

BS ISO 13579-1:2013



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

Part 1: General methodology

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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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



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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^[24] 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_{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

$E_{s,infil}$
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_{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_{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_{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 ³ (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 ³ (n)·K
$c_{pm,f1}$	mean specific heat of fuel between its provided temperature and 273,15 K	kJ/(kg·K) or kJ/m ³ (n)·K
$c_{pm,gf}$	mean specific heat of blowout between T_{gf} and 273,15K	kJ/m ³ (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 blowers 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 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 ² of furnace wall	kJ/m ²
$E_{l,wall}$	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_{others}	other energy input per ton of products	kJ/t
E_{output}	total energy output per ton of products	kJ/t
E_{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_{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_{react}	heat of reaction per ton of products	kJ/t
E_{re}	energy regenerated from the wasted thermal energy 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
$E_{\text{s,infiltr}}$	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_{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	$\text{kJ}/\text{m}^3(\text{n})$
H_h	gross calorific value per unit quantity of fuel	J/kg or $\text{kJ}/\text{m}^3(\text{n})$
H_l	net calorific value per unit quantity of fuel	J/kg or $\text{kJ}/\text{m}^3(\text{n})$
$H_{l,\text{source gas}}$	net calorific value of source gas	$\text{kJ}/\text{m}^3(\text{n})$
H_{wall}	heat storage of multilayer furnace refractory per 1m^2	kJ/m^2
h_{c0}	convection heat transfer coefficient	$\text{W}/\text{m}^2\text{K}$
h_0	enthalpy of atomization agent at reference temperature	kJ/kg
k_{parts}	heat conductivity of furnace parts of furnace installed through furnace wall	W/mK
L_{th}	theoretical power of compressor	kW
l_1, l_2, l_3	thickness of each refractory layer	M
l_{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_{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

Symbol	Meaning	Unit
P_s	absolute pressure of atmosphere	MPa
P_{sf}	saturated water vapour pressure	Pa
P_f	absolute pressure of fuel/air	Pa
p_h	static pressure of fluid measured at the inlet of furnaces	kPa
Δp_o	difference of pressure at openings	Pa
Q_{blower}	power of blower	kW
Q_{pumps}	power of pump	kW
Q_{comp}	power of compressor	kW
$Q_{aux,installed}$	electrical power consumed in each of installed electrical auxiliary equipment measured per ton of products	kW
$Q_{aux,fluid}$	electrical power used for fluid transfer per ton of products	kW
q_c	heat flux by convection	W/m ²
q_e	energy flux emitted from the furnace surface	W/m ²
q_h	heat energy loss from hearth	W/m ²
q_r	heat flux by radiation	W/m ²
q_t	energy flux through the furnace refractory	W/m ²
R_f	flow rate of fluid at the condition of atmosphere	m ³ (n)/min
R	latent heat of water vapour	kJ/kg
r_f	flow rate of fluid measured at the inlet of furnaces	m ³ /min
$S_{surface}$	surface area of furnace	m ²
S_{hearth}	surface area of furnace hearth	m ²
$S_{opening}$	area of openings	m ²
S_{parts}	cross-sectional area of furnace parts installed through furnace wall	m ²
T_a	ambient temperature	K
T_{a1}	temperature of combustion air provided	K
T_{atm1}	temperature of atmospheric gas provided	K
T_{atm2}	temperature of atmospheric gas discharged	K
$T_{E,max,i}$	maximum temperature of exhaust gas from regenerative burners in a single cycle	K
$T_{E,min}$	minimum temperature of exhaust gas from regenerative burners in a single cycle	K
T_E	temperature of mean exhaust gas	K
T_{f1}	temperature of fuel provided	K
T_{gf}	temperature of blowout	K
T_h	temperature of hearth surface	K
T_{j1}	temperature of jigs/fixtures at the time of loading to the area of energy balance	K
T_{j2}	temperature of jigs/fixtures at the time of extracting from the area of the energy balance	K
T_{p1}	average temperature of products at the time of loading to the area of energy balance	K
T_{p2}	average temperature of products at the time of extracting from the area of the energy balance	K
T_w	temperature of furnace wall surface	K

