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TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

Test methods of plasma equipment for electroheat and electrochemical applications

Méthodes d'essai des équipements plasma pour applications électrothermiques et électrochimiques

IEC/TS 60680:2008

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TEST METHODS OF PLASMA EQUIPMENT FOR ELECTROHEAT AND ELECTROCHEMICAL APPLICATIONS

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 60680, which is a technical specification, has been prepared by IEC technical committee 27: Industrial electroheating equipment.

This first edition of IEC 60680/TS cancels and replaces the first edition of International Standard IEC 60680 published in 1980. It constitutes a technical revision.

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

- the previous edition focused on arc heating means and on spraying applications – this TS applies to all means of production of thermal plasma, i.e. arc and induction heating, and to the equipment directly coupled to these means;
- new items/issues have been added:
  - test methods for inductive plasma torch systems and for thermochemical treatment equipment (4.1.2, 5.1.2, 4.2.2, 5.2.2);
  - new test methods for spraying applications (4.2.1.3, 5.2.1.2);
  - protection against electromagnetic emissions (including Annex B);
  - detailed efficiency definitions, for both arc and inductive heating torch and system (Annex A and Annex C);
- terms and definitions have been updated according to the second edition of IEC 60050-841.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
27/581/DTS	27/605A/RVC

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

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

The committee has decided that the contents of this publication will remain unchanged until the 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

TEST METHODS OF PLASMA EQUIPMENT FOR ELECTROHEAT AND ELECTROCHEMICAL APPLICATIONS

1 Scope and object

This Technical Specification specifies test methods for

a) thermal plasma torch systems:
   - arc plasma systems;
   - inductive plasma systems;

b) installation using thermal plasma torch systems:
   - spraying equipment;
   - solid, liquid and gaseous charge heating and thermochemical treatment equipment.

Test methods for plasma torches for welding, cutting and allied processes are specified in IEC 60974-7.

The object of this specification is to standardize the test methods and conditions for determining the main parameters and technical characteristics of thermal plasma torch systems and of installations (or equipment) using one or more plasma torch systems.

Not all the tests specified are applicable to every type of equipment, covered by this specification. It is necessary to select those tests which are applicable to a specified plasma torch system or installation. This selection is effective in the specification.

Safety requirements for systems and installations or equipment specified in a) and b) are given in IEC/TS 60519-5.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-841 and the following apply.

3.1
plasma
any ionized gas consisting of free electrons, ions and neutral particles (atoms and/or molecules and/or radicals), electrically neutral on a macroscopic scale and electrically conductive

[IEV 841-31-01, modified]

3.2
thermal plasma
plasma in local thermodynamic equilibrium, at around atmospheric pressure or above

NOTE In IEC standards, related to equipment or installations, the use of the plain word "plasma" for "thermal plasma" is tolerated.

[IEV 841-31-07]

3.3
plasma heating
method of heating using thermal plasma as a heat source

[IEV 841-31-02]

3.4
arc plasma
arc thermal plasma
thermal plasma generated by an electric discharge between electrodes in a fluid

NOTE The plasma arc column is characterized by high current density, up to 100 A/mm^2, at pressures of the same order as atmospheric pressure.

[IEV 841-31-10]

3.5
inductive plasma
thermal plasma in which ionization is obtained by excitation of a gas in a high-frequency electromagnetic field

[IEV 841-31-12, modified]

3.6
plasma gas
any gas, vapour or fluid to be brought to the state of plasma

[IEV 841-31-14]

3.7
plasma torch
electroheat equipment in which an inlet gas stream is converted by electric energy supplied to a plasma flow prior to its ejection

[IEV 841-31-29]

3.8
arc plasma torch
electroheat equipment in which an inlet gas stream is converted to a plasma flow by electric energy supplied from an arc discharge prior to its ejection

NOTE Arc plasma torches can be supplied either by AC or DC current.

