

ISO/TC 244

Secretariat: JISC

Voting begins on:  
2012-09-19

Voting terminates on:  
2012-11-19

---

---

## Industrial furnaces and associated processing equipment — Method of measuring energy balance and calculating efficiency —

### Part 1: General methodology

*Fours industriels et équipements associés — Méthode de mesure du  
bilan énergétique et de calcul de l'efficacité —*

*Partie 1: Méthode générale*

RECIPIENTS OF THIS DRAFT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.



---

---

Reference number  
ISO/FDIS 13579-1:2012(E)

**iTeh STANDARD PREVIEW**  
(standards.iteh.ai)  
Full standard:  
<https://standards.iteh.ai/catalog/standards/sist/0e46961a-352b-4d58-9896-b67e17929353/iso-13579-1-2013>

### Copyright notice

This ISO document is a Draft International Standard and is copyright-protected by ISO. Except as permitted under the applicable laws of the user's country, neither this ISO draft nor any extract from it may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, photocopying, recording or otherwise, without prior written permission being secured.

Requests for permission to reproduce should be addressed to either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

Reproduction may be subject to royalty payments or a licensing agreement.

Violators may be prosecuted.

# Contents

Page

Foreword .....	v
Introduction.....	vi
<b>1 Scope .....</b>	<b>1</b>
<b>2 Normative references .....</b>	<b>1</b>
<b>3 Terms and definitions .....</b>	<b>1</b>
3.1 Terms related to type of energy used in this part of ISO 13579 .....	1
<b>4 Symbols used in this part of ISO 13579 .....</b>	<b>5</b>
<b>5 Basic principles .....</b>	<b>10</b>
5.1 General .....	10
5.2 Energy flow diagram .....	13
5.3 Process Heating Assessment Survey Tool .....	13
<b>6 Basic conditions of measurement and calculation .....</b>	<b>14</b>
6.1 State of furnace .....	14
6.2 Duration of measurement .....	14
6.3 Unit of specific energy consumption .....	14
6.4 Reference conditions .....	14
6.5 Unit of amount of gas .....	14
6.6 Fuel .....	14
<b>7 Type of energy evaluated in this part of ISO 13579 and its systematisation .....</b>	<b>15</b>
7.1 General .....	15
7.2 Energy balance .....	15
7.3 Thermal energy balance .....	17
7.4 Energy balance of electrical generation .....	18
7.5 Recycled energy .....	18
<b>8 Measurement method .....</b>	<b>18</b>
8.1 General .....	18
8.2 Fuel .....	19
8.3 Atomization agent .....	19
8.4 Combustion air and exhaust gas .....	20
8.5 Controlled atmospheric gas .....	24
8.6 Products and jigs/fixtures for product handling .....	25
8.7 Temperature of furnace surface .....	25
8.8 Furnace inner wall temperature .....	25
8.9 Inner furnace pressure .....	25
8.10 Cooling water .....	26
8.11 Electrical auxiliary equipment .....	26
8.12 Generation of utilities .....	26
8.13 Recycled energy .....	26
<b>9 Calculation .....</b>	<b>26</b>
9.1 General provisions .....	26
9.2 Total energy input .....	27
9.3 Total energy output .....	30
9.4 Total energy efficiency .....	34
<b>10 Energy balance evaluation report .....</b>	<b>35</b>
<b>Annex A (informative) Assesment of uncertainty of the total energy efficiency .....</b>	<b>37</b>
<b>Annex B (informative) Measurement method concerning regenerative burners .....</b>	<b>39</b>

<b>Annex C (informative) Reference data .....</b>	<b>40</b>
<b>Annex D (informative) Calculation of moisture content of fuel and air .....</b>	<b>49</b>
<b>Annex E (informative) Calculations of heat storage of furnace wall, furnace wall temperature profile and heat loss by furnace wall in serial batch-type furnace process.....</b>	<b>50</b>
<b>Annex F (informative) Calculation of wall loss and heat loss of discharged blowout from furnace opening .....</b>	<b>56</b>
<b>Annex G (informative) Calculation of energy for fluid transfer .....</b>	<b>60</b>
<b>Annex H (informative) Example of energy balance sheet .....</b>	<b>63</b>
<b>Bibliography.....</b>	<b>65</b>

**iTeh STANDARD PREVIEW**  
(standards.iteh.ai)  
Full standard:  
<https://standards.iteh.ai/catalog/standards/sist/0e46961a-352b-4d58-9896-b67e17929353/iso-13579-1-2013>

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13579-1 was prepared by Technical Committee ISO/TC 244, *Industrial furnaces and associated thermal processing equipment*.

