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IS 8753 (1977): Code for acceptance tests on stationary steam generators of the power station type [MED 1: Boilers and Pressure Vessels]







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Indian Standard

CODE FOR ACCEPTANCE TESTS ON STATIONARY STEAM GENERATORS OF THE POWER STATION TYPE

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Indian Standard CODE FOR ACCEPTANCE TESTS ON STATIONARY STEAM GENERATORS OF THE POWER STATION TYPE

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Indian Standard

CODE FOR

ACCEPTANCE TESTS ON STATIONARY STEAM GENERATORS OF THE POWER STATION TYPE

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 21 November 1977, after the draft finalized by the Boilers Sectional Committee had been approved by the Mcchanical Engineering Division Council.

0.2 This standard has been drawn to assist power station engineers and other interested parties in the assessment of the output and efficiency of various types of heating installations.

0.3 Consequent upon the adoption of SI units (International System) for use in this country, only these units have been specified in this standard. For conversion factors *see* SP:5-1969 Guide to the use of International system (SI) units.

1. SCOPE

1.1 This Standard 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 the 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 standard. 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. **0.4** In the preparation of this standard considerable assistance has been derived from the following publications:

- ISO/R 889-1968 Test code for stationary steam generators of the power station type. International Organization for Standardization.
- BS 2885 : 1974 Code for acceptance tests on stationary steam generators of the power station type. British Standards Institution.

0.5 A list of Indian Standards referred to in this standard is given in Appendix A.

The question of contractual tolerances is outside the scope of this standard. 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 standard applies to large direct fired steam generators, primarily of the water tube type, which may be equipped with superheaters, reheaters, economizers, 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, or a combination of any of these fuels.

A method for the determination of quantity and enthalpy of combustion air is given in Appendix B to cover cases where quantity of air is not directly measured.

2. TERMINOLOGY

2.1 The following definitions in addition to those given in IS : 1350 (Part II)-1970 and IS : 3810-1966 shall apply.

2.1.1 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 distrubution 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.

2.1.2 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.

2.1.3 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.

2.1.4 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.

2.1.5 Calorific Value — Calorific values shall be expressed in terms of the joule or its equivalent:

All calorific values used shall be those at constant pressure and corrected to one atmosphere standard pressure = 1.01325 bar*. The standard reference temperature for the calorific values of solid, liquid and gaseous fuels shall be 25° C. The calorific values at constant pressure as defined in 1S : 1350 (Part II)-1970 shall be used.

3. GUIDING PRINCIPLES

3.1 Method of Determining Efficiency — A test according to Method A (see 1.1) 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,

*1 bar = 10^{2} kPa.

expressed as percentages, from 100 percent, 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 appropriate clauses under 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 **3.2**(a) to **3.2**(c), 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 preheated combustion air and external air, as well as for deviations of steam throughput and fuel analysis, 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 1).
- That the specified working conditions can reasonably be met and that the appropriate fuel(s) can be burned at the necessary rate(s) (see 3.2).
- 4) Correction curves or tables for deviation of test conditions from stipulated operating conditions (see 3.2).
- 5) The number and duration of the tests (see 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 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, that is, either through the determination of a complete heat balance by Method A or through an evaluation by Method B (see 1 and 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 operation 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 and refuse samples (see 4.12 and 4.14).
- 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, that is, cleanliness of contact surfaces, wear and tightness, and the operation of cleaning equipment (see 3.4).
- 17) The operation of blow-down and, if to be used, the method of measurement (see 3.4).
- 18) The operation of integral ash-quenching equipment (see 3.4).
- 19) The method of measurement of fuel (see 4.11).
- 20) The method of sampling fuel (see 4.12).
- 21) The method of fuel grindability determination (see 4.12 and 4.22).
- 22) The method of determining the mass of refuse (see 4.14).
- 23) The method of assessment of heat losses from water-filled ash hopper and from solid residues of combustion (see 4.16).

- 24) The method of sampling refuse (see 4.15).
- 25) The method of flue gas analysis (see 4.7).
- 26) The method of measuring feed water (see **4.8**).
- 27) The instruments to be used for temperature measurement (see 4.5).
- 28) When testing according to Method B the value to be adopted, where necessary, for radiation and convection loss (see 4.18).
- 29) The methods of steam purity measurements and correction, and of boiler-water conditioning (see 4.23).
- 30) The location of instruments (see 4.3).
- 31) The measurement intervals (see 4.3).
- 32) The conditions under which a test should be terminated as unsatisfactory (see 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 by more than ± 3 percent from the test value;
- b) The extreme values of steam pressure should not differ from one another by more than 6 percent, and

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 percent.

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 3.1 and 3.2).

3.5 Preliminary Test — A preliminary test should be made for the purpose of:

- a) checking the operation of all instruments;
- b) the training of observers and other test personnel; and
- 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 **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, and
- 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 should, therefore, be observed for an adequate period before commencement and after termination of the test.

In view of these conditions it is recommended that in-cases where, in compliance with 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 conditions of **3.6** the plant should be run under test conditions for not less than 1 hour berfore 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 directly 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.

If retort stoker firing is employed, 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 should 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, is usually sufficient.

Except in the case of tests of long duration, when the precaution noted in 3.6 should be observed, it is not desirable to change observers during a test. It is recommended (see 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 should 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 **3.4** as having to be reached before the tests actually begin.

Note 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 **3.4**.

NOTE 2 — Momentary variations may exceed the limits specified in 3.4 without involving the rejection of the test providing that, taking into account the frequency, duration and time of occurrence of the variations, the parties agree that the variations 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 this code involves the determination of all or part of the following quantities:

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

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

The use of unconventional means of making and recording test measurements is permitted, provided that the accuracy and suitability of such methods can be demonstrated to the satisfaction of the parties concerned.

4.2 Type and Calibration of Instruments — In this clause are given alternative methods of measurement which can be employed and the parties to the tests should 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 flow measurements, the interval between readings should normally be 10 min to 15 min provided that there are not less than 25 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 readings, and the 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. The log sheets should include the reference number of all instruments.

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 (see IS : 4825-1968),
- b) Electric resistance thermometers with Wheatstone bridge or similar 'null' balance instrument, and
- c) High-grade thermocouples used with a potentiometer or digital voltmeter of suitable accuracy (see IS: 2054-1962, IS: 2055-1962, IS: 2056-1962 and IS: 2057-1962).

4.5.2 The following precautions should be observed during temperature measurement:

- a) If possible, the locations for temperature measurement should be so chosen or arranged that both velocity and temperature distribution are reasonably uniform over the crosssectional area of the pipe, flue or duct at the measuring point. For large ducts it is recommended, and in tests according to Method B it is essential, that multi-point sampling be employed.
- b) The method of measurement should be such as to minimize the quantity of heat transmitted through radiation or convection to and from the thermometer, other than heat from the medium being measured. Where this is not possible, the necessary corrections should 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 suitable insulating 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. The measuring instrument should be in contact with the bottom of the pocket.

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 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 and up to but not including 300 mm internal diameter, some in lination 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 centreline.

For pipes of 300 mm 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 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 accommodate the thermometer or temperature-measuring element. It is important that the thermometer pockets and walls should be cleaned 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 mcdia, the heat-receiving part of the apparatus should not be in a dead space.
- j) 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.

k) 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 flow is employed a similar result should be secured.

4.6 Pressure Measurement — Steam and water pressures should be measured by calibrated Bourdon-type gauges (see IS: 3624-1966) 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 percent of the working pressure should 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 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 provided that allowance is made for any difference in level between the tapping points.

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 tomperature 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 4.5.2(k)].

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 or oxygen. 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 multipoint 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. A suitable apparatus is the Orsat and using this for carbon dioxide or oxygen the interval could be, for example, 15 min. When the test is made according to Method B, it is necessary to use a more sensitive apparatus for the detection of unburnt gas.

4.8 Determination of Steam Output — The steam output should be determined either 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 water or steam measurement, reference should be made to IS : 2952 (Part I)-1964 or IS : 4477 (Part I)-1967.

- 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 flowmeter.

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 $\pm 0.1\%$. 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 IS : 2952 (Part I)-1964 or IS : 4477 (Part I)-1967. 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 **4.5** and **4.6**.

4.12 Sampling and Analysis of Fuel - Solid fuel should be sampled and analysed in accordance with 1S: 436 (Part I)-1964, IS: 436 (Part II)-1965 and IS: 1350 (Part I)-1969. The degree The degree of accuracy in sampling should be to 0.25 percent 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 the above characteristics should be determined separately if possible 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 percent 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 or near the pump discharge. The ultimate analysis, calorific value, viscosity and density should be determined [see IS: 1460-1974, IS: 1593-1971, IS: 7575-1975 and IS: 1448 (P: 8, P: 7, P: 16, P: 25)].

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, or 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 gasproducing 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 should be made for the enthalpy of the air admitted to the unit at other points, and the humidity of the combustion air should 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, riddings, 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.

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 should 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 and mixed as thoroughly as possible. Quantities in excess of 100 kg should be subdivided by coning and halving and quartering by the well-known methods employed for subdivision of large samples of coal, until the mass of the subdivided sample is reduced to between 50 kg and 100 kg. Samples of 100 kg and less should be subdivided by a mechanical sample-divider of a type approved for subdivision 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 pulverized 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, the losses 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:

- a) loss due to sensible heat of dry gases;
- b) loss due to heating and evaporation of water from the fuel, including the combined water of the mineral matter and that from the combustion of hydrogen;
- c) loss due to heating of the moisture contained in the combustion air; and
- d) loss due to unburnt gases.

Determination of these different losses makes it necessary to know:

- 1) proximate analysis and ultimate analysis of the fuel (see 4.12);
- carbon content of the unburnt solid matter (see 4.15);
- 3) analysis of the gases of combustion (see 4.7);
- 4) temperature of the gases of combustion (see 4.5); and
- 5) temperature and humidity of the combustion air (see 4.13).

4.18 Radiation and Convection Loss — In a test according to Method B, the loss due to radiation and convection should be evaluated. The appropriate figure is the gross loss from the unit's casing, that is, no allowance is made for recuperation, the air temperature having been measured in accordance with this code (see 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 or 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 airflow 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 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 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 boiler 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 suitable 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, CO_2 and/or O_2 at I.D. fan outlet, 2)
 - CO₂ and/or O₂ at air-heater inlet, 3)
 - 4) CO_2 and/or O_2 at air-heater outlet.
- Gas temperature at air-heater inlet, **d**) 1) Gas temperature at air-heater outlet, **9**\ 3) Gas temperature of I.D. fan outlet.
- 1) Air temperature at air intakes, e)
 - 2) Air temperature at F.D. fan outlet.
- Draught at I.D. fan inlet and outlet, f) 1) Draught at F.D. fan inlet and outlet, 2) 3) Furnace draught.
- Power input to I.D. fan motor. 1) g)
- 2) Power input to F.D. fan motor.
- 1) I.D. fan speeds. h)
 - 2) F.D. fan speeds.
- Voltage. i)
- Frequency. k)
- 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 (for example, size grading, grindability and chemical composition), and samples of the pulverized fuel should be taken (see 4.12) for grading and, where applicable, moisture determination. The grindability deter-mination 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.
- Pressure of air, and of gas if used for drying.
- Speeds of rotation of pulverizer, primary air fan or exhauster, and classifier.
- g) Power for pulverizer and primary air fan or exhauster.
- h) Particulars of mill settings.
- j) Mill reject rate.
- k) Other data, such as sealing air fan power and feeder power, as necessary.

