BRITISH STANDARD

BS 4954-1:
1973

Methods for

Testing and rating induction units for air distribution systems —

Part 1: Thermal and aerodynamic performance

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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 Gas Corporation
British Mechanical Engineering Confederation
British Oil and Gas Firing Equipment Manufacturers' Association
British Refrigeration and Air Conditioning Association*
Department of the Environment
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Electricity Council, The Central Electricity Generating Board and the Area Boards in England and Wales
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Society of British Gas Industries
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 Establishment
Greater London Council
Oil Appliance Manufacturers' Association
Steel Radiator and Convector Manufacturers' Association
Unit Heater Manufacturers' Association

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Contents

Foreword

Part 1 of this British Standard has been prepared under the authority of the Refrigeration, Heating and Air Conditioning Industry Standards Committee, to meet the needs expressed by industry. Part 2, dealing with acoustic testing and rating of induction units, will be published later.

The Committee acknowledge their debt to the Heating and Ventilating Research Association for the Association's work in formulating the methods of testing which appear in this Part of the standard. This work was carried out under a Department of Trade and Industry contract.

The test methods enable the thermal and aerodynamic performance of an induction unit to be evaluated at any water and air flow rate and temperature within the range of the variables employed for the test.

The aerodynamic test methods deal with four aspects of a unit's performance:

1) The pressure loss of the primary air supply.

2) The relationship between the primary air flow rate and the nozzle pressure. Since the inlet velocity profile effects will be small, the data obtained in this test may be used by a site engineer to assist him in balancing an air distribution system.

3) The inlet plenum leakage flow rate.

4) The induction ratio.

Two heat transfer test methods are given, one for operation over a limited range of temperatures and the other for a wider range of temperatures.

Examples of calculations from the test data are included.

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 26, 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 British Standard specifies methods of test for induction units with water coils for either (or both) heating and sensible cooling duties. It gives instructions for the calculation, interpretation and interpolation of the test results for the thermal and aerodynamic rating of the units.

NOTE The titles of the British Standards referred to in this Part of this standard are shown on page 26.

2 Definitions

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

2.1
induction unit

an assembly in which the treated primary air, received under pressure from a central plant, is discharged at high velocity through a series of nozzles fitted within the unit. This high velocity discharge causes an induction process, inside the unit, and thus an inflow of secondary air from the treated space into the unit. Some or all of the induced secondary air entering the unit may pass through a heat exchanger. The induced secondary air then mixes with the primary air and is discharged into the treated space

2.2
primary air

conditioned air fed to the nozzles in an induction unit

2.3
secondary air

air from the space being conditioned which is induced into the unit by the action of the primary air ejected from the nozzles. The secondary air generally passes through a heat exchanger

2.4
nozzle

a device so designed as to give low energy loss and thus produce a maximum throw by minimum entrainment

2.5
unitary type induction unit

this type of induction unit is a discrete device, but several may be grouped and linked together by their primary air supply ducting

2.6
modular (continuous) type induction unit

this type of induction unit consists of a series of sections, modular in length, so designed as to enable them to be connected together to form a single unit completely filling the wall space allocated

2.7
reference nozzle

this is one of the primary air supply nozzles which is selected as a reference nozzle for the purpose of comparing primary air pressures at different times during the test procedure

2.8
reference air

atmospheric air having a density of 1.2 kg/m^3 at a temperature of 20 °C, a pressure of 101 325 N/m^2, and 43 % relative humidity

3 Nomenclature

Symbol	Definition	Units
A_p	Area of primary air supply duct	m^2
A_t	Area of water supply tube	m^2
c_{pw}	Specific heat capacity of water	kJ/kg K
H_D	Hydraulic diameter (= 4 × area/perimeter)	m

Symbol	Definition	Units
K_W	Hydraulic pressure drop temperature correction factor	—
m	Water mass flow rate	kg/s
p_b	Barometric pressure	N/m^2
p_F	Static pressure upstream of flowmeter	N/m^2
p_i	Static pressure at primary air inlet	N/m^2
p_{ir}	Static pressure at primary air corrected to reference conditions	N/m^2
p_T	Total pressure	N/m^2
p_R	Pressure at reference total pressure tube	N/m^2
Δp_c	Coil hydraulic pressure drop corrected for height	N/m^2
Δp_{ct}	Coil hydraulic pressure drop at reference temperature of 10 °C (cooling), 80 °C (heating)	N/m^2
Δp_F	Pressure drop across air flowmeter	N/m^2
Q_a	Heat transferred under free delivery	kW
Q_c	Heat transferred with unit connected to air flow chamber	kW
ρ	Air density	kg/m^3
ρ_F	Air density at flowmeter	kg/m^3
ρ_w	Water density	kg/m^3
t_a	Secondary air inlet temperature	°C
t_i	Primary air inlet temperature	°C
t_F	Air temperature at flowmeter	°C
t_{wi}	Inlet water temperature	°C
t_{wo}	Outlet water temperature	°C
V_p	Primary air volume flow rate	m^3/s
V_F	Primary air volume flow rate at flowmeter	m^3/s
V_s	Secondary air volume flow rate	m^3/s
V_T	Total ($V_p + V_s$) air volume flow rate	m^3/s

The suffix r is used to denote reference conditions. A bar over the symbol indicates the mean of several test results.

4 Instrumentation

4.1 Temperature

4.1.1 The measurement of temperature shall be by means of mercury-in-glass thermometers, resistance thermometers or thermocouple and potentiometer. Temperature measuring instruments shall comply with the requirements of BS 1041.

4.1.2 The water temperature at entry and exit shall be measured by means of instruments inserted in oil-filled pockets similar to those shown in Figure 1. If mercury-in-glass thermometers are used they shall comply with the requirements of BS 593, partial immersion ranges, and shall be graduated in intervals not exceeding 0.1 °C.

4.1.3 All temperature measuring instruments shall be calibrated against a reference thermometer accurate to 0.05 °C, which has been calibrated by NPL or another approved authority.

4.1.4 Air temperature measuring instruments shall be shielded against radiation by means of shields similar to those shown in Figure 2.

4.2 Water flow measurement

4.2.1 The measurement of water flow shall be preferably by means of direct weighing, (for water temperatures above 90 °C it is advantageous to use one of the methods described in BS 1042). The water leaving the test rig shall be collected in vessels of known weight, and weighed on a weighing machine, having an accuracy of 0.1 % over the range of weights used in the test. The weight of each vessel used shall not exceed 50 % of the weight of its normal contents. Precautions shall be taken to minimize evaporation from the vessels awaiting weighing. The net weight of each charge shall be recorded by weighing the vessel both after emptying the previous charge and after filling.

4.2.2 The above method is suitable for water exit temperatures up to about 90 °C using the arrangement of equipment shown in Figure 3. For higher water exit temperatures it may be necessary to cool the water leaving the unit before it is discharged into the measuring vessel. Care shall be taken to check any after-cooler for leaks.

4.2.3 An alternative to the method of direct weighing described in **4.2.1** is shown in Figure 4, together with a suitable water supply system for water temperature above 90 °C.

4.3 Air flow measurement

4.3.1 Air flow measurement shall be in accordance with BS 1042-1, or alternatively a flowmeter may be calibrated in situ using the methods given in BS 1042-2[1)].

4.3.2 Leakage flow rates may be measured by means of a calibrated variable area flowmeter or integrating air flowmeter.

4.4 Pressure measurement

4.4.1 Wall static pressures shall be measured with static taps conforming to the requirements specified in BS 1042-2[1)].

4.4.2 Pressures shall be measured by means of an instrument with scale intervals no greater than 2 % of the indicated reading with the exception of pressures below 50 N/m^2, in which case the maximum interval shall be to 1 N/m^2.

4.4.3 Static pressures shall be measured with liquid-filled manometers. An inverted U-tube manometer, similar to that shown in Figure 5 shall be used for the measurement of hydraulic pressure drop.

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

5 Test for total pressure loss of primary air supply

5.1 A test duct of cross-sectional dimensions equal to the nominal dimensions of the primary air inlet, and of minimum length six hydraulic diameters (H_D), shall be connected to the primary air inlet.

NOTE If the inlet is not of circular or rectangular cross section a transition section of minimum length 2 H_D and of constant area may be connected between the primary air inlet and the test duct.

5.2 A flow straightener shall be located at the upstream termination of the test duct. A wire mesh screen (having a free area from 60 % to 70 %) shall be located two test duct hydraulic diameters downstream of the flow straightener. A ring of four static pressure taps shall be fitted at a point two test duct hydraulic diameters from the downstream termination of the test duct. The test duct shall be connected to an air supply system arranged similarly to the system shown in Figure 6. The supply air temperature is to be measured at the flowmeter and on the test duct centre-line one test duct hydraulic diameter upstream of the pressure taps.

5.3 The test shall be carried out and results analysed in the following way:

1) Set the primary air flow damper (if fitted) fully open.

2) Start the air supply fan and set the air flow rate to the desired level. The results may be recorded when the supply air flow rate has not varied by more than 2 % over a period of five minutes and the air inlet temperature has not varied by more than 2 °C over a similar period.

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1) In course of preparation.

