BS EN 60519-6:2011

BSI Standards Publication

Safety in electroheat installations

Part 6: Specifications for safety in industrial microwave heating equipment

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National foreword

This British Standard is the UK implementation of EN 60519-6:2011. It is identical to IEC 60519-6:2011. It supersedes BS EN 60519-6:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/27, Electroheating.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Safety in electroheat installations - Part 6: Specifications for safety in industrial microwave heating equipment (IEC 60519-6:2011)

Sécurité dans les installations électrothermiques - Partie 6: Spécifications pour les installations de chauffage industriel à hyperfréquences (CEI 60519-6:2011)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

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Foreword

The text of document 27/704/CDV, future edition 3 of IEC 60519-6, prepared by IEC TC 27, Industrial electroheating, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60519-6 on 2011-03-03.

This European Standard supersedes EN 60519-6:2002.

The significant changes with respect to EN 60519-6:2002 are as follows:

– the third edition of EN 60519-1:2003 has been taken into account (the structure of clauses was adapted to it as far as practicable);

– some definitions are modified or brought into line with IEC 60050-841:2004;

– clauses on abnormal operation, access openings, microwave enclosure and barriers are added;

– the microwave leakage measurements are in a normative Annex A;

– an informative Annex B on the rationales for microwave exposure and leakage limits is added;

– Bibliography is added.

This part of EN 60519 is to be used in conjunction with EN 60519-1:2003. It is intended to specify particular requirements for industrial microwave heating equipment. This Part 6 supplements or modifies the corresponding clauses of EN 60519-1, so as to convert it into an EN standard. Where a particular sub-clause of Part 1 is not mentioned in this Part 6, that sub-clause applies as far as is reasonable. Where this standard states "addition", modification" or "replacement", the relevant text of Part 1 is to be adapted accordingly.

NOTE Sub-clauses and notes which are additional to those in Part 2 are numbered starting from 101, additional items and annexes are lettered aa, bb or AA, BB, etc.

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

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-12-03
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-03-03

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60519-6:2011 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60335-2-25	NOTE	Harmonized as EN 60335-2-25.
IEC 60335-2-90	NOTE	Harmonized as EN 60335-2-90.
IEC 61010-2-010	NOTE	Harmonized as EN 61010-2-010.
IEC 62311:2007	NOTE	Harmonized as EN 62311:2008 (modified)

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-841	2004	International Electrotechnical Vocabulary (IEV) - Part 841: Industrial electroheat	-	-
IEC 60519-1	2003	Safety in electroheat installations - Part 1: General requirements	EN 60519-1[1)]	2003
IEC 61307	-	Industrial microwave heating installations - Test methods for the determination of power output	EN 61307	-
IEC 60417-DB	-	Graphical symbols for use on equipment	-	-

[1)] EN 60519-1 is superseded by EN 60519-1:2011, which is based on IEC 60519-1:2010.

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INTRODUCTION

This edition of IEC 60519-6 contains updates and revisions of IEC 60519-6:2002, which was used over several years. It specifies safety requirements for industrial microwave heating equipment and installations specially designed for specific applications, unlike household, commercial and laboratory microwave appliances. Criteria for discrimination between these categories are dealt with in the scope.

SAFETY IN ELECTROHEAT INSTALLATIONS –

Part 6: Specifications for safety in industrial microwave heating equipment

1 Scope

This part of IEC 60519 is applicable to equipment using microwave energy alone or in combination with other kinds of energy for industrial heating of materials.

This part is applicable to industrial microwave heating equipment operating in the frequency range 300 MHz to 300 GHz.

NOTE 1 Since the wavelength of the high end of the microwave band at 300 GHz is very short and particular leakage measurement instrumentation is needed in the low end of the band, the microwave leakage specification in Annex A applies only for the ISM frequencies between 800 MHz and 6 GHz. The centre frequencies of these are 2,45 GHz and 5,8 GHz universally, and between 896 MHz and 918 MHz in some regions. For such microwave equipment IEC 62311 applies. For other microwave frequencies, the basic restriction as addressed in informative Annex B or the ICNIRP Guidelines (see Bibliography) may be used.

This part 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).

NOTE 2 Since microwave tunnel ovens and also some other types of microwave equipment may be either for commercial, laboratory or industrial use, the following criteria are suitable for determination of the classification as industrial equipment:

– commercial equipment is typically designed and planned for series production of many identical units, whereas industrial equipment is typically produced in small series or even as single units. The processed goods are consumed or ready for final use at the end of the heating process.
– laboratory heating equipment is for preparing material in a laboratory environment, and the processed material is immediately available for investigations or further processing. Regular production of large quantities of material is not foreseen.
– with industrial equipment, the processed goods are not immediately accessible to the end user, and the goods may additionally not be in a final state from the perspective of the end user.

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

IEC 60417, *Graphical symbols for use on equipment*

IEC 60519-1:2003, *Safety in electroheat installations – Part 1: General requirements*

IEC 61307, *Industrial microwave heating installations – Test methods for the determination of power output*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60519-1:2003 and IEC 60050-841, as well as the following apply.

3.1
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]

3.2
microwave applicator
structure which applies the microwave energy to the load

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

3.3
microwave cavity
space enclosed by inner metal walls and a door or an access opening and in which the load is placed

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

3.4
microwave load
objects introduced into the microwave applicator or microwave cavity

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

3.5
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 applicators or cavities, interconnecting cables and waveguides, control circuitry, means for transporting the microwave load, and ventilation equipment

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

3.6
microwave leakage
superficial power density of microwave radiation escaping from the microwave heating equipment

3.7
microwave access barrier
physical barrier, which has the property of microwave transparency, limiting access to the microwave enclosure, mounted outside the microwave enclosure and can only be removed with the aid of tools

NOTE 1 The function of the microwave access barrier is to act solely as a mechanical barrier.

NOTE 2 Microwave access barriers may be fixed to the microwave heating equipment or not, and are in the latter case a part of the installation.

NOTE 3 Devices such as an array of metal chains or hinged metal plates at entrance and exit ports intended to reduce microwave leakage are not considered microwave access barriers.

3.8
microwave enclosure
structure which is intended to confine the microwave energy to a defined region

NOTE 1 Examples are a cavity, door seals and waveguides.

NOTE 2 Microwave access barriers mounted outside the microwave enclosure are not considered as a part of the microwave enclosure.

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

3.9
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

3.10
maintenance door
all structural features of any part of the microwave heating equipment which can be opened or removed without the use of a tool to provide access to other locations than the microwave applicator or microwave cavity

3.11
cover
structural feature of any part of the microwave heating equipment which can be opened or removed by the use of a tool to provide access for routine maintenance, service, replacement of expendable parts, etc.

3.12
entrance or exit port
openings in the microwave enclosure through which the microwave load moves

3.13
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.

