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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Installations for electroheating and electromagnetic processing – Test methods for induction through-heating installations

Installations pour traitement électrothermique et électromagnétique – Méthodes d'essai pour les installations de chauffage par induction

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INSTALLATIONS FOR ELECTROHEATING AND ELECTROMAGNETIC PROCESSING – TEST METHODS FOR INDUCTION THROUGH-HEATING INSTALLATIONS

FOREWORD

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

FDIS	Report on voting
27/1118/FDIS	27/1119/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 International Standard is to be used in conjunction with IEC 60398:2015.

The clauses of this document supplement, modify or replace clauses of IEC 60398. When this document states “addition”, "modification" or “replacement”, the relevant text in IEC 60398 is to be adapted accordingly.

Subclauses which are additional to those in IEC 60398 are numbered starting from 101. Additional annexes are numbered AA, BB, etc.

The committee has decided that the contents of this document 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 document. At this date, the document will be

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- withdrawn,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

INTRODUCTION

Induction through-heating and induction melting are very important applications of induction heating. However, an induction through-heating installation is more complex than an induction melting furnace, as it includes more heating manners, varieties and sizes. In addition, some performance tests which are very useful to users, for example the determination of temperature homogeneity of billets and energy efficiency of the installation, are not easy to carry out.

Induction through-heating installations are widely used in many industries for example machine building and metallurgy, for heating billets or workpieces of alloy steel, copper, aluminum, etc. before their subsequent hot forming (e.g. forging, extruding and rolling), with clean and fast heating, easy temperature control and automation as well as a high degree of energy-saving.

This document was prepared on the basis of IEC 60398:2015, with some references made to IEC 62076:2006 and “Induction Heating – Industrial Applications” published by UIE in 1992.

INSTALLATIONS FOR ELECTROHEATING AND ELECTROMAGNETIC PROCESSING – TEST METHODS FOR INDUCTION THROUGH-HEATING INSTALLATIONS

1 Scope

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

This document specifies the test procedures, conditions and methods for determining the main performance parameters and operational characteristics of induction through-heating installations.

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 60519-3.

This document is applicable to the induction heating installations which through-heat the whole or part of metal billet or workpiece for its subsequent hot forming (e.g. forging, extruding and rolling), using low, mains or medium frequencies. It is possible to use it as a reference for other induction heating installations for heat-treatment and other purposes as well as superconducting DC induction through-heating installations.

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

This clause of IEC 60398:2015 is applicable except as follows.

Replacement:

The following standards are referred to in the text in such a way that some or all of their contents constitutes requirements of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced standard (including any amendments) applies.

Modification:

Delete footnotes

Additions:

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

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

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1 Sixth edition under preparation. Stage at the time of publication: IEC PRVC 60519-1:2019.

IEC 60519-3:2005, *Safety in electroheat installations – Part 3: Particular requirements for induction and conduction heating and induction melting installations*

3 Terms and definitions

This clause of IEC 60398:2015 is applicable except as follows.

Replacement:

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

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

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

Additions:

NOTE 101 For the following definitions of terms related to some parts and electrical parameters of power circuit of induction through-heating equipment, see also the explanatory diagrams in Annex AA. The symbols are also listed in Annex BB.

3.101
induction through-heating installation
installation comprising induction through-heating equipment and the electrical and mechanical auxiliaries necessary for the operation and utilization of the equipment

Note 1 to entry: The electrical auxiliaries comprise all electrical components in the power circuit of induction through-heating equipment, power supply for mechanical auxiliaries and control system; and the mechanical auxiliaries comprise billet handling mechanism and its mechanical power as well as water cooling system, etc.

3.102
induction through-heating equipment
equipment consisting of one or more heating inductors, supporting frames (cabinets) and the connections for cooling water and electricity, etc., for induction heating and holding of billet

3.103
batch heating
repetitive static heating manner, which involves placing an individual billet into a heating inductor for heating and holding, and then extracting it

[SOURCE: IEC 62076:2006, 3.39， modified – The differences between induction through-heating and induction melting in workload name and technological process have been considered.]

