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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial electroheating equipment – Test methods for submerged-arc furnaces

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Chauffage électrique industriel – Méthodes d'essai des fours à arc submergé

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL ELECTROHEATING EQUIPMENT – TEST METHODS FOR SUBMERGED-ARC FURNACES

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the latest edition of this publication.

International Standard IEC 60683 has been prepared by IEC technical committee 27: Industrial electroheating.

This second edition cancels and replaces the previous edition published in 1980 and constitutes a technical revision.

Significant technical changes with respect to the previous edition are as follows:

– Clause 1 (*Scope and object*) – the types of furnaces covered by this standard are more clearly defined.
– Clause 2 (*Normative references*) and Clause 3 (*Terms and definitions*) have been updated and completed.
– A new Clause 4 (*Features of the SAF sytem*) has been added; it mainly concentrates on the tests necessary for high voltage/high current electrical equipment in the installation.
– Clause 5 (*Tests and general conditions*) and Clause 6 (*Technical tests*) have been modified according to today's requirements for safe operation of a SAF.

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

CDV	Report on voting
27/780/CDV	27/797/RVC

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

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

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

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INDUSTRIAL ELECTROHEATING EQUIPMENT – TEST METHODS FOR SUBMERGED-ARC FURNACES

1 Scope and object

This International Standard specifies test procedures, conditions and methods according to which the main parameters and the main operational characteristics of a submerged-arc furnace (SAF) with rated electrical power levels above 500 kVA are established.

This standard is applicable to SAF with one or more electrodes.

In order to determine further technical or economic assessments, additional tests may be necessary.

Tests for some special equipment for semiconductor converter controlled furnaces, such as controlled rectifiers or controlled a.c. converters, are covered by IEC 60146-1-1.

2 Normative references

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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 60398, *Industrial electroheating installations – General test methods*

IEC 60683:2011
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IEC 60519-1:2010, *Safety in electroheating installations – Part 1: General requirements*

IEC 60519-4, *Safety in electroheat installations – Part 4: Particular requirements for arc furnace installations*

3 Terms and definitions

For the purposes of this document the terms and definitions given in IEC 600519-1:2010 and the following apply.

NOTE Refer to International Electrotechnical Vocabulary, IEC 60050, for general definitions. Terms relating to industrial electroheat are defined in IEC 60050-841.

3.1
active power
P
mean value of the instantaneous power p (in kW) taken under periodic conditions over one period of time T (in h):

$$P = \frac{1}{T}\int_0^T p\,dt$$

NOTE Active power instantaneous value (r.m.s.) measured at any time, including all phases.

[IEC 60050-131:2002, 131-11-42, modified]

3.2
apparent power
S
power rating of the transformer, energizing the SAF (in MVA)

$$S = UI = \sqrt{P^2 + Q^2} \quad \text{(for single-phase SAF)}$$

$$S = \sqrt{3}\ UI \quad \text{(for three-phase SAF)}$$

where

U is the voltage, r.m.s., sinusoidal value (in kV)

I is the current, r.m.s. sinusoidal value (in kA)

[IEC 60050-131:2002, 131-11-41, modified]

3.3
bottom electrode
SAFdc electrical conductive elements integrated in the SAF bottom (mainly connected as anode)

3.4
cold state
thermal state of a furnace and its installation, when the temperature of all parts is equal to ambient temperature

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3.5
cold test
test of the entire furnace installation, including functions, connections, movements and instrumentation, prior hot commissioning, following erection

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3.6
dead band
finite range of electrical values within which a variation of the input variable does not produce any measurable change in the output variable

[IEC 60050-351:2006, 351-24-14, modified]

3.7
electrode
part produced from conductive material to transfer the electric current to the process

NOTE For types of electrodes, see 4.5.