3) The following data shall be recorded:

p_b	Barometric pressure	(N/m²)
p_F	Static pressure upstream of the flowmeter	(N/m²)
Δp_F	Pressure drop across the flowmeter	(N/m²)
p_i	Static pressure at the primary air inlet	(N/m²)
t_F	Air temperature at the flowmeter	(°C)
t_i	Primary air inlet temperature	(°C)

4) Calculate the inlet static pressure for the reference air density of 1.2 kg/m³ from the equation:

$$p_{ir} = \frac{p_i \ \rho_r}{\rho_i}$$

where:

p_{ir} is the inlet static pressure corrected to reference conditions (N/m²)

ρ_i is the inlet air density, at $(p_b + p_i)$ and at t_i

$$\rho_i = \frac{293 \ (p_b + p_i) \ 1.2}{(273 + t_i) \ 101\ 325} \quad \text{(kg/m}^3\text{)}$$

5) Calculate the air flow rate for the reference air density of 1.2 kg/m³ from the equation:

$$V_{pr} = \frac{V_F \ \rho_F}{\rho_r}$$

where:

V_{pr} is the primary air flow rate corrected to reference conditions (m³/s)

V_F is the air flow rate measured at the flowmeter (m³/s)

ρ_F is the air density measured at the flowmeter, at $(p_b + p_F)$ and at t_F (kg/m³)

$$\rho_F = \frac{293 \ (p_b + p_F) \ 1.2}{(273 + t_F) \ 101\ 325} \quad \text{(kg/m}^3\text{)}$$

6) Calculate the total pressure loss from the equation:

$$p_T = p_{ir} + \frac{(V_{pr})^2 \ \rho_r}{2 \ A_p^{\ 2}}$$

where:

A_p is the area of primary air supply duct (m²)

6 Test for the relationship between primary air flow rate and nozzle pressure

The balancing of an induction unit system is usually carried out by estimating the primary air flow rate from the total pressure measured at a reference nozzle. If this test is to be of value the reference nozzle must be clearly marked, and a total head tube of sufficient size connected to the reference nozzle.

6.1 The unit under test shall be connected to the air supply system described in Clause **5**.

6.2 One of the primary air supply nozzles shall be selected as a reference nozzle and a total head tube (in this case a length of straight tube will be suitable) fitted tightly into its neck.

6.3 The primary air flow damper shall be set fully open and when the steady state conditions given in **5.3** have been obtained the following data shall be recorded:

p_b	Barometric pressure	(N/m²)
p_F	Static pressure upstream of the flowmeter	(N/m²)
Δp_F	Flowmeter pressure drop	(N/m²)
p_R	Pressure measured by the total pressure tube	(N/m²)

6.4 The measured air flow rate shall be corrected to that at the reference density of 1.2 kg/m³ by the equation:

$$V_{pr} = \frac{V_F \, \rho_F}{\rho_r} = \frac{V_F \, \rho_F}{1.2}$$

7 Test for inlet plenum leakage

7.1 All primary flow nozzles shall be blanked off, the primary air flow damper set fully open and the unit connected to an air supply system similar to that shown in Figure 7.

7.2 The supply pressure shall be increased to the maximum recommended pressure, this pressure shall be held for a minimum period of 15 min and then rapidly reduced to zero. The supply pressure shall then be increased to the maximum recommended pressure and held at this pressure for a further 15 min at the end of which the air flow rate shall be read and recorded as the inlet plenum leakage rate at the test pressure.

NOTE If an integrating flowmeter is employed measurement may commence ten minutes after the second pressurization.

8 Heat transfer measurements

8.1 Test facility

8.1.1 The unit shall be tested with a minimum clear distance (m) in the direction of discharge of either 3m or $5\sqrt{A}$ [where A is the unit outlet area (m2)], whichever is the greater.

8.1.2 Units designed for mounting on, 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 appliance, and to a minimum height of 2.5 m. Insulating material with a thermal conductivity not exceeding 1W/m K and of 10 mm minimum thickness shall be used between the appliance and any adjacent surfaces.

8.1.3 If a unit is of modular construction and designed such that unlimited runs may be used then a minimum length of 2 m shall be tested between side walls. These side walls shall extend to a minimum height of 2.5 m and to a minimum distance of 2 m in front of the unit.

8.1.4 Units designed to be used in a specific situation shall be tested under conditions reflecting this situation.

8.1.5 The test shall take place in a space where vertical and horizontal temperature gradients do not exceed 0.5 °C/m.

8.2 Inlet air temperature measurement

8.2.1 The inlet air temperature shall be measured at the stations indicated in Figure 8.

8.2.2 The inlet air temperature shall be either:

1) The mean of the measured temperatures in the case of the bounded unit shown in Figure 8a.

2) For unbounded units the traverse path shown in Figure 8a shall be used. The mean of all temperatures within 1 °C of the lowest (heating) or 1 °C of the highest (cooling) shall be taken. If more than one quarter of the temperatures recorded are greater (less than) 1 °C above (below) the lowest (highest) for heating (cooling), then the length of the temperature traverse lines shall be doubled with a corresponding increase in the number of measuring stations. If at least half of the measured temperatures are within 1 °C of the lowest (heating) or highest (cooling) then the mean of the sample within this limit shall be taken as the mean inlet air temperature.

8.2.3 If the above conditions cannot be met then the test area shall be increased until satisfactory conditions are achieved.

8.3 Heat transfer apparatus

8.3.1 There shall be available a means for providing and controlling a continuous supply of water at any temperature and flow rate that may be required for the test.

8.3.2 The apparatus shall be arranged generally as in Figure 3 and Figure 4 depending upon the fluid temperature.

8.3.3 The pipework shall be arranged to give an unobstructed straight run at entry and exit from the unit under test, the pipe diameter being equal to that demanded by the unit connections and of length equal to five pipe diameters. The thermometer pockets being positioned such that the water flow is upwards towards the thermometer.

8.3.4 Hydraulic resistance side wall tappings shall be fitted adjacent to the connections to the unit. These tappings shall be as specified in Figure 5a and connected to form a piezometric ring. The hydraulic pressure drop shall be measured by means of an inverted U-tube manometer similar to that shown in Figure 5b.

8.3.5 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 K.

8.4 General test instructions

8.4.1 The primary air inlet temperature and secondary air inlet temperature shall be in the range 15 °C to 25 °C.

8.4.2 Cooling tests are for sensible heat transfer only and the inlet water temperature shall not be less than the inlet air dew point temperature.

8.4.3 Before commencing the test the following operations shall be carried out:

1) Bleed the water system to remove all air.

2) Start the air supply system and set to the desired flow rate.

3) Circulate the water through the coil and regulate the flow and temperature to those desired for the test.

4) Record the barometric pressure.

8.4.4 The test shall be carried out under steady state conditions, and these shall be said to exist when the following measurements do not vary over a period of 30 minutes by more than the specified amount from their mean value.

1)	Inlet air temperature (t_a)	± 0.5 °C ± 1.0 °C	(cooling) (heating)
2)	Inlet water temperature (t_{wi})	± 0.5 °C ± 1.0 °C	(cooling) (heating)
3)	Water flow rate (m)	± 2 %	
4)	Primary air flow rate (V)	± 2 %	

8.4.5 The test shall not occupy less than 30 min and complete sets of readings (t_a, t_{wi}, t_{wo}, m, V) shall be taken at intervals not greater than ten minutes and successive readings shall not vary by more than the amount specified for steady state conditions in **8.4.4**.

8.4.6 The hydraulic pressure drop shall be measured during the test period.

8.5 Calculations

8.5.1 *Heat transferred.* The heat transferred shall be calculated from the equation:

$$Q_a = c_{pw}\bar{m}\,(\bar{t}_{wi} + \bar{t}_{wo})$$

where:

Q_a is the heat transferred (kW)

c_{pw} is the specific heat capacity of the water at the mean water temperature $\frac{(\bar{t}_{wi} + \bar{t}_{wo})}{2}$ (kJ/kg K)

$\bar{t}_{wi}$ is the mean inlet water temperature (mean of measurement in test period) (°C)

$\bar{t}_{wo}$ is the mean outlet water temperature (mean of measurements in test period) (°C)

$\bar{m}$ is the mean water mass flow rate (mean of measurements in test period) (kg/s) (computed from flowmeter readings or by the total mass flow of water during the test period, divided by the duration of the test)

8.5.2 *Primary air flow rate.* The air flow rate shall be computed from the air flowmeter drop, temperature, static pressure, and barometric pressure and converted to the flow rate at reference conditions by the equation:

$$V_{pr} = \frac{V_F \rho_F}{\rho_r}$$

8.5.3 *Hydraulic pressure drop.* The hydraulic pressure drop shall be corrected for any head difference between the inlet and outlet pressure taps and then converted to the drop at:

10 °C for cooling duty

80 °C for heating duty

by means of the equation:

$\Delta p_{ct} = \Delta p_c / K_w$

where:

Δp_c is the hydraulic pressure drop corrected for head difference (N/m^2)

K_w is the hydraulic pressure drop correction coefficient as obtained from Figure 13a or Figure 13b

9 Secondary air flow measurement

9.1 The unit under test shall be connected to a chamber similar to that shown in Figure 9. The cross-sectional area of the chamber shall be such that the mean chamber velocity is not greater than 40 % of the mean discharge velocity from the unit outlet. The chamber volume shall be such that at the maximum unit air flow the number of air changes is less than 1.5 per second. The flowmeter and fan shall be connected to the chamber as shown in Figure 9.

9.2 The primary air supply system described in Clause **5** shall be connected to the primary air supply inlet and the necessary heat transfer equipment connected to the unit coil.

9.3 The chamber and the junction between the chamber and the appliance shall be carefully sealed against leaks.

9.4 All primary air flow measurements shall be carried out using the techniques described in Clause **5**. The flowmeter pressure drop, static pressure and temperature shall be recorded at the beginning and end of the test. The primary air flow rate shall not vary by more than 2 % during the test.