3.104
stage heating
heating manner having two or more heating inductors, in which, for a two heating inductor equipment for example, the billet is firstly placed into a heating inductor for heating, secondly moved to another heating inductor for holding and then extracted

3.105
continuous heating
heating manner, in which the billets progress continuously or rhythmically through one or more heating inductors for heating and holding

[SOURCE: IEC 62076:2006, 3.40， modified – The differences between induction through-heating and induction melting in workload name and technological process have been considered.]

3.106
lining
<heating inductor> part of inductor, which is placed between the induction coil and heated billet as a thermal insulation, and usually consists of a refractory layer and a temperature holding layer or is directly formed by ramming or pouring refractory materials

3.107
power circuit of induction through-heating equipment
circuit consisting of the power source(s) and compensated circuit(s) of the induction through-heating equipment, including the conductors connecting both

3.108
power source
equipment for the supply of power to the compensated circuit of induction through-heating equipment, being mains frequency single phase or three phases power supply or semiconductor frequency converter and having the following main specified characteristics:

- frequency f_2 or frequency band $f_{21}....f_{22}$
- voltage U_2 (RMS value)
- current I_2 (RMS value)
- active power P_2

[SOURCE: IEC 62076:2006, 3.13， modified – The types of power source used have been specified and supplemented, see Annex AA.]

3.109
compensated circuit of induction through-heating equipment
electric circuit comprising one or more inductors, a compensating capacitor bank and a load-matching transformer (if applicable)

Note 1 to entry: See Annex AA.

3.110
mass of test billets
G_{test}
out of the through-heated billets, total mass of those qualified used for the determination of specific energy consumption and productivity

3.111
dimensions of billet
maximum dimensions of the overall billets with any transport or protection means, which the induction through-heating equipment is designed for and is marked on the rating plate, expressed in diameter × length or width × thickness × length

3.112
billet temperature
θ_b
temperature of the billet at a given time of the through-heating cycle

3.113
starting temperature of billet
θ_{bs}
temperature of the billet at the beginning of the through-heating cycle

3.114
final temperature of billet
θ_{bf}
temperature of the billet attained at the end of the holding period of the through-heating cycle

3.115
rated temperature of billet
θ_{br}
temperature to be requested by through-heating technology for the billet of a given material, which the induction through-heating equipment is designed for and which is marked on the rating plate

3.116
temperature homogeneity of billet
$\Delta\theta_b$
homogeneous degree of billet temperature when it is extracted after heating and holding, which is expressed as the maximum and minimum deviations of the temperatures measured at the temperature measuring points with the rated temperature of the billet (they may be positive or negative), or expressed as the transverse (radial) temperature difference and the longitudinal temperature difference of the billet for the long billets with a circular or rectangular, etc. uniform cross section

Note 1 to entry: Requirements and measuring conditions for the determination of billet temperature homogeneity are specified in Annex CC.

3.117
transverse temperature difference of billet
radial temperature difference of billet

$\Delta\theta_{bt(r)}$
maximum and minimum temperature differences which may be positive or negative, between periphery and centre on the cross section of a long billet with a uniform cross section when it is extracted after its heating and holding

Note 1 to entry: Usually, the temperature at the centre of a billet cross section is lower.

Note 2 to entry: The radial temperature difference $\Delta\theta_{br}$ applies for a billet with a circular cross section.

3.118
longitudinal temperature difference of billet
$\Delta\theta_{bl}$
difference between the maximum temperature and the minimum temperature along the longitudinal direction of a long billet with a uniform cross section when it is extracted after its heating and holding

Note 1 to entry: Usually, the temperature at two ends of a billet is lower.

3.119
inlet temperature of cooling water
θ_{wi}
temperature of the cooling water when entering the cooling water circuit of the heating inductor

[SOURCE: IEC 62076:2006, 3.33， modified – The term and its symbol have been changed, the words “coolant” and “inductor assembly” have been replaced by “cooling water” and “heating inductor”.]

3.120
outlet temperature of cooling water
θ_{wo}
temperature of the cooling water when leaving the cooling water circuit of the heating inductor, with the induction through-heating equipment operating at rated conditions

[SOURCE: IEC 62076:2006, 3.34， modified – The term and its symbol have been changed, the words “coolant”, “inductor assembly” and “furnace” have been replaced respectively by “cooling water”, “heating inductor” and “induction through-heating equipment”.]

