IEC 60676

Edition 3.0 2011-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial electroheating equipment – Test methods for direct arc furnaces

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

IEC 60676:2011

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:
Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC 60676

Edition 3.0 2011-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial electroheating equipment – Test methods for direct arc furnaces

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX R

ICS 25.180.10

ISBN 978-2-88912-725-2

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL ELECTROHEATING EQUIPMENT – TEST METHODS FOR DIRECT ARC FURNACES

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60676 has been prepared by IEC technical committee 27: Industrial electroheating.

This third edition cancels and replaces the previous edition published in 2002 and constitutes a technical revision.

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

– Clause 1 (*Scope and object*) – types of furnaces are more clearly defined.
– Clause 2 (*Normative references*) and Clause 3 (*Terms and definitions*) have been updated and completed.
– New Clause 4 (*Features of the EAFsystem*) has been added; it mainly concentrates on the tests necessary for high-voltage / high-current electrical equipment in the installation.
– Clause 5 (*Type of tests and general conditions of their performance*) and Clause 6 (*Technical tests*) have been modified according to today's requirements for safe operation of an EAF.

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

FDIS	Report on voting
27/816/FDIS	27/837/RVD

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INDUSTRIAL ELECTROHEATING EQUIPMENT – TEST METHODS FOR DIRECT 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 electric arc furnaces (EAF) operated either with alternating current (EAFac) or with direct current (EAFdc) with a capacity above 500 kg/heat are established.

The EAF technology is also applicable to furnaces, in which liquid metal is kept at high temperature or superheated to casting temperature (e.g. in a ladle furnace (LF), operated with alternating current).

Test methods for some special equipment, e.g. controlled rectifiers for EAFdc, are covered by IEC 60146-1-1.

Test methods for submerged arc furnaces (SAF) are covered by IEC 60683.

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

IEC 60519-1, *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 60519-1:2010 and the following apply.

NOTE Refer to International Electrotechnical Vocabulary, IEC 600500, 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 EAF (in MVA)

$$S = \sqrt{3}\, UI \qquad \text{(for three-phase EAF)}$$

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
arc furnace
furnace with a vessel, in which a metallic charge is heated mainly by electric arc using alternating current (EAFac) or direct current (EAFdc)

[IEC 60050-841:2004, 841-26-05, modified]

3.4
arc furnace transformer
transformer changing medium/high voltage electrical supply to low voltage and high current for an EAF

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

3.5
asymmetry factor
K
difference between maximum and minimum impedance of any phase, divided by the mean impedance of all three phases (in %)

NOTE Not applicable for EAFdc.

3.6
capacity (of EAF)
volume of liquid material, which can be produced in the EAF (in t)

NOTE Whether metric or short tonnes according to pre-requisites.

[IEC 60050-841:2004, 841-21-40, modified]

3.7
cold state (of EAF installation)
thermal state of EAF installation when the temperature of all parts equals the ambient temperature

3.8
electric arc furnace using alternating current
EAFac
furnace, in which electric arcs between the electrodes and the process material are formed, using three-phase alternating current

NOTE Ladle furnace (LF) is operated under the same conditions.

[IEC 60050-841:2004, 841-26-07, modified]

3.9
electric arc furnace using direct current
EAFdc
furnace, in which the direct current is induced via a bottom electrode (anode) to the material to be processed, forming arcs between the material and the electrode from top (cathode)

[IEC 60050-841:2004, 841-26-06, modified]

3.10
EAF electrode
part produced from high density graphite to transfer the electrical energy forming arcs between tip and charge material

NOTE In EAFdc, a bottom electrode (anode) is metallic or conductive material in the bottom of an EAF and arcs are formed between the charge material and the graphite electrode from top (cathode).

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

3.11
electrode clamp
metallic, water cooled equipment to hold the electrode and supply current for arcing to the electrode

[IEC 60050-841:2004, 841-26-39, modified]

3.12
heat

mass of liquid material which is tapped after one process from an EAF into a ladle (in t)

3.13
high-current line

assembly to conduct the high current between transformer secondary bushings and electrode(s) of an EAF

NOTE It consists of the bus bar system, cables and either a current tube system or current conducting electrode arm to the electrodes.

[IEC 60050-841:2004, 841-26-54, modified]

3.14
hot state (of EAF)
thermal state of an EAF in which the components and charge material are at a temperature above 600 °C and a steady-state temperature of the components is reached

3.15
medium/high-voltage switchgear
medium/high-voltage switchgear connecting the EAF transformer to the electrical supply by switching on/off under load

NOTE EAF circuit switchgear capable for up to 150 operations under load per day.

3.16
operational short circuit
short circuit due to direct contact of at least two electrodes in an EAFac with charge/liquid material

NOTE In EAFdc, short circuit is reached if the electrode from top is in contact with the charge/liquid material.

[IEC 60050-841:2004, 841-26-70, modified]

3.17
phase rotation
phase sequence of the electromagnetic field (counter clock wise seen from top of the furnace)

3.18
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.

3.19
power-on time (time p-on)
time (in min) between first arcing and tapping, in which the electrodes are under current

3.20
production rate
total quantity of metal (in t) tapped, divided by the tap-to-tap time (in h)

3.21
reactive power
Q
total reactive electrical power (in MVAr) used in the system, measured on the primary side of the transformer

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

3.22
rectifier for direct current
device by means of which alternating current is transferred into direct current for EAFdc

3.23
reactor
reactor connected in series to the EAFac transformer to minimise impacts on the electrical supply created by the arcs and ensure arc stability during the process

3.24
shell
body of EAF made from steel and covered by a roof

[IEC 60050-841:2004, 841-26-20, modified]

3.25
smoothing choke (shunt reactor)
inductor smoothing electrical high frequency fluctuations in d.c. technology, due to changes in arc conditions

NOTE In case multiple rectifiers are coupled in the system, inductors can decrease the fluctuations as well.

