Methods for

Testing and rating fan coil units, unit heaters and unit coolers —

Part 1: Thermal and volumetric performance for heating duties; without additional ducting

UDC 697.356.001.42 + 697.971.001.42

Co-operating organizations

The Refrigeration, Heating and Air Conditioning Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Consulting Engineers*
Association of Manufacturers of Domestic Electrical Appliances
Boiler and Radiator Manufacturers Association*
British Mechanical Engineering Confederation
British Oil and Gas Firing Equipment Manufacturers Association
British Refrigeration and Air Conditioning Association*
Department of Health and Social Security*
Department of the Environment
Electricity Council, The Central Electricity Generating Board and the Area Boards in England and Wales
Engineering Equipment Users Association
Gas Council
Heating and Ventilating Contractors' Association*
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Royal Institute of British Architects
Water-tube Boilermakers Association

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Department of the Environment, Building Research Station
Greater London Council
Oil Appliances Manufacturers Association
Steel Radiators & Convector Manufacturers Association
Unit Heater Manufacturers Association

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Foreword

This Part of this British Standard has been prepared under the authority of the Refrigeration, Heating and Air Conditioning Industry Standards Committee in response to requests from industry.

The committee acknowledge their debt to the Heating and Ventilating Research Association for the Association's work in formulating the methods of testing that appear in this standard.

Part 2 of this standard will give methods of testing and rating for cooling duties without additional ducting. It is intended that further Parts will deal with units fitted with ducting acoustic aspects of testing and construction and safety requirements.

The general approach to the test methods described has been to consider the simplest practical method of carrying out the measurements without any unnecessary sacrifice of accuracy. The main test method permits thermal rating to be carried out in a large open space, and does not make any attempt to relate the primary fluid heat transfer with the heat transferred to the secondary fluid. This test method is very desirable when testing certain units that recirculate the heated air, as it allows this recirculation to be measured and corrected for in the test results.

It is appreciated that some of the larger units may not be suitable for testing in an open laboratory because it may be impossible to obtain steady state conditions and to this end a second test method has been introduced where the heat is ducted away from the unit. The test is necessarily more complex involving the calibration of the test chamber.

The standard relates to equipment with capacities of up to the equivalent of 75 kW.

Where reference is made to British Standards for which no metric version is available then the appropriate British Standard in imperial units shall be used in conjunction with BS 350, "*Conversion factors and tables*": attention is also drawn to BS 3763, "*The International System of units (SI)*".

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 Scope

This Part of this British Standard deals with methods of carrying out thermal and volumetric tests on forced convection units containing fluid-to-air heat exchangers and incorporating their own fans. The units are for heating applications and the tests are to be carried out on units in an essentially clean condition.

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

2 Definitions

2.1
fan coil unit

a fluid-to-air heat exchanger apparatus through which air is passed by its electrically powered fan system and which is intended for general commercial use in the field of generating comfort conditions. This unit may or may not contain filters

2.2
unit heater

a fluid-to-air heat exchanger apparatus through which air is passed by an electrically powered fan system and which is intended for general industrial use in environmental control. This unit may or may not contain filters

2.3
essentially clean conditions

these conditions are defined when further cleaning of a unit does not affect the rating figures

2.4
reference air conditions (heating)

temperature, 20 °C; absolute pressure, 1.013 bar[1)]; relative humidity, 43 %; density, 1.200 kg/m^3

3 Operating characteristics of units

3.1 The primary medium shall be any of the following fluids:

Water

Steam

Heat transfer fluid (excluding primary refrigerants).

3.2 The operating conditions of the units shall lie within the following ranges:

Water up to 100 °C

Pressurized water from 100 °C to 200 °C

Steam between atmospheric pressure and a gauge pressure of 8 bar[1)]

Heat transfer fluid up to 100 °C for atmospheric pressure and from 100 °C to 200 °C when pressurized.

3.3 The air volume flow rate of the unit shall lie within the range 25×10^{-3} m^3/s to 5 m^3/s.

3.4 There is no restriction on the mounting of these units, provided that they are tested while mounted in a way representative of their intended use.

3.5 The requirements of the methods for individual tests may be followed to determine the performance of a unit at one specified set of conditions; where the performance at conditions other than those of the actual test are to be stated, the full schedule of tests specified in the standard is to be completed.

[1)] 1 bar = 10^5 N/m^2.

4 Nomenclature

Symbol	Quality	Unit
c_p	specific heat capacity	kJ/kg °C
K_w	temperature correction factor	—
L	latent heat of evaporation	kJ/kg
M	total mass flow of liquid	kg
M_t	net weight of condensate formed during test	kg
M_n	net weight of condensate formed during no load	kg
Δp	primary fluid pressure drop	N/m^2
Δp_r	primary fluid pressure drop at a reference temperature of 80 °C	N/m^2
Q	rate of heat emission	kW
Q_a	rate of heat emission based on true inlet air temperature	kW
Q_m	rate of heat emission based on room air temperature	kW
q_r	air volume flow rate at reference conditions	m^3/s
q_f	primary fluid volume flow rate	m^3/s
q_{fr}	primary fluid volume flow rate at reference temperature of 80 °C	m^3/s
ρ_r	reference air density	kg/m^3
ρ_m	air density at test conditions	kg/m^3
ρ_f	primary fluid density at mean liquid temperature	kg/m^3
ρ_{fr}	primary fluid density at reference temperature of 80 °C	kg/m^3
T_t	duration of test	s
T_n	duration of no load test	s
t_a	entering air temperature	°C
t_i	inlet liquid temperature	°C
t_o	outlet liquid temperature	°C
t_R	room air temperature	°C
t_3	saturated steam temperature	°C
w	liquid mass flow rate	kg/s

5 Objects of the test method

The object of the tests is to establish the performance of the unit over a specified range of primary and secondary fluid conditions and space temperatures. The test procedures set out in this standard are for the determination of:

1) the gross thermal output;

2) the primary fluid pressure drop;

3) the secondary flow rate, where required.

6 Testing conditions

6.1 Primary fluid — liquid. The unit shall be tested at a minimum of three primary fluid inlet temperatures. The selected temperatures shall cover the range of duty over which the appliance is to be rated, that is, to within 10 % at either end of the range.

Suitable inlet temperatures may be:

For inlet temperature up to 100 °C: at 50 °C, 70 °C, 90 °C.

For inlet temperature between 100 °C and 200 °C: at 130 °C, 150 °C, 180 °C.

6.2 Primary fluid — steam. Gauge pressures for the tests shall be selected such that temperature intervals are not greater than 20 °C, and that a minimum of three test points are obtained. The steam shall have a minimum of 1.5 °C superheat to ensure the absence of entrained moisture, and a maximum of 3 °C superheat.

6.3 Entering air conditions. The entering air temperature shall be within the range 15 – 25 °C.

6.4 Primary fluid flow rate. For duties quoted over a range of primary fluid flow rates, tests shall be carried out at a minimum of three primary fluid flow rates, spaced approximately equally over the required range and covering the range to within 10 % at either end.

6.5 Electrical supply conditions. The tests shall be carried out at the rated voltage and frequency of the unit.

7 Steady state conditions

Tests shall be carried out under steady state conditions and these are considered to be established if during 30 min the measurements given in Table 1 do not vary by more than the specified amount.

Table 1 — Steady state conditions

Quantity	Permitted variation from mean
Room air temperature, as defined in **11.1**	0.5 °C
Entering air temperature, as defined in **11.2**	0.5 °C
Entering liquid temperature	0.5 °C range: less than 100 °C 1 °C range: between 100 °C and 200 °C
Liquid flow rate	2 %
Steam rate of condensation	3 %
Supply voltage	± 2.5 % of rated voltage.

8 Instrumentation

8.1 Steam

8.1.1 *Temperature*. Temperature measurement shall comply with the requirements of BS 1041-2, BS 1041-3 and BS 1041-4.

Thermometers, thermocouples and resistance thermometers shall be calibrated to a precision of 0.5 °C against a NPL thermometer (accurate to 0.25 °C) and shall be used in pockets similar to those shown in Figure 1a, situated at the entry and outlet of the unit between 100 mm and 200 mm for the unit connections.

8.1.2 *Pressure*. Pressure gauges shall comply with the requirements of Clause **30***a* of BS 1780:1960. They shall be at least 150 mm in diameter and shall have a total scale range not more than three times the measured test pressure. For test pressures below 0.3 bar, a liquid manometer is desirable.

8.1.3 *Mass flow*. Mass flow measurement shall be by weight of condensate. The weighing apparatus shall not have an error greater than ± 5 g over the range of weights used in the test.

8.2 Hot water

8.2.1 *Temperature*. The measurement of temperature of the water at entry and exit shall comply with the requirements of BS 1041. If liquid-in-glass thermometers are used, they shall be graduated for partial immersion at intervals of 0.1 °C and shall comply with the requirements of BS 593.

Thermometers, thermocouples and resistance thermometers shall be calibrated to a precision of 0.1 °C against a NPL thermometer (accurate to 0.05 °C) and shall be used in pockets similar to those shown in Figure 1b, situated at the entry and outlet of the unit between 100 mm and 200 mm from the unit connections.

8.2.2 *Pressure*. The pressure drop across the unit shall be measured with an inverted U-tube manometer similar to that shown in Figure 2. The manometer shall be vertical and calibrated in intervals not exceeding 2 % of the measured drop.

8.2.3 *Mass flow*. Mass flow shall be preferably measured by direct weighing. Weighing machines shall have an error of not greater than ± 50 g over the range of weights used in the test. Collecting vessels shall not weigh more than 50 % of their normal contents.

Flow rate may also be measured by means of an orifice plate installed in accordance with BS 1042-1.

8.3 Air

8.3.1 *Temperature*. Measurements of air temperature shall be made with mercury-in-glass thermometers, thermocouples or resistance thermometers, calibrated to 0.1 °C against a NPL Class A thermometer. Thermometers shall be graduated at intervals not greater than 0.1 °C and calibrated for total immersion.

