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

Part 4: Furnaces with protective or reactive atmosphere

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

Partie 4: Fours à atmosphère contrôlée ou active

Reference number
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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 13579-4 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

All calculations within this part of ISO 13579 are based on the location of equipment at 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 4: Furnaces with protective or reactive atmosphere

1 Scope

This part of ISO 13579 specifies general methodology for measuring energy balance and calculating the efficiency of the process involving furnaces with protective or reactive atmosphere as designed by the furnace manufacturers. This general methodology includes:

— measurement methods;

— calculations (general calculation);

— evaluation report.

This part of ISO 13579 is not applicable to any efficiencies related to the process itself outside of furnaces with protective or reactive atmosphere.

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*

ISO 13579-1:2013, *Industrial furnaces and associated processing equipment — Method of measuring energy balance and calculating efficiency — Part 1: General methodology*

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 relating 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 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

3.1.2.4
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
$E_{s,infilt}$
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}
total 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
$E_{therm,out}$
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 3.1.5.12.

3.1.5.2
effective energy
E_{effect}
enthalpy that products gain in the area of energy balance

3.1.5.3
jig loss
$E_{l,jig}$
enthalpy that jigs for handling the products gained in the area of energy balance measurement

3.1.5.4
sensible heat of exhaust gas
$E_{exhaust}$
sensible heat of expended gas which is emitted from the area of energy balance measurement

3.1.5.5
heat storage loss by batch furnace
$E_{l,storage}$
sensible heat which a furnace refractory gains within a batch furnace operation cycle

3.1.5.6
sensible heat loss of atmospheric gas
$E_{s,atm}$
sensible heat which atmospheric gas for thermal processing gains through the area of energy balance

3.1.5.7
wall loss
$E_{l,wall}$
thermal energy emitted from the surface of industrial furnaces by radiation and convection

3.1.5.8
heat loss of discharged blowout from furnace opening
$E_{l,blowout}$
sensible heat of blowout gas emitted from the furnace opening

3.1.5.9
heat loss of radiation from furnace opening
$E_{l,opening}$
thermal energy emitted from the furnace opening by radiation

3.1.5.10
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.

3.1.5.11
cooling water loss
$E_{l,cw}$
thermal energy brought out by cooling water from the area of energy balance measurement

3.1.5.12
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 being entered 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 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

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

NOTE Tons used are metric tons.

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

Symbol	Meaning	Unit
$c_{pm,p2}$	mean specific heat of products between T_{p2} and 273,15 K	kJ/(kg·K)
$c_{pm,ps}$	mean specific heat of products between T_s and 273,15 K	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
$E_{aux,installed}$	aggregate of energy used in installed electrical auxiliary equipment 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 per ton of products	kJ/t
$E_{h,fuel}$	calorific value of fuel per ton of products	kJ/t

Symbol	Meaning	Unit
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 furnace per ton of products	kJ/t
$E_{l,wall}$	wall loss per ton of products	kJ/t
E_{others}	other energy input 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	
$E_{s,air}$	sensible heat of combustion air or other oxydant per ton of products	kJ/t
$E_{s,atm}$	sensible heat loss of atmospheric gas per ton of products	kJ/t
$E_{s,atomize}$	sensible heat of atomization agent per ton of products	kJ/t
$E_{s,fuel}$	sensible heat of fuel per ton of products	kJ/t
$E_{s,infilt}$	sensible heat of infiltration air per ton of products	kJ/t
$E_{s,oxid}$	sensible heat of oxidized substance per ton of products	kJ/t
$E_{therm,out}$	thermal (output) energy per ton of products	kJ/t
$E_{utility}$	energy used for generation of utilities per ton of products	kJ/t
$E_{u,atm,gen}$	energy used for generation of atmospheric gas per ton of products	kJ/t
$E_{u,atm,cal}$	calorific value of source gas of atmospheric gas per ton of products	kJ/t
$E_{u,oxy}$	energy for generation of oxygen per ton of products	kJ/t
$E_{u,steam}$	energy for generation of steam per ton of products	kJ/t
M_{loss}	loss of mass per ton of products	kg/t
M_p	mass of products	kg or t
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 extraction from the area of the energy balance	K
η_1	total energy efficiency	—
η_e	regional electrical generation efficiency	—
σ_1	absolute error of thermocouple	°C
σ_2	absolute error of compensation lead wire	°C
σ_3	absolute error of output device of thermocouple	°C

5 Basic principles

5.1 General

The area of energy balance measurement shall be determined.

NOTE Examples of the determination of the area of energy balance measurement of furnaces with protective or reactive atmospheres are shown in Figure 1 and Figure 2.