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 (see IS: 3025-1964) and the concentration of dissolved solids ascertained, preferably by a gravimetric method or, in the case of high pressure boilers, by photometric method.

The following observations should also be made:

- a) Drum-water level or levels.
- b) Feed and steam rates.
- c) Saturated steam pressure or temperature.
- d) 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, 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 form the procedure laid down in this code which may have been agreed between

the parties in accordance with 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 alter-ing 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 in 6.

TABLE 1 SYMBOLS AND UNITS (METHODICAL)

(Clause 5.6)

| QUANTITY | Symbol | Unit |
|--|------------------|-------------|
| Quantities (by mass unless otherwise stated) | | · |
| Feed water | W | ka/a |
| Superheated steam | W | kg/s |
| Reheated steam at inlet) | W | kale |
| Reheated steam at outlet hirst reheater | W ³ | kale |
| Boiler blow-down | 142 | kg/s |
| Superheated but not reheated steam | IAZ | kg/s |
| Superheater spray water | 14Z | kg/s |
| First reheater spray water | 14/ | Kg/S |
| Second reheater spray water | 14Z 8 | kg/s |
| Water corresponding to drum level variation during the test | | Kg/s |
| Reheated steam at inlet | 10 IAZ | Kg/S |
| Reheated steam at outlet { second reheater | W 31 | kg/s |
| Total combustion air entering system | VV 41 14/ | Kg/S |
| Gases of combustion leaving system | W a | Kg/S |
| Fuel (rate of firing, by mass) | ^W g | kg/s |
| Fuel to independently fired driver (rate of firing by mass) | | kg/s |
| Fuel (rate of firing hy volume at reference pressure A and temperature t | | Kg/S |
| as the only fiel only γ | C2 | mº/s |
| Slag in the slag tank | D | 1 |
| The short transmission of the dust-collecting plant | D_1 | kg/s |
| Ev ash discharged to the flue | D_{3} | Kg/S |
| Biddings | D_3 | kg/s |
| Ashnir refuse | D_5 | kg/s |
| Total solid residues | D_6 | kg/s |
| | $D_{\mathbf{r}}$ | Kg/S |
| Pressures | | |
| Feed water | <i>b</i> . | har* |
| Superheated steam | <i>h</i> | bar |
| Reheated steam at inlet) | P2 h. | bar |
| Reheated steam at outlet hist reheater | P3 b. | bar |
| Boiler blow-down (=drum pressure) | P4 b- | bar |
| Superheater spray water | P5 | har |
| First reheater spray water | P7 \$2 | bar |
| Second reheater spray water | P8 b. | har |
| Reference pressure of calorific value and of rate of firing (in the case of gaseous fuel) | <i>p</i> , | mhar |
| Ambient atmospheric pressure | P 10 | mbar |
| Fuel oil entering boiler | P 11 h. | har |
| Reheated steam at inlet | P 18 | bar |
| Reheated steam at outlet) second reneater | p_{A1} | bar |
| Temberatures | | |
| Feed water | _ | |
| Superheated steam | | °C |
| Baharted steam | t_2 | °C |
| Reheated steam at milet) first reheater | t_3 | °C |
| Superheated steam at outlet) | t_4 | °C |
| Superheater spray water | t ₇ | °C |
| First reneater spray water | t ₈ | °C |
| Second reneater spray water | t ₉ | °C |
| Reference temperature of the calorific value (and of the volume rating in the | | |
| case of a gaseous fuel) | t ₁₀ | °C |
| ruei entering unit | t ₁₁ | °C |
| *1 bar = 10^2 kPa. Throughout this code 'bar' signifies 'bar gauge' unless otherwise stat | ted | • |
| and a second the second s | | (Continue |
| | | 1 GUILLITHU |

(Continued)

| Quantity | Symbol | Unit |
|---|-------------------------|----------------------|
| Combustion air at entry to air intakes | tin | °C |
| Combustion air leaving fan | 12 | <u>.</u> |
| Combustion air entering additional heater | t., | °Č |
| Combustion air leaving additional heater | t_{15} | °Č |
| Flue gases leaving last recuperator of boiler | t_{18} | °Č |
| Temperature indicated by the 'wet bulb' thermometer of the psychrometer | 10 | . • |
| at fan inlet | t., | $^{\circ}\mathrm{C}$ |
| Fuel oil entering furnace | t18 | °Ĉ |
| Reheated steam at inlet) second reheater | t31 | °C |
| Reheated steam at outlet | t ₄₁ | °C |
| Steam Saturation Prossures | | |
| Steam Saturation 1 ressures | | |
| At temperature l_{12} psychrometer at fan inlet | p_{12} | mbar |
| At temperature t_{17} , 1, 7 | p ₁₇ | mbar |
| Enthalpies | | |
| Fuel oil | h. | kI/ka |
| Feed water | | hJ/hg |
| Superheated steam | h_1 | ⊷j/≞g kT/kα |
| Reheated steam at inlet | h. | ▲J/▲g k I/ka |
| Reheated steam at outlet hirst reheater | h_3 | k 1/kg |
| Boiler blow-down (boiler drum water) | h. | kI/kg |
| Superheater spray water | h. | k I/ka |
| First reheater spray water | h. | kI/ka |
| Second reheater spray water | h, | ki/kg |
| Combustion air entering additional heater | h | k l/kg |
| Combustion air leaving additional heater | h | k I/kg |
| Reheated steam at inlet | h_1 | k I/kg |
| Reheated steam at outlet second reneater | h.1 | kI/kg |
| | | -07-8. |
| Calorific Values | | |
| Gross calorific value by mass measured at constant volume (and corrected to | | |
| reference temperature t_{10} | 0 m | k1/kg |
| Gross calorific value by volume measured at constant pressure (and corrected to | 2,81) 1 | |
| reference temperature t_{10}) | 0. | kI/m ³ |
| Gross calorific value by mass at constant pressure (and reference temperature t_{10}) | \widetilde{H}_{1}^{n} | k l/kg |
| Net calorific value by mass at constant pressure (and at reference temperature t_{10}) | H_2 | k I/kg |
| Calorific value of unburned matter content in the solid residue of combustion | H_3 | kJ/kg |
| Composition of Fuel by Mass | | |
| Composition of Face by Mass | | |
| Water content by mass | E | kg/kg |
| Ash content by mass | Z | kg/kg |
| Carbon content by mass | C | kg/kg |
| nydrogen content by mass* | H | kg/kg |
| Nurogen content by mass | л О | Kg/Kg |
| Computible subjut content by mass | U C | Kg/Kg |
| Combustible suphul content by mass | 3 | KG/KG |
| Characteristics Peculiar to Gaseous Fuels | - | |
| Molecular volume | V | m³/kmol |
| Hydrogen content by volume | d | 0/ |
| C_xH_y hydrocarbon content by volume | e | % |
| Number of atoms of $C_x H_y$ hydrocarbons | | , . |
| carbon | x | |
| hydrogen | у | |
| Density at reference pressure and temperature $(t_{10} \text{ and } p_{10})$ | М | kg/m³ |
| $\mathbf{U}_{1} \neq 0$ that a f 0 - model $\mathbf{U}_{1} \neq (1, 1, -1)$ | 0 | |
| reat Juput of Generating Unit (total) | Ϋ́ | kW |
| rical output of generating sections and superheater | Q1 | kW |
| rical output of first reneater | Q2 | kW |
| meat output of second reneater | L 3 | ĸw |
| Heat Input to Generating Unit | | |
| By the fuel* | F. | 1-11/ |
| By the additional heat in the combustion air* | F. | L 10/ |
| By heating and atomizing liquid fuel | <u>0</u> . | kW. |
| Fraction of fuel lost in the form of free hydrogen in the gases of combustion | Ť, | ka/ka |
| | | ~6/~6 |

TABLE 1 SYMBOLS AND UNITS (METHODICAL) - Contd

*In the case of solid fuel, this includes the hydrogen present in the water of constitution of the mineral matter.

| TABLE 1 SYMBOLS AND UNITS (METHODICAL) — Contd | | | | | | | |
|--|--|--|--|--|--|--|--|
| QUANTITY | Symbol | Unit | | | | | |
| Unburned Matter in the Solid Residue | | | | | | | |
| Carbon content of: (a) slag in the slag tank (b) fly ash trapped in the dust collecting plant (c) fly ash discharged to the flue (d) riddlings (e) ashpit refuse Mean carbon content of all solid residue Fraction of flucture scheme in the which encider | i 1 2 3 5 5 6 6 6 6 | % % % % | | | | | |
| raction of fuer lost as carbon in the solid residue | C | kg/kg | | | | | |
| Composition of Flue Gases by Volume | | | | | | | |
| $\begin{array}{l} CO_{2} \text{ content} \\ CO \text{ content} \\ CH_{4} \text{ content} \\ O_{3} \text{ content} \\ SO_{2} \text{ content} \\ N_{3} \text{ content} \\ H_{3} \text{ content} \\ C_{n}H_{m} \text{ content} \end{array}$ | a_1 a_2 a_3 a_4 a_5 a_6 a_7 a_8 | 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 | | | | | |
| Heat Due to Heating | | | | | | | |
| Of the gaseous products of combustion other than CO₂: (a) between 0°C and initial temperature (b) between 0°C and final temperature (c) of the CO₂ in the gaseous products of combustion: (a) between 0°C and initial temperature (b) between 0°C and final temperature | r_1 r_3 r_1 r_2 | kJ/m³ _n kJ/m³ _n kJ/m³ _n kJ/m³ _n | | | | | |
| Sundry Quantities | | | | | | | |
| Mean specific heat (at constant pressure) of a liquid fuel between t_{10} and t_{16} Fly ash of the flue gases, by mass Water vapour content of the combustion air, by mass Degree of humidity of the combustion air | f k ₁ k ₂ K | kJ/(kg K) kg/kg kg/kg % | | | | | |
| Heat Account Losses | | | | | | | |
| Loss due to unburned solid matter Loss due to unburned gas Loss due to sensible heat of dry gas Loss due to sensible heat of dry gas Loss due to evaporation of water in the fuel and of combustion water Loss due to heating of the vapour from the fuel and of the combustion water Loss due to heating of the vapour from the combustion air Loss due to radiation to environment Residual loss Total heat losses Nore — The corresponding percentage heat losses are represented by the symbols P' to P'_{a} and P'_{t} . | $\begin{array}{c}P_1\\P_2\\P_3\\P_4\\P_5\\P_6\\P_7\\P_8\\P_t\end{array}$ | k]/kg kJ/kg kJ/kg kJ/kg kJ/kg kJ/kg kJ/kg kJ/kg kJ/kg | | | | | |
| | | , | | | | | |
| Based on the gross calorific value of the fuel Based on the net calorific value of the fuel | R R' | 0/0 0/ /0 | | | | | |
| * To be treated as negative heat outputs in the computations. | | | | | | | |