Temperature measuring instruments shall be shielded against radiation; suitable shields are shown in Figure 3. Inlet air temperatures shall be measured by thermocouples or resistance thermometers capable of being shielded as in Figure 3b.

8.3.2 *Flow rate*. Flow meters should comply with the requirements of BS 1042-1. Where the recommendations of BS 1042-1 cannot be followed, the flow meter may be calibrated in situ. It is suggested that the orifice plate at the junction of a void and duct be employed, as described in Clause **49** of BS 1042-1:1964.

8.3.3 ***Pressure***

8.3.3.1 The minimum differential pressure readings for flow measurement shall be 25 N/m^2 for inclined U-tube manometers and micro-manometers, and 500 N/m^2 for vertical U-tube manometers.

8.3.3.2 Manometers shall be calibrated against an accepted standard.

8.3.3.3 It shall be possible to read the manometer to an accuracy of 0.5 N/m^2 over a pressure differential of 25 – 50 N/m^2 and to 1 % at higher differential pressures.

9 Test equipment

9.1 Steam. The steam supply and consumption test equipment shall be as detailed below and arranged as shown in Figure 4.

9.1.1 The length of pipe between the steam pressure and temperature measurement positions and the unit casing shall not exceed 300 mm and shall be insulated with at least 40 mm thickness of insulating material having a thermal conductivity not exceeding 0.06 W/m °C.

9.1.2 The pipe conveying the condensate to the sight glass shall not exceed a total length of 1 m and shall be insulated as described in **9.1.1**.

9.1.3 An air cock, throttle valve, pressure gauge or manometer, a temperature measuring instrument and a separator with drain shall be fixed in the steam pipe close to the steam inlet of the unit, as means for controlling and indicating the steam pressure and temperature. The use of a superheater, preferably electrically heated, is also advisable.

9.1.4 An air cock, automatic or otherwise, a sight glass with water level indicator and a throttle valve shall be fixed close to the heater condensate outlet.

9.1.5 The condensate shall be collected and weighed and means shall be employed to minimize loss by evaporation. An after-cooler may be employed, if desired.

9.2 Hot water or heat transfer fluid

9.2.1 There shall be available a means for providing a continuous supply of heated fluid, together with a means for controlling the temperature of this fluid at any desired temperature that may be required for the test.

9.2.2 There shall be available a means for providing a constant flow of fluid, such as a constant head tank or a circulation pump.

9.2.3 Figure 5 shows the arrangement of the hot water test equipment.

9.2.4 For water temperatures above 95 °C, a closed pressure vessel such as a boiler operating at constant pressure should be used as the source of hot water, and an after-cooler inserted before the water control valve at the discharge end. A typical arrangement is shown in Figure 6.

9.2.5 The pipework shall be arranged to give an unobstructed straight run at entry to and exit from the appliance, the pipe diameter being equal to that demanded by the unit connections and of length at least equal to five pipe diameters.

9.2.6 Hydraulic resistance side wall tappings shall be adjacent to the connection to the appliance. The tappings shall be as specified in Figure 7 and connected to form a piezometric ring.

9.2.7 The lengths of pipe between the temperature measurement positions, the unit connections and the unit casing shall be insulated with at least 40 mm thickness of insulating material having a thermal conductivity not exceeding 0.06 W/m °C.

9.2.8 When mass flow measurement is determined by weighing, means shall be taken to minimize evaporation from vessels awaiting weighing.

10 Test facility

In many cases it will be possible to test units in the open laboratory and the test arrangement described in **10.1** will be suitable. In the case of the larger unit heaters it may not be possible to obtain steady state conditions and the heated air may have to be ducted away, in this case the tests can be carried out with the unit connected to the air flow rate measuring apparatus described in **10.2**, except where recirculation of the heated air occurs.

10.1 Open laboratory testing

10.1.1 The unit shall be tested with a minimum of 3 m or $5\sqrt{A}$ (where A is the outlet area, m^2), whichever is the greater, of clear space in the direction of discharge.

10.1.2 Units designed for mounting or standing against a surface shall be tested standing against a surface. This surface shall extend to a minimum of 1.5 m on either side of the unit, and to a height of 2.5 m or to the unit height, whichever is the greater.

10.1.3 Freely suspended units shall be tested with a minimum of 2 m clear space around them and the requisite space in the direction of discharge (**10.1.1**).

10.1.4 If a unit is designed for use in a specific situation then the test facility shall reflect this situation.

10.1.5 Insulating material with a thermal conductivity not less than 1 W/m °C and of 10 mm minimum thickness shall be used between the unit and any adjacent surfaces.

10.1.6 The test shall take place in a space where vertical and horizontal temperature gradients do not exceed 0.5 °C/m when the unit is not operating.

10.2 Air flow rate apparatus

10.2.1 The unit shall be connected to a chamber as shown in Figure 8.

10.2.2 The chamber volume shall be such that the number of air changes, with the unit set for maximum flow, is less than 1.7 per second. The cross-sectional area of the chamber shall be such that the mean chamber velocity is no greater than 40 % of the mean discharge velocity from the unit outlet.

10.2.3 The chamber shall be connected to a flow meter and booster fan with a means of varying the air flow rate as shown in Figure 8.

11 Air temperature measurement

The selection of a suitable fan coil unit or unit heater is very often based upon its output at some specified value of room temperature. The room temperature is not necessarily equal to the unit inlet temperature. It will not be so if the design of the unit allows a proportion of the heated air to circulate from outlet to inlet.

11.1 Room temperature

11.1.1 Measure the room air temperature at the stations indicated in Figure 9. If at least 75 % of all the measured temperatures are within 1 °C of the lowest then the mean of the sample within this limit shall be taken as the mean room temperature (t_R). If more than 25 % of the temperatures recorded are greater than 1 °C above the lowest, then the length of the temperature traverse lines shall be doubled, with a corresponding increase in the number of measuring stations. Provided that at least 50 % of the measured temperatures are within 1 °C of the lowest measured temperature, the mean of the sample within this limit shall be taken as the mean room temperature.

11.1.2 If the conditions stated in **11.1.1** cannot be met, the size of the space in which the test is being carried out shall be increased until satisfactory conditions are achieved, or the unit tested in accordance with **14.2** provided that recirculation of the heated air does not occur.

11.2 Unit entering air temperature

11.2.1 Measure the unit entering air temperature (t_a) 10 mm in front of the inlet grille (or inlet grilles) by means of point measuring instruments; see Figure 3b.

11.2.2 Measuring stations shall be evenly distributed about the inlet (or inlets) as shown in Figure 10. At least four measuring stations per inlet shall be employed, and an extra measuring station shall be introduced for every degree Celsius deviation of individual readings from the mean temperature.

For example, if the measured temperatures are: 19.2, 20, 20.6 and 18.5 °C, the mean of these is 19.6 °C, and two extra stations will be required.

11.2.3 The additional temperature measuring stations shall be located as shown in Figure 10.

12 Test method (Primary fluid measurements)

12.1 Steam as primary fluid

12.1.1 With steam at the required pressure the condensate control is adjusted such that the condensate level is visible in the sight glass. The test shall be started only after a state of equilibrium has been reached. Such a state of equilibrium may be considered to exist when the conditions of **7** are satisfied.

12.1.2 Each test shall be continued until three consecutive sets of readings, each taken over a 15 min period (one of which may be taken at the completion of the last 15 min of the equilibrium period), give rated outputs agreeing to within ± 2 %.

12.1.3 The supply steam temperature (t_s) shall be read at the beginning and end of each test and at intervals of 15 min during the test. All readings of the supply steam temperature (t_s) shall conform to the conditions of superheat laid down in **6.2**.

12.1.4 The supply steam pressure shall be read at intervals of 15 min during the test and successive readings shall not vary from their mean value by more than ± 5 % absolute.

12.1.5 The total condensate shall be collected and weighed on the apparatus described in **8.1.3**. The weight of condensate collected in each 15 min period of the test shall also be noted and the condensation rate during any one of these periods shall not vary by more than ± 3 % from the mean.

12.1.6 A no-load test to determine the amount of steam which is condensed by the steam and condensate piping, between the temperature measuring station and the condensate collecting vessel, shall be made. This no-load test shall be run under the same conditions and following the same procedure as provided for testing the appliance itself. The degree of superheat shall be at least 1.5 °C and not more than 3 °C.

One of the two following methods for determining no-load condensation shall be employed.

1) Move either the supply piping or the condensate piping and the condensate seal and join them directly using the shortest possible connection. The condensate collected per hour will then represent the total no-load correction.

2) If the piping is inflexible, substitute in place of the test unit a pipe of the same diameter and insulated in exactly the same manner as the condensate piping. The condensate collected per hour shall be divided by the total length of pipe from inlet temperature measuring station to condensate seal and then multiplied by the length of the permanent condensate piping. This value will then represent the total no-load correction as in **12.1.6** 1) above.

12.2 Hot water as primary fluid

12.2.1 The water temperatures shall be selected in conformity with **6.1**.

12.2.2 Before starting a test the unit and all supply piping shall be thoroughly vented by means of manual or automatic air vents.

12.2.3 The test shall be started only after a state of equilibrium has been reached. Such a state of equilibrium may be considered to exist when the conditions of **7** are satisfied.

12.2.4 Each test shall be continued until three consecutive sets of readings, each taken over a period of 15 min, give rated outputs agreeing within ± 2 %.

12.2.5 During any test the variation in water flow rate shall not exceed 2 % and the air temperature (mean inlet and room) shall not differ by more ± 1 °C from the mean temperature recorded during the equilibrium period.

12.2.6 The following readings shall be taken.

1) Water flow rate shall be measured in the manner specified in **8.2.3**.

2) Water temperatures shall be read at the beginning and end of the test and at intervals of 5 min. The extreme readings of each instrument shall not differ by more than 0.5 °C. The range of water temperature difference readings obtained during the test shall not exceed 0.25 °C. The average of the inlet water temperatures and the average of the outlet water temperatures over the appropriate period shall be used for calculation.

3) The pressure drop across the unit under test shall be read at the beginning and end of the test.

