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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial microwave heating installations – Test methods for the determination of power output

Installations industrielles de chauffage à hyperfréquence – Méthodes d'essai pour la determination de la puissance de sortie

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL MICROWAVE HEATING INSTALLATIONS – TEST METHODS FOR THE DETERMINATION OF POWER OUTPUT

FOREWORD

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International Standard IEC 61307 has been prepared by IEC technical committee 27: Industrial electroheating.

This third edition cancels and replaces the second edition published in 2006. It constitutes a technical revision .

This edition includes the following significant technical changes with respect to the previous edition:-

a) it covers how to measure not only the microwave power output of all typical equipment designs, but also the system efficiency, including the standby and hibernation modes;
b) the handling of the former A and B types of equipment is replaced by measurements of the available microwave power output and microwave workload power, respectively.

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

CDV	Report on voting
27/761/CDV	27/782/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.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INDUSTRIAL MICROWAVE HEATING INSTALLATIONS – TEST METHODS FOR THE DETERMINATION OF POWER OUTPUT

1 Scope

This International Standard specifies test methods for the determination of the available microwave output power and the efficiency of frequency conversion from the electrical input in industrial microwave heating installations.

This standard also specifies test methods for assessing the microwave power deposition in the microwave workload – the microwave workload power, in microwave-only installations.

This standard is applicable to industrial microwave heating equipment and installations in the frequency range from 300 MHz to 300 GHz.

This standard relates to industrial microwave heating equipment operating under normal load.

This standard does not apply to appliances for household and similar use (covered by IEC 60335-2-25), commercial use (covered by IEC 60335-2-90) or laboratory use (covered by IEC 61010-2-010).

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.

IEC 60050-221:1990, *International Electrotechnical Vocabulary – Chapter 221: Magnetic materials and components*
Amendment 1(1993)
Amendment 2 (1999)
Amendment 3 (2007)

IEC 60050-841:2004, *International Electrotechnical Vocabulary – Part 841: Industrial electroheat*

IEC 60050-726:1982, *International Electrotechnical Vocabulary – Chapter 726: Transmission lines and waveguides*

IEC 60519-6, *Safety in electroheat installations – Part 6: Specifications for safety in industrial microwave heating equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60519-6 and IEC 60050-841 as well as the following apply.

3.1
calorimetric power meter
calorimeter power meter
power meter which uses temperature rise in a medium as a means of measuring absorbed power

NOTE The medium, typically water, is either the power-absorbing agent or has heat transferred to it from a power-absorbing element.

[IEC 60050-726:1982, 726-21-10]

3.2
circulator
passive device having three or more ports in which the power entering any port is transmitted to the next port according to a given order of sequence

NOTE The typical forms are junction circulators [IEC 60050-221:1990, 221-05-14] of the T junction [IEC 60050-726:1982, 726-17-12] or Y junction [IEC 60050-726:1982, 726-17-13].

[IEC 60050-221:1990, 221-05-11, modified]

3.3
cross coupling (between generators)
appearance of undesired microwave energy in a microwave generator or the transmission line output port of a microwave generator assembly caused by one or several other microwave generators or microwave generator assemblies

3.4
electrical efficiency of microwave heating equipment
quotient between the available microwave power output and the electric input to the mains frequency power supply or microwave generator assembly, at power settings for normal operation

3.5
insertion loss
loss resulting from the insertion of a network into a transmission system, the ratio of the power delivered to that part of the system following the network, before insertion of the network, to the power delivered to that same part after insertion of the network

NOTE The insertion loss is generally expressed in decibels.

[IEC 60050-726:1982, 726-06-07]

3.6
isolation (of a three-port circulator)
reverse attenuation between the main output port and main input port, with all ports being impedance matched

NOTE 1 The isolation should not be confused with the reverse loss occurring between adjacent ports.

NOTE 2 This is a special case of cross coupling of a circulator [IEC 60050-726:1982, 726-16-06].

3.7
means of access
all structural features of the microwave heating equipment which can be opened or removed without the use of a tool to provide access to the interior of the microwave applicator or microwave cavity

3.8
microwave applicator
structure which applies the microwave energy to the load

[IEC 60050-841:2004, 841-29-11]

3.9
microwave cavity
space enclosed by inner metal walls and a door or an access opening and in which the microwave load is placed

[IEC 60050-841:2004, 841-29-19, modified]

3.10
microwave enclosure
structure which is intended to confine the microwave energy to a defined region

NOTE Examples are a cavity, door seals and waveguides.