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

3.14
interlock
mechanical or electrical safety device or system, the function of which is to prohibit one class of events if another class of condition does not exist

NOTE For example, a microwave interlock prohibits the operation of a microwave generator, if the means of access are not closed.

3.15
microwave output power
microwave power as defined and measured according to IEC 61307

3.16
normal load
nominal microwave load at full microwave output power as specified by the manufacturer's documentation

3.17
normal operation
range of microwave output power and normal loads in allowable working conditions of the microwave heating equipment, as agreed between the manufacturer and user

3.18
reference surface
fictitious surface in the vicinity of mainly entrance and exit ports, located as a consequence of microwave leakage measurements

NOTE 1 If the microwave leakage reading without microwave access barrier is less or equal to the limits of Annex A, the reference surface is the surface of the geometric opening of the microwave enclosure.

NOTE 2 See 6.3 and Figures A.1, A.2 and A.3 for further explanations.

4 Classification of electroheat equipment according to voltage bands

Clause 4 of IEC 60519-1:2003 applies.

5 Classification of electroheat equipment according to frequency bands

Clause 5 of IEC 60519-1:2003 applies.

6 General requirements

Clause 6 of IEC 60519-1:2003 applies except as follows.

6.1 Electroheating equipment

Additional subclause:

6.1.101 Abnormal operation

Any single electrical or mechanical fault in the microwave heating equipment shall not result in energising of a microwave generator under normal operation.

NOTE 1 A mechanical fault in an array of metal chains or hinged metal plates at entrance and exit ports intended to reduce microwave leakage, is a single fault condition.

NOTE 2 Compliance with this requirement may be checked by inspection of the circuit diagrams and/or with the microwave leakage measurement as specified in Annex A.

For the purpose of testing, all maintenance doors, means of access and microwave access barriers are removed or opened, except those which incorporate microwave interlocks which prohibit generation of microwave power when removed or open. Attempts of normal operation are then made and shall not result in microwave leakage exceeding the limit in Annex A.

Operation of microwave heating equipment for continuous processing under conditions of interruption of the flow of microwave load(s) shall not result in a temporary microwave leakage exceeding the limit specified in Annex A, but with a limit of 100 W/m^2.

Attempts to operate the microwave heating equipment without microwave load shall not result in microwave leakage exceeding the limit specified in Annex A, but with a limit of 100 W/m^2.

NOTE 3 Compliance with this requirement can be checked by detecting microwave emission by an active microwave leakage monitor which switches off the microwave generator in order for the requirements of Annex A to be fulfilled. Defeating the sensor circuit is considered a single fault condition, as is interruption of the flow of microwave load(s).

6.3 Static charges – stray fields – electric and/or magnetic fields

Additional subclauses:

6.3.101 Microwave leakage

Compliance for microwave leakage with the safety requirements is checked by measurements according to Annex A.

6.3.102 Protection against microwave leakage

Microwave heating equipment shall be designed, constructed and operated as to provide adequate protection against radiation hazards due to microwave leakage.

The microwave heating equipment shall be provided with a device giving adequate indication when the microwave power is switched on and which is clearly visible to anyone entering the general area of the installation.

Where the microwave power can be or is varied by a user control, an indicator shall show the operator the level of microwave power applied.

There shall be a key switch, code panel, card reader or similar device on the control panel requiring the insertion of a key, input of a code or card or similar before microwave power can be generated.

6.3.103 Protection against access to microwave containing regions

Microwave heating equipment including microwave access barriers installed in order to limit access of personnel to a distance from the microwave enclosure are either enclosing the entrance or exit port and mounted on the microwave heating equipment, or not a part of it but of the installation and may then be essentially only vertical. Both types shall comply with the following:

- the microwave access barrier shall not be constructed of metal or microwave-absorbing material in such a way that it can guide or absorb microwaves;
- dimensions of the accessible opening of the microwave access barrier as such shall not be larger than the openings of the microwave enclosure which they protect, with a maximum of 65 mm × 65 mm; the requirement of maximum dimensions 65 mm × 65 mm is not applicable for any openings in microwave access barriers through which the microwave loads move;
- the microwave access barrier shall either be removable only with the aid of a tool, or its removal shall operate at least one interlock;
- microwave access barriers that are only vertical and located along the microwave load transport direction shall start at maximum 75 mm and end at least 1 800 mm above the floor.

NOTE 1 Microwave access barriers that are only vertical may be supported by some few metal poles or similar.

NOTE 2 For microwave access barriers which are not fixed to the microwave heating equipment and are instead a part of the installation, 15.2.7 also applies.

NOTE 3 The ≤65 mm × 65 mm requirement on accessible opening dimensions are for prohibiting insertion of the human hand, as is the <Ø 75 mm requirement in Table 1. The ≥1 800 mm barrier height requirement, with the warning sign in 15.2.7, is for making it obvious that access is not allowed; the ≤75 mm limit is for prohibiting access by arm's length while simplifying cleaning of the floor.

The dimensional and location requirements on microwave access barriers in relation to the type of barrier and the dimension and type of opening are given in Table 1. The barrier geometry is calculated from the reference surface. In order for this to be determined, microwave access barriers are removed and their associated interlocks are defeated.

The location of the reference surface is determined as follows. Microwave leakage is measured according to Annex A. The spacer tip of the microwave leakage instrument is moved over and away from the external surface of the microwave heating equipment to locate the highest microwave leakage, particular attention being given the openings. The region inside a geometric opening into the microwave enclosure is not regarded as accessible during these measurements.

If the microwave leakage reading is less than the limit of Annex A, the reference surface is at the surface of the geometric opening of the microwave enclosure.

If the microwave leakage reading exceeds the limit of Annex A, the locations of the sensor (not the tip) further away from the microwave enclosure where this value is measured are recorded. The position of the reference surface away from the surface of the microwave heating equipment is then determined as 50 mm straight inwards from these sensor positions and towards the surface of the microwave heating equipment.

Table 1 – Dimensional requirements on microwave access barriers

Opening dimension	Allowed use	Required barrier length	Notes on microwave frequencies
Allows the insertion of a Ø 75 mm or 65 mm × 65 mm object	Entrance or exit ports, and microwave access barriers that are only vertical	5 × the minor axis length of an ellipse inscribing the opening, but maximum 850 mm from the reference surface; only sideways/ behind for microwave access barriers that are only vertical	At about 915 MHz, there is unattenuated propagation in a 160 mm long but narrow slot, and an energy decay distance of about 50 mm in a Ø 130 mm opening. However, loads may convey surface waves.
Allows the insertion of an object with dimensions between Ø 75 mm and 20 mm × 50 mm	Entrance or exit ports, and microwave access barriers that are only vertical	180 mm from the reference surface; only sideways/ behind for microwave access barriers that are only vertical	At Ø 75 mm, the energy decay distance is about 2 mm at about 915 MHz, and very long at 2,45 GHz. There is unattenuated propagation at 5,8 GHz. However, high permittivity loads may convey surface waves.
Allows the insertion of an object with dimensions between 20 mm × 50 mm and Ø 12 mm	Any purpose	80 mm from the reference surface	At 20 mm × 50 mm, cut-off is very efficient for about 915 MHz; the energy decay distance is 30 mm at 2,45 GHz and there is unattenuated propagation at 5,8 GHz. However, continuous high permittivity loads may convey surface waves.
Allows the insertion of an object with dimensions less than Ø 12 mm	Any purpose	—	There is a very efficient cut-off for all ISM frequencies. Surface wave propagation at continuous loads in the opening may exist.