12.3 Heat transfer fluid as primary fluid. The test method shall be the same as that described in **12.1**, with measurements of heat transfer liquid temperatures, pressures and flow rates replacing values for water.

13 Test method (Open laboratory test)

13.1 The unit to be tested shall be set up as described in **10.1**, air flow measurement being carried out by the method described in **14**.

13.2 After a condition of equilibrium has been achieved (see **7**, **11** and **12**), the recording of measurements may commence, as described in **11** and **12**.

13.3 Temperature measurements made after the state of equilibrium has been reached shall be at 5 min intervals, each measurement averaged and the mean values employed in the analysis of results.

13.4 Analysis of results — steam as primary fluid

13.4.1 The rating of the unit shall be calculated for each test using the following formula:

$$Q = \left(\frac{M_t}{T_t} - \frac{M_n}{T_n}\right) . L$$

where Q = output (kW)

M_t = net weight of condensate formed during test (kg)

M_n = net weight of condensate formed during no load test (kg)

T_t = duration of test (s)

T_n = duration of no load test (s)

L = latent heat of evaporation corresponding to the saturated steam temperature in the appliance during the test. The reading of the pressure gauge and the barometric pressure shall be used to determine this steam temperature (kJ/kg)

13.4.2 The room temperature (t_R) and the entering air temperature (t_a) shall be compared and if $(t_a - t_R) \geqslant 0.02\ (t_s - t_a)$ then the procedure described in **13.4.4** shall be followed, if $(t_a - t_R) < 0.02\ (t_s - t_a)$ then the test data shall be analysed as described in **13.4.3**.

13.4.3 The values of thermal rating (Q) of the unit determined under **13.4.1** shall be plotted on logarithmic graph paper against the difference between the saturated steam temperature and the entering air temperature $(t_s - t_a)$. The performance curve shall be the best straight line drawn through the test points.

13.4.4 If $(t_a - t_R) \geqslant 0.02\ (t_s - t_a)$ then some of the heated air may be returning directly to the unit inlet. In general the quantity of air recirculating will be a function of the unit outlet temperature and the room air temperature.

In order to determine the interdependence of these variables it is necessary to carry out the following procedure.

1) Plot Q against $(t_s - t_a)$ on logarithmic graph paper.

2) From the graph prepared under **13.4.4** 1), substitute t_R for t_a and obtain the heat transfer figure Q_m, where Q_m is the rating the unit would have if there were no recirculation. The actual heat transfer (Q_a) under test conditions, corresponding to the t_R used to obtain Q_m, may be obtained from the test results (from $t_s - t_a$). The ratio Q_a/Q_m shall then be calculated. See example in Figure 11.

The ratio $Q_m/(t_R + 273)$ shall also be calculated, (where Q_m is obtained from the above) and Q_a/Q_m shall be plotted against this parameter on linear graph paper (see Figure 13b).

13.4.5 The analysis described in **13.4.1** to **13.4.4**, shall be carried out for each air flow rate employed.

13.4.6 Tests carried out on units with variable inlet or outlet geometry shall be referenced to the particular geometry employed in the test.

13.4.7 If it is not possible to obtain steady state conditions in the open laboratory over the desired range of test conditions, and there is no recirculation, i.e. $(t_s - t_R) < 0.02\ (t_s - t_a)$, then the unit may be tested with its outlet connected to the air volume measuring apparatus as described in **14.2**.

13.5 Analysis of results — liquid primary fluid

13.5.1 The rating of the unit shall be calculated for each test using the following formulae:

1) For weight or volume method:

$$Q = \frac{Mc_p (t_i - t_o)}{T_t}$$

where Q = output (kW)
M = total mass flow (kg)
T_t = duration of test (s)
t_i = average fluid inlet temperature (°C)
c_p = specific heat capacity (kJ/kg °C)
t_o = average outlet liquid temperature (°C).

2) For direct mass flow measurement (i.e. orifice plate):

$Q = wc_p (t_i - t_o)$

where w = water mass flow rate (kg/s).

13.5.2 The room temperature (t_R) and the entering air temperature (t_a) shall be compared and if $(t_a - t_R) \geqslant 0.02\ (t_o - t_a)$ then the procedure described in **13.4.4** shall be followed (t_o replacing t_s in the formulae). If $(t_a - t_R) < 0.02\ (t_o - t_a)$, then the test data shall be analysed as described in **13.5.3**.

NOTE In all formulae the air-water temperature difference may be computed using t_i or $(t_i + t_o)/2$ instead of t_o.

13.5.3 The thermal rating Q of the unit determined under **13.5.1** shall be plotted on logarithmic graph paper against the difference between the water outlet temperature (t_o) and the room temperature (t_R), and the best straight line drawn through the points to obtain the performance curve.

13.5.4 The analysis described in **13.5.1** to **13.5.3**, shall be carried out for each air flow rate employed.

13.5.5 Tests carried out on units with variable inlet or outlet geometry shall be referenced to the particular geometry employed in the test.

13.5.6 If it is not possible to obtain steady state conditions in the open laboratory over the desired range of test conditions, and there is no recirculation, i.e. $(t_a - t_R) < 0.02\ (t_o - t_a)$, then the appliance may be rated with its outlet connected to the air volume measuring apparatus as described in **14.2**.

13.5.7 The hydraulic pressure drop shall be corrected for any difference in height between the inlet and outlet measuring stations and converted to the pressure drop at a mean water temperature of 80 °C, by means of the following equation:

$$\Delta p_c = \frac{\Delta p_m}{K_w}$$

where Δp_c is the hydraulic pressure drop at 80 °C (N/m^2)
Δp_m is the measured hydraulic pressure drop corrected for height difference (N/m^2)
K_w is the temperature correction factor, obtained from Figure 14, at the mean test water temperature.

Δp_c shall be plotted against the water mass flow rate on logarithmic graph paper and the best line through the test points shall be used (in conjunction with the above equation) to determine the pressure drop at any flow rate within, and to ± 10 % outside, the range of the variables used during the test.

14 Air volume measurement rating

14.1 Measurement of air volume alone

14.1.1 The unit shall be connected to the chamber described in **10.2**.

14.1.2 The chamber and the junction between the chamber and the unit shall be carefully sealed against leaks.

14.1.3 The necessary equipment for primary fluid heat transfer measurements shall be connected to the appliance (see **9**).

14.1.4 All primary fluid measurements shall be carried out using the techniques described in **12**.

14.1.5 The entering air temperature shall be measured in accordance with **11.2**.

14.1.6 The desired unit fan speed shall be selected and primary fluid conditions set for a duty in the centre of the normal recommended working range.

14.1.7 The static pressure in the chamber shall be set to zero by means of the auxiliary fan connected to the chamber, and the procedure described in **12** shall be carried out. (It is not necessary to measure t_R.)

14.1.8 The thermal output (Q_c) of the unit shall be calculated using the methods described in **13.4.1** and **13.5.1**.

The pressure drop across the flow meter shall be recorded at three equally spaced time intervals during the test and the mean value used to compute the volume flow.

The temperature at the flow meter shall be recorded at similar intervals to all other temperature measurements and the mean value computed.

The barometric pressure shall also be recorded.

The air volume rate shall be converted to the volume flow under standard conditions by the following equation:

$$q_r = q_m \rho_m / \rho_r$$

where q_r = air volume flow rate at reference temperature and pressure (m^3/s)

q_m = air volume flow rate measured (m^3/s)

ρ_m = air density at conditions measured at the flow meter (kg/m^3)

ρ_r = reference air density = 1.200 Kg/m^3.

14.1.9 The thermal output (Q_a) that would have been obtained with the unit delivering air to an open space shall be calculated from the curves obtained in **13.4.3** and **13.5.3** [or a plot of Q against ($t_s - t_a$) or ($t_o - t_a$) described in **13.4.4** if the unit recirculates some of the heated air]. This output shall be divided by the thermal output (Q_c) obtained under **14.1.8** above and the ratio plotted against the air volume flow rate (q_r) on logarithmic graph paper (see Figure 12). If the thermal rating ratio (Q_a/Q_c) is between 0.95 and 1.05 then the measured air flow rate (converted to reference conditions) may be taken to be the unit air volume flow rate. If the thermal rating ratio is outside these limits then further tests shall be carried out as described below.

If the thermal rating ratio (Q_a/Q_c) is less than unity an auxiliary fan shall be set to increase the chamber static pressure to approximately 5 N/m^2, otherwise a chamber static pressure of – 5 N/m^2 shall be set. A minimum of three chamber static pressures shall be selected, the third being chosen such that the test results straddle a thermal rating ratio of unity. The procedure described in **14.1.5** to **14.1.9** shall be followed for each new value of chamber static pressure.

14.1.10 The unit air volume flow rate shall be determined from the plot of thermal rating ratio against air volume flow, as shown in Figure 12.

14.2 Joint thermal rating and air volume measurement. This method may be adopted on larger equipment where a relatively reduced thermal output is desirable, so as to permit stabilization of laboratory conditions. It may be carried out with lower primary fluid temperatures than those that are recommended for normal use.

14.2.1 At least two tests at different primary fluid inlet temperatures (not more then 10 °C apart) but at the same primary fluid flow rate and unit fan setting or damper setting (these tests may be at lower primary fluid temperatures than those that would normally be recommended) shall be carried out in the open laboratory to determine the thermal rating for free delivery. If recirculation of heated air occurs then all thermal tests shall be carried out in the open laboratory.

14.2.2 The thermal ratings for the tests described under **14.2.1** shall be calculated and plotted as described in **13**, and a straight line drawn between the points.

14.2.3 The unit, with its controls set as in the tests carried out under **14.2.1**, shall be connected to the test chamber described in **10.2**. The primary fluid flow rate shall be set to that employed previously (**14.2.1**), and the inlet primary fluid temperature shall be adjusted to a value mid-way between the extreme values of those used in the test carried out under **14.2.1**. The auxiliary fan shall be set to give a chamber static pressure of zero. The thermal rating, air volume flow and thermal rating ratio shall be calculated as described in **14.1**. If the value of the thermal ratio is between 0.98 and 1.02 then it is unnecessary to carry out any further tests. If, however, this ratio is outside these limits a further test shall be carried out as described in **14.1.9**.