TABLE 2 SYMBOLS AND UNITS (ALPHABETICAL)

(Clause 5.6)

| Symbol | QUANTITY | Unit |
|--|---|--|
| $a_1 \\ a_3 \\ a_4 \\ a_6 \\ a_6 \\ a_7$ | CO ₃ content of flue gases by volume CO content of flue gases by volume CH ₄ content of flue gases by volume O ₃ content of flue gases by volume SO ₅ content of flue gases by volume N ₃ content of flue gases by volume H ₃ content of flue gases by volume | 0/0 9/0 0/0 0/0 0/0 0/0 0/0 0/0 |
| | | (Continued) |

| Symbol | QUANTITY | Unit |
|-----------------------|---|-------------------|
| as | C_nH_m content of flue gases by volume | % |
| Ċ | Carbon content of fuel, by mass | kg/kg |
| C' | Fraction of fuel lost as carbon in the solid residue | kg/kg |
| C_1 | Rate of firing of fuel by mass | kg/s |
| C_{11} | Rate of firing of fuel to independently hred dryer, by mass | kg/s |
| C_2 | Rate of firing of gaseous fuel, by volume, at t_{10} and p_{10} | 0/ |
| d | Hydrogen content of gaseous fuel, by volume | 70 km/n |
| D_1 | Quantity of slag in the slag tank | kg/s |
| D_{1} | Quantity of the san trapped in the dust concerning plant | kg/s |
| D_{3} | Quantity of ny ash discharged to the fue | kg/s |
| D_{5} | Quantity of radomits | kg/s |
| | Quantity of astipit reliate | kg/s |
| DT | C H by the control of the second field by volume | 0/ |
| , F | Water content of fuel by mass | kg/kg |
| , F | Mean specific heat (at constant pressure) of liquid fuel between t_{10} and t_{10} | kJ/(kg K) |
| F. | Heat input to the boiler from the additional heat in the combustion air | k I/(kg K) |
| $\vec{F_{o}}$ | Heat input to the boiler from the fuel | kJ/(kg K) |
| h | Enthalpy of fuel oil | kJ/kg |
| h. | Enthalpy of feed water | k]/kg |
| h | Enthalpy of superheated steam | kJ/kg |
| h_{3} | Enthalpy of reheated steam at inlet) first reheater | kJ/kg |
| h_1 | Enthalpy of reheated steam at outlet | k J/kg |
| h ₅ | Enthalpy of boiler blow-down (boiler drum water) | k j/kg |
| h_7 | Enthalpy of superheater spray water | kJ/kg |
| $h_{\rm s}$ | Enthalpy of first reheater spray water | kJ/kg |
| h_9 | Enthalpy of second reheater spray water | KJ/Kg |
| h ₁₁ | Enthalpy of combustion air entering additional heater | KJ/Kg |
| h ₁₂ | Enthalpy of combustion air leaving additional heater | KJ/Kg |
| h ₃₁ | Enthalpy of reheated steam at milet second reheater | k J/Kg |
| h_{41} | Enthalpy of reheated steam at outlet | KJ/Kg kg/kg |
| H | Hydrogen content of fuel, by mass ⁻ | kg/kg |
| H' U | Fraction of fuel lost in the form of thee hydrogen in the gases of combustion | kI/ka |
| H_1 | Gross calorine value of fuel, by mass, at constant pressure and at t_{10} | k I/kg |
| n_2 | Net calorine value of fuel, by mass, at constant pressure and at t_{10} | k I/kg |
| ;; | Caloring value of the slag in the slag tank | % |
| ;1 | Carbon content of the sign and transed tin the dust collecting plant | 6/ |
| 12 1 | Carbon content of the fly ash displayed to the flue | 6/ |
| 3 | Carbon content of the riddlings | 0/0 |
| i. | Carbon content of the aspit refuse | % |
| im. | Mean carbon content of all solid residue | 07 70 |
| k_1 | Fly ash content of the flue gases, by mass | kg/kg |
| k_{2} | Water content of the combustion air, by mass | kg/kg |
| Ň | Degree of the humidity of the combustion air | % |
| M | Density of a gaseous fuel at t_{10} and p_{10} | kg/m ³ |
| \mathcal{N} | Nitrogen content of fuel, by mass | kg/kg |
| 0 | Oxygen content of fuel, by mass | kg/kg |
| p ₁ | Feed water pressure | bar |
| p_2 | Superheated steam pressure | bar |
| P3 | Pressure of reheated steam at inlet } first reheater | bar |
| P ₄ | Pressure of reheated steam at outlet | bar |
| p_5 | Boiler blow-down pressure (drum pressure) | bar |
| <i>p</i> ₇ | Superneater spray water pressure | bar |
| p_8 | rist reneat spray water pressure | bar |
| P9 | Deference pressure of colorific value and of rate of firing (in the case of a gaseous fuel) | mbar |
| P10 | Ambient atmospheric pressure | mbar |
| P11 b.a | Steam saturation pressure at t_{a} psychrometer at | mbar |
| P12 | Steam saturation pressure at t_{12} potential of at | mbar |
| P17 | Pressure of fuel oil entering boiler | bar |
| 18 18 | Pressure of reheated steam at inlet | bar |
| <i>p</i> 31 | Pressure of reheated steam at outlet | bar |
| \tilde{P}_1 | Loss due to unburnt solid matter | k]/kg |
| P. | Loss due to unburnt gas | kJ/kg |
| P_3 | Loss due to sensible heat of dry gas | kJ/kg |
| $P_{A}^{"}$ | Loss due to evaporation of water in the fuel and of combustion water | kJ/kg |

 TABLE 2 SYMBOLS AND UNITS (ALPHABETICAL) - Contd

*In the case of solid fuel, this includes the hydrogen present in the water of constitution of the mineral matter. $\dagger 1 bar = 10^2 kPa.$

| | TABLE 2 SYMBOLS AND UNITS (ALPHABETICAL) — Contd | |
|----------------------------|--|---|
| Symbol | QUANTITY | Unit |
| P5 P6 P7 P8 Pt | Loss due to heating of the vapour from the fuel and of the combustion water Loss due to heating of the vapour of the combustion air Loss due to radiation to environment Residual loss Total heat losses | kJ/kg kJ/kg kJ/kg kJ/kg kJ/kg |
| | Note — The corresponding percentage heat losses are represented by the symbols P'_1 to P'_0 and P'_1 | |
| $Q_{gr,v}$ | Gross calorific value of the fuel, by mass, measured at constant volume (and corrected | kJ/kg |
| Q, | Gross calorific value of gaseous fuel, by volume, measured at constant pressure (and corrected to t_{ab}) | kJ/m ^s |
| Q | Heat output of generating unit (total) | kW |
| Q_1 | Heat output of generating sections and superheater | kW |
| Q_2 | Heat output of inst reneater | k vv VW |
| \tilde{O} | Heat input in heating and atomizing fuch | kW |
| r_1 | Heat due to heating of the gaseous products of combustion (other than CO_2), between $0^{\circ}C$ and initial temperature | kJ/m³ _N |
| r ₂ | Heat due to heating of the gaseous products of combustion (other than CO_2), between $0^{\circ}C$ and final temperature | $kJ/m^{\boldsymbol{8}}{}_{\boldsymbol{N}}$ |
| r'1 | Heat due to heating of the CO_2 in the gaseous products of combustion between $0^{\circ}C$ and initial temperature | $kJ/m^{\boldsymbol{3}}{}_{\boldsymbol{N}}$ |
| r'2 | Heat due to heating of the CO_2 in the gaseous products of combustion between $0^{\circ}C$ and final temperature | $kJ/m^{\boldsymbol{s}}{}_{_{\boldsymbol{N}}}$ |
| 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 |
| t_1 | Feed water temperature | °C |
| <i>t</i> ₂ | Superheated steam temperature | -C |
| | Reheated steam temperature at inlet | ŝ |
| 14 † | Reneated steam temperature at outlet) | °C |
| t - | First reheater spray water temperature | č |
| t. | Second reheater spray water temperature | °Č |
| t ₁₀ | Reference temperature of the calorific value (and of the volume rating in the case of a gaseous fuel) | °C |
| t ₁₁ | Temperature of fuel entering unit | °C |
| t_{12}^{-} | Temperature of combustion air at entry to air intakes | °C |
| t_{13} | Temperature of combustion air leaving fan | °C |
| t ₁₄ | Temperature of combustion air entering additional heater | °C |
| t ₁₅ | Temperature of combustion air leaving additional heater | D° D |
| | Temperature of flue gases leaving last recuperator of boller | °C |
| t ₁₇ | Temperature of fuel entering furnace | č |
| t _c , | Temperature of reheated steam at inlet | °Č |
| t 11 | Temperature of reheated steam at outlet second reheater | °C |
| V | Molecular volume of gaseous fuel | m³/kmol |
| W_1 | Quantity of feed water | kg/s |
| W_{2} | Quantity of superheated steam | kg/s |
| W_3 | Quantity of reheated steam entering) first reheater | kg/s |
| | Quantity of reheated steam leaving | kg/s |
| | Quantity of boller blow-down | kg/s |
| W_{\bullet}^{6} | Quantity of superior water in the superheater | kg/s |
| W. | Ouantity of spray water in the first reheater | kg/s |
| W ₉ | Quantity of spray water in the second reheater | kg/s |
| W_{10} | Quantity of water corresponding to the variation in the drum level during the test | kg/s |
| W_{31} | Quantity of reheated steam entering } second reheater | kg/s |
| W41 | Quantity of reheated steam leaving 1 | kg/s |
| Wa | Total of combustion air entering system | kg/s |
| Wg | Quantity of flue gases leaving system | kg/s |
| x | Number of carbon atoms $in the C_x H_y$ hydrocarbons | _ |
| ź | Proportion of inert matter in the fuel, by mass | kg/kg |
| \sim | A toportion of metri matter in the fact, by these | **5!**S |

6. FORM OF REPORT RECOMMENDED

6.1 A suitable form of report is given below. The description of the plant and the conduct and results of the test given in the succeeding pages have been tabulated in the following order:

- I) General information and design data
- 11) Methods of measurement, sampling and analysis employed
- 111) Mean observations and fuel data
- IVY Computation of heat account
- V' Thermal efficiency and heat account