9.5 The air inlet temperature shall be measured in accordance with **8.2**.

9.6 The desired unit primary air flow rate shall be selected and water temperature and flow rate set for a duty in the centre of the normal recommended working range.

9.7 The static pressure in the chamber shall be set to zero by means of the auxiliary fan connected to the chamber and the instructions described in **8.4** carried out.

9.8 1) The thermal output (Q_c) of the appliance shall be calculated using the methods described in **8.5**.

2) The pressure drop across the chamber air flowmeter shall be recorded at three equally spaced time intervals during the test and the mean value used to compute the air flow rate.

3) The temperature at the chamber air flowmeter shall be recorded at similar intervals to all other temperature measurements and the mean value computed.

4) The barometric pressure shall also be recorded.

5) The air volume flow rate shall be converted to the flow under reference conditions by the equation:

$V_{Tr} = V_T \rho_{FC} / \rho_r$

where:

V_{Tr} is the chamber air volume flow rate at reference temperature and pressure (m^3/s)

V_T is the chamber air volume flow rate measured (m^3/s)

ρ_{FC} is the air density at conditions measured at the chamber air flowmeter (kg/m^3)

9.9 The thermal output (Q_a) that would have been obtained with the appliance delivering air to an open space shall be calculated from the heat transfer measurements under free delivery. This output shall be divided by the thermal output (Q_c) obtained under **9.8** above. If the thermal rating ratio (Q_a/Q_c) is between 0.97 and 1.03 then the measured air flow rate (converted to reference conditions) may be taken to be the total appliance air volume flow rate. If the thermal rating ratio is outside these limits then further tests shall be carried out as described below.

9.10 if the thermal rating ratio (Q_a/Q_c) is less than unity, the auxiliary fan shall be set to increase the chamber static pressure to approximately 5 N/m², otherwise a chamber static pressure of – 5 N/m² shall be set. A minimum of three chamber static pressures shall be selected, the third being chosen such that the test results fall either side of a thermal rating ratio of unity. The procedure described in **9.5** to **9.9** shall be followed for each new value of chamber static pressure. Care shall be taken to ensure that the primary air flow rate is held constant.

9.11 The total air volume flow rate V_{Tr} shall be determined from the plot of thermal rating ratio against air volume flow, as shown in Figure 10.

9.12 The secondary air flow rate shall be calculated from the equation:

$$V_{sr} = V_{Tr} - V_{pr}$$

where:

V_{sr}	is the secondary air flow rate corrected to reference conditions	(m³/s)
V_{Tr}	is the total chamber air volume flow rate corrected to reference conditions	(m³/s)
V_{pr}	is the primary air flow rate corrected to reference conditions	(m³/s)

10 Interpretation of test results and rating

The test results shall only be applied to the particular configuration of any variable geometrical and constructional items employed in the test, i.e. if different nozzle arrangements are offered then each arrangement shall be tested. If a unit is equipped with separate heating and cooling coils and a proportioning damper to control the secondary air flow, thermal tests shall be carried out under full heating and full cooling conditions. The bypassed coil shall be supplied with water at a mean temperature and flow rate.

10.1 Total pressure loss of primary air supply. The test described under Clause **5** shall be carried out at a minimum of five equally spaced primary air flow rates. The total pressure loss shall be plotted against the corrected primary air flow rate on logarithmic graph paper and the best straight line drawn through the test points. Results may be extrapolated to 10 % beyond the maximum and minimum air flow rates employed.

10.2 The relationship between primary air flow rate and nozzle pressure. The test described under Clause **6** shall be carried out at a minimum of five primary air flow rates equally spread throughout the flow range, and the nozzle pressure plotted against the corrected primary air flow rate on logarithmic graph paper. The best straight line shall be drawn through the test points. Results may be extrapolated to 10 % beyond the maximum and minimum air flow rates employed.

10.3 Inlet plenum leakage. The inlet plenum leakage, determined from the test described in Clause **7** shall be reported as:

X (m³/s) at an inlet static pressure of Y (N/m²)

10.4 Thermal rating. Both heating and sensible cooling test shall be analysed similarly. Two rating methods are described; the simplified test series will in general be applied only to cooling duties although under some circumstances it will be applicable to heating duties. It will be seen that temperature differences are given for heating. The water-air temperature difference should be reversed when cooling duties are considered. The tests will enable the thermal performance of the unit to be determined at any primary air and water flow rate and temperature within and to 10 % outside the range of the test measurements. The error involved in the test method, interpolations, and extrapolations is unlikely to exceed 5 %.

10.4.1 ***Simplified test series***

10.4.1.1 This simplified method may be employed for rating under conditions where the difference between the inlet water and air temperature is restricted to a range of 20 °C (e.g. from say 50 °C to 70 °C). The following tests shall be carried out:

Test series	Water flow rate m	Primary air flow rate V_p	Inlet temperature difference $(t_{wi} - t_a)$
	kg/s	m^3/s	°C
1	set near bottom range	near top of range	three different, evenly spread
2	top and middle of range	near top of range	near middle of range
3	middle, top and bottom of range	near middle of range	near middle of range
4	middle, top and bottom of range	near bottom of range	near middle of range

Top and bottom of range shall be taken to mean within 10 % of the top and bottom, near middle of range shall be taken to be within 20 % of the mid point of the range. Air and water flow rates employed for top, bottom and middle of range shall be the same for each test to within 1 % of the original values used.

10.4.1.2 The following graphs shall be plotted on logarithmic graph paper as shown in Figure 11.

1) From test series 1 (see **10.4.1.1**) draw line 1 [Q_a versus $(t_{wi} - t_a)$], the best straight line through the test points. No point shall be more than 2 % of Q from this line. If a greater deviation is found then this method may not be used and the full test method as described in **10.4.2** shall be employed.

2) From tests 2, 3 and 4 complete the set of curves A by plotting the measured Q_a versus $(\bar{t}_{wi} - \bar{t}_a)$ and drawing lines parallel to line 1 through the test points.

3) Select a value of $(\bar{t}_{wi} - \bar{t}_a)$ at the centre of the test range (15 °C from the example in Figure 11) and using the values of Q_a where lines A intercept this constant temperature line carry out the cross plots for curves B and C. (Variation of heat transferred with water and air flow rates respectively at a constant temperature differential). Using these sets of curves it will be possible to determine the performance of the unit within the range of the test data.

10.4.2 *Full test series.* Similar plots to those described in **10.4.1** shall be obtained from the following tests:

Test series	Water flow rate, m	Primary air flow rate, V_p	Inlet temperature difference, $(\bar{t}_{wi} - \bar{t}_a)$
	kg/s	m^3/s	°C
1	near top of range	near top of range	bottom, middle and top range
2	near top of range	near middle of range	bottom, middle and top range
3	near top of range	near bottom of range	bottom, middle and top range
4	near middle of range	near top of range	bottom, middle and top range
5	near middle of range	near middle of range	bottom, middle and top range
6	near middle of range	near bottom range	bottom, middle and top range
7	near bottom of range	near top of range	bottom, middle and top range
8	near bottom of range	near middle of range	bottom, middle and top range
9	near bottom of range	near bottom of range	bottom, middle and top range

The best straight line shall be drawn through each set of points and if any point is more than 2 % Q_a from this line a further two tests at two different values of $(\bar{t}_{wi} - \bar{t}_a)$ shall be carried out to determine whether or not the characteristics are adequately represented by straight lines.

10.5 Hydraulic pressure drop. The corrected hydraulic pressure drop (Δp_{ct}, determined as described in **8.5.3**) shall be plotted against water mass flow rate ($\overline{m}$) on logarithmic graph paper. This plot shall be used for the determination of the hydraulic pressure drop at water flow rates other than those employed in the test.

10.6 Secondary air flow rate

10.6.1 The test described in Clause **9** shall be carried out at the three primary air flow rates equal (to within 1 %) to those employed in the thermal rating tests (see **10.4**). The secondary air flow rates so determined shall be plotted against primary air flow rate on logarithmic graph paper.

10.6.2 The induction ratio (V_{sr}/V_{pr}) shall be plotted against primary air flow rate on logarithmic graph paper.

10.6.3 The two curves described in the above clauses shall be used for the determination of secondary air flow rate and induction ratio at primary air flow rates other than those employed in the test.

11 Thermal rating examples

11.1 Performance calculation at given inlet conditions. It is required to produce heat transfer data for the unit with the characteristics shown in Figure 11 at the following inlet conditions:

Primary air volume flow rate:	0.2, 0.25, 0.3 m³/s
Water mass flow rate:	0.05 kg/s at 40 °C
Water mass flow rate:	0.07 kg/s at 30 °C
Inlet air temperature	20 °C

From curves B and C in Figure 11 it is possible to draw the cross plots D and E shown in Figure 12. The basic rating at an inlet water-air temperature difference of 15 °C can now be obtained from these curves. Because of the errors involved in interpolations the basic rating from both sets shall be used (as shown in the table in Figure 12) and a mean basic rating calculated.

