
Draft for Development

**Methods of type testing heating
boilers for thermal performance**

Part 1. Direct method

Projet à développer

Méthodes d'essai de type du rendement thermique des chaudières

Partie 1. Méthode directe

Entwurf zur weiteren Ausarbeitung

Verfahren für die Baumusterprüfung der Wärmeleistung von Heizkesseln

Teil 1. Direktes Verfahren

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This publication is not to be regarded as a British Standard. It is being issued in the Draft for Development series of publications and is of a provisional nature because the procedures described herein require testing facilities that may not be generally available at present. In addition certain of the procedures may subsequently need modification in the light of practical experience. It is recommended that this Draft for Development should be applied on this provisional basis so that information and experience of its practical applications may be obtained. Those who use the document are urged to write to BSI giving their experience in applying this publication. Constructive proposals for improvement and more precise definitions will be welcomed.

The intention is to publish this document as a British Standard in due course and with such amendments as experience shows to be necessary.

The British Standards Institution request that, because of the provisional nature of the publication, its reference number should not be marked on products.

Foreword

This Draft for Development, which has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee, is based on a proposal of the International Organization for Standardization (ISO) for type testing heating boilers for thermal performance. This proposal has been prepared by ISO/TC 116/SC 2 'Boilers' and is currently being incorporated by CEN TC/57 of the European Committee for Standardization (CEN) in its work on heating boilers.

For the application of this Draft for Development to various types of boiler, reference should be made to the appropriate construction or performance standards.

The type testing outlined applies to manufacturers' ranges of standard boilers. This Draft for Development sets down methods of test for manufacturers and others concerned, and ensures that measurements of the performance of

heating boilers are carried out by uniform procedures and under uniform conditions so that measurements conducted by different manufacturers or in different test laboratories and statements of performance quoted in manufacturers' literature will be on a properly comparable basis to the benefit of both user and manufacturer. Attention is drawn to the purpose of this Draft for Development which does not conflict with that of BS 845 relating to the acceptance of individual installations.

This Draft for Development makes use of the direct method of test to give results to an accuracy as prescribed in 4.3. It is intended to issue in due course Part 2 of this Draft for Development covering the indirect method of test.

This Draft for Development is not concerned with levels of performance and does not give maximum or minimum operating conditions.

Draft for Development

Methods of type testing heating boilers for thermal performance

Part 1. Direct method

1. Scope

1.1 This Part of this Draft for Development covers the direct method of performance testing for boilers for central heating and indirect hot water supply, and fired with solid, liquid or gaseous fuels.

1.2 It is generally intended that these tests should be carried out in manufacturers' test departments or in independent test stations. This, however, does not preclude testing on site provided that the stipulated accuracies of measurement can be achieved.

1.3 This Draft for Development is applicable to hot water and steam boilers and prescribes tests to be undertaken at the working conditions as specified for the heat carrier.

1.4 This Draft for Development is concerned mainly with the performance testing of boilers as used for central heating purposes but those with built-in hot water generators are included (see 7.5.1.4).

2. References

The titles of the standards publications referred to in this Draft for Development are listed on the inside back cover.

3. Definitions

For the purposes of this Draft for Development the following definitions apply.

3.1 General boiler terminology

3.1.1 category 1 boiler. A boiler designed to supply useful heat only through the heat-carrying medium.

3.1.2 category 2 boiler. A boiler designed to supply useful heat through the heat-carrying medium and also by direct emission from its surface to the room.

This type of boiler usually has a rating not exceeding 44 kW total output.

3.1.3 rated heat output to heat carrier. The maximum useful heat output to the heat carrier in unit time specified by the manufacturer of which the boiler is continuously capable.

3.1.4 rated heat output to room. The maximum useful heat output to the room in unit time specified by the manufacturer of which the boiler is continuously capable. (category 2 boilers only).

3.1.5 rated total heat output. The sum of the outputs given in 3.1.3 and 3.1.4 (category 2 boilers only).

3.1.6 turn down ratio. The ratio of maximum and minimum fuel inputs for continuous firing in unit time specified by the manufacturer. Turn down ratio can also be expressed in terms of boiler output provided the appropriate efficiencies are known.

3.1.7 minimum output. The minimum useful heat output in unit time of which the boiler is capable with the continuous operation of the firing equipment at the turn down ratio specified in 3.1.6.