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;

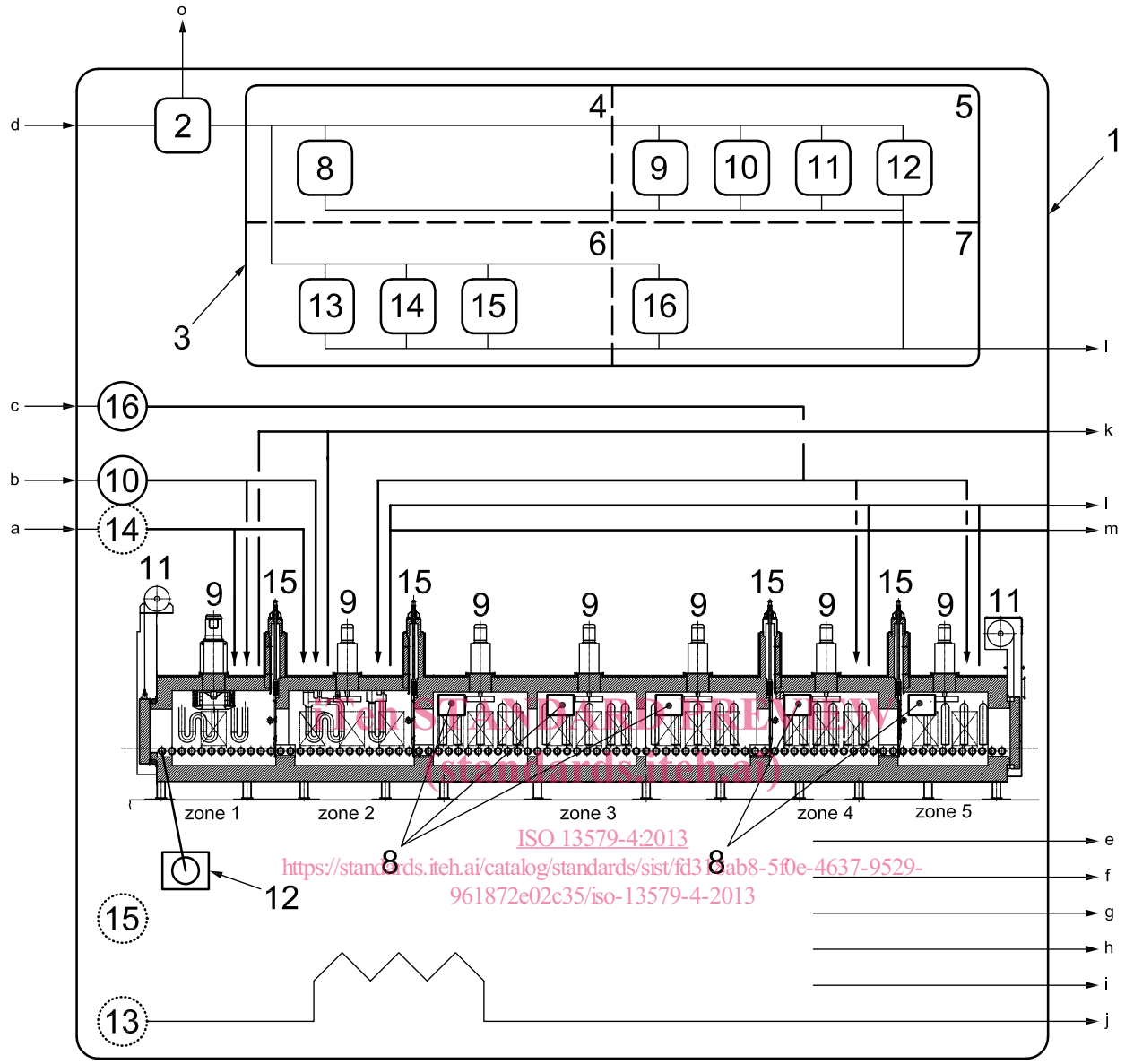
- thermal energy output, $E_{therm,out}$;
- energy consumed in electrical auxiliary equipment, E_{aux};
- energy used for generation of utilities, $E_{utilities}$;
- electrical generation loss, $E_{l,eg}$.

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 energy balance measurement is required to 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).

