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TECHNICAL SPECIFICATION

Energy efficiency in electroheating installations

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ENERGY EFFICIENCY IN ELECTROHEATING INSTALLATIONS

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62796, which is a technical specification, has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
27/882/DTS	27/903/RVC

Full information on the voting for the approval of this technical specification 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

- transformed into an International Standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This Technical Specification (TS) was prepared by a working group of IEC TC 27, whose overall intent was to develop guidelines for the classification of industrial electroheating systems, which allow for the determination of the performance/efficiency of a given system and a comparison with other systems of that class.

The initial technical considerations suggested that TC 27 should at first limit its focus on determination of energy consumption for a defined output of processed workload. The next step should then be consideration of performance characteristics influencing the energy efficiency, such as metallurgical or thermal processing particulars. However, during the course of the work, it turned out that comparisons of performance can best be made by specifying different workloads for different kinds of comparisons.

Measurements of efficiencies are split into two main categories: electrical-only and of the electroheating in normal operation. The latter has a relationship to other performance aspects which are also dealt with.

Testing requires specification limits on workload and three kinds are defined:

– normal workloads – i.e. such within the specifications provided by the manufacturer;
– dummy workloads – artificial items specially designed to very efficiently absorb the available output power without being processed or modified as the normal workload, and by that promoting the accuracy of enthalpy increase measurements;
– performance test workloads – artificial or partially artificial workloads specially designed for discrimination of processing results.

The TS provides general methods for determination of the efficiency of electroheating systems and is intended to assist in creating a consistent terminology and structure in various TC 27 test standards dealing with specific equipment types. The TS material is to be covered by the future third edition of IEC 60398 [3][1].

1 Numbers in square brackets refer to the Bibliography.

ENERGY EFFICIENCY IN ELECTROHEATING INSTALLATIONS

1 Scope and object

This Technical Specification is applicable to industrial electroheating installations using electric energy as input, alone or in combination with other kinds of energy. However, external combustible fuel energy input is not dealt with, and all considerations begin at the electric only mains frequency source to which the installation is connected. Any external voltage transformation from the supply network to the plant into a special voltage which is fed into the installation is not dealt with in this Technical Specification, since it is not considered a responsibility of the manufacturer of the installation.

The object of this Technical Specification is to provide methods for determination of the efficiency of a given system as well as enabling comparisons with other equipment using the same principle for processing of the workload.

For satisfactory comparisons to be possible, differences in end product quality and influences of environmental factors on heat recovery are included.

Heat recovery aspects are dealt with but limited to the temperature changes, the specific heat capacity characteristics, and the physical properties of the usually fluidic substance obtained from the installation and employed for energy recovery use. Conversion into mechanical energy is dealt with.

Adaptation to the needs of operation and performance management as might be necessary for the implementation or application of smart grid technologies, is addressed but no test methods are given.

A guideline is provided for the development of the detailed electroheating efficiency tests for the particular test method standards. The different principles of electroheating for processing a workload, and types of equipment, are given in Clause 1 of IEC 60519-1:2010.

If energy from combustible gases or liquids is used in addition to electric energy, the measurement and calculation of the energy efficiency contribution of combustion in the installation are made according to the relevant ISO standards. These may deal with the electric energy input in other ways than in this Technical Specification.

NOTE The relevant standards in the ISO 13579 series are listed in the Bibliography [4 – 7].

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

For the purposes of this document, terms and definitions given in IEC 60519-1:2010 and the following apply.

NOTE General definitions are given in IEC 60050, International Electrotechnical Vocabulary [1]. Terms relating to industrial electroheat are defined in IEC 60050-841.

3.1 General concepts

3.1.1
enthalpy increase

sum of energy added through heating of an object and the mechanical work of expansion of it done in pushing against the ambient (atmospheric) pressure

Note 1 to entry: The energy of the mechanical work of expansion is stored in the surroundings and can be recovered if the system collapses back to its initial state.

3.1.2
exergy

maximum fraction of energy in a system including a medium at an initial temperature T_1 which can be converted into useful work during a process at the end of which the system temperature is T_0

Note 1 to entry: This is the theoretical quantity related to the endoreversible thermal efficiency of a heat engine.