3.26
specific electrical energy consumption
quotient of electrical energy consumed (in kWh) during melting and superheating of the metal (in t) tapped at a specified temperature

[IEC 60050-841:2004, 841-22-72, modified]

3.27
tap-to-tap time
t_{ttt}
time (in min) between end of tapping of previous heat and end of tapping of actual heat

4 Features of the EAF system

4.1 General

In the EAF ferrous metal (e.g. steel or liquid iron) or non-ferrous metal (e.g. copper, nickel or corundum etc.) can be produced. The EAF can be charged with solid or liquid material.

4.2 Electrical assembly of EAF

In the electrical assembly of an EAF the following equipment is included:

a) main circuit, i.e.:
   - medium/high voltage supply line including switchgear,
   - reactive power compensation (if applicable),
   - alternating current series reactor (if applicable),
   - EAF transformer,
   - high current bus bar system,
   - high current cables,
   - electrode arm system,
   - EAFdc: controlled rectifier and shunt reactor for direct current,
   - EAFac: three graphite electrodes from top,
   - EAFdc: specific electrode(s) in the bottom and graphite electrode(s) from top;

b) equipment to control all electrical parameters of the installation (i.e. boards, panels, desks, controls measuring and signalling devices etc.).

4.3 Furnace construction

The EAF consists of a vessel, covered by a roof, which can be opened for charging or maintenance.

The EAF is constructed from steel according to its nominal capacity. The bottom is lined with refractory to hold the liquid metal and slag. The side walls above the bottom are either lined with refractory or issued with water cooled side wall panels. The roof is either totally refractory clad or water cooled with a refractory centre piece around the electrodes.

The EAF capacity: according to the free volume of the furnace bottom and the specific density of the respective material to be molten in the EAF. The vessel: in horizontal position, metal surface below defined sill line, which allows the minimum amount of slag on top of the liquid material. Vessel lined according to design definitions.

NOTE Specific density of the respective material to be agreed upon between the supplier and user.

4.4 Water cooling

In specific cases electrical parts of the EAF shall be cooled by water.

NOTE In addition, cooling water is necessary to cool the vessel, roof and hydraulic system.

It shall be differentiated between the following cooling water circuits for the electrical equipment:

a) transformer, cooled by oil, which is indirectly cooled by water;
b) high current bus bar system including cables;
c) electrode arms;
d) semiconductor devices, cooled by special treated water, which is indirectly cooled by water.

5 Type of tests and general conditions of their performance

5.1 General

Tests shall be in accordance with the specifications given in IEC 60398.

During test procedures IEC 60519-1 and IEC 60519-4 shall be taken into account.

Tests shall be performed independently of the status of the SVC (Static Var Compensation) equipment.

Fluctuations in power supply should be minimal and symmetry of the three phases shall be maximized.

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.

5.2 List of tests during cold and hot state

The following tests with respect to the electrical equipment shall be conducted before the EAF is ready for operation and at regular intervals or following repair and modifications:

a) verification of electrical insulation of the high/medium voltage equipment and the high current lines (see 6.1.2),
b) cooling water system for transformer and high current system (see 6.2),
c) speed and motion of electrode system (see 6.3),
d) phase rotation test (see 6.7),
e) check of all safety devices and interlocks.

The following tests shall be made in hot state of the EAF:

f) short circuit during operation (see 6.4),
g) phase reactance symmetry (see 6.4.4),
h) specific electrical energy consumption (see 6.5),
i) specific production rate (see 6.5),
j) net power-on time (see 6.5.2),
k) power factor (see 6.5.2),

l) specific electrode consumption (see 6.6).

NOTE Additional tests are covered by commissioning and operation manuals issued by the supplier.

6 Technical tests

6.1 Electrical insulation of high-current system

6.1.1 General

Electrical insulation test shall be carried out on the EAF, empty in cold state without any cooling water in the system (water supply hoses disconnected) and electrodes in position.

EAFdc: transformer (controlled rectifier) and measurement systems on the secondary side shall be disconnected from the high current system.

6.1.2 Insulation resistance

Insulation shall be tested by means of a mega ohmmeter according to IEC 60398:1999, subclauses 7.1.2 and 7.1.3.

The tests shall be performed as follows:

– disconnect furnace transformer (EAFac) or rectifier (EAFdc) from the high current system,
– measure insulation between each phase and the EAF structure (earthed). The minimum value shall be 1 kΩ/V rated voltage.

The insulation test of the bottom electrode(s) shall be performed according to the commissioning or operation manual, issued by the supplier.

6.2 Cooling water system

Tests shall be carried out during normal production and EAF in hot state.

The following specific information of the cooling water is necessary in this respect:

– flow rate (in m^3/h),
– inlet and outlet pressure (in bar),
– maximum inlet and outlet temperature (in °C),
– quality (i.e. hardness, conductivity, etc.).

Cooling water composition, properties, pressure and inlet temperature shall be according to supplier's recommendations.

Cooling water flow rate q (in m^3/h) shall be calculated according to the following formula:

$$q = \frac{Q_m}{t} \tag{1}$$

where

Q_m is the measured quantity of water [in m^3];
t is the time required for the test [in h].