IEC 60779

Edition 3.0 2020-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Installations for electroheating and electromagnetic processing – Test methods for electroslag remelting furnaces

Installations pour traitement électrothermique et électromagnétique – Méthodes d'essai des fours de refusion sous laitier électroconducteur

IEC 60779:2020-06(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 25.180.10

ISBN 978-2-8322-8447-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INSTALLATIONS FOR ELECTROHEATING AND ELECTROMAGNETIC PROCESSING – TEST METHODS FOR ELECTROSLAG REMELTING FURNACES

FOREWORD

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International Standard IEC 60779 has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing.

This third edition cancels and replaces the second edition published in 2005. It constitutes a technical revision.

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

– the structure has been redrafted according to IEC 60398:2015;
– the scope and object have been redrafted;
– the terms/definitions, normative references and bibliography have been updated and completed;
– all test methods and content from IEC 60779:2005 that have been included in IEC 60398:2015 have been removed to avoid any duplication.

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

FDIS	Report on voting
27/1128/FDIS	27/1130/RVD

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

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

This standard is to be read in conjunction with IEC 60398:2015. It supplements or modifies 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 is reasonable. When a particular subclause of IEC 60398:2015 is not applicable, the word “Void” is used.

Additional specific provisions to those in IEC 60398:2015, given as individual clauses or subclauses, are numbered starting from 101.

NOTE The following numbering system is used:

– subclauses, tables and figures that are numbered starting from 101 are additional to those in IEC 60398:2015;

– unless notes are in a new subclause or involve notes in IEC 60398:2015, they are numbered starting from 101, including those in a replaced clause or subclause;

– additional annexes are lettered AA, BB, etc.

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

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

INSTALLATIONS FOR ELECTROHEATING AND ELECTROMAGNETIC PROCESSING – TEST METHODS FOR ELECTROSLAG REMELTING FURNACES

1 Scope

Clause 1 of IEC 60398:2015 is replaced by the following.

Replacement:

This International Standard specifies the test procedures, conditions and methods for determining the main performance parameters and operational characteristics of electroslag remelting furnaces.

Measurements and tests that are solely used for the verification of safety requirements of the installations are outside the scope of this document and are covered by IEC 60519-1 and IEC 60519-8.

This document applies to industrial electroslag remelting furnaces, the rated capacity of which is equal to, or greater than, 50 kg.

This document is applicable to industrial electroslag remelting furnaces having one or more electrodes and having different melting power supplies, such as alternating current, direct current, or low-frequency current.

This document includes the concept and material on energy efficiency dealing with the electrical and processing parts of the installations, as well as the overall performance.

2 Normative references

Clause 2 of IEC 60398:2015 is applicable except as follows.

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.

Modification:

Delete the footnotes.

Additions:

IEC 60398:2015, *Installations for electroheating and electromagnetic processing – General performance test methods*

IEC 60519-8, *Safety in installations for electroheating and electromagnetic processing – Part 8: Particular requirements for electroslag remelting furnaces*

IEC 60676:2011, *Industrial electroheating equipment – Test methods for direct arc furnaces*

3 Terms and definitions

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

3.1 General

Additions:

3.1.101
electroheating installation with an electroslag remelting furnace
complete assembly of electroheating equipment and electrical and mechanical accessories necessary for operation and utilization of an electroslag remelting furnace

3.1.102
power of an electroheating installation
apparent power S (in kVA) or active power P (in kW) measured at the input of the supply line

3.1.103
power factor of an electroheating installation
cosφ
ratio of the active power to the apparent power measured at the input of the supply line

3.1.104
on-load voltage of an electroslag remelting furnace
U_F
voltage measured between two points, which, depending on the type of a furnace, are either the base plate, the electrode clamping device(s) bringing the melting electrical current to the consumable electrode(s)/stub(s), or the point of common connection of the multiple return conductors

Note 1 to entry: In case of a furnace without two electrodes corresponding to single-phase AC power supply, voltage is measured between the base plate and the electrode clamping device(s), seeing U_F in Figure AA.1 and Figure AA.2.

Note 2 to entry: In case of a furnace with two electrodes corresponding to single-phase AC power supply, voltage is measured between the two electrode clamping devices.

