BS EN 60703:2009

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Test methods for electroheating installations with electron guns

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National foreword

This British Standard is the UK implementation of EN 60703:2009. It is identical to IEC 60703:2008. It supersedes BS 7689:1993 which is withdrawn.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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EUROPEAN STANDARD

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EN 60703

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Supersedes HD 440 S1:1983

English version

Test methods for electroheating installations with electron guns
(IEC 60703:2008)

Méthodes d'essai des installations électrothermiques comportant des canons à électrons
(CEI 60703:2008)

Prüfverfahren für Elektrowärmeanlagen mit Elektronenkanonen
(IEC 60703:2008)

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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.

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: avenue Marnix 17, B - 1000 Brussels

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Foreword

The text of document 27/628/CDV, future edition 2 of IEC 60703, prepared by IEC TC 27, Industrial electroheating equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60703 on 2008-12-01.

This European Standard supersedes HD 440 S1:1983.

The significant changes with respect to HD 440 S1:1983 are as follows:

– EN 60519-7:2008 has been taken into account;

– test requirements have been completed with new items important for testing and acceptance of installations.

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)	2009-09-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2011-12-01

Annex ZA has been added by CENELEC.

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Endorsement notice

The text of the International Standard IEC 60703:2008 was approved by CENELEC as a European Standard without any modification.

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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 60204-1 (mod)	2005	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	EN 60204-1	2006
IEC 60204-11	2000	Safety of machinery - Electrical equipment of machines - Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV	EN 60204-11	2000
IEC 60398	1999	Industrial electroheating installations - General test methods	EN 60398	1999
IEC 60519-1	2003	Safety in electroheat installations - Part 1: General requirements	EN 60519-1	2003
IEC 60519-7	2008	Safety in electroheat installations - Part 7: Particular requirements for installations with electron guns	EN 60519-7	2008

CONTENTS

TEST METHODS FOR ELECTROHEATING INSTALLATIONS WITH ELECTRON GUNS

1 Scope and object

This International Standard applies to electroheating installations comprising one or more electron guns as heating source.

The object of this standard is the standardization of test methods to determine the essential parameters, technical data and characteristics of electroheating installations comprising one or more electron guns.

The standard does not contain a mandatory list of tests and is not restrictive. Tests may be selected from the proposed list. The specification established by agreement between the user and the manufacturer of electroheating installations can supplement these recommendations but should not be in contradiction with them.

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 (IEV) – Part 841: Industrial electroheat*

IEC 60204-1:2005, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-11:2000, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

IEC 60398:1999, *Industrial electroheating installations – General test methods*

IEC 60519-1:2004, *Safety in electroheat installations – Part 1: General requirements*

IEC 60519-7:2008, *Safety in electroheat installations – Part 7: Particular requirements for installations with electron guns*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-841, IEC 60519-7 (some of which are repeated here) and the following apply.

3.1
electron beam
electron flux emitted from one source (cathode or plasma) and moving along the exactly determined tracks at very great velocities

[IEV 841-30-01, modified]

3.2
electron (beam) gun
system of generating, forming and accelerating one or more electron beams

[IEV 841-30-08, modified]

3.3
anode (of an electron gun)
electrode capable of educing and accelerating electrons from the medium of lower conductivity

[IEV 841-22-31, modified]

3.4
cathode (of an electron gun)
electrode capable of emitting electrons from the medium of low conductivity and also of receiving positive carriers, if necessary

[IEV 841-22-32, modified]

3.5
beam accelerating voltage
potential difference between the cathode and the anode, to generate an electric field for acceleration of the electrons

[IEV 841-30-29]

3.6
high-voltage power supply
source of the acceleration voltage and of the emission current for electron guns

3.7
return conductor
electrical interconnection between the high-voltage power supply (positive pole) and anodic part of the electron gun system including the vacuum chamber around the workpiece

3.8
interlock
device that prevents activation of a piece of equipment when any form of hazard or danger exists

3.9
vacuum chamber
enclosed space of a vacuum plant constructed in such a way that it can withstand a rarefied atmosphere inside, in which the workpiece to be treated is placed

3.10
electron gun chamber
vacuum chamber in which the electron gun is located

NOTE This chamber may be separated from the workpiece by an aperture, so that between the electron gun and the workpiece a pressure difference can be established.

