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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Safety in electroheat installations –
Part 7: Particular requirements for installations with electron guns

Sécurité dans les installations électrothermiques –
Partie 7: Exigences particulières pour les installations comportant des canons à électrons

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SAFETY IN ELECTROHEAT INSTALLATIONS –

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FOREWORD

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International Standard IEC 60519-7 has been prepared by IEC technical committee 27: Industrial electroheating equipment.

This second edition cancels and replaces the first edition published in 1983 and constitutes a technical revision.

The significant changes with respect to the previous edition are as follows:

- the latest edition of IEC 60519-1 has been taken into account (the structure of clauses was adapted to it as far as practicable);
- some definitions have been modified or brought into line with IEC 60050-841:2004;
- Clauses 4 and 5 were added;
- requirements for the earthing system were updated according to technical progress;
- the arrangement of the return conductor was changed to avoid earthing connections from the process current as far as possible;

- possible risks caused by certain processes or components were described in Clause 14.

This part of IEC 60519 is to be used in conjunction with IEC 60519-1:2003. It is intended to specify particular requirements for electroheating installations with electron guns.

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

FDIS	Report on voting
27/578/CDV	27/622/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 list of all parts of the IEC 60519 series, under the general title *Safety in electroheat installations*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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.

SAFETY IN ELECTROHEAT INSTALLATIONS –

Part 7: Particular requirements for installations with electron guns

1 Scope

This part of IEC 60519 deals with safety of electroheat installations with electron guns. It applies to all the electroheat applications with electron guns.

This standard, whilst prepared for electroheat installations with electron guns may, however, also be used for non-thermal applications with electron guns and equipment employing glow discharge systems, where applicable.

This standard applies also to high-voltage sources feeding electron guns.

All requirements of IEC 60519-1 apply. Additional requirements for installations covered by this part of the standard are given in Clauses 6 to 16.

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

IEC 60364-4-43, *Electrical installations of buildings – Part 4-43: Protection for safety – Protection against overcurrent*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-841, IEC 60519-1 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 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 heat 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 focussing system
electromagnetic coil, system of coils or capacitor plates for focusing the electron beam over the charge heating surface

[IEV 841-30-27, modified]

4 Components of electron beam installations

An electron beam installation primarily consists of:

a) an electron gun;
b) a high-voltage power supply;
c) an electron beam deflection and focussing system including the necessary current supply and control systems;
d) an electron beam bending system;
e) a process chamber and workpiece handling;
f) a vacuum plant;
g) a control system;
h) facilities (electrical supply, cooling liquid, pneumatics, hydraulics, etc.).

NOTE Some components are only in specific installations, for example there is no bending system in many installations.

5 Types of electron guns

The principle of electron beam exploited in electron guns is mainly used in

- optical applications (for example CRT, video projection, image scanning, electron microscopy),
- other non-thermal applications (for example polymer modification, curing, sterilization, disinfection) and
- electroheat applications.

Typical electroheat applications are for example melting, heating, evaporation and surface treatment.

Depending on the application, electron beam guns can be classified according to

- the level of the acceleration voltage,
- the rated power,
- the electron beam geometry and
- the system for beam deflection and bending.

6 Main risks

Electron guns used for electroheat applications, due to their properties, may basically generate the following risks:

- high-voltage electric shock (see Clauses 7, 8, 9 and 11);
- X-rays (see Clause 15);
- thermal destruction of components inside a vacuum chamber caused by high energy density (see Clause 14).

In addition, there may exist hazards caused by components of the electron beam installation like a vacuum plant (see Clause 12) and by the process realized by electron beam guns (see Clause 14).

7 Earthing of high-voltage parts in gun chamber during maintenance

7.1 Manual earthing device

After switching off the high-voltage supply and gaining access by opening the door of the electron gun chamber or the housing of the electron gun, a portable earthing device of an approved design shall be used to remove any remaining charge before touching parts, which are normally live during operation.

The highly flexible earth conductor of the portable earthing device shall be permanently fixed to its earthing point. This earth connection point shall be visible for easy checking by the operator and be clearly and durably marked.

7.2 Mechanical earthing system

Alternatively, a mechanically self-acting earthing mechanism that is activated by the mechanical action of opening the gun chamber may be installed, provided that the proper function of this self-acting mechanism can be easily checked by eyesight from a safe distance.

7.3 Automatic earthing system

Alternatively, an automatically operating earthing mechanism may be installed under the following conditions:

a) the mechanism is automatically activated when the gun operation is stopped;

b) the proper functioning of the automatic mechanism is detected by a fail-proof automatic detection system;

c) a signal visible to personnel opening the gun chamber indicates proper functioning of the automatic earthing system;

d) an electro-mechanic lock of approved design disables opening of the gun chamber before the proper functioning of the earthing device has been positively detected.

Also, in the immediate vicinity of the high-voltage supply(ies), portable earthing devices shall be installed so as to be clearly visible.