Note 3 to entry: In case of a furnace of a coaxial design for a single-phase AC power supply, the voltage is measured between the electrode clamping device and the point of common connection of the multiple return conductors, seeing U_F in Figure AA.3.

3.1.105
rated furnace frequency
f_n
value corresponding to the rated furnace current, if the furnace is built for a frequency range

Note 1 to entry: The rated furnace frequency is expressed in Hz.

3.1.106
rated furnace current
I_n
maximum current for continuous operation for which the furnace is designed

3.1.107
rated values of an electroslag remelting furnace
rated values, including rated furnace current I_n, rated furnace power P_n, and rated furnace frequency f_n, for which the furnace is designed

3.1.108
melting rate of consumable electrode
V_m
quantity of remelted consumable electrode(s) measured in kilograms within a unit time

Note 1 to entry: The melting rate of consumable electrode is expressed as kg/min.

3.2 Energy efficiency

Addition:

3.2.101
specific energy consumption
e
ratio of the total amount of electric energy measured at the input of the supply line, which is consumed by an electroheating installation for melting the charge in normal operating conditions agreed upon between the manufacturer and the user, to the weight of the ingot produced

Note 1 to entry: The specific energy consumption is expressed as kWh/kg.

3.3 State and parts

Additions:

3.3.101
continuous operation of a furnace
operation during which the solid ingot is produced and solidified and the consumable electrode is progressively added during the whole process

3.3.102
steady state of an electroslag remelting furnace
state of a furnace in which, in continuous operation, electrical and thermal parameters have reached relatively constant values

3.3.103
mould of an electroslag remelting furnace
water-cooled non-consumable crucible which shapes the ingot to be produced by the electroslag remelting process and which contains the molten slag

3.3.104
consumable electrode
solid part(s) in contact with the molten slag which carries the electrical current necessary for the melting operation and is constituted of the material necessary for the formation of the ingot

3.3.105
water-cooled base plate of an electroslag remelting furnace
water-cooled plate installed at the bottom of the mould to contain liquid metal and slag at the beginning of melting in any case, and connected to the cable(s) or busbar(s) to make sure that the current flows through the secondary electrical circuit in the case of furnace operation with one consumable electrode

3.3.106
furnace high-voltage switch
high-voltage switch for switching on and off, under load, the furnace transformer, in accordance with operating requirements

3.3.107
electroslag remelting furnace transformer
transformer supplying an electroslag remelting furnace

3.3.108
secondary electrical circuit of an electroslag remelting furnace
electrical circuit which is closed by the melting power supply and may include

a) output terminals of melting power supply;
b) high-current feeder (busbars and/or cables);
c) bus switches, if required;
d) electrode clamp;
e) electrode stub;
f) consumable electrode or electrodes (depending on the connection system);
g) conductive molten slag (not included in the short-circuit test);
h) remelted ingot (not included in the case of the furnace with more than two electrodes);
i) base plate (depending on the connection system)

3.3.109
electrode clamp
metallic, water-cooled equipment for holding an electrode and supplying the current to the electrode

3.3.110
coaxial arrangement of the electroslag remelting furnace
arrangement of more than two return conductors symmetrically positioned around the crucible for the electroslag remelting furnace

4 Basic provisions for testing and test conditions

Clause 4 of IEC 60398:2015 is applicable.

5 Comparing equipment or installations

Clause 5 of IEC 60398:2015 is applicable.

6 Measurements and workloads

Clause 6 of IEC 60398:2015 is applicable except as follows.

6.4.3 Measurement positions

Addition:

For measurement positions of all electrical parameters of the power circuit of electroslag remelting equipment, see Figure AA.1-Figure AA.3, being at output terminals of supply disconnecting device for the electric consumption measurement of the power circuit, and at the output terminals of the power distribution cabinet in shop for other electrical and mechanical auxiliaries (see 4.3 of IEC 60398:2015).

7 Numerical modelling

Clause 7 of IEC 60398:2015 is applicable.

8 Technical tests

Clause 8 of IEC 60398:2015 is applicable except as follows.

Additions:

8.100 Measurement of the effective stroke of the electrode ram motion

The effective stroke of the electrode ram motion is the distance between the upper limited position and the lower limited position of the electrode ram where the motion stops.