The minimum distance between the plane of a meshed microwave access barrier and the reference surface shall be according to Table 1, using the mesh opening dimensions. The same principle applies to the barrier start height above the floor.

In the determination of the location of microwave access barriers that are only vertical and located along the microwave load transport direction, the horizontal projection of the maximum extension of the reference surface shall be used.

NOTE 4 In order to simplify the design of microwave access barriers, the projections of the maximum horizontal and vertical extensions of the reference surface is normally used. This, and the use of Table 1 are exemplified in Figures A.1, A.2 and A.3.

6.5 Ionizing radiation

Addition:

The X-ray leakage from the generator, measured in the same locations as specified in 6.3.5, shall not exceed the value specified by national authorities responsible for public health.

7 Isolation and switching

Clause 7 of IEC 60519-1:2003 applies.

8 Connection to the supply network and internal connections

Clause 8 of IEC 60519-1:2003 applies.

9 Protection against electric shock

Clause 9 of IEC 60519-1:2003 applies except as follows.

9.1 General

Addition:

NOTE Microwave frequencies do not cause electric shock.

Additional subclause:

9.101 Accessibility to high voltage parts

Maintenance doors allowing access to high voltage parts and/or the microwave generator for maintenance shall be provided with key locks.

NOTE If microwave exposure may also occur, Subclause 12.3.2 applies.

10 Protection against overcurrent

Clause 10 of IEC 60519-1:2003 applies.

11 Equipotential bonding

Clause 11 of IEC 60519-1:2003 applies except as follows.

11.4.2

Replacement:

Earthing of one of the high voltage poles of the microwave generator is allowed.

If the high voltage power supply and the microwave generator are not in the same metal housing and have a common chassis, an additional high voltage cable, in addition to normal means for earthing, having the same class of insulation as for the high voltage cables, shall be mounted between the chassis of the high voltage power supply and the microwave generator chassis. The mounting point shall not be used for any other purpose.

12 Control circuits and control functions

Clause 12 of IEC 60519-1:2003 applies except as follows.

Additional subclauses:

12.101 Requirements for microwave interlocking devices

12.101.1 Means of access

The opening of a means of access of microwave heating equipment shall operate two microwave interlocks, designed for high security and long-term operation. These interlocks shall prohibit the operation of any microwave generator.

NOTE If not obvious by the main electrical circuit design, the operation of the microwave generator is verified by the leakage measurement according to Annex A.

The failure of any single electrical or mechanical component shall not cause all microwave interlocks on any means of access to be inoperative.

The failure of one of the two electromechanical microwave interlocks on the means of access to perform its intended function shall trigger an alarm and at the same time render the microwave heating equipment inoperative.

12.101.2 Maintenance doors and covers

The opening or removal of each maintenance door or cover shall operate at least one interlock, or be provided with a key lock, if the microwave exposure may exceed the value specified in Annex A with the maintenance door or cover removed.

12.101.3 Microwave absorbing means

In microwave heating equipment with means for absorbing microwave energy which require flow of a liquid, reduction of liquid flow at the output of any absorbing means shall operate at least one interlock, if the said reduction results in microwave leakage in excess of the limit specified in Annex A.

In microwave heating equipment with means for absorbing microwave energy without any dedicated cooling, the absorbing function shall not be impaired by excessive temperature rises in the absorber. This is tested under normal operation, and also under conditions of abnormal operation as specified in 6.1.2. The absorbing means shall remain securely in place and not be degraded.

13 Protection against thermal influences

Clause 13 of IEC 60519-1:2003 applies.

14 Risk of fire and danger of explosion

Clause 14 of IEC 60519-1:2003 applies except as follows.

Addition:

Microwave heating equipment shall be so designed, constructed and operated that risks of burns, fire, and explosions are minimised as far as practicable. In addition to the provisions of IEC 60519-1:2003, the following requirements shall be met when applicable:

Additional subclauses:

14.101 Risk of fire

If a fire which would present a safety hazard can result from overheating of the microwave load, it is recommended, as far as possible and practicable, to provide the microwave heating equipment with automatic means to:

- indicate the existence of a fire;
- eliminate microwave and other energy input to the material in the event of a fire;
- stop material flow through the applicator or, if decided according to the risk analysis, to quickly remove material in the event of a fire in order to extinguish the fire;
- extinguish a fire quickly.

The operating instructions given by the manufacturer shall indicate that, if such a fire can be initiated by an arc in the applicator, the provisions of 16.3.4 shall also apply.

When the microwave heating equipment is operated in premises liable to the risk of hazardous fires, the provisions of 14.2 shall apply.

NOTE Materials may be overheated to high temperatures without initially catching fire, due to lack of oxygen. Once materials are exposed to ambient atmosphere, a violent fire may suddenly start.

14.102 Risk of explosion

The operating instructions given by the manufacturer shall indicate that microwave heating shall not be employed in premises liable to risk of explosion, nor shall it normally be applied to microwave loads which if heated would result in an explosion risk. Where it is necessary to apply microwave heating to such microwave loads, the following precautions shall be observed.

If gases liberated from the microwave load during the heating process are potentially explosive, special precautions shall be taken to avoid the formation of an explosive atmosphere in the microwave applicator or microwave cavity. It is recommended that:

- sufficient air be supplied to the microwave applicator or microwave cavity to ensure that the vapour-to-air ratio does not exceed one-quarter of the lower flammable limit. If this is not possible, the process is to be performed in an inert atmosphere;
- means be provided for automatically cutting off the microwave power input to the microwave applicator or microwave cavity if the exhaust system fails;
- particular standards dealing with explosive protection shall be taken into consideration.

The risk of superheating of liquid microwave loads shall be taken care of. It is recommended that

- pre-testing is carried out and particular restrictions are applied;
- shields prohibiting eruption towards personnel are installed.

15 Marking, labelling and technical documentation

Clause 15 of IEC 60519-1:2003 applies except as follows.

15.1 Marking

Modification:

e) Rated voltage is rated input voltage.
f) Rated current is rated input current.

Addition:

aa) identification of the principal connections (for example, reference number of a drawing showing the principal circuit of the microwave heating equipment).

bb) maximum voltage within the generator, microwave frequency and maximum power output of the microwave generator, in compliance with IEC 61307.

