

Methods of testing

Pumps

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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 standard:

Association of Hydraulic Equipment Manufacturers	Institution of Electrical Engineers
British Hydromechanics Research Association	Institution of Mining Engineers
British Pump Manufacturers Association	Institution of Water Engineers
	Metropolitan Water Board

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Foreword

This standard makes reference to the following British Standards:

BS 89, *Electrical indicating instruments*.

BS 269, *Rules for methods of declaring efficiency of electrical machinery (excluding traction motors)*.

BS 353, *Methods of testing water turbine efficiency*.

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*¹⁾.

BS 1780, *Bourdon tube pressure and vacuum gauges*.

BS 3435, *Measurement of electrical power and energy in acceptance testing*.

BS 3680, *Methods of measurement of liquid flow in open channels*.

BS 3680-2A, *Dilution methods. Constant rate injection*.

BS 3680-3, *Velocity area methods*.

BS 3680-4A, *Thin plate weirs and venturi flumes*.

This British Standard which has been prepared under the authority of the Mechanical Engineering Industry Standards Committee forms one of a series providing methods of test for pumps. It supersedes BS 599, BS 1939 and also:

BS 722:1937, *Borehole and well pump tests*.

BS 723:1937, *Sewage pump tests*.

BS 724:1937, *Vaporizing liquid pump tests*.

Standard arrangements and procedures are described for testing a pump individually without reference to its final installation conditions, or the effect upon it of any associated fittings. These will be the usual conditions in which a pump is tested at the maker's works.

Pump performance may be affected by conditions of the final site installation and procedures are described for carrying out "Standard tests" on certain types of installation of which an overall performance is required. The conditions in which pumps are finally installed, however, often do not permit reliable test measurements, and recommendations are made concerning the procedure to be adopted where the layout precludes tests in conformity with the standard or where installation tests are required which cover plant ancillary to the pump itself.

Since the publication of this British Standard in 1939, much experimental evidence has been obtained, not only on the flow conditions at the inlet and the outlet of pumps, but also on the precautions necessary when using various methods of measuring flow and head. It has now been established that high standards of accuracy cannot be obtained by using some of the simple and convenient methods of measurement hitherto recommended.

The standard lays down different methods of measuring pressure, discharge and power, and these have been placed in three Classes, A, B and C, in descending order of accuracy, and the degree of accuracy to be expected in each class is specified in Section 4.

It is expected that the methods of measurement used for testing the majority of pumps will be those classified as Class C. The methods of measurement classified as Class B may be employed where a higher degree of accuracy is required. Class A methods of measurement will necessitate laboratory conditions, and may be employed exceptionally on tests where the attainment of high accuracy is held to justify the greatly increased time and cost expended; such tests might for instance, be undertaken on prototypes or models of very large pumps which could not themselves conveniently be tested.

¹⁾ In the course of preparation.

Tests may be made in which the methods of measurement do not all fall into one class and the method of arriving at the combined limit of error when calculating the pump efficiency is described in Appendix A.

Notes on the estimation of limits of error, and the effect of disturbed flow on head measurements are given in Appendix A and Appendix B.

Acknowledgement is made to British Hydromechanics Research Association Reports numbers SP 625 and PR 685 for the material for Figure 2a and Figure 2b.

NOTE 1 Where metric equivalents are stated the figures in British units are to be regarded as the standard. The metric conversions are approximate. More accurate conversions should be based on the tables in BS 350, "Conversion factors and tables".

NOTE 2 In place of the customary, but incorrect, use of the pound and kilogramme as units of force, the units called pound-force (abbreviation lbf) and kilogramme-force (abbreviation kgf) have been used in this standard. These are forces which when acting on a body of mass one pound, or kilogramme respectively, give it an acceleration equal to that of standard gravity.

NOTE 3 Except for the hydraulic pressure test (see Clause 5) the requirements for Class A, B and C tests are given in BS 5316, "Acceptance test for centrifugal, mixed flow and axial pumps", Part 1, "Class C tests", Part 2, "Class B tests" and Part 3 "precision class tests".

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 to iv, pages 1 to 40 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.

Section 1. General

1 Scope

This British Standard specifies the methods to be employed in the determination of the performance and efficiency of pumps handling fluids which behave as homogeneous liquids.

The formulae quoted are based on the assumption that the liquid handled is clean water at a temperature of 62 °F (16.6 °C) with a weight density of 62.35 lb/ft³ (998.75 kg/m³).

