

JIS

JAPANESE INDUSTRIAL STANDARD

Heat balancing of pottery and refractory firing periodic kiln

JIS R 0302—1991

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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Heat balancing of pottery and refractory
firing periodic kiln

R 0302-1991

1. Scope

This Japanese Industrial Standard specifies heat balancing of pottery and refractory firing periodic kiln fired by liquid or gaseous fuel.

Remarks 1. This Standard may apply besides the above scope to carbon products, grinding wheels and other ceramic products.

2. Applicable Standards to this Standard are shown in the following:

JIS K 2249-Testing Methods for Density of Crude Oil and Petroleum Products, and Petroleum Measurement Tables Based on Reference Temperature of 15°C

JIS K 2251-Crude Petroleum and Petroleum Products - Sampling

JIS K 2270-Crude Petroleum and Petroleum Products - Determination of Carbon Residue

JIS K 2272-Testing Methods for Ash and Sulfated Ash of Crude Oil and Petroleum Products

JIS K 2275-Testing Methods for Water Content of Crude Oil and Petroleum Products

JIS K 2279-Testing Method for Heat of Combustion of Liquid Hydrocarbon Fuel by Bomb Calorimeter

JIS K 2301-Fuel Gases and Natural Gas - Methods for Chemical Analysis and Testing

JIS K 2541-Testing Methods for Sulfur in Crude Oil and Petroleum Products

3. In this Standard the units and numerical values shown in { } are in accordance with the traditional units and appended for informative reference.

2. Reference

2.1 Heat balancing shall be in accordance with the operating results in one period of firing (period from the beginning to the end of firing).

2.2 Heat balancing shall be performed per 1 t of fired wares drawn out of a kiln.

2.3 Heat balancing shall be based on ordinary temperature as the reference, and as to heating value of fuel, the lower heating value at using shall be used.

3. Records and measurements

3.1 Records relating to kiln Records relating to kilns shall be as follows:

- (1) Classification and type
- (2) Size (length, width, and height or diameter and height)
- (3) Effective floor area
- (4) Effective internal volume
- (5) Surface area of each part (ceiling, side wall and bottom), classification and mass of refractory.
- (6) Type of combustion equipment (including type, capacity and number of burners.)
- (7) Type of ventilation equipment, type and capacity of fan as well as size of stacks.
- (8) Classification, type and capacity of waste heat utilization facility.
- (9) History

3.2 Items to be measured Items to be measured shall be as follows:

- (1) Date and time of measurement and name of measuring person.
- (2) Weather, atmospheric pressure, temperature of outside air as well as temperature and humidity in room.
- (3) Combustion equipment and ventilation equipment and their condition.
- (4) Name of fired wares
- (5) Load factor of kiln⁽¹⁾
- (6) Period of time of firing
- (7) Atmosphere in a kiln⁽²⁾
- (8) Classification, composition, properties, heating value, temperature and amount of used fuel.
- (9) Volume, temperature and pressure of primary and secondary airs for combustion.
- (10) Classification, mass, contained combustible components and temperature at the time of taking into kiln of unfired wares⁽³⁾, sheaths and tools.
- (11) Mass and the maximum firing temperature of fired wares⁽⁴⁾.
- (12) Volume, temperature, pressure and composition of combustion exhaust gas.
- (13) Temperature of a kiln body⁽⁵⁾

- (14) Volume, temperature and pressure of exhaust gas and the like introduced to a waste heat utilization facility and the like.

Notes ⁽¹⁾ Load factor of kiln means the ratio of actual load mass to reference capacity at the time of design or in actual results.

⁽²⁾ Atmosphere in a kiln means the atmosphere in a kiln at each definite period of time from the beginning to the end of burning of fuel.

⁽³⁾ Unfired wares mean the not-yet-fired pottery, refractory, etc.

⁽⁴⁾ Fired wares mean the fired pottery, refractory, etc.

⁽⁵⁾ Temperature of kiln body means the temperature of each part of kiln body (ceiling, side wall and floor of kiln) at each definite period of time from the beginning to the end of burning of fuel.