The measurement shall be made with a meter ruler when the main power of the furnace is off.

8.101 Measurement of the speed of the electrode motion

The measurement shall be made with manual control of the moving system of the electrode in two directions under the condition that the furnace is equipped with the electrode(s) of the largest weight and length allowed by the designer.

NOTE The measurement can be made by another method, for example, using electric signal control.

The measurement of the speed of motion shall be carried out by means of a stop-watch (or electronic time-base control), noting the distance covered by the electrode arm relative to its fixed support.

8.102 Measurement of the time interval for exchanging electrodes

The purpose of this test is to check if the time interval for exchanging electrodes meets the requirements agreed between the manufacturer and the user when the furnace is equipped with two sets of electrode feed drive systems.

The time to be measured with a stop-watch is the time interval from the moment when the secondary current becomes zero after the first electrode has melted and pulled out of the molten slag to the moment when the next electrode is dipped into the slag pool and the secondary current flows in the circuit.

8.103 Measurement of the open-circuit secondary voltage of the electroheating installation

This test shall be carried out across the melting power supply terminals (see item 6 in Figure AA.1).

If the installation is provided with a regulation system, the minimum and the maximum open-circuit secondary voltages shall be measured.

8.104 Measurement of the electrical parameters of the secondary circuit of the electroheating installation

8.104.1 General

The purpose of this test is to check if the characteristics of the secondary circuit of the furnace meet the requirements agreed between the manufacturer and the user.

8.104.2 Carrying out a short-circuit test

This test, which is not applicable for DC electroslag remelting furnace, shall be carried out under the following conditions. The furnace shall be equipped with the electrode(s) of the largest weight and length allowed by the designer. The electrical and magnetic properties of the electrode material shall be defined beforehand. The electrode(s) shall be brought into electrical contact with the base plate. The possible test circuit is shown in Figure AA.1. A suitable alternative method may be used by mutual agreement between the manufacturer and the user.

The voltage supply shall be set at its minimum.

The voltage shall be increased progressively until the rated current of the furnace is achieved.

The tests are carried out at least twice. For every test, the following electrical parameters shall be measured or calculated.

a) Active power P_2 on the secondary side of the furnace transformer – measured with wattmeters.

If, in some cases, it is difficult to measure P_2, the active power P_1 shall be measured on the primary side of the furnace transformer with wattmeters, and then P_2 calculated as:

$$P_2 = P_1 - P_{CuT} \quad (1)$$

b) I_2, U_2 on the secondary side of the furnace transformer – measured with ammeters and voltmeters, respectively.

c) Calculation of the following secondary values:

$$S_2 = I_2 U_2 \quad (2)$$

$$R_2 = \frac{P_2}{I_2^2} \quad (3)$$

$$Z_2 = \frac{U_2}{I_2} \quad (4)$$

$$X_2 = \sqrt{Z_2^2 - R_2^2} \quad (5)$$

$$\cos \varphi_2 = \frac{P_2}{S_2} \quad (6)$$

where

P_1 is the active power measured during the test on the primary side by a wattmeter;

P_2 is the active power measured during the test on the secondary side by a wattmeter or calculated;

P_{CuT} is the transformer load loss for the tap on which the test was performed (the value is taken from the manufacturer's specification);

S_2 is the apparent power measured during the test on the secondary side of the transformer;

I_2 is the rated secondary transformer current when the test was performed;

U_2 is the secondary transformer voltage when the rated secondary transformer current is achieved;

R_2 is the resistance of the secondary circuit;

X_2 is the reactance of the secondary circuit;

Z_2 is the impedance of the secondary circuit;

$\cos\varphi_2$ is the power factor of the secondary circuit.

In the case of a furnace with a three-phase AC power supply corresponding to three consumable electrodes, the test method should refer to 6.4 of IEC 60676:2011. The test conditions are the same as those described in 6.4 of IEC 60676:2011.

8.104.3 Measurement of electrical parameters of the secondary circuit under normal operating conditions

If the short-circuit test gives rise to some difficulties and brings about damage of the base plate, it may be agreed between the manufacturer and the user that this test shall be replaced by tests which prove that, in the normal operating conditions of the furnace, the electrical parameters of the secondary circuit remain in the range stated by the manufacturer.