It also includes details of the special precautions to be taken where the tests are to be carried out using liquids which are hot, are viscous, are liable to evolve vapour or gases, vary in density or contain solids in suspension.

The standard does not specify requirements for the testing of oil hydraulic positive displacement (OHPD) pumps.

2 Classes of measurement

To facilitate estimation of the accuracy with which a test is conducted, methods of measurement are specified in three classes, A, B and C, in descending order of accuracy. The procedures applicable for measurement in each class are laid down in the following sections, and the choice of method may be made in accordance with the requirements of the test.

A 95 per cent degree of confidence is used throughout this standard. The estimated limits of error corresponding to this degree of confidence in derived quantities (for example efficiency) can be calculated in accordance with the provisions for Appendix A.

The limits of uncertainty laid down in this standard are those applicable to measurements taken and to the quantities calculated therefrom; they do not apply to discrepancies between specified and actual performance.

Section 2. Symbols and terminology

3 Symbols

Discharge (volume rate of flow)	Q
Discharge (ft ³ /sec or m ³ /sec)	Q_c
Discharge (gals/min)	Q_g
Head	H
Total inlet head	H_i
Total outlet head	H_o
Pump total head	$(H_o - H_i)$
Net positive suction head	NPSH
Pressure head	h_p
Inlet pressure head	h_{pi}
Outlet pressure head	h_{po}
Positional head	z
Velocity head	h_v
Velocity	V
Inlet velocity	V_i
Outlet velocity	V_o
Gravitational acceleration	g
Vapour pressure head	h_{pv}
Horsepower	hp
Pump power input	P_i
Pump power output (water horsepower)	P_o

Gallons	gal
Cubic feet	ft ³
Cubic metres	m ³
Weight density	w
Kinematic viscosity	ν
Pump efficiency	η
Overall efficiency	η_o
Driving unit efficiency	η_D

4 Terminology

The positional datum. (See Figure 1.) For centrifugal, mixed flow or axial flow pumps, the positional datum shall be taken as the elevation of the highest point of the entrance edges of the first stage impeller blades, whatever the disposition of the shaft.

For reciprocating pumps the positional datum shall be taken as the evaluation of the horizontal plane through the centre of gravity of the volumes swept out by the rams, pistons or corresponding parts.

Head. This is the excess energy content of the liquid per unit weight above that of still liquid at absolute zero pressure at the positional datum, expressed in units of length.

It comprises three components:

- i) *Pressure head.* The pressure energy per unit weight of the liquid, it is equal to:

$$\frac{\text{absolute pressure}}{\text{weight density at atmospheric pressure and test temperature}} \times \left(1 - \frac{\text{absolute pressure}}{2 \times \text{bulk modulus of fluid at test temperature}} \right)$$

In many cases the second term in brackets may be neglected (i.e. the fluid may be considered incompressible). For the purpose of this standard, this may be done when the value of the expression

$$\left(\frac{\text{absolute pressure} \times 100}{2 \times \text{bulk modulus of fluid at test temperature}} \right)$$

is one quarter or less of the permissible percentage for the appropriate class of pressure measurement.

NOTE Where the test temperature exceeds the boiling point of the liquid at atmospheric pressure, which is the case with many boiler feed pumps, the pressure head may be taken as the absolute pressure multiplied by the mean specific volume. The mean specific volume should be the arithmetic mean of the actual specific volume at the pump inlet and the specific volume corresponding to pump inlet entropy and pump outlet pressure. For water these values can be obtained from steam tables.

- ii) *Positional head* Positional head at any point in a liquid is the height of that point above the positional datum.

- iii) *Velocity head.* The kinetic energy per unit weight of the liquid. It is defined by the expression:

$$h_v = \frac{V^2}{2g}$$

Total inlet head. (H_i) The algebraic sum of the pressure head, the positional head, and the velocity head at the point of measurement on the inlet side of the pump.

Total outlet head. (H_o) The algebraic sum of the pressure head, the positional head and the velocity head at the point of measurement on the outlet side of the pump.

Pump total head. The head imparted to the liquid by the pump. It is the excess of the outlet head over the inlet head, ($H_o - H_i$).

Net positive suction pressure head, (NPSH) more accurately termed the *Net positive inlet head*, is the inlet head less the vapour pressure of the liquid expressed in feet of the liquid pumped.