3.1.3
heat engine

system that performs the conversion of thermal energy into mechanical work by bringing a working medium from a high temperature state to a lower temperature state

Note 1 to entry: In the context of this document, the mechanical work is either used directly with an external generator to create electricity, or with a second external heat engine operating in the heating mode for increasing the temperature of a part of the hot medium, for further use.

3.1.4
energy recoverability

usefulness of a hot substance obtained in or from a process for providing energy back into the process or to an external purpose

Note 1 to entry: The usefulness depends on the temperature and ease of handling of the hot substance, and on the temperature of the recipient.

Note 2 to entry: Transformation into mechanical energy by heat engines is a separate item.

Note 3 to entry: Transformation into chemical energy is not included.

Note 4 to entry: Any heat of combustion of the substance is excluded.

3.2 Equipment, operations and workloads

3.2.1
ambient conditions

environmental conditions

characteristics of the environment which may affect performance of a device or system

EXAMPLE Pressure, temperature, humidity, radiation, vibration.

3.2.2
equipment capacity

measure of the production rate capability of equipment in normal operation

EXAMPLE Flow, mass or volume.

Note 1 to entry: The *equipment capacity* does not refer to the volume of the working space.

3.2.3
equipment class
group within a type of equipment, using the same principle for processing of the workload and the size of this as well as the equipment capacity

Note 1 to entry: An example of type is equipment for induction heating, and a class example is such equipment for metal wire heating in a specified capacity interval, using medium frequency.

3.2.4
efficiency, <of an electroheating installation>
ratio of the usable enthalpy increase in the workload to the electric energy supplied to it at the location of the equipment, during a cycle of batch operation or stationary operation during a suitable time period for measurements

[SOURCE: IEC 60050-841:2004, 841-22-70, modified – Enthalpy increase in the workload is specified instead of useful energy, and measurement time limits have been added.]

3.2.5
performance, <of an electroheating installation>
degree to which the intended functions, including energy or power consumption and output as well as the result of the treatment of the workload are accomplished

3.2.6
end product quality
degree to which a set of inherent characteristics of a processed workload fulfils requirements

3.2.7
power factor
under periodic conditions, ratio of the absolute value of the active power P to the apparent power S

Note 1 to entry: This is applied to the supply network under normal operation.

[SOURCE: IEC/TS 62257-12-1:2007 [2], 3.4, modified – Note 1 to entry has been added.]

3.2.8
cold start-up
process by which the equipment is energised into hot standby operation from the cold state, including all other start-up operations which enable the equipment to run under normal operation

Note 1 to entry: This mode of operation applies to cases where there is a significant energy consumption needed for obtaining a state of the equipment allowing the actual processing of the workload, see 6.1.

3.2.9
holding power
electric power consumption during which the workload is kept in the treatment chamber at a specified temperature

Note 1 to entry: The temperature is typically maintained during a time intended to equalize the workload temperature.

Note 2 to entry: This mode of operation is not applicable for certain types of electroheating equipment.

3.2.10
hot standby operation
mode of operation of the installation occurring immediately after normal operation

Note 1 to entry: This mode of operation of the equipment is with its hot state remaining, without workload, and with the means of operation ready for prompt normal operation.

3.2.11
normal operation
range of output settings with the normal workload in allowable working conditions of the equipment, as specified in the manufacturer's documentation

3.2.12
normal workload
object being processed at nominal output power, as specified in the manufacturer's documentation

Note 1 to entry: The workload is called charge in some electroheating contexts.

Note 2 to entry: The workload includes any container, holder or other device necessary for the processing and which is directly or indirectly subjected to the output power. The processed object/material as such is also called load.

3.2.13
dummy workload
artificial item with known thermal properties, designed for accurate enthalpy increase measurements by absorbing the available output power

3.2.14
performance test workload
artificial or partially artificial workload designed for discrimination of processing results

Note 1 to entry: Examples of such results are relative slag content, relative or absolute areas or volumes of unsatisfactorily processed material.