ISO 13579 consists of the following parts, under the general title *Industrial furnaces and associated processing equipment — Method of measuring energy balance and calculating efficiency*:

- *Part 1: General methodology*
- *Part 3: Reheating furnaces for steel*
- *Part 2: Batch-type aluminium melting furnaces*
- *Part 4: Furnaces with protective or reactive atmosphere*

## Introduction

Prevention of global warming is a significant issue which needs to be solved on the world scale. For this purpose, it is necessary not only to reduce energy consumption dramatically, but at the same time also ensure a convenient and comfortable daily life for everyone.

It is critical to use energy as efficiently as possible to fulfil these requirements.

Although industrial furnaces play an important role in maintaining everyone's life, on the other hand, they consume a great amount of energy. In order to tackle the above-mentioned issues, it is important to

- establish an International Standard (i.e. the ISO 13579 series), which specifies the energy efficiency of industrial furnaces in a reasonable manner,
- control energy consumption by using the collected measurement data based on ISO 13579 (all parts), and
- improve efficiency.

Furthermore, this part of ISO 13579 can be applied as a fair guideline for utilizing the Clean Development Mechanism (CDM), which was developed under the Kyoto Protocol<sup>[24]</sup> for measures used to prevent global warming.

All calculations within ISO 13579 (all parts) are based on the location of equipment under reference conditions.

NOTE For equipment intended to be installed above or below sea level, it is expected that the impact of the elevation be calculated for that location.

# Industrial furnaces and associated processing equipment — Method of measuring energy balance and calculating efficiency —

## Part 1: General methodology

### 1 Scope

This part of ISO 13579 specifies a general methodology for measuring energy balance and calculating the efficiency of the process involving industrial furnaces and associated processing equipment as designed by furnace manufacturers. This general methodology includes:

- measurement methods;
- calculations (general calculation);
- an energy balance evaluation report.

This part of ISO 13579 is not applicable to any efficiencies related to the process itself outside of industrial furnaces and associated processing equipment (e.g. in a rolling mill process, the reheating furnace is intended to be the only part covered by this part of ISO 13579).

### 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.

ISO 13574, *Industrial furnaces and associated processing equipment — Vocabulary*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13574 and the following apply.

#### 3.1 Terms related to type of energy used in this part of ISO 13579

##### 3.1.1 Total energy input

###### 3.1.1.1 total energy input

$E_{\text{input}}$

aggregate of measured energy input brought into the area of energy balance, and which is composed of fuel equivalent energy and other energy input

### 3.1.2 Fuel equivalent energy

#### 3.1.2.1

##### **fuel equivalent energy**

$E_{fe}$   
aggregate of input energy which is composed of calorific value of fuel, calorific value of waste, calorific value of source gas of atmospheric gas and fuel equivalent energy of electricity

#### 3.1.2.2

##### **calorific value of fuel**

$E_{h,fuel}$   
heat of combustion of fuel which is consumed and used for heating products in the area of energy balance

#### 3.1.2.3

##### **calorific value of waste**

$E_{h,waste}$   
calorific value of waste which is brought to the area of energy balance with products

EXAMPLE Waste oil on aluminium scrap.

#### 3.1.2.4

##### **calorific value of source gas of atmospheric gas**

$E_{fe,atm,cal}$   
calorific value of source gas of atmospheric gas which is used as protective and reactive atmospheres

#### 3.1.2.5

##### **fuel equivalent energy of electricity**

$E_{fe,el}$   
aggregate of fuel equivalent energy of electricity converted from each occurrence of electrical energy consumptions in the area of energy balance

### 3.1.3 Other energy input

#### 3.1.3.1

##### **other energy input**

$E_{others}$   
energy that is composed of sensible heat of fuel, sensible heat of combustion air or other oxidant, sensible heat of atomization agent for liquid fuel, heat of reaction and sensible heat of infiltration air

#### 3.1.3.2

##### **heat of reaction**

$E_{react}$   
heat generated by the oxidation reaction of products in the area of energy balance measurement

EXAMPLE The formation of scale of steel products during the oxidation reaction.

#### 3.1.3.3

##### **sensible heat of infiltration air**

$E_{s,infiltr}$   
sensible heat of air that leaks into the furnace through supply/discharge port or gaps in the operating systems of the furnace

Note 1 to entry This term may be replaced with "sensible heat of false air".