3.121
equipment duty at rated conditions
rated equipment duty
induction through-heating equipment operation with specified dimensions of lining and billet, specified billet quantity, rated power and rated frequency range without exceeding the maximum voltage and current defined by the supplier

3.122
thermal steady state
<equipment> thermal state in which the whole energy input into the induction through-heating equipment is used for the compensation of its thermal losses

Note 1 to entry: In thermal steady state, the temperatures of all constructional components of induction through-heating equipment and all the outlet temperatures of the cooling water are relatively stable and do not rise.

[SOURCE: IEC 62076:2006, 3.36, modified – The “furnace” has been replaced by “induction through-heating equipment” and the note added.]

3.123
hot state
<equipment> thermal steady state of the induction through-heating equipment when the billet is at its final temperature

[SOURCE: IEC 60683:2011, 3.13， modified – The definition suitable for induction through-heating equipment has been given with the ambiguous term “thermal condition” replaced by “thermal steady state” and “furnace” by “induction through-heating equipment”.]

3.124
cold state
<equipment> thermal state in which the induction through-heating equipment is not energized and the temperature of the whole equipment is at ambient temperature

[SOURCE: IEC 60683:2011, 3.4， modified – The definition suitable for induction through-heating equipment has been given.]

3.125
holding power
P_h
<equipment> active power supplied to the power circuit of induction through-heating equipment, in order to maintain the specified billet at a specified temperature for its temperature homogeneity

[SOURCE: IEC 60398:2015, 3.3.2， modified – The original definition including its two notes, has been simplified according to induction through-heating equipment.]

3.126
electrical energy consumption of the equipment
electrical energy supplied to the power circuit of induction through-heating equipment during the defined time period

Note 1 to entry: E_{ae}.is the active electrical energy consumption.

Note 2 to entry: E_{re} is the reactive electrical energy consumption.

[SOURCE: IEC 62076:2006, 3.42， modified – The words “energy consumption” and “furnace” have been changed to “electrical energy consumption” and “induction through-heating equipment”, and "during the defined time period" and the notes have been added.]

3.127
electrical energy consumption of the installation
active electrical energy consumption
E_{ai}
electrical energy supplied to the induction through-heating installation during the defined time period, including the active electrical energy consumption of the equipment E_{ae} and the active electrical energy consumption of electrical and mechanical auxiliaries of the equipment E_{aa}

3.128
specific electrical energy consumption of the equipment/installation
e_e/e_i
ratio of the electrical energy consumption of the equipment/installation E_{ae}/E_{ai} for heating specified billets from their starting temperature θ_{bs} to rated temperature θ_{br} and then holding them for temperature homogeneity, to the total mass of qualified billets of those through-heated billets, during a complete cycle of the batch heating type installation or a longer defined time period of the continuous heating type and stage heating type installations

Note 1 to entry: For a partial through-heating application, only the total mass of the through-heated parts of qualified billets is considered.

[SOURCE: IEC 60398:2015, 3.2.3， modified – The words “energy consumption” and “energy” have been changed to “electrical energy consumption”, the definition suitable for three types of induction through-heating equipment/installation has been given with a note added.]

3.129
productivity
g

<installation> ratio of the total mass of qualified billets of those through-heated billets for heating specified billets from their starting temperature θ_{bs} to rated temperature θ_{br} and then holding them for temperature homogeneity, to the time of a complete cycle of the batch heating type installation or a longer defined time period of the continuous heating type and stage heating type installations, during the complete cycle or the defined time period

Note 1 to entry: For partial through-heating application, only the total mass of the through-heated parts of qualified billets is considered.

[SOURCE: IEC 60050-841:2004, 841-22-71, modified – The definition suitable for three types of induction through-heating installation has been given with a note added.]

3.130
heating efficiency of the equipment/installation
η_e/η_i
ratio of the usable enthalpy increase in the qualified billets of those through-heated billets to the active electrical energy consumption of the equipment E_{ae} or to the active electrical energy consumption of the installation E_{ai} during a complete cycle of the batch heating type installation or a longer defined time period of the continuous heating type and stage heating type installations

[SOURCE: IEC 60398:2015, 3.2.4， modified – The definition suitable for three types of induction through-heating equipment/installation has been given.]