REPORT

- d) Dust extraction plant performance
- e) Draught plant performance
- f) Pulverizer 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/s | W_{2} | | •• | •• | |
| 002 | Final steam temperature | °Ĉ | t_2 | • • | •• | •• | |
| 003 | Initial temperature of feed water Gauge pressure of steam | °C | t_1 | | •• | •• | |
| 004 | in the saturated steam space | | | | | | |
| | in boiler† | bar | \$ ₅ | •• | •• | •• | |
| 005 | at the superheater outlet Reheated steam quantity | bar | p_2 | ••• | •• | •• | |
| 006 | first reheater | kg/s | W_{a} | | •• | •• | |
| 007 | second reheater | kg/s | W ₃₁ | | •• | •• | |
| | Gauge pressure of steam | | | | | | |
| 008 | at first reheater inlet | bar | p 8 | •• | • • | •• | |
| 009 | at first reheater outlet | bar | p4 | •• | •• | •• | |
| 010 | at second reheater inlet | bar | p ₃₁ | •• | ••• | •• | |
| 011 | at second reheater outlet Temperature of steam | bar | P ₄₁ | •• | •• | •• | |
| 012 | at first reheater inlet | °C | to | | •• | •• | |
| 013 | at first reheater outlet | °Õ | t. | | •• | | |
| 014 | at second reheater inlet | ۵° | t ₉₁ | •• | | •• | |
| 015 | at second reheater outlet | °C | t ₄₁ | •• | •• | •• | |
| | Overall thermal efficiency | | | | | | |
| 016 | based on net calorific value | %. | R' | •• | •• | •• | |
| 017 | based on gross calorific value | % | Ŕ | •• | •• | •• | |
| 018 | Characteristics of fuels on which t | he above | evaporation | and efficiency | are based | | |
| 019 | Brief description of the plant | | - | | | | |
| 020 | Date first commissioned. | | | | | | |

*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.

| 021 022 023 024 | Condition of plant at time of test hours of steaming since commissioning hours of steaming since last cleaning extent and method of cleaning condition of auxiliary equipment |
|--|--|
| B) | Firing Equipment |
| | a) Solid Fuel |
| 025 026 027 028 029 | Description of fuel Description of stoker Maker's name Size of gratem long×m wide=m ² Power consumption of stoker motor |
| 040 | b) Pulverized Fuel |
| 030 031 032 033 034 035 036 037 | Description of fuel. Brief description of system. Method of drying. Number and description of pulverizers. Maker's rating of pulverizers. Specified size grading at above rating. System of transporting pulverized fuel. Number, description and arrangement of burners. |
| | Power consumption of |
| 038 039 040 | pulverizer |
| | c) Oil Fuel |
| 041 042 043 044 045 046 | Type of fuel |
| | d) Gaseous Fuel |
| 047 048 049 | Description of fuel Number, description and arrangement of burners Maker's rating of burner(s), totalkg/s (at a temperature of°C and a gauge pressure ofbar) |
| | e) Waste Heat |
| 050 051 052 | Nature of gas |
| C) | Furnace |
| 053 054 055 056 056 | Type of furnace. Type of furnace bottom. Maker's name. Method of cooling furnace walls. Furnace volume*. m ^a |
| D) | Evaporating Section |
| 058 059 060 | Type Maker's name Heating surface |
| 061 062 | Type of circulation Power consumption of circulating pumps |

*Basis of computation to be stated.

| E) | Superheater |
|---|---|
| 063 064 | Type of superheater |
| 065 | nimam [*] |
| 066 | secondary* |
| F) | Main Steam Temperature Control |
| 067 068 069 070 071 072 073 | Type. Maker's name. Maker's name. Location. Location. Cooling surface (where applicable). Source of spray water. Tolerance on steam temperature. Load range over which steam temperature is to be maintained. |
| G) | Steam Reheater |
| 074 | Type of steam reheater |
| 075 076 | Maker's name Location |
| 077 078 | first reheater |
| H) | Reheated Steam Temperature Control |
| 079 | Туре |
| 080 | Maker's name |
| 082 | Cooling surface (where applicable) |
| 083 | Source of spray water |
| 084 085 | Tolerance on steam temperature Load range over which steam temperature is to be maintainedkg/s |
| J) | Economizer |
| 086 | Type of economizer |
| 087 | Maker's name |
| 088 | primary* |
| 089 | secondary*mª |
| 090 | Power consumption of circulating pump (if any)kW |
| K) | Air Heater |
| 091 | Type of air heater |
| 092 | Maker's name. |
| 003 | neating surface |
| 093 | high temperature (air) m^2 |
| 095 | Power consumption of air heaterkW |
| M) | Dust Collecting Plant |
| 096 | Type |
| 097 | Maker's name |
| 099 | Power consumption of dust collecting plantkW |
| 100 | Efficiency of collection |
| | I ne draught loss and the efficiency are given for a flue gas discharge rate at 0° C. 1.013.25 har of $m^{3/s}$ |
| | corresponding to an evaporation rate ofkg/s |

^{*}The terms 'primary' and 'secondary' relate to the position in the feed or steam circuit.

| N) | Draught Plant |
|-------------------|---|
| 101 102 103 | Method of producing draught |
| 104 105 | Area of chimney at top |
| 106 107 | description |
| 108 109 | description |
| 110 111 | description |
| 112 113 | description |
| P) | Automatic Combustion Control |
| 114 | Description (for example, function, type, make) |
| Q) | Methods of Cleaning Heating Surfaces (Gas Side) on Load |
| 115 | Boiler, including furnace |
| 116 117 | primary* secondary* Steam reheater |
| 118 119 | first reheater second reheater Economizer |
| 120 121 | primary* secondary* |
| 122 123 | Air heater low temperature (air) high temperature (air) |
| II) | METHODS OF MEASUREMENT, SAMPLING AND ANALYSIS EMPLOYED |
| A) | Methods of Measurement |
| 151 152 | Method of determining fuel consumption Method of determining the quantity of |
| | Method of determining water quantity |
| 153 | at entry to unit |
| 155 | to blow-down |
| 156 | to and from slag tank |
| 157 | to and from ash hopper |
| 158 | saturated steam. |
| 159 | v superheated steam |
| 161 | methods of measuring temperatures |
| 162 163 | method of measuring pressures and draughts 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 |
| 168 | Method of sampling and analysing flue gases |
| _ | |

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

III) MEAN OBSERVATIONS AND FUEL DATA [ADJUSTED FOR INSTRUMENTAL CORRECTIONS (see 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 | °C | <i>w</i> ₁ | •• |
| 204 Temperature | har | ግ ሰ. | |
| 205 Gauge pressure | k1/kg | h_1 | • • |
| 200 Linuarpy | 0, 0 | • | |
| Feed Leaving Secondary Economizer (if fitted)* | 20 | | |
| 207 Temperature | han | | •• |
| 208 Gauge pressure | bar kl/kg | | •• |
| 209 Enthalpy | ⊷ J/∾6 | | |
| Water in Drum | | | |
| 210 Gauge pressure | bar | \$ 5 | •• |
| 211 Enthalpy | kJ/kg | h ₅ | |
| 212 Level at beginning of test | mm | | |
| 213 Level at end of test | ha | | |
| 214 Increase in drum content | ka/s | w | |
| 215 Average rate of increase in drum content | rg/3 | 10 | |
| 216 Average rate of blow-down test period | kg/s | W_{5} | |
| | | | |
| Spray Water for Main Steam Temperature Control | 1 | 147 | ļ |
| 217 Quantity | kg/s | W ₇ | |
| 218 Temperature | har | | |
| 219 Gauge pressure | k I/kg | $\begin{array}{c} \mu_{7} \\ h_{-} \end{array}$ | |
| 220 Enthalpy | | 1 | |
| Spray Water for Steam Temperature Control of First Reheater | | | |
| 221 Quantity | kg/s | W_8 | |
| 222 Temperature | °C | | |
| 223 Gauge pressure | bar | <i>P</i> ₈ | 1 |
| 224 Enthalpy | кJ/кg | h ₈ | ••• |
| Spray Water for Steam Temperature Control of Second Baheater | ن ھ | | |
| 225 Ouantity | kg/s | Wa | |
| 226 Temperature | ϰ | | |
| 227 Gauge pressure | bar | p, | |
| 228 Enthalpy | kJ/kg | h ₉ | |
| C) Steam | | | |
| | | | |
| Entering Primary's Superheater | °C | | 1 |
| 229 Temperature | u har | | |
| 230 Gauge pressure | 0/2 | | |
| 231 Dryness fraction 939 Enthalny | kľ/kg | 1 _ | |
| 204 Buttapy | | 1 | J |

*Excluding attemperating spray water. †Datum level to be stated in Report. †This figure is negative if the drum content decreases. §The terms 'primary' and 'secondary' relate to the position in the feed or steam circuit.

| | Unit | Symbol | VALUE |
|--|----------------------------|---|-----------------|
| Leaving Primary* Superheater 233 Quantity 234 Temperature 235 Gauge pressure 236 Enthalpy | kg/s °C bar kJ/kg | | |
| Leaving Attemperator (if any) 237 Temperature 238 Gauge pressure 239 Enthalpy | °C bar kJ/kg | | •• |
| Entering Secondary* Superheater 240 Temperature 241 Gauge pressure 242 Enthalpy | °C bar kJ/kg | · · · · · · · · · · · · · · · · · · · | •.• |
| Leaving Unit (that is, leaving final superheater where no following attemperator) 243 Quantity 244 Temperature 245 Gauge pressure 246 Enthalpy | kg/s °C bar kJ/kg | W_2 t_2 p_2 h_2 | ••• |
| Entering First Reheater, Before Attemperation (if any) 247 Quantity [†] 248 Temperature 249 Gauge pressure 250 Enthalpy | kg/s °C bar kJ/kg | $\begin{matrix} W_3\\t_3\\p_3\\h_3\end{matrix}$ | ••• |
| Leaving First Reheater 251 Quantity 252 Temperature 253 Gauge pressure 254 Enthalpy | kg/s °C bar kJ/kg | W4 t4 P4 h4 | ••• •• •• |
| Entering Second Reheater, Before Attemperation (if any) 255 Quantity 256 Temperature 257 Gauge pressure 258 Enthalpy | kg/s °C bar kJ/kg | W_{31} t_{31} p_{31} h_{31} | ••• •• •• |
| Leaving Second Reheater 259 Quantity 260 Temperature 261 Gauge pressure 262 Enthalpy | kg/s °C bar kJ/kg | $\begin{array}{c c} & W_{41} \\ & t_{41} \\ & p_{41} \\ & h_{41} \end{array}$ | · · · · · |

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 System Under Test |
| 266 | Screen analysis |

*The terms 'primary' and 'secondary' relate to the position in the feed or steam circuit. †The quantity $W_3 = W_4 - W_6$, W_6 being evaluated in accordance with **4.10**.

| | Proximate analysis | Unit | Before Conditioning* | After Conditioning* |
|--------------------------|---|------------------|-------------------------|------------------------|
| 267 268 269 270 | moisture (air dried sample%) volatile matter fixed carbon ash† | % % % % | | ··· ·· ·· |

| Ultimate analysis | Unit | Symbol‡ | As Fired* | Dry | Dry, Ash- Free |
|--|--|---|--------------------------------------|-----|----------------------------|
| 271 moisture 272 ash 273 carbon 274 hydrogen 275 nitrogen 276 sulphur 277 oxygen (by difference) | 0/0 0/0 0/0 0/0 0/0 0/0 | $E 	imes 100 \ {\cal Z} 	imes 100 \ {\cal Z} 	imes 100 \ {\cal C} 	imes 100 \ {\cal H} 	imes 100 \ {\cal N} 	imes 100 \ {\cal N} 	imes 100 \ {\cal S} 	imes 100 \ {\cal O} 	imes 10$ | ··· ·· ·· ·· ·· 100·0 | | ··· ··· ··· 100·0 |

| | Calorific Value of Fuel at Entry to | | | |
|-------------------|---|----------------------|--|-------|
| | System Under Test* | Unit | Symbol | VALUE |
| 278 279 | Gross Net§ | kJ/kg kJ/kg | $egin{array}{c} H_1 \ H_2 \end{array}$ | ••• |
| 280 281 282 | Rate of firing* Fuel fired per m ² of grate area Heat release per m ² of grate area | kg/s kg/s kJ/s | <u>C1</u> — | •• |

283 Method and time of cleaning grates.....

| | UNIT | Symbol | First Control Hour | Last Hour of Test |
|--|-----------|--------|--------------------------|----------------------|
| 284 Average thickness of feed | mm | | | |
| (chain or travelling grate) | | | | |
| 285 Speed of chain or travelling grate | m/s | | | |
| 286 Speed of rotary feeder | rev/s | | | |
| 287 Speed of worms | rev/s | | | |
| 288 Speed of ram | strokes/s | | | |
| 290 Power used to operate mechanical stokers | 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.

<sup>the moisture content after continoning.
†An analysis of the ash may be required.
‡Symbol applies to 'as fired' condition.
§For calculation of the net calorific value of a solid fuel, the hydrogen and oxygen contents on a dry mineral-matter-free basis and mineral-matter content are required in addition to the ultimate analysis and the gross calorific value.</sup> If required.

| | 2) Pulverized Fuel Fuel weighed | Unit | Symbol | VALUE |
|-----|--|-------|--------|-------|
| 291 | total | kg/s | | • |
| 292 | mill No | kg/s | | •• |
| 293 | mill No | kg/s | | •• |
| 294 | mill No | kg/s | | •• |
| | Mill rejects | 0, | | |
| 295 | total | kg/s | | •• |
| 296 | mill No | kg/s | | •• |
| 297 | mill No | kg/s | | •• |
| 298 | mill No | kg/s | — | •• |
| 299 | Rejects as proportion of fuel fired | % | | •• |
| 300 | Proportions of combustibles in rejects | % | | •• |
| | Calorific value of mill rejects | ,. | | |
| 301 | gross* | k]/kg | _ | •• |
| 302 | net* | kľ/kg | | •• |
| 303 | rate of firing | kg/s | C_1 | • • |
| | | | _ | |

| Item 201 | Item | $295 \times Item$ | 300×338 |
|----------------|------|-------------------|------------------|
| = 1tem 251 $-$ | Ite | m 278 (or Ite | em 279) |

| | _ Item 901 _ | Item 295 × Item 301 (or Item 302) | 1 |
|----|--------------|-----------------------------------|---|
| 0T | = 11cm 251 - | Item 278 (or Item 279) | |

| 304 | Speed of setting of classifier rev/min | |
|-----|--|---|
| | Size grading of pulverized fuel [†] | |
| 305 | retained on 300 μ m (state equivalent sieve mesh used) | |
| 306 | passing 150 μ m | |
| 307 | passing 75 μ m | |
| | 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. †Or milled peat.

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| | | Unit | Symbol | VALUE |
|-----|--|----------------|--|-------|
| | Coal dryer: moisture in fuel | | | |
| 316 | at dryer inlet | % | | |
| 317 | at dryer outlet | ó, | ······ | |
| | Flue gas heated dryer: temperature of gas | , • | | 1 |
| 318 | at dryer inlet | °C | | |
| 319 | at dryer outlet | β°G | | |
| | Independently fired dryer | | ~ | |
| 320 | fuel used | kg/s | C_{11} | |
| | Calorific value of fuel, as weighed | 1.7.0 | | 1 |
| 321 | gross | kj/kg | | |
| 322 | net | KJ/Kg | | |
| 323 | neat expanded in drying fuel | ^J/ <u>^</u> g | | |
| 524 | Analysis of gases | ŭ | | |
| 295 | carbon dioxide | 0/ | | · |
| 326 | carbon monoxide (if any) | /0 0/ | | |
| 327 | oxygen and nitrogen (by difference) | 0/0 | | •• |
| 041 | oxygen and merogen (b) emeronee) | 70 | | |
| | | | | 100.0 |
| | | | | |
| | Ashpit refuse* | | _ | |
| 328 | quantity | kg/s | | |
| 329 | per cent combustible | 07 | ⁷ 6 | |
| | b) Oil Fuel | | | |
| | Description of Fuel | | | |
| 330 | market description | | | |
| 331 | classification [†] | I | | |
| | Ultimate Analysis, at Entry to System Under Test | 0/ | $E \sim 100$ | |
| 332 | moisture | % 0/ | $\frac{E}{2} \times 100$ | 1 |
| 222 | asni | /0 0/ | $\hat{c} \stackrel{\land}{\searrow} \hat{100}$ | |
| 225 | carpon hudeo con | /0 0/ | $H \propto 100$ | |
| 330 | aulahur | 6/ 6/ | $S \times 100$ | |
| 337 | ovygen and nitrogen (by difference) | /0 0/ | | |
| 557 | oxygen and mulogen (by underende) | , U | | |
| | | | | 100.0 |
| | | | | |
| 339 | density of oil at 15.5°C | g/ml | - | |
| 341 | viscosity byviscometer at 15.5°C | cSt§ | | { |
| 342 | flash point | °C | | |
| 343 | specific heat of oil | kJ/(kg K) | f | |
| | Calorific Value of Fuel, at Entry to System Under Test * | | | l l |
| 344 | gross | kJ/kg | H_1 | • • |
| 345 | net | k]/kg | H_2 | • · |
| | Steam used in heater | James La | l | |
| 346 | quantity | Kg/S | | • · |
| 347 | gauge pressure | bar | | • |
| 348 | temperature | U kale | C | 1 . |
| 349 | rate of nring | °C | $\begin{bmatrix} 0.1\\ t \end{bmatrix}$ | |
| 300 | Oil as delivered to hurner | u | 11 '11 | 1 |
| 251 | | har | 4 | 1 |
| 301 | gauge pressure | Jui |) r18 | •• |

^{*}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.
*According to the appropriate classification for each country.
*When required, an analysis of the ash is to be made.
§I CSt = 1 mm⁴/s. Other units may be employed.
*Unless specially determined, this should be taken as 1.80 kJ/(kg K) for gas oil (4 cSt)
1.72 kJ/(kg K) for light fuel oil (30 cSt to 50 cSt)
1.68 kJ/(kg K) for medium-heavy fuel oil (120 cSt)
1.63 kJ/(kg K) for heavy or very heavy fuel oil (220 cSt to 250 cSt)

| | Unit | Symbol | VALUE |
|---|--|---------------------------------------|-------|
| 352 temperature | °C | t ₁₈ | |
| 353*temperature of drains from heater | °C | | |
| 354*enthalpy of steam at heater inlet | kJ/kg | _ | |
| 355*enthalpy of drains at heater outlet | kJ/kg | - | |
| 356 power used to operate oil pump | kŴ | | |
| Air or steam for atomizing, as delivered to burner | | - | |
| 357 quantity | kg/s | | |
| 358 gauge pressure | bar | - | |
| 359 temperature | °C | | |
| 360 heat used in atomizing oil on basis of air at t_{12} | kW | | |
| 361 power used to operate air compressor c) Gaseous Fuel and/or Waste Gas from Separate Source[†] | kW | _ | |
| Rate of firing | m 8 /a | C | |
| 362 volume | lim"/s | C_2 | |
| 363 mass | kg/s | 1 1 | |
| Gas as measured | har | | |
| 364 gauge pressure | °C | | |
| Cos os fired | u | | |
| 966 gauge pressure | bar | 1 | |
| 267 temperature | °C | | |
| 268 harometric pressure | mbar | | |
| Analysis of dry gas, percentage by volume | | | |
| 369 carbon monoxide (CO) | % | | |
| 370 carbon dioxide (CO.) | % | | |
| 371 methane (CH_4) | % | | |
| 372 ethane (C_2H_a) | % | — | |
| (propane (C_3H_8)) to be expressed | | | |
| 373 $\left\{ butane \left(\dot{C}_{4} \dot{H}_{10} \right) \right\}$ as ethane or | % | - | |
| $p_{\text{pentane}}(\dot{C}_5 H_{12})$ propane | | | |
| $374 C_x H_y$ | % | · · · · · · · · · · · · · · · · · · · | ••• |
| 375 others | % | - | 1 |
| 376 hydrogen sulphide (H_2S) | % | | |
| 377 hydrogen (H_2) | % | a | |
| $378 \text{ oxygen } (\mathbf{O}_2)$ | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | 1 - | |
| 379 nitrogen (N_2) | 1 - /1 | \overline{c} | •• |
| 380 Carbon content calculated per unit mass of gas, as inted | Kg/Kg lvg/lvg | C C | |
| 381 Sulphur content calculated per unit mass of gas, | Kg/Kg | 5 | |
| as lifeu Saturated gas | * | | |
| 200 gougo pressure | bar | | |
| 302 gauge pressure | °C | | |
| 384 relative density (air -1) | ä | | |
| Moisture content | | | |
| 385 as fired | kg/m ³ | - | |
| 386 calculated per unit mass of dry gas | kg/kg | | |
| Calorific value of saturated gas, as analysed, at 1.013 25 bar and 25°C | | | |
| 387 gross | kJ/m ^a | | |
| 388 gross | KJ/Kg | | 1 |
| 389 net | K]/Kg | | •• |
| Calorific value, as fired | 1-T /9 | | |
| 390 gross | KJ/M* 1.1/~~* | | |
| 391 net | кј/ш- Ъ]/Ба | U H | |
| 392 gross | •ህ/ቅይ k]/ka | | |
| 222 Her | ~J/~6 | 2 | |

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^{*}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.