8 High-voltage feeding

8.1 High-voltage feeder cables

The high-voltage feeder cables shall be adequately insulated and efficiently protected against mechanical damage.

Shielded cables shall be used for the high-voltage feeders or the feeder cables shall be installed inside conductive conduits or flexible hoses. Cable shields, conduits or flexible hoses shall be connected to the equipotential bonding.

When high-voltage feeder cables are laid inside conduits or flexible hoses, other cables shall not be included, except a return conductor. Each electron gun shall have its own conduit or flexible hose.

If the high-voltage feeder cable runs inside a conduit or flexible hose, the conduit or flexible hose shall extend into the high-voltage terminal connection compartment.

High-voltage feeder cables and low-voltage cables may run together inside cable trenches or cable troughs providing the high-voltage feeder cables are protected mechanically and electrically. The cable trenches or troughs are not considered as protection.

8.2 Return conductor

Each electron gun shall have its own return conductor to carry the beam current back to the high-voltage power supply in a specified way. The cross-sectional area of this conductor shall be of a size corresponding to the current of the gun but not less than 6 mm^2 copper. The return conductor shall be installed with flexible and insulated cable.

The return conductor shall be connected to earth potential at the termination point near the workpiece or the electron gun.

To enable a defined return current path, the return conductor shall not be earthed at the high-voltage power supply, but the voltage between the termination point and earth shall be limited by reliable means. If the return conductor is also directly connected to earth at the high-voltage supply, EMC requirements and grounding shall be taken under special care.

If, for special guns, a conductor of less than 6 mm^2 copper is employed, it shall be installed with special care, be mechanically protected and be at least of the size of the feeder conductors.

The voltage drop along the return conductor shall not exceed 1,5 V at rated current. Return conductors between electron guns and the high-voltage power supply shall be installed together with the feeders.

NOTE 1 Each installation should have at least two return conductors so that safety is maintained even if one fails. The exact arrangement of return conductors depends on the quality of the electrical interconnections of the electron gun chamber and the vacuum chamber as well as on the number of electron guns.

NOTE 2 In an installation with electron guns, the return current flows through the chamber and the framework of the installation in the direct surroundings of the electron gun.

8.3 Minimum distance between bare high-voltage components

Safety spacing applicable for high-voltage equipment need not be observed for electron guns and their supply as they are designed for use in dry and clean rooms. Such conditions of usage shall be specified in the manufacturer's installation instructions.

9 Protection against electric shock

The voltage supplies of the electron guns shall be switched off by safety interlocks, if:

- the electron gun chamber is opened and live parts become accessible;
- high-voltage cables are disconnected or assembled in a wrong way, and
- high-voltage enclosures of the power supply are opened.

In these cases, the interlock system shall switch off the voltage supply, discharge high-voltage capacitors and prevent resetting by reliable means.

In addition, frequently used openings shall be interlocked as long as voltage on covered parts may occur.

NOTE In the case of more than one gun in the installation, there might be the risk, that different sets of cables be connected to the high-voltage power supply and the related electron gun. Unconnected ends of these cables could become live this way. The same risk exists, if spare cables are present in the installation.

10 Protection against overcurrent and overvoltage

10.1 General requirements

According to IEC 60519-1, protective measures against overcurrent shall be provided in compliance with relevant standards, for example IEC 60364-4-43 and IEC 60204-1.

10.2 High-voltage power supply

The high-voltage power supply shall be provided with overcurrent and overvoltage protection adjustable by system settings.

The high-voltage power supply shall not be affected by excessive mains voltage.

11 Equipotential bonding

The provisions of Clause 11 of IEC 60519-1:2003 apply.

To protect operators against voltages between accessible metallic parts, equipotential bonding shall connect all conductive bodies, frames and enclosures with each other. The connection between vacuum chamber, electron gun and the high-voltage supply enclosure is especially important, but working platforms, liquid, hydraulic and gas pipes as well as metallic constructions of the building shall also be included into equipotential bonding. That way, all these parts are fixed to earth potential.

The cross-sectional area of these conductors shall be of a size corresponding to the current of the gun but not less than 6 mm^2 copper.

The equipotential bonding shall be able to carry the current of the electron beam from the surrounding of the heated work piece and of the electron gun to the termination point of the return connector without voltage drops exceeding 1,5 V.

12 Control circuits and control functions

12.1 Control circuits

Control circuits shall comply with Clause 9 of IEC 60204-1:2005 and Clause 12 of IEC 60519-1:2003.

12.2 Control functions

To avoid destruction by the electron beam, its energizing shall be possible only if the following conditions are fulfilled:

- the operating pressure is reached inside the vacuum chamber;
- the electron beam deflection system is running without any fault;
- the electron beam bending system is energized (if necessary);
- the cooling liquid is running in the specified amount;
- the gun valve is opened (if it exists).

13 Liquid cooling

Where liquid cooling is applied (e.g. in crucibles), appropriate monitoring devices shall be provided in accordance with 6.6 of IEC 60519-1:2003.