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Methods for
The thermal testing
of domestic solid fuel
burning appliances

Part 1. Flue loss method



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The following BSI references relate to the work on this standard:
Committee reference SIF/13 Draft for comment 71/40027

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*British Ironfounders' Association
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Foreword

Of recent years increasing attention has been given to the further development of domestic solid fuel space heating appliances incorporating convection, since such appliances can give higher thermal efficiencies and a more comfortable form of heating. The measurement of convection from a solid fuel appliance is complicated by the widely varying shapes of the appliances themselves and particularly of the warm air outlets. Furthermore, the earlier measuring devices all tended to alter the natural movement of the warm air.

Two methods of measurement are given in this standard and the choice of method will largely depend on laboratory facilities available. Part 1 deals with the Flue Loss Method, in which the total efficiency is obtained by determining the percentage heat content of the flue gases and the ashpit loss and deducting the sum from 100 %. The radiation efficiency and, in the case of appliances with boiler, the boiler efficiency, are determined separately and the convection efficiency is obtained by difference. Part 2 deals with the Hood Method, in which the convection warm air is collected in and flows through a hood where its heat content is measured directly.

The thermal output measured by either method should normally correspond fairly closely to that which the appliance will give under domestic conditions, but no arbitrary set of tests can cover the wide range of comfort standards, which depend upon individual habits and economy of operation. The various efficiency figures given by the test method used for the different types of appliance cannot, therefore, be directly interpreted in terms of domestic fuel economy.

The standard was originally issued in 1960 and in the present edition of Part 1 a complete revision of the analytical procedures and calculations, together with conversion to metric units, has been carried out.

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British Standard Methods for

The thermal testing of domestic solid fuel burning appliances

Part 1. Flue loss method

1. General

1.1 Scope

This Part of this British Standard describes a test method to determine the efficiency of solid fuel burning domestic heating appliances which incorporate as a design feature the production of convected heat.

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

1.2 Principle

The method is based essentially on the determination of the heat lost to the flue of the appliance. This 'flue loss' is deduced as a percentage of the heat output of the fuel burnt, from a knowledge of the temperature and the composition of the flue gases. More specifically, the increase in temperature of the flue gases over ambient temperature and the concentrations of carbon monoxide and dioxide, hydrogen and methane in excess of those in the room are averaged for the duration of the test period. Apart from a small ashpit loss, the percentage remaining after the deduction of the 'flue loss' is taken to represent the efficiency of the appliance.

1.3 Definitions

For the purposes of this part of this British Standard, the following definitions apply:

(1) *Charging to the datum.* A room heater is charged to the datum when it has been filled with fuel to the level specified in BS 3378 for the determination of the firebox capacity.

A convector open fire is charged to the datum when it has been filled with open fire test fuel so that the surface of the fuel is plane and slopes upwards from the inner edge of the topmost part of the firefront or front firebars at an angle of 35° to the horizontal, or to the bottom edge of any flue restrictor plate or of the flue opening, whichever is the lower.

This datum will normally apply even if fuels other than open fire test fuel are specified for use by the manufacturer of a convector open fire, but any recommendations made by the manufacturer may be taken into consideration.

(2) *Combustion rate.* The mass in kg of dry test fuel burned per hour.

(3) *Control dampers.* The dampers and air inlets into the ducting which control the air flow through the 'measurement section' (see 2.3). The location of these controls is shown in Fig. 1a.

(4) *De-ashing.* Clearance of ash from the firebars as far as is practicable, exclusively by means of the de-ashing mechanism.

(5) *Free area.* The cross-sectional area in square millimetres of the minimum opening in the flueway offered to the passage of the flue gases, excluding the boiler flueway, if any.

2. Assembly and use of apparatus

2.1 General

Clauses 2.2 to 2.10 indicate the specific function for which the various items of apparatus are required and how they shall be used.

