BS 4857-1:
1972

Methods for

Testing and rating terminal reheat units for air distribution systems —

Part 1: Thermal and aerodynamic performance

UDC 697.978:697.356.001.42

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:

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Association of Manufacturers of Domestic Electrical Appliances
Boiler and Radiator Manufacturers Association*
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British Oil and Gas Firing Equipment Manufacturers Association
British Refrigeration and Air Conditioning Association*
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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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Contents

Foreword

This Part 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 and is the first Part of a two Part standard. Part 2, dealing with acoustic testing and rating, 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 that appear in this standard.

The test methods presented in this Part of the standard will enable the thermal and aerodynamic performance of a terminal reheat unit to be evaluated at any water and air flow rate and temperature within the range of variables employed for the test. The air flow tests are carried out in accordance with BS. . . ., "*Testing and rating of air control devices for air distribution systems*, Part 1, "*Aerodynamic testing of constant flow rate assemblies without a heat exchanger*".[1)]

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

Examples of the use of the test data are also presented.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 16, 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)] In course of preparation.

1 Scope

This Part of this British Standard describes methods of thermal and aerodynamic testing and rating for high pressure terminal reheat units with or without flow rate controllers. It describes the equipment required and gives instructions for the calculation, interpretation and interpolation of results.

2 Definitions

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

2.1
terminal reheat device

an assembly consisting of a heat exchanger within a casing, having one air inlet. The casing may also contain some or all of the following components:

a) a manual damper;

b) a constant flow rate controller;

c) a sound attenuator.

the casing is so designed that the whole of the air discharged from the device is obtained from the inlet duct

NOTE When the device contains a constant flow rate controller, it is normally referred to as a single duct terminal reheat box. When the device contains a manual damper, it is normally referred to as a terminal reheat unit.

2.2
flow rate controller

a device mounted within the casing for the purpose of maintaining a constant air-flow rate through the casing when the pressure differential between high and low pressure sides varies within the limits for which the equipment is designed

NOTE A flow rate controller normally maintains a constant air-flow rate to within ± 5 % of the maximum air-flow rate of the device, within the pressure differential range of about 200 N/m² (2 mbar) to 1 500 N/m² (15 mbar).

there are different types of flow rate controllers, such as:

a) *Mechanical constant flow rate controller*. Self-actuating. This type derives its power from the air stream and not from any external source.

b) *Mechanical variable flow rate controller*. As for a) above, but with its flow rate varied by an external signal.

c) *Pneumatic, electric, etc., flow rate controllers.* Controllers deriving their power from an external source. They can be either of the constant or variable type.

3 Nomenclature

Symbol	Definition	Units
A_i	Area of air inlet duct	m²
A_t	Area of water supply tube	m²
c_p	Specific heat capacity	kJ/kg °C
H_D	Hydraulic diameter (= 4 × area/perimeter)	m
K_w	Temperature correction factor	—
m	Water mass flow rate	kg/s
p	Pressure relative to atmosphere	N/m²
Δp	Pressure drop	N/m²
Δp_c	Hydraulic pressure drop at 80 °C	N/m²
Δp_m	Measured hydraulic pressure drop corrected for height difference	N/m²
p_b	Atmospheric pressure	bar
Q	Heat transferred	kW

Symbol	Definition	Units
ρ	Density	kg/m³
t	Temperature	°C
U	Air velocity	m/s
V	Air volume flow rate	m³/s

Suffixes

a	inlet air
i	inlet water
o	outlet water
f	flow meter
r	reference air
s	static pressure
w	water

Reference conditions for air:	Temperature	20 °C
	Pressure	1013.25 mbar (101.325 kN/m²)
	Density	1.2 kg/m³
	Relative humidity	43 %

4 Instrumentation

4.1 Temperature

4.1.1 The measurement of temperature shall be by means of mercury-in-glass thermometers, resistance thermometers or the 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 to an accuracy of 0.1 °C.

4.2 Water flow measurement

4.2.1 The measurement of water flow shall preferably be by means of direct weighing (for water temperatures above 90 °C it would be advantageous to use one of the methods described in BS 1042 Part 1). The water leaving the test rig shall be collected in vessels of known weight, and weighed on a beam-type weighing machine, having an accuracy of 0.1 % over the range of weight used in the test. The weight of each vessel used shall not exceed 50 % of the weight of its normal contents. Means 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 2. 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 3, together with a suitable water supply system for water temperatures above 90 °C.

4.3 Air flow measurement

Air flow measurement shall comply with the requirements of BS 1042-1 or alternatively, a flow meter may be calibrated in situ using the methods given in BS 1042-2[2)].

4.4 Manometers

4.4.1 The minimum differential pressure measurement for air flow measurement shall be 25 N/m^2 for inclined U-tube manometers and micromanometers and 500 N/m^2 for vertical U-tube manometers.

4.4.2 All manometers shall be calibrated against an accepted standard.

4.4.3 It shall be possible to read all manometers to 1 % of the indicated reading.

5 Test for casing leakage

This test shall be carried out in accordance with BS . . . .[2]. In the case of units fitted with a flow control device, leakage tests shall be carried out with this device in the open position.

6 Test of constant flow rate controller characteristics

Units fitted with a constant flow rate controller shall be tested for the performance of the constant flow rate controller by the method described in BS . . . .[2].

7 Test for air flow pressure characteristics

Units fitted with a manual or remote controlled air flow damper shall be tested for the relationship between the inlet total pressure and air volume flow rate, with the damper set in the fully open position.