3.1.8 ancillary energy. The electrical (or other) energy required for mechanical draught, firing equipment, oil pumping, gas boosting, solid fuel and ash handling (energy for oil heating being included in the heat balance) also for feed water supply to steam boilers, circulation in hot water boiler flow/return bypasses and boiler controls.

3.1.9 convertible boilers (solid, liquid and gaseous fuels). Boilers designed to burn more than one category of fuel separately where a changeover necessitates dismantling and erection of the necessary firing equipment. Recommissioning by a qualified person may be necessary.

3.1.10 changeable boilers (solid, liquid and gaseous fuels). Boilers designed to burn more than one specified category of fuel separately where a changeover can be made by the user without major alteration, e.g. simple electrical switching, but the swivelling of oil and gas burners is acceptable.

3.2 Hot water boiler terminology

3.2.1 maximum operating water pressure. The maximum operating water pressure is that pressure, measured at the lowest point of the boiler, for which the boiler has been constructed.

3.2.2 water side resistance. The pressure loss which occurs in the boiler between the flow and return connection of the boiler at the water flow rate and at a specific difference between flow and return temperatures corresponding to the rated output.

3.2.3 maximum permissible water flow temperature. The maximum flow temperature specified by the manufacturer.

3.2.4 minimum permissible return temperature. The minimum return temperature specified by the manufacturer.

3.3 Firing equipment terminology

3.3.1 gas-side resistance of the boiler. The pressure difference created across the boiler by the flow of combustion gases.

3.3.2 pressure requirements in furnace. The condition required at the boiler outlet which, when modified by the boiler resistance, as defined in 3.3.1, gives a pressure acceptable to the firing equipment for satisfactory operation. For equipment designed to operate with a draught this is a negative pressure (–) created naturally

by chimney pull or mechanically by induced draught fan. A negative, zero, or positive pressure occurs at the outlet under natural or mechanical draught according to the point of balance for equipment operating at a positive pressure.

3.3.3 volume of furnace. The space provided in the design of the boiler in which combustion takes place.

3.3.4 volume of gas passages. The volume available in the combustion space and the boiler flue ways up to the boiler outlet.

3.3.5 air ratio. The relationship between the amount of air fed to the firing equipment and that required for stoichiometric combustion.

3.4 Test terminology

3.4.1 calorific value. The amount of heat liberated by the complete combustion, under specified conditions, of unit volume of a gas or unit mass of a solid or liquid. A distinction is made between:

- (a) *gross calorific value*, in the determination of which the water produced by the combustion of the fuel is assumed to be completely condensed and its latent heat released; and
- (b) *net calorific value*, in the determination of which the water produced by the combustion of the fuel is assumed to remain as a vapour.

3.4.2 direct method of test. The determination of thermal performance from thermal output and input, based on measurement. Further measurements are taken to determine the flue gas losses. Radiation and other unmeasured losses are determined by difference in the heat balance.

3.4.3 thermal input. The quantity of heat based on the amount of fuel burnt per hour and its calorific value.

3.4.4 thermal efficiency related to output to heat carrier. The relationship between the heat to the heat carrier and the thermal input excluding ancillary energy supplied to the boiler.

3.4.5 thermal efficiency related to output to room. (category 2 boilers.) The relationship between the heat to the room and the thermal input excluding ancillary energy supplied to the boiler.

3.4.6 total thermal efficiency (category 2 boilers). The sum of the efficiencies given in 3.4.4 and 3.4.5.

3.4.7 steady state. The stable operating condition of the boiler at a specified input, where the values of output (for hot water boilers, water throughput and difference in temperature between flow and return, and for steam boilers, flow, pressure and feed temperature) and flue gas temperature no longer change by defined amounts (see 7.2).

4. Test objectives

4.1 The objectives of the test procedures described are the determination, calculation and presentation of the data as given in appendix A.

4.2 The intention is for every design and size of boiler to be tested, but in the case of boilers in a range of unchanged design characteristics, which are operated with the same type of fuel, it is sufficient to test only the smallest and the largest boiler if the output ratio between the largest and the smallest boiler is not more than 1.6:1.

However, if within the same design this ratio exceeds 1.6:1, sufficient intermediate sizes should be tested to ensure that the ratio of larger and smaller boilers as tested does not exceed this figure.

4.3 The thermal efficiency determined should have a tolerance of ± 2 percentage points for boilers fired by solid fuels with mechanical stoking or by liquid or gaseous fuels and ± 4 percentage points for hand fired boilers, but see also 7.1.3.