[IEV 841-31-30]

3.9
transferred arc plasma torch
arc plasma torch in which the main arc is maintained between an internal electrode (contained within the torch) and a liquid or solid medium (or a solid workpiece), electrically conductive, constituting or including an external electrode for current return

[IEV 841-31-32]

3.10
non-transferred arc plasma torch
arc plasma torch in which the main arc is maintained between two or more electrodes regarded as torch components

[IEV 841-31-31]

3.11
plasma jet
high velocity plasma flow supplied by a non-transferred arc plasma torch or by an inductive plasma torch

[IEV 841-31-18]

3.12
non-electrode plasma torch
plasma torch with no electrode, supplied by high frequency source of inductive or capacitive type

[IEV 841-31-36)

3.13
induction plasma torch
plasma torch in which the plasma flow is generated by an a.c. high-frequency magnetic field produced by a high-frequency current established in a coil

[IEV 841-31-38, modified]

3.14
ignition of a plasma torch
initiation of the transition from non-ionized plasma gas to plasma state, carried into effect by a starting-up equipment

[IEV 841-31-15, modified]

3.15
high-frequency ignition device (of a plasma torch)
device used in an arc plasma torch to ignite the arc by a high voltage and high-frequency electric discharge between the electrodes

[IEV 841-31-16, modified]

3.16
short-circuit ignition device (of a plasma torch)
device used in an arc plasma torch to ignite the arc by creating a short circuit between the electrodes

[IEV 841-31-17]

3.17
nozzle (of a plasma torch)
part of a plasma torch allowing shaping the plasma flow prior to its ejection in order to increase its speed and/or its energy density

[IEV 841-31-40, modified]

3.18
cathode (of a non-transferred or transferred plasma torch)
negative electrode of a d.c. arc plasma torch

NOTE 1 The cathode may be made of a high electrical and thermal conductivity material, such as copper(water cooled) or of a refractory metal, such as wolfram, or of graphite, water cooled if necessary.

NOTE 2 The return current electrode of a transferred plasma torch serves sometimes as the cathode.

[IEV 841-31-42, modified]

3.19
anode (of a non-transferred or transferred plasma torch)
positive electrode of a d.c. arc plasma torch

NOTE 1 The anode is usually made of a high electrical and thermal conductivity material, such as copper, and water cooled.

NOTE 2 The return current electrode of a transferred plasma torch serves in most cases as the anode.

NOTE 3 In a non-transferred plasma torch, the anode is often the torch nozzle.

[IEV 841-31-41]

3.20
normal operation of a plasma torch
operation characterized by reproducible working conditions defined by the type and composition of the gas, its mass flow rate and the arc current

3.21
specified current of a plasma torch
maximum current which can be used (for a given plasma gas) by a plasma torch

3.22
specified power of a plasma torch
maximum power which can be used (for a given plasma gas) by a plasma torch

3.23
thermal power of a plasma torch
thermal power delivered by the torch, defined as the gas mass flow rate multiplied by its average enthalpy

3.24
energy efficiency of a plasma torch
ratio of delivered thermal power to the active input power

3.25
plasma temperature
instantaneous local temperature within a plasma

[IEV 841-31-45]

3.26
plasma average enthalpy
plasma mean enthalpy
quotient of the power delivered by the plasma torch by the plasma gas mass flow rate

[IEV 841-31-44]

3.27
plasma system
equipment for the production of thermal plasma, consisting of the plasma torch, its power supply, gas and cooling utilities and a control unit

3.28
plasma furnace
electroheat equipment comprising a refractory lined chamber in which a charge is heated by one or more plasma torches and generally used to melt or to smelt materials at high temperatures

[IEV 841-31-25]

3.29
plasma reactor
electroheat equipment comprising a chamber for a thermochemical processing of material by plasma torches

[IEV 841-31-27]

3.30
plasma installation
installation to carry on the plasma process, consisting of a plasma system and, in most cases of a plasma furnace or reactor, including all necessary auxiliary equipment for heating or thermally treating materials

3.31
plasma spraying
coating in which material introduced in the form of powder or wire and melted in a plasma jet is sprayed onto a surface

[IEV 841-31-24]

3.32
powder deposition efficiency
ratio of the mass flow rate of powder consolidated on a substrate to the mass flow rate of powder fed to the torch

4 Type and general conditions of tests

4.1 List of tests and measurements applicable to thermal plasma torch systems

4.1.1 Arc plasma systems

Arc plasma systems shall be subjected to the following tests and measurements.