Power. This is expressed in units of horsepower:

One horsepower is equivalent to 33 000 ft lb/min (745.700 watts).

Pump power input. The power absorbed by the pump, as measured at the pump input shaft.

Volume. This is expressed in either U.K. gallons or cubic feet or cubic metres.

1 U.K. gallon = 0.160 544 ft³ (0.004 546 092 m³).

Discharge (volume rate of flow). This is the volume rate of flow and shall be expressed in either gallons per minute (gal/min) or cubic feet per second (ft³/s) or cubic metres per second (m³/s).

Weight density. The weight per unit volume of a liquid expressed in pounds per cubic foot (lb/ft³) or kilogrammes per cubic metre (kg/m³).

Pump power output (water horsepower). This is defined by the expression:

$$P_o = \frac{Q_c(H_o - H_i)w}{550} = \frac{Q_g(H_o - H_i)w}{6.235 \times 33\,000}$$

Normal test condition. For the purposes of this standard a representative operating condition shall be selected, which shall be known as the normal test condition.

Pump efficiency. The ratio of the pump power output to the pump power input.

Overall efficiency. The ratio of the pump power output to the rate of input of energy to the driving unit.

Driving unit efficiency. The ratio of the output power of the driving unit to the rate of input energy to the driving unit.

Definitions

The *positional datum* for centrifugal, mixed flow or axial flow pumps shall be taken as the elevation of highest point of entrance edges of the first stage impeller-blades, whatever the disposition of the shaft.

For reciprocating pumps the positional datum shall be taken as that of the horizontal plane through the centre of gravity of the volumes

For other pumps the nearest equivalent elevation to the above shall be taken.