14.2.4 Both air volume flow and chamber static pressure shall be plotted against the thermal rating ratio (on logarithmic graph paper) and the best line drawn through the points. The value of chamber static pressure for thermal rating ratio of unity shall be set for all rating tests at a given unit fan speed setting, and the corresponding value of air volume flow rate shall be the appliance air volume flow rate.

14.2.5 The unit shall then be rated over the desired range of primary fluid flow rate and temperature while connected to the test chamber, with the auxiliary fan set to produce the chamber static pressure found under **14.2.4**. All tests shall be carried out and analysed as described in **12** and **13**, with t_R taken as t_a.

14.2.6 14.2.1 to **14.2.5** shall be repeated for each air flow setting at which it is desired to test.

14.2.7 The hydraulic pressure drop shall be measured by the method described in **13.5.7**.

15 Example of rating calculation

The mean test results on a hot water fan coil unit with a small amount of recirculation for a particular water flow rate and fan speed are shown in Table 2.

Table 2 — Test results for hypothetical fan coil unit

t_a	t_R	t_i	t_o	Q	$t_o - t_a$
°C	°C	°C	°C	kW	°C
20	16	139	120	4	100
22	16	170	147	5	125
22	17	200	172	6	150

The thermal rating (Q) is plotted against ($t_o - t_a$) as can be seen in Figure 13a. The recirculation correction factor Q_a/Q_m is obtained by dividing the known value of Q (Q_a) by the value Q would take (Q_m) if there were no recirculation, i.e. when t_a was equal to t_R (see also Figure 13a).

The abscissa on the recirculation correction curve (Figure 13b) is obtained by dividing Q_m by (t_R + 273).

The air volume flow rate will be found from curves similar to that shown in Figure 12.

The test data may be used to determine the rating at different conditions (but at the same water and air flow rates) as shown in Table 3.

Table 3 — Method of rating fan coil unit

Room temperature	$t_o - t_R$	Q_m **(from Figure 13a)**	$Q_m/(t_R+273)$ (calculated)	Q_a/Q_m **(from Figure 13b)**	$Q_a = Q_m \times (Q_a/Q_m)$
°C	°C	kW	kW/K		kW
5	125	5.0	0.018	0.935	4.68
10	120	4.8	0.0168	0.927	4.45
20	110	4.4	0.015	0.915	4.02
30	100	4.0	0.0132	0.904	3.62