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2.2 Fan

A fan shall be provided, capable of extracting $280 \text{ m}^3/\text{h}$ of flue gas at temperatures up to 150°C and at the same time of overcoming a pressure difference of 6.4 mbar^* . It shall be erected at a height of not less than 4 m from the floor.

Fan connections shall be made as shown in Fig. 1a. The discharge shall not be permitted to enter the room in which the appliance is being tested.

2.3 Measurement section

A 'measurement section' shall be provided in the test flue, which shall be constructed in accordance with the dimensions given in Fig. 2. The section shall be insulated with three layers of asbestos rope of 6 mm diameter, or with other material of a similar insulation value. The insulation shall be covered with a single layer of aluminium foil, which shall be kept bright.

The measurement section shall be connected to the fan as shown in Fig. 1a. The ducting shall incorporate a telescopic section and adjustable air inlets or dampers in the positions shown in Fig. 1a.

2.4 Temperature measurement

The hot junction of a nickel/chromium v. nickel/aluminium thermocouple (see BS 1827) of $0.6\text{--}1.2 \text{ mm}$ diameter wire shall be inserted into the fitting shown in Fig. 2 from the right-hand end, so that the junction is 6 mm short of the end of the glass or silica tube and is not touching the side. Each wire shall be covered for a distance of $125\text{--}130 \text{ mm}$ from the junction with suitable high temperature insulating tubing. A gas-tight seal shall be made where the wires enter the tube. To serve as a radiation shield a strip of bright aluminium foil, 19 mm wide, is wrapped round the outside of the glass/silica tube and fixed in position with high temperature adhesive. The assembly is then inserted into the flue. The vertical tube of the assembly is connected to a pump via a flow gauge.

The cold junction is placed behind the plane of the front opening of the appliance at a point 0.6 m from the ground and 1.2 m from the centre of the measurement section. It is protected from radiation by a cylindrical metal screen with open ends, 38 mm in diameter and 150 mm long, made of polished aluminium sheet or of mild steel covered on both sides with aluminium foil. The output from the thermocouple is measured, using an indicating or recording potentiometer, at intervals not exceeding 10 minutes .

2.5 Sampling

A sampling tube constructed as detailed in Fig. 2 shall be provided. A plug of glass wool filtering medium is inserted and the tube assembled. The sampling tube is pushed into bush A through a small wet asbestos washer. The tube is inserted into the measurement section and the bush screwed down to compress the asbestos, so forming a gas-tight seal between the sampling tube and measurement section. The sampling tube is then connected to one of the alternative assemblies described in Section 3. This connection shall be in glass tubing of internal diameter $6\text{--}10 \text{ mm}$. If rubber connectors are used, the glass should butt together and at least 50 mm of rubber tubing of wall thickness not less than 6 mm should cover the joint.

For fuels other than coke there may be tar and moisture in the flue gas sample. The tar is removed by using further filters and the moisture by using cooled traps. It will quickly become obvious in practice if these precautions are required.

It is essential that there be no leaks in either the sampling tube or sampling line, and that the materials used shall be temperature resistant and impervious to gases.

2.6 Pressure measurement

Either the static pressure at the high pressure tapping (the flue pull) or the pressure difference across the orifice plate is required. A pressure indicator or recorder shall, therefore, be provided, capable of reading to 0.01 mbar and having a range of 2 mbar . There may be an occasional demand for a manometer having a range of 10 mbar and capable of reading to 0.05 mbar .

* $1 \text{ mbar} = 10^2 \text{ Pa} = 10^2 \text{ N/m}^2 = 0.75 \text{ mmHg} = 10 \text{ mmH}_2\text{O}$

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2.7 Weighing apparatus

The masses of the fuel charged and of the ashpit residue shall be determined to within 15 g.

For the gravimetric analysis, a chemical balance is required which is sensitive to 0.1 milligram.

For weighing the appliance and the test setting, a weighing machine of capacity 300 kg sensitive to 20 g is required.

2.8 Timing devices

A timing device measuring to 0.1 s is required for timing the soap film burette. If the gravimetric train is used an additional timer is required for timing the total period of the test.