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| | | Unit | Symbol | Value |
|-----|--|----------------------|---------------|-------|
| 394 | Mean specific heat* | kJ/(kg K) | | •• |
| E) | Air | | | |
| | Ambient conditions | | . | |
| 395 | pressure† | mbar | \$°11 | • • |
| 396 | temperature | -u | $\frac{-}{r}$ | •• |
| 397 | relative humidity | % | ň | •• |
| 398 | temperature at entry to air intakes [‡] | °C Iva (Iva | l_{12} | •• |
| 399 | humidity per unit mass of dry air | kg/kg | κ2 | •• |
| | Entry to forced draught intake | °C | | |
| 400 | temperature | mbor | | •• |
| 401 | pressure | mbai | | •• |
| 400 | Entry to low temperature air neater | °C1 | | |
| 402 | temperature | mbar | | •• |
| 403 | Pressure | mbal | | •• |
| 404 | Exit from low temperature air neater | °C | | |
| 404 | temperature | mhar | | |
| 405 | Entry to high temperature air heater | mou | | |
| 106 | Entry to high temperature an heater | °C | 1 | |
| 400 | | mbar | -14 | |
| 407 | Fuit from high temperature air heater | | | |
| 408 | temperature | $^{\circ}\mathbf{C}$ | lie | |
| 400 | | mbar | -15 | |
| 105 | Tempering air to mills | | | |
| 410 | temperature | $^{\circ}\mathbf{G}$ | | |
| 411 | nressure | mbar | i | |
| 1 | Entry to mills, stoker or furnace | | | |
| 412 | temperature | $^{\circ}\mathrm{C}$ | | |
| 413 | pressure | mbar | | |
| | Exit from mills | | | |
| 414 | temperature | °C | | |
| 415 | pressure | mbar | | |
| | Primary air ducts | | | |
| 416 | temperature | °C | | •• . |
| 417 | pressure | ınbar | | |
| | Secondary air ducts | | | |
| 418 | temperature | ٠Ç | - | |
| 419 | pressure | mbar | | |
| | Tertiary air ducts | 001 | 1 | |
| 420 | temperature | , ^v G | | |
| 421 | pressure | mbar | I — | |
| 422 | Furnace draught atlevel§ | mbar | | |

F) Flue gases

| | Analysis temperature and pressure of | Α | B | С | D | E |
|-----|--------------------------------------|-----|----|-----|-------------|----------|
| | heat exchanger and dust extruction | CO | 0, | CO, | Temperature | Pressure |
| | this information is required) | % | % | % | D° | mbar |
| 423 | | •• | | | | •• |
| 424 | | • • | | | •• | •• |
| 425 | | •• | 1 | | •• | |
| 426 | | •• | | | | •• |

426

^{*}This item may be calculated proportionately from the specific heats of the fundamental constitutents of the gaseous fuel. †In circumstances of exceptional climate or altitude, or as required by **4.18**. ‡This temperature should be measured at the point at which the air enters the system of the unit. §As the pressure varies at different heights the level at which this reading is taken should be stated.

| | | Unit | Symbol | VALUE |
|------------|--|------------------------------|----------------------------------|-------|
| | Exit of low temperature air heater | | | |
| | (or economizer in the absence of an air heater) | | | |
| 427 | temperature | °Ċ | /16 | • • |
| 428 | pressure | mbar | | •• |
| | Analysis of gas exit of low temperature air | | | |
| 490 | neater, percentage by volume | 0/ | | |
| 430 | carbon monoxide (CO) | /0 0/_ | ^{<i>u</i>} ₁ | •• |
| 431 | methane (CH.) | 6 | | •• |
| 432 | oxygen (O_9) | 0/ /0 | | •• |
| 433 | sulphur dioxide (SO ₂) | % | | • • |
| 434 | nitrogen (N ₂) | % | a ₆ | • • |
| 435 | hydrogen (H ₂) | % | a7 | • • |
| 436 | hydrocarbons $(C_n H_m)$ | % | a ₈ | •• |
| 497 | Entry to induced draught fan | °C | | |
| 43/ | temperature | mhar | | •• |
| 400 | Entry to chimney | mpar | | •• |
| 439 | temperature | °C | | |
| 440 | pressure | mbar |) <u> </u> | |
| | <u> </u> | | | |
| G) | Control Valves and Dampers | | | |
| 441 | Attemperator by-pass | % open | | •• |
| 442 | Spray water for main steam temperature control | % open | | •• |
| 443 | Spray water for reheated steam temperature control | % open | | •• |
| 444 | Frimary air tempering control | % open | | •• |
| 440 | Tertiary air tempering control | % open | | •• |
| 447 | Other controls | % open | | •• |
| | | 70 1 | | |
| H) | Residues | | | |
| 448 | Condition of residue in ash-pit (powder, slag or | | 1 1 | |
| | other form) | | { | |
| 110 | Ash and chickers | ka/s | ם ו | |
| 450 | as proportion by mass of fuel (dry basis) | % | | •• |
| 451 | combustible content | 0 | l i l | •• |
| 452 | combustible content per unit mass of fuel | kg/kg | - I | •• |
| 453 | temperature as discharged | $\mathbf{\tilde{D}}^{\circ}$ | | •• |
| 454 | specific heat | kJ/(kg K) | - | |
| | Slag in slag tank | 1 / | | |
| 455 | quantity | kg/s 💑 | D_1 | •• |
| 430 | as proportion by mass of fuer (dry basis) | /0 0/ | ; | •• |
| 458 | combustible content per unit mass of fuel | /o kg/kg | | •• |
| 150 | Dust from | | } | ••• |
| 459 | quantity | kg/s | | •• |
| 460 | as proportion by mass of fuel (dry basis) | % | | •• |
| 461 | combustible content | % | i_2 | •• |
| 462 | combustible content per unit mass of fuel | kg/kg | | • • |
| 463 | temperature as discharged | $\frac{1}{2}$ | | •• |
| 404 | specific field | V) (R. V.) | - | •• |
| 465 | auantity | kg/s | D. | |
| 466 | as proportion by mass of fuel (dry basis) | 0/0 | | •• |
| 467 | combustible content | % | i3 | •• |
| 468 | combustible content per unit mass of fuel | kg/kg | - | •• |
| 469 | temperature as discharged | ۵ | l l | •• |

^{*}When the carbon dioxide content is obtained using an Orsat apparatus the value normally includes the sulphur dioxide content. To be assumed as 0.67 kJ/(kg K) if not determined.

VALUE

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| | Unit | Symbol | VALUE |
|--|---------------------------------|---------------------------------|-----------------|
| 470 specific heat Riddlings 471 quantity 472 as proportion by mass of fuel (dry basis) 473 combustible content 474 combustible content per unit mass of fuel | kJ/(kg K) kg/s % kg/kg | $\frac{D_{5}}{\frac{i_{5}}{2}}$ | ··· ·· ·· |
| J) Water Filled Ash Hopper or Slag Tank or Ash Qu | enching | | |
| Water inlet 475 temperature 476 quantity Water outlet | °C kg/s | | •• |
| 477 temperature 478 quantity | °C kg/s | | •• |
| 479 temperature 480 quantity | °C kg/s | | |

| K) Power of Auxiliaries | For information only | | Unit | Symbol | VALUE |
|--|----------------------|---------|------|--------|-------|
| | V | A | | | |
| 481 Induced draught fans | •• | | kW | | •• |
| 482 Forced draught fans | •• | •• | kW | | •• |
| 483 Secondary air fans | •• | •• | kW | | •• |
| 484 Other draught plant (to be listed) | <u> </u> | <u></u> | kW | | · · · |

| 485 | Total po | wer use | d to | produce | draught |
|-----|----------|---------|------|------------|---------|
| 486 | Stokers | | | - . | - |

487 Air heaters

488 Other auxiliaries (to be listed)

| Power used in preparing, transporting | Mill | Mill | Mill* |
|--|-----------------------|----------------------|----------------------|
| and firing pulverized fuel 489 pulverizers 490 primary fans or exhausters 491 classifiers 492 feeders and/or conveyors | *kW kW kW kW | kW kW kW kW | kW kW kW kW |

| Unit | SYMBOL | VALUE |
|------|----------|-------|
| kW | | |
| kW | | |
| kW | l | 1 |
| kW | <u> </u> | |
| kW | | |

Symbol

Unit

kW

kW kW

kW

493 Rotary dryer
494 Air compressor and fuel transfer plant
495 Other auxiliaries
496 Total power used in pulverized fuel plant
497 Total power for auxiliaries

^{*}Provision may be required for more than three mills.

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IV) COMPUTATION OF HEAT ACCOUNT

501 Steam tables used.....

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

Note — In accordance with 2.4 any heat supplied to the unit from a separate source should 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, should be computed and deducted.

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B) Heat Input

| 520 | Mechanical stokers, heat input | kW |
|-----|---|----|
| 521 | Pulverized fuel, heat input | kW |
| 522 | Oil fuel, heat input | kW |
| 523 | Gaseous fuel and/or waste gas, heat input | kW |
| 524 | Total heat input | kW |

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 should be determined from the heat output computed in accordance with IV A, plus the sum of the losses computed according to IV C to IV H inclusive on the following pages.

^{*}These items apply in cases of oil firing only.

NOTES

501 See 3.3 (15)

| 502 | Item 203 × Item 206 | W_1 h_1 |
|-----|---|---------------------------------|
| 503 | Item 217 × Item 220 | W, h, |
| 504 | Item 216 × Item 211 | $W_{s} h_{s}$ |
| 505 | Item 215 × Item 211 | $W_{10} h_5$ |
| 506 | [Item 203 + Item 217 - (Item 216 + Item 215)] × Item 246 = $[W_1 + W_7 - (W_5 + W_{10})] h_3$ | $W_2 h_2$ |
| 507 | Item 506 + Item 505 + Item 504 - Item 503 - Item 502 = $W_1(h_2 - h_1) + W_7(h_3 - h_7) - (W_5 + W_{10})(h_3 - h_5)$ | Q1* |
| 508 | Item 247 × Item 250 | W ₃ h ₃ |
| 509 | Item 221 × Item 224 | W_8h_8 |
| 510 | Item 251 \times 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 ₈₁ h ₃₁ |
| 513 | Item 225 \times Item 228 | W ₉ h ₉ |
| 514 | Item 259 \times 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 \times Item 343 \times (Item 352 – Item 350) + Item 360 | Q4 |
| 518 | Item 516 Item 517 | $Q (= Q_1 + Q_3 + Q_3 - Q_4)$ |
| 519 | Mass of air derived × Enthalpy added in external source × external air heater | |

520 Item 280 × Item 278 (or Item 279)†

521 Item 303 × Item 278 (or Item 279)† + Item 323‡

522 Item 349 × Item 344 (or Item 345)†

523 Item 363 \times Item 392 (or Item 393)[†] or Item $362 \times$ Item 390 (or Item 391)[†]

 $F_{\rm c} = C_{\rm s} H_{\rm l} (\text{or } C_{\rm s} H_{\rm s})$

 $F_{c} = C_{1}H_{1} \text{ (or } C_{1}H_{2})$

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

*In the event of the superheated steam quantity, but not the feed-water quantity, having been measured, item 507 can be written $W_3 (h_5 - h_1) + (W_5 + W_{10})(h_5 - h_1) - W_7(h_7 - h_1) = Q_1$ [using the relationship $W_1 = W_3 + (W_5 + W_{10}) - W_7$] †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.

| 10 • | 0735 - 1577 | | |
|-------------|---|--|--|
| C) | Losses Due to Solid Residue | | |
| 6 01 | Calorific value of carbon | kJ/kg | |
| | Coarse ash or slag | n an | |
| 602 | Combustible matter in coarse ash or slag | % | |
| 603 | Mass of dry coarse ash or slag per unit mass of fuel | kg/kg | |
| 604 | Heat lost by combustible matter in coarse ash or slag | kJ/kg | |
| 6 05 | 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 | |
| 6 08 | Heat lost by combustible matter in coarse dust and grit | kJ/kg | |
| 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 4.14) | kg/kg | |
| 612 | Heat lost by combustible matter in fine dust | kJ/kg | |
| 613 | Heat loss due to fine dust | % | |
| | Riddlings | | |
| 614 | Combustible matter in riddlings | % | |
| 6 15 | Mass of dry riddlings per unit mass of fuel | kg/kg | |
| 616 | Heat lost by combustible matter in riddlings | kJ/kg | |
| 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 | |
| 620 | Heat lost by combustible matter in ash from independently fired dryer | kJ/kg | |
| 621 | Heat loss due to ash from independently fired dryer | % | |
| | Total loss due to solid residue | | |
| 622 | Total heat loss by combustible matter in solid residue | kJ/kg | |
| 623 | Percentage heat loss due to combustible matter in solid residue | % | |