[IEC 60050-841:2004, 841-29-20]

3.11
microwave generator
source used to produce electromagnetic energy in the frequency range from 300 MHz to 300 GHz

[IEC 60050-841:2004, 841-29-16]

NOTE In the context of this standard, the microwave generator is only the component where the frequency conversion takes place. See 3.2.

3.12
microwave generator assembly
part of the microwave heating equipment comprising an apparatus producing microwave energy and its associated transmission line output port

NOTE 1 The assembly includes the microwave generator, the power supply of the microwave generator and its ancillary and control circuits. If a circulator is used, it is also included.

NOTE 2 Microwave heating equipment containing a microwave generator assembly was classified as Type A in earlier editions of this standard; equipment where a transmission line output port is not available was classified as Type B.

3.13
microwave heating equipment
assembly of electric and mechanical devices intended for the transfer of microwave energy to the microwave load and comprising in general power supplies, microwave generators or microwave generator assemblies with cooling arrangements and circulators if used, microwave applicators or cavities with ventilation arrangements if used, interconnecting cables and waveguides, control circuitry, and means for transporting the microwave load if used

[IEC 60050-841:2004, 841-29-06, modified]

3.14
microwave load
objects introduced into the applicator or cavity, or put in the intended position near an open applicator

[IEC 60050-841:2004, 841-29-12]

3.15
microwave transparency
property of a material having negligible absorption and reflection of microwaves

NOTE The relative permittivity of a microwave transparent material is usually less than 7 and the loss factor is usually less than 0,015. However, if the microwave workload has a low loss factor, more stringent requirements apply.

[IEC 60050-841:2004, 841-29-14, modified]

3.16
microwave workload
object to be treated by microwaves

[IEC 60050-841:2004, 841-29-13]

NOTE Workload containers are not a part of the microwave workload but of the microwave load.

3.17
normal load
nominal microwave load at full microwave output power as specified by the manufacturer's documentation

3.18
normal operation
range of microwave output power with the normal loads in allowable working conditions of the microwave heating equipment, as specified by the manufacturer's documentation

3.19
standby (mode of) operation
condition allowing immediate normal operation

NOTE 1 This mode typically occurs immediately before and after normal operation.

NOTE 2 If the treatment of the workload requires non-ambient conditions such as elevated temperature, this is maintained.

NOTE 3 By "immediate" is meant a time period consistent with normal loading, unloading or replacement of the workload.

NOTE 4 The magnetron cathode heater circuit may be switched on in this mode of operation.

4 Methods of microwave power measurements

4.1 General

Three different methods are described. Their applicability depends on the microwave frequency and power level, and if the equipment comprises a microwave generator assembly.

NOTE 1 Since the wavelength of frequencies above about 20 GHz is very short, the power deposition may be of the irradiation type with a short penetration depth. Water may not be useable with the calorimetric method, and some of the methods of measuring microwave power deposition in this standard may not be applicable. In the low end of the microwave band at 300 MHz, the microwave absorption capability of loads may be highly variable during the heating process, large load masses may be needed, and representative artificial liquid loads for calorimetry may be difficult to use.

NOTE 2 There are variabilities of the microwave absorption capability of microwave loads, and in particular the unevenness of heating of these. Therefore, the microwave workload power data or the effective microwave power data with a substitute liquid load obtained according to this standard should be treated with care. Power data is, however, important and objective factors related to the overall energy utilisation efficiency are by that also a performance factor.

NOTE 3 A method for measuring the microwave power output in household microwave ovens is specified in IEC 60705. It uses a large water load, with compensation of heat capacity of the container and of heat exchange with ambient. Technically, the method gives what is defined as the available microwave power output in this standard.

4.2 Available microwave power output

Measurements at the microwave generator assembly output port give the available microwave power output (see Clause 5).

4.3 Microwave workload power

Calorimetric measurements in a normal load, including the power losses in any containers for the microwave workload, give the microwave workload power (see Clause 6).

This is the amount of power required to achieve an aimed enthalpy change in the microwave workload within a fixed period of time. It depends on the type of microwave workload, the change of its complex permittivity with temperature, as well as any workload containers or supports, and the design of the microwave applicator or cavity.

The available microwave power output is always larger than the microwave workload power, due to some or all of the following power loss mechanisms:

– impedance mismatching of the microwave generator;
– microwave enclosure metal surface losses;
– absorption by imperfect microwave transparency of containers for the workload and any other ancillary objects in the microwave enclosure;
– microwave leakage out of the microwave enclosure;
– power losses due to cross coupling.

