

JIS

JAPANESE INDUSTRIAL STANDARD

Heat balancing of continuous dryer for ores and other materials

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Japanese industrial standard

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Heat balancing of continuous dryer
for ores and other materials

R 0304-1991

1. Scope

This Japanese Industrial Standard specifies the practical heat balancing of continuous dryer intended for ores and their processed products.

Remarks 1. The ores and processed products are defined as the following:

- (1) Ores: Coal, clay, sand, water-granulated slag, limestone, etc.
- (2) Processed products: Processed and formed products of brick, pottery, etc. and further, casting mould and the like.

2. The standards applicable to this standard shall be given in Attached Table 1.
3. The units and numerical values given in { } in this Standard are in accordance with the traditional units, and are appended for informative reference.

2. Definitions

The definitions of main terms to be used in this Standard shall be as follows:

- (1) materials All matters, from raw materials to products, which are intended for drying.
- (2) dry materials The materials in the state⁽¹⁾ of zero in moisture.

Note ⁽¹⁾ The state of zero in moisture means the state when the material has been heated at a temperature of $107 \pm 2^{\circ}\text{C}$ for not less than 1 h and the difference in moisture has become less than 0.5 %.

Furthermore, the calculation of moisture shall be in accordance with 5.3.2. However, the calculation for coal shall be in accordance with JIS M 8811.

- (3) raw materials Materials before drying.
- (4) dry products Materials after drying.

3. Basis

3.1 The heat balancing shall be in accordance with the results of a continuous not less than 5 h measurement in operating a dryer regularly.

3.2 The heat balancing shall be carried out for each 1 t of dry material in the raw materials.

3.3 The reference temperature of heat balancing shall be the ordinary temperature (temperature of the outside air).

3.4 For the calorific value of fuel, a low calorific value in using shall be used.

4. Measuring items for record

4.1 Record on equipment The record on equipment shall be as follows:

- (1) Name of factory, site and name of the person in charge
- (2) Name, number and use of dryer
- (3) Drying capacity, drying heat source and temperature of hot gas
- (4) Type of dryer, drying type, size, feeding method of raw materials, outline of operational equipment and passing time of materials
- (5) Type of combustion apparatus, area of grate, capacity and number of burners, and volume of combustion chamber
- (6) Ventilation type of ventilation apparatus, form and capacity of fan and size of chimney, name and number of joint equipment
- (7) Type of dust collector and dust collecting efficiency
- (8) Schematic drawing of dryer (describe places of measurement)

4.2 Measuring items The measuring items shall be as follows:

- (1) Period of measurement (date, time) and name of measurer
- (2) Weather, atmospheric pressure, and the temperature and humidity of the outside air
- (3) Name and shape of material
- (4) Load factor⁽²⁾
- (5) Class, brand, properties⁽³⁾, composition [at the time of use⁽³⁾], calorific value⁽³⁾ and amount of fuel to be used
- (6) Temperature, hygroscopic moisture, composition and capacity of introduced hot gas
- (7) Mass, water content, moisture content rate and temperature of raw material
- (8) Mass, water content, moisture content rate and temperature of dry products
- (9) Mass, water content, moisture content rate and temperature of circulating materials
- (10) Amount of evaporating water content

- (11) Mass and temperature of the implements and trucks
- (12) Temperature, humidity, pressure and capacity of feed-in air
- (13) Temperature, hygroscopic moisture, composition and capacity of circulating gas
- (14) Temperature, hygroscopic moisture, composition, capacity and pressure of exhaust gas
- (15) Amount of combustion residue, temperature and unburnt carbon

Notes (2) The load factor F is to be obtained according to the following formula:

$$F(\%) = \frac{b}{a} \times 100$$

where, a : designed drying capacity (t/h)
 b : dried quantity at the time of measurement (t/h)

- (3) The property, composition and calorific value of each fuel to be used shall be recorded with the following items:

(a) Coal

Grain size, caking capacity, and melting point of ash

Hygroscopic moisture (%)

Water content (%), ash content (%), volatile matter content (%), fixed carbon (%), carbon (%), hydrogen (%), oxygen (%), combustible sulphur (%), nitrogen (%)

Calorific value (measured value, constant moisture base) (kJ/kg {kcal/kg})

High calorific value (at the time of use) (kJ/kg {kcal/kg}), low calorific value (at the time of use) (kJ/kg {kcal/kg})

(b) Fuel oil

Specific gravity, viscosity

Water content (%), ash content (%), sulphur (%), carbon (%)