2.9 Radiometers

If measurement of radiation output is required, either the BCURA cage radiometer or Moll thermopiles shall be provided for this purpose. Information about the calibration and use of these instruments is given in Appendices A and B.

2.10 Electrical measurements

Instruments for measuring electrical outputs in the range 0 – 30 mV within $\pm 2\%$ (see BS 89 and BS 90) are required. These should preferably be potentiometers of either the manually or the automatically operated type. If a millivolt meter is used, the indicated output shall be corrected to take account of the input resistance with which it is being used.

3. Analysis of the flue gases

3.1 General

Any method, either chemical or physical, can be used for the analysis of the flue gases, provided that the method used will measure the concentration of each component gas to $\pm 0.05\%$ by volume.

For coke it is required only to measure the carbon monoxide and carbon dioxide content of the flue gases. A convenient method for doing this is described in 3.2.

For fuels other than coke it is necessary to take into account the hydrogen and methane formed by the partial distillation of the fuel. This can conveniently be done either by the sample storage method described in 3.3, followed by analysis, or by the gravimetric method described in 3.4.

Strictly, the rate of sampling of the flue gases should be isokinetic but, as the instantaneous rate of emission varies during a test in a manner difficult to determine, the only practicable course is to sample at a substantially constant rate.

3.2 Continuous gravimetric method (for carbon monoxide and carbon dioxide only)

3.2.1 Principle. In this method the flue gases, after extraction from the flue, are passed through a series of reagents at a constant rate. The composition is determined by measuring the volume of gas passing through the reagents, together with the increase in weight of the various absorption tubes.

3.2.2 Apparatus. The schematic arrangement of the train is shown in Fig. 3. All connections between the components of the train are glass to glass butt joints sealed with silicone rubber tubing.

Midvale or Nesbitt bulbs are used throughout as the absorption vessels. An absorbent for carbon dioxide which is known to be efficient and suitable shall be used, such as granular lithium hydroxide (0.7 – 1.2 mm) or an intimate mixture of 4 volumes of soda asbestos (0.7 – 1.2 mm) and 1 volume of dried soda lime (0.7 – 1.2 mm).

These tubes, numbered 14, 15 and 18 in Fig. 3, are two-thirds filled with the above reagent and one-third filled with anhydrous magnesium perchlorate* (0.7 – 1.2 mm) to absorb the water produced.

* Usually known as 'anhydrone'.