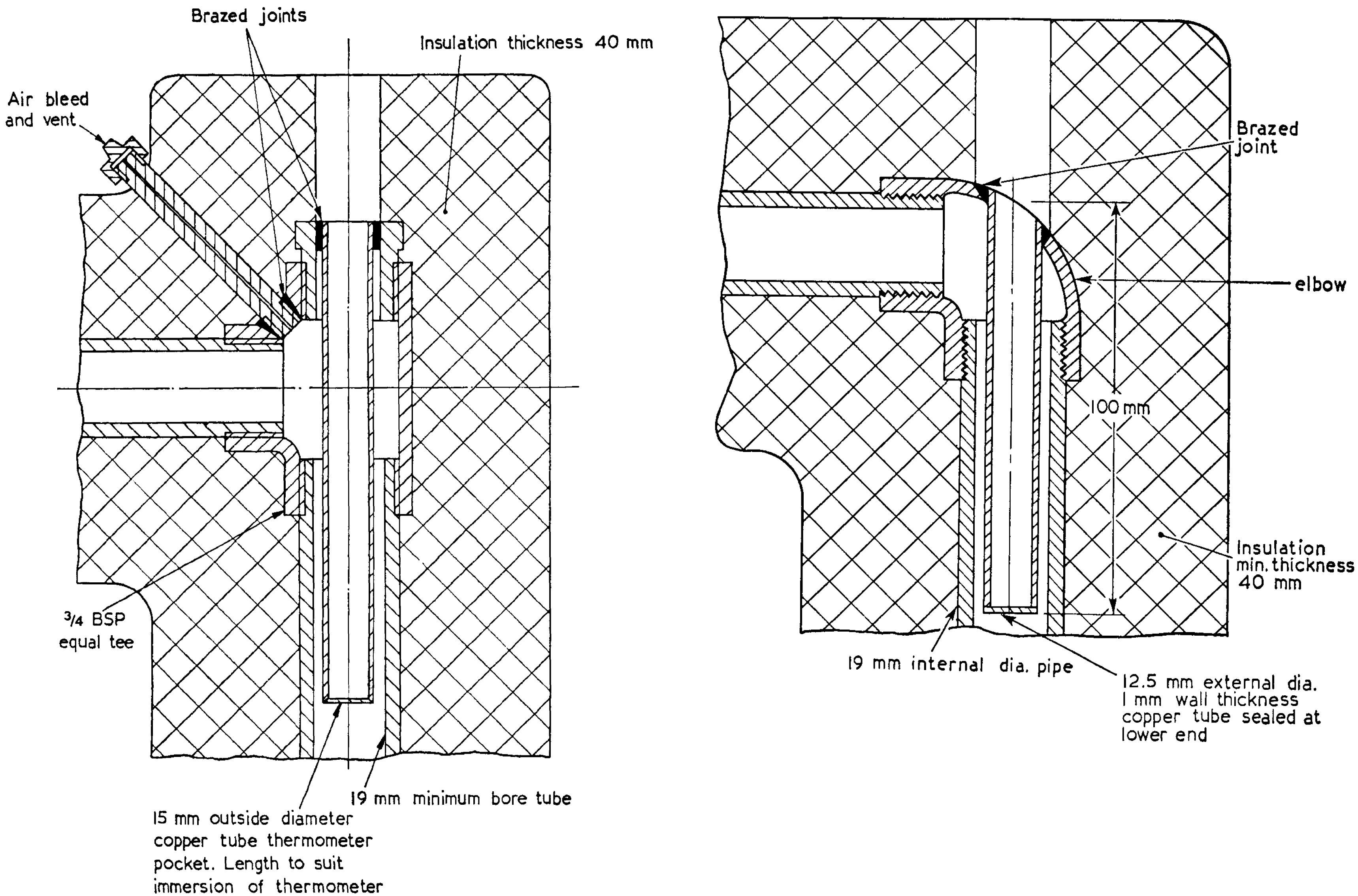


Figure 1a — Pocket for steam test

Figure 1b — Pocket for hot water test

Figure 1 — Thermometer pockets

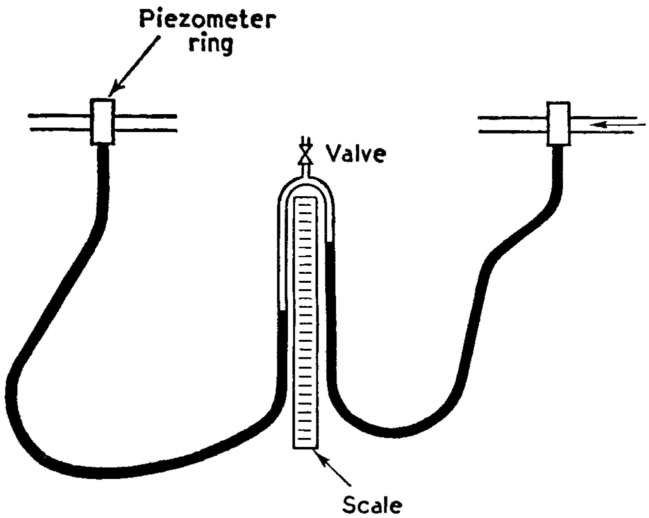


Figure 2 — Inverted tube pattern manometer

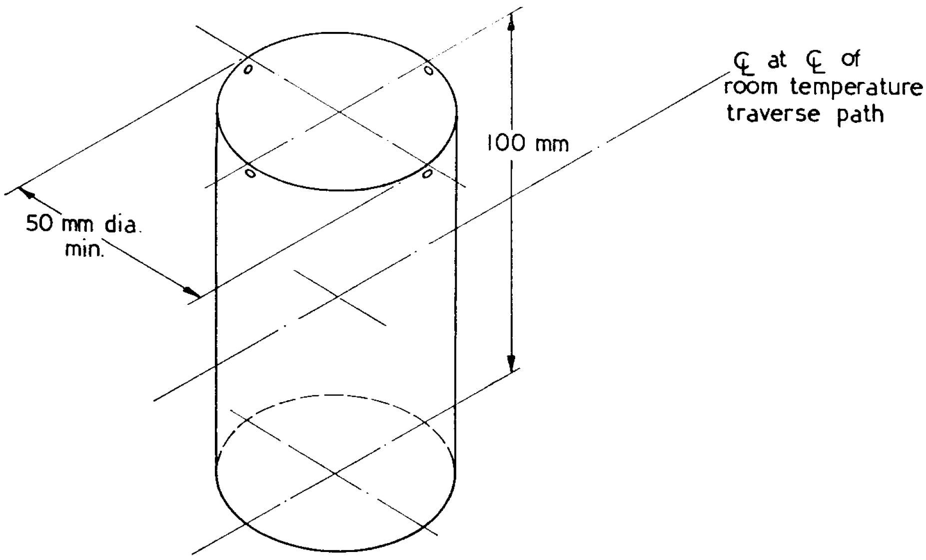


Figure 3a — Thermometer shield

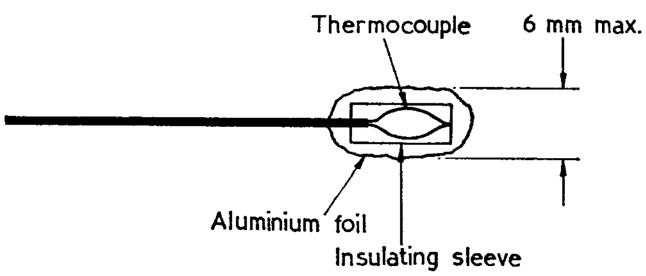
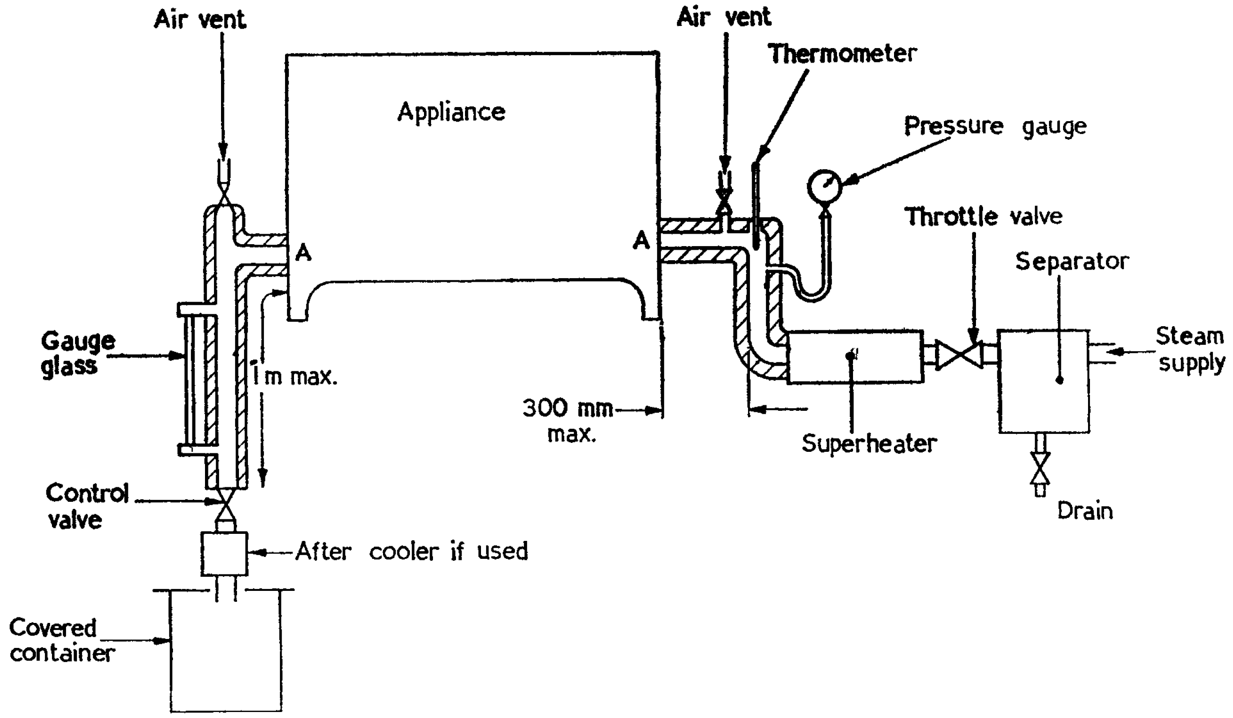


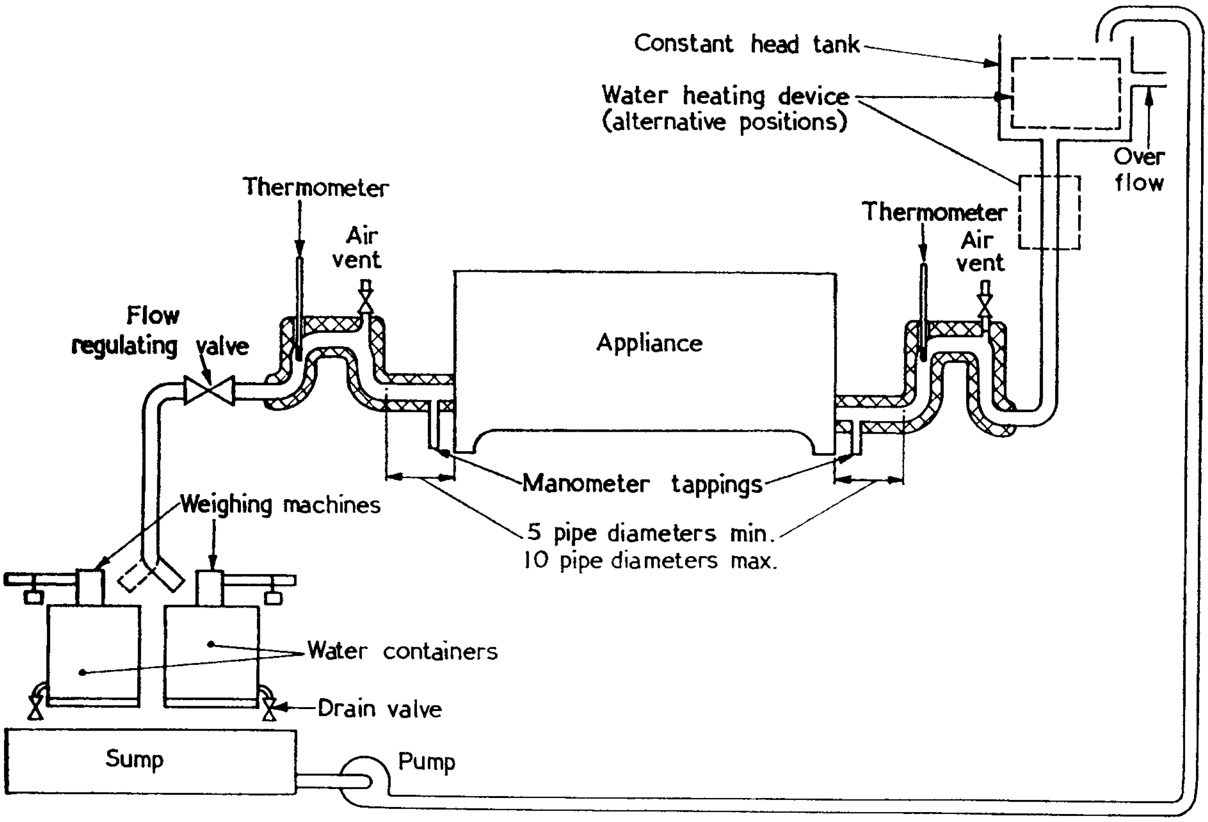
Figure 3b — Thermocouple shield