5. Test apparatus

5.1 General

5.1.1 Test room ventilation. The test room should be well ventilated so that all firing units are supplied with sufficient fresh air for normal combustion when all test rigs are being used at maximum capacity.

5.1.2 Provision for boiler draught. The individual test rigs should be built and arranged in such a way that the required draught is provided at the boiler outlet and maintained during the test with as little variation as possible. Draught control devices may be required.

5.1.3 Test rig accuracy. The test rigs should be arranged and equipped with measuring instruments detailed in clause 8 in such a way that the test requirements specified in clause 4 can be achieved.

5.1.4 Heat losses. Test rigs should be constructed with floors or supporting walls for boilers in such a way that heat losses occurring during the test are comparable with those expected to occur in practice.

5.1.5 Test rigs. The test rigs described in this clause and illustrated in figures 1 to 6 indicate general arrangements. Boiler fittings and mountings are omitted.

Only limited experience is currently available with some of the rigs in respect of design and operation. Alternative layouts may be used provided that the basic concept of each rig is maintained.

5.2 Hot water boiler test rigs

5.2.1 Low temperature (below 100 °C); see figure 1.

The flow and return of the boiler are connected by a short pipe containing a circulating pump and the boiler circuit control valve (figure 1, item 11). Cold water at a temperature t_3 is fed into the pipe on the boiler return side of this valve from a raised tank with overflow which maintains a constant head. An equivalent quantity of water at the flow temperature, t_2 , flows out of the system via a vented constant head discharge tank. The water flow rate to give the required flow temperature at the pre-set output is regulated by means of the cold water bleed control valve (figure 1, item 7). The specified temperature difference ($t_2 - t_1$) given in 7.2.2 is set by means of the boiler circuit control valve. The bleed water supply valve (figure 1, item 17) should be so adjusted that some water always overflows. Item 6, 15 and 16 in figure 1 are included only when it is desired to cool the heated bleed water prior to discharge or recirculation.

The water throughput is weighed or measured volumetrically. When weighing it is advisable always to fit a flow rate indicator as shown in order to allow spot checks of the water flow rate. The weighing tank(s) should be sufficiently large to accommodate at least the amount of water flowing out in 5 min to keep the error in the time

measurement as small as possible. Alternatively the weighing apparatus may be arranged to weigh inlet water to item 3, in which case the overflow should be returned to the weighing tank(s) or to item 8.

The boiler output to the heat carrier is determined by measuring the water throughput and determining the temperature difference ($t_2 - t_3$).

The pipework should be insulated as shown hatched on figure 1. The heat losses from this pipework and its components should be calculated or determined experimentally. If these heat losses exceed 0.1 % of the particular thermal input to the boiler, they should be incorporated in the calculation. Experimental determination of heat losses can be achieved conveniently by installing, in place of the boiler, an electrically powered heat generator to match the heat losses and measuring the energy consumption. A part of this heat input will in this case be diverted to the cooling water to maintain the feed and return temperatures in the pipework as for the actual test. The heat diverted to the cooling water should be measured and subtracted from the energy input.

The important characteristics of this rig are as follows.

- (a) The temperature difference $t_2 - t_3$ (from which the boiler output is determined) is larger than the temperature rise across the boiler itself ($t_2 - t_1$) and this is conducive to high accuracy in the determination of both the heat output to the heat carrier and the thermal efficiency related to the heat output to the heat carrier.
- (b) Thermal capacity is comparatively low and so steady state conditions are quickly obtained.
- (c) Surface heat losses from the rig are small. If determined experimentally, comparatively little electrical power is required.

5.2.2 High temperature (above 100 °C); see figure 2.

The flow and return of the boiler are connected by a short pipe containing a circulating pump and the boiler circuit control valve (figure 2, item 10). Cold water at a temperature t_3 is fed into the pipe on the boiler return side of this valve from the pressurization unit which maintains a constant pressure. An equivalent quantity of water at the flow temperature t_2 flows out of the system. The water flow rate to give the required flow temperature at the pre-set output is regulated by means of the bleed water control valve (figure 2, item 6). The specified temperature difference ($t_2 - t_1$) given in 7.2.2 is set by means of the boiler circuit control valve.

The water throughput is weighed or measured volumetrically. When weighing it is advisable always to fit a flow rate indicator as shown to allow spot checks of the water flow rate. The weighing tank(s) should be sufficiently large to accommodate at least the quantity of water flowing out in 5 min to keep the error of the time measurement as small as possible.