4.1.1.1 Arc power supply tests

Power supplies used for arc plasma generation are generally either a.c. of 50 Hz or 60 Hz, or d.c., obtained by using semiconductor devices, for example thyristors, IGBT (Insulated Gate Bipolar Transistor) or IGCT (Integrated Gate Commutated Thyristor).

For a.c. and d.c. type supply, the following tests are applicable:

a) verification of equipotential bonding by measurement;
b) measurement of insulation resistance;
c) dielectric test;
d) regulation mode test:
   – off-load test,
   – on-load test;
e) determination of energy efficiency;

For d.c. type supply only:

f) measurement of ripple factor.

4.1.1.2 Gas circuit tests

The flow/pressure characteristics of the gas circuit shall be determined.

4.1.1.3 Cooling circuit tests

The following measurements and tests are applicable:

a) determination of the flow/pressure characteristics;

b) measurement of cooling liquid inlet and outlet temperature as a function of the mass flow rate at maximum steady-state power of the plasma system;

c) measurement of the cooling liquid electrical resistivity.

4.1.1.4 Ignition test

For plasma systems ignited by a high frequency device, measurements of electromagnetic emissions around the ignition device shall be made according to the regulations in force in the country in which the plasma system is to be used. They shall comply with local regulations.

4.1.1.5 Plasma torch tests

The followings standard tests are performed assuming that the torch operates at external atmospheric conditions:

a) static sealing test under cooling liquid filling;

b) verification of equipotential bonding by measurement;

c) measurement of insulation resistance;

d) dielectric test;

e) ignition test:

- high frequency ignition device:
  - check of ignition capability for the plasma gas(es) to be used,
- short-circuit ignition device:
  - electrical continuity,
  - check of ignition capability for the plasma gas(es) to be used;

f) determination of the voltage/current characteristics at several plasma gas mass flow rates, for each specified plasma gas;

g) determination of the thermal power and electrical power under different operating conditions;

h) determination of the average enthalpy under different operating conditions;

i) determination of energy efficiency;

j) temperature measurement of accessible parts of the torch;

k) acoustic level measurement under different operating conditions;

l) electromagnetic emissions measurement under different operating conditions, according to appropriate standards;

m) for arc transferred plasma torch, thermal radiation measurement under different operating conditions;

n) electrodes erosion measurement.

NOTE This type of measurement is not obligatory and results from an agreement between the manufacturer and the user.

4.1.2 Inductive plasma systems

Inductive plasma systems shall be subjected to the following measurements and tests.

4.1.2.1 Inductive power supply tests

Power supplies used for RF inductive plasma generation are generally operated in the radio frequency MHz range (typically between 2 MHz and 27,6 MHz). Exceptionally, this range is extended downwards to the 200 kHz to 300 kHz range and upwards up to 40 MHz. Power supplies operating with frequencies in the MHz range at power levels of tens to hundreds kW are generally of the triode type oscillators.

The following tests are applicable:

a) verification of equipotential bonding by measurement;
b) measurement of insulation resistance;
c) circuit protection test;
d) determination of energy efficiency.

4.1.2.2 Gas circuit tests

See 4.1.1.2.

4.1.2.3 Cooling circuit tests

See 4.1.1.3.

4.1.2.4 Ignition test

See 4.1.1.4.

4.1.2.5 Plasma torch tests

Apply 4.1.1.5, except item n) (non-electrode torch).

4.2 List of measurements and tests applicable to installations using plasma torches

4.2.1 Spraying installations

Spraying installations shall be subjected to the following measurements and tests.

4.2.1.1 Arc plasma torch systems

See 4.1.1 for arc plasma systems.

4.2.1.2 Inductive plasma systems

See 4.1.2 for inductive plasma systems.