Hydrogen (%), oxygen (%), nitrogen (%)

Calorific value (measured value) (kJ/kg {kcal/kg})

Low calorific value (at the time of use) (kJ/kg {kcal/kg})

(c) Fuel gas

Hygroscopic moisture ($\text{g}/\text{m}^3_{\text{N}}$)

$\text{CO}_2(\%)$, $\text{CO}(\%)$, $\text{CH}_4(\%)$, $\text{O}_2(\%)$, $\text{H}_2(\%)$, $\text{CmHn}(\%)$, $\text{N}_2(\%)$

Calorific value (measured value) ($\text{kJ}/\text{m}^3_{\text{N}}$ { $\text{kcal}/\text{m}^3_{\text{N}}$ })

High calorific value (at the time of use) ($\text{kJ}/\text{m}^3_{\text{N}}$ { $\text{kcal}/\text{m}^3_{\text{N}}$ }), low calorific value (at the time of use) ($\text{kJ}/\text{m}^3_{\text{N}}$ { $\text{kcal}/\text{m}^3_{\text{N}}$ })

Remarks: m^3_{N} indicates the unit of volume at the standard condition 0°C , 110.3 kPa {760 mmHg} of gas.

5. Measuring method

5.1 Fuel

5.1.1 Measurement of amount of fuel used The fuel shall be weighed near the combustion place, as a rule.

The coal shall be weighed by a balance, as a rule.

Where a coal meter or other measuring instrument is used, the indicated quantity shall be corrected accurately.

The fuel oil is converted to mass by using the specific gravity after measuring it by a tank or a flowmeter of volumetric type.

The gas fuel is measured by a volumetric flowmeter or a differential pressure type flowmeter.

5.1.2 Test, analysis and measurement of calorific value for fuel used
The test, analysis and measurement of calorific value of fuel used shall be in accordance with the following Japanese Industrial Standards:

- (1) JIS M 8810
- (2) JIS M 8811
- (3) JIS M 8812
- (4) JIS M 8813
- (5) JIS M 8814
- (6) JIS K 2205
- (7) JIS K 2251
- (8) JIS K 2270
- (9) JIS K 2272
- (10) JIS K 2275
- (11) JIS K 2279
- (12) JIS K 2283
- (13) JIS K 2301
- (14) JIS K 2541

- Remarks 1. The composition ratio of the components of fuel gas shall be given in the state of dry.
2. The hygroscopic moisture of fuel gas is expressed by a moisture content at the time of use gas (absolute humidity g/m^3 dry basis). An actual measurement is required for the hygroscopic moisture in the gas, but the moisture content of the gas which has completed the water-washing process after production can be obtained from the steam table by considering it to be a saturated gas at the using temperature.
3. The calorific value of fuel gas may be obtained according to the calculation from the results of gas analysis.

5.2 Introduced hot gas

5.2.1 Measurement of temperature and hygroscopic moisture of gas

The temperature and hygroscopic moisture of gas shall be measured at a place as near as possible to the introduction opening. The temperature of gas shall be measured by a thermometer of suction type as far as possible with care so as to measure the average temperature of gas of a section of passage.

The hygroscopic moisture shall be determined by absorbing it with the moisture absorbent such as calcium chloride. Where the actual measurement is infeasible, the moisture shall be obtained according to the calculation from the composition and amount of fuel used in the apparatus producing hot gas.

5.2.2 Sampling and analysis of gas The sampling and analysis of gas shall be in accordance with JIS K 2301.

The analysis instrument of Orsat analyzer may be used. The measurement shall be performed for average samples as far as possible.

5.2.3 Measurement of gas quantity The gas quantity shall be measured by use of orifice or Pitot tube.

5.3 Material

5.3.1 Measurement of mass The mass of material shall be obtained from the actual measurement of the mass of its raw material, as a rule. Where the actual measurement of mass of raw material is not feasible, the mass of that material shall be calculated according to the representative sampling method.

Where the mass of a dry product shall be measured, the mass of raw material shall be obtained with considering that it is free from scattering loss.

5.3.2 Measurement of moisture content rate The moisture content rate of material shall be measured as follows: Take samples at directly before inlet of a dryer and directly behind its outlet and measure them.

The measurement of water content shall be carried out as follows: Heat the sample at a temperature of $107 \pm 2^\circ\text{C}$ for not less than 1 h, take the state, in which the sample has become constant in weight, as the basis and take a percentage of decrease in weight to the sample as a water content.

