IEC 60676

Edition 4.0 2024-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Industrial electroheating equipment – Test methods for direct arc furnaces

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

IEC 60676:2024-02(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONALE

ICS 25.180.10

ISBN 978-2-8322-8367-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INDUSTRIAL ELECTROHEATING EQUIPMENT – TEST METHODS FOR DIRECT ARC FURNACES

FOREWORD

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IEC 60676 has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) The structure has been redrafted according to IEC 60398:2015.
b) The scope has been redrafted.
c) The terms/definitions, normative references and bibliography have been updated and completed.
d) The test methods and content from IEC 60398:2015 have been confirmed, replaced, or complemented with regards to direct arc furnaces (EAF, LF).

e) The annexes from IEC 60398:2015 have been confirmed, replaced, or complemented with regards to direct arc furnaces (EAF, LF).

The text of this International Standard is based on the following documents:

Draft	Report on voting
27/1181/FDIS	27/1184/RVD

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

The language used for the development of this International Standard is English.

This standard is to be read in conjunction with IEC 60398:2015. It supplements or replaces the corresponding clauses of IEC 60398:2015. Where the text indicates a "modification" of, "addition" to or a "replacement" of the relevant provision of IEC 60398:2015, these changes are made to the relevant text of IEC 60398:2015. Where no change is necessary, the words "This clause of IEC 60398:2015 is applicable" are used. When a particular subclause of IEC 60398:2015 is not mentioned in this standard, that subclause applies as far as it is reasonable. When a particular subclause of IEC 60398:2015 is not applicable, the word "Void" is used.

In this standard, the following print types are used:

- terms defined in Clause 3: **bold type**.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Direct electrical arc furnaces are very important applications for steel scrap melting, melting of direct reduced iron (DRI), hot bricked iron (HBI) or hot metal. While ladle furnaces are mainly used for providing the required quality and final adjustment of temperature of molten steel before sending to casting machine or to vacuum treatment stations.

The manufacturer of the installation or equipment usually fulfils the following requirements, which come from different sources and are quite often in this order of priorities:

a) to enable the intended process and make the installation work properly;

b) to be cost effective during design and manufacturing;

c) to ensure that the equipment is safe to use in the sense of providing freedom from unacceptable risk of physical injury or damage to the health of the operator (safety in the narrower sense of ISO 12100:2010);

d) to ensure that the equipment is safe to use in the sense of providing freedom from unacceptable risk or physical injury or damage to the health of people, or damage to property or the environment (adding other safety aims to item c), and in the much broader definition of safety according to ISO/IEC Guide 51);

e) to prove that the equipment is cost effective to operate and uses sufficiently small amounts of energy, material and other resources.

It is usually part of the proprietary knowledge of the manufacturer or user of the equipment, to make it cost effective or enable intended processes with a benefit. IEC 60519-1 and IEC 60519-4 assist with achieving safety in the ISO 12100:2010 sense. The focus of this document is on basic requirements for measuring instrumentation and test methods concerned with energy and resource efficiency, performance of the intended process and assessing cost of ownership for installations and equipment.

This document presumes that the installation or equipment is operated and maintained only by personnel consisting of skilled or instructed persons.

INDUSTRIAL ELECTROHEATING EQUIPMENT – TEST METHODS FOR DIRECT ARC FURNACES

1 Scope

This clause of IEC 60398:2015 is replaced by the following.

Replacement:

This document specifies the basic test procedures, conditions and methods for establishing the main performance parameters and the main operational characteristics of furnaces for direct arc heating, forming arcs between the **electrode** and metal, such as electric arc furnaces using alternating current (**EAF AC**) or direct current (**EAF DC**), and ladle furnaces (LF), with rated power level above 500 kVA .

Measurements and tests that are solely used for the verification of safety requirements of equipment for direct electrical arc furnaces are outside the scope of this document and are covered by IEC 60519-1, IEC 60519-4 and ISO 13578.

This document is applicable for the commissioning, verification of design improvements or for energy related tasks with respect to energy use or energy efficiency, establishing of an energy baseline, and labelling. Some concepts from this document can directly be used as key performance indicators.

Detailed tests for specific types of electric arc furnace equipment and installations are beyond the scope of this document. This document is intended as general reference for all future test standards applicable to particular electric arc furnace equipment or installations.

This document includes the concept and material presented in IEC 60398 on energy efficiency dealing with the electrical and processing parts of the equipment, as well as the overall performance.

Test methods for some special equipment, e.g., semiconductor converters, are covered by IEC 60146-1-1 and **furnace transformers** are covered by IEC 60076 series.

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

2 Normative references

This clause of IEC 60398:2015 is replaced by the following.

Replacement:

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60398:20215, *Installations for electroheating and electromagnetic processing – General performance test methods*

IEC 60519-1, *Safety in installations for electroheating and electromagnetic processing – Part 1: General requirements*

IEC 60519-4:2021, *Safety in installations for electroheating and electromagnetic processing – Part 4: Particular requirements for arc furnace installations*

ISO 13578, *Industrial furnaces, and associated processing equipment – Safety requirements for machinery and equipment for production of steel by electric arc furnaces*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60398:2015 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org

NOTE The terms and definitions refer to EAF and/or LF where applicable.

3.1.101
active power
P
under periodic conditions, mean value, taken over one period T of the instantaneous power p

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

Note 1 to entry: Under sinusoidal conditions, the active power is the real part of the complex power S, thus P = Re (S).

Note 2 to entry: The coherent SI unit for active power is Watt, W.

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

3.1.102
apparent power
S
power rating of the **furnace transformer**, energizing the EAF or LF (in MVA)

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

where

U is the voltage, RMS, sinusoidal value [in kV]

I is the current, RMS sinusoidal value [in kA]

[SOURCE: IEC 60050-131:2002, 131-11-41, modified – more precise]

3.1.103
arc furnace
furnace with a vessel, in which metal or other charged conducting material is heated mainly by electric arc or joule effect using alternating current (AC) or direct current (DC)

[SOURCE: IEC 60050-841:2004, 841-26-05, modified – more precise]

3.1.104
arcing time
actual current flow time during power-on time

Note 1 to entry: Arcing time represents a high percentage of power on time.

Note 2 to entry: It is expressed in minutes (min).

3.1.105
asymmetry factor
K
difference between maximum and minimum impedance of any phase, divided by the mean impedance of all three phases (in %)

3.1.106
arc furnace transformer
transformer changing high voltage electrical power supply to a lower voltage and higher current for an arc furnace process

[SOURCE: IEC 60050-841:2004, 841-26-55, modified – more precise]

3.1.107
capacity
<of EAF> quantity of liquid material, which can be produced in the EAF during one heat (in t)

Note 1 to entry: Whether metric or short tons according to pre-requisites.

3.1.108
cold state
<of EAF> thermal state of EAF installation when the temperature of all parts equals the ambient temperature

3.1.109
clean bus
high voltage bus system which supplies the auxiliary equipment (e.g., motor control center, control system) where the network distortions are considered to be lower than in the dirty bus system

3.1.110
DC reactor
<smoothing choke> inductor smoothing electrical high frequency fluctuations, due to changes in arc conditions

Note 1 to entry: In case multiple **rectifiers** are coupled in the system, inductors can decrease the fluctuations as well.

3.1.111
dirty bus
high voltage bus system which supplies the **furnace transformer** and contains the network distortions from the process (e.g., flicker, harmonics)

Note 1 to entry: Distortion values on the dirty bus can exceed the limits of power quality of the grid.

