

Method for

Assessing thermal performance of low temperature hot water boilers using a test rig

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- Associated Offices Technical Committee
- Association of British Solid Fuel Appliances Manufacturers
- Association of Shell Boilermakers
- Boiler and Radiator Manufacturers' Association Limited
- British Coal Corporation
- British Combustion Equipment Manufacturers' Association
- British Foundry Association
- British Gas plc
- Building Services Research and Information Association
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- Department of Energy (Energy Efficiency Office)
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- Domestic Solid Fuel Appliances Approval Scheme
- Engineering Equipment and Materials Users' Association
- Health and Safety Executive
- Institute of Domestic Heating Engineers
- Institution of Chemical Engineers
- Society of British Gas Industries
- Waterheater Manufacturers' Association

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Foreword

This British Standard has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Policy Committee. It supersedes DD 65-1:1979 and DD 65-2:1982 which are withdrawn.

Due to the lack of authoritative information on the testing of boilers using test rigs for certain applications, the conversion of the Draft for Development into a British Standard has resulted in a restriction of the scope to hot water boilers having a rated heat output up to 600 kW only.

The test procedure detailed in this British Standard requires that boilers be connected to a test rig having closely defined characteristics. It is therefore intended that the tests be carried out in manufacturers' test facilities or in independent test stations.

For on-site thermal performance assessment of boilers for steam, hot water and high temperature heat transfer fluids, reference should be made to BS 845-1 and BS 845-2.

In order not to conflict with the work of CEN¹⁾ in the field of oil-fired boilers, it has been necessary to restrict the scope of this standard. However, pending the publication of a European standard covering oil-fired boilers up to 300 kW rated heat output, users of this standard will find the information contained useful when determining the specific requirements for such boilers.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 22, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ European Committee for Standardization.

1 Scope

1.1 This British Standard describes a procedure for assessing the thermal performance of low temperature hot water boilers which are intended for central heating or indirect hot water supply and which are fired with solid, liquid or gaseous fuels. The thermal efficiency is obtained by the direct method of test and is established to within a tolerance of ± 2 % points²⁾. Flue gas losses and loss due to combustibles in ash, where applicable, are determined by measurement. Surface heat losses and other unmeasured losses are derived by difference. Procedures are also included to determine the associated characteristics of water-side resistance and gas-side resistance.

1.2 This standard applies to boilers designed to operate at flow temperatures not exceeding 100 °C, with rated heat output between 44 kW and 600 kW when used with one or more of the following fuels:

- a) smokeless solid fuels, e.g. coke or anthracite, fired by means of automatic combustion appliances;
- b) bituminous coal fired by means of mechanical stokers;
- c) gaseous fuels of the 2nd and 3rd families (see BS 4947);

and with rated heat output between 300 kW and 600 kW when used with liquid fuels of the classes specified in BS 2869.

1.3 This standard does not apply to steam boilers or to boilers pressurized by steam.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this standard the following definitions apply.

2.1

rated heat output

the heat output(s) to the water in unit time, declared by the manufacturer, of which the boiler is capable during continuous operation

2.2

combustion equipment giving a steady heat release rate

operation of the boiler over extended periods limited only by the need to carry out servicing and maintenance of the combustion equipment and/or boiler

2.3

combustion equipment giving cyclic variations in heat release due to periodic refuelling or de-ashing operations, e.g. manually de-ashed underfeed stokers

operation of the boiler for the test period, defined by the manufacturer, for which it is capable of giving the rated heat output

2.4

turn down ratio

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

2.5

ancillary energy

the electrical (or other) energy required for mechanical draught, firing equipment, oil pumping, gas boosting, solid fuel handling and ash handling, circulation in boiler flow/return by-passes and boiler controls

2.6

convertible boilers (solid, liquid and gaseous fuels)

boilers designed to burn more than one specified category of fuel separately where a changeover necessitates dismantling and erection of the necessary firing equipment

NOTE Recommissioning by a qualified person may be necessary.

²⁾ One percentage point is one hundredth of the total amount concerned, in this instance, the heat input.

2.7

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, or the swivelling of oil and gas burners

2.8

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

2.9

gas-side resistance

the pressure difference created across the boiler by the flow of combustion gases

2.10

combustion space

the space provided in the design of the boiler in which combustion takes place

2.11

gross 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 fuel in the determination of which the water produced by combustion of the fuel is assumed to be completely condensed and its latent and sensible heat made available

NOTE Further information on calorific values of fuel was made available in BS 526 (now withdrawn). It is envisaged that the material contained in BS 526 will be revised and published as a new British Standard in due course.

