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TEST CODE
FOR STATIONARY STEAM GENERATORS
OF THE POWER STATION TYPE

1st EDITION

December 1968

For each individual country the only valid standard is the national standard of that country.

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BRIEF HISTORY

The ISO Recommendation R 889, *Test code for stationary steam generators of the power station type*, was drawn up by Technical Committee ISO/TC 64, *Methods of testing fuel-using equipment*, the Secretariat of which is held by the British Standards Institution (BSI).

Detailed work on this question by the Technical Committee led, in 1964, to the adoption of a Draft ISO Recommendation.

In May 1966, this Draft ISO Recommendation (No. 887) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Argentina	Hungary	South Africa, Rep. of
Belgium	India	Sweden
Brazil	Israel	Turkey
Chile	Italy	U.A.R.
Finland	Japan	United Kingdom
Germany	New Zealand	U.S.S.R.

Two Member Bodies opposed the approval of the Draft :

France
Ireland

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in December 1968, to accept it as an ISO RECOMMENDATION.

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TEST CODE
FOR STATIONARY STEAM GENERATORS
OF THE POWER STATION TYPE

1. SCOPE

This ISO Recommendation establishes the procedure for conducting acceptance tests on direct fired stationary steam-generating units of the power station type, and presenting the test results in tabular form.

It provides for the determination of the heat output and of the thermal efficiency. The heat output should be determined by direct measurements. The efficiency should be determined by one of the following methods :

- *Method A* : where possible, from the establishment of a complete heat balance, or
- *Method B* : where this is not possible, or where the expected accuracy of measurement of heat input or heat output is unacceptable, by the determination of all losses.

In either case the thermal efficiency may be expressed in terms of either the net or gross calorific value of the fuel.

The net thermal efficiency, based on the heat output reduced by the thermal equivalent of the power used by auxiliaries, is not employed in this ISO Recommendation. The power used by auxiliaries is to be separately recorded in its appropriate units in the test report.

Provision is also made for the determination of the performance of the draught plant and pulverizers, and also for the determination of steam purity, where such tests are required to demonstrate compliance with the provisions of a contract.

The question of contractual tolerances is outside the scope of this ISO Recommendation. The probable errors involved in performing a test may be determined by combining the individual errors likely to arise from the separate measurements by one of the established statistical procedures.

This ISO Recommendation applies to large direct fired steam generators, primarily of the water tube type, which may be equipped with

- superheaters,
- reheaters,
- economizers,
- recuperative air heaters,
- combustion and steam temperature control equipment.

The water circulation in the boilers may be by natural convection or by pump or by a combination of natural convection and pump.

The steam generators may be fired by

- solid fuel,
- liquid fuel,
- gaseous fuel,
- a combination of any of these fuels.

2. DEFINITIONS

For the purpose of this code, the following definitions apply.

2.1 **Stationary steam generating unit.** A boiler with or without any or all of the following heat exchanging components :

- superheaters,
- reheaters,
- economizers,
- air heaters,

and including

- plant for collection of grits or dusts for refiring in the furnace,
- combustion and steam temperature control equipment,
- ancillary plant or equipment which may be required for the proper operation of the unit, to an agreed specification,

but excluding

- coal handling plant up to the outlet of the raw coal bunker,
- ash handling plant (except plant for return of ash to furnaces),
- plant for handling grits and dusts for external disposal,
- oil handling plant before the inlet to the oil heater,
- gas mains up to but excluding the main gas stop valve or isolating valve to the gas distribution mains supplying the individual gas burners,
- feedwater heaters before the economizer,
- steam and feed mains except on the boiler side of the boiler isolating valves.

2.2 **Heat output.** The heat value of the steam supplied by the unit, less the heat values of any feed water and steam returned to the unit.

2.3 **Heat input.** The heat value of the fuel used by the unit, based upon the net or gross calorific value as may be required by the contract, plus any waste heat that may be supplied to the boiler from an external source under the terms of the contract.

2.4 **Thermal efficiency.** The heat output less any heat (other than waste heat) supplied to the unit from a separate thermal source other than that supplied in fuel or as mechanical or electrical energy divided by the heat input.

2.5 **Unit of calorific value.** Calorific values should be expressed in terms of the joule or its equivalent :

$$1 \text{ cal}_{IT} = 4.1868 \text{ J}$$

$$1 \text{ Btu} = 1055.06 \text{ J}$$

All calorific values should be those at constant pressure and corrected to one atmosphere standard pressure $= 1.01325 \times 10^6$ dyn/cm^2. The standard reference temperature for the calorific values of solid, liquid and gaseous fuels shall be 25 °C.

2.6 **Gross calorific value of a solid or liquid fuel at constant volume** ($Q_{gr,\ v}$). The number of heat units measured as being liberated per unit mass of fuel burned in oxygen in a bomb under standard conditions, the residual materials being taken as gaseous oxygen, carbon dioxide, sulphur dioxide and nitrogen; liquid water in equilibrium with its vapour and saturated with carbon dioxide; and ash. The gross calorific value as determined should be corrected to a standard reference temperature of 25 °C or its equivalent.

The value thus determined is sufficiently close to the calorific value at constant pressure ($Q_{gr,\ p}$) to be used without further correction.

2.7 **Net calorific value of a solid or liquid fuel** ($Q_{net, p}$). The gross calorific value as defined above, less the latent heat of evaporation at constant pressure of the water both originally contained in the fuel and formed by its combustion.

$$\left.\begin{array}{l}\text{Net calorific value at constant pressure}\\ \text{in calories per gramme}\end{array}\right\} = Q_{gr, p} - (52.5\,H + 5.8\,W)$$

$$\left.\begin{array}{l}\text{Net calorific value at constant pressure}\\ \text{in British thermal units per pound}\end{array}\right\} = 1.8\,Q_{gr, p} - (94.5\,H + 10.5\,W)$$

where

$Q_{gr, p}$ is the gross calorific value in cal/g of the fuel at constant pressure corrected to the reference conditions of 25 °C and one standard atmosphere;

H is the percentage by mass of hydrogen in the fuel substance in the condition to which $Q_{gr, v}$ (or $Q_{gr, p}$) refers and specifically excludes the hydrogen present in the moisture and in the mineral matter associated with the fuel;

W is the percentage of total moisture in the fuel substance in the condition to which $Q_{gr, v}$ (or $Q_{gr, p}$) refers and is the sum of the moisture in the fuel substance and the combined water of the mineral matter.

2.8 **Gross calorific value of a gaseous fuel at constant pressure** (Q_A). The number of heat units measured as being liberated when unit volume of the gas is burned at constant pressure in a flow calorimeter in excess air at the same temperature and pressure; the gas being measured under standard conditions of temperature, pressure and degree of saturation with water vapour, and the materials after combustion consisting of the gases, carbon dioxide, sulphur dioxide, oxygen together with nitrogen and water vapour, equal in quantity to the incoming gas and air, and liquid water equal to that produced during combustion, the pressures and temperatures before and after combustion being equal.

The standard conditions of temperature, pressure and humidity for the purpose of measurement of the volume of the gaseous fuel are 15 °C (60 °F), one standard atmosphere and complete saturation. The reference conditions of temperature and pressure at which the calorific value of a gaseous fuel should be stated are 25 °C and one standard atmosphere.

2.9 **Net calorific value of a gas at constant pressure** (Q_B). The number of heat units released per unit volume of gas when the gas is burned at constant pressure in air in a calorimeter of defined type under defined conditions and the combustion products consist of carbon dioxide, water, (from the hydrogen and the hydrocarbons) in the vapour state, oxides of sulphur, oxygen and nitrogen; the gas, the air used for its combustion and the combustion products being at the same reference temperature.

$$\left.\begin{array}{l}\text{Net calorific value of a gas}\\ \text{at constant pressure in}\\ \text{kilocalories per cubic meter}\end{array}\right\} = Q_A - \frac{105.07}{V}\left(d + \frac{ey}{2}\right)$$

$$\left.\begin{array}{l}\text{Net calorific value of a gas}\\ \text{at constant pressure in}\\ \text{British thermal units per cubic foot}\end{array}\right\} = 0.11237\,Q_A - \frac{11.807}{V}\left(d + \frac{ey}{2}\right)$$

where

Q_A is the gross calorific value of gas at constant pressure at the reference conditions of 25 °C and one standard atmosphere,

V is the kilogramme molecular volume of the standard gas in cubic metres,

d is the percentage by volume of hydrogen in the gas,

e is the percentage by volume of hydrocarbons C_xH_y in the gas,

y is the number of hydrogen atoms in C_xH_y, the calculated mean formula of the hydrocarbons.

NOTE. – The terms and symbols employed are tabulated and described in Tables 1 and 2 of section 5.

3. GUIDING PRINCIPLES

3.1 Method of determining efficiency

A test according to Method A (see section 1) requires the direct determination of the heat output and input as part of the establishment of the heat balance. In a test according to Method B, one of these primary quantities is unmeasured and the efficiency is obtained by subtracting the various losses, expressed as percentages, from 100 %, making due allowance for the effect of the heat input to the auxiliaries. Whether the heat input is measured or not, it is still necessary to carry out sampling and analysis of the fuel and the gases, as well as of the refuse. Special precautions should also be taken in relation to the determination of the losses, and these precautions are mentioned in the appropriate clauses of section 4.

3.2 Preliminary observation of plant

Before any arrangements for acceptance tests are made, the plant should be observed in operation for as long as may be necessary to confirm that the specified working conditions can reasonably be met.

Such working conditions are the following :

(*a*) *Output*

(1) from main boiler stop-valve,

(2) from reheater(s), if installed.

(*b*) *Pressure of steam*

(1) at the superheater outlet,

(2) at the inlet to the reheater(s),

(3) at the outlet from the reheater(s).

(*c*) *Temperature of feed water entering the unit*

(*d*) *Temperature of steam*

(1) at the superheater outlet,

(2) at the inlet to the reheater(s),

(3) at the outlet from the reheater(s).

(*e*) *Temperature of air*

(1) ambient air,

(2) externally preheated combustion air (if applicable).

The working conditions should be attained at positions specified in the contract, or failing such specifications, at a point immediately adjacent to the component concerned.

It should also be verified that the appropriate fuel or fuels can be burned at the necessary rates, and it should be established by flue-gas analysis that at these rates there are no significant losses due to unburnt gases.

If such preliminary observation discloses that the specified working conditions, as listed above under sub-headings (*a*) to (*e*) inclusive, cannot be met in any one or all particulars, or if the characteristics of the available fuel are different from those specified, the test may be carried out, by agreement between the parties, under the operating conditions shown to be feasible, and on agreement also on the resultant changes in the guarantee values.

It is recommended that correction curves for deviations from the reference temperature of feed-water temperature, temperature of steam at inlet to the reheater(s), externally pre-heated combustion air and external air, as well as for deviations of steam throughput, should have received the prior agreement of the parties and should preferably have been written into the contract.

3.3 Items on which agreement should be reached

The tests should be conducted by a competent experienced person who should be appointed by the parties to the test.

The parties concerned should agree, before the tests, on the following matters :

1. The extent of the duties and responsibilities of the designated competent person.
2. The specific objects of the tests (see section 1).
3. That the specified working conditions can reasonably be met and that the appropriate fuel(s) can be burned at the necessary rate(s) (see clause 3.2).
4. Correction curves or tables for deviation of test conditions from stipulated operating conditions (see clause 3.2).
5. The number and duration of the tests (see clause 3.7).
6. That the specified fuel to be used in the tests is available in adequate quantity to meet the requirements of 3 above (see also clause 3.4).
7. In the event of a plurality of fuels being burned, the ratio of the different fuels to be used.
8. The method of evaluating the efficiency, i.e. either through the determination of a complete heat balance by Method A or through an evaluation by Method B (see section 1 and clause 3.1).
9. The method of expressing the thermal efficiency, i.e. whether in terms of gross or net calorific value.
10. The general method of operating and responsibility for operating the plant during the tests.
11. If various manufacturers are involved, their respective responsibilities for the performance of the component plant items and of the plant as a whole.
12. The laboratory, or laboratories, of recognized standing to make the necessary analyses of fuel and refuse.
13. The provision of reserve fuel samples (see clause 4.12).
14. Any departure from the methods of measurement prescribed by this code.

    NOTE. – Such departures should be recorded in the Test Report.
15. The steam tables to be adopted.
16. The state of the plant, i.e. cleanliness of contact surfaces, wear and tightness, and the operation of cleaning equipment (see clause 3.4).
17. The operation of blow-down and, if to be used, the method of measurement (see clause 3.4).
18. The operation of integral ash-quenching equipment (see clause 3.4).
19. The method of measurement of fuel (see clause 4.11).
20. The method of sampling fuel (see clause 4.12).
21. The method of fuel grindability determination (see clauses 4.12 and 4.22).
22. The method of obtaining masses of refuse (see clause 4.14).
23. The method of assessment of heat losses from water-filled ash hopper and from solid residues of combustion (see clause 4.16).

24. The method of sampling refuse (clause 4.15).

25. The method of flue gas analysis (see clause 4.7).

26. The method of measuring feed-water (see clause 4.8).

27. The instruments to be used for temperature measurement (see clause 4.5).

28. When testing according to Method B the value to be adopted, where necessary, for radiation and convection loss (see clause 4.18).

29. The methods of steam purity measurements and correction, and of boiler-water conditioning (see clause 4.23).

30. The location of instruments (see clause 4.3).

31. The measurement intervals (see clause 4.3).

32. The conditions under which a test should be terminated as unsatisfactory (see clause 3.8).

3.4 Preparation for test

Before an acceptance test, the plant should be placed at the disposal of the manufacturer for examination in order to ascertain that it is in suitable condition, in particular that the steam generator is in the specified state of cleanliness.

The furnace casing, gas and air conduits, and casings of the economizer and air heater should be tested for leakage, and any abnormal leaks should be stopped before the test is started.

During the test, the cleaning equipment should not be operated except by prior agreement between the parties concerned, in which case the fact should be recorded in the test report and the times and periods of such operation should be stated.

During an acceptance test, the boiler should not be blown down nor should the integral ash-quenching equipment be operated unless such operations are specifically agreed between the parties, or specified in the contract as permissible during the test. In this event, the times and periods of operation should be recorded in the test report.

The unit under test should be completely isolated from any supplies of feed-water or fuel other than those passing through their respective measuring devices. Precautions should be taken to avoid all leakages of water or steam, inwards or outwards, which will affect the results of the test. Similar precautions should be taken with liquid or gaseous fuel. Wherever practicable unused pipes should be blanked off, otherwise continuous supervision must be possible.