[IEC 60050-841:2004, 841-26-38, modified]

3.8
furnace transformer
transformer feeding the SAF with electrical energy, supplied from the high-voltage network with suitable voltage and current ranges for operation

NOTE 1 Secondary voltage is controlled by on-load tap changer or adjusted during off-circuit.

NOTE 2 There are designs using three or more single phase transformers per furnace.

[IEC 60050-841:2004, 841-26-55, modified]

3.9
furnace electrical losses
P_{loss}
losses caused by the parts of the main electrical circuit, outside the furnace vessel

NOTE Electrical losses of high voltage supply, power factor compensation (when used) or prebaking electrodes are not included in the furnace electrical losses.

3.10
furnace
vessel which consists of bottom, shell and roof, into which the process material is charged

NOTE SAF, constructed from steel, clad with refractory, can be circular / rectangular in open, semi-closed or closed form.

[IEC 60050-841:2004, 841-26-16, modified]

3.11
high-current line
assembly to conduct high current between transformer secondary bus bars and electrode(s), connected in series- (and/or parallel), comprising flexible connections, bus bar system or high current tubes, cables, electrode arms (when used) and contact clamps

3.12
hot commissioning
heating up of the furnace till a defined production is reached

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3.13
hot state
thermal condition of the furnace as soon as hot commissioning is finished

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3.14
main electrical circuit
electrical equipment for SAF comprising high voltage supply, power factor compensation (when used), switchgear, transformer(s), semiconductor convertors (a.c. or d.c.) (when used), d.c. reactor (when used), high current line, electrode systems with electrodes and burden

3.15
power factor
cos φ
ratio of the active power to the apparent power, measured on the primary side of the transformer

$$\cos\varphi = \frac{P}{S}$$

where

P is the active power (in MW)

S is the apparent power (in MVA)

NOTE In case of harmonics, power factor is determined according to IEC 60146-1-1.

[IEC 60050-131:2002, 131-11-46, modified]

3.16
reactive power
Q
total reactive electrical power (in MVAr) generated by the main electrical circuit of a SAF, measured on all phases at the primary side of the transformer

NOTE 1 Instantaneous value of the reactive power measured at any time, including all phases.

NOTE 2 Mean value within a time interval: i.e. generated reactive energy (in MVArh) by the power-on time (in h).

[IEC 60050-131:2002, 131-11-44, modified]

3.17
reactive power compensation
action to optimize the transmission of reactive power during operation

[IEC 60050-603:1986, 603-04-28, modified]

3.18
rectifier
device by means of which alternating current is changed into direct current for SAFdc

[IEC 60050-881:1983, 881-08-11, modified]

3.19
semiconductor converter
electronic converter for electrical power with semiconductor valve devices

NOTE SAFdc: converter to control the direct current (rectifier); SAFac: converter to control alternating current to smooth the power input (graduator).

[IEC 60050-551:1998, 551-12-42, modified]

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3.20
smoothing reactor
reactor used to reduce alternating components of a pulsating current, to minimise arc impacts and to ensure arc stability during the process

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[IEC 60050-811:1991, 811-26-21, modified]

3.21
specific electric energy consumption
quantity of electrical energy (in kWh) consumed by the SAF for the production of the final product (in t), charging a defined mixture of specified raw materials or for the (s)melting of charged material (in t)

3.22
submerged arc-resistance furnace
SAF
vessel in which a combined arc / resistance heating is used to melt the charged material

[IEC 60050-841:2004, 841-26-12, modified]

4 Features of the SAF system

4.1 Electrical assembly of SAF

In the electrical assembly of a SAF, the following equipment is included:

– high-voltage supply line,
– high voltage switchgear, by which the SAF can be connected/disconnected from the electrical supply under load,
– furnace transformer(s),
– secondary bus bar system,
– semiconductor converter (a.c. or d.c.),

– equipment for reactive power compensation and/or voltage stabilization (if supplied),
– automatic power regulation system,
– boards, panels and desks,
– control, measuring and signalling devices.