4.4 Effective microwave power and efficiency

Typically, actual microwave workloads are not well suited for calorimetric measurements. Liquid substitutes are then used in calorimetric measurements, and give the effective microwave power (see Clause 7 and Clause 8).

5 Calorimetric power measurements

5.1 General

Only the principles are outlined in this standard. The applied measurement instrumentation and use shall conform to known engineering techniques. Water is the directly or indirectly power-absorbing substance.

5.2 Direct water power measurements

It is important that any directly power-absorbing water has a microwave absorption capability and load geometry which provides a good and essentially temperature independent impedance matching over the actually used temperature interval. A sodium chloride solution with specific conductivity between 200 µS/cm and 600 µS/cm shall be used for the direct absorption at frequencies below 900 MHz.

The power meter typically consists of a waveguide section, equipped with a microwave transparent tube through which the water can flow. The water shall be thoroughly mixed. The recommended water flow rate is about 1 l/min for each kilowatt but not less than 0,5 l/min. The difference between the outlet and inlet temperature shall be at least 10 K.

The inlet temperature of the water shall not exceed 35 °C, and the outlet temperature shall not exceed 60 °C. However, for microwave power levels less than 3 kW, these temperatures should be on both sides of the ambient temperature, to reduce heat loss errors.

Under operating conditions, the voltage standing wave ratio (VSWR) as measured by a network analyser with a matched waveguide transition or an equivalent measurement device replacing the microwave generator assembly and within the water temperature interval specified above, shall not exceed 1,25.

If a circulator is used, its isolation shall be greater than 20 dB and the impedance matching of the circulator with dissipative termination is to comply with this subclause.

The water flow shall be monitored, for instance by means of flow interlock switches, to avoid the formation of steam which may lead to eruption.

The power dissipated in the water is measured directly or compared with a calibrated heated water standard.

The measurement shall be carried out only when the flow rate is stable, and both the microwave generator and load operate under stable conditions. It is necessary to use high-accuracy thermometers and flowmeters to ensure that the inaccuracy of power output measurement is less than 5 %.

The available microwave power output P is calculated from the following equation:

$$P = \frac{4187 \cdot Q \cdot \Delta T}{60} \qquad (1)$$

where

P is the available microwave power output, in W;

Q is the water flow rate, in kg/min; the factor 4187 is its specific heat in J/(kg · K) and 60 is a factor resulting from units applied;

ΔT is the temperature difference in K between the water outlet and inlet temperature.

NOTE If the microwave generator assembly contains a circulator with a dissipative termination protecting the microwave generator, this may be used as power meter by short-circuiting the load port. It is then to be noted that twice the insertion loss applies for this measurement, but not in the evaluation for determination of the available microwave power output.

5.3 Dummy load power measurements

The dummy load is a matched low-reactance resistor, cooled by natural air convection, by forced air or by water. It is generally connected to the microwave generator or generator assembly by a 50 W coaxial feeder, or by a TE10 waveguide. At low power levels, natural air convection is applied and at higher power levels up to about 2 kW, forced air cooling can be applied.

NOTE Applicable dummy loads in two-port design are commercially available, providing a calibrated insertion loss at levels of -30 dB to -60 dB, suitable for the use of a commercially available power meter at its output port.

It is necessary to use high-accuracy components and instruments, to ensure that the inaccuracy of power output measurement is less than 5 %.

6 Determination of microwave workload power

This test is applicable only if the normal load is well specified with regard to specific heat and temperature rise in the process. Furthermore, it shall be possible to accurately measure the average temperature rise after processing. If the set-up is suspected to provide an inaccuracy of more than 5 % of the final result, the method described in Clause 5 or Clause 7 is instead used.

NOTE Typically, accurate tests according to this clause can be made only in continuous processing of pumpable workloads. These loads are representative only if their microwave properties are similar to those of the normal load.

The input temperature T_{in} (°C) of the microwave workload is measured. During steady-state processing, a suitable length of processed microwave workload exiting the microwave heating equipment during a predetermined time t (s) is quickly taken out as sample and thermal insulation is provided. Temperature equilibration is then accomplished by either forced convection (stirring or kneading of the sample) or by internal heat conduction, after which the output temperature T_{out} and the mass m of the sample are measured. Its specific heat c has been pre-determined.

The microwave workload power P_w is then calculated from the following equation: