

JIS

JAPANESE INDUSTRIAL STANDARD

Land boilers--Heat balancing

JIS B 8222 : 1993

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Translated
by
Japanese Standards Association

Land boilers—Heat balancing

1 Scope This Japanese Industrial Standard specifies a general procedure of heat balancing applicable for a practicable test for land boilers (including hot-water boilers) for which solid, liquid and gaseous fuel are used.

Remarks 1 This Standard specifies the heat balancing applied for an acceptance test for commercial boilers which is carried out at the time of delivery between the purchaser and manufacturer, etc. (hereafter referred to as “interested parties”). In the case of a survey for a concise boiler or a routine performance test, however, this Standard is applicable *mutatis mutandis* such as to abridge appropriately the specified items and to calculate by using the given concise formulae.

With this respect, for a special boiler and/or fuel, respective suitable means among them may be applied.

- 2 The standards cited in this Standard are given in Attached Table 1.
- 3 The units, numerical values and calculation formulae given in { } in this Standard are based on the traditional units and are appended for informative reference.

2 Terms and symbols The principal terms and symbols used in this Standard are given in Attached Table 2.

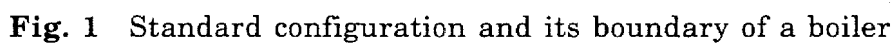
3 Conditions of heat balancing The conditions for carrying out heat balancing shall be as follows:

- (1) The heat balancing shall be carried out under steady running state of a boiler is maintained, and obtained from the operation results for at least 2 h. For small boilers for liquid or gaseous fuel, however, the test duration may be decided to be at least 1 h by agreement between the parties concerned with delivery. The test load shall generally be the rated load, and further three-quarters, half and one-quarter loads may be applied, as necessary.
- (2) As to a test on heat balancing for a boiler, each part of the boiler shall preliminarily checked to ensure that there is no leakage of fuel, steam, or water. Over the test period, the following running conditions shall be maintained. As far as there is no specific practical problem, blowing-off, soot blow, etc. shall not be carried out and working of relief valves shall be avoided during the test.

If the relief valve pops, a retest shall be carried out.

- (3) The test shall be carried out under such conditions that the boiler being tested is isolated from any other boilers.

- (4) The heat balancing shall be carried out on the unit quantity of the fuel used at the time of firing, that is, 1 kg of solid and liquid fuel, or converted 1 m³ (hereafter, this means the “converted value calculated under the standard condition” unless otherwise specific note is given) under the standard condition (temperature: 0 °C and pressure: 1 013 hPa) of gaseous fuel. In order to express the unit quantity disregarding the discrimination of solid, liquid and gaseous fuels, it shall be presented as 1 kg (or m³).
- (5) As to a calorific value, low calorific value for the fuel used at the time of firing shall be used. When higher calorific value is used due to specific reason, this matter shall be clearly stated.
- (6) The base temperature for heat balancing shall be based on the outside air temperature during the period of the test, however, the ambient temperature or air temperature in the vicinity of the outlet of the forced draft fan, etc. may be used, as necessary.
- (7) The standard configuration and its boundary of a boiler to be subjected to heat balancing is shown in Fig. 1. In the case of a superheater, reheater, economizer and air preheater lying within a boiler, those components shall be included in the boiler. However, this boundary may be modified by agreement between the parties concerned with delivery.



- (8) The term air quoted in this Standard means the air which contains steam, while the term fuel gas has two definitions. One of them is dry gas which contains no humidity, and the other one is wet gas which contains steam, etc. The unit quantity of those substances shall be presented as "per 1 kg (or m³)".
- (9) The calculation methods of boiler efficiency shall be in accordance with either equation of (a) or (b) given in the following:

(a) **Heat input-output method**

$$\eta_1 = \frac{Q_s}{H_i + Q} \times 100 \%$$

where, η_1 : boiler efficiency by heat input-output method

Q_s : useful heat output

$H_i + Q$: sum of heat input

(b) **Heat loss method**

$$\eta_2 = \left(1 - \frac{L_i}{H_i + Q} \right) \times 100 \%$$

where, η_2 : boiler efficiency by heat loss method

L_i : sum of heat loss

- (10) Heat balancing for a steam boiler shall be applied for that of hot-water boiler *mutatis mutandis*.