In preparation for any test the plant should be run for a sufficient time to attain a reasonable equilibrium of temperature and combustion at test load conditions. Normally it is recommended that the plant should have been in continuous operation for three days before the commencement of the test; of the last 12 hours, 9 hours should be at a minimum of three-quarters of the test load and the last 3 hours at the test load. During these last 3 hours the following conditions should prevail :

(*a*) the steam output should not vary more than ± 3 % from the test value;

(*b*) the extreme values of steam pressure should not differ from one another by more than 6 %;

(*c*) the extreme values of difference between the temperatures of the gas at the unit exit and the ambient air should not differ from one another by more than 6 %.

During the whole of the preliminary running the unit should be fired with the fuel(s) agreed upon for the test, unless otherwise agreed (see clause 3.1 and 3.2).

3.5 Preliminary test

A preliminary test should be made for the purposes of

(*a*) checking the operation of all instruments;

(*b*) the training of observers and other test personnel;

(*c*) establishing proper combustion conditions for the particular fuel(s) and rate(s) of burning to be employed, and ensuring the absence of unburnt gases in the flue.

Normally the duration of the preliminary test need only be such as to fulfil these purposes but, should it be established that all the requirements of a regular test are being met, the preliminary test may be continued for the full duration of an acceptance test subject to the continued compliance with the requirements of this code and as specified in clause 3.7, and, with the agreement of the parties, may be recognized retrospectively as a regular acceptance test.

3.6 Conditions at beginning and end of test

The following values should show adequate agreement at the beginning and end of the test :

(*a*) combustion conditions;

(*b*) excess air;

(*c*) rate of feeding fuel;

(*d*) rate of feeding water;

(*e*) steam pressure;

(*f*) water level in drum;

(*g*) main steam and reheat steam flows.

With grate firing, and particularly when using Method A of efficiency determination, the stock of fuel on the grate and its condition should be the same at the beginning and end of the test.

With mechanical grates, the average grate velocity and the height of the fuel layer, at least during the period of one pass of the fuel on the grate, should be the same at the beginning and end of the test. These values must, therefore, be observed for an adequate period before commencement and after termination of the test.

In view of these requirements it is recommended that in cases where, in compliance with clause 3.7, a test of long duration necessitates a change of observers during its course, the observers at the end of the test should be the same as at the beginning.

3.7 Duration of test

To meet the requirements of clause 3.6 the plant should be run under test conditions for not less than 1 hour before and after the test period, or for such time as to collect sufficient data to establish that similar and steady conditions prevailed at the beginning and end of the test. The final hour may be omitted by agreement between the parties if pulverized fuel direct fired on the unit system, gaseous or liquid fuel, is being used.

In fixing the duration of efficiency tests, the limiting factor with solid fuels is generally the time necessary to reduce the variation in the quantity of fuel in the system at the beginning and end of the test to such a small percentage of the total fuel consumption as not to influence appreciably the measured efficiency.

For plant which is fired by a travelling-grate or spreader stoker, a minimum period of 6 hours is recommended.

With retort stoker firing there should be a preliminary period of 24 hours followed by the actual test period of 24 hours minimum duration. A final control period of 12 hours should follow the actual test period.

With pulverized fuel, directly fired on the unit system, or with oil fuel or gas firing, a period of 4 hours in addition to the control period or periods is usually sufficient.

In the case of pulverized fuel not directly fired from the pulverizer, a longer period is usually necessary for the correct determination of the fuel consumption. The duration can only be determined by an examination of the plant and the possible variation of the quantity of fuel contained in the system between the point of weighing the fuel and its delivery to the furnace. The test should be of sufficient duration to reduce this variation of the quantity to a percentage of the total fuel consumed which is consistent with the required degree of accuracy of measurement.

For boilers with slag-furnaces, under certain circumstances, the foregoing test periods may need to be extended and the test duration must be the subject of agreement between the parties, having regard to the foregoing considerations, the characteristics of the plant and the desired degree of accuracy.

When testing by Method B, 4 hours, in addition to the control periods, usually suffice.

Except in the case of tests of long duration, when the precaution noted in clause 3.6 should be observed, it is not desirable to change observers during a test. It is recommended (see clause 4.3) that the intervals between readings should be so chosen as to avoid unnecessary fatigue.

3.8 Rejection of test runs

A test may be either discontinued or rejected by either of the parties after completion for reasons which must have been the subject of prior agreement and which may relate to certain eventualities, such as grave contradictions in the observed data, substantial divergencies between the properties of the fuel used and those originally laid down for the tests, etc.

In particular, the test may be discontinued or rejected if excessive variations occur of pressure or steam output, or of steam temperature.

Such variations may be considered as "excessive" and may therefore involve the rejection of the test unless otherwise provided for in the contract, if they are such as to disturb the equilibrium running defined in clause 3.4 as having to be reached before the tests actually begin.

NOTES

1. Variations during the test, if they are of long duration, may involve the rejection of the test when they correspond to deviations greater than those laid down as criteria in clause 3.4.

2. Momentary variations may exceed the limits specified in clause 3.4 without involving the rejection of the test, providing the parties, taking into account the frequency, duration and time of occurrence of the variations, are agreed that they are not such as to upset appreciably the equilibrium of temperature in the different parts of the generator.

4. INSTRUMENTS AND METHODS OF MEASUREMENT

4.1 General

Application of the requirements of section 1 involves the determination of all or part of the following quantities :

– Heat output	(see clauses 4.8 to 4.10)
– Heat input	(see clauses 4.11 to 4.13)
– Losses due to refuse	(see clauses 4.14 to 4.16)
– Losses due to flue gases	(see clause 4.17)
– Radiation and convection loss	(see clause 4.18)
– Energy used by auxiliaries	(see clause 4.19)

The object of this section is to provide rules for the correct execution of measurements relating to these quantities.

4.2 Type and calibration of instruments

In this section are given alternative methods of measurement which can be employed and the parties to the tests must agree upon the methods to be adopted. Any departure from these methods, or the use of any instruments not covered by this code, should also be the subject of prior agreement and any such deviations from the prescribed procedure shall be fully described and recorded in the test report.

Recording or integrating devices should be used only by express agreement between the parties and provided that their use will not lead to the loss of accuracy. Calibrations should be carried out before the tests of all instruments and apparatus which are vital to the objects of the tests. In some cases it may be considered necessary to repeat calibrations after the tests.

4.3 Location of instruments and periodicity of readings

The location of all instruments should be agreed upon by the parties prior to the commencement of the test. Where possible at no sacrifice of accuracy, the use of remote indicating instruments is recommended, and the location and grouping of all instruments, whether local or remote reading, should be considered from the standpoint of the observers, with the object of ensuring accurate measurements with the minimum of fatigue, having due regard to the agreed duration of the tests.

All readings should be taken at such frequency as may be necessary to determine the true average. Except for quantity measurements, the interval between readings should normally be 10 to 15 minutes provided that there should be not less than twenty-five uniformly spaced readings. If, however, there are sudden and wide fluctuations, it may be necessary to reduce this interval. In the case of flow measurements using indicating instruments, half minute intervals are recommended, unless otherwise agreed.

It should be noted that too short intervals can result in an increase in the error due to fatigue of the observers taking the readings.

As far as possible the initial and final readings of all quantitative measurements should be taken simultaneously. The steady-state values are best read off a short time before the beginning of the test period. It is recommended that all readings should be continued throughout both the initial and final control periods.

4.4 Recording of data

The observed data should be directly recorded by each observer on log sheets designed for the purpose, which log sheets should include the reference number of all instruments. It is recommended that these data should be transferred to a single master log sheet.

4.5 Temperature measurement

4.5.1 The following types of thermometer may be used for temperature measurement :

(*a*) Mercury-in-glass solid stem thermometers with scales suitable for the measurement to be made in accordance with ISO Recommendation R 386, *Principles of construction and adjustment of liquid-in-glass laboratory thermometers.*

(*b*) Electric resistance thermometers with Wheatstone bridge or similar "null" balance instrument.

(*c*) High-grade thermocouples used with a potentiometer of suitable accuracy.

4.5.2 The following precautions should be observed during temperature measurement.

(*a*) The locations for temperature measurement should be so chosen or arranged that both velocity and temperature distribution are reasonably uniform over the cross-sectional area of the pipe, flue or duct at the measuring point.

(*b*) The method of measurement must be such as to minimize the quantity of heat transmitted through radiation or convection to and from the thermometer other than that of the medium being measured. Where this is not possible, the necessary corrections must be applied.

(*c*) Thermometer pockets or wells should preferably be dry, especially for high temperature measurements, but the pocket (apart from the vicinity of the sensitive element) should be loosely packed with asbestos or similar material to reduce air circulation and loss of heat. If the use of a liquid is considered desirable to improve contact between the pocket and the sensitive element of the thermometer, only the minimum amount of liquid should be used. Care should be taken to avoid damage to the sensitive element by the liquid, and to avoid the setting up of convection currents in this liquid.

(*d*) When thermometer pockets are fitted in pipes it is desirable that the sensitive element of the thermometer should extend as near to the centre-line of the pipe as is practicable. For pipes of less than 100 mm (4 in) internal diameter the sensitive element should in all cases be situated completely within the bore of the pipe. This may mean inclining the pocket or element at an angle of less than 90° to the axis of the pipe. For the smaller pipes this can be accomplished by fitting the pocket axially at a bend.

For pipes of 100 mm (4 in) and up to 300 mm (12 in) internal diameter, some inclination of pockets and elements may be needed in the smaller pipes of the range. In the larger pipes the complete sensitive element should be in the region of the pipe centre-line.

For pipes of 300 mm (12 in) internal diameter and over, where danger of pocket vibration prevents the use of pockets reaching to the centre of the pipe, the immersed lengths should be as great as possible consistent with safety.

For pipes exceeding 460 mm (18 in) internal diameter it may be necessary to take temperature readings at several points in one plane in order to ensure that a reasonably accurate average temperature is measured.

(*e*) Pockets and walls should be as thin as possible, consistent with strength, and the inner diameter should be as small as possible, just sufficient to insert the thermometer or temperature-measuring element. It is important that the thermometer pockets and walls should be clean and free from oxides or other corrosion products.

(*f*) The stem of a mercury-in-glass thermometer should project as little as possible from the medium of which the temperature is being measured; the stem temperature of the exposed portion should be measured by means of an auxiliary thermometer and a stem correction applied.

(*g*) If a mercury-in-glass thermometer is employed at "full immersion" it should be withdrawn for reading only far enough to reveal the top of the mercury thread.

(*h*) In measuring the temperature of flowing media, the heat-receiving part of the apparatus should not be in a dead space.

(*i*) When gas or air temperatures are to be measured in ducts of large cross-sectional area, temperature traverses should first be made and single-point measurement may be adopted if a point of average temperature is found under the conditions under which the test is to be made. In other cases arrangements should be made for multi-point temperature measurement.

(*j*) The temperature of steam used for heating oil should be taken at the point at which the flow of steam is measured, which should be as near to the source of supply as convenient in order to debit the heater with any pipe losses for which it may be responsible. Where any other method of measurement of steam is employed a similar result should be secured.

4.6 Pressure measurement

Steam and water pressures should be measured by calibrated Bourdon-type gauges, dead-weight gauges or their equivalents. Diaphragm gauges should not be employed.

The scale markings of the Bourdon gauges should be of plain straight lines or dots, and a difference of 1 % of the working pressure must be easily read on the scale. Bourdon gauges should be calibrated under pressure and ambient temperature conditions approximating to those obtained during the test, using standard dead-weight test gauges before and, if required, after the tests.

The dead-weight gauges should be examined, and it should be ensured that the piston revolves freely. The diameter of the piston should be measured, and the weights should be compared with authentic standards.

Both types of gauges should preferably be located with pipes as short as possible and mounted in a location where they will not be disturbed by vibration.

They should be kept cool by means of siphon tubes or an equivalent in which steam may be condensed. To avoid errors because of unbalanced water columns in the convolutions, the siphon tubes should have as few convolutions as possible consistent with the gauge being kept cool. In order that gauges may be kept cool with a minimum number of convolutions, the gauge pipe connections should be absolutely steam tight.

Should there be evidence of pulsations shown by the gauge pointer during any test, the reasons for such pulsations should be investigated. Oscillations should not be damped by throttling the connection to the gauge.

Pressure gauges mounted on panels remote from the point of measurement may be used, provided that they are calibrated by comparison with an instrument connected in the manner described above, and provided that allowance is made for the pressure of the water column in the connecting pipe.

Dead-weight gauges for accurate pressure measurement may be connected directly to the point where the reading is required. They may, for example, be connected to the inlet and the outlet of a reheater to determine the steam pressure drop. Differential steam pressure gauges may be used for this purpose when the pressure points are at the same level.

Gas and air pressures may be measured by commercial gauges mounted on panels remote from the point of measurement, provided that they are calibrated against a liquid manometer connected at the point of measurement. Alternatively, liquid manometers may be used.

Mercury, paraffin, or other liquids may be used in manometers and corrections for density should then be applied to reduce the readings to water gauge equivalent. The density of the liquid at the working temperature should be used in conversion.

The pipe connecting the instrument to the pipe or duct should be flush with the inner surface. For ducts in which the velocity distribution in a plane at right angles to the axis is highly variable, it may be necessary to use a "side" gauge and to carry out a traverse of the area.

Pressures of steam used in heating and atomizing oil should be taken at the point at which steam is measured by means of a steam flowmeter (see clause 4.5.2 (*j*)).

4.7 Sampling and analysis of flue gases

Sampling and analysis of the flue gases leaving the unit are required, and frequently similar determinations are made at other points in the unit.

Much care is necessary in selecting the point of sampling of the flue gases. The difficulty is often accentuated by the large cross-sectional area of the flues. Stratification may be particularly bad where rotating air heaters exist and there may also be considerable variation in gas analysis over the duct due to air infiltration.

Before the test the ducts where gas analyses are required should be explored, under the conditions of load and combustion expected on the test, to ascertain the distribution of carbon dioxide. If this reveals a point where a reliable mean exists, single point sampling may be adopted with the end of the sampling tube in this position. For large ducts it is recommended, and in tests according to Method B it is essential, that multi-point sampling be employed. For those cases where reliable mean positions cannot be obtained, the best practicable method of obtaining a representative result is to sample the flue gases and make velocity measurements at the centres of equal areas across the section of the ducts in order that a weighted average may be calculated taking into account the gas temperature as well as its velocity. For some cases such velocity measurements may not be necessary and an arithmetic average will suffice.

Where the induced-draught fans, if installed, are situated adjacent to the final heat exchanger in the system, so that there is no important infiltration between the two, gas samples may be taken at the discharge of the fans, where complete mixing has taken place.

Sampling tubes should be made of material suitable for the temperature encountered. For sampling high-temperature gas, such as at a furnace or at the entrance to a waste-heat boiler, suitable water-cooled samplers should be employed. Sampling lines should be as short and straight as possible, should be accessible for cleaning and blowing out, should slope in the direction of flow, should be suitably drained if necessary, and should be maintained tight. Tests for tightness should be made at the beginning and at the end of a run.

Analyses should be made at frequent intervals, say 15 minutes for carbon dioxide or oxygen or both, for which a suitable apparatus is the Orsat. When the test is made according to Method B, it is necessary to use a more sensitive apparatus, capable of detecting any unburned combustible gas.

4.8 Determination of steam output

The steam output should be determined by measurement of the feed water quantity or, where the parties agree that this is to be preferred, having regard to the duration of the test and the water content of the boiler, by direct measurement of steam flow. Whether the determination of steam output is made by steam or water measurement, the following ISO Recommendations should be applied :

- ISO/R 541, *Measurement of fluid flow by means of orifice plates and nozzles;*
- ISO/R 781, *Measurement of fluid flow by means of venturi tubes.*

The feed water quantity may be measured by

- a venturi meter of the precision type, a nozzle or an orifice,
- actual weighing by means of tanks and suitable scales,
- calibrated volumetric measuring tanks,

as may be agreed by the parties to the test.

It is recommended that when reciprocating pumps are used, the mass or volume of the feed water should be determined, if this is permissible, having regard to the oxygen absorption of the feed water. In no case should vane-type meters be used in conjunction with reciprocating pumps, nor should the flow measurement be made with Venturi tubes, nozzles or orifices.

The drum water level should be as nearly as possible the same at the end of the tests as at the beginning and a suitable correction should be applied for any difference. The level at the beginning and end should be recorded.

All leakages at safety valves, blow-off valves, feed water heaters, pumps, joints, stuffing boxes, and through-connecting piping which may affect the test results should be eliminated, reduced to an amount which, to the satisfaction of all parties concerned, may be ignored, or measured and accounted for. Errors due to steam or water entering or leaving the equipment under test through connecting piping should be obviated by blanking off such connections or by providing open tell-tale drains to give visible assurance that no flow exists.

The amounts of water at all points where it can accumulate between points of measurement and the boiler (such as surge tanks, feed water heaters, and receiving tanks to which measuring tanks discharge) should be checked at appropriate intervals during the test and at the start and conclusion of the run, and proper allowances made.

4.9 Measurement of blow-down

Blowing down during a run should be avoided, but when the boiler is to be blown down during the test, the quantity of the blow-down should be determined where possible by direct measurement of the cooling water to any blow-down cooler and of the inlet and outlet water temperature.

4.10 Measurement of flow of reheated steam

The quantity of reheated steam should be calculated by deducting from the measured main steam quantity the amount of non-reheated steam calculated from observations on the turbine and feed heating system. Where this is not possible, the reheated steam should be measured by steam flow meter.

In addition, for reheaters, measurements of the steam temperature entering and leaving, of the steam pressure entering and leaving, and if necessary of the steam quality entering should be made.

4.11 Measurement of fuel

The solid fuel rate should be obtained by means of tipping weighers, platform weighers or weigh-bridges. The error of the machine at the range of loads weighed should be less than ± 0.1 %. Automatic apparatus may be used, provided that means are available for determining or compensating for the weight of each individual tip to the above degree of accuracy. Where such means are not available tipping should be carried out by hand. Care should be taken to see that the weighing containers are completely emptied between weighings.

The amount of fuel between the point of weighing and the point of combustion should be kept as small as possible and, wherever practicable, should be kept to the same amount at the beginning and at the end of the test. Where this is not practicable, the change in quantity of fuel so stored should be estimated and the appropriate correction made.

Fuel to be pulverized should be weighed before pulverizing.

Oil fuel should be weighed or measured in tanks that have been calibrated by direct weighing. If specifically agreed, flowmeters may be used, but these should be carefully calibrated under test conditions. The precautions referred to for solid fuel regarding storage between point of weighing and point of combustion should be observed with oil fuel.

The quantities of gaseous fuels should be measured by means of meters of the nozzle, orifice, venturi or pitot-static type.

The construction of nozzles, orifices, venturis or pitot-static tubes, their location and installation and the connecting system between the primary element and the manometer should be in accordance with the code on flow measurement (see ISO Recommendations R 541, *Measurement of fluid flow by means of orifice plates and nozzles,* and R 781, *Measurement of fluid flow by means of venturi tubes.* Where direct-reading manometers are not used for measuring differential pressure, the pressure measuring instrument should be of the precision type with the minimum number of moving parts and its setting should be checked against a water or mercury column before and after the test with the reading both rising and falling. Care should be taken to damp out pulsations of the flow which may be present. The temperature and pressure at the point of volume measurements should be measured in accordance with clauses 4.5 and 4.6 of this ISO Recommendation.

4.12 Sampling and analysis of fuel

Solid fuel should be sampled and analysed in accordance with relevant ISO Recommendations dealing with solid mineral fuels. The degree of accuracy in sampling should be to 0.25 % in ash and moisture. Reserve samples should always be taken so that in the event of mishap to the original samples or a dispute arising they will be available for analysis. The fuel should be sampled at the point of weighing for screen analysis, proximate analysis, ultimate analysis, calorific value, ash fusibility and, in the case of pulverized fuel installations, for grindability. The sampling should be on a correctly weighted basis to allow for different rates of fuel flow at each sampling point, and this can conveniently be ensured by sampling at each weigher and by taking a fixed number of increments per tip.

The grindability determination should be made by the method quoted in the contract or by an agreed method if there is no mention in the contract.

In the case of fuel mixtures, if possible, the above characteristics should be determined separately and the characteristics of the mixture found from the proportions by mass of the constituents.

The principles to be followed in the sampling of the pulverized fuel for grading determinations from a fuel pipe are as follows :

(*a*) The velocity of flow into the sampling nozzles should be within ± 10 % of the velocity within the pipe at the sampling point.

(*b*) The sampling pipe should be cleared of pulverized fuel before sampling is begun.

(*c*) Sampling should take place from a section of the fuel pipe at a sufficient distance from the pulverizer (and the exhauster, if any) in a straight length of the pipe, preferably vertical, and as far away as possible from bends.

(*d*) A traverse should be made of the pipe section at regular intervals of time throughout the test and samples drawn off from centres of equal areas, the sampling time being the same at each point.

(*e*) The weighted average of the individual gradings so obtained should be used as the average result for the test. Alternatively, the samples may be thoroughly mixed and the grading of the mixture determined.

For liquid fuels a continuous drip sample should be collected throughout the test at the pump discharge. The ultimate analysis, calorific value, viscosity and density should be determined.

Before a test is carried out using gaseous fuel, a traverse of the gaseous fuel pipes to the boiler should be made, in order to obtain the best position for obtaining an average sample.

If the composition of the gaseous fuel is expected to remain constant during the test, sampling of the fuel gas may be by means of a continuous sample, of by samples taken at regular intervals.

If it is expected that the fuel gas composition may vary significantly during the test (for instance if the fuel gas comes from an intermittent gas-producing process), agreement should be reached on the procedure to be adopted to obtain the true weighted mean calorific value.

4.13 Heat content of combustion air

The temperature of the combustion air should be measured at the designed points of air entry to the system under test, disregarding extraneous intakes. Where there is non-uniformity in the temperature, several thermometers should be used. In a test according to Method B, allowance must be made for the enthalpy of the air admitted to the unit at other points, and the humidity of the combustion air must be determined.

4.14 Measurement of refuse

The heat carried away from the unit (whether fired by coal or oil) in unburnt constituents of the ashes and flue dust should be determined. This determination is necessary in a test according to Method A in order to contribute towards the drawing up of a heat balance; in a test according to Method B the highest practicable accuracy is required in carrying it out.

The masses of ash, dust, riddlings, mill rejects and any other refuse should be determined. The weight of the flue dust may be found by carrying out representative gas sampling to obtain the dust burden (see section B.6).

Weighing of the refuse should take place preferably in the dry state. However, as any burning refuse must be quenched with water immediately upon its withdrawal from the unit, and as refuse is often wet when discharged from the handling plant, the water content must be ascertained in order that this may be allowed for in the calculations.

Where there is special difficulty in weighing any component, and especially where the carbon content of the component concerned is expected to be small, its mass may be estimated from the masses of the other components and of the total ash corresponding to the coal mass and analysis.

If it is agreed that it is impracticable to weigh any of the components, the masses may be estimated by assuming that the ash in the fuel, as determined by analysis, is distributed as deposits in the various sections of the plant in agreed proportions.

Any appreciable surface deposits which may have accumulated during the test in the furnace or elsewhere should also be noted in the test report.

4.15 Sampling and analysis of refuse

Refuse sampling can be subject to large errors and every precaution should be taken in order that representative samples are obtained.

The combustible content on a dry basis should be ascertained by an ignition method.

The method of sampling should be agreed upon before the tests by the parties to the tests.

(*a*) *Ash.* Where the loss due to combustible matter in ash is known to be small, a number of increments to form a gross sample may be taken as the hoppers are being emptied after the test. Where the loss is likely to be significant, the whole of the ash should, if practicable, be treated as the gross sample and should be crushed to 13 mm (0.5 in) and mixed as thoroughly as possible. Quantities in excess of 100 kg (200 lb) should be sub-divided by coning and halving and quartering by the well known methods employed for sub-division of large samples of coal, until the mass of the sub-divided sample is reduced to 50 to 100 kg (100 to 200 lb). Samples of 100 kg (200 lb) and less should be sub-divided by a mechanical sample-divider of a type approved for sub-division of coal samples down to a size of sample suitable for laboratory use. In the event of wetting of the ash taking place it is advisable that separate moisture samples be taken unless the mass of the dry ash is being found by calculation.

(*b*) *Other refuse.* With boilers fired with pulverised fuel where the carry forward of dust is high, this may be the most significant part of the ash loss and care should be taken to obtain representative samples. If the dust burden in the flue gases is being measured, laboratory samples for combustible content can be taken from the gross sample collected after this has been thoroughly mixed, by riffling or by means of a sample divider. If, however, a sample is taken from the hopper which has collected the dust during the test period, periodic samples to form a gross sample should be taken as the hopper is being emptied. The gross sample should then be mixed and divided as above, to obtain laboratory samples.

Where the fly ash or dust is wetted, and this refuse is weighed after wetting, the quantity of water added may be obtained by calculation in preference to direct measurement; in this case, representative samples should be taken both for moisture and for combustible content.

In addition to the main flue dust, if significant quantities are collected in other parts of the unit, gross samples should be taken and divided by means of a riffle or sample divider.

If the quantity of mill rejects or stoker riddlings is significant, the whole quantity should be considered as a gross sample and this should be reduced by halving and quartering to form laboratory samples.

4.16 Sensible heat in fuel and refuse

Where the sensible heat loss in the slag or ash is significant, as for example with slag-tap furnaces or water-filled hoppers, the sensible heat should be measured either by determining the slag or ash temperature and specific heat, or by determining the amount of water evaporated, the temperature rise and the quantity of the overflow of water.

With a water-quenched ash hopper where the losses are significant, they should be determined by measuring the amount of water evaporated and its inlet temperature.

In addition, the loss owing to water vapour entering the furnace and leaving the unit at the final gas temperature should be estimated.

For tests according to Method B the sensible heat losses of all the refuse should be determined, and in addition the loss arising from raising the temperature of the fuel up to the temperature of the air supply should be obtained from the temperature and specific heat of the fuel.

4.17 Losses due to flue gases

Losses due to flue gases consist of

- loss due to sensible heat of dry gases,
- loss due to heating and evaporation of water from the fuel,
- loss due to heating of the moisture contained in the combustion air,
- loss due to unburnt gases.

Determination of these different losses makes it necessary to know

- proximate analysis and ultimate analysis of the fuel (see clause 4.12),
- carbon content of the unburnt solid matter (see clause 4.15),
- analysis of the gases of combustion (see clause 4.7),
- temperature of the gases of combustion (see clause 4.5),
- temperature and humidity of the combustion air (see clause 4.13).

4.18 Radiation and convection loss

In a test according to Method B, the loss due to radiation and convection must be evaluated. The appropriate figure is the gross loss from the unit's casing, i.e. no allowance is made for recuperation, the air temperature having been measured in accordance with this code (see clause 4.13). This loss may be evaluated as follows :

(*a*) From the measurement of the surface temperature and ambient air temperatures of the unit together with agreed heat transfer coefficients, or from measurements with a heat flux meter of a type agreed by the parties concerned, and an accurate knowledge of the area of surface to which the above temperatures of heat fluxes refer. It is important to determine the surface of irregular parts, particularly those which are not lagged.

(*b*) Where the unit, or one of a number of identical units steaming equally, can be isolated as regards air supply, by determining the heat entering and leaving the building or isolated section thereof, by air-flow and temperature measurement at each point of entry or exit, including the entry to the air intakes of the unit, together with an agreed allowance for the building radiation loss.

(*c*) Where neither of these methods of measurement is practicable agreement should be reached before the test as to the value to be adopted for the radiation and convection loss.

4.19 Measurement of energy used by auxiliaries

Where only the total electrical energy is to be determined, this may be measured by a kilowatt-hour meter connected in the main feeder, or in each feeder if there are more than one. In this case an indication of the distribution of energy may be obtained from a comparison of the ammeter and voltmeter readings of each auxiliary motor.

Where the energy input to a particular auxiliary motor is to be determined, it should be measured directly by a kilowatt-hour meter connected in the supply to that motor.

The integrating meters, indicating instruments and current and voltage transformers should be of precision type.

Determination of the energy consumption of auxiliaries driven by other means (such as steam, hydraulic and gas turbines) should be made as agreed by the interested parties in the light of the circumstances of the individual case.

4.20 Dust collecting plant test

Where tests of mechanical dust collectors and electrostatic precipitators are required, it is convenient to carry these out concurrently with the efficiency tests.

4.21 Draught plant test

Apart from any fan tests which may have been carried out at the maker's works, the draught plant may also be tested collectively by a verification of performance at site.

When draught plant capacity tests are carried out at site, the forced-draught and induced-draught fans should be raised to their full output by adjusting the fuel-air ratio and boiler load with the furnace pressure at the specified or an agreed value.