4.2 Star-delta switch

Star-delta switch(es) is/are arranged on transformer(s) HV side. It connects the transformer HV windings to wye – or delta connection in order to modify the transformer(s) secondary voltage range by $\sqrt{3}$. Any star-delta switch can be operated in off-circuit condition only.

NOTE When three single-phase transformers are used, the star-delta switch is installed normally inside the transformer vessel. On single-phase transformers, the star-delta switches are installed at the high voltage switchgear.

4.3 Types of SAF

In general the SAF is operated using the a.c. or d.c. technology.

In the SAFac, the electrical energy is conducted to the process via 3 to 6 electrodes. In some SAFac applications (e.g. FeNi furnaces) semiconductor convertors are used for alternating current control.

In the SAFdc, electrical energy is conducted via the anode in the bottom of the furnace through the charge material to the cathode (electrode).

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Electrical energy normally forms arcs between the electrode and the charge material or heats up the charge material by the resistance heating (Joule effect).

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4.4 SAF process principles

Processing of nonferrous metal, iron alloys, waste recycling, slag and cleaning of slag is possible in the SAF.

It shall be differentiated between the following modes using the SAF for production:

a) 100 % burden resistance mode (electrodes submerged in the burden), e.g. for the production of FeCr, FeSi;
b) mix of burden and slag resistance mode (electrodes submerged in burden and slag), e.g. for slag cleaning and settling furnaces for Cu, Pb, Zn;
c) shielded arc mode (arc below electrode tip is shielded with burden and is in touch with the slag), e.g. producing FeNi;
d) open arc mode (arc below electrode tip in direct contact with the slag), e.g. in the TiO_2-slag production and waste recycling.

4.5 Types of electrodes

There are different types of electrodes, i.e.:

a) prebaked electrodes,
b) self-baking electrodes (Soederberg electrodes),
c) extrusion/composite electrodes, which are a combination of Soederberg electrodes with a prebaked electrode as a core,
d) hollow electrode system, which allow charging of fines via the centre hole (prebaked, self-baking).

The selection of the type of electrode depends mainly on:

– size of the electrode,
– produced material/metallurgy,
– economic aspects such as operational costs.

4.6 Electrode system

The electrode system consists of different options as follows:

a) an upper electrode part (for slipping and holding) and a lower electrode part, which is connected with the secondary bus bar system to conduct the electrical current to the electrode;
b) a single electrode arm with electrode clamp which holds the electrode and conducts the electrical energy.

NOTE 1 Occasionally the lower clamp can hold the electrode.

NOTE 2 The electrode port in the roof can be sealed by a gland.

4.7 Water cooling

Electrical equipment of the SAF can be cooled by water. Water circuits can be closed or open. It shall be differentiated between the following water circuits:

a) furnace transformer, cooled by oil which is indirectly cooled by water,
b) secondary bus bar system including clamps,
c) electrode glands,
d) semiconductor converter for a.c. or d.c. cooled by special treated water which is indirectly cooled by water,
e) auxiliaries,
f) d.c. reactor.

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4.8 Electrical connection

High current lines of the SAFac with 3 electrodes are mostly arranged in Knapsack connection. The furnace transformer(s) secondary windings are connected in delta at the electrode clamps. Electrodes are connected in star with the burden or slag.

NOTE In SAFac applications with low power, the delta can be closed directly at the transformer.

5 Tests and general conditions

5.1 General

Tests shall be in accordance with the specifications given in IEC 60398 and in agreement with IEC 60519-1 and IEC 60519-4.

Fluctuations in power supply shall be minimal and symmetry of the three phases shall be maximized. In case it is not feasible to switch-off reactive power compensation and/or voltage stabilization during testing, requirements are stated in this standard.

Test procedures and all measurement points are to be agreed upon between the supplier and user.

The type of measurement equipment as well as the layout and arrangement of the measurement points shall be shown in the test report, as far as relevant for the test.