15.2 Labelling

Additional subclauses:

15.2.101 Microwave heating equipment, which includes entrance and exit ports or accessible openings into the microwave enclosure, with or without microwave access barriers, shall be clearly marked in visible areas near each port or opening with a warning label (see Figure 1 a), using a graphical symbol of IEC 60417 (IEC 60417-5140:2003-04) and warning text in the necessary language(s).

15.2.102 Maintenance doors of microwave heating equipment, behind which there may be access to high voltage live parts and a microwave generator, shall be clearly marked at each such maintenance door with a warning label (see Figure 1 b) or an equivalent warning, using graphical symbols of IEC 60417 (IEC 60417-5036:2002-10 and IEC 60417-5140:2003-04) and warning text in the necessary language(s). The marking shall be located near lockpoints, if applicable.

15.2.103 Microwave access barriers, which are not a part of the microwave heating equipment, shall be clearly marked with a warning label (see Figure 1c) or an equivalent warning, using a graphical symbol of IEC 60417 (IEC 60417-5140:2003-04) and warning text in the necessary language(s). Additionally, the microwave heating equipment shall be clearly marked with the similar warning sign in an area close to the barrier.

IEC 044/11

Figure 1a) – Label near ports and openings

IEC 045/11

Figure 1b) – Label on maintenance doors

IEC 046/11

Figure 1c) – Label at and near microwave access barriers

NOTE Warning labels and signs are designed according to ISO 3864-1 (black symbols and text on yellow background).

Figure 1 – Examples of warning labels

15.2.104 Microwave heating equipment shall have the essence of the applicable following text marked in a visible area near the operation controls, in the necessary language(s):

CAUTION **Personnel must not be exposed to microwave energy** **Never operate the installation without its intended loading** **Do not remove barriers** **To maintain the microwave leakage at an acceptable value, the microwave heating equipment shall be periodically inspected and kept in good operating condition**

In cases when the installation contains accessible waveguides, the following text shall be added:

All connections, waveguides, flanges, gaskets, etc., must be secure in order to ensure that microwave leakage remains below specified limits

15.3 Technical documentation

Replacement:

Operating and maintenance instructions for the electroheating installations, according to Subclause 15.3 of IEC 60519-1:2003, including circuit diagrams and list of components in the necessary language(s), and which include precautions on how to avoid possible exposure to high voltage, microwave leakage, risk of fire and burns and explosions shall be provided in good time.

The documentation shall contain the following:

- the statement that the system is for industrial use only;
- definition of the normal operation and its limits, for which the microwave heating equipment is specified and manufactured.

NOTE Additional information necessary for shipping, installation and handling such as weight and dimensions should be given in additional documentation provided by the manufacturer.

Additional subclauses:

15.101 Operating and service instructions

Manufacturers of microwave heating equipment shall provide, for each equipment model, operating and service instructions in the necessary language(s), which include clear warnings and the precautions to be taken to avoid possible exposure to microwave leakage, as well as the risk of burns, fires, explosions and ionising radiation (see Clause 6 and Clause 14).

The instructions for use shall include the substance of the following, if applicable:

- the installation shall not be operated if there are any visible damages in the entrance and exit port regions,
- any barriers at the entrance and exit ports are intended to protect against microwave leakage, as well as personnel damages such as squeezing of hands,
- only specially instructed maintenance staff are allowed to carry out any service or repair involving possible exposure to microwave energy and high voltages.

15.102 Instructions for maintenance

The instructions for maintenance shall contain information on the following, in the necessary language(s):

- the minimum intervals between complete cleaning operations and removal of any residual material in the microwave enclosure;
- details on how to replace microwave components;
- the minimum intervals for testing, and test instructions, for any microwave sensing devices used in the interlock system.

16 Information on inspection and commissioning, and instructions for utilization and maintenance of electroheat installations

Clause 16 of IEC 60519-1:2003 applies except as follows.

Addition subclause:

16.3.101 Special precautions shall be taken to avoid the formation of arcs in the microwave applicator or microwave cavity. In addition, the operating instructions given by the manufacturer shall indicate the importance of:

- maintaining the cleanliness of the mating surface of the means of access and the microwave applicator or microwave cavity;
- ensuring that the material is not contaminated with foreign objects such as metal chips, which are likely to cause arcs.

Annex AA
(normative)

Measurement of microwave leakage

AA.1 Conditions for measurement

The normal load specified for normal operation is used. The microwave heating equipment is operated with the microwave power control at the highest setting.

Abnormal operation is also attempted, as specified in 6.1.101.

AA.2 Measurement details

The instrument reading is in W/m^2, based on the validity of the impedance of free space at the point of measurement. For this reason, a minimum distance of 50 mm between the sensor and any part of the microwave heating equipment is specified, and a non-interfering spacer providing this is used.

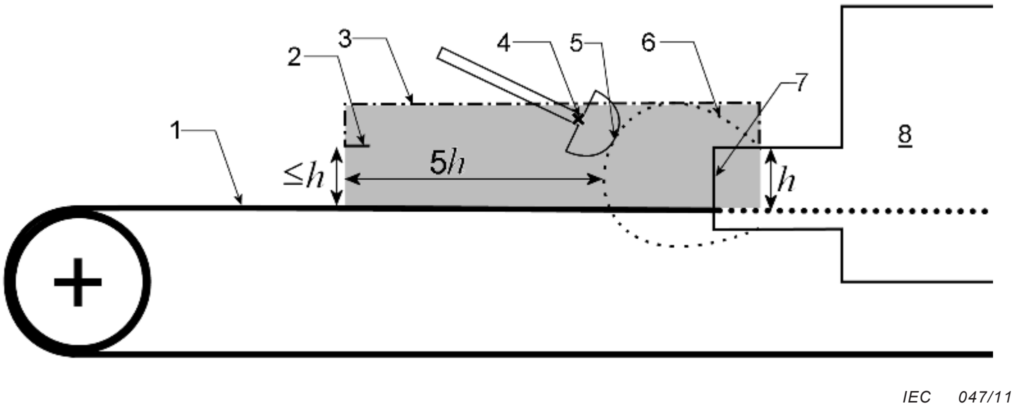
Using the 50 mm probe distance is not applicable for frequencies below 800 MHz and for frequencies above 6 000 MHz. In these low and high microwave frequency regions, only the basic restriction referred to in Note 1 of Clause 1 is applicable, and measurements shall be made to satisfy this.

Microwave leakage is determined by measuring the microwave flux density using an instrument that reaches 90 % of its steady reading in 2 s to 3 s when subjected to a stepped input signal. The required distance of 50 mm or more between the sensor and any part of the microwave heating equipment or any microwave access barrier is to be observed.

The microwave leakage reading shall not exceed 50 W/m^2.

The spacer tip is moved over and away from the external surface of the microwave heating equipment to locate the highest microwave leakage, particular attention being given to the openings and the microwave access barriers. The region inside a geometric opening into the microwave enclosure is not regarded as accessible.

