installation are to be tested;
- in case it is intended to process workloads with a complex shape, the IDWs shape shall include all relevant geometrical features of the normal workload;
- for the measurement of temperature homogeneity, the IDW shall have a comparable heat absorbing capacity, i.e. the factor of volume, density and heat capacity c_p;
- for the measurement of evaporation homogeneity, the IDW shall be made of the same material as the workload and be prepared with a comparable amount of evaporable substance;
- for the measurement of crosslinking homogeneity, the IDW shall be made of the same material as the workload.

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6 Measurements

6.1 General

More than a single measurement is recommended for the tests defined in this standard. For time resolved measurements a data logger or multi-channel electronic data acquisition system shall be used, which automatically measures and stores the necessary data in a computer readable format.

6.2 Time resolution

The necessary time resolution of the measuring equipment and the data saving rate of the storage devices depends on the installation and the specific tests to be undertaken. The measurement and storage frequency shall be so high that all relevant signal variations are recorded.

6.3 Measurements of electric data

6.3.1 All equipment for voltage measurement shall be of class 2.0 or better. The measuring equipment for a.c. current shall be able to show true rms independently of the waveform.

6.3.2 All equipment for current measurement shall be of class 2.0 or better. The current measuring equipment for a.c. current shall be able to measure true rms independently of the waveform.

6.3.3 All equipment for energy consumption measurement shall be of class 2.0 or better. The measuring equipment shall be able to measure active and reactive energy independently of the waveform.

6.3.4 All equipment for power consumption measurement shall be of class 2.0 or better. The measuring equipment shall be able to measure active and reactive power independently of the waveform.

6.3.5 Measurements of all electric values, which are part of a test of energy or power use of the installation shall be performed at the power inlet to the installation.

6.3.6 Measurements of all electric values, which are part of a test of energy or power use of the infrared emitters of the installation, shall be performed at the power outlet of the switchgear connected to the emitters; transformers, capacitor circuits or comparable devices necessary to drive the emitter are part of the switchgear.

6.3.7 Measurements of all electric values, which are part of a test of energy or power use of auxiliary equipment, shall be performed at the respective power outlet of the switchgear connected to that equipment.

6.3.8 Specific access points may be installed during manufacturing of the installation. Measuring equipment may be part of the switchgear; its energy use is considered as part of the energy use of the switchgear.

6.4 Temperature measurement

The kind of equipment used for temperature measurement depends for example on the task, temperature range, available information on the surfaces being measured, and accessibility.

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Contacting thermocouples are simple to use and reliable. They provide reliable and exact results if an intimate and non detachable contact to a surface of an object with high mass and good thermal conduction to the thermocouple is possible.

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Pyrometers and infrared cameras summarised as thermographic methods may be used for all surfaces at elevated temperature, when the emissivity of the surface is well known and when the surface is considered as lambertian – i.e. following a cosine law of angular emissivity. The used value of emissivity, the measurement wavelength and the presumed error of emissivity shall be included in all measurement reports.

The relative measurement error for all temperature measurements in compliance with this standard shall not exceed 5 % of the temperature of the measured value stated in °C. Measurement accuracy shall be included in the measurement report.

NOTE The German VDI/VDE 3511 series [19 – 26] provides information on best practices for temperature measurement in industry.

7 Technical tests

7.1 Installation performance dependence on supply voltage

The actual supply voltage or its variation influences the performance of the infrared electroheating installation, if the infrared emitters operate on this directly or via fixed transformers. This effect can be even larger, if the actual supply voltage or the declared supply voltage differs from the rated supply voltage.

The variation of power consumption of individual infrared emitters with their applied working voltage depends on the type of emitter. This data may be supplied by the manufacturer of the emitter and the variation of power consumption with its actual working voltage

- shall either be calculated using this data,