4 Measurement method The measurement items on heat balancing of a boiler shall be as given in 7.2.

In the case of determination of boiler efficiency by heat input-output method, it is necessary to obtain the heat input derived from the quantity of consumption, calorific value, etc. of fuel and the heat of absorption of generated steam, while in the case of determination of boiler efficiency by heat loss method, it is necessary to obtain the heat input derived from the quantity of consumption, calorific value, etc. of fuel and heat losses of respective parts.

Measurement of each item shall be made in accordance with the following:

4.1 Outside air temperature The outside air temperature shall be measured at the main air intakes of the boiler room. In this case, the measurement shall be made avoiding the effect of direct sunlight, radiation from the components, etc.

4.2 Fuel

4.2.1 Measurement of fuel consumption The measurement of the fuel consumption shall be made in accordance with the following:

- (1) The solid fuel shall be measured immediately before firing as far as possible in order to avoid the vaporization of moisture after measurement, and the samples shall be taken simultaneously at each time of measurement. Generally, the measurement shall be made using a balance, and when a coalmeter or other measuring instruments are used, the indicated value shall be calibrated correctly. The permissible measurement error shall generally be $\pm 1.5 \%$.

- (2) The liquid fuel shall be measured using a tank with suitable scales for actual weighing or volumetric measuring tank, or volumetric flowmeter. The values obtained by using a volumetric units shall be converted to the unit of mass by multiplying the compensated density of the fuel oil according to the passing temperature thereof through the said flowmeter. The permissible measurement error shall generally be ± 1.0 %.
- (3) The gaseous fuel shall be measured using a volumetric, orifice, or another type flowmeter, and the measured values shall be converted to the volume expressed in m^3 under the standard condition according to the pressure and temperature at the time of measurements. The permissible measurement error shall generally be ± 1.6 %.

4.2.2 Testing of samples and measurement of calorific value Sampling, testing and analysis of samples of fuel used and measurement of calorific values thereof shall generally be in accordance with the following standards:

JIS K 2249, JIS K 2251, JIS K 2270, JIS K 2272, JIS K 2275, JIS K 2279, JIS K 2301, JIS K 2541, JIS M 8801, and JISs M 8810 to 8814

4.3 Feed water

4.3.1 Measurement of quantity of feed water The quantity of feed water shall be measured using a tank with suitable scales for actual weighing or volumetric measuring tank, volumetric flowmeter, orifice, or another type flowmeter. The permissible measurement error shall generally be ± 1.0 %. In the case where the feed water has been measured once and a part of it is not supplied to the boiler, the said quantity shall be corrected. When spray water is supplied to the superheater and reheater in order to regulate the steam temperature, this quantity shall be measured [see 6.3 (1) (c) and (d)].

4.3.2 Measurement of temperature of feed water The temperature of feed water shall be measured at the inlet (at the outlet, too, if necessary) of the economizer. When any economizer is not installed, it shall be measured at the inlet of the main body of the boiler.

If an injector is used, measurement shall be made at the front thereof.

4.4 Combustion air

4.4.1 Measurement of amount of air The necessary amount of air shall be calculated from the kind and composition of the fuel and composition of the combustion gas [see 6.2 (3)]. If necessary, measurement shall be made at the outlet of the forced draft fan using an orifice, Pitot tube, or the like. When an air preheater is installed, the measurement shall be made at the outlet thereof (see **JIS B 8330**).

4.4.2 Measurement of temperature of preheated air The temperature of air shall be measured at the inlet and outlet of the air preheater. In the case where an air preheater operated by an external heat source such as extracted steam from bleeder turbine is additionally used, the air temperature at its front and back shall also be measured.