Symbol	Meaning	Unit
$T_{\text{water out}}$	cooling water temperature at its discharge port	K
$T_{\text{water in}}$	cooling water temperature at its supply port	K
T_z	temperature of inside furnace	K
t_{open}	time of opening (e.g. charge/discharge door) per ton of products	h/t
t_p	time required to process one ton of product	h/t
T_{r1}, T_{r2}	boundary temperature of refractory	K
U	mean velocity of fluid measured at the supplying point	m/s
V_{atm}	volume of atmospheric gas provided per ton of products	m ³ (n)/t
V_{atomize}	mass of atomization agent provided per ton of products	kg/t
V_{cw}	quantity of cooling water used per ton of products	kg/t
V_f	fuel consumption per ton of products	kg/t m ³ (n)/t
V_{gf}	volume of blowout per hour	m ³ /h
V_{infiltr}	infiltration air volume provided per ton of products	m ³ (n)/t
V_{me}	measured combustion air volume per ton of products	m ³ (n)/t
V_{oxy}	amount of oxygen used per ton of products	m ³ (n)/t
$V_{\text{source gas}}$	volume of source gas of atmospheric gas used per ton of products	m ³ (n)/t
x_j	volume fraction of component j of gaseous fuel	—
z	depth from the water surface	m
φ_{H_2}	volume fraction of hydrogen contained in gaseous fuel	—
φ_{N_2}	volume fraction of nitrogen contained in gaseous fuel	—
φ_{O_2}	volume fraction of oxygen contained in gaseous fuel	—
$\varphi_{\text{H}_2\text{O}}$	volume fraction of water contained in gaseous fuel	—
φ_{CO}	volume fraction of carbon monoxide contained in gaseous fuel	—
φ_{CO_2}	volume fraction of carbon dioxide contained in gaseous fuel	—
$\varphi_{\text{C}_x\text{H}_y}$	volume fraction of carbon hydrate contained in gaseous fuel	—
$\varphi_{\text{H}_2\text{S}}$	volume fraction of hydrogen sulphide contained in gaseous fuel	—
w_{C}	mass fraction of carbon contained in liquid fuel	—
w_{H}	mass fraction of hydrogen contained in liquid fuel	—
w_{O}	mass fraction of oxygen contained in liquid fuel	—
w_{S}	mass fraction of sulfur contained in liquid fuel	—
w_{W}	mass fraction of water contained in liquid fuel	—
φ_{N_2}	volume fraction of nitrogen contained in the combustion air	—
φ_{O_2}	volume fraction of oxygen contained in the combustion air	—
$\varphi_{\text{H}_2\text{O}}$	volume fraction of water contained in combustion air	—
φ_{N_2}	volume fraction of nitrogen contained in dry exhaust gas	—
φ_{O_2}	volume fraction of oxygen contained in dry exhaust gas	—
φ_{CO}	volume fraction of carbon monoxide contained in dry exhaust gas	—
φ_{CO_2}	volume fraction of carbon dioxide contained in dry exhaust gas	—
$\varphi_{\text{CO}_2\text{max}}$	maximum volume fraction of carbon dioxide contained in exhaust gas	—
φ_{N_2}	volume fraction of nitrogen contained in exhaust gas per unit quantity of fuel	m ³ (n)/kg fuel or m ³ (n)/m ³ (n) fuel