The boiler output to the heat carrier is determined by measuring the water throughput and determining the temperature difference ($t_2 - t_3$).

The pipework should be insulated as shown hatched in figure 2. The heat losses should be treated as indicated in 7.2.1.

The important characteristics of this rig are as follows.

- (a) The temperature difference $t_2 - t_3$ (from which the

boiler output is determined) is larger than the temperature rise across the boiler itself ($t_2 - t_1$) and this is conducive to high accuracy in the determination of both the heat output to the heat carrier and the thermal efficiency related to the heat output to the heat carrier.

(b) Thermal capacity is comparatively low and so steady state conditions are quickly obtained.

(c) Unlike the rig shown in figure 3 a heat exchanger is required but there are no relay operated control valves. The quantity of water weighed is only the bleed water quantity and therefore, for a given size of weighing tank(s), the maximum boiler rating which can be accommodated will be higher than for the rig described in 5.2.3.

(d) Surface heat losses from the rig are small. If determined experimentally, comparatively little electrical power is required.

5.2.3 Temperature (below or above 100 °C); see figure 3.

(alternative to figure 2) The flow and return of the boiler are connected by a short pipe containing, in series, a circulating pump, temperature sensor, flow rate indicator, circuit flow control valve, tee connection for the system pressurization unit and a return water temperature measuring point, t_1 .

During each test, cold water at temperature t_3 enters the boiler circuit upstream of the circulating pump and maintains t_1 at a constant, predetermined value. Simultaneously an equivalent mass of water at temperature t_2 passes from the boiler circuit and is immediately cooled to a constant, predetermined temperature t_6 (below 100 °C) by the injection of cold water (temperature t_3) and thorough mixing in a pump and bypass system before discharge at atmospheric pressure to the weighing tank(s) or drain via a pressure relief valve.

The pressure relief valve is pre-set for each test condition to regulate the minimum boiler pressure appropriate to the maximum water temperature within the boiler during any individual test. The system pressurization unit performs a normal duty and transfer of water between the boiler circuit and the unit is acceptable, but there should be no external make up or loss of water to or from the unit during each test. The water level in the unit should be the same at the beginning and end of each test.

The supply of cold water at reasonably constant temperature during any one test should be at a constant pressure sufficiently above the boiler water pressure to ensure satisfactory flow control by the automatic relay control valves for all conditions of the test.

The water throughput of the system is weighed or measured volumetrically. When weighing it is advisable to use the water flow indicators to allow spot checks of the respective water flow rates.

An approximate boiler heat output rate for setting up for a test may be obtained using the boiler circuit flow rate and $t_2 - t_1$ and the total cold water flow rate and $t_6 - t_3$.

Under stable conditions these two values should correlate to provide accurate trim requirements.

The boiler output to the heat carrier is determined by measuring the water throughput of the system and determining the temperature difference ($t_6 - t_3$).

All pipework and fittings should be insulated as shown hatched in figure 3. Heat losses should be considered and treated as outlined in 5.2.1.

The important characteristics of this rig are as follows.

- (a) The temperature difference ($t_6 - t_3$) of the quantity of water weighed is larger than the temperature rise across the boiler itself ($t_2 - t_1$) and this is conducive to high accuracy.
- (b) Thermal capacity and total heat losses are low, and steady state conditions are quickly obtained. Measurement of the heat losses to calibrate the rig requires relatively little electrical power.
- (c) Unlike the rig described in 5.2.2 no heat exchanger is required but relay operated control valves are included. The quantity of water weighed is the bleed water plus the quantity introduced for cooling purposes so, for a given size of weighing tank(s), the maximum boiler rating which can be accommodated will be lower than for the rig described in 5.2.2.
- (d) The rig is semi-automatic in so far as water temperatures are controlled by thermostatically controlled devices.

5.3 Steam boiler test rigs

5.3.1 Condenser type

5.3.1.1 Cooling water measurement; see figure 4.

The steam generated is condensed. The condensate returns to the boiler at temperature t_1 with the aid of a feed pump. The cooling water for the condenser is taken either from a raised tank with an overflow, which maintains a constant head, or via a pressure regulator. The cooling water quantity is set by means of the control valve(s), (figure 4, item 15) and is weighed or measured volumetrically. The water supply valve (figure 4, item 7) should be adjusted so that some water always overflows.