2.12

net calorific value

the amount of heat generated by the complete combustion, under specified conditions, of unit volume of a gas or unit mass of a solid or liquid fuel in the determination of which the water produced by the combustion of the fuel is assumed to remain as a vapour

NOTE Further information on calorific values of fuel was made available in BS 526 (now withdrawn). It is envisaged that the material contained in BS 526 will be revised and published as a new British Standard in due course.

2.13

direct procedure

the determination of thermal performance by direct measurement of the heat output and the determination of thermal efficiency by comparison with the thermal input

2.14

thermal input

the heat release rate of the firing equipment based on the amount of fuel burnt in unit time and its calorific value. For pre-heated liquid fuels, the sensible heat in the fuel above ambient temperature is also included in the thermal input

2.15

thermal efficiency

the thermal output divided by the thermal input and expressed as a percentage

3 Test facilities

3.1 General

The design and construction of the test rig, the selection of measuring instruments and the methods for determining the thermal input and output of the boiler shall be such that the error in determining the thermal efficiency does not exceed 2 percentage points.

3.2 Test room

The test room shall be ventilated.

NOTE 1 It is important that the test room is adequately ventilated but there should be no draughts likely to affect performance of the firing equipment and no undue fluctuation of the ambient temperature during testing.

NOTE 2 In determining the necessary ventilation, account should be taken of other firing equipment that may be in use at the same time as the boiler under test.

3.3 Test rig

For test purposes the boiler shall be connected to a test rig which is capable of allowing it to be operated at the specified output and with the desired flow and return temperatures. (See clause 8.)

NOTE 1 The supporting floor and/or wall for the boiler should be so arranged that heat losses occurring during the test are similar to those expected to occur in practice.

NOTE 2 Suitable test rigs are described in Appendix B and shown in Figure 1 but other arrangements may be used provided that the basic concepts of those rigs are maintained.

4 Instrumentation and measurements

4.1 Measurement tolerances

Only instruments capable of measuring within the tolerances specified in Table 1 shall be used. The instruments shall be so selected that the boiler efficiency can be determined within the prescribed tolerance (see 3.1).

NOTE Attention is drawn to the necessity for regular calibration of the measuring instruments.

4.2 Temperature measurements

4.2.1 Water temperature. The points where the measuring instruments shall be fitted are shown in Figure 1.

NOTE Proper fitting of the instruments is of particular importance. Probes should preferably be fitted into elbow joints against the direction of flow. If immersion sleeves are used 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.

4.2.2 Air temperature. The temperature of the combustion air (t_g) shall be measured at a position 0.5 m from, and at the same level as, the combustion air inlet to the firing equipment. The temperature of the ambient air (t_a) shall be measured at a position 1.5 m above the floor, 1.5 m from the front of the boiler and on the boiler centre line.

The measuring instruments shall be protected against radiant heat.

Table 1 — Measurement tolerances

Measurement	Tolerance
Atmospheric air pressure	± 0.05 mbar ^a
Boiler gas-side pressure	± 0.05 mbar ^a
Gaseous fuel pressure	± 0.05 mbar ^a
Pressure difference between flow and return connections on hot water boiler	± 0.5 mbar ^a
Water mass	(weighing) ± 0.2 % (flow meter) ± 0.25 %
Fuel mass a) solid b) liquid c) gaseous	± 0.2 % by mass ± 0.2 % by mass ± 0.5 % by volume
Time	± 0.5 s up to 1 h ± 0.1 % over 1 h
Ancillary electrical energy	± 3 %
Temperatures a) heat carrier b) flue gases	± 0.1 °C ± 5 °C
CO, CO ₂ and O ₂ for the calculation of flue gas losses	± 0.2 percentage points
^a 1 mbar = 10^2 N/m ² = 100 Pa	

4.2.3 Flue gas temperature. The temperature of the flue gases shall be measured at the point(s) indicated in 4.3.

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

4.3 Sampling and measurements

4.3.1 Flue gas

4.3.1.1 The flue gases shall be sampled and measurements made of flue draught and smoke number, as appropriate, by means of the test probe(s) located at the position(s) in the test flue (see 4.3.1.4) as specified in 4.3.1.6 and 4.3.1.7.

4.3.1.2 The carbon dioxide contents (V_{CO_2}) and carbon monoxide contents (V_{CO}) of the dry flue gases shall be measured within the tolerance shown in Table 1.

NOTE If preferred, the oxygen content may be measured instead of V_{CO_2} and this has the advantage of having the same meaning, in terms of excess air, for all fuels.

4.3.1.3 For oil-fired boilers, the Bacharach smoke number shall be measured by following the procedure detailed in 4.1 of BS 4876:1984.