### 3.1.4 Total energy output

#### 3.1.4.1

##### total energy output

$E_{\text{output}}$

aggregate of measured energy output emitted from or consumed in the area of energy balance, which is composed of thermal energy output, energy consumed in electrical auxiliary equipment, energy used for generation of utility and electrical generation loss

### 3.1.5 Thermal energy output

#### 3.1.5.1

##### thermal energy output

$E_{\text{therm,out}}$

aggregate of thermal energy which is emitted from the area of energy balance

Note 1 to entry Thermal energy output is composed of energy defined in 3.1.5.2 to 3.1.5.13.

#### 3.1.5.2

##### effective energy

$E_{\text{effect}}$

enthalpy that products gained in the area of energy balance

#### 3.1.5.3

##### jig loss

$E_{\text{l,jig}}$

enthalpy that jigs for handling the products gained in the area of energy balance measurement

#### 3.1.5.4

##### sensible heat of oxidized substance

$E_{\text{l,oxid}}$

sensible heat of substances which have reacted with oxygen, formed in the thermal process brought out from the area of energy balance measurement

#### 3.1.5.5

##### sensible heat of exhaust gas

$E_{\text{exhaust}}$

sensible heat of expended gas which is emitted from the area of energy balance measurement

#### 3.1.5.6

##### heat storage loss by batch-type furnace

$E_{\text{l,storage}}$

sensible heat which a furnace refractory gains within a batch-type furnace operation cycle

#### 3.1.5.7

##### sensible heat loss of atmospheric gas

$E_{\text{s,atm}}$

sensible heat which atmospheric gas for thermal processing gains through the area of energy balance

#### 3.1.5.8

##### wall loss

$E_{\text{l,wall}}$

thermal energy emitted from the surface of industrial furnaces by radiation and convection

#### 3.1.5.9

##### heat loss of discharged blowout from furnace opening

$E_{\text{l,blowout}}$

sensible heat of blowout gas emitted from the furnace opening

### 3.1.5.10

#### heat loss of radiation from furnace opening

$E_{l,opening}$

thermal energy emitted from the furnace opening by radiation

### 3.1.5.11

#### heat loss from furnace parts installed through furnace wall

$E_{l,parts}$

thermal energy emitted through furnace parts which are installed through furnace wall

EXAMPLE As in the case of a roller hearth furnace.

### 3.1.5.12

#### cooling water loss

$E_{l,cw}$

thermal energy brought out by cooling water from the area of energy balance measurement

### 3.1.5.13

#### other losses

$E_{l,other}$

unmeasured thermal energy losses from the area of energy balance

## 3.1.6 Energy consumed in electrical auxiliary equipment

### 3.1.6.1

#### energy consumed in electrical auxiliary equipment

$E_{aux}$

energy utilized in electrical auxiliary equipment which is composed of energy consumed in installed electrical auxiliary equipment and energy used for fluid transfer

### 3.1.6.2

#### energy consumed in installed electrical auxiliary equipment

$E_{aux,installed}$

aggregate of total energy used in installed electrical auxiliary equipment (e.g. fans, pumps) installed in the area of energy balance

### 3.1.6.3

#### energy used for fluid transfer

$E_{aux,fluid}$

aggregate of energy for fluid transfer calculated from the property of the fluid

EXAMPLE For cooling water, fuel, etc.

## 3.1.7 Energy used for generation of utility

### 3.1.7.1

#### utility

service other than fuel and electricity provided to the area of energy balance

EXAMPLE Oxygen, steam and atmospheric gas.

### 3.1.7.2

#### energy used for generation of utilities

$E_{utility}$

aggregate of energy for the generation of utilities used in the area of energy balance

### 3.1.8 Electrical generation loss

#### 3.1.8.1

##### electrical generation loss

$E_{l,eg}$

energy loss in electrical generation which is backcalculated from fuel equivalent energy and total consumed electrical energy

### 3.1.9 Thermal energy balance

#### 3.1.9.1

##### thermal energy input from electrical heating source

heat energy entering the process from an electrical heating source, such as an electrical heater emitted to the area of energy balance

#### 3.1.9.2

##### circulating heat

heat that circulates within equipment or system installed in the area of energy balance

### 3.1.10 Energy balance of electrical generation

#### 3.1.10.1

##### total consumed electrical energy

$E_{e,total}$

aggregate of electrical energy which is consumed in the area of energy balance and equal to the sum of thermal energy input from electrical heating source, energy consumed in electrical auxiliary equipment and electrical energy used for the generation of utility

#### 3.1.10.2

##### electrical energy used for generation of utilities

$E_{e,utility}$

aggregate of electrical energy consumed for generation of utilities (e.g. generation of oxygen) used in the area of energy balance

### 3.1.11 Recycled energy

#### 3.1.11.1

##### recycled energy

$E_{re}$

energy that is regenerated from the wasted thermal energy from the area of energy balance

EXAMPLE Energy reused in waste gas boiler.