The dryness fraction of the steam is required for information and is determined from the separator (figure 4, item 12), which should comply with the requirements of BS 3812.

The boiler output to the heat carrier is determined from the measured quantity of cooling water and the temperature difference ($t_5 - t_4$).

The system should be insulated as shown hatched in figure 4. The heat losses from these surfaces should be determined experimentally. If these heat losses exceed 0.1 % of the particular thermal input to the boiler, they should be incorporated in the calculations. Experimental determination of heat losses can be achieved conveniently by installing, in place of the boiler, an electrically powered heat generator to match the heat losses and measuring the energy consumption.

The important characteristics of this rig are as follows.

- (a) It enables the boiler output to the heat carrier to be determined without the need for an accurate measurement of the dryness fraction of the steam.
- (b) It is the cooling water to the heat exchanger which is weighed and this is a larger quantity than the boiler feed water. Therefore, for a given size of weighing tank(s) the maximum boiler rating which can be accommodated will be lower than for the rigs described in 5.3.1.2 and 5.3.2 in which the feed water is weighed.

(c) Unlike the rig described in 5.3.1.2 and 5.3.2, heat is lost from an appreciable area of test rig surface and this loss has to be determined.

5.3.1.2 Condensate or feed water measurement; see figure 5. The steam generated is condensed and the condensate is weighed, or measured volumetrically. A water separator is provided (figure 5, item 13) and the dryness fraction is determined in accordance with BS 3812.

The boiler output to the heat carrier is determined from the measured quantity of condensate or feed water, temperature t_1 and the heat content of the steam.

The pipework should be insulated as shown hatched in figure 5. The heat losses from these surfaces should be determined and taken into account in the calculations as specified in 5.3.1.1.

The important characteristics of this rig are as follows.

- (a) It requires an accurate determination of the dryness fraction of the steam.
- (b) It is the condensate or feed water which is weighed and, for a given size of boiler, this will be a smaller quantity of water than the cooling water which is weighed in the rig described in 5.3.1.1. Therefore, for a given size of weighing tank(s), the maximum boiler rating which can be accommodated will be higher than for the rig described in 5.3.1.1.
- (c) Unlike the rig described in 5.3.1.1, heat losses affecting the calculations arise from a very small area of test rig surface and can be determined easily.
- (d) Unlike the rig described in 5.3.2, condensing equipment is required, but the feed water is conserved and there is no possibility of environmental problems arising from the discharge of steam to atmosphere.

5.3.2 Steam discharge type; see figure 6. The steam generated is discharged to atmosphere and the feed water is weighed, or measured volumetrically subject to the accuracy specified in table 1. A water separator is provided (figure 6, item 9) and the dryness fraction is determined in accordance with BS 3812.

The boiler output to the heat carrier is determined from the measured quantity of feed water at temperature t_1 and the heat content of the steam.

The pipework should be insulated as shown hatched in figure 6. The heat losses from the surfaces should be determined and taken into account in the calculations as specified in 5.3.1.1.

The important characteristics of this rig are as follows.

- (a) It requires an accurate determination of the dryness fraction of the steam.
- (b) It is the boiler feed water which is weighed and, for a given size of boiler, this will be a smaller quantity of water than the cooling water which is weighed in the rig described in 5.3.1.1. Therefore, for a given size of weighing tank(s), the upper limit of boiler rating which can be tested will be higher than for the rig described in 5.3.1.1.
- (c) Unlike the rig described in 5.3.1.1 heat is lost from a very small area of test rig surface and should be determined easily.
- (d) Unlike the rig described in 5.3.1.2 no condensing equipment is required, but there is the possibility of

environmental problems arising due to the discharge of steam to atmosphere.

5.4 Flue gas measuring devices*

5.4.1 For boilers using solid, liquid and gaseous fuels without draught diverters, the measuring section shown in figure 7, which should be fitted at the beginning of the flue gas connection, will contain the individual measuring points as shown. As a rule, the measuring section should be vertical, and it may only be horizontal when lack of space makes this necessary.

The diameter of the measuring section should correspond to the diameter of the flue gas outlet of the boiler. Requirements in respect of the individual measuring points are shown in figure 8.

5.4.2 If the flue gas measuring section specified in 5.4.1 cannot be accommodated, reticular measurement should be adopted for which probe traversing may be used. All probe connections should be carefully sealed against leakage.