3.11
electron beam deflection system
electromagnetic coil or deflecting electrodes system, applied to place the beam to different working positions or move the beam over the charge heating surface

[IEV 841-30-25, modified]

3.12
electron beam bending system
electromagnetic coil or permanent magnet for changing the direction of the electron beam outside the electron gun

3.13
electron beam focusing system
electromagnetic coil, system of coils or capacitor plates for focusing the electron beam over the charge heating surface

[IEV 841-30-27, modified]

3.14
beam pattern
image created by a cyclic time function of electron beam positions or a superposition of such cycles

3.15
maximum deflection angle
angle between electron beam attitude without any deflection and at maximum activation in one direction

3.16
deflection limits
limits of a defined area that may proceed with the electron beam without danger for the equipment at reasonable power distribution

3.17
maximum deflection frequency
frequency, at which the amplitude of the deflected beam is reduced to one half in relation to a static deflection caused by the dynamic performance of the complete deflection system

3.18
beam power
product of electron beam current and acceleration voltage

3.19
cathode current
electron current flowing from cathode

NOTE 1 The electron beam current arriving at the workpiece may either be lower than the cathode current, or up to several orders of magnitude larger than the emission current if ion bombardment is also present.

NOTE 2 There is a difference between the possible emission current and the circulated current; cathode current is limited by the space charge.

3.20
rated power (of an electron gun)
product of acceleration voltage and cathode current

4 General test requirements

4.1 Test procedure

The test procedure includes tests and measurements, which can be grouped as follows:

a) Tests of auxiliary facilities (Clause 5);

b) Tests of electron gun system (Clause 6);

c) Production run tests (Clause 7).

The tests of group a) shall be finished before proceeding to the group b) tests. The test procedure shall include all relevant tests of groups a) and b). Production run tests of group c) are only recommendations, their necessity depends on the beam properties requested by the application.

4.2 Test intervals

The test procedure shall be carried out immediately

- after the erection of the electron beam gun installation,
- after general repair work,
- after an accident caused by the electron beam gun installation,
- after substantial modifications of the installation.

The test procedure shall be repeated at least once a year. A shorter period may be determined by the manufacturer or by the user of the installation.

After a repair of a single component the relevant test(s) is also required and may be limited to functionalities directly influenced by this component.

4.3 Ambient conditions

The tests shall be carried out in the ambient conditions stated in Table 1, unless other conditions are specified by the manufacturer.

Table 1 – Ambient conditions for tests

Ambient temperature	°C	Normal	20
		Minimum	15
		Maximum	40
Relative humidity	%	Maximum	85
Altitude above sea level	m	Maximum	1 000
NOTE When the ambient conditions are beyond the values listed in this table, the measured values shall be corrected in accordance with the relevant rules.			

The ambient temperature is considered as an average value. All quantities dependent on the temperature shall refer to the ambient temperature of 20 °C, the so-called reference ambient temperature.

5 Test of auxiliary facilities

5.1 Assembly check

Completeness and integrity of equipment of the electron gun installation shall be verified. Particular attention shall be given to:

- safety appliances and danger signs,
- lock-out devices,
- X-ray shields including lead glass view ports.

5.2 Test of electrical equipment

5.2.1 General

Basically, the test of electrical equipment including control system shall be carried out in accordance with IEC 60204-1, IEC 60398 and IEC 60204-11. Special test procedures for the electrical equipment for electroheat installations with electron guns are stated in the following subclauses. Special tests for electron guns and the high-voltage supply are given in Clause 6.

5.2.2 Continuity of return conductor and equipotential bonding

The return conductor and equipotential bonding shall be visually inspected for compliance with IEC 60519-1 and IEC 60519-7 and a check for tightness of the connections shall be made.

The continuity of the protective bonding and the return conductor shall be verified by injecting current of at least 10 A at 50 Hz or 60 Hz derived from an electrically separated extra low voltage source for a period of at least 10 s. Deviating from IEC 60204-1, the measured voltage drop shall not exceed 1,0 V in the case of return conductor and equipotential bonding between process chamber, electron gun and the high-voltage supply.

5.2.3 Test of safety interlocks and alarm system

The test shall be performed in accordance with IEC 60398.

Special care should be given to the interlocks for the acceleration voltage and, if it exists, to the automatic earthing system (see 6.2.1 and 6.2.2).

When testing interlocks, only the control circuits shall be live. The power circuits should be only switched on for tests of monitoring circuits, which need these voltages.

5.3 Test of liquid cooling system

The test shall be carried out in accordance with IEC 60398. If some parts and electrical devices cannot withstand 1,5 times the maximum pressure, for example double wall vacuum chambers, turbo molecular pumps and heat exchangers in electrical cabinets, they shall be bypassed or disconnected and individually tested according to manufacturer's instructions.