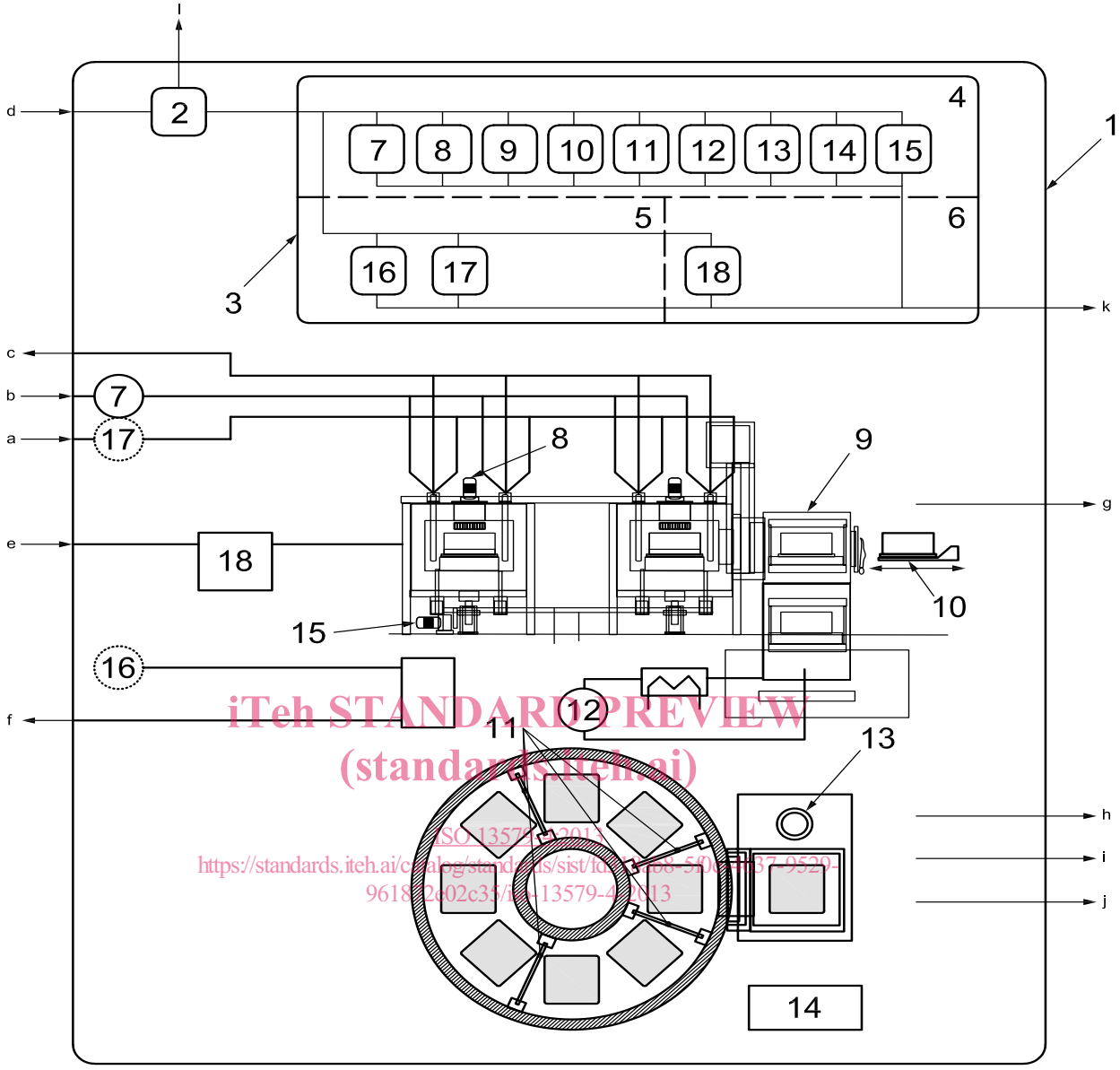


Key

1 area of energy balance
2 electrical generation
3 electrical auxiliary equipment
4 electrical heating equipment
5 installed electrical auxiliary equipment
6 equipment for fluid transfer
7 equipment for generation of utilities
8 electrical heater
9 RC fan
10 combustion blower
11 motor (door)
12 motor (roller hearth drive)
13 cooling water pump
14 fuel transfer equipment
15 compressor and air cylinder for internal door
16 atmospheric gas generator

a Sensible heat of fuel.
b Sensible heat of combustion air.
c Calorific value of source gas of atmospheric gas.
d Fuel equivalent energy of electricity.
e Effective energy.
f Wall loss.
g Heat loss of radiation from furnace opening.
h Heat loss from parts through furnace wall.
i Jig loss.
j Cooling water loss.
k Sensible heat of exhaust gas.
l Calorific value of source gas of atmospheric gas.
m Sensible heat loss of atmospheric gas.
n Energy consumed in electrical auxiliary equipment.
o Electrical generation loss.

Figure 1 — Example of determination of the area of energy balance — Continuous carburizing furnace



Key

1	area of energy balance	10	charging and discharging
2	electrical generation	11	intermediate door
3	electrical auxiliary equipment	12	oil pump
4	installed electrical auxiliary equipment	13	oil agitator
5	equipment for fluid transfer	14	control unit
6	equipment for generation of utilities	15	rotary hearth drive
7	combustion fan	16	cooling water pump
8	recirculation fan	17	fuel transfer equipment
9	elevator drive	18	atmospheric gas generator

a	Sensible heat of fuel.	g	Calorific value of source gas of atmospheric gas.
b	Sensible heat of combustion air.	h	Effective energy.
c	Sensible heat of exhaust gas.	i	Heat loss from furnace (e.g. wall loss).
d	Fuel equivalent energy of electricity.	j	Sensible heat loss of process gas.
e	Calorific value of source gas of atmospheric gas.	k	Energy consumed in electrical auxiliary equipment.
f	Cooling water loss.	l	Electrical generation loss.

Figure 2 — Example of determination of the area of energy balance — Rotary hearth furnace