If it is not possible to load the fans fully without exceeding safe limits of boiler load or steam temperature, data should be collected at the maximum fan load permissible, as it may be possible to estimate from this and the fan characteristics whether the draught plant is capable of meeting the specified requirements.

Fan output may be estimated from the fuel and gas data or, where the arrangement of flues and ducts permits, may be measured by pitot-static tube. The power consumption of the individual fan motors should be measured by kilowatt-hour meters and the fan draughts and pressures by means of water manometers.

In order to assess the draught plant performance at site, the following observations should be made.

(*a*) Boiler output.

(*b*) Fuel mass and analysis, or gas and air flow measurement.

(*c*) (1) CO_2 and/or O_2 at boiler outlet.
(2) CO_2 and/or O_2 at I.D. fan outlet.
(3) CO_2 and/or O_2 at air-heater inlet.
(4) CO_2 and/or O_2 at air-heater outlet.

(*d*) (1) Gas temperature at air-heater inlet.
(2) Gas temperature at air-heater outlet.
(3) Gas temperature of I.D. fan outlet.

(*e*) (1) Air temperature at air intakes.
(2) Air temperature at F.D. fan outlet.

(*f*) (1) Draught at I.D. fan inlet and outlet.
(2) Draught at F.D. fan inlet and outlet.

(*g*) (1) Power input to I.D. fan motor.
(2) Power input to F.D. fan motor.

(*h*) Furnace draught.

(*j*) (1) I.D. fan speeds.
(2) F.D. fan speeds.

(*k*) Voltage.

(*l*) Frequency.

(*m*) Barometric pressure.

It is generally desirable that the draught plant test, if required, should be conducted immediately after an efficiency test, in which case it may be unnecessary to repeat the fuel sampling and analysis.

4.22 Pulverizer test

In the event of any specified capacity of a pulverizer not being attained during the thermal efficiency tests made on the unit, the pulverizer performance at such specified capacity may be demonstrated in a supplementary test, the output of the rest of the pulverizing plant being proportionately reduced at the same time so that the evaporation of the unit does not exceed the maximum specified.

Samples of the fuel supplied to the selected pulverizer should be taken for the determination of such characteristics as form the basis of the specified performance (e.g. size grading, grindability and chemical composition), and samples of the pulverized fuel should be taken (see clause 4.12) for grading and, where applicable, moisture determination. The grindability determination should be made by the method quoted in the contract or by an agreed method if there is no mention in the contract.

The following observations should also be made :

(*a*) Rate of output of pulverized fuel.

(*b*) Temperature of air
  (1) at high-temperature air-heater outlet,
  (2) at tempering air duct,
  (3) entering pulverizer.

(*c*) Temperature of air and pulverized fuel mixture leaving pulverizer.

(*d*) Temperature of gas (if used for drying) entering and leaving dryer.

(*e*) Pressures of air, and of gas if used for drying.

(*f*) Speeds of rotation of pulverizer, primary air fan, exhauster and classifier.

(*g*) Power for pulverizer and exhauster and primary air fan.

(*h*) Particulars of mill settings.

4.23 Steam purity measurements

The determination of impurities in the steam may be made by an agreed method, using condensed samples of steam taken from the outlet of the boiler after the superheater, or from any other location at which the purity is guaranteed or is the subject of investigation. Where the condenser to be used does not include a de-gasifying portion, samples of condensed steam should be taken for analysis for dissolved gases, the rates of correction to be applied to conductivity measurements in respect of various dissolved gases being agreed upon before the test.

The concentration of dissolved solids in the boiler water and the means of attaining the required concentration should be agreed upon before the test. During the test, samples of the boiler water should be taken and the concentration of dissolved solids ascertained, preferably by a gravimetric method or, in the case of high pressure boilers, by a photometric method.

The following observations should also be made :

- drum-water level or levels,
- feed and steam rates,
- saturated steam pressure or temperature,
- times of soot blowing, blowing-down and ashing or any other circumstances which may affect the operation of the unit.

5. TEST REPORT

5.1 The test report should contain the corrected measurements and all data required for evaluating and assessing the results of the test therefrom. The corrected measurements should be the original test observations, averaged where necessary, and adjusted for instrumental corrections only. Copies of the test observers' original log-sheets should be included, unless they have previously been supplied to all parties to the test.

5.2 The test report should include general information and design data relating to the plant, together with a statement of the specified or guaranteed values of the quantities which the test is intended to establish. It should also include notes on the methods of measurement, sampling and analysis adopted, in as concise a form as possible, but in sufficient detail to establish that the test has been conducted in conformity with the provisions of this code.

5.3 Any departures from the procedure laid down in this code which may have been agreed between the parties in accordance with clause 3.3 should be described under the appropriate entries in the test report.

5.4 It is recommended that there should be included with the test report a diagram of the installation indicating the measuring points, a copy of the master log-sheets and a copy of any recorder charts relevant to the constancy of the test conditions.

5.5 The test report should be set out in the manner indicated in the following pages. Any section or item which is inapplicable to a particular test should be omitted from the report, without altering the sequence and numbering of the remaining items. If any particular test requires the addition of extra items they should be inserted without upsetting the standard sequence and numbering.

5.6 The symbols and units employed in the test report and in the calculations are listed in Tables 1 and 2. The methodical classification by numbers is indicated from page 33 onwards.

5.7 In Annexes A and B alternative methods are given which, by agreement, may be used to make some of the computations and to calculate quantities which are occasionally required. The methods may be simplified or added to as required and units other than metric may be employed.

TABLE 1 – **Symbols and units**
(Methodical)

Quantity	Symbol	Unit	
		Metric system	Inch-pound system
Quantities (by mass unless otherwise stated)			
Feed water	W_1	kg/h	lb/h
Superheated steam	W_2	"	"
Reheated steam at inlet } first reheater	W_3	"	"
Reheated steam at outlet } first reheater	W_4	"	"
Boiler blow-down	W_5	"	"
Superheated but not reheated steam	W_6	"	"
Superheated spray water	W_7	"	"
First reheater spray water	W_8	"	"
Second reheater spray water	W_9	"	"
Water corresponding to drum level variation during the test	W_{10}	"	"
Reheated steam at inlet } second reheater	W_{31}	"	"
Reheated steam at outlet } second reheater	W_{41}	"	"
Total combustion air entering system	W_a	"	"
Gases of combustion leaving system	W_g	"	"
Fuel (rate of firing, by mass)	C_1	"	"
Fuel to independently fired dryer (rate of firing, by mass)	C_{11}	"	"
Fuel (rate of firing, by volume, at reference pressure p_{10} and temperature t_{10} : gaseous fuel only)	C_2	m^3/h	ft^3/h
Slag in the slag tank	D_1	kg/h	lb/h
Fly ash trapped in the dust-collecting plant	D_2	"	"
Fly ash discharged to the flue	D_3	"	"
Riddlings	D_5	"	"
Ashpit refuse	D_6	"	"
Total solid residues	D_T	"	"
Pressures			
Feed water	p_1	kgf/cm^2 *	lbf/in^2 *
Superheated steam	p_2	"	"
Reheated steam at inlet } first reheater	p_3	"	"
Reheated steam at outlet } first reheater	p_4	"	"
Boiler blow-down (= drum pressure)	p_5	"	"
Superheater spray water	p_7	"	"
First reheater spray water	p_8	"	"
Second reheater spray water	p_9	"	"
Reference pressure of calorific value and of rate of firing (in the case of gaseous fuel)	p_{10}	mmHg abs	inHg abs
Ambient atmospheric pressure	p_{11}	"	"
Fuel oil entering boiler	p_{18}	kgf/cm^2	lbf/in^2
Reheated steam at inlet } second reheater	p_{31}	"	"
Reheated steam at outlet } second reheater	p_{41}	"	"

* Throughout this Code "kgf/cm^2" signifies "kgf/cm^2 effective" and "lbf/in^2" signifies "lbf/in^2 gauge", unless otherwise stated.

TABLE 1 – **Symbols and units** *(continued)*
(Methodical)

Quantity	Symbol	Unit	
		Metric system	Inch-pound system
Temperatures			
Feed water	t_1	°C	°F
Superheated steam	t_2	°C	°F
Reheated steam at inlet } first reheater	t_3	°C	°F
Reheated steam at outlet } first reheater	t_4	°C	°F
Superheater spray water	t_7	°C	°F
First reheater spray water	t_8	°C	°F
Second reheater spray water	t_9	°C	°F
Reference temperature of the calorific value (and of the volume rating in the case of a gaseous fuel)	t_{10}	°C	°F
Fuel entering unit	t_{11}	°C	°F
Combustion air at entry to air intakes	t_{12}	°C	°F
Combustion air leaving fan	t_{13}	°C	°F
Combustion air entering additional heater	t_{14}	°C	°F
Combustion air leaving additional heater	t_{15}	°C	°F
Gases of combustion leaving last recuperator of boiler	t_{16}	°C	°F
Temperature indicated by the "wet bulb" thermometer of the psychrometer at fan inlet	t_{17}	°C	°F
Fuel oil entering furnace	t_{18}	°C	°F
Reheated steam at inlet } second reheater	t_{31}	°C	°F
Reheated steam at outlet } second reheater	t_{41}	°C	°F
Steam saturation pressures			
At temperature t_{12} } psychrometer at fan inlet	p_{12}	mmHg abs	inHg abs
At temperature t_{17} } psychrometer at fan inlet	p_{17}	"	"
Enthalpies			
Fuel oil	h_0	kcal/kg	Btu/lb
Feed water	h_1	"	"
Superheated steam	h_2	"	"
Reheated steam at inlet } first reheater	h_3	"	"
Reheated steam at outlet } first reheater	h_4	"	"
Boiler blow down (boiler drum water)	h_5	"	"
Superheater spray water	h_7	"	"
First reheater spray water	h_8	"	"
Second reheater spray water	h_9	"	"
Combustion air entering additional heater	h_{11}	"	"
Combustion air leaving additional heater	h_{12}	"	"
Reheated steam at inlet } second reheater	h_{31}	"	"
Reheated steam at outlet } second reheater	h_{41}	"	"

TABLE 1 – **Symbols and units** *(continued)*
(Methodical)

Quantity	Symbol	Unit	
		Metric system	Inch-pound system
Calorific values			
Gross calorific value by mass measured at constant volume (and corrected to reference temperature t_{10})	$Q_{gr, v}$	kcal/kg	Btu/lb
Gross calorific value by volume measured at constant pressure (and corrected to reference temperature t_{10})	Q_A	kcal/m³	Btu/ft³
Gross calorific value by mass at constant pressure (and reference temperature t_{10})	H_1	kcal/kg	Btu/lb
Net calorific value by mass at constant pressure (and at reference temperature t_{10})	H_2	”	”
Calorific value of unburned matter content in the solid residue of combustion	H_3	”	”
Composition of fuel by mass			
Water content by mass	E	kg/kg	lb/lb
Inert matter content by mass	Z	”	”
Carbon content by mass	C	”	”
Hydrogen content by mass	H	”	”
Nitrogen content by mass	N	”	”
Oxygen content by mass	O	”	”
Combustible sulphur content by mass	S	”	”
Characteristics peculiar to gaseous fuels			
Molecular volume	V	m³/kmol	ft³/kmol
Hydrogen content by volume	d	%	%
C_xH_y hydrocarbon content by volume	e	%	%
Number of atoms of C_xH_y hydrocarbons			
(carbon)	x	–	–
(hydrogen)	y	–	–
Density at reference pressure and temperature (t_{10} and p_{10})	M	kg/m³	lb/ft³
Heat output of generating unit (total)	Q	kcal/h	Btu/h
Heat output of generating sections and superheater	Q_1	”	”
Heat output of first reheater	Q_2	”	”
Heat output of second reheater	Q_3	”	”
Heat input to generating unit			
By the fuel*	F_c	”	”
By the additional heat in the combustion air*	F_a	”	”
By heating and atomizing liquid fuel	Q_4	”	”
Fraction of fuel lost in the form of free hydrogen in the gases of combustion	H'	kg/kg	lb/lb

* To be treated as negative heat outputs in the computations.

TABLE 1 – **Symbols and units** (*conclusion*)
(Methodical)

Quantity	Symbol	Unit	
		Metric system	Inch-pound system
Unburned matter in the solid residue			
Carbon content of the			
– slag in the slag tank	i_1	%	%
– fly ash trapped in the dust collecting plant	i_2	%	%
– fly ash discharged to the flue	i_3	%	%
– riddlings	i_5	%	%
– ashpit refuse	i_6	%	%
Mean carbon content of all solid residue	i_m	%	%
Fraction of fuel lost as carbon in the solid residue	C'	kg/kg	lb/lb
Composition of gases of combustion by volume			
CO_2 content	a_1	%	%
CO content	a_2	%	%
CH_4 content	a_3	%	%
O_2 content	a_4	%	%
SO_2 content	a_5	%	%
N_2 content	a_6	%	%
H_2 content	a_7	%	%
C_nH_m content	a_8	%	%
Heat due to heating			
– of the gaseous products of combustion other than CO_2 :			
(between 0 °C and initial temperature)	r_1	$kcal/m^3{}_N$	$Btu/ft^3{}_N$
(between 0 °C and final temperature)	r_2	"	"
– of the CO_2 of the gases of combustion			
(between 0 °C and initial temperature)	r'_1	"	"
(between 0 °C and final temperature)	r'_2	"	"
Sundry quantities			
Mean specific heat (at constant pressure) of a liquid fuel between t_{10} and t_{18}	f	kcal/kg.degC	Btu/lb.degF
Fly ash of the flue gases, by mass	k_1	kg/kg	lb/lb
Water vapour content of the combustion air, by mass	K_2	kg/kg	lb/lb
Degree of humidity of the combustion air	K	%	%
Heat account losses			
Loss due to unburned solid matter	P_1	kcal/kg	Btu/lb
Loss due to unburned gas	P_2	"	"
Loss due to sensible heat of dry gas	P_3	"	"
Loss due to evaporation of water in the fuel and of combustion water	P_4	"	"
Loss due to heating of the vapour from the fuel and of the combustion water	P_5	"	"
Loss due to heating of the vapour from the combustion air	P_6	"	"
Loss due to radiation to environment	P_7	"	"
Residual loss	P_8	"	"
Total heat losses	P_t	"	"
NOTE. – The corresponding percentage heat losses are represented by the symbols P'_1 to P'_8 and P'_t			
Thermal efficiency			
Based on the gross calorific value of the fuel	R	%	%
Based on the net calorific value of the fuel	R'	%	%