7.1 An air inlet duct of internal dimensions equal to the nominal dimensions of the inlet of the unit under test, and of a minimum straight length $5\frac{1}{2}$ hydraulic diameters, shall be fitted to the unit inlet. A ring of four wall static taps (constructed to BS 1042-2[2]) shall be fitted at a point $1\frac{1}{2}$ inlet duct hydraulic diameters from the unit inlet; a flow straightener shall be fitted 4 hydraulic diameters and a wire screen 3 hydraulic diameters upstream from the static taps. The unit and duct assembly shall be connected to an air flow meter, fan and flow control system as shown in Figure 4.

7.2 The inlet air temperature shall be measured at a point, $\frac{1}{2}$ hydraulic diameter downstream of the static taps, at the four stations indicated in the inset diagram in Figure 4. The inlet air temperature (t_a) shall be the mean of these four measurements.

7.3 The desired air flow shall be set and when steady state conditions have been achieved measurements of the following shall be recorded.

NOTE For the purposes of this test steady state conditions are said to exist when the inlet air temperature has not varied by more than 0.25 °C and the flow meter pressure drop and static pressure at the unit inlet have not varied by more than 2 % over a period of 5 min.

Δp_f flow meter pressure drop (N/m^2)

p_{s_f} static pressure upstream of the flow meter (N/m^2)

t_f the temperature at the flow meter (°C)

p_s the unit inlet static pressure (N/m^2)

t_a the unit inlet temperature (mean of four) (°C) and

p_b the atmospheric pressure (bar).

The air volume flow rate at the flow meter (V_f) is calculated from Δp_f, p_s, t_f, and p_b.

The mean velocity at the unit inlet (U_i), is calculated from the following equation.

$$U_i = \frac{V_f}{A_i} \times \frac{\rho_f}{\rho_i}$$

where A_i is the area of the inlet duct (m^2)

ρ_f is the density of air at the flow meter (kg/m^3)

ρ_i is the density of air at the unit inlet (kg/m^3).

[2] BS . . . . "*Testing and rating of air control devices for air distribution systems*", Part 1, "*Aerodynamic testing of constant flow rate assemblies without a heat exchanger*". (In course of preparation.)

The mean inlet total pressure (p_T) at reference conditions is calculated from the following equation

$$p_T = \frac{\rho_i \, p_s}{\rho_r} + \tfrac{1}{2} \rho_r U_i^2 \left(\frac{\rho_i}{\rho_r} \right)$$

where ρ_r is the reference density of air = 1.2 kg/m^3.

7.4 The test described above shall be repeated at four other air flow rates spread evenly through the flow range of the unit, covering this range to within 20 % at each end. The total pressure (ρ_T) shall be plotted against the flow rate converted to reference conditions ($V_r = V_f \rho_f/\rho_r$), on logarithmic graph paper, and the best straight line drawn through the experimental points. This line shall be used for the determination of the total pressure loss of the unit with the inlet damper fully open.

8 Heat transfer measurements

The test apparatus and measurements described in this clause will enable the performance of the unit to be determined at any air and water flow rate and temperature within and to 10 % outside of the range of test measurements. The error involved in the interpolations and extrapolations should not exceed 5 %. Two test methods are described, one for a limited temperature range and one for a wide temperature range.

8.1 Heat transfer apparatus

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

8.1.2 Typical arrangements of the apparatus are shown in Figure 2 and Figure 3.

8.1.3 The pipework shall be arranged to give an unobstructed straight run at entry to 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.

8.1.4 Hydraulic resistance side wall tappings shall be fitted adjacent to the connections to the unit. These tappings shall be as specified in Figure 5*a* 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 5*b*.

8.1.5 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 °C.

8.1.6 The air supply system described in **7** shall be connected to the unit air inlet, and an outlet duct(s) of internal dimensions equal to those of unit outlet(s) and of length equal to at least 2 outlet hydraulic diameters fitted to the unit outlet(s).

8.2 General test instructions

8.2.1 The inlet air temperature shall be in the range from 15 °C to 25 °C and shall not differ from the temperature in the space surrounding the unit under test by more than 2 °C.

8.2.2 Before commencing the test the following 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.

8.2.3 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 min by more than the specified amount from their mean value.

Inlet air temperature (t_a)	1.0 °C
Inlet water temperature (t_i)	1.0 °C
Water flow rate (m)	2 %
Air flow rate (V)	2 %

8.2.4 The duration of the test shall be not less than 30 min and complete sets of readings (t_a, t_i, t_o, m, V) shall be taken at intervals not greater than 10 min and successive readings shall not vary by more than the amount specified for steady state conditions in **8.2.3**.

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

8.3 Calculations

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

$$Q = c_{p_w} m (\bar{t}_i - \bar{t}_o)$$

where Q is the heat transferred (kW)

c_{p_w} is the specific heat capacity of the water at the mean water temperature $(\bar{t}_i + \bar{t}_o)/2$ (kJ/kg °C)

$\bar{t}_i$ is the mean inlet water temperature (mean of measurements in test period, °C)

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

m mean water mass flow rate (mean of measurements in test period, kg/s) computed from flow meter readings or by the total mass flow of the water during the test divided by the duration of the test.

8.3.2 *Air flow rate.* The air flow rate shall be computed from the air flow meter drop, temperature, static pressure and barometric pressure as described in **7.3** and converted to the flow rate at reference conditions by the equation:

$$V_r = V_f \rho_f / \rho$$

8.3.3 *Hydraulic pressure drop.* 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 equation:

$$\Delta p_c = \Delta p_m / K_w$$

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 6, 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 test variables.