4 General aspects of energy efficiency measurements in electroheating

4.1 General

Clause 4 deals with the instrumentation and some general non-electric factors connected with energy efficiency measurements. Clause 5 deals with the requirements for comparative testing, Clause 6 with measurements of electric power and ancillary energy factors, and Clause 7 with the measurements of efficiencies.

4.2 Instrumentation

Electric instruments shall be of class 2 or better. Other instrumentation shall allow measurement inaccuracies of maximally 2 %, with the exception of measurements of quantities having only a small influence on the overall power/energy data, and for workload enthalpy increase.

It may be unavoidable to accept inaccuracies exceeding 2 % of the enthalpy increase under conditions addressed in 4.4 and 4.5, as well as for large solid workloads. Specifications on instrumentation and accuracy requirements on those quantities shall be stated in the test method standard for the particular type of equipment.

4.3 Ambient conditions and initial temperature of the workload

Ambient conditions, in particular the temperature, will influence the energy efficiency, and even more so the need for integrated or ancillary cooling or preheating equipment. The energy recoverability is also affected.

Installations of the same type and class may thus be different depending on the specified ambient conditions, in particular with regard to the limits of specified ambient temperature at nominal power operation. Also the initial temperature of the workload is important in many cases and its variations shall be considered. Satisfactory comparison of installations requires specification and report of these variations and of the ambient conditions throughout the tests.

Construction differences with regard to cooling and heat recovery between installations or equipment to be compared shall be stated in the calculations and test report.

The ambient conditions are of importance for the use in external recovery of energy, since a lower ambient temperature provides an improved efficiency of heat engines. This is dealt with in Clause 8.

4.4 Non-ambient pressures

4.4.1 The energy of compression or liquefaction of gaseous fuels – and of other gases including oxygen, other oxidants and passive gases such as inert gases – shall not be included in the used and lost energy calculations of the equipment if the compression has taken place external to the equipment.

4.4.2 The energy of compression or decompression of steam, air or any other gas in the process chamber, including vacuuming, integral to the process, shall be included in the used and lost energy calculations of the equipment.

4.5 Chemical reactions

The exothermic or endothermic chemical energy involving any reactive gases in the processing of the workload shall be either included or not included, as stated in the test method standard for the particular type of equipment.

4.6 Cooling and heat leakage to ambient

4.6.1 The cycle of batch operation for the measurement shall begin after hot standby operation.

4.6.2 The cooling action by any excess reactive and/or inert gases in the processing of the workload shall be included in the calculation of used and lost energy of the installation.

4.6.3 Any cooling of the processed workload to ambient or for further treatment shall not be included in the calculations of used and lost energy of the installation, unless a significant part of this heat is transferred back into the process. Such recycling of heat shall be reported separately, to allow comparisons with other equipment in the same class but without this feature.

5 Workload categories and requirements

5.1 General

Satisfactory comparisons under normal operation are typically possible only within the same equipment class. A likely condition is then that the manufacturer's specifications allow for some deviations in workloads and settings so that comparative tests can be made with workloads being identical with respect to the process. If that is not the case, comparisons may be deprecated but equipment with a very narrow equipment capacity interval is by that declared to have a performance disadvantage.

With many processes, the end result will not be directly related to an overall enthalpy increase of an actual workload. There are three basic cases, described in the following and using one of the following:

– a normal workload,

– a dummy workload or

– a performance test workload.

The reliance on the manufacturer's specifications is motivated by safety and by the principle that the equipment shall be allowed to do its best. The manufacturer is therefore referred to in the definitions of normal operation and normal workload. Since the specifications of the dummy workload and performance test workload are typically not by the manufacturer, safety precautions shall be observed by the party or parties carrying out the tests.

5.2 Use of workloads for comparative tests

For comparative tests, the workloads shall be equal and chosen within the manufacturer's specification limits for normal operation. The same workload category and amount shall be used throughout. This includes any container, holder or other device which is directly or indirectly subjected to the output power and then removed from the equipment when the heating process is finished, and may be reused.