5.4.3 For boilers with draught diverters the measured values should be obtained immediately before the draught diverter. In the case of a draught diverter with circular cross section, a sampling probe for the measurement of the composition and temperature of the flue gases, as shown in figure 9, should be used to obtain reliable mean values. In the case of a draught diverter of rectangular cross section a sampling probe as shown in figure 10 should be used and the arms adapted to the cross section of the flue gas duct at the boiler exit. The appliance should be fitted with the minimum length of secondary flue as required by the manufacturer.

5.4.4 Particular care should be taken when measuring the flue gas temperature, and CO₂ and CO contents of the flue gas for a gas fired boiler equipped with draught diverter which is attached directly to the boiler without a primary flue. A series of readings should be taken over the full cross section through which the products of combustion are emitted to the draught diverter, and it is necessary to ensure that they are not affected by air dilution.

5.5 Measurement of liquid fuels. When weighing the quantity of fuel, the oil pipe to the burner, as well as any return pipe to the fuel oil tank, should be suspended freely from the weighing tank (figure 11). The latter pipe should be bent into the horizontal plane at the lower end so that the discharge does not bring any additional force to bear on the contents of the weighing tank.

In the case of volumetric measurement of the fuel consumption, a thermometer is required to measure the temperature of the fuel oil. This temperature should be maintained within a range of $\pm 5^\circ\text{C}$ of the initial setting.

5.6 Measurement of gaseous fuels. To determine the volume of gas consumed during the test a gas meter is inserted in the supply pipe having a capacity appropriate to the maximum input. Suitable equipment is required to measure gas temperature, dew point and pressure as well as atmospheric pressure. As an aid to maintaining the measurement tolerances specified in table 1, the meter should be recalibrated at intervals not exceeding six months.

5.7 Equipment for the determination of water side resistance (figure 12). The water flows from the feed water

*An alternative to the procedure given in this subclause will be described in Part 2.

supply via the pressure regulator, the water meter, the pressure control valve and the measuring length I into the boiler and from there via the measuring length II into the overflow tank and is then discharged. The resistance of the boiler is read on a differential gauge. To avoid measuring errors the pressure-sensing connections should be flush with the internal wall of the measuring section and pipes should be carefully deburred. The inside diameter of the measuring lengths I and II should be equal to the diameter of the smallest standard connection available for the boiler.

Before or after the actual test the two measuring lengths I and II should be directly connected and their pressure loss also determined for different flow rates and plotted. This pressure loss should then be subtracted from the total pressure loss (measuring lengths plus boiler).

6. Test preparations

6.1 Installation of boiler on test

6.1.1 The boiler and combustion equipment should be installed and adjusted in accordance with the manufacturer's instructions and a hydraulic test carried out.

6.1.2 Where the test is not carried out at the boiler manufacturer's premises it is recommended that he or his authorized representative participates in the erecting, hydraulic testing and preliminary running of the boiler and gives instructions as necessary.

6.1.3 Upon completion of the preliminary running for purpose of adjustment, the cleanliness of the boiler flueways should be to the manufacturer's satisfaction after any necessary cleaning. The performance tests should then be carried out without any further cleaning or adjustment of the boiler. It is important to ensure that the waterways are free from scale.

When the performance tests are carried out on convertible boilers (3.1.9) the boiler may be cleaned before each fuel change. For changeable boilers, (3.1.10) see 7.5.1.2.

After cleaning, the boiler should be closed up to comply with the manufacturer's instructions for leak tightness on the flue gas side.

6.2 Fuels

6.2.1 General. The tests should be carried out with the fuel or fuels and the appropriate grades specified by the boiler manufacturer.

6.2.2 Solid fuels. The size and other relevant characteristics of the test fuel should correspond to that specified by the manufacturer.

6.2.3 Liquid fuels. The fuel, to be selected by the manufacturer, should be to a class specified in BS 2869. The temperature of the oil at the burner inlet connection should be as specified by the manufacturer and should be stated.

6.2.4 Gaseous fuels. Tests should be carried out using the gas family (-ies) for which the boiler is to be supplied. Full details of the reference gases for each family are given in BS 4947.

6.3 Boiler draught. During the tests the draught at the boiler exit should be maintained within the limits specified by the boiler manufacturer.

7. Test procedure

7.1 Basis of output tests

7.1.1 For all boilers the test should be carried out at or within 5 % excess of the rated output or outputs to the heat carrier.