TABLE 2 – **Symbols and units**
(Alphabetical)

Symbol	Quantity	Unit	
		Metric system	Inch-pound system
a_1	CO_2 Content of gases of combustion by volume	%	%
a_2	CO Content of gases of combustion by volume	%	%
a_3	CH_4 Content of gases of combustion by volume	%	%
a_4	O_2 Content of gases of combustion by volume	%	%
a_5	SO_2 Content of gases of combustion by volume	%	%
a_6	N_2 Content of gases of combustion by volume	%	%
a_7	H_2 Content of gases of combustion by volume	%	%
a_8	C_nH_m Content of gases of combustion by volume	%	%
C	Carbon content of fuel, by mass	kg/kg	lb/lb
C'	Fraction of fuel lost by carbon in the solid residue	"	"
C_1	Rate of firing of fuel by mass	kg/h	lb/h
C_{11}	Rate of firing of fuel to independently fired dryer, by mass	"	"
C_2	Rate of firing of gaseous fuel, by volume, at t_{10} and p_{10}	m^3/h	ft^3/h
d	Hydrogen content of a gaseous fuel, by volume	%	%
D_1	Quantity of slag in the slag tank	kg/h	lb/h
D_2	Quantity of fly ash trapped in the dust collecting plant	"	"
D_3	Quantity of fly ash discharged to the flue	"	"
D_5	Quantity of riddlings	"	"
D_6	Quantity of ashpit refuse	"	"
D_T	Quantity of total solid residues	"	"
e	C_xH_y hydrocarbon content of a gaseous fuel, by volume	%	%
E	Water content of fuel, by mass	kg/kg	lb/lb
f	Mean specific heat (at constant pressure) of a liquid fuel between t_{10} and t_{18}	kcal/kg.degC	Btu/lb.degF
F_a	Heat input to the boiler from the additional heat in the combustion air	"	"
F_c	Heat input to the boiler from the fuel	"	"
h_0	Enthalpy of fuel oil	kcal/kg	Btu/lb
h_1	Enthalpy of feed water	"	"
h_2	Enthalpy of superheated steam	"	"
h_3	Enthalpy of reheated steam at inlet } first reheater	"	"
h_4	Enthalpy of reheated steam at outlet } first reheater	"	"
h_5	Enthalpy of boiler blow down (boiler drum water)	"	"
h_7	Enthalpy of superheater spray water	"	"
h_8	Enthalpy of first reheater spray water	"	"
h_9	Enthalpy of second reheater spray water	"	"
h_{11}	Enthalpy of combustion air entering additional heater	"	"
h_{12}	Enthalpy of combustion air leaving additional heater	"	"
h_{31}	Enthalpy of reheated steam at inlet } second reheater	"	"
h_{41}	Enthalpy of reheated steam at outlet } second reheater	"	"

TABLE 2 – **Symbols and units** *(continued)*

(Alphabetical)

Symbol	Quantity	Unit – Metric system	Unit – Inch-pound system
H	Hydrogen content of fuel, by mass	kg/kg	lb/lb
H'	Fraction of fuel lost in the form of free hydrogen in the gases of combustion	,,	,,
H_1	Gross calorific value of fuel, by mass at constant pressure and at t_{10}	kcal/kg	Btu/lb
H_2	Net calorific value of fuel, by mass, at constant pressure and at t_{10}	,,	,,
H_3	Calorific value of unburnt matter in the solid residue of combustion	,,	,,
i_1	Carbon content of the slag in the slag tank	%	%
i_2	Carbon content of the fly ash trapped in the dust collecting plant	%	%
i_3	Carbon content of the fly ash discharged to the flue	%	%
i_5	Carbon content of the riddlings	%	%
i_6	Carbon content of the ashpit refuse	%	%
i_m	Mean carbon content of all solid residue	%	%
k_1	Fly ash content of the flue gases, by mass	kg/kg	lb/lb
k_2	Water vapour content of the combustion air by mass	kg/kg	lb/lb
K	Degree of the humidity of the combustion air	%	%
M	Density of a gaseous fuel at t_{10} and p_{10}	kg/m^3	lb/ft^3
N	Nitrogen content of fuel, by mass	kg/kg	lb/lb
O	Oxygen content of fuel, by mass	,,	,,
p_1	Feed water pressure	kgf/cm^2 *	lbf/in^2 *
p_2	Superheated steam pressure	,,	,,
p_3	Pressure of reheated steam at inlet } first reheater	,,	,,
p_4	Pressure of reheated steam at outlet } first reheater	,,	,,
p_5	Boiler blow-down pressure (drum pressure)	,,	,,
p_7	Superheater spray water pressure	,,	,,
p_8	First reheat spray water pressure	,,	,,
p_9	Second reheat spray water pressure	,,	,,
p_{10}	Reference pressure of calorific value and of rate of firing (in the case of a gaseous fuel)	mmHg abs	inHg abs
p_{11}	Ambient atmospheric pressure	,,	,,
p_{12}	Steam saturation pressure at t_{12} } psychrometer at fan inlet	,,	,,
p_{17}	Steam saturation pressure at t_{17} } psychrometer at fan inlet	,,	,,
p_{18}	Pressure of fuel oil entering boiler	kgf/cm^2	lbf/in^2
p_{31}	Pressure of reheated steam at inlet } second reheater	,,	,,
p_{41}	Pressure of reheated steam at outlet } second reheater	,,	,,
P_1	Loss due to unburnt solid matter	kcal/kg	Btu/lb
P_2	Loss due to unburnt gas	,,	,,
P_3	Loss due to sensible heat of dry gas	,,	,,
P_4	Loss due to evaporation of water in the fuel and of combustion water	,,	,,
P_5	Loss due to heating of the vapour from the fuel and of the combustion water	,,	,,
P_6	Loss due to heating of the vapour of the combustion air	,,	,,
P_7	Loss due to radiation to environment	,,	,,
P_8	Residual loss	,,	,,
P_t	Total heat losses	,,	,,
	NOTE. – The corresponding percentage heat losses are represented by the symbols P'_1 to P'_8 and P'_t.		

* Throughout this ISO Recommendation "kgf/cm^2" signifies "kgf/cm^2 effective" and "lbf/in^2" signifies "lbf/in^{2}gauge" unless otherwise stated.

TABLE 2 – **Symbols and units** (*continued*)
(Alphabetical)

Symbol	Quantity	Unit – Metric system	Unit – Inch-pound system
$Q_{gr,v}$	Gross calorific value of the fuel, by mass measured at constant volume (and corrected to reference temperature t_{10})	kcal/kg	Btu/lb
Q_A	Gross calorific value of gaseous fuel, by volume, measured at constant pressure (and corrected to t_{10})	kcal/m^3	Btu/ft^3
Q	Heat output of generating unit (total)	kcal/h	Btu/h
Q_1	Heat output of generating sections and superheater	"	"
Q_2	Heat output of first reheater	"	"
Q_3	Heat output of second reheater	"	"
Q_4	Heat input in heating and atomizing fuel	"	"
r_1	Heat due to heating of the gaseous products of combustion (other than CO_2), between 0 °C and initial temperature	kcal/m$^3{}_N$	Btu/ft$^3{}_N$
r_2	Heat due to heating of the gaseous products of combustion (other than CO_2), between 0 °C and final temperature	"	"
r'_1	Heat due to heating of the CO_2 of the gases of combustion between 0 °C and initial temperature	"	"
r'_2	Heat due to heating of the CO_2 of the gases of combustion between 0 °C and final temperature	"	"
R	Thermal efficiency based on the gross calorific value of the fuel	%	%
R'	Thermal efficiency based on the net calorific value of the fuel	%	%
S	Combustible sulphur content of fuel, by mass	kg/kg	lb/lb
t_1	Feed water temperature	°C	°F
t_2	Superheated steam temperature	°C	°F
t_3	Preheated steam temperature at inlet } first reheater	°C	°F
t_4	Preheated steam temperature at outlet } first reheater	°C	°F
t_7	Superheater spray water temperature	°C	°F
t_8	First reheater spray water temperature	°C	°F
t_9	Second reheater spray water temperature	°C	°F
t_{10}	Reference temperature of the calorific value (and of the volume rating in the case of a gaseous fuel)	°C	°F
t_{11}	Temperature of fuel entering unit	°C	°F
t_{12}	Temperature of combustion air at entry to air intakes	°C	°F
t_{13}	Temperature of combustion air leaving fan	°C	°F
t_{14}	Temperature of combustion air entering additional heater	°C	°F
t_{15}	Temperature of combustion air leaving additional heater	°C	°F
t_{16}	Temperature of gases of combustion leaving last recuperator of boiler	°C	°F
t_{17}	Temperature indicated by the "wet" bulb thermometer of the psychrometer at fan inlet	°C	°F
t_{18}	Temperature of fuel entering furnace	°C	°F
t_{31}	Temperature of reheated steam at inlet } second reheater	°C	°F
t_{41}	Temperature of reheated steam at outlet } second reheater	°C	°F

TABLE 2 – **Symbols and units** (*concluded*)
(Alphabetical)

Symbol	Quantity	Unit	
		Metric system	Inch-pound system
V	Molecular volume of a gaseous fuel	m^3/kmol	ft^3/kmol
W_1	Quantity of feed water	kg/h	lb/h
W_2	Quantity of superheated steam	”	”
W_3	Quantity of reheated steam entering } first reheater	”	”
W_4	Quantity of reheated steam leaving } first reheater	”	”
W_5	Quantity of boiler blow-down	”	”
W_6	Quantity of superheated but not reheated steam	”	”
W_7	Quantity of spray water in the superheater	”	”
W_8	Quantity of spray water in the first reheater	”	”
W_9	Quantity of spray water in the second reheater	”	”
W_{10}	Quantity of water corresponding to the variation in the drum level during the test	”	”
W_{31}	Quantity of reheated steam entering } second reheater	”	”
W_{41}	Quantity of reheated steam leaving } second reheater	”	”
W_a	Total of combustion air entering system	”	”
W_g	Quantity of gases of combustion leaving system	”	”
x	Number of carbon atoms } in the C_xH_y hydrocarbons	–	–
y	Number of hydrogen atoms } in the C_xH_y hydrocarbons	–	–
Z	Proportion of inert matter (“steriles”) in the fuel by mass	kg/kg	lb/lb

6. FORM OF REPORT TO BE USED

REPORT

On the acceptance test of a . . . . Unit No. . . . .

At . . . .

Made at the request of . . . .

Under the direction of . . . .

and in the presence of . . . .

Date of test . . . .

Object of test : Compliance with specification in respect of some or all of the following requirements

(*a*) Output.

(*b*) Efficiency.

(*c*) Steam temperature.

(*d*) Dust extraction plant performance.

(*e*) Draught plant performance.

(*f*) Pulveriser performance.

(*g*) Steam purity.

Signature of engineer directing the test . . . .

Date . . . .

I. GENERAL INFORMATION AND DESIGN DATA*

A. Design performance

		Unit		Rating			
				Symbol	Normal economic	Maximum continuous	Short-term overload
001	Evaporation	kg/h	lb/h	W_2	. . .	. . .	. . .
	Pressure of steam						
002	In the saturated steam space in boiler**	kgf/cm^2***	lbf/in^2***	p_5	. . .	. . .	. . .
003	At the superheater outlet	"	"	p_2	. . .	. . .	. . .
004	Final steam temperature	°C	°F	t_2	. . .	. . .	. . .
005	Initial temperature of feed water	°C	°F	t_1	. . .	. . .	. . .
	Reheated steam quantity						
006	1st reheater	kg/h	lb/h	W_3	. . .	. . .	. . .
007	2nd reheater	"	"	W_{31}	. . .	. . .	. . .
	Pressure of steam						
008	At 1st reheater inlet	kgf/cm^2***	lbf/in^2***	p_3	. . .	. . .	. . .
009	At 1st reheater outlet	"	"	p_4	. . .	. . .	. . .
010	At 2nd reheater inlet	"	"	p_{31}	. . .	. . .	. . .
011	At 2nd reheater outlet	"	"	p_{41}	. . .	. . .	. . .
	Temperature of steam						
012	At 1st reheater inlet	°C	°F	t_3	. . .	. . .	. . .
013	At 1st reheater outlet	°C	°F	t_4	. . .	. . .	. . .
014	At 2nd reheater inlet	°C	°F	t_{31}	. . .	. . .	. . .
015	At 2nd reheater outlet	°C	°F	t_{41}	. . .	. . .	. . .
	Overall thermal efficiency						
016	Based on net calorific value	%	%	R'	. . .	. . .	. . .
017	Based on gross calorific value	%	%	R	. . .	. . .	. . .

018 Characteristics of fuels on which the above evaporation and efficiency are based . . . .

019 Brief description of the plant . . . .

020 Date first commissioned . . . .

Condition of plant at time of test

021 Hours of steaming since commissioning . . . .

022 Hours of steaming since last cleaning . . . .

023 Extent and method of cleaning . . . .

024 Condition of auxiliary equipment . . . .

* Items which are the subject of guarantees to be indicated by an asterisk.

** For forced-flow steam generators with no fixed steam and water line, this is measured at the superheater inlet.

*** Throughout this ISO Recommendation "lbf/in^2" signifies "lbf/in^2 gauge" and "kgf/cm^2" signifies "kgf/cm^2 effective" unless otherwise stated.

B. Firing equipment

(*a*) *Solid fuel*

025 Description of fuel . . . .
026 Description of stoker . . . .
027 Maker's name . . . .
028 Size of grate . . . .
. . . . . m long × . . . . m wide . . . . ft long × . . . . ft wide
= . . . . m^2 = ... ft^2
029 Power consumption of stoker motor . . . .

(*b*) *Pulverized fuel*

030 Description of fuel . . . .
031 Brief description of system . . . .
032 Method of drying . . . .
033 Number and description of pulverizers . . . .
034 Maker's rating of pulverizers . . . . . . kg/h . . . . . lb/h
035 Specified size grading at above rating . . . .
036 System of transporting pulverized fuel . . . .
037 Number, description and arrangement of burners . . . .

Power consumption of
038 – pulverizer . . . .
039 – exhauster . . . .
040 – classifier . . . .

(*c*) *Oil fuel*

041 Type of fuel . . . .
042 Method of fuel preparation . . . .
043 Method of atomizing fuel . . . .
044 Number, description and arrangement of burners . . . .
045 Maker's rating of burner(s), total . . . . . . kg/h . . . . . lb/h
(at a temperature of . . . . . . °C . . . . . . °F
and a pressure of . . . . . kgf/cm^2 . . . . lbf/in^2)
046 Power or steam consumption for oil atomization . . . .