4.5 Steam for heating of fuel or blowing into furnace The amount of steam blown into the furnace used for heating of fuel, atomizing of fuel, etc. shall generally be measured using respective flowmeters.

4.6 Generated steam

4.6.1 Measurement of amount of generated steam The amount of main generated steam shall generally be calculated from the quantity of feed water. When a steam flowmeter is equipped, the measured value therefrom shall be considered as informative reference values.

In the case where a part of generated steam is used for heating of fuel, blowing into the furnace, preheating of air, etc., those amounts shall be measured and subtracted from the quantity of water fed.

The amount of steam at the inlet of the reheater shall be determined by subtracting the amount of grand steam and extracted steam from bleeder turbine from the amount of main steam.

The amount of steam at the outlet of the reheater shall be determined by adding the quantity of spray for reheater to the amount of steam at the inlet of the reheater.

Further, the position of water level of the boiler and other conditions at the time of commencement and termination of the test shall be almost equal.

With this respect, when measurements on the abovementioned values used for compensation are difficult, roughly estimated values shall be used.

4.6.2 Measurement of temperatures of superheated steam and reheated steam The measurement of temperatures of superheated steam and reheated steam shall be made at the points closely to the outlets of the superheater and reheater. When a temperature controller is equipped at each outlet, the measurement shall be made at its behind.

For a reheater, measurement shall additionally be made at its inlet.

4.6.3 Measurement of steam pressure The saturated steam pressure shall be measured at the drum of boiler or equivalent position thereto. The pressure of superheated steam and reheated steam shall be measured at each position where respective temperatures are measured. When there is difference in height between the detection point of pressure and the pressure gauge, the pressure shall be corrected corresponding to the level of water column in the connecting pipe.

4.6.4 Measurement of dryness of saturated steam The dryness of saturated steam shall be measured at the position closely to the outlet of the drum of boiler or equivalent position thereto using a condensation calorimeter, throttling calorimeter, etc.

4.7 Exhaust gas (combustion gas)

4.7.1 Measurement of exhaust gas temperature The temperature of exhaust gas shall be measured at the outlet of the final heater of boiler. Measurement shall also be made at the outlet of the main body of boiler, at the outlet and inlet of the superheater, reheater, economizer and air preheater, as necessary.

As to gas temperature, it shall try to obtain the mean temperature of each flue cross section.

4.7.2 Sampling of specimen of exhaust gas and chemical analysis The sampling position of the exhaust gas shall be at the outlet of the economizer (in the case where any economizer is not equipped, it shall be at the outlet of the main body of boiler or superheater).

Further, if an air preheater is equipped, measurement shall also be made at its outlet. The sampling scheme shall generally be in accordance with **JIS K 0095**.

For chemical analysis of exhaust gas, an Orsat gas analyzer shall generally be used. When an electric or instrumental analysis apparatus is used, appropriate calibration shall be carried out using an Orsat gas analyzer or certified reference gas.

4.8 Blast pressure

4.8.1 Measurement of blast pressure (static pressure) The blast pressure shall be measured at the discharge opening of the forced draft fan using a water column pressure gauge, etc. Additional measurements shall be made at the inlet and outlet of the air preheater, burner air chamber, etc., as necessary.

4.8.2 Measurement of exhaust gas pressure The exhaust gas pressure shall be measured at the position where the exhaust gas goes out from the final heater using a water column pressure gauge, etc. Additional measurements shall be made at inward the furnace, the outlet of main body of boiler and the inlet and outlet of economizer, air preheater and induced draft fan, as necessary.

4.9 Combustion residue

4.9.1 Measurement of quantity of combustion residue The quantity of combustion residue shall be calculated according to the fuel consumption, ash content in the fuel and unburned combustibles content in the combustion residue. When it is feasible to measure actually the quantity of combustion residue, the said quantity shall be used.