Symbol	Meaning	Unit
$\varphi_{<O_2>}$	volume fraction of oxygen contained in dry exhaust gas per unit quantity of fuel	$m^3(n)/kg$ fuel or $m^3(n)/m^3(n)$ fuel
$\varphi_{<H_2O>}$	volume fraction of water contained in dry exhaust gas per unit quantity of fuel	$m^3(n)/kg$ fuel or $m^3(n)/m^3(n)$ fuel
$\varphi_{<CO_2>}$	volume fraction of carbon dioxide contained in dry exhaust gas per unit quantity of fuel	$m^3(n)/kg$ fuel or $m^3(n)/m^3(n)$ fuel
$\varphi_{<SO_2>}$	volume fraction of sulfur dioxide contained in dry exhaust gas per unit quantity of fuel	$m^3(n)/kg$ fuel or $m^3(n)/m^3(n)$ fuel
$\varphi_{<H_2S>}$	volume fraction of hydrogen sulfide contained in dry exhaust gas per unit quantity of fuel	$m^3(n)/kg$ fuel or $m^3(n)/m^3(n)$ fuel
α_f	coefficient of friction	—
α_{hearth}	coefficient determined by the shape of hearth	—
α_m	tolerance of machinery	—
α_{opening}	coefficient determined from the shape of openings	—
α_{oxy}	energy consumption rate for production per 1 normal cubic metre of oxygen	kWh/ $m^3(n)$
ε_1	emissivity of furnace surface	—
ε_2	coefficient of determined from the shape of furnace openings	—
η_1	total energy efficiency	—
η_c	overall adiabatic efficiency of compressor	—
η_e	regional electrical generation efficiency	—
η_p	efficiency of pump	—
η_t	overall adiabatic efficiency of compressor	—
η_s	static pressure efficiency of blower	—
κ	ratio of specific heat of fluid	—
λ	heat conductivity of furnace refractory	W/mK
ρ_1, ρ_2, ρ_3	density of each refractory layer	kg/ m^3
ρ_f	density of fluid	kg/ m^3
σ	Stephen-Boltzmann constant	kJ/ m^2 h K ⁴
ϕ	relative humidity	—

5 Basic principles

5.1 General

The area of energy balance measurement shall be determined.

NOTE An example of determination of the area of energy balance measurement is shown in Figure 1.

The following aspects shall be included in the energy balance measurement:

- a) energy input;
 - fuel equivalent energy, E_{fe} ;
 - other energy input, E_{others} ;

b) energy output:

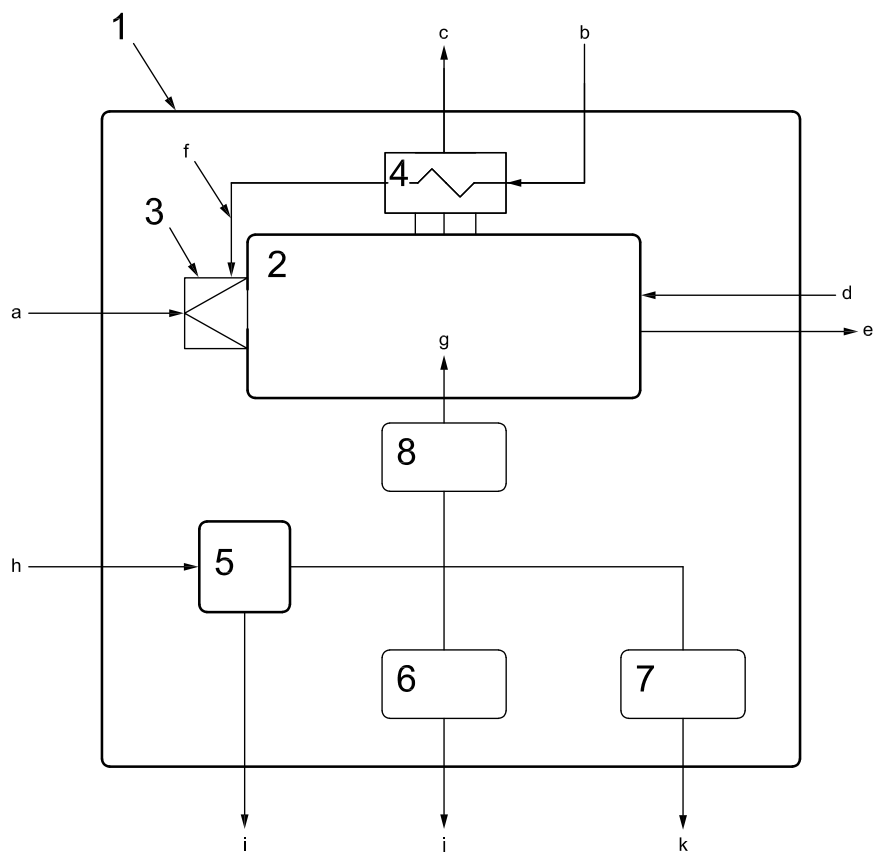
- thermal energy output, $E_{\text{therm,out}}$;
- energy consumed in electrical auxiliary equipment, E_{aux} ;
- energy used for generation of utilities, $E_{\text{utilities}}$;
- electrical generation loss, $E_{\text{I,eg}}$.