8.4 Rating tests

8.4.1 *Simplified test series*

8.4.1.1 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 50 °C to 70 °C). The following tests shall be carried out at the conditions indicated in the table:

Test series	**Water flow rate** m **(kg/s)**	**Air flow rate** V m^3/s	**Inlet temperature difference** t$(\bar{t}_i - \bar{t}_a)$ (°C)
1	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 2 % of the original values used.

8.4.1.2 The following graphs shall be plotted, with reference to Figure 7.

1) From Test series 1 (see **8.4.1.1**) draw line Q versus $(\bar{t}_i - \bar{t}_a)$, 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 **8.4.2** shall be employed.

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

3) Select a value of $(\bar{t}_i - \bar{t}_a)$ at the centre of the test range (15 °C for the example in Figure 7). Using the values of Q where curves 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 rate, 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.

8.4.2 *Full test method.* The full test method is employed for rating under conditions where the difference between inlet water and air temperatures has a range greater than 20 °C. Similar plots to those described in **8.4.1** shall be obtained from the following tests.

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

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

9 Rating examples

9.1 Performance calculation at given inlet conditions. It is required to produce heat transfer data, for the unit with the characteristics shown in Figure 7 at the following inlet conditions.

Air volume flow rate	0.2, 0.25, 0.3 m^3/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 7 it is possible to draw the cross-plots D and E shown in Figure 8. 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 8) 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 8) 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 as follows.

Air flow rate *V*	**Water flow rate** *m*	**Inlet water temperature** t_i	**Heat transferred** *Q*
m^3/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

9.2 Calculation of the suitability of a unit for a particular duty. It is required to check if a reheat unit with the characteristics shown in Figure 7 will be suitable for heating an air flow rate of 0.3 m^3/s from 15 °C to 25 °C with an 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 **9.1** and are shown in Figure 8. The required heat transfer is 3.64 kW; it can be seen in Figure 8 that for an inlet water-air differential of 18 °C and $m = 0.7$, $V = 0.3$ 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.

9.3 Calculation of rating using wide range data from the full test series. The calculation procedures are similar to those described in the examples **9.1** and **9.2** for the restricted range test. Because of the possibility of non-linearity in the temperature-heat transfer characteristics, cross-plots shall be carried out at the required temperature differences and at the required 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* versus water flow at constant air flow rate, and *Q* versus air flow at a constant water flow rate.