(*d*) *Gaseous fuel*

047 Description of fuel . . . .
048 Number, description and arrangement of burners . . . .
049 Maker's rating of burner(s) total . . . . . . kg/h . . . . . lb/h
(at a temperature of . . . . . . °C . . . . . . °F
and a pressure of . . . . kgf/cm^2 . . . . lbf/in^2)

(*e*) *Waste heat*

050 Origin of waste heat . . . .
051 Nature of gas . . . .
052 Method and position of introduction . . . .

C. Furnace

053	Type of furnace		
054	Type of furnace bottom		
055	Maker's name		
056	Method of cooling furnace walls		
057	Furnace volume*	m^3	ft^3

D. Evaporating section

058	Type		
059	Maker's name		
060	Heating surface	m^2	ft^2
	(including water walls)	m^2	ft^2
061	Type of circulation		
062	Power consumption of circulating pumps		

E. Superheater

063	Type of superheater		
064	Maker's name		
	Heating surface		
065	– Primary**	m^2	ft^2
066	– Secondary**	m^2	ft^2

F. Main steam temperature control

067	Type		
068	Maker's name		
069	Location		
070	Cooling surface (where applicable)	m^2	ft^2
071	Source of spray water		
072	Tolerance on steam temperature		
073	Load range over which steam temperature is to be maintained	kg/h	lb/h

G. Steam reheater

074	Type of steam reheater		
075	Maker's name		
076	Location		
	Heating surface		
077	– First reheater	m^2	ft^2
078	– Second reheater	m^2	ft^2

* Basis of computation to be stated.

** The terms "primary" and "secondary" relate to the position in the feed or steam circuit.

H. Reheated steam temperature control

079 Type . . . .
080 Maker's name . . . .
081 Location . . . .
082 Cooling surface (where applicable) . . . . m^2 . . . . . . ft^2
083 Source of spray water . . . .
084 Tolerance on steam temperature . . . .
085 Load range over which steam temperature is to be maintained . . . . kg/h . . . . . lb/h

I. Economizer

086 Type of economizer . . . .
087 Maker's name . . . .

Heating surface
088 – Primary* . . . . m^2 . . . . . . ft^2
089 – Secondary* . . . . m^2 . . . . . . ft^2
090 Power consumption of circulating pump (if any) . . . .

J. Air heater

091 Type of air heater . . . .
092 Maker's name . . . .

Heating surface
093 – Low temperature (air) . . . . m^2 . . . . . . ft^2
094 – High temperature (air) . . . . m^2 . . . . . . ft^2
095 Power consumption of air heater . . . .

K. Dust collecting plant

096 Type . . . .
097 Maker's name . . . .
098 Draught loss . . . . mmH_2O . . . inH_2O
099 Power consumption of dust collecting plant . . . .
100 Efficiency of collection
The draught loss and the efficiency
are given for a flue gas discharge rate at s.t.p. of . . . . m^3/h . . . . . ft^3/h
corresponding to an evaporation rate of . . . . kg/h . . . . . lb/h

L. Draught plant

101 Method of producing draught . . . .
102 Height of chimney above . . . . m . . . . . . ft
103 Area of chimney at bottom . . . . m^2 . . . . . . ft^2
104 Area of chimney at top . . . . m^2 . . . . . . ft^2
105 Number of boilers connected to chimney . . . .

* The terms "primary" and "secondary" relate to the position in the feed or steam circuit.

Induced draught fans
106 Description . . . .
107 Power consumption . . . .

Forced draught fans
108 Description . . . .
109 Power consumption . . . .

Secondary air fans
110 Description . . . .
111 Power consumption . . . .

Other draught plant (if any)
112 Description . . . .
113 Power consumption . . . .

M. Automatic combustion control

114 Description (e.g. function, type, make) . . . .

N. Methods of cleaning heating surfaces (gas side) on load

115 Boiler, including furnace . . . .

Superheater
116 – Primary* . . . .
117 – Secondary* . . . .

Steam reheater
118 – First reheater . . . .
119 – Second reheater . . . .

Economizer
120 – Primary* . . . .
121 – Secondary* . . . .

Air heater
122 – Low temperature (air) . . . .
123 – High temperature (air) . . . .

* The terms "primary" and "secondary" relate to the position in the feed or steam circuit.

II. METHODS OF MEASUREMENT AND SAMPLING AND ANALYSIS EMPLOYED

A. Methods of measurement

151 Method of determining fuel consumption . . . .

152 Method of determining the quantity of riddlings, mill rejects,
ash and dust . . . .

Method of determining water quantity

153 – at entry to unit . . . .

154 – to spray type attemperator . . . .

155 – to blow-down . . . .

156 – to and from slag tank . . . .

157 – to and from ash hopper . . . .

Method of determining steam quantity

158 – Saturated steam . . . .

159 – Superheated steam . . . .

160 – Reheated steam . . . .

161 – Methods of measuring temperatures . . . .

162 – Method of measuring pressures and draughts . . . .

163 – Method of measuring the energy consumption of the auxiliaries . . . .

B. Methods of sampling and analysis

164 Method of sampling and analysing fuel . . . .

165 Method of sampling and analysing ash . . . .

166 Method of sampling and analysing riddlings or mill rejects . . . .

167 Method of sampling and analysing dust . . . .

168 Methods of sampling and analysing flue gases . . . .

III. MEAN OBSERVATIONS AND FUEL DATA

(adjusted for instrumental corrections, see clause 5.1)

A. General

201 Test made at rating of . . . .

202 Date and duration of test . . . .

B. Water	Unit		Symbol	Value
Feed entering unit (at economizer if fitted)*				
203 Quantity	kg/h	lb/h	W_1	. . . .
204 Temperature	°C	°F	t_1	. . . .
205 Pressure	kgf/cm²	lbf/in²	p_1	. . . .
206 Enthalpy	kcal/kg	Btu/lb	h_1	. . . .
Feed leaving secondary economizer (if fitted)*				
207 Temperature	°C	°F	—	. . . .
208 Pressure	kgf/cm²	lbf/in²	—	. . . .
209 Enthalpy	kcal/kg	Btu/lb	—	. . . .
Water in drum				
210 Pressure	kgf/cm²	lbf/in²	p_5	. . . .
211 Enthalpy	kcal/kg	Btu/lb	h_5	. . . .
212 Level at beginning of test**	mm	in	—	. . . .
213 Level at end of test**	mm	in	—	. . . .
214 Increase*** in drum content	kg	lb	—	. . . .
215 Average rate of increase in drum content during test period	kg/h	lb/h	W_{10}	. . . .
216 Average rate of blow-down during test period	"	"	W_5	. . . .
Spray water for main steam temperature control				
217 Quantity	kg/h	lb/h	W_7	. . . .
218 Temperature	°C	°F	t_7	. . . .
219 Pressure	kgf/cm²	lbf/in²	p_7	. . . .
220 Enthalpy	kcal/kg	Btu/lb	h_7	. . . .
Spray water for steam temperature control of first reheater				
221 Quantity	kg/h	lb/h	W_8	. . . .
222 Temperature	°C	°F	t_8	. . . .
223 Pressure	kgf/cm²	lbf/in²	p_8	. . . .
224 Enthalpy	kcal/kg	Btu/lb	h_8	. . . .
Spray water for steam temperature control of second reheater				
225 Quantity	kg/h	lb/h	W_9	. . . .
226 Temperature	°C	°F	t_9	. . . .
227 Pressure	kgf/cm²	lbf/in²	p_9	. . . .
228 Enthalpy	kcal/kg	Btu/lb	h_9	. . . .

* Excluding attemperating spray water.

** Datum level to be stated in Report.

*** This figure is negative if the drum content decreases.

C. Steam	Unit		Symbol	Value
Entering primary superheater*				
229 Temperature	°C	°F	–	. . .
230 Pressure	kgf/cm^2	lbf/in^2	–	. . .
231 Dryness fraction	%	%	–	. . .
232 Enthalpy	kcal/kg	Btu/lb	–	. . .
Leaving primary superheater*				
233 Quantity	kg/h	lb/h	–	. . .
234 Temperature	°C	°F	–	. . .
235 Pressure	kgf/cm^2	lbf/in^2	–	. . .
236 Enthalpy	kcal/kg	Btu/lb	–	. . .
Leaving attemperator (if any)				
237 Temperature	°C	°F	–	. . .
238 Pressure	kgf/cm^2	lbf/in^2	–	. . .
239 Enthalpy	kcal/kg	Btu/lb	–	. . .
Entering secondary superheater*				
240 Temperature	°C	°F	–	. . .
241 Pressure	kgf/cm^2	lbf/in^2	–	. . .
242 Enthalpy	kcal/kg	Btu/lb	–	. . .
Leaving unit (i.e. leaving final superheater where no following attemperator)				
243 Quantity	kg/h	lb/h	W_2	. . .
244 Temperature	°C	°F	t_2	. . .
245 Pressure	kgf/cm^2	lbf/in^2	p_2	. . .
246 Enthalpy	kcal/kg	Btu/lb	h_2	. . .
Entering first reheater, before attemperation (if any)				
247 Quantity**	kg/h	lb/h	W_3	. . .
248 Temperature	°C	°F	t_3	. . .
249 Pressure	kgf/cm^2	lbf/in^2	p_3	. . .
250 Enthalpy	kcal/kg	Btu/lb	h_3	. . .
Leaving first reheater				
251 Quantity	kg/h	lb/h	W_4	. . .
252 Temperature	°C	°F	t_4	. . .
253 Pressure	kgf/cm^2	lbf/in^2	p_4	. . .
254 Enthalpy	kcal/kg	Btu/lb	h_4	. . .
Entering second reheater, before attemperation (if any)				
255 Quantity	kg/h	lb/h	W_{31}	. . .
256 Temperature	°C	°F	t_{31}	. . .
257 Pressure	kgf/cm^2	lbf/in^2	p_{31}	. . .
258 Enthalpy	kcal/kg	Btu/lb	h_{31}	. . .
Leaving second reheater				
259 Quantity	kg/h	lb/h	W_{41}	. . .
260 Temperature	°C	°F	t_{41}	. . .
261 Pressure	kgf/cm^2	lbf/in^2	p_{41}	. . .
262 Enthalpy	kcal/kg	Btu/lb	h_{41}	. . .

* The terms "primary" and "secondary" relate to the position in the feed or steam circuit.

** The quantity $W_3 = W_2 - W_6$, W_6 being evaluated in accordance with clause 4.10 of this ISO Recommendation.

D. Fuel and firing equipment

(*a*) *Solid fuel*

Description of fuel

263 Market description . . . .
264 Supplier's classification . . . .
265 Seam and colliery, or other indication of origin . . . .

Analysis of fuel, at entry to the system under test

266 Screen analysis

Proximate analysis

No.	Item	Unit	Before conditioning*	After conditioning*
267	Moisture (air dried sample . . . %)	%	. . . . . .	. . . . . .
268	Volatile matter	%	. . . . . .	. . . . . .
269	Fixed carbon	%	. . . . . .	. . . . . .
270	Ash**	%	. . . . . .	. . . . . .

Ultimate analysis

No.	Item	Unit	Symbol***	As fired*	Dry	Dry ash-free
271	Moisture	%	$E \times 100$	. . .	—	—
272	Ash	%	$Z \times 100$	. . .	. .	. . . . . .
273	Carbon	%	$C \times 100$	. . .	. .	. . . . . .
274	Hydrogen	%	$H \times 100$	. . .	. .	. . . . . .
275	Nitrogen	%	$N \times 100$	. . .	. .	. . . . . .
276	Sulphur	%	$S \times 100$	. . .	. .	. . . . . .
277	Oxygen (by difference)	%	$O \times 100$	. . .	. .	. . . . . .
				100.0	100.0	100.0

No.	Item	Unit		Symbol	Value
	*Calorific value of fuel at entry to the system under test**				
278	Gross	kcal/kg	Btu/lb	H_1	. . .
279	Net	kcal/kg	Btu/lb	H_2	. . .
	(1) *Mechanical stokers*				
280	Rate of firing*	kg/h	lb/h	C_1	. . .
281	Fuel fired per m² or per ft² of grate area	kg/h	lb/h	—	. . .
282	Heat release per m² or per ft² of grate area	kcal/h	Btu/h	—	. . .

283 Method and time of cleaning grates . . . .

No.	Item	Unit		Symbol	First control hour	Last hour of test
284	Average thickness of feed (chain or travelling grate)	cm	in	—	. . .	. . .
285	Speed of chain or travelling grate	m/h	ft/h	—	. . .	. . .
286	Speed of rotary feeder	rev/h	rev/h	—	. . .	. . .
287	Speed of worm	rev/h	rev/h	—	. . .	. . .
288	Number of ram strokes per hour or speed of ram	strokes/h	strokes/h	—	. . .	. . .
290	Power used to operate mechanical stokers	kW	kW	—	. . .	. . .

* If steam and/or water conditioning is used the rate of firing, the analysis and the calorific value should be adjusted to the moisture content after conditioning.

** An analysis of the ash may be required.

*** Symbol applies to "as fired" condition.

		Unit		Symbol	Value
	(2) *Pulverized fuel*				
	Fuel weighed				
291	Total	kg/h	lb/h	–	. . .
292	Mill No. . . .	,,	,,	–	. . .
293	Mill No. . . .	,,	,,	–	. . .
294	Mill No. . . .	,,	,,	–	. . .
	Mill rejects				
295	Total	kg/h	lb/h	–	. . .
296	Mill No. . . .	,,	,,	–	. . .
297	Mill No. . . .	,,	,,	–	. . .
298	Mill No. . . .				
299	Rejects as proportion of fuel fired	%	%	–	. . .
300	Proportions of combustibles in rejects	%	%	–	. . .
	Calorific value of mill rejects				
301	Gross*	kcal/kg	Btu/lb	–	. . .
302	Net*	,,	,,	–	. . .
303	Rate of firing	kg/h	lb/h	C_1	. . .

$$= \text{Item 291} - \frac{\text{Item 295} \times \text{Item 300} \times 80.8^{**}}{\text{Item 278 (or 279)}}$$

$$\text{or} = \text{Item 291} - \frac{\text{Item 295} \times \text{Item 301 (or 302)}}{\text{Item 278 (or 279)}}$$

304 Speed of setting of classifier . . . . rev/min

*Size grading of pulverized fuel****

305 Retained on 300 µm (state equivalent sieve mesh used) . . . . %
306 Passing 150 µm . . . . %
307 Passing 75 µm . . . . %

Grindability

308 Test method . . . .
309 Index . . . .

Fusibility of ash

(to be recorded in cases of cyclone and wet bottom furnaces and in other cases where required by the parties to the test)

		Oxidizing atmosphere		Reducing atmosphere	
			°C		°C
310 311	Deformation temperature	310		311	
312 313	Hemisphere temperature	312		313	
314 315	Flow temperature	314		315	

* Delete item which does not apply.
** For British units, replace factor 80.8 by 145.4.
*** Or milled peat.