Line 1 from curves A is then plotted and the mean basic rating plotted on the 15 °C temperature difference line. Lines (curves F in Figure 12) are drawn parallel to line 1 through the mean basic rating and the heat transfer determined from the interception of the inlet water-air temperature difference with these lines. Thus the rating of the unit under the prescribed conditions is:

Primary air volume flow rate	Water flow rate	Inlet water temperature	Heat transferred
m³/s	kg/s	°C	kW
0.2	0.05	40	2.9
0.25	0.05	40	3.1
0.3	0.05	40	3.4
0.2	0.07	30	1.6
0.25	0.07	30	1.78
0.3	0.07	30	1.9

11.2 Calculation of the suitability of a unit for a particular duty. It is required to check if an induction unit with the characteristics shown in Figure 11 will be suitable for a heating duty of 3.6 kW with a primary air flow rate of 0.3 m³/s, an inlet air temperature of 15 °C, inlet water temperature of 33 °C, and a water flow rate of 0.07 kg/s.

The necessary cross plots have already been carried out for the example in **11.1** and are shown in Figure 12. The required heat transfer is 3.6 kW, and it can be seen in Figure 12 that for an inlet air-water differential of 18 °C and $m = 0.07$, $V = 0.3$ the thermal output will be 3.52 kW, which is within 5 % of the required output and consequently the unit is suitable for this duty.

11.3 Calculation of rating using wide range data from the full test series. The calculation procedures are similar to those described in the examples in **11.1** and **11.2** for the restricted range test, but because of the possibility of non-linearity in the temperature-heat transfer characteristics cross plots shall be carried out at the required temperature differences, primary air and water flow rates. Complementary plots shall be used and mean values determined, for instance the heat transferred at a given inlet temperature differential may be obtained from a cross plot of Q_a versus water flow at constant air flow rate, and Q_a versus air flow at a constant water flow rate.