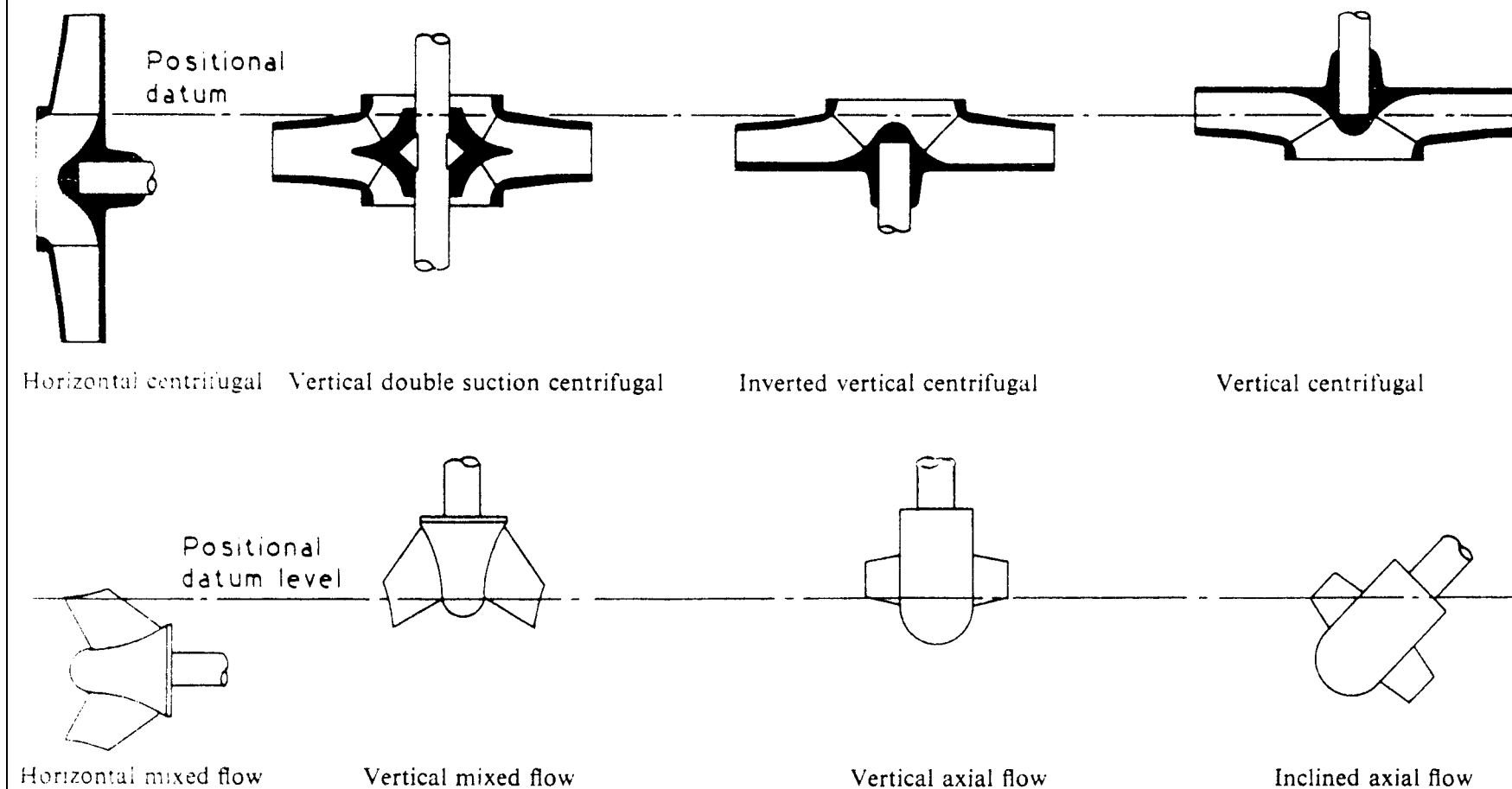


Figure 1 — Illustration defining the positional datum for different types of impeller pumps

Section 3. Test procedure and test installation conditions

5 Hydraulic pressure test

All parts of the pump subject to pressure shall be submitted to a hydraulic test pressure not less than $1.5 \times$ the maximum pressure which can occur within the pump, for a minimum period of five minutes, or such maximum pressure plus $1\,000\text{ lbf/in}^2$ (70.3070 kgf/cm^2) ($6.894\,76 \times 10^6\text{ N/m}^2$), whichever is the less.

6 Duration and range of performance test

To verify the mechanical conditions of the pump it shall be run continuously for not less than one hour. The duration of the test shall be sufficient to attain consistent results within this period.

Each test run shall begin only when steady test conditions have been established.

All measurements relating to a single test condition shall be taken simultaneously.

The time of all readings must be recorded and where multiple readings are taken to reduce random errors (see Clause 24) they shall be taken at equal intervals of time.

As far as possible results should be computed as the test proceeds so that any errors and inconsistency in reading can be detected and investigated during the test.

Where it is necessary to determine performance over a range of operating conditions a sufficient number of observations shall be taken to establish the performance within the limits of error stated in Section 4.

7 Control of head

The head required for testing may be obtained by throttling in the outlet pipe. If it is necessary to reduce the inlet pressure by throttling in the inlet pipe reference should be made to Section 5, Clause 27.

8 Test arrangements

a. Standard test conditions. Ideally a pump should be tested under the conditions in which it is intended to be used. A standard test arrangement should be used if site conditions permit, or are unknown, or do not need to be considered. This arrangement is described below, together with other permissible arrangements.