4.9.2 Sampling of combustion residue and measurement of unburned combustibles Sampling of combustion residue shall be carried out in accordance with **JIS M 8811**. Measurement of unburned combustibles shall be in accordance with 5 (Determination of ash content) in **JIS M 8812**.

4.10 Interval of measurement The sampling of specimen of the fuel and measurement of pressure, temperature, etc. of steam, air and exhaust gas shall be carried out at a definite interval, respectively, unless measuring instruments with recorders are used. Important ones are exemplified as follows:

Sampling of specimen of coal: As many times as possible during the period of the test (see **JIS M 8811**)

Sampling of specimen of liquid and gaseous fuel, and measurement of dryness of steam: At least twice during the period of the test

Pressure and temperature of steam, and temperature of feed water: at 10 min to 30 min intervals

Flow rate of feed water and fuel consumption: at 5 min to 30 min intervals

Pressure and temperature of air, exhaust gas, etc.: at 15 min to 30 min intervals

Sampling of specimen of exhaust gas: at 30 min intervals (as many times as possible, in the case of hand firing of coal)

5 Test preparation and notice of running

5.1 Examination of conditions of boiler and repair [see 3 (2)] Before the test, every part of the boiler shall be examined, arrangement shall be carried out to avoid all leakages of steam and water (especially, leakage from the blow down valve), and any defects such as refractory and heat insulating materials shall be rectified.

The state of contamination or control (date and method of cleaning before the test, state and time duration of running after cleaning, circumstances of repair, etc.) of internal and external parts shall be recorded.

5.2 Preparation of auxiliary machinery The functions of a fuel supply system, combustion system, ash handling system, ventilator, water feeding system, water level gauge, automatic control system, other auxiliary machinery, measuring instruments, etc. shall be inspected and adjusted previously to prevent any hindrance during the test.

5.3 Preparation of measuring apparatus Necessary measuring apparatus shall be inspected and calibrated previously, and installed at each specified position.

If a bypass is equipped to a measuring apparatus for feed water and fuel, it shall be ensured that there is no leakage.

5.4 Regulating of running state of boiler Before the test, the boiler shall be regulated to ensure the specified running conditions and to maintain such conditions over the appropriate period (generally, at least 1 h) depending on the type of boiler. When it is confirmed that successive good running conditions of the boiler is prospected, it shall be progressed to an official test.

5.5 Positioning of measurer A measurer shall be stationed by assigning its post previously, and trained during the test run period carried out before the official test, as far as possible, to measure correctly since the first measurement made at the commencement of the test.

5.6 Blowing-off, soot blow, sampling of specimen of feed water, etc. [see 3 (2)] Blowing-off, soot blow, sampling of specimen of feed water, boiler water, generated steam, etc. shall be carried out prior to commencement of the test, and must not carry out during the official test.

5.7 Variation of measured values The variation of volume and pressure of generated steam shall not exceed the following range:

Variation of volume of generated steam: ± 10 % of average

Variation of pressure of steam: ± 6 % of average

6 Calculation

6.1 Composition of fuel The composition of fuel used for calculation shall be that of fuel used at the time of firing, and as follows:

- (1) **For solid fuel** The total moisture (as fired basis), composition by industrial chemical analysis (equilibrium moisture of coal at about 75 % relative humidity and room temperature) and composition by elementary analysis (dry basis) of the fuel used at the time of firing shall be obtained in accordance with **JIS M 8801** and **JISs M 8810 to 8813**, then the content thereof shall be computed by converting the bases.