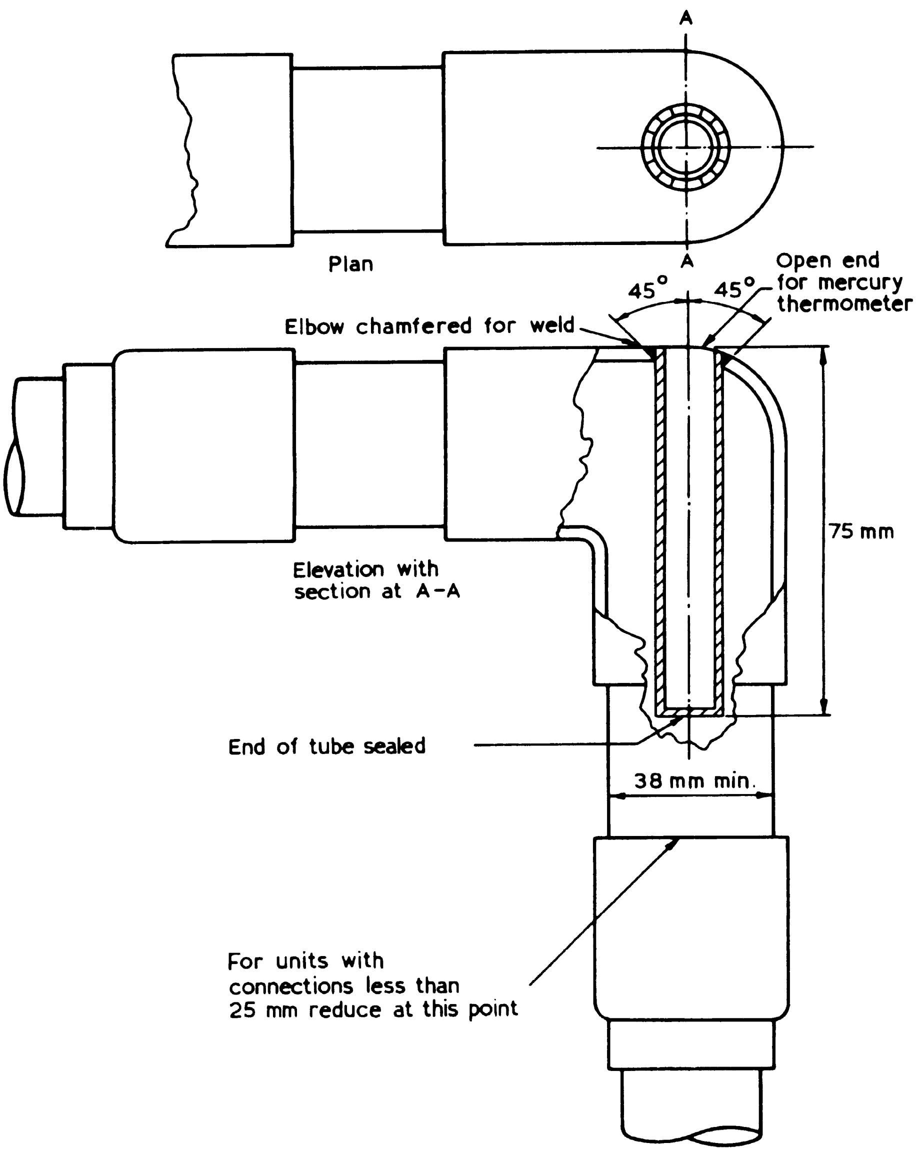


Figure 1 — Thermometer pockets in pipes of less than 75 mm diameter

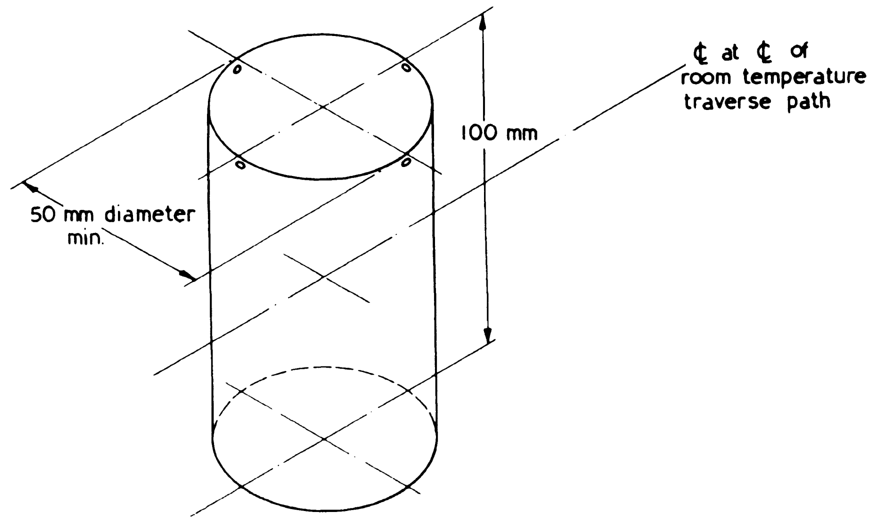


Figure 2a — Thermometer shield

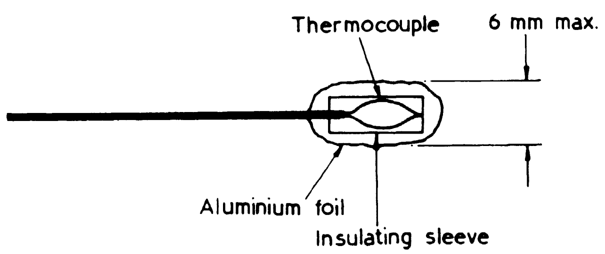
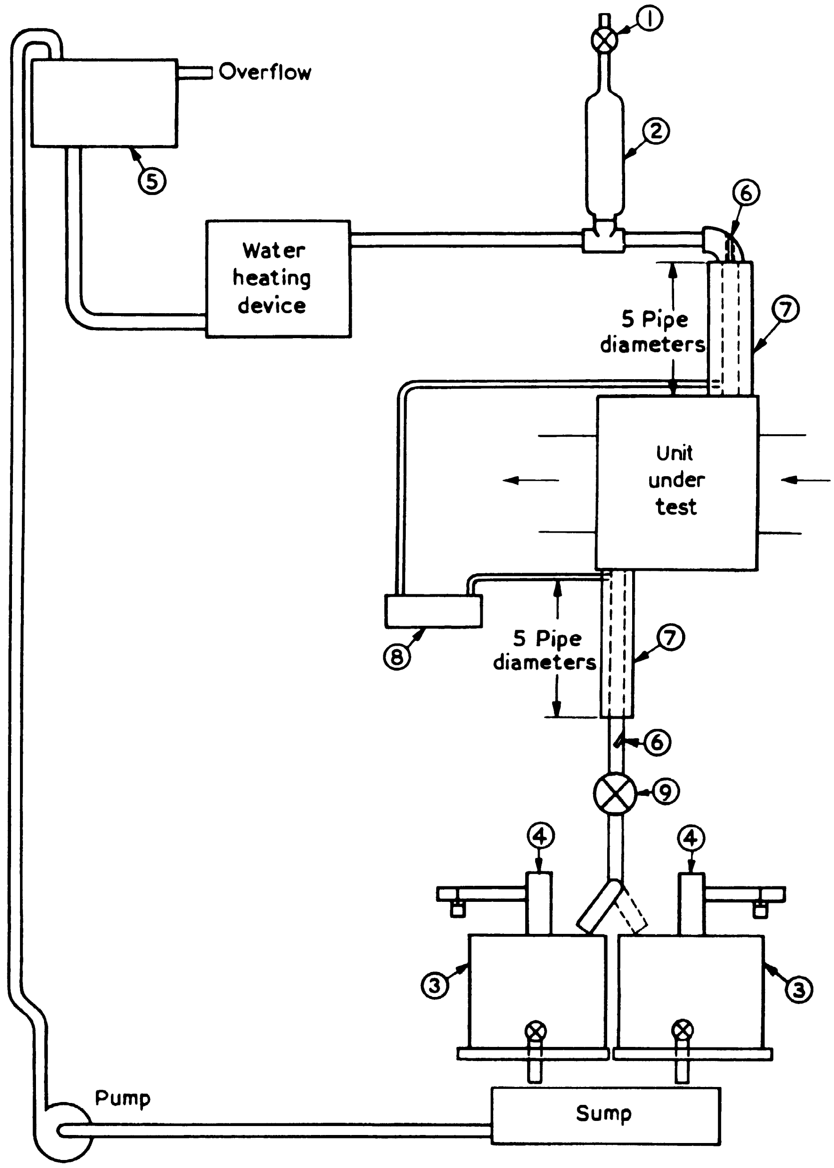
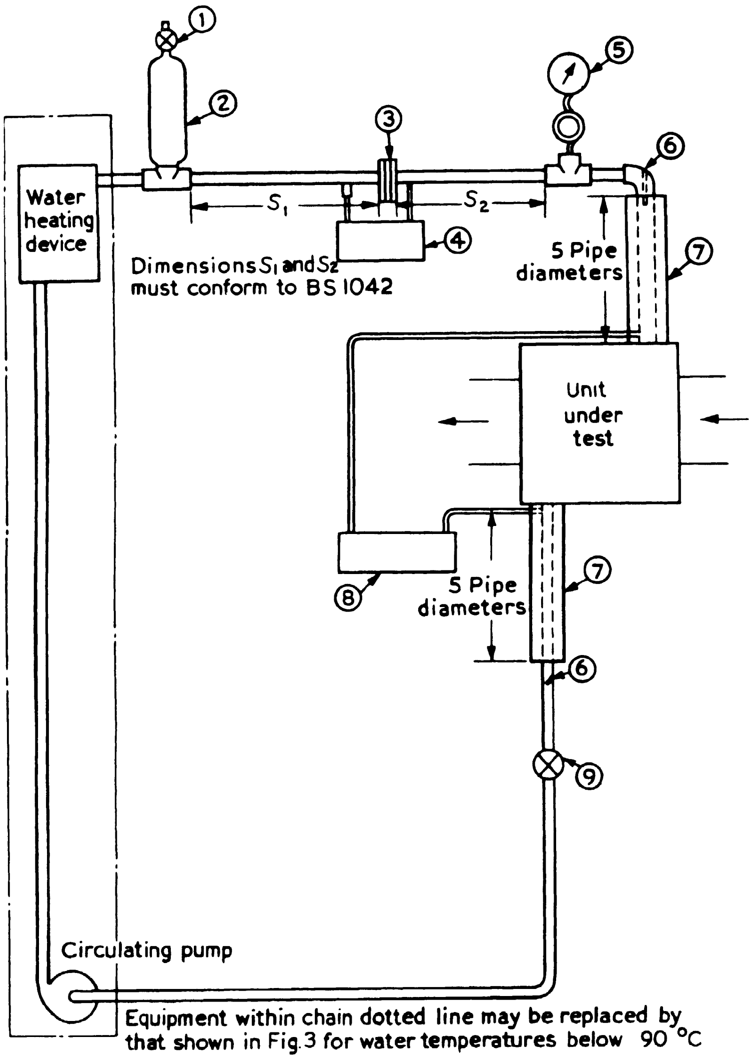


Figure 2b — Thermocouple shield



Key
1. Air cock
2. Air receiver
3. Water container
4. Beam type weighing machine
5. Constant level tank
6. Thermometer pocket
7. Insulated unobstructed section of pipe
8. Manometer
9. Flow regulating valve

Figure 3 — Typical open circuit test equipment



Key

1. Air cock
2. Air receiver
3. Water flow meter
4. Manometer
5. Pressure gauge (optional)
6. Thermometer pocket
7. Insulated length
8. Manometer
9. Flow control valve

Figure 4 — Typical closed circuit test equipment

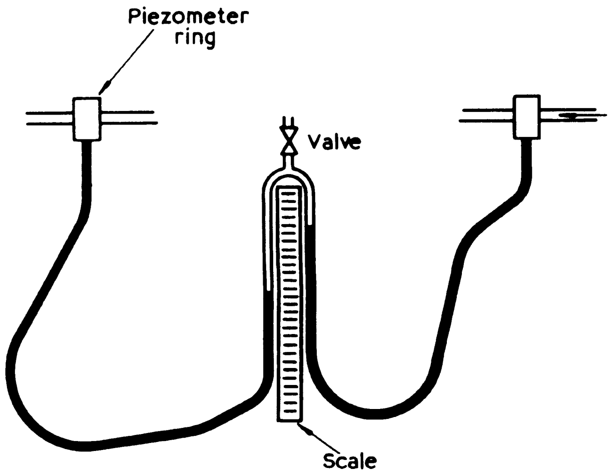
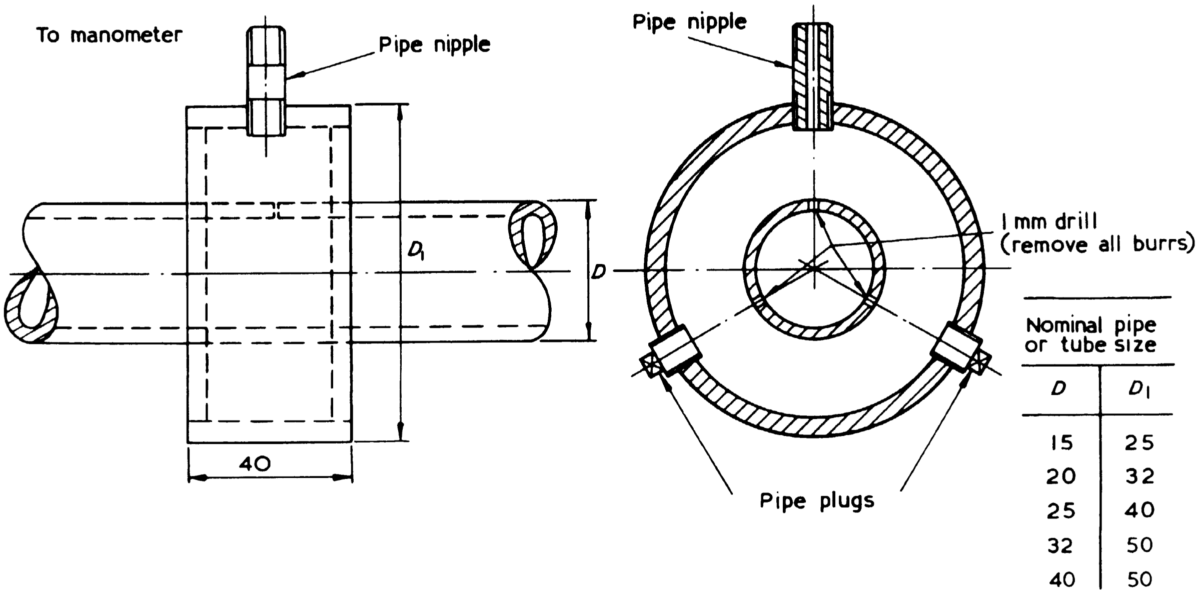


Figure 5a — Inverted tube pattern manometer



Nominal pipe or tube size	
D	D_1
15	25
20	32
25	40
32	50
40	50

Figure 5b — Piezometer ring

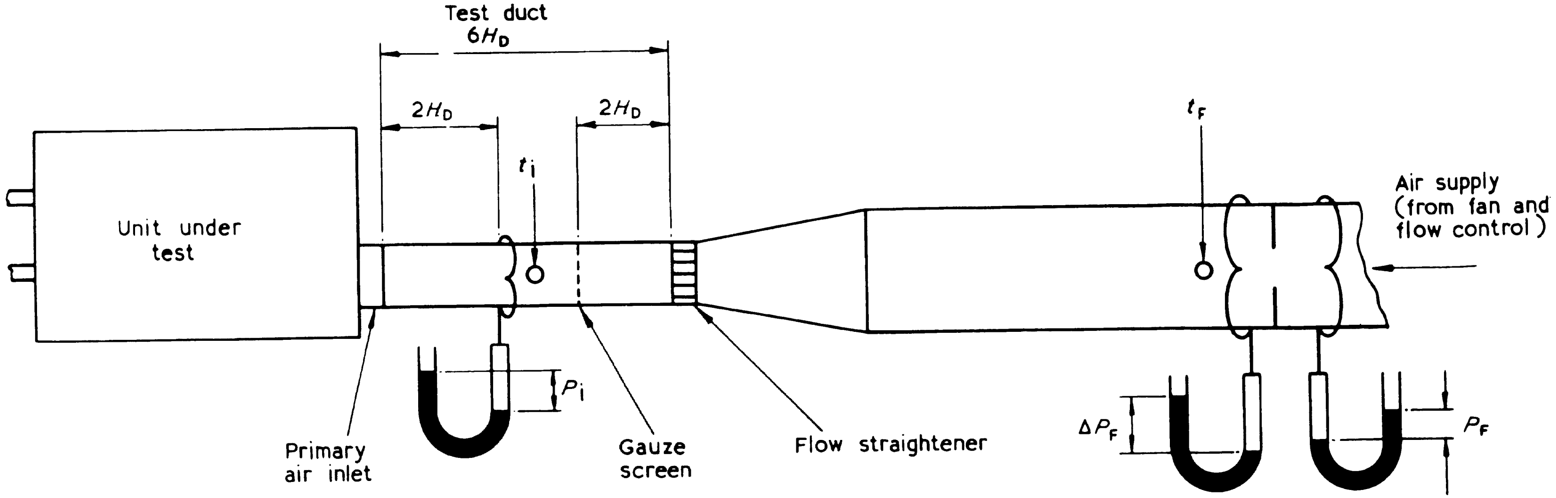


Figure 6 — Test for total pressure loss of primary air supply — typical arrangement