7.1.2 In addition to the requirement in 7.1.1, boilers offered by the manufacturers with firing equipment providing 'high/low' firing rates should be tested also at the low rate. In the case of the firing equipment being fully modulating over a range, the additional tests should be at the lowest and middle firing rates. Such tests should be carried out within ± 5 % of the intended output.

7.1.3 For category 2 boilers the heat emitted to the boiler room is not determined by measurement; it is obtained as the balance of the heat account and is the same quantity as that described in tests on category 1 boilers as 'loss due to heat emitted from the surface of the boiler, and other unmeasured losses'.

As the unmeasured losses are unquantified it follows that, for category 2 boilers, the quantity of heat emitted to the boiler room, the total quantity of useful heat and the total thermal efficiency will not be obtained to the same accuracy as the quantity and thermal efficiency of heat to the heat carrier.

7.2 Settings prior to tests

7.2.1 General. During the preliminary running of hot water boilers, settings of flow rate, flow and return temperatures, draught at the boiler exit, primary and secondary air, etc., as required for the tests in 7.1.1 and 7.1.2 should be made to establish a steady state prior to commencement of the test.

For steam boilers, flow, pressure and feed water temperature require to be set in place of hot water flow rate and flow and return temperatures.

Additionally for solid fuel fired boilers the steady state is regarded as reached when, at the required output, firebed conditions in respect of depth, ash and clinker formation are constant, or as near constant as the method of firing will permit. These conditions should be attained 1 h before the test period and maintained for 1 h after the test but see also 7.4.2.

In the case of steam boilers the water level should be the same at the end as at the beginning of the test, no blow down should take place, and care should be taken to ensure that no steam is discharged from the safety valves.

In the case of a boiler fitted with a continuous blowdown system, whenever practicable this should be closed for the period of the test. When this is not practicable the blowdown mass flow and heat content should be taken into account.

7.2.2 Hot water boilers. For tests on hot water boilers the flow and return temperatures should be set as specified in the appropriate performance standard for normal operation.

7.2.3 Steam boilers. For tests on steam boilers the pressure should be set as specified in the appropriate performance standard for normal operation.

7.2.4 Steady state. The steady state is regarded as reached if, under constant firing conditions, the boiler thermal output does not change from the predetermined setting by more than ± 1 % and the flue gas temperature by more

than 5 °C over four consecutive readings at 15 min intervals.

7.3 Constant conditions during tests. The output and efficiency values to be determined apply to the continuous operation of the boiler under the constant conditions established prior to the test as in 7.2. Requirements for steam boilers as given in 7.2.4 should also be observed.

7.4 Duration of tests

7.4.1 Oil and gas fired boilers. For oil and gas fired boilers the test should last at least 30 min. The test should be repeated and if the thermal efficiencies vary by more than ± 1 percentage point, testing should be continued until the permissible variation between two successive test periods is not exceeded.

7.4.2 Solid fuel fired boilers. For solid fuel combustion appliances giving a steady heat release rate (e.g. chain grate and coking stokers) a full load test lasts at least 6 h. For appliances that give cyclic variations in heat release due to periodic re-fuelling and/or de-ashing operations (e.g. hand fired units and underfeed or gravity feed stokers) a full-load test lasts at least 24 h and begins and ends at corresponding points on the first and last cycles covered by the test period. The test should be repeated, and if the thermal efficiencies vary by more than ± 2 %, testing should be continued until the permissible variation between two successive test periods is not exceeded.

7.5 Running of tests

7.5.1 General

7.5.1.1 During a test no manual interface with combustion settings should occur. With automatic 'high/low' or fully modulating firing equipment no interference should be permitted between tests at rated output and lower firing rates.

7.5.1.2 For changeable boilers, consecutive tests should be undertaken with each of the fuels with no intermediate cleaning being permitted. Additional tests with cleaned boiler flue ways should be undertaken with the fuels used in the reverse order. Adjustments to the burner at changeover should not be permitted.

7.5.1.3 Temperatures and pressures should be measured at intervals of not more than 5 min. Flue gas composition should be determined at intervals of not more than 15 min, with a minimum of three measurements per test. Wherever possible recording instruments should be used.

7.5.1.4 For boilers with built-in hot water generators no draw-off of domestic hot water should occur during the test. However, if by necessity of boiler design, the full output is dependent on a proportion of the heat being supplied to domestic hot water, e.g. if the latter is generated directly by heat transmission from surfaces in contact with combustion products, the thermal contents of both central heating and domestic hot water supplies should be taken into account in determining the heat balance. In these circumstances the maximum central heating output should be specified by the manufacturer.