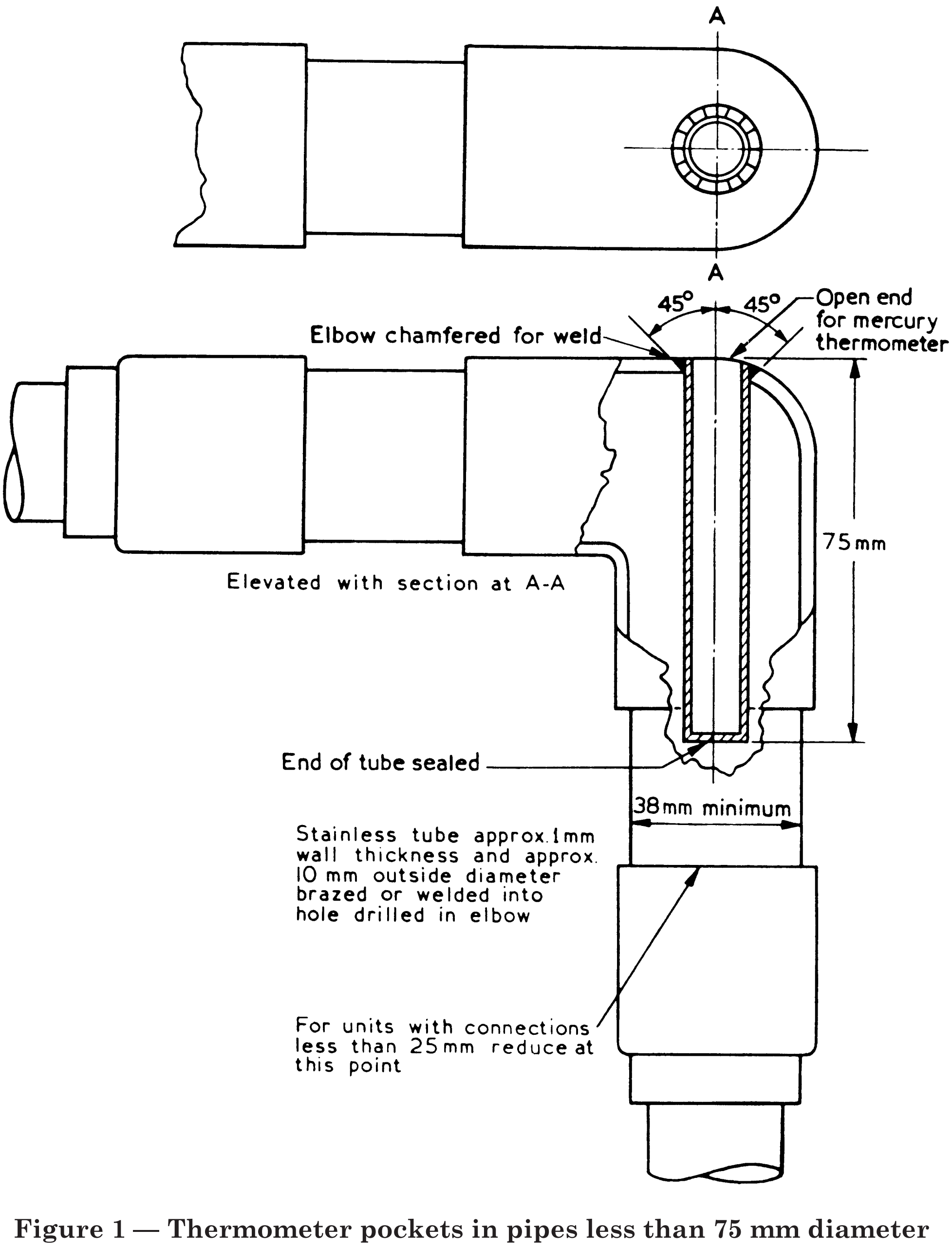

Figure 1 — Thermometer pockets in pipes less than 75 mm diameter

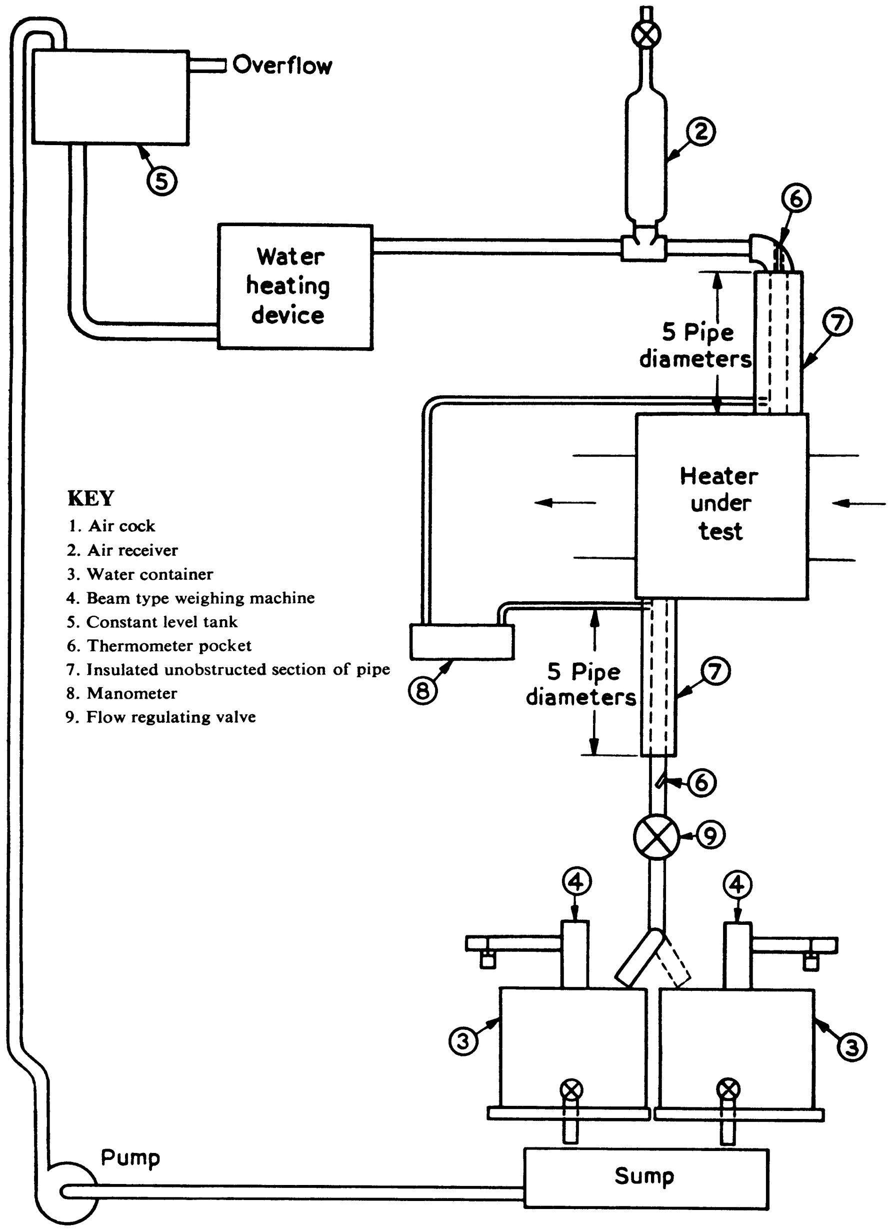

Figure 2 — Typical open circuit test equipment

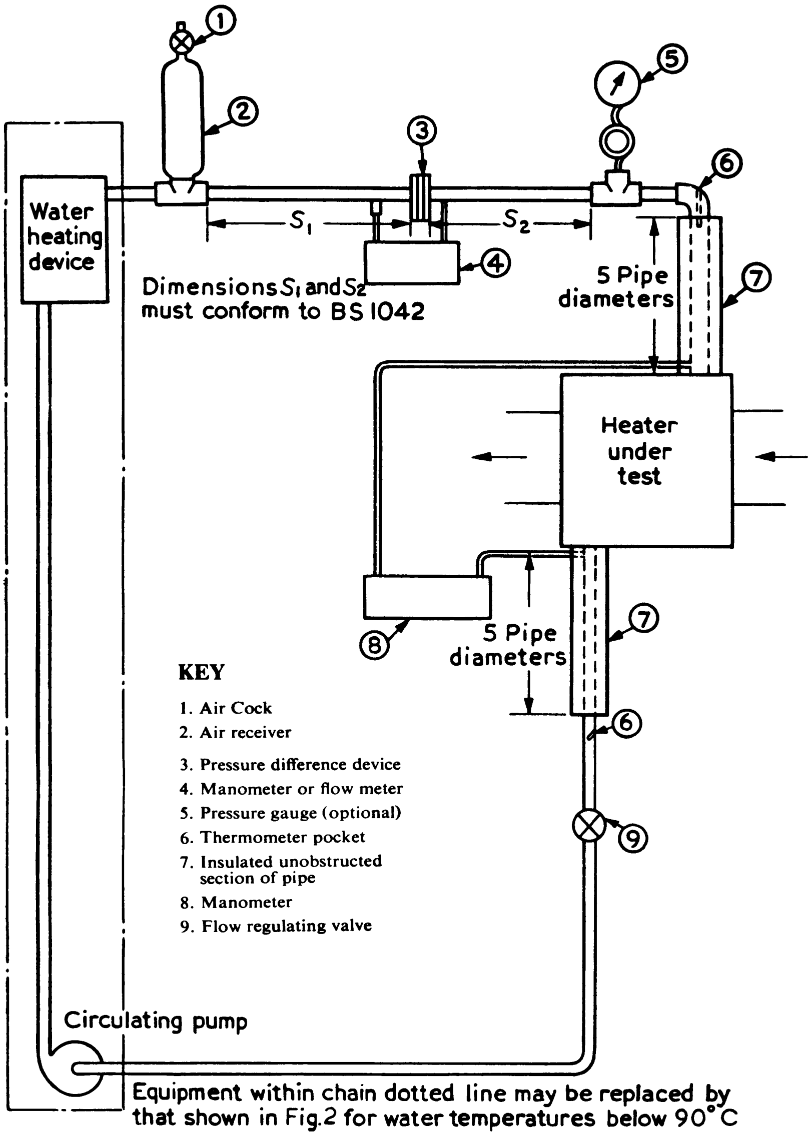

Figure 3 — Typical closed circuit test equipment