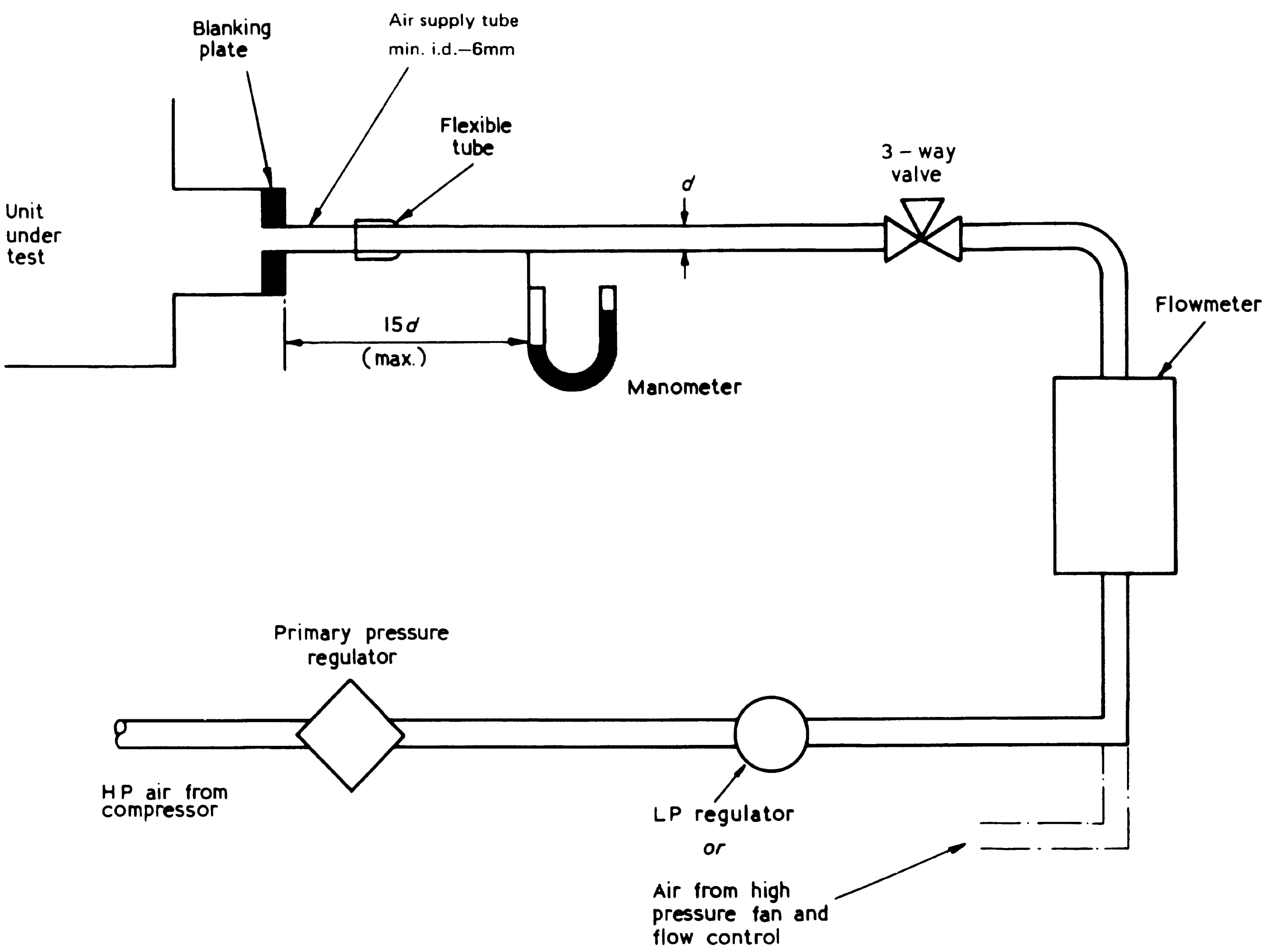
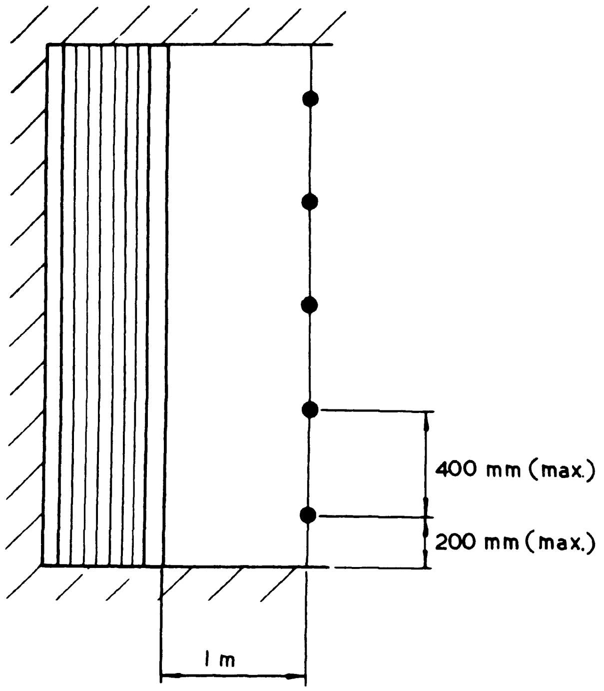


Figure 7 — Air supply arrangement for leakage test



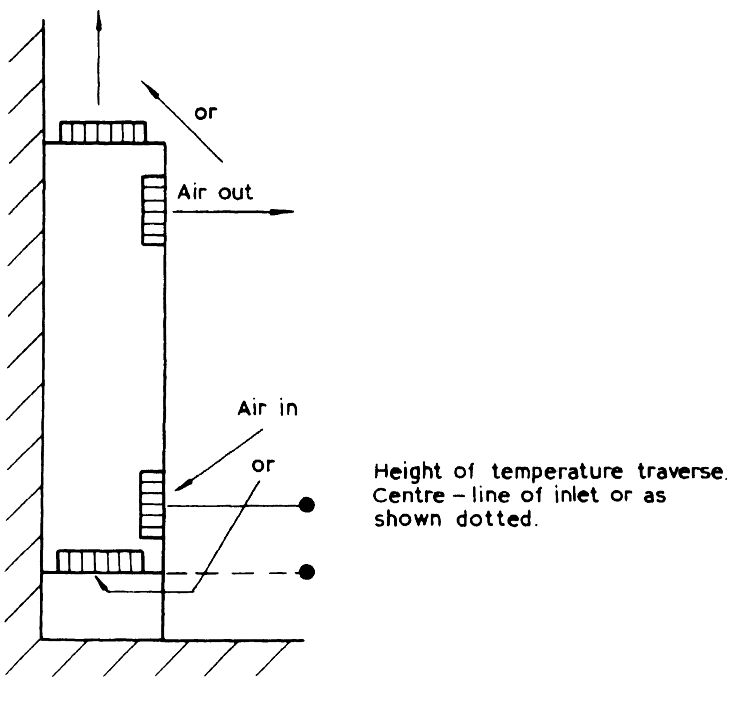


Figure 8a — Location of inlet air temperature measuring stations — bounded unit

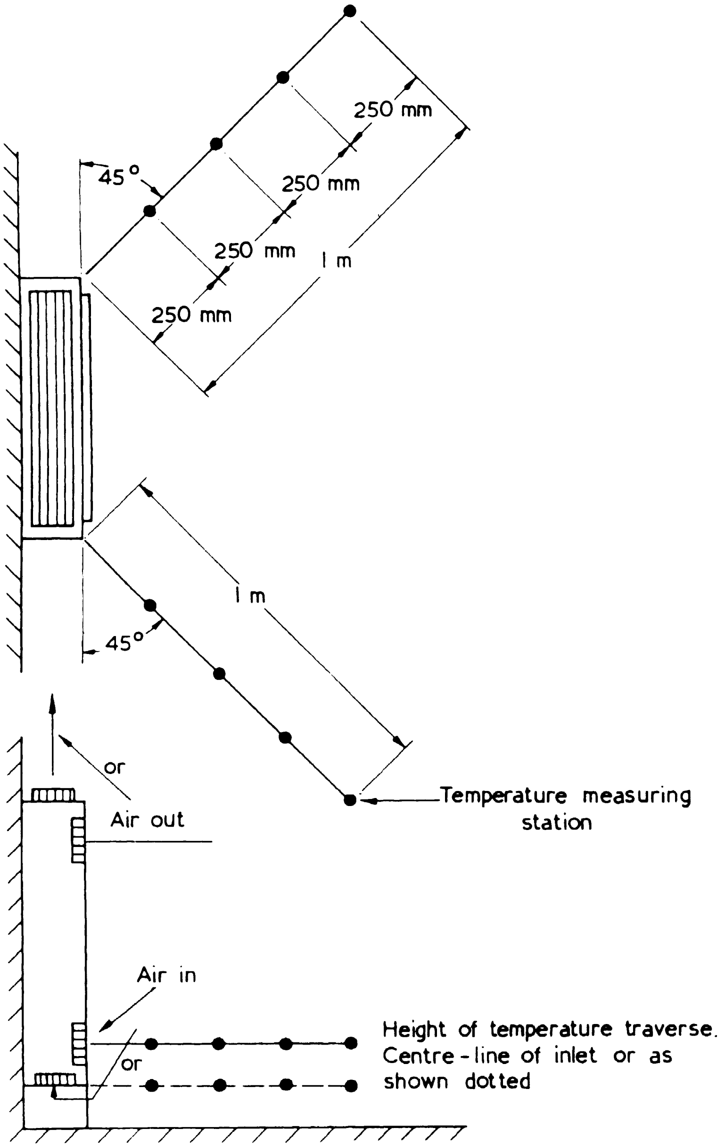
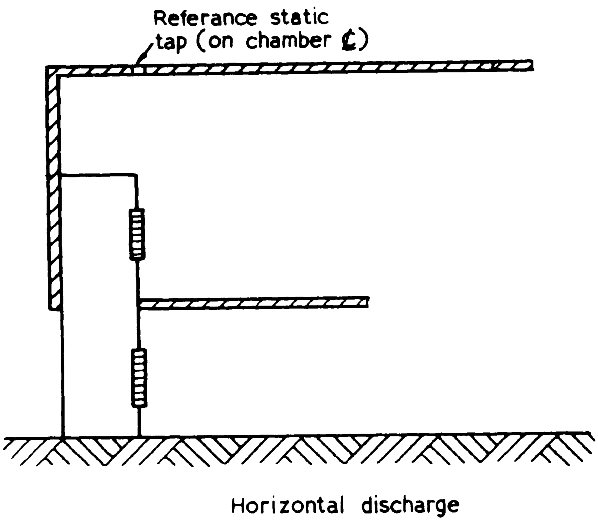