Due to load movement, the size of and distance between the individual load items, any missing load item or load interruption in conveyorised microwave heating equipment, and also depending on the conveyor speed, the measured leakage may vary strongly in time. In such cases, the average leakage under the most onerous 20 s interval shall be used, is to be applied. Depending on the actual time constant of the instrument, readings are then taken every 2 s or 3 s and a ceiling value of 250 W/m^2 shall then apply.



Key

1 Conveyor belt. The microwave load is not shown, and the dimension h is without it.

2 Microwave access barrier opening. Its height is less or equal to the accessible height h of the entrance or exit port, which is measured between the top of the conveyor belt and the ceiling in the entrance or exit port.

3 Microwave access barrier roof (dot-dashed line), its level being at the reference surface outside the entrance or exit port where the probe antenna is located when the microwave leakage limit under normal operation is 50 W/m^2.

4 Microwave leakage measurement probe antenna, located 50 mm away from the probe tip.

5 Position of the leakage measurement probe spacer for determination of the reference surface location.

6 Projection of the maximum horizontal extension of the reference surface (dotted line) outside the entrance or exit port where the measured microwave leakage under normal operation (i.e. with microwave load (not shown here), but without microwave access barrier) is 50 W/m^2.

7 Entrance or exit port.

8 Microwave applicator or microwave cavity. This, and the entrance and exit port sections, constitute the microwave enclosure.

NOTE 1 The Figure is drawn for the case where the accessible height h of the entrance or exit port (7) is defined as 75 mm $< h \leq$ 170 mm (see Table 1). The fingers, the hand and a part of the arm can then be inserted. The required barrier length of Table 1 as distance between the reference surface (6) and the microwave access barrier opening (2) is then $5 \times h$, i.e. greater than 375 mm and less than or equal to 850 mm.

NOTE 2 The Figure is drawn as seen from the side. The same requirements on the microwave access barrier in relation to the reference surface (6) applies also in horizontal directions, as seen from above and below.

NOTE 3 If the reference surface extends also below the conveyor belt (1) and is accessible, it will also extend into this region. However, the required barrier length of Table 1 and also the microwave access barrier as such may need to be extended as a consequence of the measurements in 6.1.2 (abnormal operation).

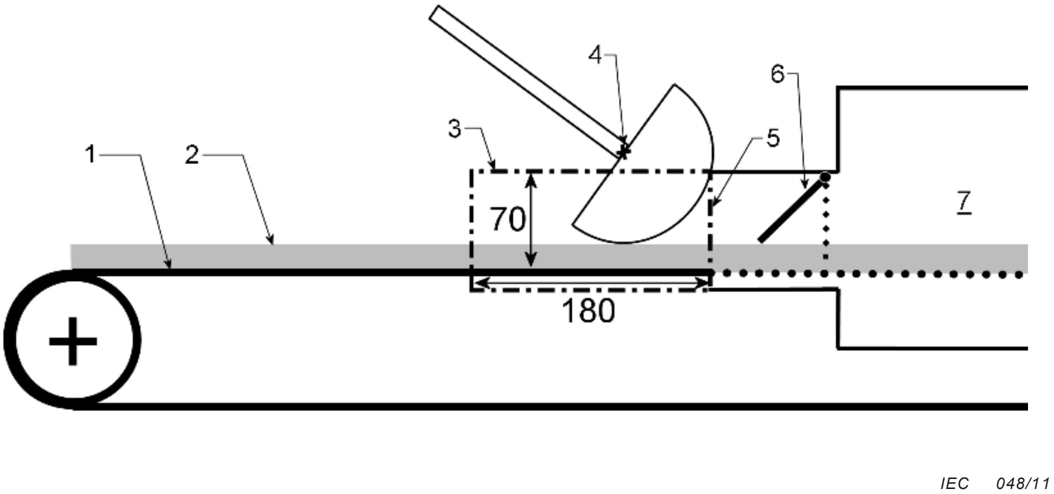
NOTE 4 The microwave access barrier in this Figure is of a homogeneous (typically plastic) material, and is located just outside the reference surface (6). If the microwave access barrier is meshed or has holes, the requirements in Table 1 stipulate a location further away from the reference surface (6).

NOTE 5 As an alternative to a microwave access barrier with sides and ceiling, a vertical microwave access barrier at each side of the conveyor belt (1) outside the exit or entrance port (7) may be employed. That case is illustrated in Figure A.3.

NOTE 6 The microwave enclosure is defined in 3.8 and includes the microwave applicator or microwave cavity (8) and the structures ending with the exit port and entrance port (7). Microwave access barriers are not included.

Figure AA.1 – Large microwave access barrier for conveyorised microwave heating equipment

Dimensions in millimetres



Key

1 Conveyor belt

2 Microwave load

3 Microwave access barrier (dot-dashed line), its accessible height of 70 mm includes the height of the microwave load

4 Probe antenna of the leakage measurement instrument with a 50 mm spacer. The measured microwave leakage is in this case less than 50 W/m^2 at the entrance or exit port in this case, with the spacer contacting the entrance or exit port opening (but not interior) as well as the top of the microwave load. As a consequence, there is no reference surface outside the entrance or exit port as in Figures A.1 and A.3. The microwave leakage is measured under normal operation, i.e. with microwave load and the hinged metal plate (6) in place, but without microwave access barrier.

5 Entrance or exit port

6 Hinged metal plate, following the top of the microwave load and hanging down (dashed line) when there is no microwave load. See also NOTE 3 in 3.7 and NOTE 1 in 6.1.2.

7 Microwave applicator or microwave cavity

NOTE 1 The Figure is drawn for the case where the accessible height h of the entrance or exit port (5) is chosen to be h = 70 mm (see Table 1). Fingers and a part of the hand can then be inserted.

NOTE 2 A hinged metal plate (6) cannot determine the position of the entrance or exit port (5), neither can it be a part of a microwave access barrier (3). It may reduce microwave leakage and it can determine only the position of the reference surface.