5.3 Use of normal workloads for enthalpy determination

If possible, identical normal workloads shall be used for comparative testing and show a calculable and relevant enthalpy increase during normal operation.

The heat capacity of containers, holders or other devices also being heated may vary between equipment types. The enthalpy increase of the workload and that of the actual processed load shall be separated in the test method standard for the particular type of equipment. Both results shall be used for the comparison.

The methodology for measuring enthalpy increase shall be clearly specified in the test method standard for the particular type of equipment.

5.4 Use of dummy workloads for enthalpy determinations

The application of dummy workloads does typically not consider end product quality. Overall enthalpy increase is a relevant variable, but normal workloads may cause problems with respect to reproducibility or enthalpy measurement accuracy. They may furthermore be very expensive, or be complicated to use for measurements due to possibilities of explosion or emission of noxious gases.

Dummy workloads shall be used if the parties involved agree that they may be used instead of normal workloads. Dummy workload specifications shall then be stated in the test method standard for the particular type of equipment. If containers, holders or other devices are used, they shall be considered as with normal workloads.

The methodology for measuring enthalpy increase shall be clearly specified in the test method standard for the particular type of equipment.

5.5 Use of performance test workloads

In cases where the processing result in terms of enthalpy is not the only or the relevant concern, comparisons using performance test workloads shall be carried out, to verify any significant performance differences. Both performance test workloads and dummy workloads shall then be used if deemed to be relevant.

There are also cases where dummy workloads and enthalpy measurements are not meaningful or cannot be carried out, in e.g. surface deposition, seam annealing and laser cutting processes, where the evenness in processing result is more important than the overall enthalpy increase in the workload. Comparisons within the same equipment class may then result in very similar results with a dummy workload but significant end product quality differences in a processed normal workload. Normal workloads may then be the only realistic type of workload for comparative testing, and the equipment capacity as a consequence not being possible to express in terms of enthalpy increase in any workload.

The performance test workload specifications and test procedures as well as the parameters and criteria used for performance evaluation shall be stated in the test method standard for the particular type of equipment. The electrical energy consumption and conversion measurements in 7.2 but not the efficiency measurements according to the principles in 7.3 shall then be carried out.

6 Measurement of electric power and ancillary energy factors

6.1 Measurement of cold start-up energy consumption and time

The following applies for comparative measurements on equipment of the same class, provided operation without a workload is consistent with normal use.

– The equipment is operated without a workload of any kind if possible, or else with a suitable workload.

– Any preheating of the treatment chamber or zone to arrive at a state as close as reasonable to hot standby operation is carried out, if applicable.

– The cold start-up total electric and other energy consumption and time are measured.

NOTE Examples of preheating are by particular resistive heating of the treatment chamber walls, steam condensation, or pre-runs with suitable workloads emitting radiant heat or steam.

6.2 Measurement of hot standby power

The following applies for comparative tests of different batch type equipment of the same class:

– The equipment is operated without workload of any kind.

– Conditions of hot standby operation are maintained.

NOTE 1 The energy consumption due to pressurising or depressurising (including vacuuming) of the treatment chamber is dealt with in 6.3.

NOTE 2 Specifications on what items are to be included and excluded in measurements of hot standby operation power consumption are given in the respective standards.

6.3 Measurement of pressurising and depressurising energy consumption

The most onerous of workload introduction and removal from the treatment chamber with respect to 4.4.2 is used. If there is a tank and valve system for compression energy recovery as a part of the installation, the energy consumption reduction by this – i.e. the overall enthalpy increase – shall be considered.

6.4 Measurement of holding power

The following applies for comparative tests of different batch type equipment of the same class, if applicable:

– The equipment is operated with a hot/ready, processed normal workload, unless explicitly assessed as improper.

– The temperature of the workload is kept constant, using particular control settings for this purpose.

– The stationary electric power consumption and also any other energy consumption as specified in 4.3 are measured.

NOTE 1 The holding power feature of an installation can exist due to a need for workload temperature equilibration after the process proper. The feature does not exist in some types of equipment.

NOTE 2 The major difference between hot standby and holding is that the workload is present in the latter case, and can emit radiant, convective or conductive energy to its ambient. This is then compensated by external energy supply to maintain the workload temperature.