## 4 Symbols used in this part of ISO 13579

For the purposes of this document, the following symbols apply.

NOTE 1 Tons used are metric tons.

NOTE 2 For the units of volume of gas, see 6.5.

Symbol	Meaning	Unit
$A$	combustion air volume provided per ton of products	$m^3(n)/t$
$A_0$	theoretical volume of combustion air required per unit quantity of fuel	$m^3(n)/kg$ or $m^3(n)/m^3(n)$
$C$	heat conductivity of hearth material	$W/mK$

Symbol	Meaning	Unit
$c_{pm,atm1}$	mean specific heat of atmospheric gas between $T_{atm1}$ and 273,15 K	kJ/(kg·K)
$c_{pm,atm2}$	mean specific heat of atmospheric gas between $T_{atm2}$ and 273,15 K	kJ/(kg·K)
$c_{pm,j1}$	mean specific heat of jigs/fixtures between $T_{j1}$ and 273,15 K	kJ/(kg·K)
$c_{pm,j2}$	mean specific heat of jigs/fixtures between $T_{j2}$ and 273,15 K	kJ/(kg·K)
$c_{pm,E}$	mean specific heat of exhaust gas between $T_E$ and 273,15 K	kJ/(kg·K)
$c_{pm,a}$	mean specific heat of combustion air between ambient temperature and 273,15 K	kJ/(m <sup>3</sup> (n)·K)
$c_{pm,a1}$	mean specific heat of combustion air between its specified temperature and 273,15 K	kJ/(kg·K) or kJ/m <sup>3</sup> (n)·K
$c_{pm,f1}$	mean specific heat of fuel between its provided temperature and 273,15 K	kJ/(kg·K) or kJ/m <sup>3</sup> (n)·K
$c_{pm,gf}$	mean specific heat of blowout between $T_{gf}$ and 273,15K	kJ/m <sup>3</sup> (n)·K
$c_{pm,p1}$	mean specific heat of products between $T_{p1}$ and 273,15 K	kJ/(kg·K)
$c_{pm,p2}$	mean specific heat of products between $T_{p2}$ and 273,15 K	kJ/(kg·K)
$c_{pm,ri}$	mean specific heat of refractory of each layer	kJ/(kg·K)
$E_{aux}$	energy consumed in electrical auxiliary equipment per ton of products	kJ/t
$E_{aux,fluid}$	aggregate of energy used for fluid transfer per ton of products	kJ/t
$E_{aux,fluid,bl}$	energy used for fluid transfer by blowers per ton of products	kJ/t
$E_{aux,fluid,comp}$	energy used for fluid transfer by compressors per ton of products	kJ/t
$E_{aux,fluid,pump}$	energy used for fluid transfer by pumps per ton of products	kJ/t
$E_{aux,installed}$	aggregate of energy used in installed electrical auxiliary equipment per ton of products	kJ/t
$E_{e,utility}$	Electrical energy used for generation of utility per ton of products	kJ/t
$E_{effect}$	effective energy per ton of products	kJ/t
$E_{exhaust}$	sensible heat of exhaust gas per ton of products	kJ/t
$E_{fe}$	fuel equivalent energy of electricity per ton of products	kJ/t
$E_{fe,atm,cal}$	calorific value of source gas of atmospheric gas per ton of products	kJ/t
$E_{fe,el}$	fuel equivalent energy of electricity per ton of products	kJ/t
$E_{h,fuel}$	calorific value of fuel per ton of products	kJ/t
$E_{h,waste}$	calorific value of waste per ton of products	kJ/t
$E_{input}$	total energy input per ton of products	kJ/t
$E_{l,blowout}$	heat loss of discharged blowout from furnace opening per ton of products	kJ/t
$E_{l,cw}$	cooling water loss per ton of products	kJ/t
$E_{l,eg}$	energy loss in electrical generation	kJ/t
$E_{l,jig}$	jig loss per ton of products	kJ/t
$E_{l,opening}$	heat loss of radiation from furnace opening per ton of products	kJ/t
$E_{l,other}$	other losses per ton of products	kJ/t
$E_{l,parts}$	Heat loss from furnace parts installed through furnace wall	kJ/t
$E_{l,storage}$	heat storage loss by batch-type furnace per ton of products	kJ/t
$e_{l,storage}$	heat storage loss by batch-type furnace per 1m <sup>2</sup> of furnace wall	kJ/m <sup>2</sup>
$E_{l,wall}$	wall loss per ton of products	kJ/t
$E_{l,wall,1}$	wall loss from furnace wall and flue per ton of products	kJ/t
$E_{l,wall,2}$	wall loss from hearth per ton of products	kJ/t