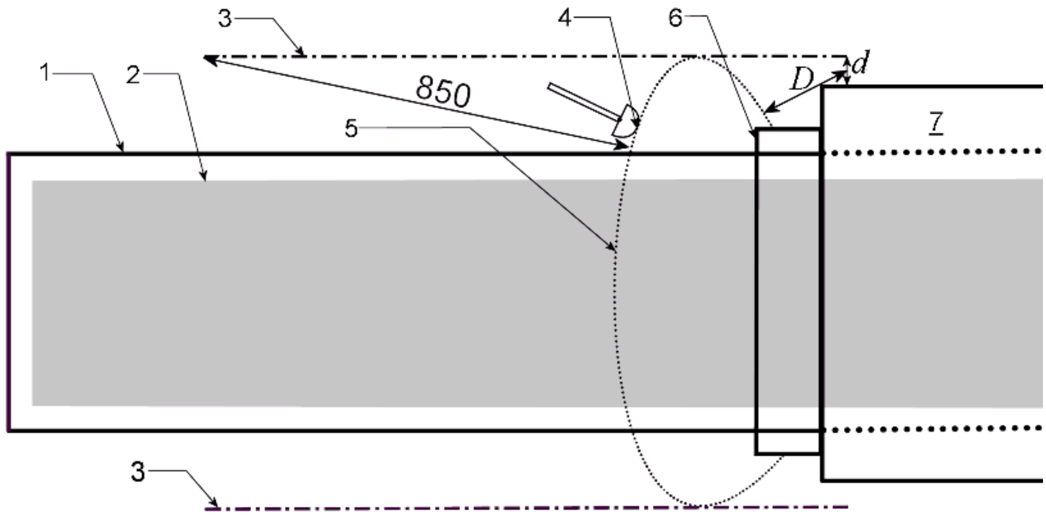
NOTE 3 Since microwave leakage is less than 50 W/m^2 at the entrance or exit port (5), the required barrier length becomes 180 mm from the entrance or exit port (5). However, the required barrier length of Table 1 and so the microwave access barrier (3) may need to be extended as a consequence of the measurements in 6.1.2 (abnormal operation).

NOTE 4 The microwave access barrier (3) in this Figure is of a homogeneous (typically plastic) material. Since Table 1 stipulates a location of the microwave access barrier (3) further away from the exit (or entrance) port (5), this is not practical.

NOTE 5 The microwave enclosure is defined in 3.8 and includes the microwave applicator or microwave cavity (7) and the structures ending with the entrance and exit port (5). Microwave access barriers (3) are not included. The hinged metal plate (6) is included.

Figure AA.2 – Small microwave access barrier for conveyorised microwave heating equipment

Dimensions in millimetres



Key

1 Conveyor belt

2 Microwave load

3 Microwave access barrier (dot-dashed line). Details on height etc., see 6.3.5.

4 The leakage measurement instrument with a 50 mm spacer. The measured microwave leakage of 50 W/m^2 determines the position of the reference surface (5), see 6.3.5. The microwave leakage is measured under normal operation, i.e. with microwave load, but without microwave access barrier

5 Projection of the maximum horizontal extension of the reference surface

6 Entrance or exit port

7 Microwave applicator or microwave cavity

NOTE 1 The Figure is drawn for the case where the accessible height *h* of the entrance or exit port (6) is larger than 170 mm (see Table 1). The fingers, the hand and the arm up to the shoulder joint can then be inserted. The required barrier length of Table 1 as distance between the reference surface (5) and the microwave access barrier is then 850 mm.

NOTE 2 A hinged metal plate (not drawn here; its is shown in Figure A.2) cannot determine the position of the entrance or exit port (6), neither can it be a part of a microwave access barrier (3). It can determine only the position of the reference surface. However, the required barrier length of Table 1 and so the microwave access barrier may need to be extended as a consequence of the measurements in 6.1.2 (abnormal operation).

NOTE 3 If the d value is less than or equal to 20 mm, D is 80 mm. If the d value is larger than 20 mm and less than or equal to 75 mm, D is 180 mm. If d is larger, D is $5 \times d$, with a maximum of 850 mm (see Table 1).

NOTE 4 The microwave access barriers (3) in this Figure are of a homogeneous (typically plastic) material, since they are located just outside the reference surface (5). If the barriers are meshed or have holes, these cannot be larger than 65 × 65 mm (see 6.3.5). Table 1 then stipulates a location of the the microwave access barriers (3) further away from the reference surface (5).

NOTE 5 The microwave enclosure is defined in 3.8 and includes the microwave applicator or microwave cavity (7) and the structures ending with the entrance and exit port (6). Microwave access barriers (3) are not included.

Figure AA.3 – Vertical-only microwave access barriers for conveyorised microwave heating equipment

Annex BB
(informative)

Rationales for the microwave access barrier and associated leakage tests

BB.1 The standard measurement of microwave leakage

There are several commercial instruments on the market. Those that perform sufficiently well for the purpose have a small, reasonably isotropic (omnidirectional) sensor at the end of a plastic rod. The sensor reacts to the electric field only. There is also a non-disturbing sensor spacer, which is used to determine a 50 mm minimum distance between the sensor and any part of the microwave equipment or installation, as specified in the standard. Testing of instruments include calibration in the farfield (the inaccuracy is allowed to be about ±20 %), and one or two tests intended to show that the sensor is “electrically small” so that it does not itself cause interference (standing waves) to objects nearby.

The scale on microwave leakage instruments is not in the same units as what is actually measured (V/m) but instead in W/m^2 (or mW/cm^2). The conversion is correct only in the free space plane wave case, where the wave impedance is 377 Ω and there is unidirectional propagation. Since a standing wave is the sum of two waves propagating in different directions, and the probe is not direction sensitive, the field impedance then becomes smaller or larger than 377 Ω, so that the instrument reading becomes erroneous. Erroneous readings are also obtained in strongly curved nearfields and with the probe in a waveguide or similar where there is a single or multiple mode (having a different impedance).

The minimum 50 mm distance between the instrument sensor and any accessible part of the appliance was specified more than 35 years ago when the first microwave oven leakage standard was created. The major reasons were that it was found desirable to use the same type of instruments which were used for far-field exposure measurements, and that it was concluded that an electric field sensor instrument would not indicate a proper value for determining the outgoing power flux density if the probe was located a) where the field curvature was very significant (in comparison with the wavelength), b) in the presence of any standing waves near the sensor. A reasonable compromise with the need to measure emission (i.e. in the source region, so that the “leaking spot” could be found) was found to be 50 mm for the 2 450 MHz ISM band. Even if it was noted in the instrument literature at the time that the same 50 mm distance would be less appropriate for the lower ISM band at 915 MHz, the matter was not considered so problematic that the specification was modified. There are to-day instruments available that cover also the 5 800 MHz ISM band.

The historical reason for the choice of the maximum allowed level of 50 W/m^2 (= 5 mW/cm^2) was a result of an existing regulation on free space power flux density of up to 100 W/m^2 being acceptable in commercial and industrial environments, plus considerations of a possibility of two or more microwave ovens or generators being located close to each other. Later, when household microwave ovens came on the market, the nature of door leakage was found to typically be from only some few leaking spots, so that the power flux density decreased almost quadratically with the distance away from these. There was no reason why the user would remain very near the closed door of an operating oven, and widely publicised investigations showed that the actual exposure of any part of the human body became very low, particularly in consideration of a reasonable averaging time of 5 min to 10 min for hazard assessment. As a result, the 50 W/m^2 limit was applied to household microwave ovens as well as industrial installations.

In the beginning of the 1970’s, the US authorities responsible for radiation safety found some quality problems with some microwave oven models, and introduced a 10 W/m^2 “factory limit” for new unused ovens, in order to dampen any public concerns. Only one or two other countries followed.