5.4 Test of actuation systems

The electron beam installation may be equipped with different actuation systems like compressed air, hydraulics and electric motion systems. These systems shall be tested according to the relevant standards and manufacturer's instructions. Particular attention shall be given to:

- protective devices against overload and mechanical malfunction,
- means to safeguard personnel against dangerous movements.

5.5 Vacuum test

Measurement shall be carried out using an ionization vacuum gauge when the installation is clean.

A pressure of 10^{-2} Pa or lower shall be attained in the electron gun chamber, when the cathode is cold. For this measurement, the vacuum chamber shall be separated from the gun chamber, or if not possible, the vacuum chamber shall be cleaned and no workpiece shall be placed inside the chamber.

After heating up, the cathode shall be degassed for 30 min, then a pressure of 5×10^{-2} Pa or lower shall be attained.

The required pressure for the vacuum chamber depends on the process and the kind of separation between a gun chamber and vacuum chamber. In any case, the pressure inside the gun chamber shall be below the level of 5×10^{-2} Pa also in the case of maximum specified process pressure inside the vacuum chamber.

6 Test of electron gun system

6.1 Electron gun

6.1.1 Condition of parts

The individual parts of the electron gun shall be checked regarding cleanness, tightness and adjustment according to the manufacturer's maintenance instruction. Particular care should be given to the cathode system.

6.1.2 Moveable parts

If the electron gun has any moveable parts, like for example a vario cathode or vario anode, the movement shall be checked regarding smooth running, limits and accuracy of positioning.

6.1.3 Insulation resistance tests

The insulation resistance between high voltage conductors and ground shall be measured according to Clause 19 of IEC 60204-11 (2000).

6.2 High-voltage power supply including cables

6.2.1 Earthing system

6.2.1.1 Test of earthing stick

All parts of the earthing stick, the earthing cable as well as the connections to ground and to the hooks shall be carefully inspected. Damaged parts shall be replaced, immediately.

6.2.1.2 Test of automatic earthing systems

Connection wires, contacts and control devices shall be checked visually.

Beside the test of reliable operation of each earthing device, it is also necessary to check the monitoring circuits for earth connection. For this purpose, a piece of paper is put between the contacts. The simulation of this failure may only be done as long as power circuits are switched off in a safe way.

6.2.2 Safety installation

Beside the test of reliable operation of each safety device and the right assignment, it is also necessary to check whether the monitoring circuits for redundant elements can detect a single failure. The simulation of such a failure may only be done as long as power circuits are switched off in a safe way.

6.2.3 High voltage connectors

The insulation resistance between high voltage conductors and ground shall be measured according to Clause 19 of IEC 60204-11 (2000). Connections to ground or other potentials shall be temporarily disconnected for the measurement.

The cleanness of connectors and the right assignment of the high voltage cables to the connectors at high voltage supply and electron gun shall be carefully checked.

6.2.4 Calibration of internal measurement systems

The measurement of acceleration voltage and return current shall be calibrated periodically. The reference measuring instruments shall have an accuracy of at least class 0,5. The same accuracy is necessary for voltage divider and shunts, if they are used for the calibration.

In the case that the power is calculated by means of an analogue multiplier, this device shall be calibrated, too.

NOTE In most cases, it is not possible for the high voltage supply to measure the real beam current. The return current may be used as an equivalent.

6.2.5 Test of over-current protection device

6.2.5.1 Testing with a short circuit

The current drawn from the high-voltage power supply shall be increased to a level higher than its rated value, and the over-current control device shall operate at the specified current. The preferred method of performing this test is to apply a short circuit to the output terminals of the high-voltage supply taking suitable precautions to avoid damage to equipment and hazard to personnel.

6.2.5.2 Test of the normal functioning of the over-current protection device

Before rated power tests may be carried out, the normal functioning of the over-current protection device shall be first tested by increasing the emission current above its rated value, in accordance with the manufacturer's specification.

6.3 Test of electron beam bending system

The performance of a bending system may be checked with the help of a reference beam pattern. This pattern is created during the first installation corresponding to fix points inside the chamber, at the crucible or the work piece support, respectively. The stored reference beam pattern shall be applied on a regular basis under similar conditions (acceleration voltage, beam power, bending current) to check the stability of the bending system.

Alternatively, the magnetic field can be measured at several defined points (for example at a virtual grid in the plane of the bended gun axis). If the magnetic field is generated by an electromagnetic coil, the magnetic field shall be recorded as well as the corresponding current through the coil.