Determine the energy input and energy output which goes into and comes out of the area of energy balance, based on the measurement data.

The total energy input into the area shall balance the total energy output from the area.

The result of the energy balance measurement shall be summarized into energy input and energy output in an energy balance sheet with necessary information, such as equipment summary, measurement condition and measurement data.

Thermal energy balance and electrical generation may be created as subcategories (see 7.3 and 7.4).



Key

1 area of energy balance

2 furnace chamber

3 burner

4 heat exchanger

5 electrical generation

6 electrical auxiliary equipment

7 generation of utilities

8 electrical heating

a Calorific value, $E_{h,fuel}$, and sensible heat of fuel, $E_{s,fuel}$.

b Sensible heat of combustion air, $E_{s,air}$.

c Sensible heat of exhaust gas, $E_{exhaust}$.

d Thermal energy input, such as heat of reaction, E_{react} , and sensible heat of infiltration air, $E_{s,infil}$.

e Thermal energy output, such as effective energy, E_{effect} , and heat losses.

f Circulating heat plus sensible heat of combustion air.

g Thermal energy input from electrical heating sources.

h Fuel equivalent energy of electricity, $E_{fe,el}$.

i Electrical generation loss, $E_{l,eg}$.

j Electrical energy consumption in electrical auxiliary equipment, E_{aux} .

k Electrical energy consumption for generation of utilities, $E_{u,atm,gen}$.

Figure 1 — Example of determination of the area of energy balance measurement

5.2 Energy flow diagram

The energy flow diagram is a useful tool to represent input and output energy flow (see Figure 2).

NOTE An energy flow diagram is also known as a Sankey diagram.