4. Measuring methods

4.1 Composition, heating value and used amount of fuel The composition, heating value and used amount of fuel shall be as follows:

- (1) Measure the composition of fuel according to the following Japanese Industrial Standards.

(a) JIS K 2251

(b) JIS K 2270

(c) JIS K 2272

(d) JIS K 2275

(e) JIS K 2301

(f) JIS K 2541

- (2) Measure the heating value of fuel according to JIS K 2279.

- (3) Among fuels, measure the used amount of liquid fuel with a volumetric flowmeter and convert to mass by specific gravity⁽⁶⁾ of liquid fuel.

- (4) Among fuels, measure the used amount of gaseous fuel by using an orifice, an area flowmeter or a volumetric flowmeter.

Note ⁽⁶⁾ Measure the specific gravity of fuel oil according to JIS K 2249.

4.2 Volume, temperature, and pressure of air for combustion The volume, temperature, and pressure of air for combustion shall be measured as follows:

- (1) Calculate the volume of air for combustion from the composition of fuel and exhaust gas for combustion, and measure the volume of preheat- ing air among air for combustion by using an orifice, an area flowmeter or a Pitot tube, a hot-wire anemometer and a wind-mill anemometer.

- (2) Measure the temperature of preheating air, in the case where the air for combustion is preheated, at the entrance and exit of a preheating equipment.
- (3) Measure the pressure of air for combustion in the case of forced draft by using a water-column pressure gauge at the exhaust port of a blower.

4.3 Mass of unfired wares, fired wares, sheaths and tools as well as moisture content, combustible components, and temperature of unfired wares Mass of unfired wares, fired wares, sheaths, and tools as well as moisture content, combustible components and temperature of unfired wares shall be measured as follows:

- (1) Measure the mass of unfired wares, fired wares, sheaths and tools relating to the total amount. However, in case where it is impossible to measure the total amount, measure the mass relating to the samples taken at random, and from the results the total amount may be calculated.
- (2) As to a moisture content, and combustible components of unfired wares, relating to the samples taken at random, measure the adhering water content and crystal water content and combustible components.
- (3) As to the thermometers in the case of measuring the firing temperature of unfired wares, use a thermoelectric thermometer, a radiation thermometer or an optical thermometer.

4.4 Temperature and composition of combustion exhaust gas The temperature and composition of combustion exhaust gas shall be measured as follows:

- (1) Measure the temperature of combustion exhaust gas at the main gas flue near the kiln.
- (2) Make the sampling position for analysis of composition of combustion exhaust gas, the gas flue near the kiln and perform the sampling according to the method of JIS K 2301.
- (3) As to analysis of composition of combustion exhaust gas, use an Orsat analyzer, a Hempel analyzer, or instrumental analyzers of infrared, magnetic types, etc.

4.5 Temperature of kiln body As to the temperature of kiln body, at each definite period of time from the beginning to the end of burning of fuel, the ceiling, side wall and floor, their inner and outer surfaces shall be measured. However, in case where it is difficult to measure the floor of the kiln, it may be substituted by estimated value.

5. Items of heat balancing and their calculation methods

Heat balancing shall be performed relating to the items given in the left column of Table 1 according to the calculation methods given in the right column of the same table respectively.