7 Measurement of efficiencies

7.1 General

Clause 7 deals with two kinds of measurements in addition to what is dealt with in Clauses 5 and 6, and as addressed in 4.1:

– electric-only conversion efficiency, specifications in 7.2;

– electroheating efficiency in normal operation, guidelines in 7.3.

7.2 Measurement of electric-only conversion efficiency

The input electric power and power factor and the electric output power flow are measured and reported under normal operation with equal workload specification. The workload is then either a normal, a dummy or a performance test workload.

All measurements of the electric energy consumption shall reflect specific consumption by defined parts of the installation during a defined time period or a specified operation. The following shall be reported, if applicable:

a) The energy consumption of a batch type installation during one cycle; this may be measured and averaged over a defined number of cycles. The number of cycles and variation of energy consumption shall be recorded in the measurement report.

b) The energy consumption of equipment for continuous operation during processing of a defined amount of workload.

c) The energy consumption of the equipment over a complete production cycle – for example from morning to evening.

If the final frequency conversion is by a standardised component, its manufacturer data may be used.

Any ancillary electric power needed for energising a component or assembly for the final frequency conversion is included in the electric input from the supply network. The electric power consumption by any cooling devices is not included, neither of any other control circuit. If there is an external voltage transformation from the external network supplying the plant to a special voltage which is fed into the equipment, these transformation losses are not included.

7.3 Measurement of electroheating energy consumption and efficiency

In addition to the specifications in Clause 5, the power consumption of the mechanical accessories needed for the operation and use of the electroheating equipment shall be considered separately.

Any ancillary cooling or preheating equipment not being a part of the equipment under test is also considered as separate in Clause 8.

8 Energy recovery

8.1 General

In general, the media by which thermal energy waste or release from the equipment occurs are fluids. Losses transferred through any insulation to the ambient will generate convective streams with low energy content above ambient and may not be recoverable. Fluids streaming from the process itself may have a high energy content well served for recovery and are in the focus of the following.

The energy recoverability is defined by five factors:

– the heat capacity per mass unit of the fluid which has extracted the energy, in J/(K·kg);
– the flow rate of this fluid, in kg/s;
– the temperature of this fluid immediately after extraction, in °C;
– the ambient temperature where the transported energy is to be used as thermal energy, or to be converted into mechanical or chemical energy, in °C;
– the availability of the energy being a constant flow or pulsed, depending on ramping-up and down following start and end of equipment operation, the continuity and fluctuations of the output of the recoverable energy, continuous or batch processing being of particular importance.

The first factor is a measure of the simplicity of transport and of prospective heat losses in the transport from the location of generation to that of recovery.

The second factor is a measure of the speed of heat transfer and the prospective usefulness of the thermal energy, as such.

The combination of the third and fourth factors is a measure of the prospective usefulness in a heat engine or for other purposes.

The fifth factor is related to the practical usefulness of the available recovered energy and any need for energy storage.

8.2 Temperature and pressure of the fluid

These two quantities are measured just after extraction from the equipment. Any mechanical energy for compression or decompression per volume unit conditioned for transport of the fluid is also measured.

NOTE Mechanical energy and thermal energy are recorded separately.

8.3 Hot fluid heat capacity performance factor

This is calculated from tabulated physical and thermal property specifications of the actual gas or liquid. The overall heat capacity per volume unit of the medium used for transporting the thermal energy is determined as the integral of the thermal energy per volume unit over the actual initial and usage temperature interval.

Since the density of gases varies with temperature and pressure, corrections for pressure and any added mechanical energy for pressurising are included. A pressure increase will result in a possibility for faster energy transport. However, any heat losses in transport are not included in the heat capacity performance factor.

NOTE The Bibliography items [8] and [9] give information on sources for heat capacity and other thermal data.

8.4 Calculations of thermal recovery in the process

These are made if the manufacturer provides optional energy recovery means with the equipment. The measurements and evaluations in Clause 7 are then made, with and without the recovery means. Any power consumption of these means is included.