4.2.1.3 Plasma spraying equipment measurements and tests

In spraying applications, the material to be treated is a powder, wire or liquid. The following measurements and tests are applicable:

a) powder used for operation:
   1) determination of range of particle size,
   2) determination of the fluidity of the feeding particles flow,
   3) determination of the carrier gas circuit mass flow rate/pressure characteristics,

4) determination of maximum feed rate as a function of the maximum power of the equipment,

5) determination of the powder deposition efficiency (3.32);

b) wire used for operation:

1) determination of the wire diameter,

2) determination of maximum feed rate as a function of the maximum power of the equipment;

c) liquid used for operation:

1) injection system:

– characterization of the gas atomization,

– characterization of the mechanical injection (drops or jets);

2) solutions:

– concentration of the precursor and composition,

– solvent used;

3) suspension:

– solvent used,

– dispersant used,

– determination of the particle size and morphology,

– determination of the particle weight percentage.

The workpiece shall be grounded when using plasma transferred arc reclamation.

4.2.2 Solid, liquid and gaseous charge heating and electrochemical installations

Solid, liquid and gaseous charge heating and electrochemical installations shall be subjected to the following measurements and tests:

4.2.2.1 Thermal plasma torch systems

See 4.1.1 and 4.1.2.

Item b) of 4.1.1.3 shall take into account the extra losses in the plasma torch cooling circuit due to the location, partial or total, of the torch in the high temperature atmosphere of the furnace or reactor.

4.2.2.2 Heating and thermochemical treatment equipment

The following measurements and tests are applicable:

a) determination of the gas circuit pressure/temperature characteristics, including gas(es) used for the torch, for different operating conditions;

b) verification of equipotential bonding by measurement;

c) acoustic level measurement;

d) temperature measurement of accessible parts of the equipment (in particular the furnace and/or the reactor);

e) identification of risks linked to the production of toxic products;

f) identification of the explosion hazard situations;

g) measurement of cooling liquid inlet and outlet temperatures as a function of the mass flow rate at maximum continuous power of the equipment;

h) determination of the cooling circuit mass flow rate/pressure characteristics.

4.3 General test conditions

General test conditions according to IEC 60398 apply.

5 Description of testing and measuring methods

5.1 Tests applicable to plasma systems

5.1.1 Arc plasma torch systems

5.1.1.1 Arc power supply tests

For a.c. and d.c. type systems the following measurements and tests apply:

a) verification of equipotential bonding by measurement:

a current of 10 A shall be applied to measure the mass continuity, in mΩ;

b) measurement of insulation resistance:

a voltage of 500 V d.c. shall be applied for 1 min without breakdown for low voltage circuits;

a voltage of 1 000 V d.c. shall be applied for 1 min without breakdown for high voltage circuits;

for low voltage circuits, the insulation resistance shall be not less than 3 MΩ;

for high voltage circuits, the insulation resistance shall be not less than 100 MΩ;

c) dielectric test:

a practically sinusoidal voltage of mains frequency 50 Hz or 60 Hz, the value of which is specified below, is applied for 1 min;

at the beginning of the test, the voltage applied is less than half of the prescribed value, and is then rapidly raised to the test value.

The specified values are as follows:

– installation with a rated voltage lower than or equal to 50 V; test voltage: 500 V;

– installation with a rated voltage U above 50 V; test voltage $2U$ + 1 000 V (minimum 1 500 V);

d) regulation mode tests:

- measurement of the open-circuit voltage;
- on-load tests:
  - – short-circuit tests,
  - – resistive load tests (resistance value lower than 1 Ω) to determine the current accuracy;

e) determination of energy efficiency:

measurement of the energy losses, at low voltage and operating currents, to determine the energy efficiency, by measuring the input and output power at rated conditions as specified.

For d.c. type systems the following measurement applies:

f) measurement of ripple factor:

measurement of the current ripple at specified power (agreed between the manufacturer and the user) with resistive load.

NOTE The ripple factor is defined as the ratio of the root mean square value of the ripple to the mean d.c. value of the measured current.