Table 1

1. Heat input	Item	Calculation method
(1) Heat of combustion of fuel Q_d (kJ {kcal})		$Q_d = m_f \times H_i$ where, m_f : used amount of fuel per 1 t of fired wares (kg or m^3) H_i : lower heating value of fuel (kJ/kg { kcal/kg } or kJ/m^3 { kcal/ m^3 }) Remarks: For example, in the case of gaseous fuel of a certain composition, the lower heating value of fuel H_i (kJ/m^3 { kcal/ m^3 }) can be calculated from the following formula. However, in () volume percentage (%) of components of gaseous fuel is indicated. $H_i = 30.5(CO) + 25.7(H_2) + 85.5(CH_4) + 153.7(C_2H_6) + 210(C_3H_8) + 292(C_4H_{10})$
(2) Sensible heat of fuel Q_b (kJ {kcal})		$Q_b = m_f \times C_f \times (t_f - t)$ where, m_f : used amount of fuel per 1 t of fired wares (kg or m^3) C_f : specific heat of fuel (kJ/kg $^{\circ}C$ { kcal/kg $^{\circ}C$ } or kJ/m^3 $^{\circ}C$ { kcal/ m^3 $^{\circ}C$ }) t_f : temperature of fuel ($^{\circ}C$) t : ordinary temperature ($^{\circ}C$) Remarks: Specific heat of liquid fuel is to be taken as 1.88 kJ/kg $^{\circ}C$ { 0.45 kcal/kg $^{\circ}C$ } and specific heat of gaseous fuel is to be calculated from the composition.

Table 1 (Continued)

Item	Calculation method
(3) Heat carried in by air for combustion Q_c (kJ/kcal))	$Q_c = \frac{Q_{cl}}{m_o}$ $Q_{cl} = \Sigma [V_c \times C_c \times (t_c - t)]$ where, Q_{cl} : heat carried in by total air for combustion (kJ/kcal)) m_o : total mass of fired wares (t) V_c : amount of air for combustion in each period of time from the beginning to the end of burning of fuel (m^3_N) C_c : specific heat of air for each combustion ($kJ/m^3_N \text{ } ^\circ C$ { kcal/$m^3_N \text{ } ^\circ C$ }) t_c : temperature of air for each combustion ($^\circ C$) t : ordinary temperature ($^\circ C$) Remarks: Heat carried in by air for combustion is to be the sum of heat preserved by air for combustion calculated separately in each definite period obtained by dividing the time from the beginning to the end of burning of fuel.

Table 1 (Continued)

Item	Calculation method
(4) Heat carried in by unfired wares, sheaths, tools and cars, and heat of combustion of combustible components Q_d (kJ{kcal})	(a) Heat carried in by unfired wares Q_{d1} (kJ{kcal}) $Q_{d1} = m_m \times C_m \times (t_m - t)$ where, m_m : mass of unfired wares per 1 t of fired wares (kg) C_m : average specific heat of unfired wares (kJ/kg °C {kcal/kg °C}) t_m : temperature of unfired wares at the time of taking into the kiln (°C) t : ordinary temperature (°C) (b) Heat carried in by sheaths and tools Q_{d2} (kJ{kcal}) $Q_{d2} = m_{st} \times C_{st} \times (t_{st} - t)$ where, m_{st} : mass of sheaths and tools per 1 t of fired wares (kg) C_{st} : specific heat of sheaths and tools (kJ/kg °C {kcal/kg °C}) t_{st} : temperature of sheaths and tools at the time of taking into the kiln (°C) t : ordinary temperature (°C)

Table 1 (Continued)

Item	Calculation method
	(c) Heat carried in by cars Q_{as} (kJ{kcal}) $Q_{as} = m_{cb} \times C_{cb} \times (t_{cb} - t)$ where, m_{cb} : mass of cars per 1 t of fired wares (kg) C_{cb} : specific heat of cars (kJ/kg °C {kcal/kg °C}) t_{cb} : temperature of cars at the time of taking into the kiln (°C) t : ordinary temperature (°C) (d) Heat of combustion of combustible components contained in unfired wares Q_{a4} (kJ{kcal}) $Q_{a4} = m_i \times H_{ib}$ where, m_i : mass of combustible components contained in unfired wares per 1 t of fired wares (kg) H_{ib} : effective heating value of combustible components (kJ/kg {kcal/kg}) (e) Heat carried in by unfired wares, sheaths, tools and cars and heat of combustion of combustible components Q_d (kJ{kcal}) $Q_d = Q_{a1} + Q_{a2} + Q_{a3} + Q_{a4}$

Table 1 (Continued)