H,

i₁

 D_1 C_1

 i_{1} D_{1} $\overline{C_{1}}$

 $\frac{1}{C_1}$

 i_5 D_5 C_1

 i_{0} $\frac{D_{0}}{C_{1}}$

 p_1 100 p_1

 $\overline{H_1}$ or $\overline{H_2}$

 $\frac{D_1 \times i_1 \times H_3}{C_1 \times 100}$

 $\frac{D_1 \times i_1 \times H_2}{C_1 \times H_1 \text{ or } H_2}$

 $\frac{D_{\rm a} \times i_{\rm a} \times H_{\rm s}}{C_{\rm 1} \times 100}$

 $\frac{D_3 \times i_3 \times H_3}{C_1 \times H_1 \text{ or } H_3}$

 $\frac{D_3 \times i_3 \times H_3}{C_1 \times 100}$

 $\frac{D_3 \times i_3 \times H_3}{C_1 \times H_1 \text{ or } H_2}$

 $\frac{D_{\mathbf{5}} \times \mathbf{i}_{\mathbf{5}} \times H_{\mathbf{3}}}{C_{\mathbf{1}} \times 100}$

 $\frac{D_5 \times i_8 \times H_3}{C_1 \times H_3 \text{ or } H_2}$

 $\frac{D_{6} \times i_{6} \times H_{3}}{C_{1} \times 100}$

 $\frac{D_6 \times i_6 \times H_3}{C_1 \times H_1 \text{ or } H_3}$

NOTES 601 Normally 33 820 k. J/kg* 602 Item 451 or Item 457 Item 450 or Item 456 603 100 Item 601 \times Item 602 \times Item 603 604 100 Item 604×100 605 Item 278 or Item 279 Item 461 606 Item 460 607 100 Item 601 \times Item 606 \times Item 607 608 100 Item 608×100 609 Item 278 or Item 279 610 Item 467 Item 466 611 100 Item 601 \times Item 610 \times Item 611 612 100 Item 612 × 100 613 Item 278 or Item 279 614 Item 473 Item 472 615 100 Item 601 \times Item 614 \times Item 615 616 100 Item 616×100 617 Item 278 or Item 279 618 Item 329 Item 328 619 Item 303 Item $601 \times$ Item $618 \times$ Item 619620 100 Item 620×100 621 Item 278 or Item 279 622 Item 604 + Item 608 + Item 612 + Item 616 + Item 620

623 Item 605 + Item 609 + Item 613 + Item 617 + Item 621

*If the greater part of the unburnt 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.

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 |
| 62 5 | Pure ash in coarse dust per unit mass of fuel | kg/kg |
| 626 | Pure ash in fine dust (fly ash) per unit mass of fuel | kg/kg |
| 627 | Pure ash in coarse riddlings per unit mass of fuel | kg/kg |
| 628 | Pure ash in coarse ash from dryer per unit mass of fuel | kg/kg |
| 62 9 | Balance of pure ash per unit mass of fuel | kg/kg |
| 630 | Equivalent mass of unweighed residue per unit mass of fuel | kg/kg |
| | 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 | kJ/kg |
| 632 | Heat lost in sensible heat of dust and grit | kJ/kg |
| 633 | Total heat lost in sensible heat of solid residues | kJ/kg |
| D) I | osses Due to Unburnt Gas | |
| 701 | CO in flue gases per unit mass of fuel | kg/kg |
| 702 | Calorific value of CO [†] | kJ/kg |
| 703 | Heat loss due to unburnt CO | kJ/kg |
| 704 | Hydrocarbons in flue gases per unit mass of fuel | kg/kg |
| 705 | Calorific value of hydrocarbons [†] | kJ/kg |
| 706 | Heat loss due to unburnt hydrocarbons | kJ/kg |
| 707 | Heat loss due to unburnt gas per unit mass of fuel | kJ/kg |

*To be estimated on the basis of the determinations on the weighed refuse. It is recommended that these values should be obtained from the most recent available data.

NOTES

| 624 | $\frac{\text{Item } 603 \times (100 - \text{Item } 602)}{100}$ | $\frac{D_1(100-i_1)}{100 C_1}$ |
|-------------|--|---|
| 625 | $\frac{\text{Item } 607 \times (100 - \text{Item } 606)}{100}$ | $\frac{D_{\rm s}(100-i_2)}{100C_1}$ |
| 626 | $\frac{\text{Item 611} \times (100 - \text{Item 610})}{100}$ | $\frac{D_{3} (100-i_{3})}{100 C_{1}}$ |
| 627 | $\frac{1100 - 1100 - 1100}{100}$ | $\frac{D_{5} (100 - i_{5})}{100 C_{1}}$ |
| 628 | $\frac{\text{Item 619} \times (100 - \text{Item 618})}{100}$ | $\frac{D_{6} (100 - i_{6})}{100 C_{1}}$ |
| 62 9 | Item 272-Item 624-Item 625-Item 626-Item 627-Item 628 | |

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

 $\frac{11 \text{tem } 629 \times 100}{100 - \% \text{ combustible matter in unweighed residue}}$

- 631 Item 603×Item 454×(Item 453-Item 398)
- $632 \quad [Item 607 \times Item 464 \times (Item 463 Item 398)] + [Item 611 \times Item 470 \times (Item 469 Item 398)]$
- 633 Item 631 + Item 632

| 701 | 7×Item 430 | /Item 273, 334 or 380 | Item 276, 336 or 381 | Itoma 452 45 | \$8 462 469 and 474 |
|-----|--|-----------------------|----------------------|---------------|-----------------------|
| /01 | $3 (\text{Item } 429 + \text{Item } 430 + \Sigma n C_n H_m)$ | 100 | 267 | 11cms 452, 45 | 10, 402, 400 and 474) |

 $\Sigma_n C_n H_m$ represents the sum of the values of $nC_n H_m$ for each hydrocarbon present in the flue gas. It is numerically equal to the volume of carbon dioxide produced by the combustion of the hydrocarbon during the analysis of the flue gas.

- 703 Item 701 × Item 702
- $704 \quad \frac{(12n+m)C_{n}H_{m}}{12 (\text{Item } 429 + \text{Item } 430 + \sum nC_{n}H_{m})} \left(\frac{\text{Item } 273, 334 \text{ or } 380}{100} + \frac{\text{Item } 276, 336 \text{ or } 381}{267} \text{Items } 425, 458, 462, 468 \text{ and } 474\right)^{*}$
- Where more than one hydrocarbon is present the above equation must be applied separately to each hydrocarbon C_nH_m and the results added, C_nH_m in the equation being the volumetric percentage of each individual hydrocarbon.
- 705 Where more than one hydrocarbon is present the calorific value of each is required.
- 706 Item 704×Item 705

Where more than one hydrocarbon is present, Item 704 and 705 applicable to each are multiplied together and the results are then added.

707 Item 703 + Item 706 = P_2 .

*The term $\frac{1 \text{tem 276, 336 or 381}}{267}$ only applies when the carbon dioxide content is obtained using an Orsat apparatus, which normally gives a value including the sulphur dioxide content.

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İŠ : 8753 - 1977

E) Loss Due to Sensible Heat in Dry Flue Gases

| 708 | Dry flue gases per unit mass of fuel | kg mol/kg |
|-----|--|-----------|
| 709 | Sensible heat lost in dry flue gas per unit mass of fuel | kJ/kg |

F) Losses Due to Moisture and Hydrogen

| 801 | Moisture per unit mass of fuel | kg/kg |
|-----|--|-------|
| 802 | Moisture due to hydrogen per unit mass of fuel | kg/kg |
| 803 | Total moisture in flue gases per unit mass of fuel | kg/kg |

| 804 | Heat per unit mass of moisture in flue gas above air inlet temperature | kJ/kg |
|-----|--|----------------|
| 805 | Heat loss due to moisture in flue gas per unit mass of fuel | k J /kg |

G) Losses Due to Sensible Heat of Water Vapour

| 806 Sensible heat loss per unit mass of fuel | kJ/kg |
|--|-------|
|--|-------|

H) Losses Due to Moisture in Combustion Air

| 807 | Combustion air per unit mass of fuel | kg/kg |
|-----|---|-------|
| 808 | Relative humidity of combustion air at entry to system under test | % |
| 809 | Water vapour content of combustion air | kg/kg |
| 810 | Heat loss due to moisture in combustion air | kJ/kg |

NOTES

| 709 | 100 | (Item 273, 334 or 380 | Item 276, 336 or 381 | Item 452, 458, 462. | 468 and 474 |
|-----|---|-----------------------|----------------------|---------------------|---------------|
| /00 | 12 (Item 429+Item 430+ ΣnC_nH_m) | 100 | 267 | | , |

709 Item $708 \times 30.6 \times (\text{Item } 427 - \text{Item } 398) = P_a$

The kilogram molecular specific heats for the individual constituents are as follows:

| Constituent | CO2 | CO | O ₂ | N ₂ | H ₂ | SO3 | CH4 | C_2H_2 | C_2H_4 | C ₂ H ₆ |
|-------------|------|------|----------------|----------------|----------------|------|------|----------|------------------|-------------------------------|
| kg-mol Cp | 39.8 | 29.3 | 29.3 | 29.3 | 29.3 | 42·3 | 39.8 | 41.5 | 4 8·6 | 48 ∙6 |

The value chosen for the weighted average kilogram molecular specific heat, namely 30.6, is within 1% of the true weighted average for any composition of gases likely to be encountered in practice.

| 801 | From Item 271 or Item 332 or Item 385 | == <i>E</i> |
|-----|---|-------------|
| 802 | $\frac{9}{100}$ × percentage hydrogen by mass in fuel (from Item 274, 335 or 377) | =9H |

If free hydrogen is present in the combustion gases it is necessary to make an adjustment to the above.

803 Item 801 + Item 802

When using Method A, it is normally only necessary to take account of the moisture content of the combustion air in conditions of high humidity of the ambient air. When using Method B, allowance should always be made for the moisture content of the combustion air.

- 804 1.88 (Item 427-25†)+2442+4.2 (25†-Item 398) $=P_4+P_5$
- 805 Item 803 × Item 804

With gaseous fuels it is [Item $802 \times \text{Item } 804$] + [Item 801×1.88 (Item 427 - Item 398)] since moisture in gaseous fuels already exists in the form of vapour.