Figure 3 — Shields for thermometer and thermocouple



A-A points to be connected for no-load test

Figure 4 — Steam test equipment



Water supply arrangement shown applicable to a maximum water temperature of 95 °C.
For higher temperature, supply is from a boiler or other pressure vessel, and an aftercooler is necessary prior to flow regulating valve.

Figure 5 — Hot water test equipment

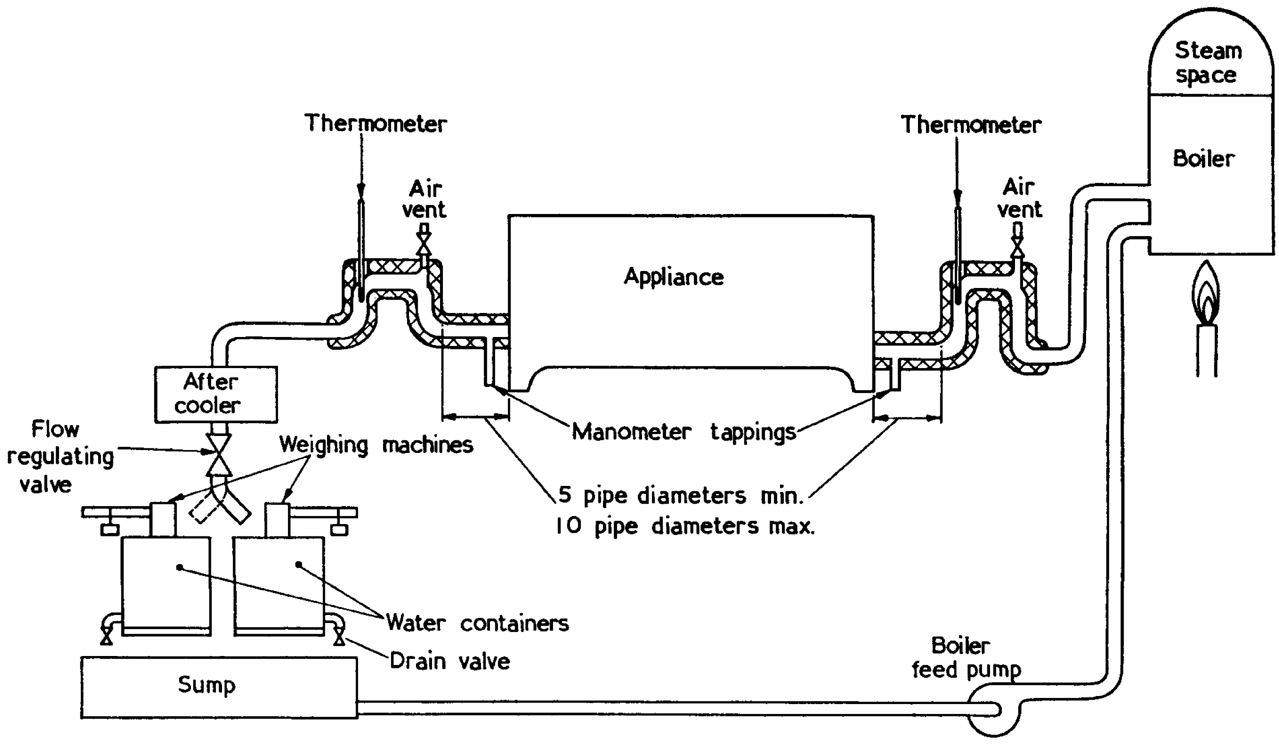


Figure 6 — Hot water test equipment (maximum water temperature above 95 °C)