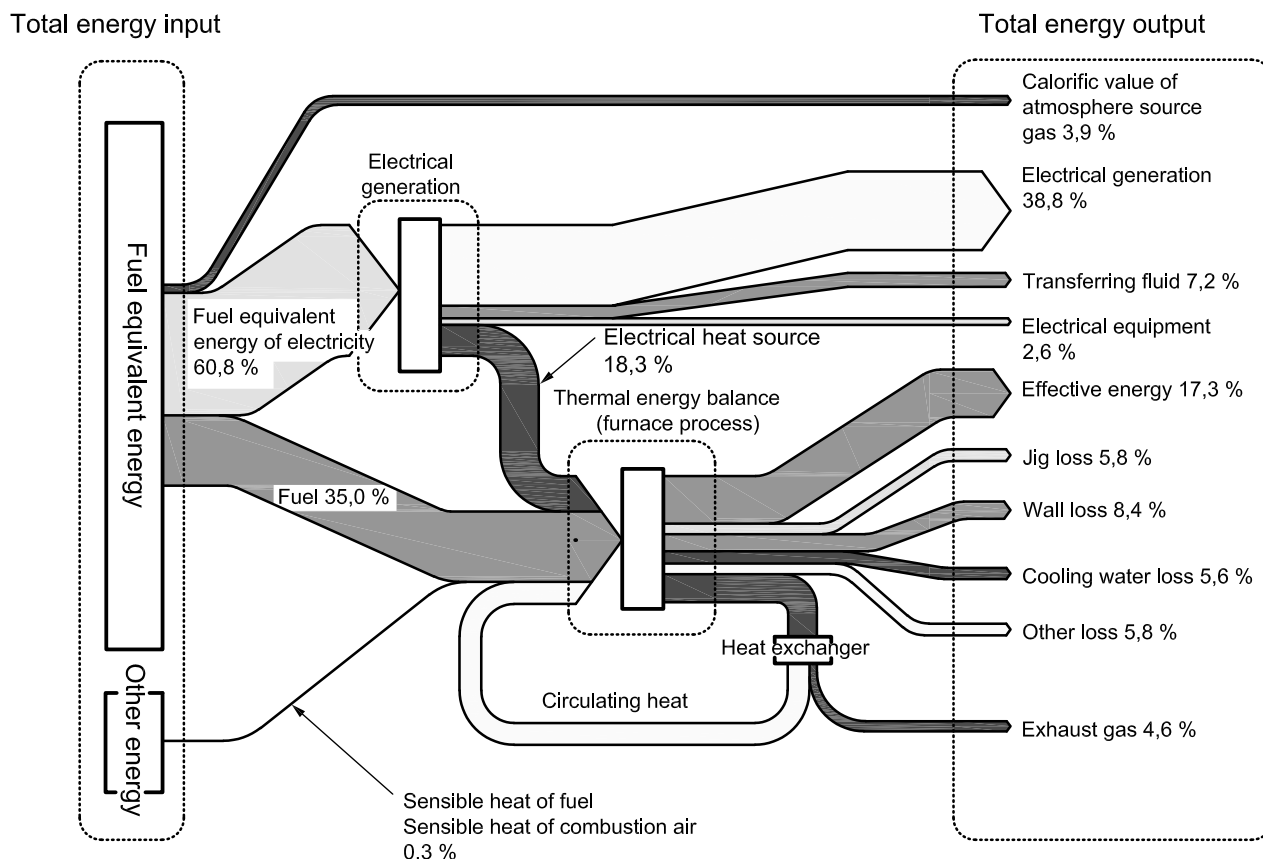


Figure 2 — Example of energy flow diagram (Sankey diagram) of industrial furnace

5.3 Process Heating Assessment Survey Tool

Developed by the U.S. Department of Energy, the software Process Heating Assessment and Survey Tool (PHAST)^[25] provides an introduction to process heating methods and tools to improve thermal efficiency of heating equipment. The tool is used to survey process heating equipment that uses fuel, steam or electricity, and identify the most energy-intensive equipment. Users may also perform an energy (heat) balance on selected equipment (furnaces) to identify and reduce non-productive energy use, compare performance of the furnace under various operating conditions and test "what-if" scenarios.

The thermal energy calculation function may be used as a tool which supplements the calculation specified in this part of ISO 13579, such as:

- sensible heat of material (effective energy);
- jig loss;
- calculations related to combustion;
- sensible heat of atmospheric gas;
- wall loss;
- heat loss of radiation from furnace opening;

- cooling water loss;
- exhaust gas losses.

6 Basic conditions of measurement and calculation

6.1 State of furnace

Furnaces subject to measurement shall be operated under normal conditions and

- in the case of continuous furnaces, the temperature and throughput shall be in the steady state considered in the design calculation, and
- in the case of batch-type furnaces, the temperature cycle and throughput shall be as considered in the design calculation.

Normal operating conditions are generally based on nominal conditions stipulated in the specification. But in the case of no specified condition, it may be defined by the supplier, e.g. two thirds of design throughput.

6.2 Duration of measurement

In the case of continuous furnaces, the duration of the energy balance measurement should be at least twice as long as the time the products stay in the furnace chamber.

In the case of batch-type furnaces, calculations shall be performed for each batch.

6.3 Unit of specific energy consumption

The basic unit of specific energy consumption shall be one kilo joule per ton (i.e. 1 000 kg) (kJ/t) of product, unless otherwise specified.

6.4 Reference conditions

The reference conditions shall be 0 °C (273,15 K) and 101 325 Pa, unless otherwise specified.

6.5 Unit of amount of gas

The values of amount of gas represented in this part of ISO 13579 shall be expressed in terms of volume under the reference conditions specified in 6.4, unless otherwise specified.

The unit of volume under the reference conditions shall be expressed in normal cubic metres [$\text{m}^3(\text{n})$], unless otherwise specified.

NOTE $2,24 \times 10^2$ normal cubic metres is equivalent to 1 mol.

6.6 Fuel

The unit quantity of fuel is

- 1 kg in the case of liquid fuel, or
- one normal cubic metre [$1 \text{ m}^3(\text{n})$] in the case of gaseous fuel.

In this part of ISO 13579, net calorific value of fuel is used as a calorific value.