i) *Inlet connections.*

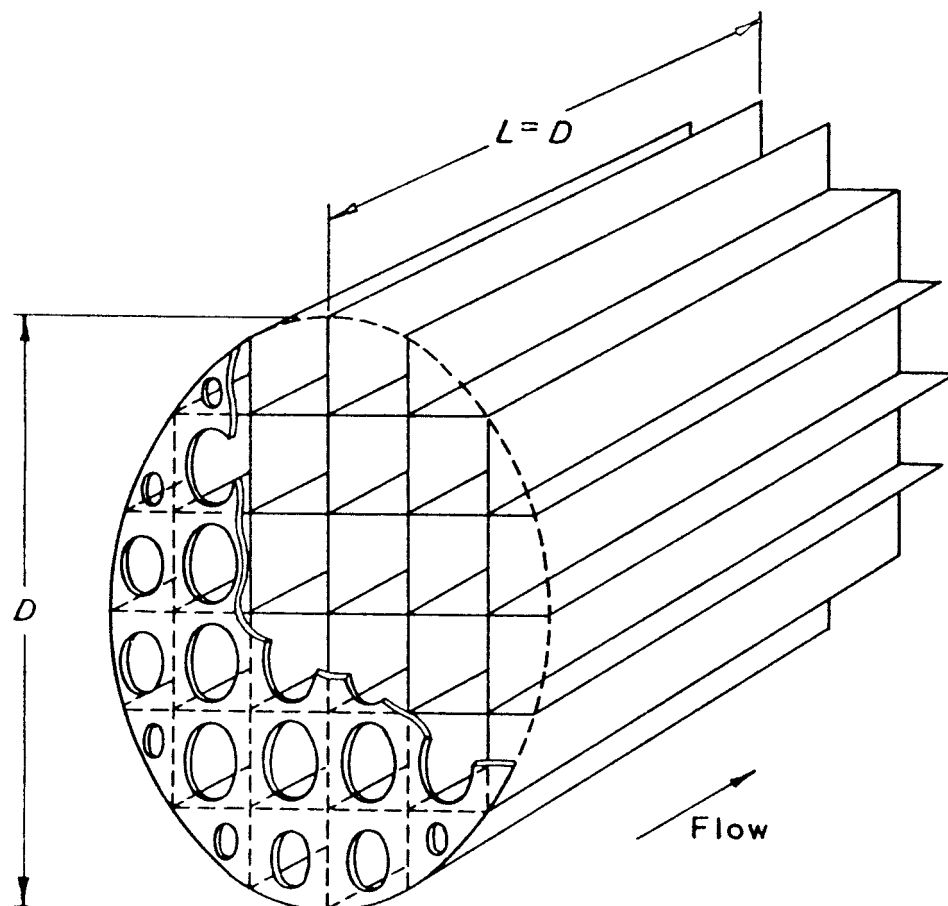


Figure 2a.

Figure 2a and Figure 2b are taken from BHRA reports numbers SP 625 and PR 685.
See Foreword.