		Unit		Symbol	Value
	Coal dryer – moisture in fuel				
316	At dryer inlet	%	%	–	. . .
317	At dryer outlet	%	%	–	. . .
	Flue gas heated dryer – temperature of gas				
318	At dryer inlet	°C	°F	–	. . .
319	At dryer outlet	°C	°F	–	. . .
	Independently fired dryer				
320	Fuel used	kg/h	lb/h	C_{11}	. . .
	Calorific value of fuel, as weighed				
321	Gross	kcal/kg	Btu/lb	–	. . .
322	Net	"	"	–	. . .
323	Heat expended in drying fuel	"	"	–	. . .
324	Temperature of gases at outlet	°C	°F	–	. . .
	Analysis of gases				
325	Carbon dioxide	%	%	–	. . .
326	Carbon monoxide (if any)	%	%	–	. . .
327	Oxygen and nitrogen (by difference)	%	%	–	. . .
					100.0
	Ashpit refuse (1)				
328	Quantity	kg/h	lb/h	D_6	. . .
329	Per cent combustible	%	%	i_6	. . .
	(*b*) *Oil fuel*				
330	Market description				
331	Classification (2)				
	Ultimate analysis, at entry to system under test				
332	Moisture	%	%	$E \times 100$	. . .
333	Ash (3)	%	%	$Z \times 100$	. . .
334	Carbon	%	%	$C \times 100$	. . .
335	Hydrogen	%	%	$H \times 100$	. . .
336	Sulphur	%	%	$S \times 100$	. . .
337	Oxygen and nitrogen (by difference)	%	%	–	. . .
					100.0
338	Relative density of oil at 60/60 °F, or			–	. . .
339	Density of oil at 15.5 °C	g/ml	g/ml	–	. . .
340	Viscosity (Redwood No. 1) at 60 °F (4)	cSt	cSt	–	. . .
341	Viscosity by . . . viscometer at 15.5 °C (4)	cSt	cSt	–	. . .
342	Flash point	°C	°F	–	. . .
343	Specific heat of oil (5)			f	. . .
	Calorific value of fuel, at entry to system under test				
344	Gross	kcal/kg	Btu/lb	H_1	. . .
345	Net	"	"	H_2	. . .

(1) This item is included for those cases where it may be desirable to obtain data on the performance of a particular dryer. In some cases it may be necessary to include an appropriate loss in the heat account.

(2) According to the appropriate classification for each country.

(3) When required, an analysis of the ash shall be made.

(4) Other units may be employed.

(5) Unless specially determined, this should be taken as
0.43 for gas oil (4 cSt)
0.41 for light fuel oil (30–50 cSt)
0.40 for medium-heavy fuel oil (120 cSt)
0.39 for heavy or very heavy fuel oil (220–250 cSt)

		Unit		Symbol	Value
	Steam used in heater				
346	Quantity	kg/h	lb/h	–	. . .
347	Pressure	kgf/cm^2	lbf/in^2	–	. . .
348	Temperature	°C	°F	–	. . .
349	Rate of firing	kg/h	lb/h	C_1	. . .
350	Temperature of oil as weighed	°C	°F	t_{11}	. . .
	Oil as delivered to burner				
351	Pressure	kgf/cm^2	lbf/in^2	p_{18}	. . .
352	Temperature	°C	°F	t_{18}	. . .
353*	Temperature of drains from heater	°C	°F	–	. . .
354*	Enthalpy of steam at heater inlet	kcal/kg	Btu/lb	–	. . .
355*	Enthalpy of drains at heater outlet	kcal/kg	Btu/lb	–	. . .
356	Power used to operate oil pump	kW	kW	–	. . .
	Air or steam for atomizing, as delivered to burner				
357	Quantity	kg/h	lb/h	–	. . .
358	Pressure	kgf/cm^2	lbf/in^2	–	. . .
359	Temperature	°C	°F	–	. . .
360	Heat used in atomizing oil on basis of air at t_{12}	kcal/h	Btu/h	–	. . .
361	Power used to operate air compressor	kW	kW	–	. . .
	(*c*) *Gaseous fuel and/or waste gas from separate source***				
	Rate of firing				
362	Volume	m^3/h	ft^3/h	C_2	. . .
363	Mass	kg/h	lb/h	C_1	. . .
	Gas as measured				
364	Pressure	kgf/cm^2	lbf/in^2	–	. . .
365	Temperature	°C	°F	–	. . .
	Gas as fired				
366	Pressure	kgf/cm^2	lbf/in^2	–	. . .
367	Temperature	°C	°F	–	. . .
368	Barometric pressure	mmHg	inHg	–	. . .
	Analysis of dry gas, percentage by volume				
369	Carbon monoxide (CO)	%	%	–	. . .
370	Carbon dioxide (CO_2)	%	%	–	. . .
371	Methane (CH_4)	%	%	–	. . .
372	Ethane (C_2H_6)	%	%	–	. . .
373	Propane (C_3H_8), Butane (C_4H_{10}), Pentane (C_5H_{12}) } to be expressed as ethane or propane	%	%	–	. . .
374	C_xH_y	%	%	*e*	. . .
375	Others	%	%	–	. . .
376	Hydrogen sulphide (H_2S)	%	%	–	. . .
377	Hydrogen (H_2)	%	%	*d*	. . .
378	Oxygen (O_2)	%	%	–	. . .
379	Nitrogen (N_2)	%	%	–	. . .
380	Carbon content calculated per unit mass of gas, as fired	kg/kg	lb/lb	*C*	. . .
381	Sulphur content calculated per unit mass of gas, as fired	kg/kg	lb/lb	*S*	. . .

* These items only to be recorded when the heater is part of the system under test.

** For waste-heat firing the items appropriate to the gas used are to be entered in this section. For mixed gaseous fuel and waste gas firing each item is to be calculated for the mixture as fired.

		Unit		Symbol	Value
	Saturated gas				
382	Pressure	kgf/cm²	lbf/in²	–	. . .
383	Temperature	°C	°F	–	. . .
384	Relative density (air = 1)			–	. . .
	Moisture content				
385	As fired	g/m³	grains/ft³	–	. . .
386	Calculated per unit mass of dry gas	kg/kg	lb/lb	–	. . .
	Calorific value of saturated gas, as analysed, at 1 standard atmosphere and 25 °C (77 °F)				
387	Gross	kcal/m³	Btu/ft³	–	. . .
388	Gross	kcal/kg	Btu/lb	–	. . .
389	Net	”	”	–	. . .
	Calorific value, as fired				
390	Gross	kcal/m³	Btu/ft³	Q_A	. . .
391	Net	”	”	Q_B	. . .
392	Gross	kcal/kg	Btu/lb	H_1	. . .
393	Net	”	”	H_2	. . .
394	Mean specific heat*				
E.	**Air**				
	Ambient conditions				
395	Pressure**	mmHg	inHg	p_{11}	. . .
396	Temperature	°C	°F	–	. . .
397	Humidity	%	%	K	. . .
398	Temperature at entry to air intakes***	°C	°F	t_{12}	. . .
399	Humidity per unit mass of dry air	kg/kg	lb/lb	K_2	. . .
	Entry to forced draught intake				
400	Temperature	°C	°F	–	. . .
401	Pressure	mmH_2O	inH_2O	–	. . .
	Entry to low temperature air heater				
402	Temperature	°C	°F	–	. . .
403	Pressure	mmH_2O	inH_2O	–	. . .
	Exit from low temperature air heater				
404	Temperature	°C	°F	–	. . .
405	Pressure	mmH_2O	inH_2O	–	. . .
	Entry to high temperature air heater				
406	Temperature	°C	°F	t_{14}	. . .
407	Pressure	mmH_2O	inH_2O	–	. . .
	Exit from high temperature air heater				
408	Temperature	°C	°F	t_{15}	. . .
409	Pressure	mmH_2O	inH_2O	–	. . .
	Tempering air to mills				
410	Temperature	°C	°F	–	. . .
411	Pressure	mmH_2O	inH_2O	–	. . .

* This item may be calculated proportionately from the specific heats of the fundamental constituents of the gaseous fuel.

** In circumstances of exceptional climate or altitude, or as required by clause 4.18 of this ISO Recommendation.

*** This temperature should be measured at the point at which the air enters the system of the unit.

		Unit		Symbol	Value
	Entry to mills, stoker or furnace				
412	Temperature	°C	°F	–	. . .
413	Pressure	mmH_2O	inH_2O	–	. . .
	Exit from mills				
414	Temperature	°C	°F	–	. . .
415	Pressure	mmH_2O	inH_2O	–	. . .
	Primary air ducts				
416	Temperature	°C	°F	–	. . .
417	Pressure	mmH_2O	inH_2O	–	. . .
	Secondary air ducts				
418	Temperature	°C	°F	–	. . .
419	Pressure	mmH_2O	inH_2O	–	. . .
	Tertiary air ducts				
420	Temperature	°C	°F	–	. . .
421	Pressure	mmH_2O	inH_2O	–	. . .
422	Furnace draught at . . . level*	mmH_2O	inH_2O	–	. . .

F. **Flue gases**

Analysis temperature and pressure of gases entering and leaving the following heat exchangers and dust extraction plant. (Locations to be inserted when this information is required).

		A	B	C	D		E	
		CO	O_2	CO_2	Temperature		Pressure	
		%	%	%	°C	°F	mmH_2O	inH_2O
423	. . . .	. . . .	. . . .	. . . .	.	.	. .	. .
424	. . . .	. . . .	. . . .	. . . .	.	.	. .	. .
425	. . . .	. . . .	. . . .	. . . .	.	.	. .	. .
426	. . . .	. . . .	. . . .	. . . .	.	.	. .	. .

		Unit		Symbol	Value
	Exit of low temperature air heater (or economizer in the absence of an air heater) :				
427	Temperature	°C	°F	t_{16}	. . .
428	Pressure	mmH_2O	inH_2O	–	. . .
	Analysis of gas at exit of low temperature air heater, percentage by volume				
429	Carbon dioxide (CO_2)	%	%	a_1	. . .
430	Carbon monoxide (CO)	%	%	a_2	. . .
431	Methane (CH_4)	%	%	a_3	. . .
432	Oxygen (O_2)	%	%	a_4	. . .
433	Sulphur dioxide (SO_2)	%	%	a_5	. . .
434	Nitrogen (N_2)	%	%	a_6	. . .
435	Hydrogen (H_2)	%	%	a_7	. . .
436	Hydrocarbons (C_nH_m)	%	%	a_8	. . .
	Entry to induced draught fan				
437	Temperature	°C	°F	–	. . .
438	Pressure	mmH_2O	inH_2O	–	. . .
	Entry to chimney				
439	Temperature	°C	°F	–	. . .
440	Pressure	mmH_2O	inH_2O	–	. . .

* As the pressure varies at different heights the level at which this reading is taken should be stated.

		Unit		Symbol	Value
G.	**Control valves and dampers**				
441	Attemperator by-pass	% open	% open	—	. . .
442	Spray water for main steam temperature control	% open	% open	—	. . .
443	Spray water for reheated steam temperature control	% open	% open	—	. . .
444	Primary air tempering control	% open	% open	—	. . .
445	Secondary air tempering control	% open	% open	—	. . .
446	Tertiary air tempering control	% open	% open	—	. . .
447	Other controls	% open	% open	—	. . .
H.	**Residues**				
448	Condition of residue in ash-pit (powder, slag or other form) . . .				
	Ash and clinkers				
449	Quantity	kg/h	lb/h	D_1	. . .
450	As proportion by mass of fuel (dry basis)	%	%	—	. . .
451	Combustible content	%	%	i_1	. . .
452	Combustible content per unit mass of fuel	kg/kg	lb/lb	—	. . .
453	Temperature as discharged	°C	°F	—	. . .
454	Specific heat*			—	. . .
	Slag in slag tank				
455	Quantity	kg/h	lb/h	D_1	. . .
456	As proportion by mass of fuel (dry basis)	%	%	—	. . .
457	Combustible content	%	%	i_1	. . .
458	Combustible content per unit mass of fuel	kg/kg	lb/lb	—	. . .
	Dust from				
459	Quantity	kg/h	lb/h	D_2	. . .
460	As proportion by mass of fuel (dry basis)	%	%	—	. . .
461	Combustible content	%	%	i_2	. . .
462	Combustible content per unit mass of fuel	kg/kg	lb/lb	—	. . .
463	Temperature as discharged	°C	°F	—	. . .
464	Specific heat			—	. . .
	Dust from				
465	Quantity	kg/h	lb/h	D_3	. . .
466	As proportion by mass of fuel (dry basis)	%	%	—	. . .
467	Combustible content	%	%	i_3	. . .
468	Combustible content per unit mass of fuel	kg/kg	lb/lb	—	. . .
469	Temperature as discharged	°C	°F	—	. . .
470	Specific heat			—	. . .
	Riddlings				
471	Quantity	kg/h	lb/h	D_5	. . .
472	As proportion by mass of fuel (dry basis)	%	%	—	. . .
473	Combustible content	%	%	i_5	. . .
474	Combustible content per unit mass of fuel	kg/kg	lb/lb	—	. . .

* To be assumed as 0.16 kcal/(kg.°C) if not determined.

J. Water-filled ash hopper or slag tank or ash quenching

	Unit		Symbol	Value
Water inlet				
475 Temperature	°C	°F	–	. . .
476 Quantity	kg/h	lb/h	–	. . .
Water outlet				
477 Temperature	°C	°F	–	. . .
478 Quantity	kg/h	lb/h	–	. . .
Quenching spray water				
479 Temperature	°C	°F	–	. . .
480 Quantity	kg/h	lb/h	–	. . .

K. Power for auxiliaries

	For information only		Unit	Symbol	Value
	Volts	Ampères			
481 Induced draught fans	. . .	. . .	kW	–	. . .
482 Forced draught fans	. . .	. . .	kW	–	. . .
483 Secondary air fans	. . .	. . .	kW	–	. . .
484 Other draught plant (to be listed)	. . .	. . .	kW	–	. . .