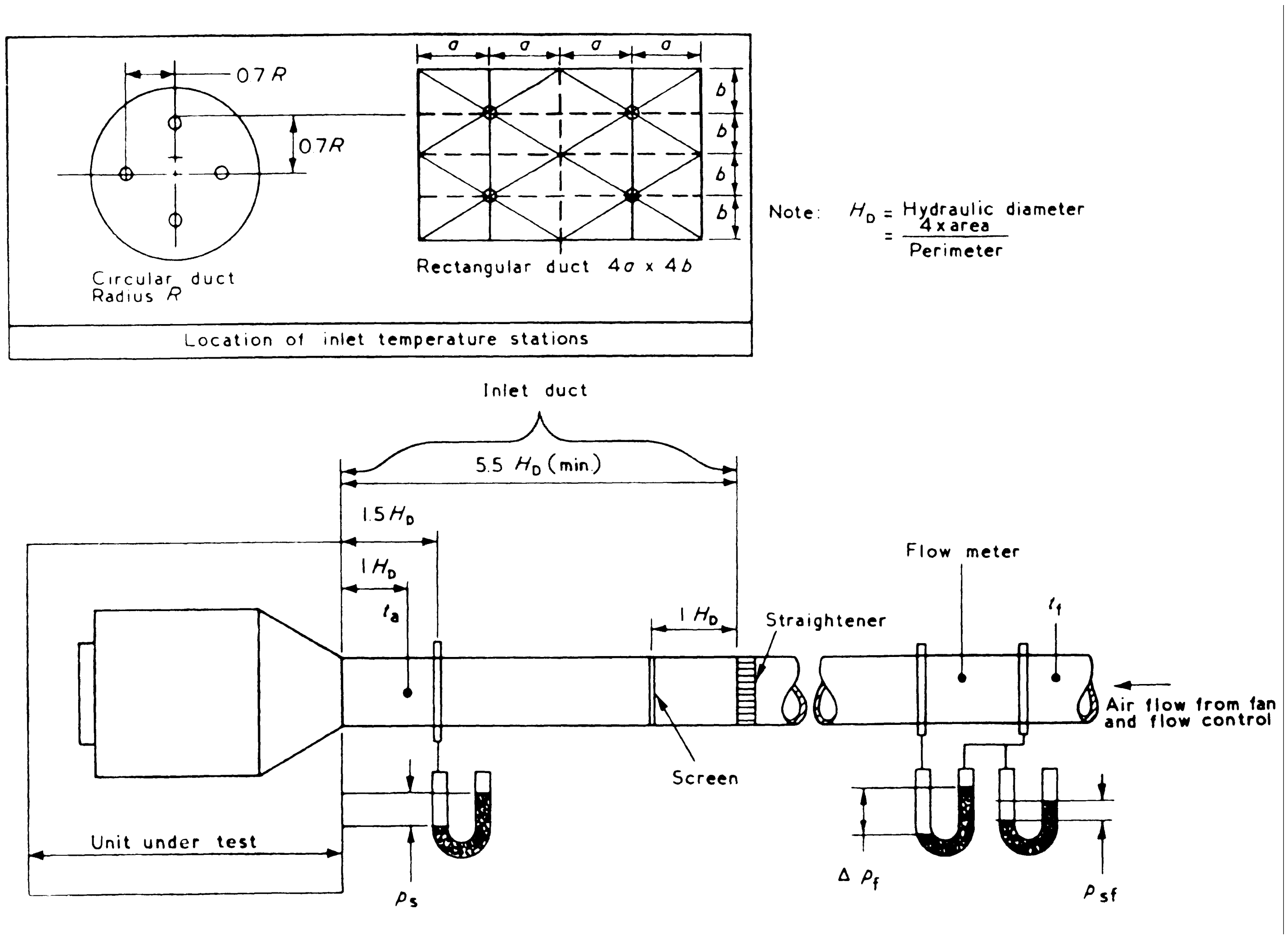

Figure 4 — Inlet air supply

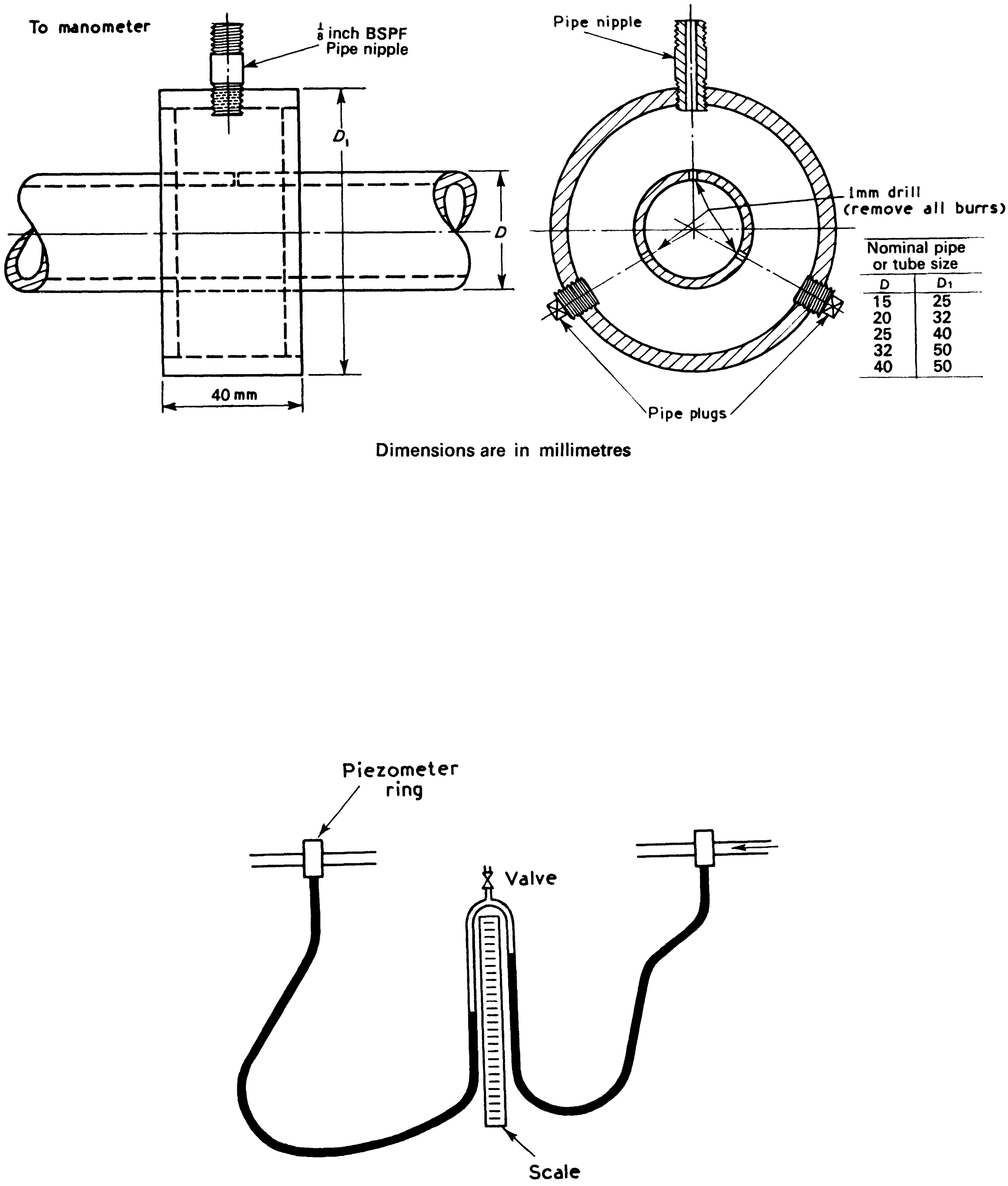

Figure 5 — Piezometer ring and inverted tube pattern manometer

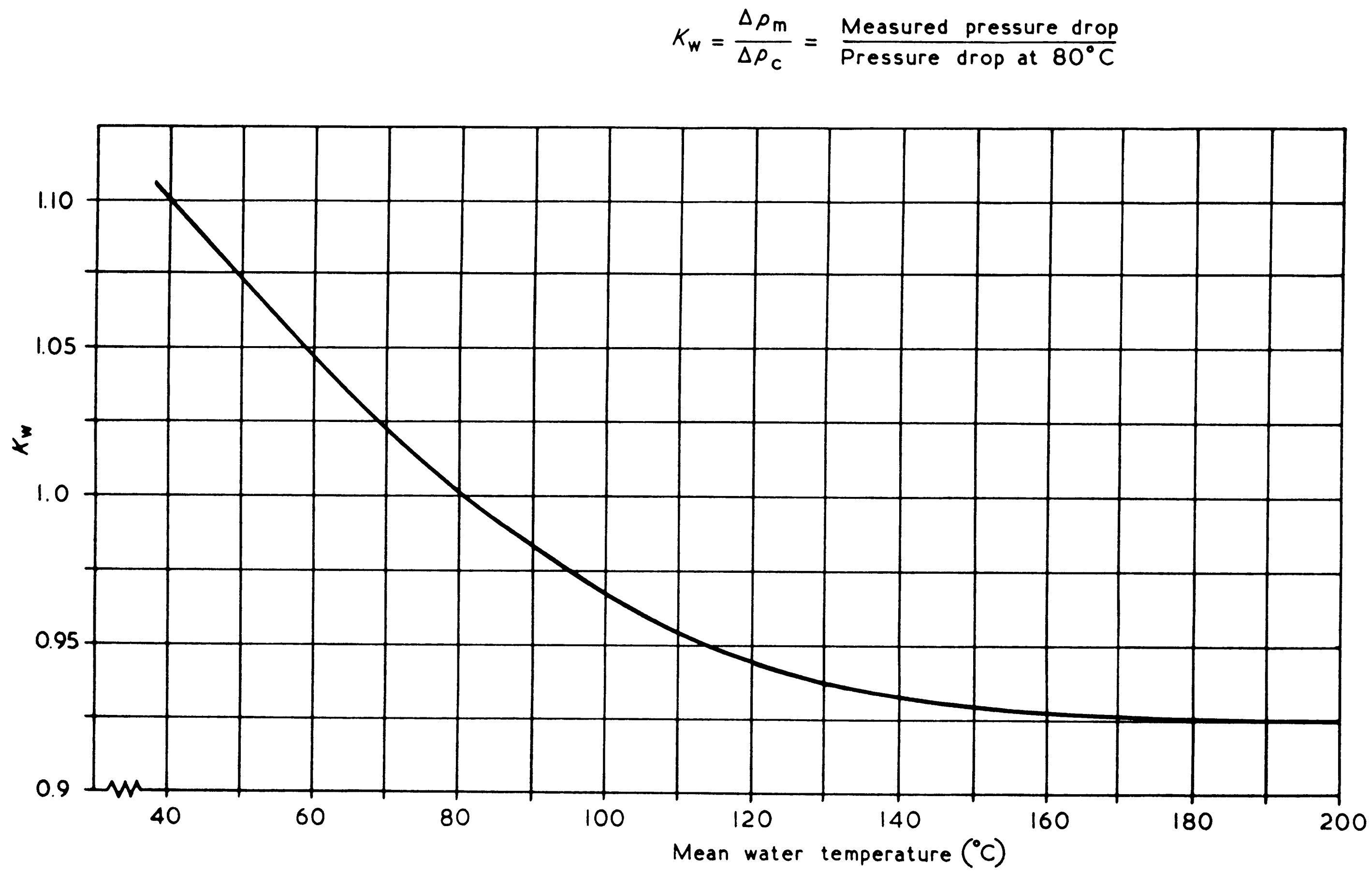

Figure 6 — Water temperature correction factor