When the total moisture (as fired basis) is presented as w percentage of mass (hereafter referred to as only "mass %"), the moisture by industrial chemical analysis (equilibrium moisture of coal at about 75 % relative humidity and room temperature) is presented as w_1 mass %, and ash is a_1 mass %, respectively, and carbon, hydrogen, combustible sulfur and nitrogen by elementary analysis (dry basis) are presented as c_0 , h_0 , s_0 and n_0 mass %, respectively, whereby the content of carbon, hydrogen, combustible sulfur, nitrogen, ash and oxygen (c , h , s , n , a and o mass %, respectively) of solid fuel as firing basis are determined according to the following formulae:

$$c = \frac{100-w}{100} c_0 \text{ mass \%}, \quad h = \frac{100-w}{100} h_0 \text{ mass \%}$$

$$s = \frac{100-w}{100} s_0 \text{ mass \%}, \quad n = \frac{100-w}{100} n_0 \text{ mass \%}$$

$$a = \frac{100-w}{100-w_1} a_1 \text{ mass \%}, \quad o = 100 - (c + h + s + n + a + w) \text{ mass \%}$$

- (2) **For liquid fuel** The content of carbon, hydrogen, sulfur, nitrogen, ash, oxygen and moisture determined according to **JIS K 2251**, **JIS K 2270**, **JIS K 2272** and **JIS K 2275** shall be presented as c , h , s , n , a , o and w mass %, respectively.
- (3) **For gaseous fuel** The content of each composition of gas that is the fuel used at the time of firing shall be determined, and hydrogen, carbon monoxide, various kinds of hydrocarbon, carbon dioxide (carbonic acid gas), nitrogen, oxygen and steam shall be presented as h_2 , co , $c_x h_y$ (ch_4 , c_2h_4 , c_2h_6 , c_3h_6 , c_3h_8 , c_4h_8 , c_4h_{10} , etc.), co_2 , n_2 , o_2 and w volume %, respectively.

6.2 Heat input The calculation of heat input shall always be carried out based on 1 kg (or m³) of fuel used at the time of firing in accordance with the following:

- (1) **Calorific value for fuel used at the time of firing** As to calorific values for fuels used at the time of firing, higher calorific value thereof shall be measured actually using respective calorimeters, then low calorific values for solid, liquid and gaseous fuel shall be determined, respectively, as given in the following:

- (a) **For solid fuel** The higher calorific value of equilibrated sample at about 75 % relative humidity and room temperature shall be measured actually in accordance with **JIS M 8814** of which the said value shall be presented as H_0 , the higher and low calorific values for the fuel used at the time of firing shall be presented as H_h and H_l , respectively, and they shall be determined according to the following formulae:

$$\text{Higher calorific value } H_h = \frac{100-w}{100-w_1} H_0 \text{ kJ/kg \{kcal/kg\}}$$

$$\begin{aligned} \text{Low calorific value } H_l &= H_h - 25(9h + w) \text{ kJ/kg} \\ &\{ H_l = H_h - 5.9(9h + w) \text{ kcal/kg} \} \end{aligned}$$

Remarks : When an elementary analysis is omitted, h % [6.1 (1)] may be given as follows:

$$h = 5.7 \frac{100 - (w_1 + a_1)}{100} \times \frac{100 - w}{100 - w_1} \%$$

where, the coefficient 5.7 is the mean content of hydrogen (dry ash free base) of the Japanese coal.

- (b) **For liquid fuel** The higher calorific value measured in accordance with **JIS K 2279** shall be presented as H_h , and the low calorific value H_l shall be determined according to the following formulae:

$$\begin{aligned} H_l &= H_h - 25(9h + w) \text{ kJ/kg} \\ &\{ H_l = H_h - 5.9(9h + w) \text{ kcal/kg} \} \end{aligned}$$

Remarks : When an elementary analysis is omitted, h mass % may be given as follows:

Kerosine, gas oil and crude oil: 13 mass %, fuel oil (average): 12 mass % (fuel oil A: 13 mass %, fuel oil B: 12 mass % and fuel oil C: 11 mass %)

Further, H_l can be roughly estimated by putting $w = 0$ into the abovementioned formulae. In addition, for petroleum fuel, H_l can be roughly estimated according to the density.