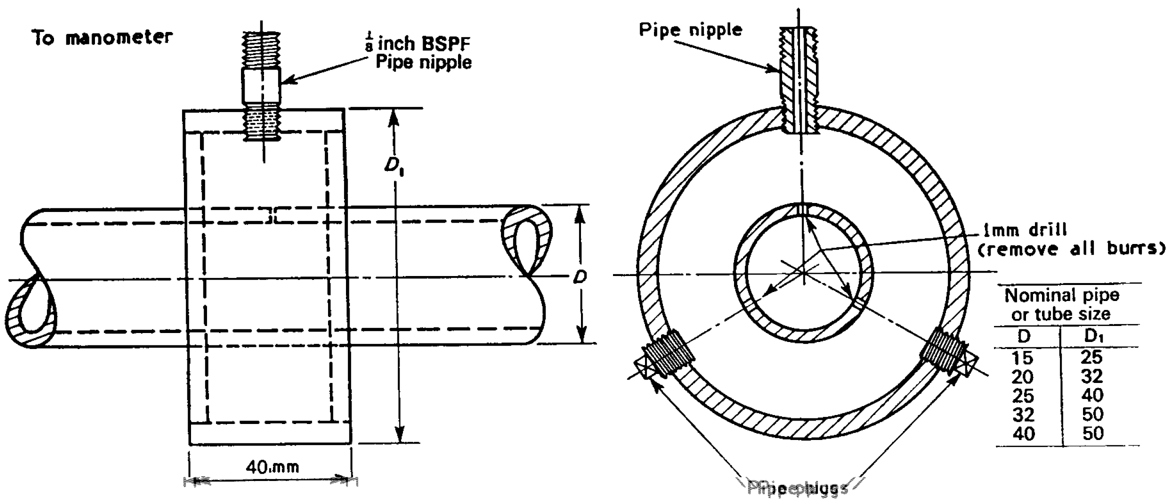


Figure 7 — Piezometer ring

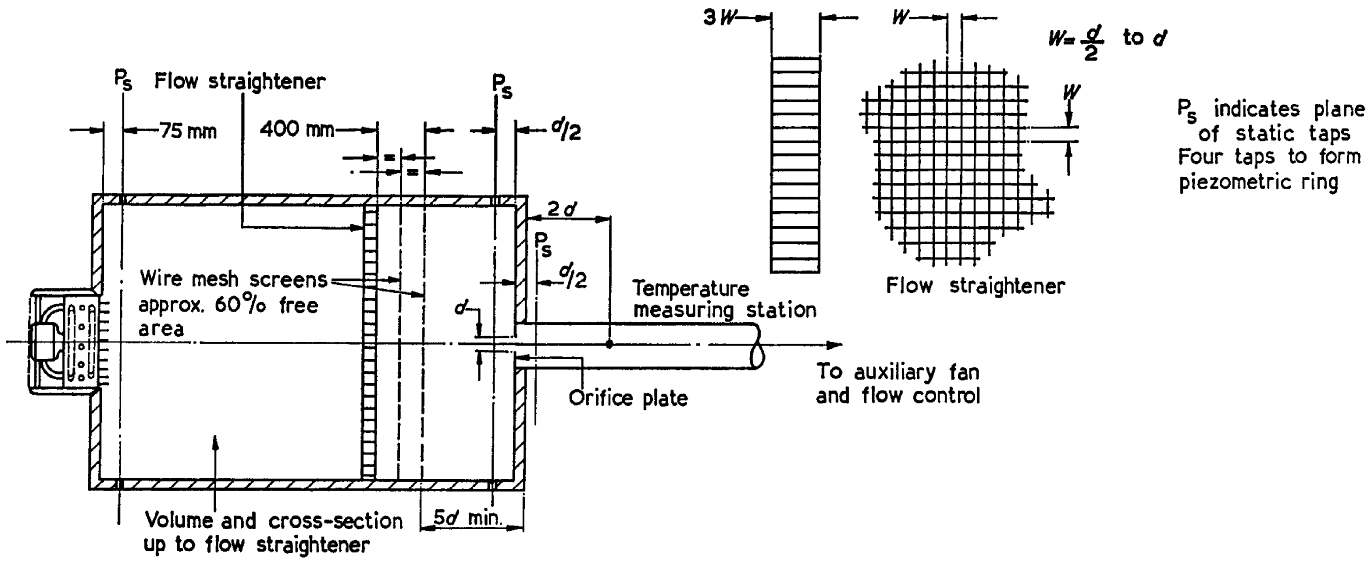


Figure 8a — Horizontal unit heater

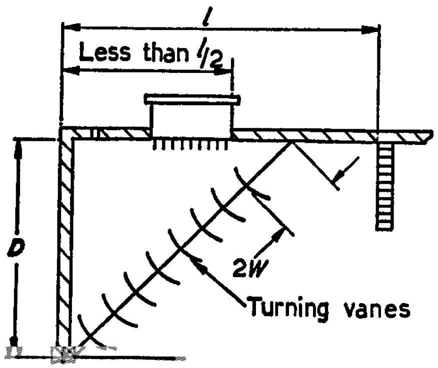


Figure 8b — Vertical unit heater

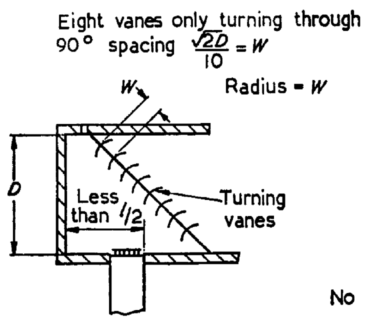


Figure 8c — Vertical discharge fan convector

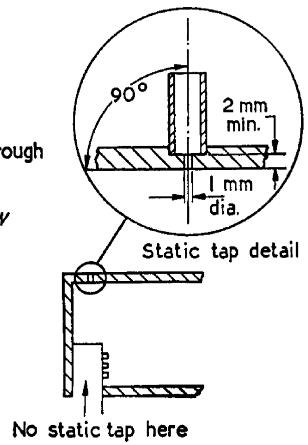


Figure 8d — Horizontal discharge fan convector

Figure 8 — Air flow chamber

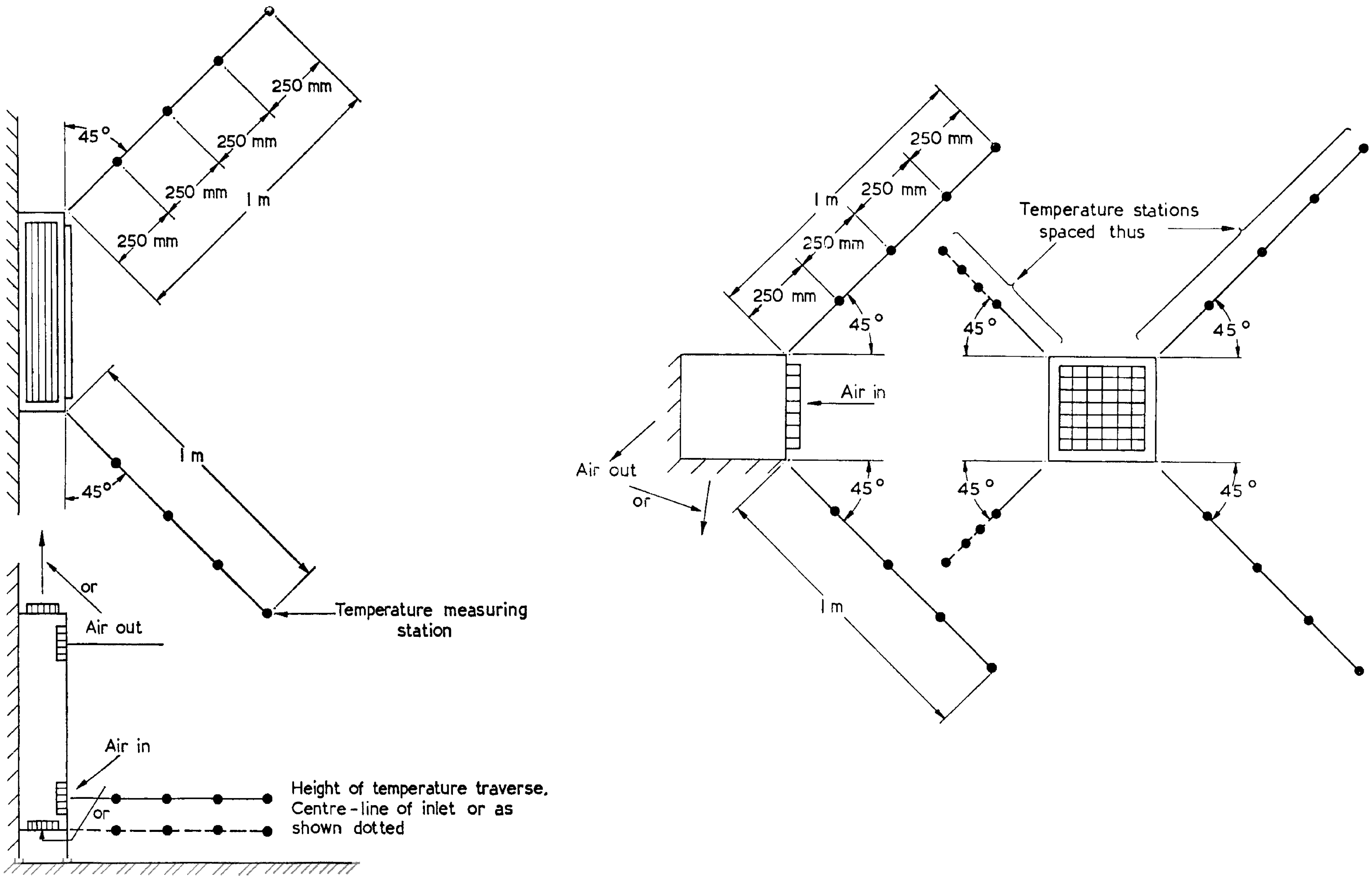


Figure 9a — Free standing appliance

Figure 9b — Suspended unit

Figure 9 — Room temperature measuring stations

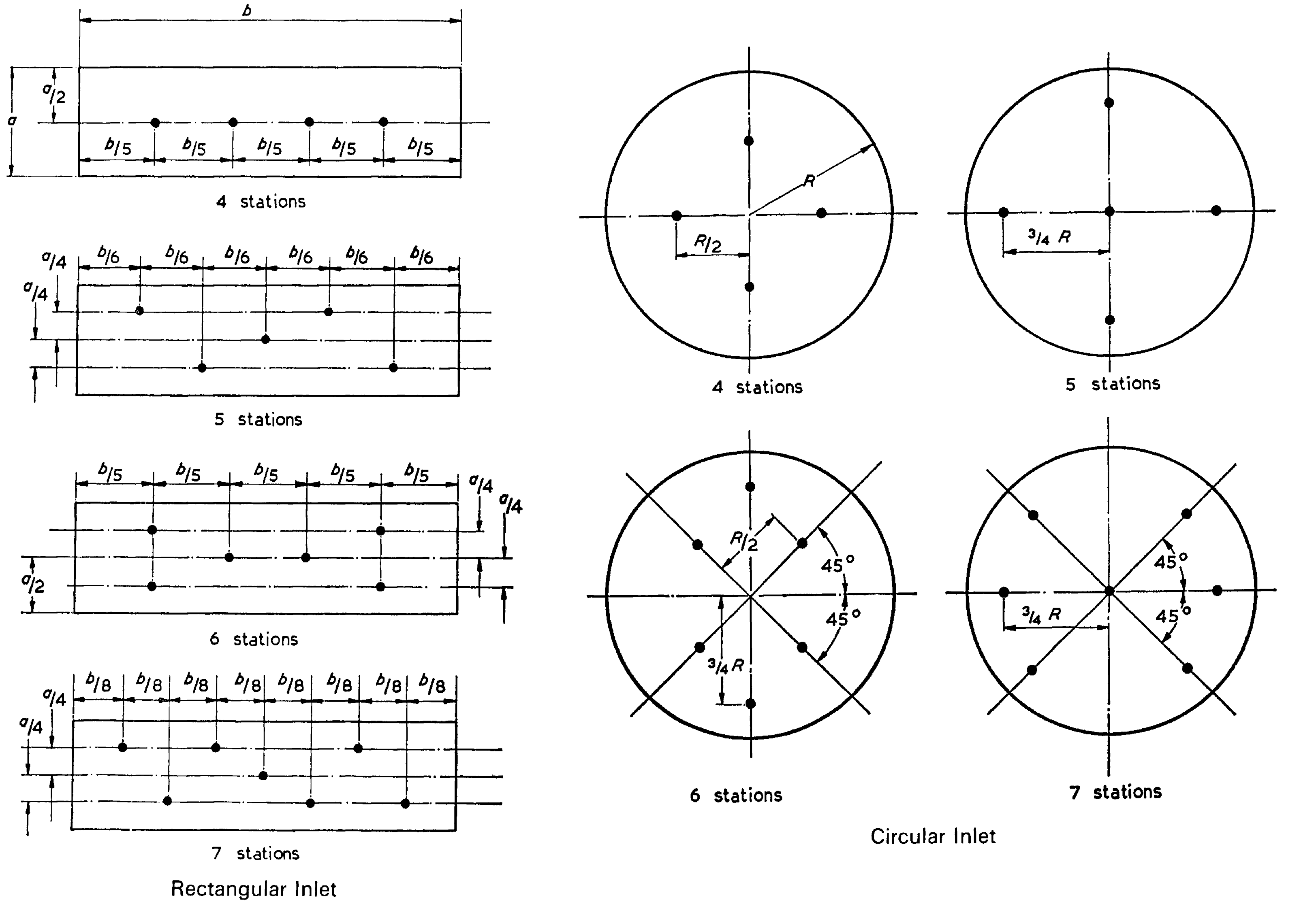


Figure 10 — Inlet temperature measurement

Assumed test results (arbitary units):

Q	ts	tR	ta	ts-tR	ts-ta
2.0	2.7	0.4	0.7	2.3	2.0
3.6	4.4	0.4	0.6	4.0	3.8
5.0	6.0	0.4	0.6	5.6	5.4