3.1.112
disconnector
grounding switch
motor operated non load switch providing visible safety distance and connection to ground installed between the furnace switchgear and the furnace transformer

3.1.113
electric arc furnace using alternating current
EAF AC
furnace, in which electric arcs between the electrodes and conducting material are formed, using alternating current

[SOURCE: IEC 60050-841:2004, 841-26-07 modified – more precise]

3.1.114
electric arc furnace using direct current
EAF DC
furnace, in which the direct current is conducted via bottom electrode(s) (anode) to the material to be processed, forming arcs between the material and the electrode(s) from top (cathode)

[SOURCE: IEC 60050-841:2004, 841-26-06, modified – more precise]

3.1.115
EAF electrode
LF electrode
part produced from high density graphite to transfer the electrical energy forming arcs between tip and charge material

[SOURCE: IEC 60050-841:2004, 841-26-38, modified – more precise]

3.1.116
furnace shell

vessel of **arc furnace** made from metal (currently: steel) and covered by a roof

[SOURCE: IEC 60050-841:2004, 841-26-20, modified – more precise]

3.1.117
furnace switchgear
high-voltage switchgear connecting the **furnace transformer** to the electrical supply providing switching on/off under load

3.1.118
heat melt
liquid metal which is tapped after one process batch from an EAF into a ladle

Note 1 to entry: One heat produced during one process cycle.

3.1.119
high current system
assembly of conductors to carry the high current between **furnace transformer** secondary bushings and **electrode(s)**

Note 1 to entry: It consists of the bus bar system, cables and either a current tube system or current conducting **electrode** arm to the electrodes.

[SOURCE: IEC 60050-841:2004, 841-26-54, modified – more precise]

3.1.120
hot state
<of EAF> thermal state of an EAF in which the lining temperature is above 600 °C and a steady-state temperature of the components is reached

3.1.121
operational short circuit
short circuit due to direct contact of at least two electrodes in an **EAF AC** with charge/liquid material

Note 1 to entry: In **EAF DC**, short circuit is reached if the **electrode** from the top is in contact with the charge/liquid material.

[SOURCE: IEC 60050-841:2004, 841-26-70, modified – more precise]

3.1.122
phase rotation
phase sequence of the electromagnetic field

3.1.123
power factor
λ
ratio of the **active power** to the **apparent power** measured on the primary side of the **furnace transformer**

$$\lambda = \frac{P}{S}$$

where

P is the active power [in MW]

S is the apparent power [in MVA]

Note 1 to entry: cos φ contains only fundamental grid frequency, 50 / 60 Hz.

Note 2 to entry: λ contains the fundamental and harmonic frequencies.

3.1.124
power on time
time p-on
time from first arcing till switching off the furnace circuit breaker per **heat**

Note 1 to entry: It is expressed in minutes (min).

3.1.125
process time
actual time during of energy input (electrical, gas, oxygen, etc.)

Note 1 to entry: It is expressed in minutes (min).

3.1.126
production rate
total quantity of metal (in t) tapped, divided by the **tap-to-tap time**

Note 1 to entry: It is expressed in t/h.

3.1.127
reactive power
Q
total reactive electrical power (in MVAr) used in the system, measured on the primary side of the **furnace transformer**

$$Q = \sqrt{S^2 - P^2} \quad \text{(for three-phase system)}$$

[SOURCE: IEC 60050-131:2002, 131-11-44, modified – more precise]

3.1.128
rectifier
<of EAF> device by means of which alternating current is transferred into direct current

3.1.129
series reactor
reactor connected in series to the **furnace transformer** to minimise impacts on the electrical supply created by the arcs and ensure arc stability during the process

3.1.130
specific electrical energy consumption
<of EAF> quotient of electrical energy consumed (in kWh) during melting and superheating of the metal (in t) tapped at a specified temperature

Note 1 to entry: It is expressed in kWh/t.

[SOURCE: IEC 60050-841:2004, 841-22-72, modified – more precise]

3.1.131
tap to tap time
t_{ttt}
time between end of tapping of previous heat and end of tapping of actual heat

Note 1 to entry: It is expressed in minutes (min).

3.2 Abbreviated terms

AC	Alternating current
CT	Current transformer
DC	Direct current
DRI	Direct reduced iron
EAF	Electric arc furnace
HBI	Hot briquetted iron
LF	Ladle furnace
LPG	Liquid petrol gas
PT	Potential transformer
SAF	Submerged arc furnace
SVC	Static VAr compensation