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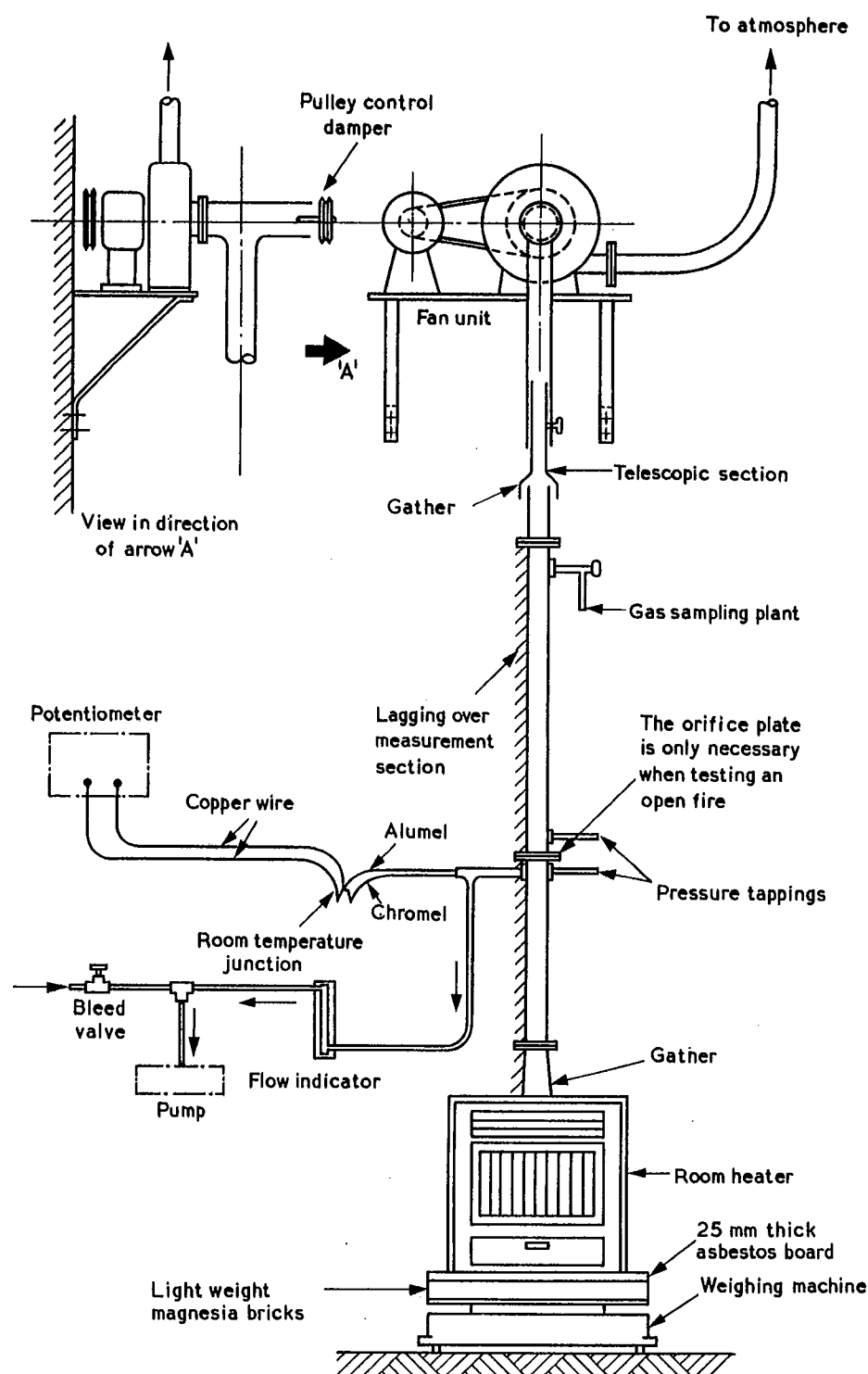