The moisture content rate shall be obtained from the water content according to the following formula:

$$x(\%) = \frac{w}{100-w} \times 100$$

where, x : moisture content (percentage in dry mass)
 w : water content % (percentage in wet mass)

The moisture content of coal shall be measured in accordance with JIS M 8811.

5.3.3 Measurement of temperature The temperature of material shall be measured at directly before the inlet and directly behind the outlet of dryer.

5.4 Implements, and trucks

5.4.1 Measurement of mass The mass of implements and trucks shall be obtained by actual measurement the refractory part, iron part and other parts⁽⁴⁾ separately.

Note ⁽⁴⁾ Other parts stand for a wood part and the like, and they are mentioned expressly when the materials other than the refractory part and iron have been used.

5.4.2 Measurement of temperature Measure the temperatures at the inlet and outlet of the refractory part, iron part and others⁽⁴⁾ for the implements and trucks.

5.5 Feeding-in air

5.5.1 Measurement of air temperature Where the air temperature has been preheated by an other heat source, measure the temperature of preheated air at a place as near as possible to the feed opening. Where not preheated, take the temperature of the outside air as a temperature of feed-in air.

5.5.2 Measurement of humidity in air The humidity in the air shall be obtained as follows: Measure the relative humidity by a psychrometer and calculate the absolute humidity.

5.5.3 Measurement of air pressure Measure a static pressure at a place near the feed-in opening to obtain the air pressure.

5.5.4 Measurement of amount of air The amount of air shall be calculated from the composition of fuel and combustion gas, but the amount preheated by other heat source out of air shall be measured by an orifice or a Pitot tube.

5.6 Circulation gas

5.6.1 Measurement of the temperature and hygroscopic moisture of gas The temperature and hygroscopic moisture of gas shall be measured at the extract opening of gas in accordance with 5.2.1, as appropriate.

5.6.2 Sampling and analysis of gas The sampling and analysis of gas shall be in accordance with 5.2.2, as appropriate.

5.6.3 Measurement of amount of gas The amount of gas shall be measured in accordance with 5.2.3, as appropriate.

5.7 Exhaust gas

5.7.1 Measurement of temperature and hygroscopic moisture of gas The temperature and hygroscopic moisture of gas shall be measured at the outlet of dryer in accordance with 5.2.1, as appropriate, as a rule.

5.7.2 Sampling and analysis of gas The sampling of gas shall be performed at the outlet of dryer, as a rule, and CO₂, O₂, CO and N₂ shall be measured in accordance with 5.2.2, as appropriate.

5.7.3 Measurement of amount of gas The amount of exhaust gas shall be obtained according to the calculation from the composition of fuel and composition of exhaust gas in the case where only the fuel is used for the dry heat source. In the case where a hot gas is introduced from another heat source, the amount of exhaust gas shall be obtained by the actual measurement.

5.8 Combustion residue

5.8.1 Measurement of combustion residue The combustion residue shall be calculated from the amount of fuel used, ash of fuel, and rate of unburnt carbon in the residue. In the case where the measurement is feasible, the actual measured value shall be taken as the combustion residue.

5.8.2 Measurement of temperature of combustion residue The temperature of combustion residue shall be obtained from the actual measurement of ash directly after the exhaust.

5.8.3 Measurement of unburnt carbon in the residue The unburnt carbon shall be measured in accordance with JIS M 8812, as appropriate.

6. Item of heat balancing and it's calculation method

The heat balancing shall be performed according to the method given in the right column of Table 1 on each item in the left column of the same table. The following calculations shall be performed per 1 t of dry material.

Furthermore, the method for converting the analysis value of fuel to the value at the time of use and the methods for calculating the amount of exhaust gas, air ratio of the amount of exhaust gas, theoretical amount of air for combustion and amount of steam in the exhaust gas shall be in accordance with Annex 1 and Annex 2, respectively.