Figure 8b — Location of inlet air temperature measuring stations — free standing unit



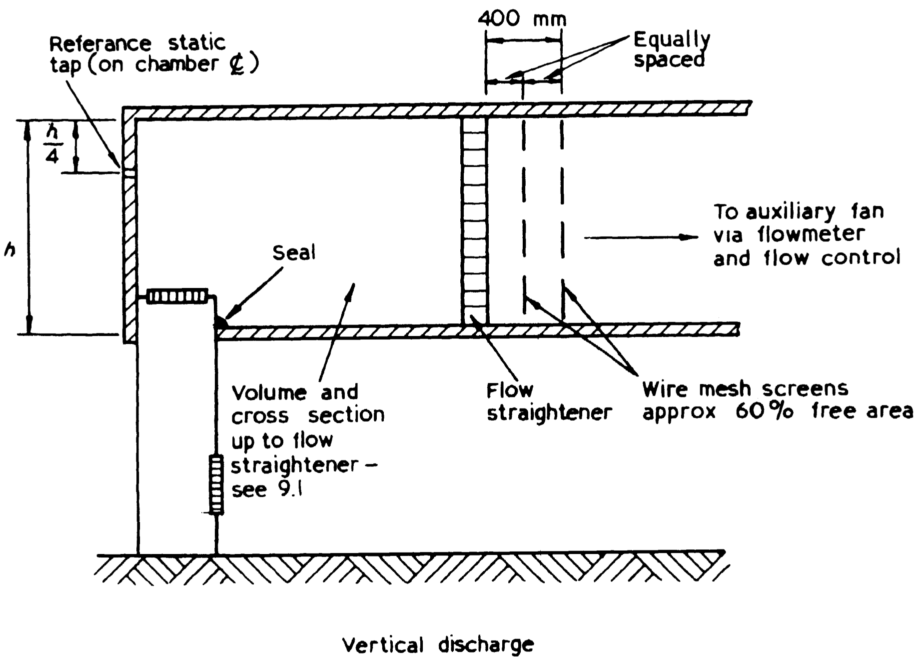


Figure 9 — Air flow chamber

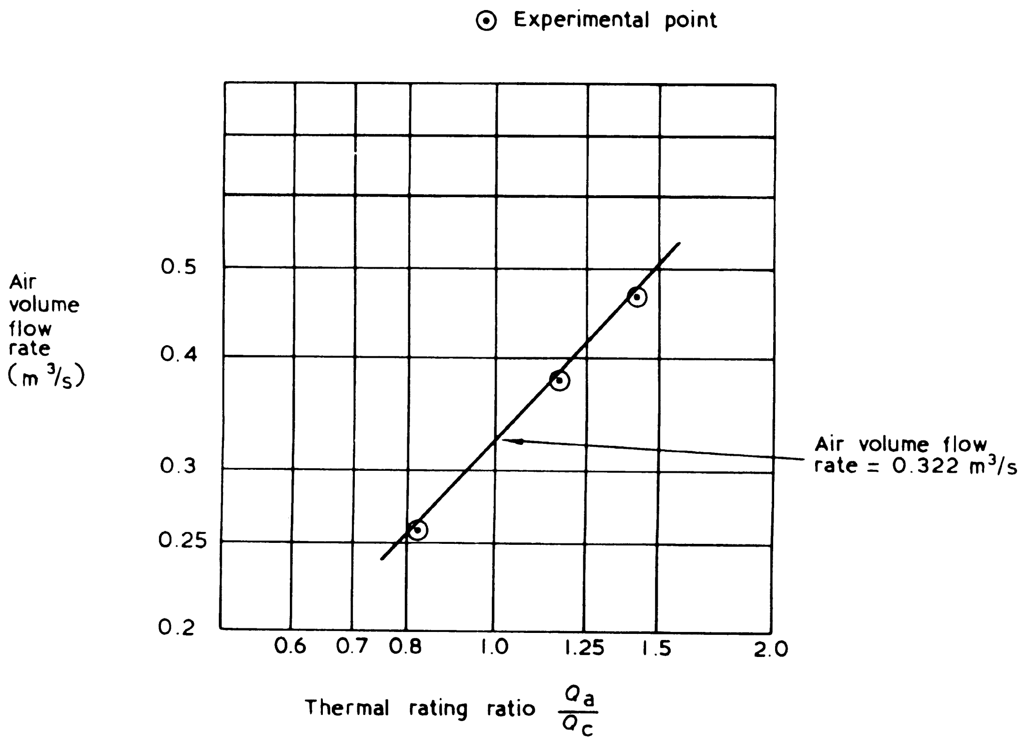


Figure 10 — Determination of air volume flow rate

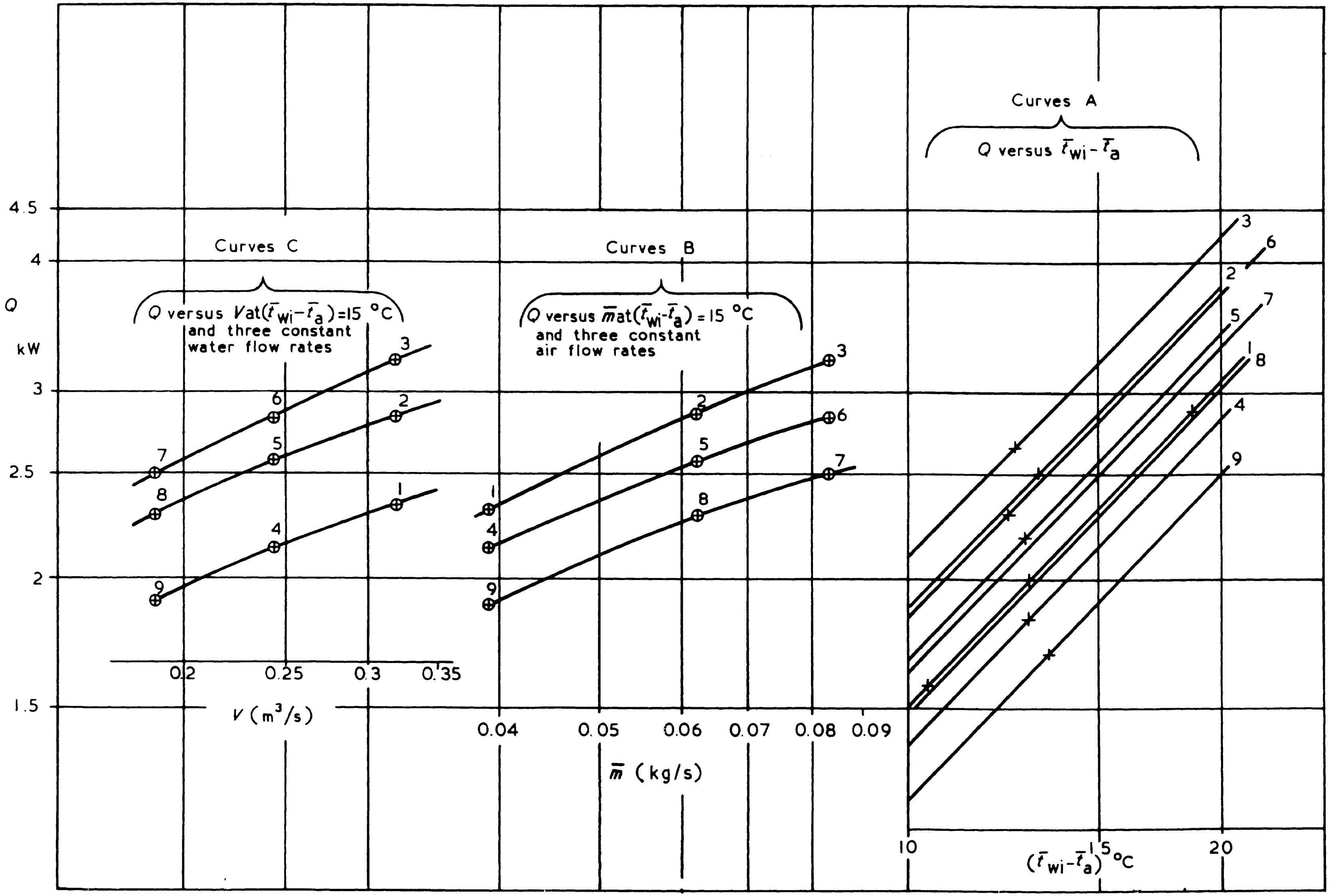


Figure 11 — Thermal characteristics

V (m³/s)	0.2	0.25	0.3
m (kg/s)	Basic rating		
0.05	2.15 / 2.17	2.38 / 2.38	2.55 / 2.52
0.07	2.5 / 2.46	2.72 / 2.72	2.92 / 2.9