- (c) **For gaseous fuel** The higher calorific value measured in accordance with **JIS K 2301** shall be presented as H_h , and the low calorific value H_l shall be determined according to the following formulae:

$$\begin{aligned} H_l &= H_h - 20 \left[(h_2) + \frac{1}{2} \sum y c_x h_y + w_v \right] \text{ kJ/m}^3 \\ &\left\{ H_l = H_h - 4.7 \left[(h_2) + \frac{1}{2} \sum y c_x h_y + w_v \right] \text{ kcal/m}^3 \right\} \end{aligned}$$

Remarks 1 When a chemical composition analysis is omitted and the exhaust gas drain D kg of the calorimeter is measured at the time of measurement of the higher calorific value, H_l can be roughly estimated according to the following formulae:

$$H_l = H_h - 2500 D/G_f \text{ kJ/m}^3$$

$$\{H_l = H_h - 590 D/G_f \text{ kcal/m}^3\}$$

where, $G_f \text{ m}^3$ is the amount of fired fuel gas during firing of $D \text{ kg}$ is measured.

- 2 If the content (volume %) of each component of the gaseous fuel is known, H_l can be roughly estimated according to the following formulae:

$$H_l = 108.3(h_2) + 126.1c_o + 360ch_4 + 596c_2h_4 + 646c_2h_6 + 878c_3h_6 + 934c_3h_8 + 1180c_4h_8 + 1235c_4h_{10} \text{ kJ/m}^3$$

$$\{H_l = 25.9(h_2) + 30.1c_o + 86.1ch_4 + 142c_2h_4 + 154c_2h_6 + 210c_3h_6 + 223c_3h_8 + 282c_4h_8 + 295c_4h_{10} \text{ kcal/m}^3\}$$

- (2) **Heat input due to sensible heat of fuel (in the case where fuel is preheated by external heat source)** The heat input Q_1 due to the sensible heat of the fuel shall be determined according to the following formulae:

$$Q_1 = c_f(t_f - t_0) \text{ kJ/kg (or m}^3\text{) \{kcal/kg (or m}^3\text{)}}$$

where, c_f : mean specific heat of fuel $\text{kJ/kg (or m}^3\text{) K}$
 $\{\text{kcal/kg (or m}^3\text{) }^\circ\text{C}\}$

t_f : fuel temperature after heating $^\circ\text{C}$

t_0 : base temperature $^\circ\text{C}$

When specific heat of the fuel is not measured actually, the following values shall be adopted:

Coal: 1.05 {0.25}, fuel oil: 1.9 {0.45}, kerosine, gas oil and crude oil: 2.0 to 2.1 {0.48 to 0.50} kJ/kgK { $\text{kcal/kg}^\circ\text{C}$ }

Produced town gas: 1.4 {0.34}, natural gas: 1.6 to 1.8 {0.38 to 0.42},

L.P.G. (according to its composition): 2.9 to 4.2 {0.7 to 1.0} $\text{kJ/m}^3\text{K}$ { $\text{kcal/m}^3^\circ\text{C}$ }

Remarks: In the case where a part of generated steam from the test boiler is used for preheating of fuel, such quantity of heat shall be considered as the "circulating heat" to be excluded from the abovementioned calorific values.

- (3) **Heat input due to sensible heat of air (in the case where air is preheated by external heat source, e.g. extracted steam from bleeder turbine)** The heat input Q_2 due to the sensible heat of air shall be determined according to the following formulae:

$$Q_2 = A c_a(t_a - t_0) \text{ kJ/kg (or m}^3\text{) \{kcal/kg (or m}^3\text{)}}$$

where, A : amount of air (incl. steam) per 1 kg (or m^3) of fuel m^3/kg (or m^3)

c_a : mean specific heat of air $\doteq 1.30 \text{ kJ/m}^3\text{K}$ { $0.31 \text{ kcal/m}^3^\circ\text{C}$ }

t_a : air temperature after heating $^\circ\text{C}$

t_0 : base temperature $^\circ\text{C}$