Figure 2 — Flow normalizer

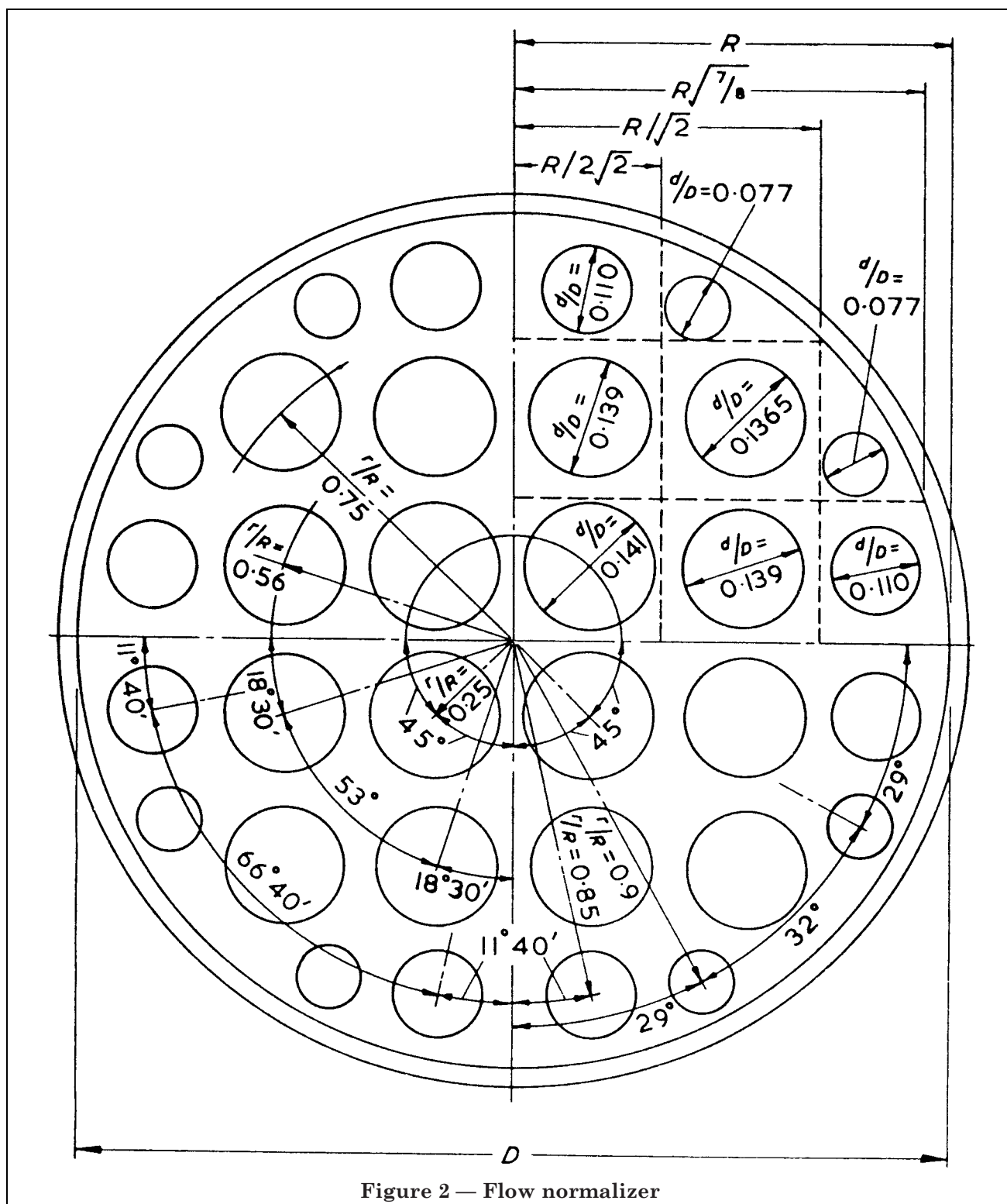


Figure 2 — Flow normalizer

A flow normalizer of diameter larger than that of the pump inlet may be used with a straight taper pipe at the outlet end, but the specified length of parallel pipe must still be included.

Where the inlet velocity head does not exceed 5 per cent of the pump total head the inlet conditions may be as specified for Class B measurements.

The nominal bore of the straight parallel pipe shall be the same as the bore of the pump inlet to which it is connected.

ii) *Outlet connections.*

The nominal bore of the straight parallel pipe shall be the same as the bore of the pump outlet to which it is connected.

b. Pumping installation under standard conditions. Standard tests can be carried out on a combination of a pump and associated fittings of the final site installation or an exact reproduction thereof or fittings introduced for testing purposes and taken as forming part of the pump itself, provided that connections on the inlet and outlet sides of the whole combination can be made in accordance with Subclause 8 a. Measurements shall then be taken in accordance with Subclauses 10 a i) and 10 b i).

c. Pumping installation under submerged conditions. Where a pump, or a combination of a pump and its fittings, is tested or installed in conditions where standard connections on either inlet or outlet as described in Subclause 8 a cannot be made owing to inaccessibility or submergence, measurements shall be taken in accordance with Subclauses 10 a iii) and 10 b iii).

d. Borehole and deep-well pumps. Borehole and deep-well pumps cannot usually be tested with their complete lengths of delivery main, and consequently the loss of head in the portions omitted, and the power absorbed by any shafting therein, cannot be measured. A thrust bearing, if fitted, would also be more lightly loaded than when eventually installed.

It is preferable, therefore, that the specified normal test condition (see Clause 4) of a pump of this type should be based upon the conditions under which measurements can actually be made. The measurements of head shall then be taken in accordance with Subclause 8 a and 8 b. Additional losses of head and power caused by the remainder of the installation can then be assessed and the overall performance confirmed by the test on site, if required.

e. Self-priming pumps. When a pump is specified to be self-priming it shall be tested at the specified elevation above the still surface of the liquid and drawing through an inlet pipe of the specified volume and disposition both vertical and horizontal.

When the pump is specified to deal with a mixture of water and air, it shall be tested with a controlled inlet of air, through a calibrated device for air measurement.

When the pump is to be tested at a position where the local barometric pressure differs from that specified or where the liquid is other than cold water, steps shall be taken to ensure that the NPSH conforms with that under the specified condition.

f. Pumping installation under non-standard conditions. Where it is impracticable to test a pump in accordance with the standard test conditions specified in Subclauses 8a and 8b, or where alternatively it is required to ascertain the performance of a pump, not under standard conditions, but under the conditions in which it will work when installed, or where it is desired to test the performance of a pumping installation including items other than the pump itself, then the following decisions shall be made and recorded with the test results:

- i) The precise range of the items to be included in the installation to be tested.

NOTE Where auxiliary plant is involved, whether the consumption of each individual item is or is not to be debited to the installation.

- ii) The exact positions in the proposed layout at which inlet head and outlet head (or their difference) are to be measured.
- iii) The point in the circuit, the flow past which is to be credited to the installation.
- iv) The nature of the supply of energy (e.g. mechanical, electric, fuel, steam, hydraulic, pneumatic).
- v) The position, or positions, at which the supply of energy is to be measured.
- vi) The method as laid down in the foregoing specification which is to be used for hydraulic measurements; the method as laid down in other relevant British Standards to be used for the measurement of power, fuel, etc., both quantitative and, where necessary, qualitative; the method of measurement to be used where no British Standard exists.
- vii) The extent to which the conditions pertaining during the tests may vary from the specified conditions.
- viii) Where lubricating oil or other consumable stores are to be taken into consideration, the methods of measurement to be used for these.
- ix) The proposed date(s), usually referred to the date of installation, of the tests, their duration and the frequency with which readings are to be taken.