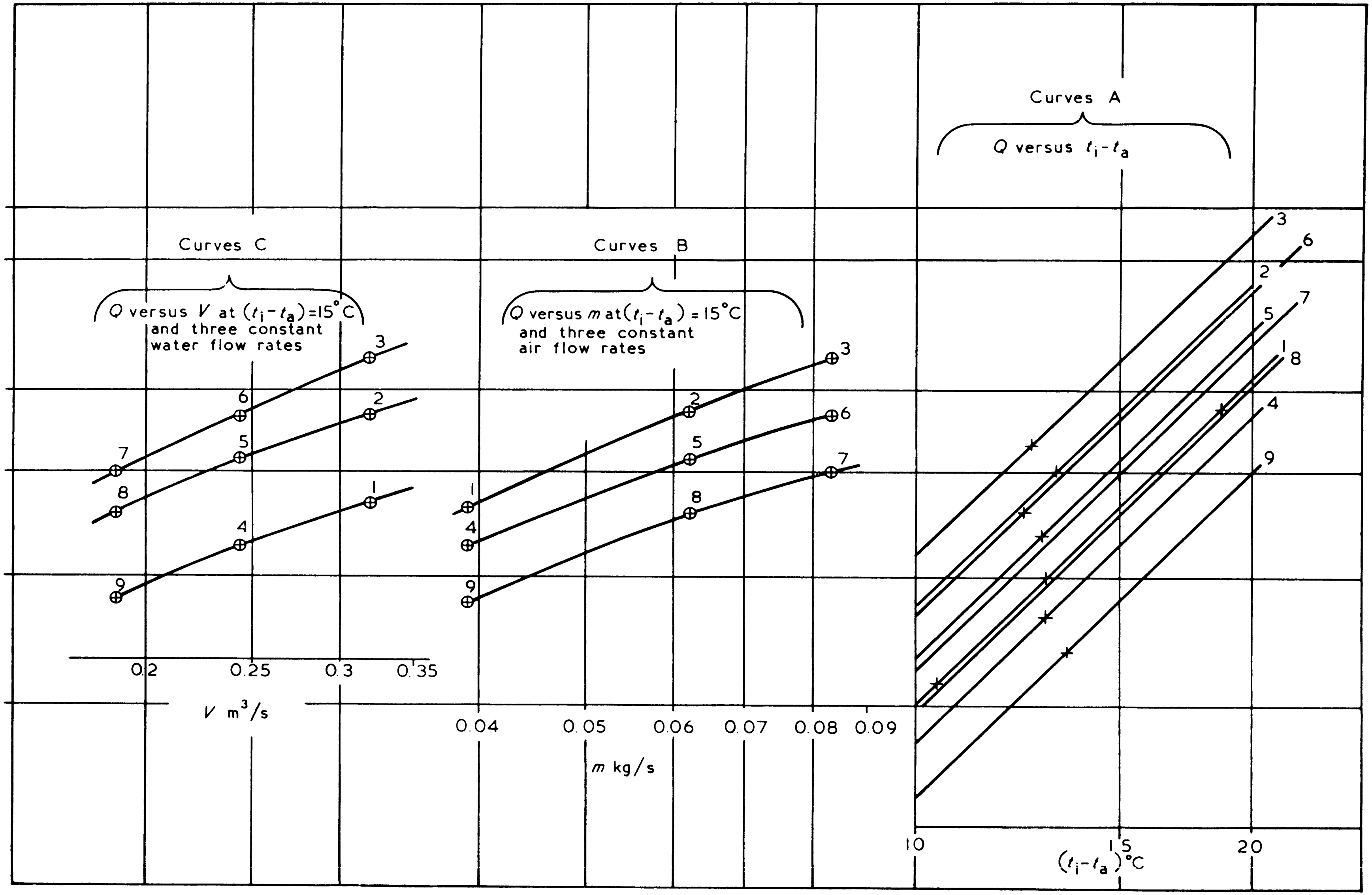

Figure 7 — Thermal characteristics

Vm³/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 $(t_i - t_a) = 15$ °C.
Curves F from mean basic rating dotted lines parallel to line 1 in Figure 7.
Curves D and E are cross-plots from B and C in Figure 7.