4.3.1.4 The boiler flue outlet shall be fitted with the appropriate test flue as shown in Figure 2. The test flue shall be vertical and shall have the same nominal diameter (or cross-sectional area) as the flue outlet. The height (h) of the test flue shall be the greatest of the following:

- a) four times the nominal diameter of the flue;
- b) 1 m;
- c) at least the minimum specified by the manufacturer for satisfactory operation of the boiler.

4.3.1.5 The location of the probe(s) for sampling the combustion products and measurement of the Bacharach smoke number for oil-fired boilers shall be as shown in Figure 2. The point of entry of each probe into the test flue shall be sealed against leakage.

NOTE Sufficient measurements should be taken over the cross-section of the flue to ensure reliability of the values obtained.

4.3.1.6 For boilers equipped with an integral draught diverter, the location of the test probe(s) shall be as indicated in Figure 2.

4.3.1.7 For boilers equipped with a separate draught diverter the test probe shall be located either before or after the diverter.

NOTE 1 It is preferred that the test probe be located prior to the diverter.

NOTE 2 The height of secondary flue specified for test purposes is such as to avoid undue dilution of the flue gases by air entrained at the draught diverter and consequent inaccuracy in the measured values. This dilution effect should be borne in mind if it is desired to carry out flue loss measurements on boilers connected to a flue of significantly greater height.

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

4.3.3 Gas-side resistance. The flue gas pressure shall be measured at the combustion products sampling point (see Figure 2). The gas-side resistance of the boiler shall be measured when the heating surfaces are clean and the boiler is operated at rated output and in accordance with the manufacturer's instructions.

For oil- and gas-fired boilers with a closed combustion chamber, the pressure in the flame space shall be measured with a static tube positioned adjacent to the burner entry.

For solid-fuel-fired boilers, the pressure above the firebed shall be measured with a static tube positioned above the firebed.

4.3.4 Water-side resistance. The water-side resistance shall be measured using the equipment shown in Figure 3.

NOTE The feed water to the boiler flows from the feed water 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. This equipment may be incorporated in the test rig.

To avoid measuring errors, the pressure-sensing connections shall be flush with the internal wall of the measuring section and pipes shall be carefully deburred.

The inside diameter of the measuring lengths I and II shall be equal to the diameter of the smallest standard connection available for the boiler.

Before or after the boiler test the two measuring lengths I and II shall be directly connected and their pressure loss determined and plotted for different flow rates. This pressure loss shall then be subtracted from the total pressure loss, i.e. the pressure loss sustained over the measuring lengths I and II and the boiler, to give the water-side resistance.

5 Test fuels

5.1 Selection

5.1.1 General. The tests shall be carried out with the fuel or fuels of the appropriate grades specified by the boiler manufacturer.

5.1.2 Solid fuels. The size and other relevant characteristics of the test fuel shall be as specified by the manufacturer.

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

5.1.4 Gaseous fuels. Tests shall be carried out using either a distributed gas of the family specified by the manufacturer or the corresponding reference gas (see BS 4947).

5.2 Measurement

5.2.1 Solid fuels. The quantity of fuel in the combustion system shall be the same at the beginning and at the end of the test period. The amount of fuel added during the test shall be weighed.

NOTE 1 To increase the accuracy of measurement, the fuel in hoppers should be levelled to the same datum line before and after test.

NOTE 2 A correction should be made for any significant change in the moisture content of the fuel that may occur between the weighing point and the furnace.

5.2.2 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, shall be suspended freely from the weighing tank (see Figure 4). The return pipe shall be horizontal 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, the temperature of the fuel oil shall be maintained within a range of $\pm 5^\circ\text{C}$ of the initial setting.

5.2.3 Gaseous fuels. To determine the volume of gas consumed during the test a gas meter shall be provided in the supply pipe and shall have a capacity appropriate to the maximum input.

NOTE Suitable equipment is required to measure gas temperature, dew point and pressure as well as atmospheric pressure.

5.3 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 characteristics of the fuel, as required.

6 Installation and adjustment

The boiler and firing equipment shall be installed connected to the test rig (see 3.3) and adjusted, in accordance with the manufacturer's instructions, for the fuel(s) to be used.

The fuel flow rate (where applicable), the water flow rate, flow and return temperatures, draught at the boiler exit and primary and secondary air volume shall be set to the values required for the test.

NOTE 1 Except where otherwise specified (see 10.2), precautions should be taken to prevent water temperature control thermostats or variable controls from acting to interfere with the preset test conditions.

Where the boiler flueways may have been fouled during a period of preliminary running (see clause 7) they shall be cleaned and the boiler then closed up in accordance with the manufacturer's instructions. No further cleaning or adjustment of the boiler shall be carried out during the duration of the test.

NOTE 2 It is important to ensure that the boiler waterways remain free from scale.