8.5 Determination of external energy recoverability

The determination of external energy recoverability is by stating and describing the five factors listed in 8.1, and calculating the transported thermal power from the temperature difference multiplied with the heat capacity per mass unit and the mass flow rate. The unit of the resulting value is in W or kW.

Satisfactory comparisons are very dependent on the ambient temperature which varies among locations of different installations of the same type and class. The ambient temperature may be important in the individual case; see 4.3.

8.6 Calculation of the endoreversible thermal efficiency for a heat engine (exergy)

In case of high temperature thermal release (see 8.4), a standard ambient temperature of 20 °C at the location of the heat engine is used for theoretical and comparative calculations to be possible. However, other temperatures (such as worst-case, i.e. the highest occurring) may be used, in agreement with the parties whose installations are to be compared.

The internal efficiency of the heat engine is a separate matter and is not covered by this Technical Specification. The endoreversible thermal efficiency η is calculated as

$$\eta = 1 - \sqrt{\frac{T_\mathrm{c}}{T_\mathrm{h}}}$$

where T_c is the cold (ambient) temperature and T_h the hot temperature (in the mass flow from the equipment), both in K.

A correction is applied and recorded for any net energy spent on pressurising and depressurising of the medium fed into the heat engine. This shall include any pressure energy gains by heating of a gaseous medium by thermal or mechanical/adiabatic compression/decompression.

9 Aspects of management of operation flexibility (smart grid connectivity)

9.1 Load management and smart grid

Load management is the process of balancing the supply of electricity on the network with the electrical load by adjusting or controlling the load rather than the output of the power station or the grid. This may be achieved by direct intervention by the utility in real time, by the use of frequency sensitive relays triggering circuit breakers (ripple control), by time clocks, or by using special tariffs to influence user behaviour. Telecommunication techniques, so-called smart grid applications, can facilitate the interaction between the utility and user.

9.2 Applicability to electroheating installations

Some types of electroheating installations tend to consume very significant amounts of electric power. This makes it interesting for the user to be able to react to the actual price of electric power consumption, and thus rather quickly reduce the electric power consumption of the installation by semiautomatic, automatic or remotely controlled “tuning down” during periods of peak general or plant-specific demand of electricity, then with short-term losses of equipment capacity but still in normal operation. Optimal control can be achieved by making use of load management and smart grid techniques.

In addition to the factors in the following 9.3 and 9.4, factors which are relevant for smart grid connectivity are cold start-up energy consumption and time in 6.1, hot standby power in 6.2 and holding power in 6.4.

9.3 Tune down times

Tune down times related to smart grid connectivity for continuously operating installations are important and shall be specified. This also applies to reductions of the capacity under normal operation.

NOTE Tune down times are considered the most relevant for avoiding peak general demand periods and the resulting short-term cost increase of electrical energy.

Tune down times for batch installations shall in principle be the same as for continuously operating installations, but measurements are in practice adapted to a sequence of cold start-up time and cool-down time. For continuously operating installations, normal operation may allow a capacity reduction to half or less from that at full power setting. If that is the case, this half setting, as well as the lowest power setting under normal operation, are tested.

9.4 Shut-down and start-up capability evaluations

The manufacturer shall specify what kind(s) of tune down are accepted, in addition to that in 9.3: complete shutdown, holding (6.4), or hot standby (6.2). If any or all of these alternatives are considered unrealistic by the manufacturer, e.g. due to very time-consuming operations and/or product waste, that conclusion is also reported.

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[1] IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

[2] IEC/TS 62257-12-1:2007, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 12-1: Selection of self-ballasted lamps (CFL) for rural electrification systems and recommendations for household lighting equipment*

[3] IEC 60398, *Installations for electroheating and electromagnetic processing – General test methods*[2]

[4] ISO 13579-1, *Industrial furnaces and associated processing equipment – Method of measuring energy balance and calculating efficiency – Part 1: General methodology*

[5] ISO 13579-2, *Industrial furnaces and associated processing equipment – Method of measuring energy balance and calculating efficiency – Part 2: Reheating furnaces for steel*

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2 Under consideration.

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