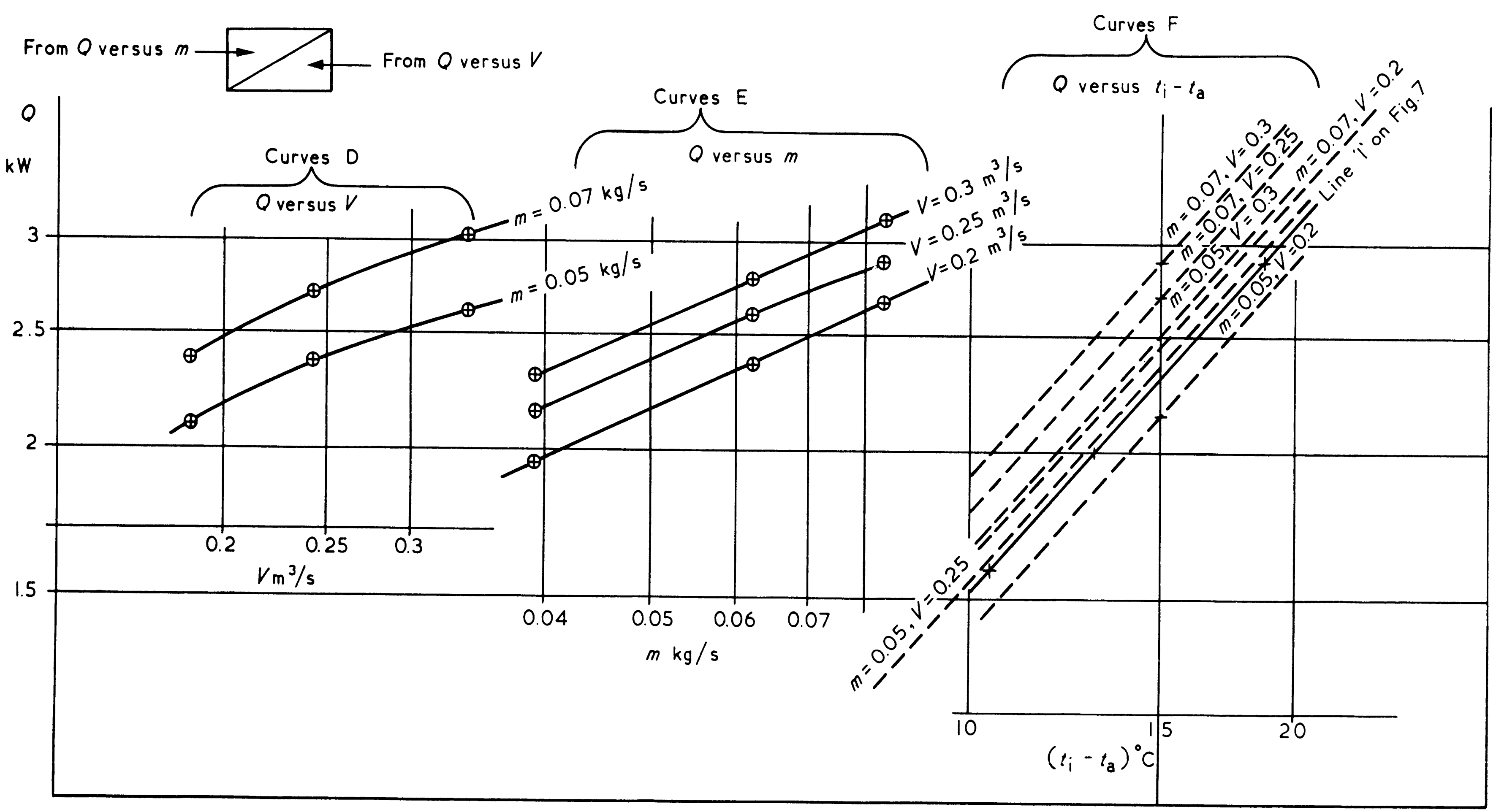

Figure 8 — Rating example

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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 1042, *Measurement of fluid flow in pipes.*

BS 1042-1, *Orifice plates, nozzles and venturi tubes.*

BS 1042-2, *Pilot tubes.*

BS......., *Testing and rating of air control devices for air distribution systems — Part 1: Aerodynamic testing of constant flow rate assemblies without a heat exchanger*[3].

[3] In course of preparation

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