Fig. 1a. Test installation (flue loss method). Schematic arrangement

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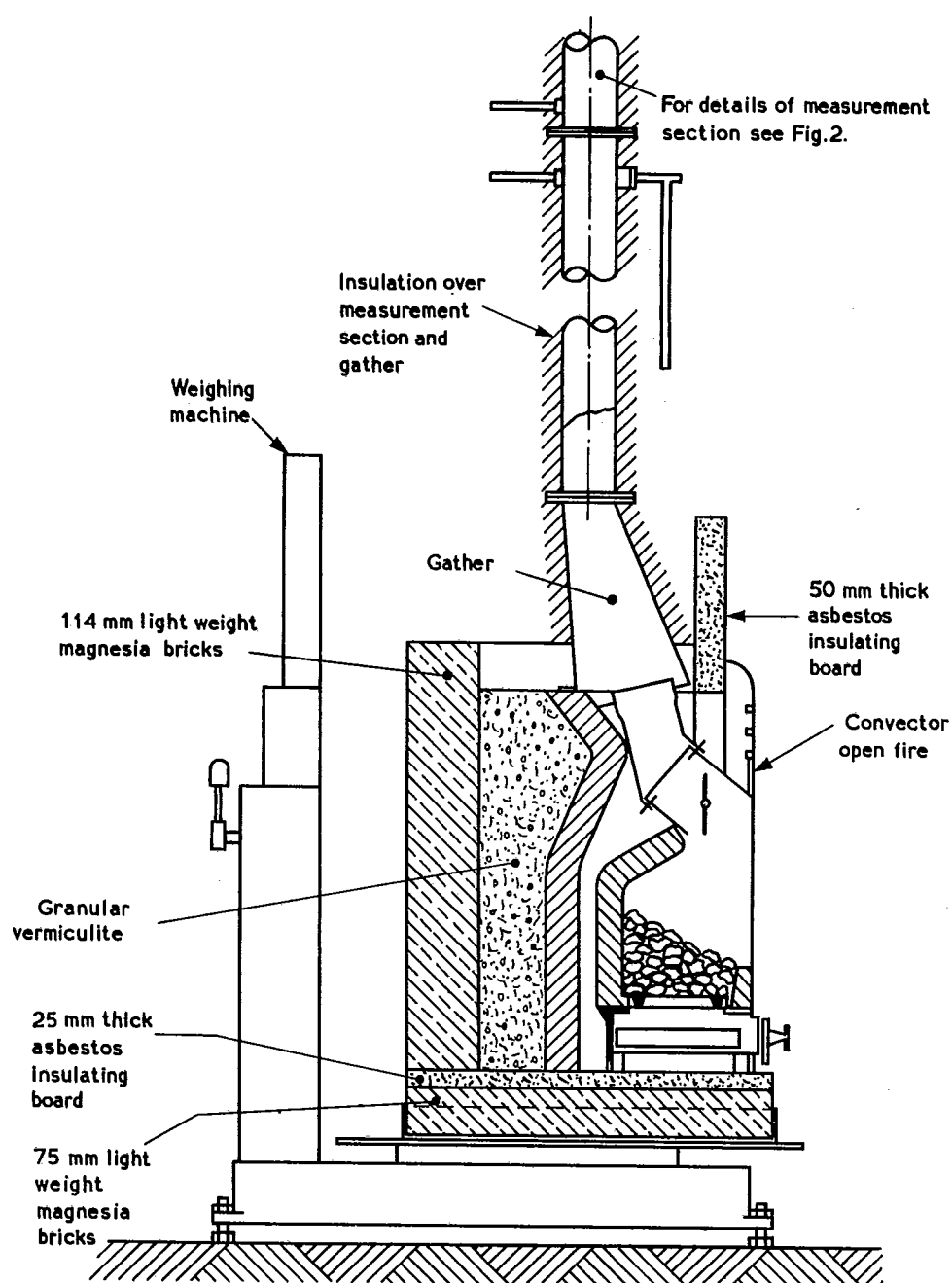


Fig. 1b. Test installation (flue loss method). Flue attachment to convective open fire.