4 Basic provisions for testing and test conditions

This clause of IEC 60398:2015 is applicable except as follows.

4.3 Boundaries of the energy using system for testing

Additional subclause:

4.3.101 Boundaries of induction through-heating installation for testing

The energy consumption of an induction through-heating installation shall also include:

a) energy consumption of the power circuit of the induction through-heating equipment for heating and holding billets;

b) energy consumption of the control system of the installation.

The corresponding energy consumption supplied by some public service, for example hydraulic and/or pneumatic pumping station(s) to the installation, may be estimated according to the practical use or ignored when it is very small compared with the whole energy consumption of the installation.

4.4 General requirements for testing

This subclause of IEC 60398:2015 is applicable except for the following replacement and additions.

Replacement (of the first paragraph of this subclause of IEC 60398:2015):

The relevant safety requirements in IEC 60519-1:—, IEC 60519-3:2005 and the manufacturer's instructions shall be observed and necessary protective measures taken during all tests, to ensure safety.

Additions:

The tests of an induction through-heating installation are divided into cold state tests and hot state tests. Unless otherwise specified, the hot state tests shall be undertaken after the cold state tests are qualified.

The cold state tests shall be undertaken after manufacture or repair as well as during installation and regulation in the cold state. Installation and test preparation shall be carried out according to the manufacturer's instructions. Before the test, the electrical connections, switches, control system and some dimensions, etc. of the installation shall be inspected.

The hot state tests shall be undertaken with a new lining of specified dimensions and materials as agreed between the manufacturer and the user. The requirements for test billets shall be in accordance with 6.7.101. The technological process for heating and holding shall be agreed between the manufacturer and the user. The technological process also includes the loading, temperature measurement and unloading of billet. Where a test is to be performed in the hot state (see 3.123), the induction through-heating equipment shall have been in operation for at least 8 h (depending on the dimensions of billet or agreed between the manufacturer and the user) prior to the test. In the case where it starts with a new lining, it shall have been in operation for at least 24 h prior to the test.

The electrical data at the input of the supply line to be established by the tests of items b), c) and e) of 8.3 are related to the rated voltage U_n and the rated frequency f_n. Admissible deviations from the rated voltage and frequency shall be agreed between the manufacturer and the user. If during the test these deviations are exceeded, this shall be taken into account in the evaluation.

In the case where a mains transformer is used solely for the induction through-heating equipment, the electrical values at the input of the supply line may be determined from the corresponding values on the secondary side of the transformer taking into account its characteristic.

All measurements are to be taken using appropriate devices and following accurately the instructions for their use. The accuracy tolerances of all measuring instrument or devices (for values of electrical data, temperature and mass) shall be established and agreed between the manufacturer and the user.

In addition, all equipment composing the induction through-heating installation shall comply with their relevant specifications.

Attention should be drawn to the different parameters to be considered as regards the rated values of an induction through-heating equipment and to the tests intended for their verification; irrespective of the size of the equipment, its performance depends on:

– the heating type of the equipment;
– the design of the equipment and its heating inductor themselves;
– the material, shape and dimensions of the billet;
– the type and automation degree of the handling mechanisms of the billet;
– the type and frequency of the power supply unit used to feed the equipment;
– the type of control and regulating system of the power supply unit for the equipment;
– the ability of the power supply unit of the equipment to react to rapid variations of reactive power.

4.6 Environmental conditions during tests

Addition:

The inlet and outlet temperatures of cooling water of cooling circuits, especially for heating inductors, shall observe the manufacturer's instructions. Excessive or less cooling will influence the measurement of energy efficiency.

5 Comparing equipment or installations

This clause of IEC 60398:2015 is applicable.

6 Measurements and workloads

This clause of IEC 60398:2015 is applicable except as follows.

6.3 Frequency measurement

Addition:

The accuracy of frequency measurement shall be of class 1.5 or better for mains frequency and medium frequency.

6.4 Measurement of electric data

6.4.1 Supply voltage

Addition:

NOTE Information on the influences of actual supply voltage or its variation on the performance of the installation can be found in 8.10 of IEC 60398:2015.