Table 1

Item		Calculation method
1. Heat input Q_i (kJ/kcal)	(1) Heat of combustion of fuel Q_a (kJ/kcal)	$Q_a = m_f \times H_i$ where, m_f : amount of fuel to be used per 1 t of dry material (kg or m^3) H_i : low calorific value at the time of use of fuel (kJ/kg {kcal/kg} or kJ/m^3 {kcal/ m^3 })
	(2) Sensible heat of fuel Q_b (kJ/kcal)	Calculate only when preheated by other heat source. (a) Sensible heat of dry fuel Q_{bi} (kJ {kcal}) $Q_{bi} = m_{df} \times C_{df} \times (t_f - t)$ where, m_{df} : amount of dry fuel used per 1 t of dry material (kg or m^3) C_{df} : average specific heat of dry fuel (kJ/kg °C {kcal/kg °C} or kJ/m^3 °C {kcal/ m^3 °C}) t_f : using temperature of fuel (°C) t : ordinary temperature (°C) Remarks: The specific heat of gas fuel is to be obtained by calculation from the following formula in accordance with the specific heat of gas of that component (Informative reference Table 1). $C_f = \frac{1}{100} [C_{fco} + (CO_2) + C_{fao} + (O_2) + C_{fH} \times (H_2) + C_{fco} \times (CO) + C_{fCH_4} \times (CH_4) + \dots]$ where, C_{fco} : specific heat of carbon dioxide (kJ/ m^3 °C {kcal/ m^3 °C})

Table 1 (Continued)

Item	Calculation method
(Cont'd)	C_{ρ, O_2} : specific heat of oxygen $(\text{kJ}/\text{m}^3 \text{ } ^\circ\text{C} \{ \text{kcal}/\text{m}^3 \text{ } ^\circ\text{C} \})$ C_{ρ, H_2} : specific heat of hydrogen $(\text{kJ}/\text{m}^3 \text{ } ^\circ\text{C} \{ \text{kcal}/\text{m}^3 \text{ } ^\circ\text{C} \})$ $C_{\rho, \text{CO}}$: specific heat of carbon monoxide $(\text{kJ}/\text{m}^3 \text{ } ^\circ\text{C}$ $\{ \text{kcal}/\text{m}^3 \text{ } ^\circ\text{C} \})$ C_{ρ, CH_4} : specific heat of methane $(\text{kJ}/\text{m}^3 \text{ } ^\circ\text{C} \{ \text{kcal}/\text{m}^3 \text{ } ^\circ\text{C} \})$ (CO_2) : amount of carbon dioxide in the fuel (%) (O_2) : amount of oxygen in the fuel (%) (H_2) : amount of hydrogen in the fuel (%) (CO) : amount of carbon monoxide in the fuel (%) (CH_4) : amount of methane gas in the fuel (%)
	(b) Sensible heat of total water content of fuel $Q_{s2}(\text{kJ} \{ \text{kcal} \})$ $Q_{s2} = m_r \times C_w \times (t_r - t)$ where, m_r : amount of total water content of fuel used 1 t of dry material (kg) C_w : specific heat of water $(\text{kJ}/\text{kg } ^\circ\text{C} \{ \text{kcal}/\text{kg } ^\circ\text{C} \})$

Table 1 (Continued)

Item	Calculation method
(Cont'd)	t_f : using temperature of fuel ($^{\circ}\text{C}$) t : ordinary temperature ($^{\circ}\text{C}$) Remarks: C_w shall be 4 kJ/kg $^{\circ}\text{C}$ {1 kcal/kg $^{\circ}\text{C}$}. (c) Sensible heat of fuel Q_b (kJ {kcal}) $Q_b = Q_{b1} + Q_{b2}$ where, Q_{b1} : sensible heat of dry fuel (kJ {kcal}) Q_{b2} : sensible heat of total water content of fuel (kJ {kcal})
(3) Sensible heat of introduced hot gas Q_c (kJ {kcal})	(a) Sensible heat of dry introduced hot gas Q_{c1} (kJ {kcal}) $Q_{c1} = V_{dg} \times C_{dg} \times (t_{dg} - t)$ where, V_{dg} : amount of dry introduced hot gas per 1 t of dry material (m^3) C_{dg} : specific heat of dry introduced hot gas (kJ/m^3 $^{\circ}\text{C}$ {kcal/m^3 $^{\circ}\text{C}$}) t_{dg} : temperature of introduced hot gas ($^{\circ}\text{C}$) t : ordinary temperature ($^{\circ}\text{C}$) Remarks: C_{dg} is to be obtained from its composition by the calculation in the same manner as in 1 (2) (a) Remarks. (b) Sensible heat of hygroscopic moisture in the introduced hot gas Q_{c2} (kJ {kcal}) $Q_{c2} = m_{dgs} \times C_s \times (t_{dg} - t)$

Table 1 (Continued)