6.4 Test of electron beam deflection system

Before using the electron gun in production, the following properties of the deflection system shall be checked:

- the condition of cables, connectors and amplifiers (visual check),
- coil resistance or inductance and insulation resistance (see 6.5),
- the right assignment of deflection directions,
- the correlation between deflection angle and coil current,
- the functioning of the amplifiers and
- the functioning of electron beam interlock in case of deflection system faults.

The parameters of the beam deflection shall be tested under hot run conditions (see 7.1).

6.5 Test of electron beam focusing system

The test of the focusing system includes:

- a visual check of cables, connectors and amplifiers,
- the measurement of coil resistance or coil inductance,
- the insulation resistance measurement from coils to ground and to the coils of the deflection system and
- checking the functioning of the amplifiers.

The insulation resistance shall have a value higher than 100 kΩ. It shall be measured at extra-low voltage only.

7 Production run tests

7.1 Properties of beam deflection

7.1.1 Deflection limits

The deflection system should have the possibility to define limits, which restrict a processing area for the beam. Before the electron beam is made visible with an adequate pattern at a sample, preliminary limits are set to start the test with a small processing area. After checking the effectiveness of the limits for the beam deflection, the processing area may be enlarged step by step.

7.1.2 Frequency response

For detection of the maximum deflection frequency, the beam pattern is made visible by bombarding a sample with the electron beam. In the case of deflection in two directions, a circle should be the preferred pattern. Starting with a low deflection value (lower than one tenth of the expected maximum), the frequency is being increased till the pattern is reduced to half of its size. The test pattern size shall be 10 % of the maximum deflection angle, unless other conditions are specified by the manufacturer.

7.1.3 Linearity of deflection angle

A beam pattern is made visible by bombarding a sample with the electron beam. In the case of deflection in two directions, a circle should be the preferred pattern. The pattern is drawn with a frequency much lower than the maximum deflection frequency. The amplitude is increased in 5 to 10 equal steps from 10 % to 100 % of the maximum deflection angle.

In case that the equipment does not allow to operate the gun with its maximum deflection angle, the test is determined by the deflection limits.

7.2 Rated power test

The rated power is defined as the product of the cathode current and the acceleration voltage. The cathode current is measured as return current at the cold end of the acceleration voltage supply.

To reduce risks for service personnel, the internal measurement devices of high-voltage supply can be used for identification of rated power, after calibration according to 6.2.4.

7.3 Testing of electron beam parameters

7.3.1 Beam power

A workpiece or collector is installed, electrically insulated inside the vacuum chamber and connected via a shunt with low resistance to the return conductor. The beam current is given by the resistance of the shunt and the measured voltage drop over the shunt. The beam power is the product of this current and the acceleration voltage.

NOTE A damaged shunt can cause dangerous voltages at the measurement connection to the workpiece.

7.3.2 Beam diameter

7.3.2.1 Collector with slit

The beam is scanned via a collector with a slit. The period is measured, when the current flowing via the collector is less than 10 % of the beam current. Drawing a circle on a collector with radial arranged slits allows the measurement of the beam dimension in several directions.

7.3.2.2 Drilling test

A hole is drilled by the beam into a sample located next to the workpiece. It shall be ensured that heat from the workpiece does not influence the size of the hole.

The shape of the spot should be visually inspected in order to detect the focusing symmetry.

NOTE The beam diameter is also influenced by the beam current and vacuum conditions.

7.4 Measurement of surface temperature of heated devices

The temperature measurement shall be done by a thermocouple, resistance thermometer or pyrometer according to IEC 60398.

7.5 Long-term stability under hot run conditions

The installation with electron gun is operated under nominal conditions.

Voltages and currents for supply of the cathode system and the gun shall attain stable values according to the specifications after at the latest 30 min.

After 8 h run, it shall be checked whether heat or radiation cause changes or destructions at components of the installation. Special care shall be given to:

- the condition of cathode system,
- the mobility of moveable parts,
- vacuum and water seals,
- the condition of crucibles, supports, shielding and similar equipment.

7.6 X-ray test

The test shall be carried out in accordance with national requirements.

The X-ray emission test shall be carried out after any replacement of X-ray shielding of relevant parts of the gun chamber and vacuum chamber.

7.7 Testing related to electromagnetic effects

The measurements connected with EMC issues and influence of electromagnetic fields on people according to 6.4 of IEC 60519-1 (2003) apply.

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