Symbol	Meaning	Unit
$E_{\text{others}}$	other energy input per ton of products	kJ/t
$E_{\text{output}}$	total energy output per ton of products	kJ/t
$E_{\text{p1}}$	sensible heat (or enthalpy) of products at the time when products are loaded in the area of energy balance per ton of products	kJ/t
$E_{\text{p2}}$	sensible heat (or enthalpy) of products at the time when products are extracted from the area of energy balance per ton of products	kJ/t
$E_{\text{react}}$	heat of reaction per ton of products	kJ/t
$E_{\text{s,air}}$	sensible heat of combustion air or other oxydant per ton of products	kJ/t
$E_{\text{s,atm}}$	sensible heat loss of atmospheric gas per ton of products	kJ/t
$E_{\text{s,atomize}}$	sensible heat of atomization agent per ton of products	kJ/t
$E_{\text{s,fuel}}$	sensible heat of fuel per ton of products	kJ/t
$E_{\text{s,infil}}$	sensible heat of infiltration air per ton of products	kJ/t
$E_{\text{s,oxid}}$	sensible heat of oxidized substance per ton of products	kJ/t
$E_{\text{therm,out}}$	thermal (output) energy per ton of products	kJ/t
$E_{\text{utility}}$	energy used for generation of utilities per ton of products	kJ/t
$E_{\text{u,atm,gen}}$	energy used for generation of atmospheric gas per ton of products	kJ/t
$E_{\text{u,atm,cal}}$	calorific value of source gas of atmospheric gas per ton of products	kJ/t
$E_{\text{u,oxy}}$	energy for generation of oxygen per ton of products	kJ/t
$E_{\text{u,steam}}$	energy for generation of steam per ton of products	kJ/t
$G_0$	theoretical volume of exhaust gas per unit quantity of fuel	$\text{m}^3(\text{n})/\text{kg}$ or $\text{m}^3(\text{n})/\text{m}^3(\text{n})$
$G'_0$	theoretical volume of dry exhaust gas per unit quantity of fuel	$\text{m}^3(\text{n})/\text{kg}$ or $\text{m}^3(\text{n})/\text{m}^3(\text{n})$
$H_d$	net pump head of pump	M
$H_j$	net calorific value of component j of gaseous fuel	kJ/ $\text{m}^3(\text{n})$
$H_h$	gross calorific value per unit quantity of fuel	J/kg or kJ/ $\text{m}^3(\text{n})$
$H_l$	net calorific value per unit quantity of fuel	J/kg or kJ/ $\text{m}^3(\text{n})$
$H_{\text{l,source gas}}$	net calorific value of source gas	kJ/ $\text{m}^3(\text{n})$
$H_{\text{wall}}$	heat storage of multilayer furnace refractory per $1\text{m}^2$	kJ/ $\text{m}^2$
$h_{\text{co}}$	convection heat transfer coefficient	W/ $\text{m}^2\text{K}$
$h_0$	enthalpy of atomization agent at reference temperature	kJ/kg
$k_{\text{parts}}$	heat conductivity of furnace parts of furnace installed through furnace wall	W/mK
$L_{\text{th}}$	theoretical power of compressor	kW
$l_1, l_2, l_3$	thickness of each refractory layer	M
$l_{\text{iw}}$	inner dimension between sidewalls of furnace	M
$l_w$	thickness of furnace wall	M
$M_j$	mass of jigs/fixtures used per ton of products	kg/t
$M_{\text{loss}}$	loss of mass per ton of products	kg/t
$M_p$	mass of products	kg or t
$m$	excess combustion air ratio	—
$P_d$	absolute pressure of fluid at the inlet of furnace	MPa
$P_h$	static pressure at the inlet	kPa
$P_s$	absolute pressure of atmosphere	MPa