Item	Calculation method
(Cont'd)	where, m_{ds} : amount of steam in the introduced hot gas per 1 t of dry material (kg) C_s : average specific heat of steam (kJ/kg °C {kcal/kg °C}) t_{dg} : temperature of introduced hot gas (°C) t : ordinary temperature (°C) (c) Sensible heat of introduced hot gas Q_c (kJ {kcal}) $Q_c = Q_{c1} + Q_{c2}$ where, Q_{c1} : sensible heat of dry introduced hot gas (kJ {kcal}) Q_{c2} : sensible heat of hygroscopic moisture in the introduced hot gas (kJ {kcal})
(4) Sensible heat of raw material Q_d (kJ {kcal})	Calculate only when preheated by other heat source. (a) Sensible heat of dry material Q_{d1} (kJ {kcal}) $Q_{d1} = m \times C_m \times (t_m - t)$ where, m : dry material 1000 (kg) C_m : specific heat of dry material (kJ/kg °C {kcal/kg °C}) t_m : temperature of raw material (°C) t : ordinary temperature (°C)

Table 1 (Continued)

Item		Calculation method
(Cont'd)		(b) Sensible heat of water content in the raw material Q_{a2} (kJ {kcal}) $Q_{a2} = m_{mr} \times C_w \times (t_m - t)$ where, m_{mr} : amount of included water per 1 t of dry material (kg) C_w : specific heat of water (kJ/kg °C {kcal/kg °C}) t_m : temperature of raw material (°C) t : ordinary temperature (°C) (c) Sensible heat of raw material Q_d (kJ {kcal}) $Q_d = Q_{d1} + Q_{d2}$ where, Q_{d1} : sensible heat of dry material (kJ {kcal}) Q_{d2} : sensible heat of water content in the raw material (kJ {kcal})
(5) Sensible heat of feed-in air Q_e (kJ {kcal})		Calculate only when preheated by other heat source. (a) Sensible heat of dry air Q_e (kJ {kcal}) $Q_{e1} = V_A \times C_a \times (t_A - t)$ where, V_A : amount of dry feed-in air per 1 t of dry material (m³_N) C_a : average specific heat of dry air (kJ/m³_N °C {kcal/m³_N °C}) t_A : temperature of air (°C) t : ordinary temperature (°C)

Table 1 (Continued)

Item	Calculation method
(Cont'd)	(b) Sensible heat of water content in the air Q_{e2} (kJ {kcal}) $Q_{e2} = m_{AS} \times C_s \times (t_A - t)$ where, m_{AS} : amount of steam in the air per 1 t of dry material (kg) C_s : average specific heat of steam (kJ/kg °C {kcal/kg °C}) t_A : temperature of air (°C) t : ordinary temperature (°C) Remarks: m_{AS} is to be calculated according to the following formula after obtaining the relative humidity at that time usually. $m_{AS} = \frac{29}{22.4} \times A_1 \times Z$ where, A_1 : amount of air used per 1 t of dry material (m^3_N) (in accordance with Annex 2) Z : absolute humidity (c) Sensible heat of feed-in air Q_e (kJ {kcal}) $Q_e = Q_{e1} + Q_{e2}$ where, Q_{e1} : sensible heat of dry air (kJ {kcal}) Q_{e2} : sensible heat of water content in the air (kJ {kcal})

Table 1 (Continued)

(Cont'd)	Item	Calculation method
(6)	Sensible heat brought in by the implements and trucks Q_f (kJ {kcal})	(a) Sensible heat brought in by the refractory part Q_n (kJ {kcal}) where, m_b : mass of the refractory part of implements and trucks per 1 t of dry material (kg) $Q_n = m_b \times C_b \times (t_b - t)$ C_b : average specific heat of the refractory part (kJ/kg °C {kcal/kg °C}) t_b : feeding-in temperature (°C) t : ordinary temperature (°C)
(b)	Sensible heat brought in by the iron part Q_2 (kJ {kcal})	(b) Sensible heat brought in by the iron part Q_2 (kJ {kcal}) where, m_i : mass of the iron part of implements and trucks per 1 t of dry material (kg) $Q_2 = m_i \times C_i \times (t_i - t)$ C_i : specific heat of iron part (kJ/kg °C {kcal/kg °C}) t_i : feed-in temperature (°C) t : ordinary temperature (°C)
(c)	Sensible heat brought in by other parts Q_o (kJ {kcal})	(c) Sensible heat brought in by other parts Q_o (kJ {kcal}) $Q_o = m_o \times C_o \times (t_o - t)$