806 Item 805-[(Item 278-Item 279) or (Item 344-Item 345) or (Item 390-Item 391) or (Item 392-Item 393)]

The above treatment uses the air inlet temperature as a reference point and, as the difference between the gross and net calorific values has been deducted from the total moisture loss, Item 805, the residue is not strictly the sensible heat loss, since it includes the difference between the latent heat of water at the air inlet temperature and the latent heat of water at 25°C, which would otherwise have to be computed for the heat balance on the net calorific value.

807 Mass of air required for combustion

| 808 | As determined by psychrometer at entry to system under test (see Item 397) | == <i>K</i> |
|-----|---|-------------|
| 809 | Item 399 | $=K_{2}$ |
| 810 | Item $807 \times \text{Item } 809 \times 1.88 \text{ (Item } 427 - \text{Item } 398)$ | |
| | $= \frac{W_{a}}{C_{1}} \times k_{a} \times 1.88 \ (t_{16} - t_{12})$ | =P, |

^{*}The term $\frac{\text{'Item 276, 336 or 381'}}{267}$ only applies when the carbon dioxide contents is obtained using an Orsat apparatus, which normally gives a value including the sulphur dioxide content.

^{†25°}C being the reference temperature for determination of calorific values: see Clause 2.

V) THERMAL EFFICIENCY AND HEAT ACCOUNT

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Heat accounts may be calculated on gross or net calorific values and either or both may be quoted as below. _

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| | | Symbol | Gross Calorific Value | Net Calorific Value |
|-----------------|--|-----------|-----------------------------|---------------------------|
| 001 | The second of the second has Mashed A) | | % | % |
| 901 | I nermal emclency (for test by Method A) | | •• | •• |
| 902 | Thermal efficiency (for test by Method B) | _ | | •• |
| 903 | Losses due to residue a) combustible in ash b) combustible in coarse dust c) combustible in fine dust | | | |
| | a) combustible in riddings e) combustible in ash from independently fired dryer f) sensible heat of solid residue | | | ••• |
| | | | | |
| 904 | Losses due to flue gases a) unburnt gas b) sensible heat in dry gas c) net calorific value d) gross calorific value e) heat in atomizing air or steam | | ••• •• •• •• | · · · · · · · |
| | | | | |
| 905 | Losses due to water-filled ash hoppers, slag tanks or ash quenching | . — | | ••• |
| | | | | |
| 906 | Loss due to moisture in combustion air | - | •• | •• |
| 9 07 | Loss in heating fuel up to air supply temperature | . | | •• |
| 908 | Balance of account, including radiation and other unmeasured loses (for test by Method A) | | | |
| 909 | Radiation and convection loss (for test by Method B) | | | ••• |
| 910 | Heat equivalent of auxiliary power (for test by Method B) | | | |

Item 516 (or Item 518, less Item 519 where applicable) \times 100 901 Item 520, 521, 522, 523 or 524 902 100 - (Item 903 + Item 904 + Item 905 + Item 906 + Item 907 + Item 909 + Item 910) 903 Gross Net Item 604 \times 100 Item 604×100 -Item 605 a) Item 278 or Item 344 Item 279 or Item 345 Item 608 \times 100 Item 608×100 b) =Item 609 Item 278 or Item 344 Item 279 or Item 345 Item 612×100 Item 612×100 c) =Item 613 Item 278 or Item 344 Item 279 or Item 345 Item 616 \times 100 Item 616×100 d) =Item 617 Item 278 or Item 344 Item 279 or Item 345 Item 620×100 Item 620×100 =Item 621 c) Item 278 or Item 344 Item 279 or Item 345 Item 633×100 Item 633×100 **f**) Item 278 or Item 344 Item 279 or Item 345 904 Item 707 \times 100 Item 707 \times 100 a) Item 278 or Item 344 or Item 392 Item 279 or Item 345 or Item 393 Item 709 \times 100 Item 709×100 b) Item 278 or Item 344 or Item 392 Item 279 or Item 345 or Item 393 Item 805×100 **c**) Item 278 or Item 344 or Item 392 Item 806 \times 100 **d**) Item 279 or Item 345 or Item 393 Item $357 \times 100 \times$ (heat in air between limits of Items 427 and 398) Item 357 \times Item 804 \times 100 e) or Item 349 × (Item 344 or Item 345) Item 349 × (Item 344 or Item 345) 905 For water-filled ash hoppers or slag tanks $(1 \text{ (Item 476 - Item 478)} [(100 - \text{ Item 475}) + 539 \cdot 1 + 0.5 (\text{ Item 427 - 100})] + \text{ Item 478} (\text{ Item 477 - Item 475})' \times 418 \cdot 7$ Item 520 or Item 521 For ash quenching Item 480 [$(100 - \text{Item } 479) + 539 \cdot 1 + 0 \cdot 5$ (Item 427 - 100)] × 418.7 Item 520 or Item 521 Item 810×100 Item 810×100 906 Item 278 or Item 344 or Item 392 Item 279 or Item 345 or Item 393 The sensible heat per unit mass of fuel between the limits t_{12} and t_{11} is to be computed. 907 908 100 - (Item 901 + Item 903 + Item 904 + Item 905 + Item 906)Item 909 will have been determined by agreement (or see 4.18) prior to the test in accordance with this standard, and 909 represents the gross radiation and convection, no allowance being made for recuperation, the air inlet temperature having been determined in accordance with this standard.

910 The heat equivalent, per unit mass of fuel, of the shaft power of all the auxiliaries, acting between the sections at which t_{12} and t_{16} are measured, divided by Item 278, 279, Item 344, 345, or Item 392, 393, as appropriate. This term has a negative sign in the heat account.

APPENDIX A

(Clause 0.5)

LIST OF INDIAN STANDARDS

- IS: 436 (Part I)-1964 Methods for sampling of coal and coke: Part I Sampling of coal (revised)
- IS: 436 (Part II)-1965 Methods for sampling of coal and coke : Part II Sampling of coke (revised)
- IS: 1350 (Part I)-1969 Methods of test for coal and coke: Part I Proximate analysis (first revision)
- IS: 1350 (Part II)-1970 Methods of test for coal and coke: Part II Determination of calorific value (first revision)
- **1S: 1448** Methods of test for petroleum and its products:
 - [P:6]-1960 Calorific value by bomb calorimeter method
 - [P:7]-1960 Calorific value by calculation
 - [P:16]-1967 Density by hydrometer method (first revision)
 - [P: 25]-1960 Kinematic viscosity
- IS: 1460-1974 Diesel fuels (second revision)
- IS: 1593-1971 Fuel oils (first revision)
- IS: 2054-1962 Reference table for nickel/chromium-nickel/aluminium thermocouples

- IS: 2055-1962 Reference tables for platinum/ rhodium-platinum thermocouples
- IS: 2056-1962 Reference tables for copper-constantan thermocouples
- IS: 2057-1962 Reference tables for iron-constantan thermocouples
- IS: 2952 (Part I)-1964 Recommendation for methods of measurement of fluid flow by means of orifice plate and nozzles: Part I Incompressible fluids
- IS: 3025-1964 Methods of sampling and test (physical and chemical) for water used in industry
- IS: 3624-1966 Bourdon tube pressure and vacuum gauges
- IS: 3810-1966 Glossary of terms used in coal preparation practice
- IS: 4477 (Part I)-1967 Methods of measurement of fluid flow by means of venturi meters : Part I Liquids
- IS: 4825-1968 Laboratory and reference thermometers
- IS: 7575-1975 Emergency specification for diesel fuels

APPENDIX B

(Clause 1.1)

DETERMINATION OF QUANTITY AND ENTHALPY OF COMBUSTION AIR

B-1. QUANTITY OF COMBUSTION AIR, W_{a}

B-1.1 The quantity of combustion air may be *calculated* by the following equation:

$$W_{\mathbf{s}} = W_{\mathbf{g}} + D_{\mathbf{T}} - C_{\mathbf{1}} \qquad \dots \qquad (\mathbf{B-1})$$

 W_g has as its value

$$W_{g} = C_{1} \left[(\bar{C} - \bar{C}') \frac{11a_{1} + 4a_{3} + 8a_{4} + 7(a_{2} + a_{6}) + 16a_{5}}{3(a_{1} + a_{2} + a_{3})} + 9(\bar{H} - \bar{H}') + \bar{E} \right] \qquad (B-2)$$

where

 \overline{C}' is determined in connection with the determination of the loss due to unburnt solid matter,

- a_1 and a_5 are not generally measured separately (the Orsat apparatus gives the total a_1+a_5),
- a_6 is not generally measured directly but is calculated by difference from 100

$$a_6 = 100 - (a_1 + a_2 + a_3 + a_4 + a_5)$$

Equation (B-2) then simplifies to

$$W_{g} = C_{1} \left[(\bar{C} - \bar{C}') \frac{700 + 4a_{1} - 3a_{3} + a_{4} + 9a_{5}}{3(a_{1} + a_{2} + a_{3})} + 9(\bar{H} - \bar{H}') + \bar{E} \right] \dots (B-3)$$

 $D_{\rm T}$ is determined in connection with the loss due to unburnt solid matter (Item 624 -630) and $D_{\rm T}=D_1+D_2+D_3+D_5+D_6$.

B-2. ENTHALPY OF THE COMBUSTION AIR

[Entering (h_{11}) and leaving (h_{12}) the additional air heater and supplied from a source *external* to the system under test.]

B-2.1 In the present calculation, W_{a} is in most cases taken as representing dry air.

B-2.2 Table B-1 shows the values that can be taken for h_{11} and h_{12} , as a function of the corresponding temperatures t_{14} and t_{15} .

TABLE B-1 VALUES* WHICH CAN BE ADOPTED FOR h_{11} AND h_{12} AS A FUNCTION OF TEMPERATURE CORRESPONDING TO t_{14} AND t_{15}

| (Clause | B-2.2) | |
|---------|--------|--|
|---------|--------|--|

| Value of t_{14} or t_{15} | | Value of h_{11} or h_{12} | | LUE OF h_{11} OR h_{13} VALUE OF t_{14} OF | | VALUE OF h_1 | 1 OR h12 |
|-----------------------------------|------------|-------------------------------|---|--|----|-------------------------|---|
| 0 | °C | 0.000 | kcal/kg | 220 | °C | 5 3 ·20 3 | kcal/kg |
| 20 | ,, | 4.788 | " | 240 | " | 58.122 | ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, |
| 40 | 32 | 9.586 | ,, | 260 | ,, | 63.065 | |
| 60 | ,, | 14.394 | ** | 280 ** | | 68·032 | |
| 80 | ** | 19-203 | 5 3 | 300 | " | 73.010 | ** |
| 100 | ** | 24.032 | ** | 900 | ** | 75.010 | 33 |
| 120 | ** | 28-861 | ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, | 520 | ** | 78-022 | " |
| 140 | ,, | 33-693 | , ,, | 340 | ** | 83-04 5 | IJ |
| 160 | 93 | 38 ·550 | ,, | 360 | " | 88.081 | ,, |
| 180 | 9 9 | 43-421 | 33 | 380 | ** | 93 ·155 | ,, |
| 200 | ,, | 48·30 5 | 33 | 400 | " | 98 ·253 | |

*These values have been prepared from KEENAN and KAYE, Gas Tables, New York, 1948.