7.5.1.5 The gas side resistance of the boiler should be measured when the heating surfaces are clean and the boiler is operated at rated output and in accordance with the manufacturer's instructions.

7.5.2 Solid fuel fired boilers

7.5.2.1 Before the test is started, the boiler should be

de-ashed and subsequent ash removal carried out in accordance with the manufacturer's instructions. If de-ashing causes cyclic variations in heat release, the periods between de-ashing operations should be kept constant during the course of the test.

The combustion residues produced during the test period are weighed and sampled for analysis. Weighing of the refuse should take place preferably in the dry state. If water is used to quench burning refuse or to facilitate handling, the water content should be ascertained in order that this may be allowed for in the calculations. Where a grit arrestor is fitted, the grit should be weighed and sampled for analysis.

7.5.2.2 In the case of hand firing, the refuelling technique specified in the manufacturer's technical literature should be used throughout the tests and should be quoted in the test report.

7.5.2.3 The boiler manufacturer's claims regarding recovery from banking and response to kindling controls should be checked.

Table 1. Instrument tolerances

Item	Instrument tolerance
1. Atmospheric air pressure	± 0.05 mbar*
2. Boiler gas side pressure	± 0.05 mbar
3. Gaseous fuel pressure	± 0.05 mbar
4. Steam pressure	± 1 %
5. Pressure difference between flow and return connections on hot water boiler	± 0.5 mbar
6. Water mass	± 0.1 %
7. Fuel mass (a) solid (b) liquid (c) gaseous	± 0.1 % by mass ± 0.1 % by mass ± 0.5 % by volume
8. Time	± 0.5 s up to 1 h ± 0.1 % over 1 h
9. Ancillary electrical energy	± 3 %
10. Temperatures (a) heat carrier (b) flue gases	± 0.1 °C ± 5 °C
11. Dryness fraction (when used in calculations)	± 0.1 %
12. CO, CO ₂ and O ₂ for the calculation of flue gas losses	± 0.2 Percentage points

*1 mbar = 10^2 N/m² = 100 Pa

8. Measurements and instrumentation

8.1 Measurement tolerances. Only measuring devices having the tolerances specified in table 1 and which comply with the requirements specified in the following sections should be used. They should be so selected that the boiler efficiency can be determined within the prescribed tolerance of ± 2 %.

8.2 Temperature measurements

8.2.1 Water temperature. The points where the measuring instruments should be fitted are shown in figures 1 to 6.

Proper fitting of the instruments for the temperature measurement of the heat carrier is of particular importance. Probes should preferably be fitted into elbow joints against the direction of flow (see example in figure 13). If immersion sleeves are used for the measurement of the heat carrier temperature, these should be tight-fitting and thin-walled to keep the heat dissipation at the point of measurement as small as possible and to avoid delays in response. Thermometers for the measurement of the room temperature should be fitted with a protective shield against radiant heat.

8.2.2 Flue gas temperature. The use of a suction pyrometer for flue gas temperature measurement has advantages in the accuracy of the determination.

When thermo-electric methods are used, potentiometric instruments are preferred as they eliminate lead resistance errors. Otherwise compensating cables should be used.

8.3 Fuel sampling and analysis. An overall sample of the fuel used is taken according to the appropriate standards specifying the method of sampling the various fuels (see table 2). This sample is used for the determination of the calorific value and the chemical composition.

Table 2. British Standards for sampling and analysis of fuels

	Fuel		
	Solid	Liquid	Gaseous
Sampling	BS 1017	—	—
Analysis	BS 1016	BS 4379	BS 3156 : Parts 1, 3 and 4 BS 3804

8.4 Combustion residues from solid fuel. Samples of the refuse from the ashpit and grit arrestor should be taken in order to determine the combustible contents.

8.5 Flue gas composition. The measured carbon dioxide, $V_{\text{CO}_2, \text{m}}$ (i.e. CO₂ + SO₂) and measured carbon monoxide $V_{\text{CO}, \text{m}}$ (i.e. CO + H₂) contents of the dry flue gases should be measured within the tolerance shown in table 1. If preferred, the oxygen content may be measured instead of $V_{\text{CO}_2, \text{m}}$ and this has the advantage of having the same meaning, in terms of excess air, for all fuels.