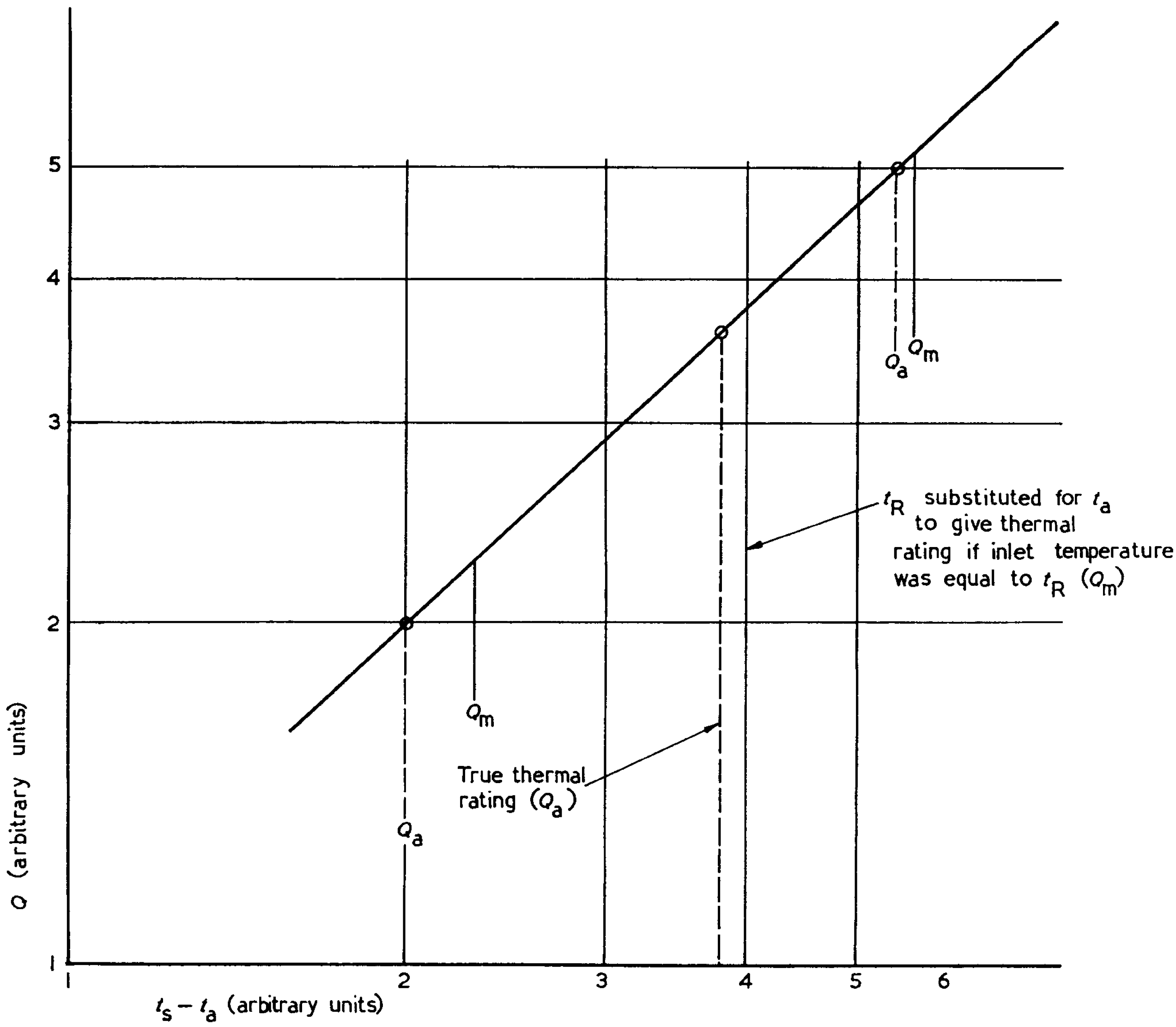


Figure 11 — Determination of Q_a and Q_m

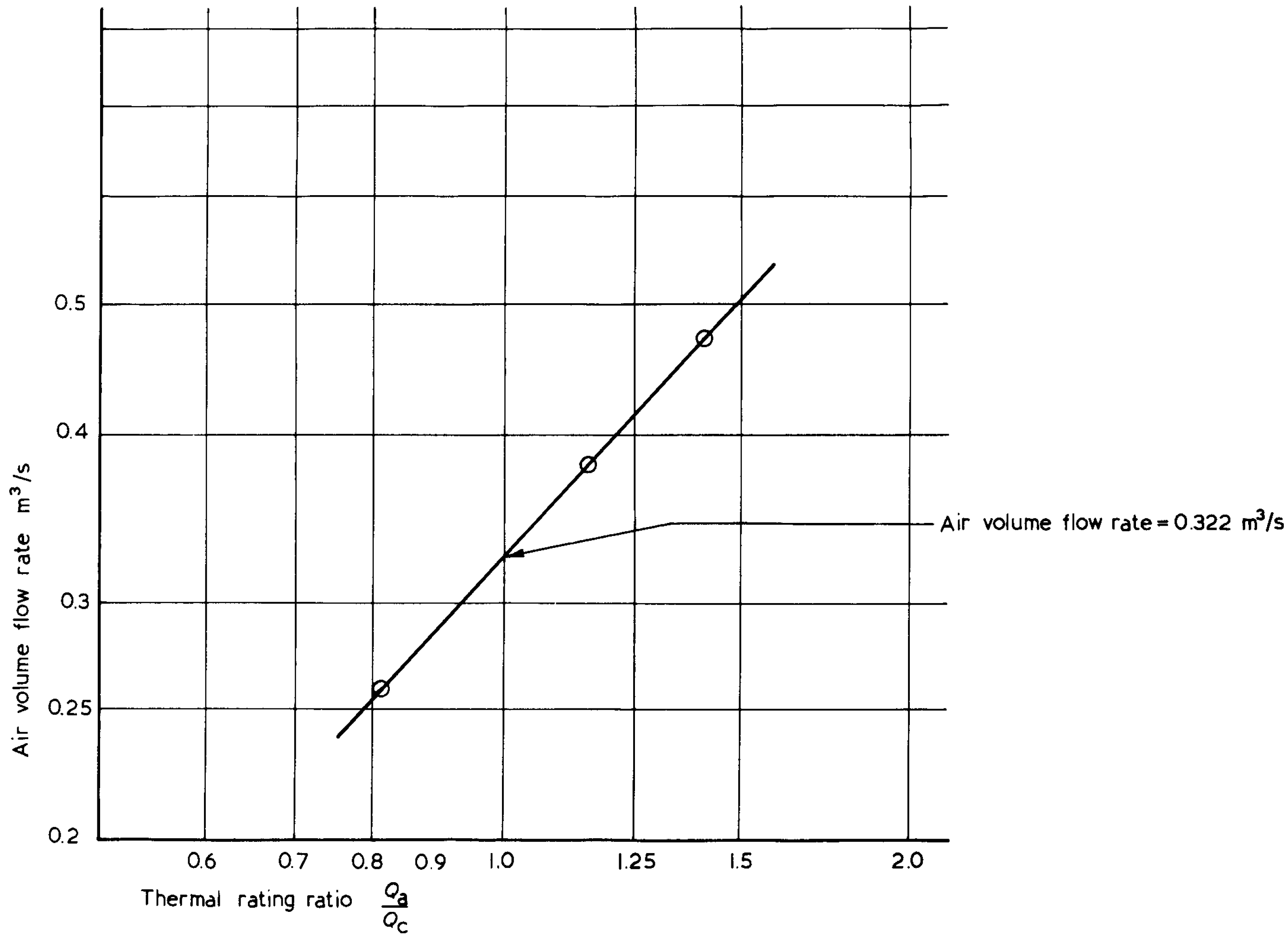


Figure 12 — Determination of air volume flow rate

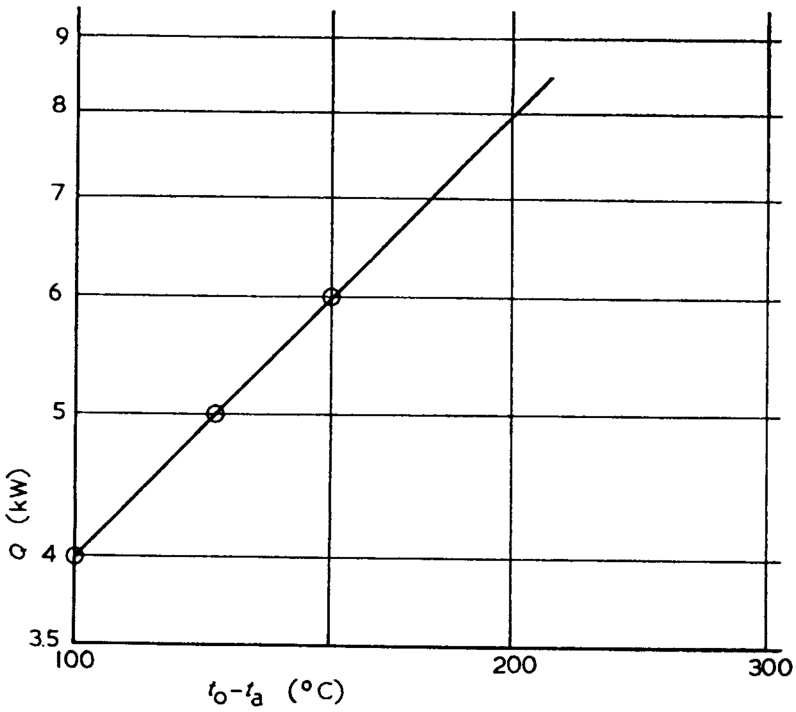


Figure 13a — Thermal output

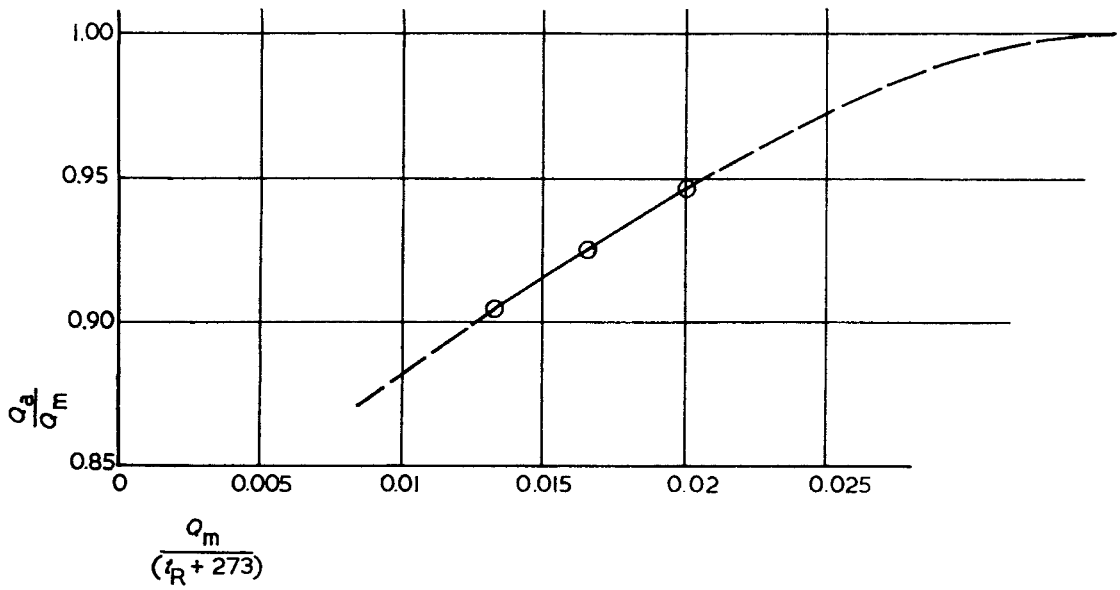


Figure 13b — Recirculation correction curve

Figure 13 — Rating example

$$K_w = \frac{\Delta p_m}{\Delta p_c} = \frac{\text{Measured pressure drop}}{\text{Pressure drop at 80°C}}$$

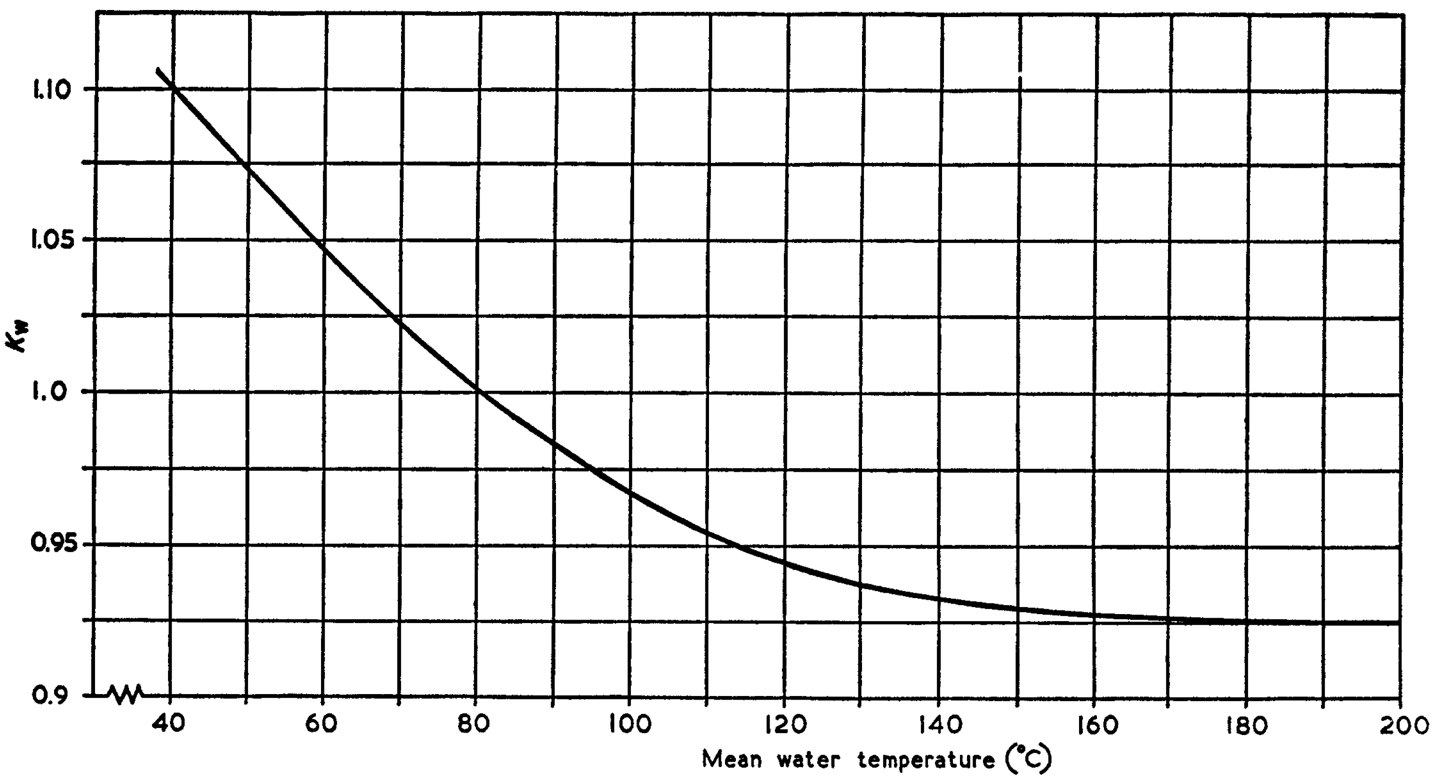


Figure 14 — Water temperature correction factor

Publications referred to

This standard makes reference to the following British Standards:
BS 593, *Laboratory thermometers*.
BS 1041, *Code for temperature measurement*.
BS 1041-2, *Expansion thermometers*.
BS 1041-3, *Industrial resistance thermometry*.
BS 1041-4, *Thermocouples*.
BS 1042, *Methods for the measurement of fluid flow in pipes*.
BS 1042-1, *Orifice plates, nozzles and venturi tubes*.
BS 1780, *Bourdon tube pressure and vacuum gauges*.

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