In the meantime, the IEC/SC 61B (*Safety of microwave ovens*) oven safety standard was successively developed and the value 50 W/m^2 became the worldwide limit after all tests. TC 27 followed, with the same limit. In the 1980's, leakage measurements at covers for lamp replacement was dealt with by SC 61B. The hole array in the cavity wall, at the lamp, can of course leak microwaves. The size of the cover may be such that the 50 mm distance to the nearest appliance part can be maintained also with the sensor almost inside the external housing from which the cover has been removed. A case had been reported where the instrument reading was quite high in this condition, but there was a very low reading with the whole housing removed. The reason for the high reading was that a standing wave inside the housing had been created. There was an electric field but no real leakage since the standing wave is the sum of an outwards- and inwards-going wave and may have no net power flux. In addition, if a finger would be put into the opening, the standing wave would disappear and only the real leakage become the possible hazard. SC 61B added a statement to the standard to the effect that the instrument sensor should not be closer to the opening plane than 50 mm, i.e. the region inside the cover should not be considered accessible with regard to the leakage measurement. The same principle is adhered to in this Standard.

BB.2 Microwave hazards – the basic restriction

Microwave exposure is considered to be potentially hazardous if the heating of parts of the human body exceeds certain values. These are specified as SAR values (specific absorption rate) and are expressed in W/kg tissue. The lowest SAR value of whole-body exposure where there may be some risks has been found to be 4 W/kg. A safety factor of 10 is subsequently applied for microwave workers (instructed persons), and a further safety factor of 5 for the general public (ordinary persons), resulting in the basic restriction of 0,4 W/kg and 0,08 W/kg in the two cases. Local, non-hazardous exposure limited to the head and trunk may be up to 10 W/kg and 2 W/kg, respectively. Twice this (20 W/kg and 4 W/kg) are considered non-hazardous locally in the extremities (including hands and fingers). The integration volumes are then over any 10 g body mass. These values apply for microwave frequencies up to 10 GHz. Interestingly, the time integration is set to 6 min. As will be discussed below, a shorter integration time is used in this Standard.

BB.3 Microwave hazard evaluation – the free space exposure method

For all practical exposure situations (except from communication devices such as mobile phones for which a total source maximum power concept may apply), two simplified verification methods are used in industry and for protection of microwave workers and the general public: a maximum allowed far-field power flux density far away from the source, and an emission standard for appliances such as microwave ovens and industrial microwave equipment.

The issue is now if the relaxation of SAR values for parts of the body, in combination with the integration volume, are compatible with the free space exposure method.

When parts of the human body having a small radius of curvature are heated, diffraction, resonant and other focussing or amplification phenomena may occur. In the case of the frequencies about 915 MHz and 2 450 MHz, the internal wavelengths in tissues as well as the penetration depth limitation result in only fingers being of major interest. In principle, also bent knuckles and elbows could create focussing effects, but fingers are definitely much more problematic with regard to the effects discussed here. It is not assumed that other protruding parts of the body such as the nose, ears or penis are brought very close to microwave leakage sources in commercial or household microwave heating equipment.

The following modelling results indicate the degree of compatibility between the basic restriction and the free space exposure method:

Numerical modelling using commercially available electromagnetic software was used. A finger with 13 mm diameter and typical dielectric data (homogeneous, with the complex permittivity ε = 40 – j10, where the loss factor ε''(10) is lowered in consideration of bone and tendons) was exposed to 10 W/m^2 in free space. The strongest absorption occurred for TMz polarisation (i.e. with the impinging electric field parallel to the finger axis) and the mode in the finger then becomes of the TMz_1 type, having two opposite axial zones of maximum heating intensity. The maximum power intensity becomes 5 W/dm^3 and the average over the worst 10 cm^3 becomes about 1,8 W/dm^3.

If the finger would be exposed to a plane wave with a power flux density of 50 W/m^2 - that which is allowed from household and commercial microwave ovens, etc. - the maximum value would become 25 W/dm^3 and the 10 cm^3 integrated value would become 9 W/dm^3.

The conclusions are that:

- The ordinary person basic restriction is exceeded. However, ordinary persons are with today's standards only exposed to microwave ovens with a door, where the leakage source is so small that the high intensity is over a significantly smaller volume of the finger. Additionally, there is no reason to keep the hand near the closed door of an operating microwave oven. Actually, there are numerous reports from experimental investigations in the 1970's which clearly indicate that the averaged exposure level over several minutes is 10 times to 100 times lower than 10 W/m^2. Hence, the actual absorption is within the SAR limit.
- The instructed person basic restriction is about the same as the actual SAR value. However, the actual situation with an operator occupied with load removal at the port of continuously operating conveyorised microwave equipment for long periods is more onerous than with a microwave oven with a door, but the working hand can typically not be near the opening more than about half the time. An additional aggravating factor is that the tunnel opening is larger than an oven door as a leakage source, so that the region with a high microwave energy density may extend further out than from an oven door. Hence, the construction of the tunnel end regions as well as the measurement method are intended to ensure that SAR values in the human finger equal to that at 50 W/m^2 far field exposure are not exceeded.
- The operating conditions of the conveyorised microwave equipment shall be such that any higher average leakage levels do not occur. However, parts of a tunnel microwave oven can be operated empty with the operator still removing loads. Hence, a temporarily higher value can then be accepted, provided the integrated energy is under control.

BB.4 Microwave hazards from openings in cavities, and from exit and entrance ports

The actually absorbed microwave power in a part of the human body is always very dependent on the field configuration, and the field configuration at the body part is also strongly modified by the part itself. This means that even knowledge about the true power flux density or the electric field intensity cannot be used to assess the actual microwave absorption rate - it becomes necessary to establish a more complete *scenario* before any calculations of the absorption can be made. Hence, the leakage intensity measured as a quasi-plane free space wave at 50 mm or more away from the source will now not alone determine the level of hazard. The actual hazard also depends on:

- any possibility of access into a region where there is microwave energy;
- the size of the opening, which may determine the type of field characteristics, or allow several kinds of microwave field characteristics;
- any objects, including a load to be heated or a part of the body in the opening, which may also determine the type of field characteristics.

The access situation is of course crucial and must be standardised in some ways so that reasonably simple and objective procedures and requirements can be established. Since only the arm, hand and finger are considered to be the parts of the body which may get in contact with or be inserted into openings in this kind of microwave equipment, two important issues can be directly quantified:

1) all geometric factors; and
2) as addressed above, these parts of the body are less sensitive than for example the head.

An important principle is that a “hazard boundary” (called reference surface in this Standard) is defined somewhere in the vicinity of the opening surface and that a leakage instrument reading of 50 W/m^2 is to apply for the tests. This means that what remains is to construct tests which will ensure, with reasonable certainty, that actual power densities (in W/m^3 or SAR values in W/kg) in human fingers, hand or arm “contacting” the reference surface will not exceed those caused by a “normal” leakage source such as a microwave oven door region giving a power flux density reading of 50 W/m^2 at 50 mm distance from any part of the microwave equipment.