Item	Calculation method
(5) Heat accumulated in kiln body Q_e (kJ{kcal})	$Q_e = \frac{Q_{ei}}{m_o}$ $Q_{ei} = \Sigma [m_r \times C_r \times (t_r - t)]$ where, Q_{ei} : total heat accumulated in kiln body (kJ{kcal}) m_o : total mass of fired wares (t) m_r : mass of refractory of each part in kiln body (ceiling, side wall and bottom) (kg) C_r : average specific heat of refractory in kiln body (kJ/kg °C {kcal/kg °C}) t_r : average temperature of inner and outer surfaces of kiln body (°C) t : ordinary temperature (°C) Remarks 1. Heat accumulated in kiln body is separately calculated for ceiling, side wall and bottom. 2. Average temperature of inner and outer surfaces of kiln body is to be that at the time when fuel is beginning to fire.

Table 1 (Continued)

Item	Calculation method
(6) Total heat input Q_1 (kJ{ kcal})	$Q_1 = Q_a + Q_b + Q_c + Q_d + Q_e$ where, Q_a : heat of combustion of fuel (kJ{ kcal}) Q_b : sensible heat of fuel (kJ { kcal}) Q_c : heat accumulated in kiln body (kJ{ kcal}) Q_d : heat carried in by unfired wares, sheaths, tools and cars, and heat of combustion of combustible components (kJ { kcal}) Q_e : heat accumulated in kiln body (kJ { kcal})
2. Heat output Q_2 (kJ{ kcal})	$Q_2 = m_x \times (I_x - I'_x)$ where, m_x : adhered water content of unfired wares per 1 t of fired wares (kg) I_x : enthalpy of steam evaporated from adhered water content of unfired wares (kJ/kg { kcal/kg}) I'_x : enthalpy of adhered water content of unfired wares (kJ/kg{ kcal/kg}) Remarks: Enthalpy of steam evaporated from adhering water content of unfired wares is to be taken as the enthalpy of steam at 125°C 2713 kJ/kg { 648 kcal/kg}.

Table 1 (Continued)

Item	Calculation method
(2) Heat carried away by steam evaporated from crystal water content of unfired wares Q_g (kJ {kcal})	$Q_g = m_y \times (I_y - I'_y)$ where, m_y : crystal water content of unfired wares per 1 t of fired wares (kg) I_y : enthalpy of steam evaporated from crystal water content of unfired wares (kJ/kg {kcal/kg}) I'_y : enthalpy of crystal water content of unfired wares (kJ/kg {kcal/kg}) Remarks: Enthalpy of steam evaporated from crystal water content of unfired wares is to be taken as the enthalpy of steam at 550 °C 3596 kJ/kg {859 kcal/kg}.
(3) Heat required for decomposition of clay Q_h (kJ {kcal})	$Q_h = m_{cl} \times Q_p$ where, m_{cl} : amount of clay in unfired wares per 1 t of fired wares (kg) Q_p : heat required for decomposition of 1 kg of clay (kJ/kg {kcal/kg}) Remarks: Heat required for decomposition of clay is to be taken as 1088 kJ/kg {260 kcal/kg}.

Table 1 (Continued)

Item	Calculation method
(4) Heat required for firing of unfired wares Q_i (kJ {kcal})	$Q_i = 1000 \times C'_m \times (t'_m - t_m)$ where, C'_m : average specific heat of fired wares (kJ/kg °C {kcal/kg °C}) t'_m : firing temperature of fired wares (°C) t_m : temperature of unfired wares at the time of taking into the kiln (°C)
(5) Heat required for heating sheaths and tools Q_j (kJ {kcal})	$Q_j = m_{st} \times C'_{st} \times (t'_{st} - t_{st})$ where, m_{st} : mass of sheaths and tools per 1 t of fired wares (kg) C'_{st} : average specific heat of sheaths and tools (kJ/kg °C {kcal/kg °C}) t'_{st} : firing temperature of sheaths and tools (°C) t_{st} : temperature of sheaths and tools at the time of taking into the kiln (°C)