The measurement shall be carried out during continuous operation of the furnace after steady state has been achieved while the furnace is working at its rated current (I_n).

a) In the case of a furnace equipped with single-phase AC power supply

The tests are carried out at least twice. For every test, the following electrical parameters shall be measured or calculated.

1) Active power P2 on the secondary side of the furnace transformer – measured with wattmeters.

If, in some cases, it is difficult to measure P_2, the active power P_1 shall be measured on the primary side of the furnace transformer with wattmeters, and then calculated as:

$$P_2 = P_1 - P_{CuT} \tag{7}$$

2) Current I_2 on the secondary side of the furnace transformer – measured with ammeters, and voltages U_2, U_F measured with voltmeters.

3) Then the following secondary values are calculated:

$$S_2 = I_2 U_2 \tag{8}$$

$$\cos\varphi_2 = \frac{P_2}{S_2} \tag{9}$$

where

U_F is the on-load voltage of an electroslag remelting furnace.

b) In the case of a furnace equipped with a three-phase AC power supply

The possible test circuit is shown in Figure AA.2. The tests are carried out at least twice. For every test, the following electrical parameters shall be measured or calculated.

1) Active powers P_{2A}, P_{2B}, P_{2C} on the secondary side of the furnace transformer measured with wattmeters.

If, in some cases, it is difficult to measure P_{2A}, P_{2B}, P_{2C}, the active power P_{1A}, P_{1B}, P_{1C} shall be measured on the primary side of the furnace transformer with wattmeters, and then P_{2A}, P_{2B}, P_{2C} calculated:

$$P_{2A} = P_{1A} - 1/3P_{CuT} \qquad P_{2B} = P_{1B} - 1/3P_{CuT} \qquad P_{2C} = P_{1C} - 1/3P_{CuT} \tag{10}$$

2) Currents I_{2A}, I_{2B}, I_{2C}, on the secondary side of furnace transformer measured with ammeters, and voltages U_{2A}, U_{2B}, U_{2C}, U_{FA}, U_{FB}, U_{FC} measured with voltmeters.

3) Then the following secondary values are calculated:

$$S_{2\mu} = U_{2\mu} \cdot I_{2\mu} \tag{11}$$

$$Q_{2\mu} = \sqrt{S_{2\mu}^2 - P_{2\mu}^2} \tag{12}$$

$$S_{2\Sigma}^2 = \left(\sum_{\mu=1}^{3} P_{2\mu}\right)^2 + \left(\sum_{\mu=1}^{3} Q_{2\mu}\right)^2 = P_{2\Sigma}^2 + Q_{2\Sigma}^2 \tag{13}$$

$$P_{2\Sigma} = P_{2A} + P_{2B} + P_{2C} \tag{14}$$

$$\cos\varphi_2 = \frac{P_{2\Sigma}}{S_{2\Sigma}} \tag{15}$$

where

P_{1A}, P_{1B}, P_{1C} are the phase powers measured on the primary side by wattmeters;

P_{2A}, P_{2B}, P_{2C} are the phase powers measured on the secondary side by wattmeters or calculated;

P_{CuT} is the three-phase transformer load loss for the tap on which the test was performed (the value is taken from the manufacturer's specification);

μ is the phase A, B, C, respectively;

$I_{2\mu}$ is the rated current of each phase (μ = A, B, C) measured on the secondary side by ammeter;

$U_{2\mu}$ is the phase voltages of each phase (μ = A, B, C) measured on the secondary side by voltmeter;

$P_{2\mu}$ is the active power of each phase (μ = A, B, C) on the secondary side;

$Q_{2\mu}$ is the reactive power of each phase (μ = A, B, C) on the secondary side;

$S_{2\mu}$ is the apparent power of each phase (μ = A, B, C) on the secondary side;

$P_{2\Sigma}$, $Q_{2\Sigma}$,$S_{2\Sigma}$ are the total active power, total reactive power and total apparent power on the secondary side, respectively;

U_{FA}, U_{FB}, U_{FC} are the phase on-load voltages of an electroslag remelting furnace.