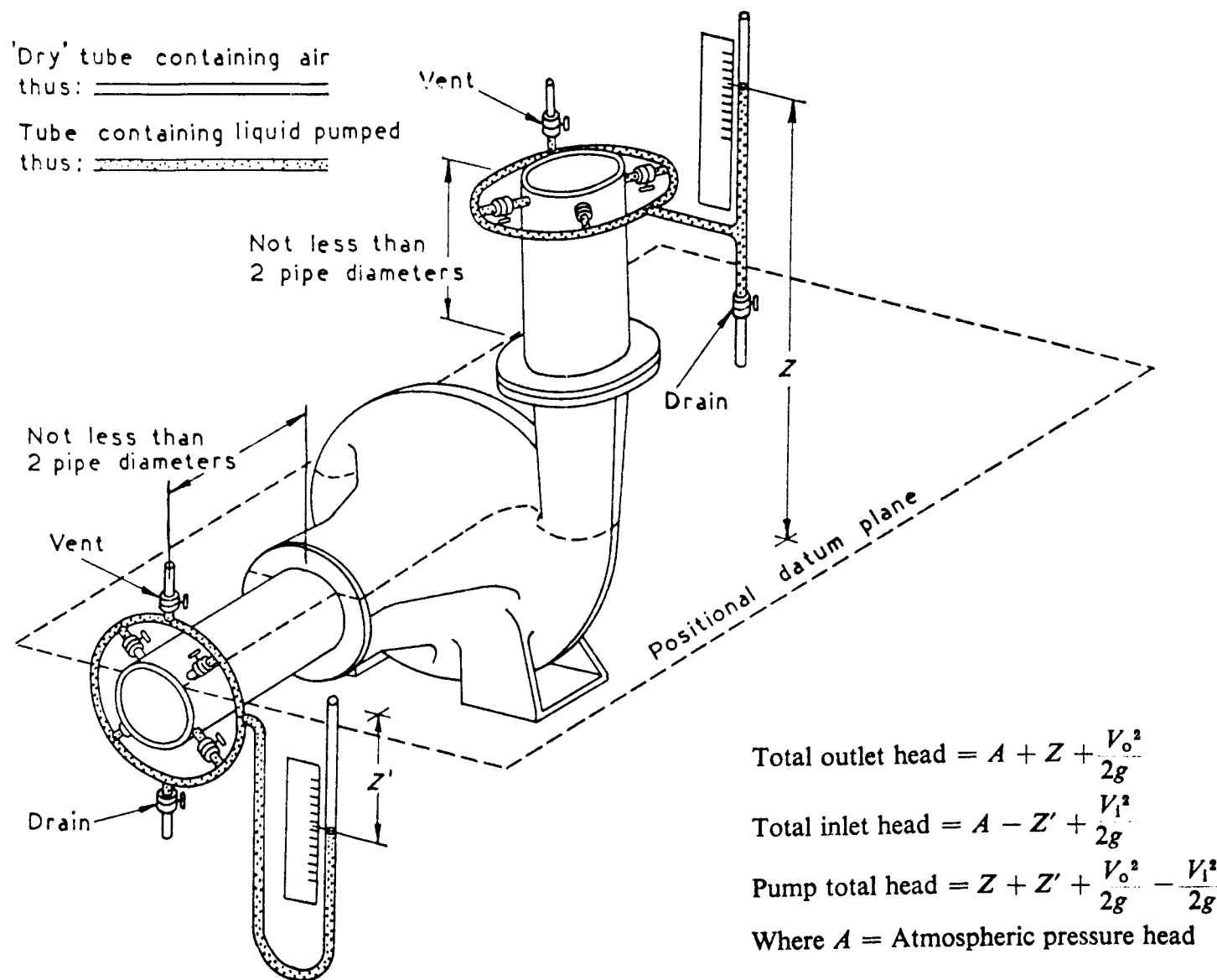


Figure 3a — Ring connections for measurement of head using liquid pumped in manometers