The field configuration then becomes the issue, i.e. how to obtain realistic measurement results with the same type of instruments as used for microwave ovens with a door. Clearly, there is a need for simplification and standardisation. In this Standard, a method of non-shielding microwave barriers is used.

BB.5 The time averaging

There are only two time integration specifications in the existing international standards:

a) 6 min for whole-body exposure; and
b) criteria for duty cycles in cases of very short pulses such as from radar transmitters.

Additionally, in some national legislation on non-ionising radiation there is a ceiling value of exposure; a ceiling value of e.g. 250 W/m^2 and a 10 W/m^2 average may be interpreted as maximum $6 \times 60/(250/10) = 14{,}4$ s isolated strong exposure being allowed during any 6 min interval.

The 6 min integration time is quite compatible with typical cases of irradiation of parts of the body having a radius of curvature larger than about one free space wavelength of 2 450 MHz microwaves. In such cases essentially a plane damped wave propagation can be assumed, as well as a depth of 30 mm to 40 mm in the tissue over which equilibration by heat conduction takes place. Using the heat conductivity data and the Fourier heat conduction equation then results in a time constant (i.e. about 63 % of the stationary conditions have occurred) of about 5 min. A useful comparison is with boiling of an egg in water: it takes about 5 min for the centre to reach a temperature of about 65 °C.

The most onerous heating pattern in a Ø 13 mm finger under plane wave 2 450 MHz irradiation is uneven, with about 5 mm distance between the hot and cold areas. It can be shown that the overall microwave coupling is strongest for about Ø 16 mm finger diameter. The corresponding distance between hot and cold areas then becomes 7 mm or less. The corresponding dimension becomes about three times larger at 915 MHz, possibly resulting in local overheating in the hand and lower arm. A quite pronounced local overheating by resonance effects may occur in fingers at 5 800 MHz. The sensations of heat may then be quite weak.

The Fourier heat conduction equation is spatially quadratic. Using the boiling of a Ø 40 mm egg in 5 min having distance between the cold and hot regions is 20 mm as a basis, a 7 mm distance would be similarly equilibrated in $(7/20)^2$ of 5×60 s, i.e. about 35 s integration time is adequate.

However, there is another factor also to be considered: even a very localised heating rate should not be so high that there will be any risk of pain or injury during the time of integration. A suitable acceptable local temperature rise may be set to 5 K, in consideration of both that the skin area with heat-sensing nerves will be heated at least by conduction and that such a temperature rise under short term conditions will not cause any injury in the fingers. A normal person will feel and react to a temperature increase of the same order or less - about 3 K - within some very few seconds.

A homogeneous SAR value of 20 W/kg (the basic restriction for instructed person fingers) will result in a temperature rise rate of about 0,5 K/min.

Now suppose that only e.g. the tip of a finger absorbs all power and the remainder of the 10 g absorbs no power. Such scenarios are actually not uncommon and may occur, e.g. with the finger contacting damaged microwave oven seals and in some nearfield cases, for example at so-called cut-off openings (see the notes in Table 1). The volume of that part of the tip that absorbs microwaves is now set to 0,5 cm^3 (which is the volume of a hemisphere with Ø 12 mm). Using this in relation to the 10 cm^3 of the basic restriction, one obtains a 20 times faster "allowed" temperature rise rate of 10 K/min. This will also mean that the person will feel the heating of the finger within 20 s. Since the equilibration by heat conduction has about the same time constant as above, one again arrives at about 30 s suitable integration time.

There is an extreme case of the tip of the finger touching a leaking narrow slot in a metal surface. The local SAR value becomes very dependent on the dryness of the skin. As an example, a Ø 13 mm fingertip with 1 mm dry skin is pressed against the centre of a 2 mm wide and 100 mm long slot, at 2 450 MHz. This has a leakage that would be measured to 50 W/m^2 at 50 mm distance (i.e. the electric field strength is 137 V/m) with no finger. The local SAR value then becomes about 30 W/dm^3, over a 4 mm wide and 1,5 mm deep volume. This local value is in itself approximately within the *basic restriction*. If the finger is wet and the skin is thin, the local SAR value may be up to 50 times larger but the two small heated volumes contacting the slot sides are then only about 1 mm wide and deep. The thermal equilibration distance is now over only 2 mm, so the heat conduction has now a time constant of $(2/20)^2 \times 5 \times 60$ s = 3 s. The local, thermally insulated heating rate could be up to 40 K/min. However, heat conduction would result in a stationary temperature rise of less than about 3 K, which is also acceptable. Hence, there is no need to have a shorter integration time than about 30 s even in this most onerous case of high local SAR values in microwave cavity oven situations.

BB.6 Conclusions and modifications of the standards for ovens with a cavity door

The 6 min time of integration specified in existing international standards is inadequate for the purposes, which were first investigated by SC 61B. A more realistic value would be 30 s. A slightly shorter time (20 s) is specified in the normative Annex A, Clause A.2. There may be case of open-ended microwave applicators intended for heating of a contacting load. Such applicators may cause almost instantaneous injury if contacted by any part of the body when in operation, and other provisions for safety must be applied.

The existing emission standard for microwave ovens specifies an integration time of about 2 s for the measurement. This is for historical and practical rather than safety reasons. A typical household microwave oven has either a ceiling stirrer or a turntable, and with the specified circularly cylindrical test load the leakage variation periodicity will be comparable to or less than the specified integration time. Measurements are then correct and made easily and quickly with the present standard.

Since conveyorised microwave heating equipment behaves quite differently and there is no reason to introduce limitations on construction which have no relevance to safety considerations, 20 s time of integration for leakage measurements are suitable. However, the instrument integration time of 2 s to 3 s is maintained.

In addition, a maximum measured value of 250 W/m^2 with the instrument integration time of 2 s to 3 s is introduced, to simplify instrument specifications and handling as well as the numerical integration in cases of highly variable leakage. Such strong variability may occur for example in microwave equipment with a protective device consisting of a built-in leakage monitor coupled to a cut-out.

Bibliography

IEC 60335-2-25, *Household and similar electrical appliances – Safety – Part 2-25: Particular requirements for microwave ovens, including combination microwave ovens*

IEC 60335-2-90, *Household and similar electrical appliances – Safety – Part 2-90: Particular requirements for commercial microwave ovens*

IEC 61010-2-010, *Safety requirements for electrical equipment for measurement, control and laboratory use – Part 2-010: Particular requirements for laboratory equipment for the heating of materials*

IEC 62311:2007, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)*

ICNIRP Guidelines: *Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz) – Health Physics April 1998, Volume 74, Number 4: 494-522*, and http://www.icnirp.de/documents/emfgdl.pdf

ISO 3864-1:2002, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs in workplaces and public areas*

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