Basic rating at $(t_{wi} - t_a) = 15\ °C$

Curves F from mean basic rating, dotted lines parallel to line 1 in Fig. 11

Curves D and E, cross plots from B and C in Fig. 11

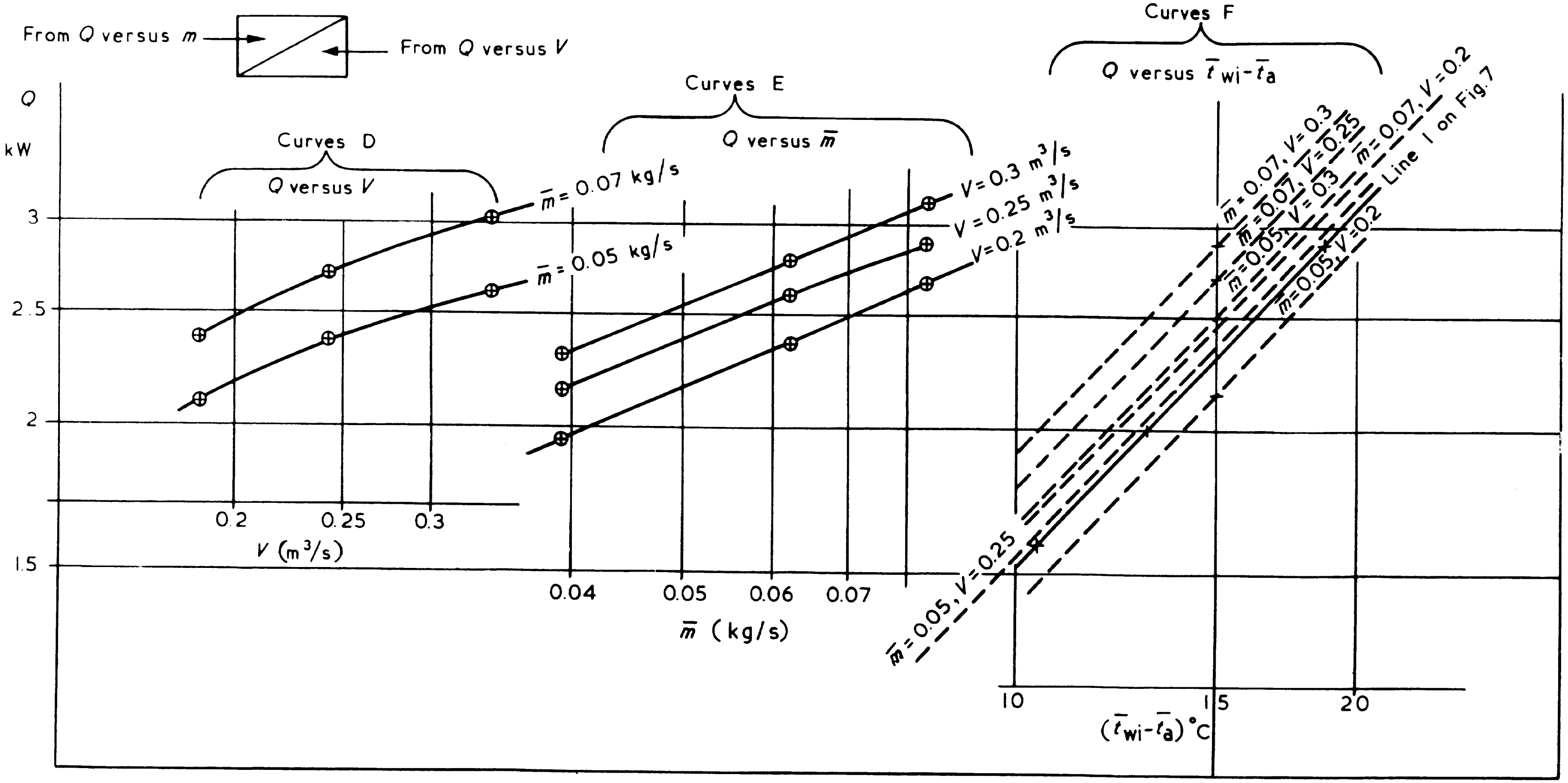


Figure 12 — Thermal rating example

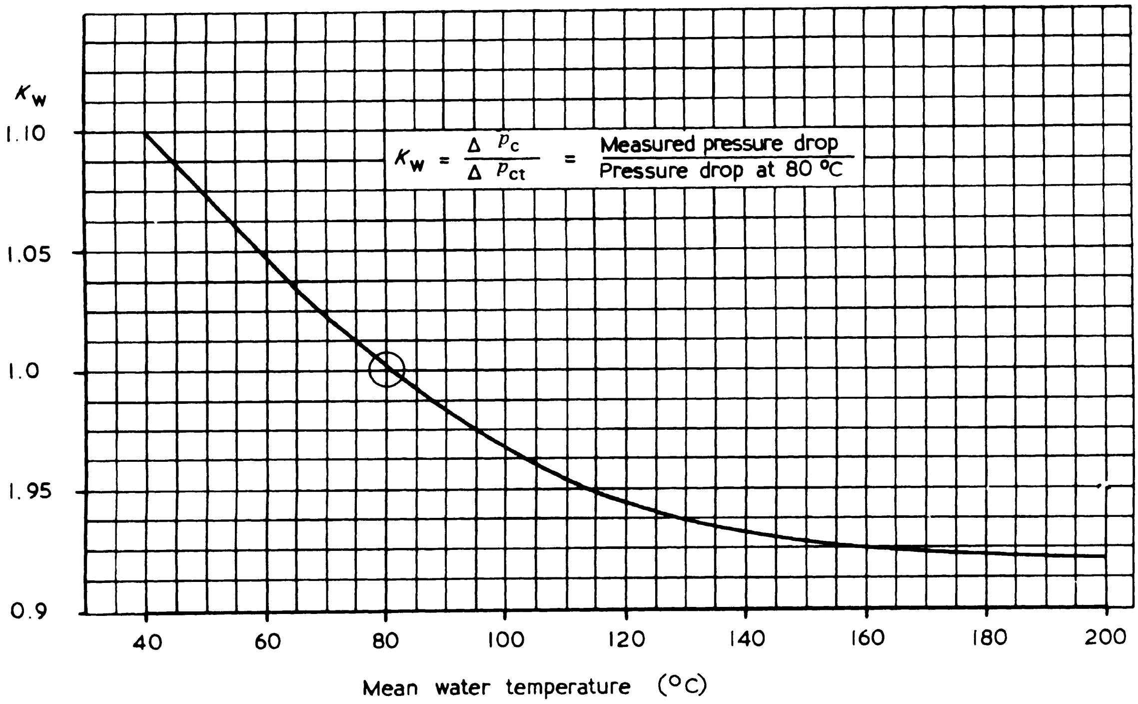


Figure 13a — Water temperature correction factor — heating

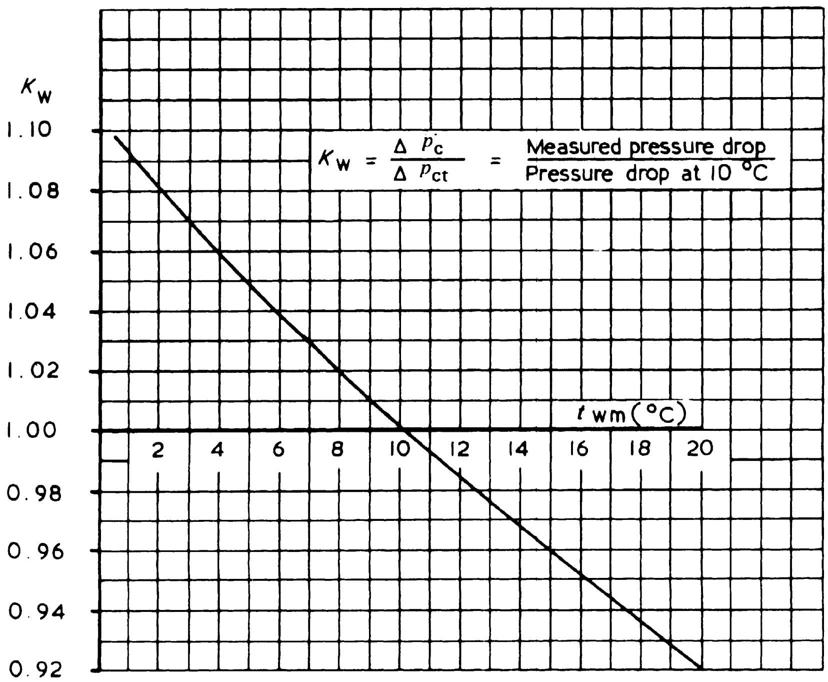


Figure 13b — Water temperature correction factor — cooling

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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 1042-2, *Pitot tubes*[2].

[2] In course of preparation.

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