7 Type of energy evaluated in this part of ISO 13579 and its systematization

7.1 General

The energy evaluated in this part of ISO 13579 and their symbols are defined in Clause 3.

All energy shall be expressed in kilojoules per ton of product (kJ/t), unless otherwise specified.

7.2 Energy balance

Systematization of energy evaluated in this part of ISO 13579 is described in Table 1.

Table 1 — Systematization of type of energy evaluated in this part of ISO 13579 — Overall energy balance

Type of energy			
Total energy input/output	Intermediate category	Detailed item	
Total energy input, E_{input}	Fuel equivalent energy, E_{fe}	Calorific value of fuel, $E_{h,fuel}$	
		Calorific value of waste, $E_{h,waste}$	
		Calorific value of source gas of atmospheric gas, $E_{fe,atm,cal}$	
		Fuel equivalent energy of electricity, $E_{fe,el}$	
	Other energy input, E_{others}	Sensible heat of fuel, $E_{s,fuel}$	
		Sensible heat of combustion air, $E_{s,air}$	
		Sensible heat of atomization agent, $E_{s,atomize}$	
		Heat of reaction, E_{react}	
		Sensible heat of infiltration air, $E_{s,infil}$	
Total energy output, E_{output}	Thermal energy, $E_{therm,out}$	Effective energy, E_{effect}	
		Jig loss, $E_{l,jig}$	
		Sensible heat of oxidized substance, $E_{s,oxid}$	
		Sensible heat of exhaust gas, $E_{exhaust}$	
		Heat storage loss by batch-type furnace, $E_{l,storage}$	
		Sensible heat loss of atmospheric gas, $E_{s,atm}$	
		Wall loss, $E_{l,wall}$	
		Heat loss of discharged blowout from furnace opening, $E_{l,blowout}$	
		Heat loss of radiation from furnace opening, $E_{l,opening}$	
		Heat loss from furnace parts installed through furnace wall, $E_{l,parts}$	
		Cooling water loss, $E_{l,cw}$	
		Other losses, $E_{l,other}$	
	Electrical auxiliary equipment, E_{aux}	Energy consumed in installed electrical auxiliary equipment, $E_{aux,installed}$, blowers, etc.	
		Energy used for fluid transfer, $E_{aux,fluid}$, cooling water, etc.	
	Generation of utilities, $E_{utility}$	Oxygen, $E_{u,oxy}$	
		Steam, $E_{u,steam}$	
		Atmospheric gas	energy for generation, $E_{u,atm,gen}$
			calorific value of source gas, $E_{u,atm,cal}$
		Electrical generation loss, $E_{l,eq}$	

7.2.1 Total energy input

See 3.1.1.

7.2.2 Fuel equivalent energy

See 3.1.2.

The calorific value of source gas of atmospheric gas, $E_{fe,atm,cal}$, shall be added as energy input even though the atmospheric gas is emitted from the furnace in an unburned state.

Regional electrical generation efficiency shall be applied to the convention of fuel equivalent energy of electricity, $E_{fe,el}$.

7.2.3 Other energy input

See 3.1.3.

7.2.4 Total energy output

See 3.1.4.

7.2.5 Thermal energy output

See 3.1.5.

7.2.6 Energy consumed in electrical auxiliary equipment

See 3.1.6.

If part of the energy consumed in electrical auxiliary equipment, $E_{aux,installed}$, is used as thermal energy in the heating process, the thermal energy shall be subtracted from the total energy consumed in the installed electrical auxiliary equipment.

Energy used for fluid transfer, $E_{aux,fluid}$, shall be applied when energy consumed in auxiliary electrical equipment for fluid transfer, such as a pump, cannot be determined from the measurement of electrical energy supplied to the equipment (e.g. cooling water supplied from the factory facilities).

7.2.7 Energy used for generation of utility

See 3.1.7.

Energy used for generation of utilities, $E_{utility}$, other than oxygen, steam and atmospheric gas for heat treatment may be excluded.

Energy for generation of atmospheric gas for heat treatment shall include calorific value of source gas, $E_{u,atm,cal}$, and the energy for generation of the atmospheric gas, $E_{u,atm,gen}$.

7.2.8 Electrical generation loss

See 3.1.8.