	Unit	Symbol	Value
485 Total power used to produce draught	kW	–	. . .
486 Stokers	kW	–	. . .
487 Air heaters	kW	–	. . .
488 Other auxiliaries (to be listed)	kW	–	. . .

Power used in preparing, transporting and firing pulverized fuel

	Mill	Mill	Mill . . . .*
489 Pulverizers	kW	kW	kW . . . .
490 Primary fans or exhausters	kW	kW	kW . . . .
491 Classifiers	kW	kW	kW . . . .
492 Feeders and/or conveyors	kW	kW	kW . . . .

	Unit	Symbol	Value
493 Rotary dryer	kW	–	. . .
494 Air compressor and fuel transfer plant	kW	–	. . .
495 Other auxiliaries	kW	–	. . .
496 Total power used in pulverized fuel plant	kW	–	. . .
497 Total power for auxiliaries	kW	–	. . .

* Provision may be required for more than three mills.

IV. COMPUTATION OF HEAT ACCOUNT

501 Steam tables used . . . .

		kcal/h	Btu/h
A.	**Heat output**		
502	Heat in feed water supplied to unit per hour	,,	,,
503	Heat in superheater spray water per hour	,,	,,
504	Heat in blow-down per hour	,,	,,
505	Heat in water retained in drum by rise in water level, per hour	,,	,,
506	Heat in steam delivered at superheater outlet, per hour	,,	,,
507	Heat output of generating sections and superheater, per hour	,,	,,
508	Heat in steam entering first reheater, before attemperation if any, per hour	,,	,,
509	Heat in first reheater spray water, per hour	,,	,,
510	Heat in steam leaving first reheater, per hour	,,	,,
511	Heat output of first reheater, per hour	,,	,,
512	Heat in steam entering second reheater, before attemperation if any, per hour	,,	,,
513	Heater in second reheater spray water, per hour	,,	,,
514	Heat in steam leaving second reheater, per hour	,,	,,
515	Heat output of second reheater, per hour	,,	,,
516	Total heat output of complete unit, per hour	,,	,,
517*	Heat used in heating and atomizing oil, per hour	,,	,,
518*	Net total heat output of complete unit, per hour	,,	,,
519	Heat added to combustion air from separate source, per hour	,,	,,

NOTE. – In accordance with clause 2.1 of this ISO Recommendation any heat supplied to the unit from a separate source must be deducted from the heat output in computing the thermal efficiency. Item 517 provides for the heat used in heating and atomizing oil; in addition, the heat added to the combustion air, if from a separate source, must also be computed and deducted.

* These items apply in cases of oil firing only.

NOTES

501 See clause 3.3 (point 15) of this ISO Recommendation.

502 Item 203 × Item 206 $= W_1 h_1$

503 Item 217 × Item 220 $= W_7 h_7$

504 Item 216 × Item 211 $= W_5 h_5$

505 Item 215 × Item 211 $= W_{10} h_5$

506 [Item 203 + Item 217 − (Item 216 + Item 215)] × Item 246
$= [(W_1 + W_7 - (W_5 + W_{10})] h_2$ $= W_2 h_2$

507 Item 506 + Item 505 + Item 504 − Item 503 − Item 502
$= W_1 (h_2 - h_1) + W_7 (h_2 - h_7) - (W_5 + W_{10}) (h_2 - h_5)$ $= Q_1$ *

508 Item 247 × Item 250 $= W_3 h_3$

509 Item 221 × Item 224 $= W_8 h_8$

510 Item 251 × Item 254 $= (W_3 + W_8) h_4$

511 Item 510 − (Item 509 + Item 508)
$= W_3 (h_4 - h_3) + W_8 (h_4 - h_8)$ $= Q_2$

512 Item 255 × Item 258 $= W_{31} h_{31}$

513 Item 225 × Item 228 $= W_9 h_9$

514 Item 259 × Item 262 $= (W_{31} + W_9) h_{41}$

515 Item 514 − (Item 513 + Item 512)
$= W_{31} (h_{41} - h_{31}) + W_9 (h_{41} - h_9)$ $= Q_3$

516 Item 507 + Item 511 + Item 515 $= Q (= Q_1 + Q_2 + Q_3)$

517 Item 349 × Item 343 × (Item 352 − Item 350) + Item 360 $= Q_4$

518 Item 516 − Item 517 $= Q (= Q_1 + Q_2 + Q_3 - Q_4)$

519 Mass of air derived from external source × *enthalpy added in* external air heater**

* In the event of the superheated steam quantity, but not the feed-water quantity, having been measured, item 507 can be written

$$W_2 (h_2 - h_1) + (W_5 + W_{10}) (h_5 - h_1) - W_7 (h_7 - h_1) = Q_1$$

(Using the relationship $W_1 = W_2 + (W_5 + W_{10}) - W_7$).

** In cases where the combustion air is not directly measured the method given in Annex A of this ISO Recommendation may be used for calculation.

B.	**Heat input**	kcal/h	Btu/h
520	Mechanical stokers, heat input per hour	,,	,,
521	Pulverized fuel, heat input per hour	,,	,,
522	Oil fuel, heat input per hour	,,	,,
523	Gaseous fuel and/or waste gas, heat input per hour	,,	,,
524	Total heat input per hour	,,	,,

NOTE. – In certain cases it may not be possible to determine the heat input by the computations given above.

In such cases the heat input shall be determined from the heat output computed in accordance with Section IV A., page 51, plus the sum of the losses computed according to Sections IV C to H inclusive on the following pages.

NOTES

520	Item 280 × Item 278 (or Item 279)*	$F_c = C_1H_1$ (or C_1H_2)
521	Item 303 × Item 278 (or Item 279)* + Item 323**	$F_c = C_1H_1$ (or C_1H_2)
522	Item 349 × Item 344 (or Item 345)*	$F_c = C_1H_1$ (or C_1H_2)
523	Item 363 × Item 392 (or Item 393)*	$F_c = C_1H_1$ (or C_1H_2)
	or Item 362 × Item 390 (or Item 391)*	$F_c = C_2H_1$ (or C_2H_2)

524 The sum of all or part of the previous items as applicable in cases of mixed fuel firing.

* Items in brackets apply if thermal efficiency is required to be expressed on the net calorific value of the fuel.

** Applies in cases where heat is supplied by an independently fired dryer.

C. Losses due to solid residue

601	Calorific value of carbon	kcal/kg	Btu/lb
	Coarse ash or slag		
602	Combustible matter in coarse ash or slag	%	%
603	Mass of dry coarse ash or slag per unit mass of fuel	kg/kg	lb/lb
604	Heat lost by combustible in coarse ash or slag	kcal/kg	Btu/lb
605	Heat loss due to coarse ash or slag	%	%
	Coarse dust and grit		
606	Combustible matter in coarse dust and grit	%	%
607	Mass of dry coarse dust and grit per unit mass of fuel	kg/kg	lb/lb
608	Heat lost by combustible in coarse dust and grit	kcal/kg	Btu/lb
609	Heat loss due to coarse dust and grit	%	%
	Fine dust (fly ash)		
610	Combustible matter in fine dust	%	%
611	Mass of dry fine dust per unit mass of fuel (see clause 4.14)	kg/kg	lb/lb
612	Heat lost by combustible in fine dust	kcal/kg	Btu/lb
613	Heat loss due to fine dust*	%	%

* See also section B.6.

NOTES

601	Normally 8080 kcal/kg* or 14 540 Btu/lb	H_3
602	Item 451 or 457	i_1
603	$\frac{\text{Item 450 or 456}}{100}$	D_1/C_1
604	$\frac{\text{Item 601} \times \text{Item 602} \times \text{Item 603}}{100}$	$\frac{D_1 \times i_1 \times H_3}{C_1 \times 100}$
605	$\frac{\text{Item 604} \times 100}{\text{Item 278 or Item 279}}$	$\frac{D_1 \times i_1 \times H_3}{C_1 \times H_1 \text{ or } H_2}$
606	Item 461	i_2
607	$\frac{\text{Item 460}}{100}$	D_2/C_1
608	$\frac{\text{Item 601} \times \text{Item 606} \times \text{Item 607}}{100}$	$\frac{D_2 \times i_2 \times H_3}{C_1 \times 100}$
609	$\frac{\text{Item 608} \times 100}{\text{Item 278 or Item 279}}$	$\frac{D_2 \times i_2 \times H_3}{C_1 \times H_1 \text{ or } H_2}$
610	Item 467	i_3
611	$\frac{\text{Item 466}}{100}$	D_3/C_1
612	$\frac{\text{Item 601} \times \text{Item 610} \times \text{Item 611}}{100}$	$\frac{D_3 \times i_3 \times H_3}{C_1 \times 100}$
613	$\frac{\text{Item 612} \times 100}{\text{Item 278 or Item 279}}$	$\frac{D_3 \times i_3 \times H_3}{C_1 \times H_1 \text{ or } H_2}$

* If the greater part of the unburned residue is in the form of partly distilled coal and not of amorphous carbon, H_3 is replaced by the calorific value (measured by calorimetric bomb and calculated on the dry basis) of this partly distilled coal.

C. **Losses due to solid residue** (*continued*)

Riddlings

614	Combustible matter in riddlings	%	%
615	Mass of dry riddlings per unit mass of fuel	kg/kg	lb/lb
616	Heat lost by combustible in riddlings	kcal/kg	Btu/lb
617	Heat loss due to riddlings	%	%
	Ash from independently fired dryer		
618	Combustible matter in ash from independently fired dryer	%	%
619	Mass of dry ash from independently fired dryer per unit mass of fuel	kg/kg	lb/lb
620	Heat lost by combustible in ash from independently fired dryer	kcal/kg	Btu/lb
621	Heat loss due to ash from independently fired dryer	%	%
	Total loss due to solid residue		
622	Total heat lost by combustible matter in solid residue	kcal/kg	Btu/lb
623	Percentage heat loss due to combustible matter in solid residue	%	%
	Pure ash account (for those cases where balance of ash is not weighed*)		
624	Pure ash in coarse ash or slag per unit mass of fuel	kg/kg	lb/lb
625	Pure ash in coarse dust per unit mass of fuel	kg/kg	lb/lb
626	Pure ash in fine dust (fly ash) per unit mass of fuel	kg/kg	lb/lb
627	Pure ash in coarse riddlings per unit mass of fuel	kg/kg	lb/lb
628	Pure ash in coarse ash from dryer per unit mass of fuel	kg/kg	lb/lb

* To be estimated on the basis of the determinations on the weighed refuse.

NOTES*

614	Item 473	i_5
615	$\dfrac{\text{Item 472}}{100}$	D_5/C_1
616	$\dfrac{\text{Item 601} \times \text{Item 614} \times \text{Item 615}}{100}$	$\dfrac{D_5 \times i_5 \times H_3}{C_1 \times 100}$
617	$\dfrac{\text{Item 616} \times 100}{\text{Item 278 or Item 279}}$	$\dfrac{D_5 \times i_5 \times H_3}{C_1 \times H_1 \text{ or } H_2}$
618	Item 329	i_6
619	$\dfrac{\text{Item 328}}{\text{Item 303}}$	D_6/C_1
620	$\dfrac{\text{Item 601} \times \text{Item 618} \times \text{Item 619}}{100}$	$\dfrac{D_6 \times i_6 \times H_3}{C_1 \times 100}$
621	$\dfrac{\text{Item 620} \times 100}{\text{Item 278 or Item 279}}$	$\dfrac{D_6 \times i_6 \times H_3}{C_1 \times H_1 \text{ or } H_2}$
622	Item 604 + Item 608 + Item 612 + Item 616 + Item 620	P_1
623	Item 605 + Item 609 + Item 613 + Item 617 + Item 621	$\dfrac{100\,P_1}{H_1 \text{ or } H_2}$
624	Item 603 × (100 – Item 602)/100	$\dfrac{D_1\,(100 - i_1)}{100\,C_1}$
625	Item 607 × (100 – Item 606)/100	$\dfrac{D_2\,(100 - i_2)}{100\,C_1}$
626	Item 611 × (100 – Item 610)/100	$\dfrac{D_3\,(100 - i_3)}{100\,C_1}$
627	Item 615 × (100 – Item 614)/100	$\dfrac{D_5\,(100 - i_5)}{100\,C_1}$
628	Item 619 × (100 – Item 618)/100	$\dfrac{D_6\,(100 - i_6)}{100\,C_1}$

* For alternative methods of computation, see Annex B.

C. Losses due to solid residue (*concluded*)

629	Balance of pure ash per unit mass of fuel	kg/kg	lb/lb
630	Equivalent mass of unweighed residue per unit mass of fuel	kg/kg	lb/lb
	Losses due to sensible heat of solid residue (if unquenched in water-filled ash hoppers or slag tank)		
631	Heat lost in sensible heat of ashes and clinker	kcal/kg	Btu/lb
632	Heat lost in sensible heat of dust and grit	kcal/kg	Btu/lb
633	Total heat lost in sensible heat of solid residues	kcal/kg	Btu/lb

NOTES*

629 Item 272 – Item 624 – Item 625 – Item 626 – Item 627 – Item 628

$$\overline{Z} = \frac{D_1\,(100 - i_1) + D_2\,(100 - i_2) + D_3\,(100 - i_3) + D_5\,(100 - i_5) + D_6\,(100 - i_6)}{100\,C_1}$$

630 $\dfrac{\text{Item 629} \times 100}{100 - \%\ \text{combustible matter in unweighed residue}}$

631 Item 603 (or Item 630) × Item 454 × (Item 453 – Item 398)

632 Item 607 × Item 464 × (Item 463 – Item 398) + Item 611 × Item 470 × (Item 469 – Item 398)

633 Item 631 + Item 632.

* For alternative methods of computation, see Annex B.

D. Losses due to unburnt gas

701	CO in flue gases per unit mass of fuel	kg/kg	lb/lb
702	Calorific value of CO*	kcal/kg	Btu/lb
703	Heat loss due to unburnt CO	"	"
704	Hydrocarbons in flue gases per unit mass of fuel	kg/kg	lb/lb
705	Calorific value of hydrocarbons*	kcal/kg	Btu/lb
706	Heat loss due to unburnt hydrocarbons	"	"
707	Heat loss due to unburnt gas per unit mass of fuel	"	"

E. Loss due to sensible heat in dry flue gases

708	Dry flue gases per unit mass of fuel	kmol/kg	lb mol/lb
709	Sensible heat lost in dry flue gas per unit mass of fuel	kcal/kg	Btu/lb

* It is recommended that these values should be obtained from the most recent available data.