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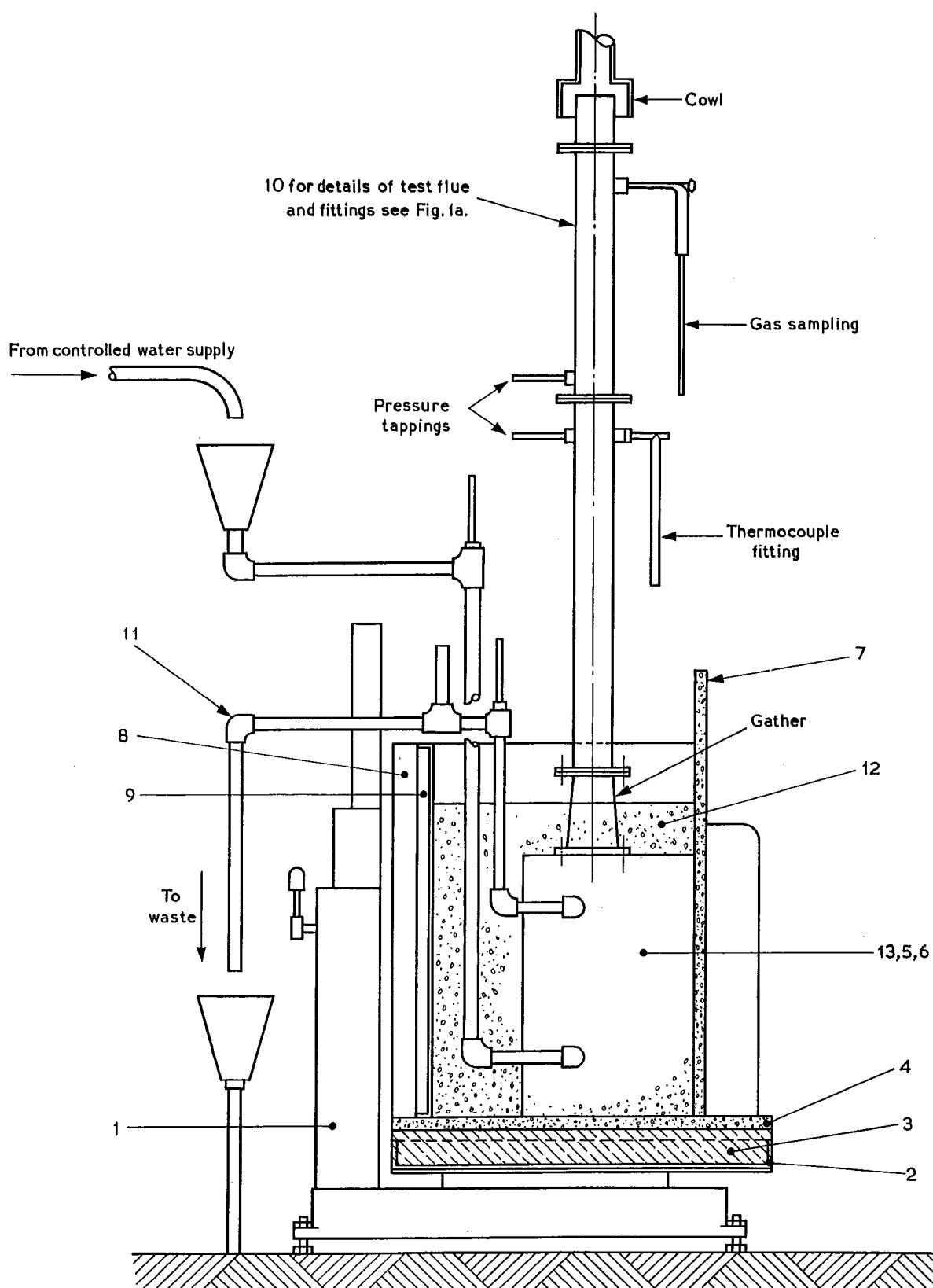


Fig. 1c. Test installation (flue loss method). Typical part sectional view of inset type room heater with boiler under flue loss method test conditions

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List of component parts for room heater test installation (Fig. 1c.)

Item	Component	Material	Number off	Total mass	Remarks
1	Platform scales capacity 300 kg x 50 g divisions Zero backwards		1	kg	Platform 760 mm x 660 mm
2	Tray	Aluminium 1.6 mm	1	2.3	For retaining item 3 660 mm x 762 mm x 57 mm deep
3	Bricks Light weight magnesia	Refractory	21	16.3	
4	Base	Marinite 36	1	7.3	787 mm x 787 mm x 25.4 mm thick
5	Appliance and fittings		1	144.2	Typical inset type room heater with back boiler
6	Water in boiler		1	27.2	27.28 litres
7	Surround	Marinite 36	1	6.8	914 mm x 914 mm x 25.4 mm thick
8	Sides	Aluminium 2 mm	2	5.9	762 mm x 610 mm x 25.4 mm deep
9	Back	Aluminium 2 mm	1	3.6	762 mm x 686 mm x 25.4 mm deep
10	Test flue with gather and fittings		1	14.5	
11	Plumbing Pipes and fittings		1	9.5	
12	Granular vermiculite		1 bag	8.2	
13	Fuel for appliance	Coke		11.3	
				257	Total mass on scales

