



ESDU 66030

Issued October 1966
Reprinted at Amendment C
March 2007

Pressure losses in flowmetering devices

ESDU Copyright material. For current status contact ESDU.

Endorsed by
The Institution of Mechanical Engineers

AVA Documents
Document Sharing Hub

ESDU DATA ITEMS

Data Items provide validated information in engineering design and analysis for use by, or under the supervision of, professionally qualified engineers. The data are founded on an evaluation of all the relevant information, both published and unpublished, and are invariably supported by original work of ESDU staff engineers or consultants. The whole process is subject to independent review for which crucial support is provided by industrial companies, government research laboratories, universities and others from around the world through the participation of some of their leading experts on ESDU Technical Committees. This process ensures that the results of much valuable work (theoretical, experimental and operational), which may not be widely available or in a readily usable form, can be communicated concisely and accurately to the engineering community.

We are constantly striving to develop new work and review data already issued. Any comments arising out of your use of our data, or any suggestions for new topics or information that might lead to improvements, will help us to provide a better service.

THE PREPARATION OF THIS DATA ITEM

The work of the Engineering Sciences Data Unit on this series is monitored and guided by Technical Committees of the Institution of Mechanical Engineers. The Committee responsible for this particular Memorandum was the Fluid Mechanics and Thermodynamics Committee, which had the following constitution:

Chairman	
Prof. A.J. Ede	— University of Aston in Birmingham
Vice-Chairman	
Mr E.C. Firman	— Central Electricity Research Laboratories
Members	
Dr A.D. Carmichael	— Imperial College of Science and Technology
Mr A.G. Chapman	— Associated Electrical Industries
Mr M.D.C. Doyle	— University of Liverpool
Mr A. Linford	— The British Hydromechanics Research Association
Dr D.L. Linning	— United Kingdom Atomic Energy Authority
Mr G.J.F. Reid	— British Petroleum Co. Ltd
Miss B. Shilling	— Royal Aircraft Establishment.

The members of the staff of the Engineering Sciences Data Unit concerned were:

Mr A.J. Ward Smith	— Head of Fluid Mechanics and Thermodynamics Group
Mr B.C. Freeman	— Fluid Mechanics and Thermodynamics Group.

The Fluid Mechanics and Thermodynamics Committee, which first met in May 1964, has the co-operation of many engineers and scientists in industry, research establishments and universities from whom much assistance and unpublished information is being received. Particular assistance with the preparation of this Item had been received from Mr W.J. Ramsay of the National Engineering Laboratory.

PRESSURE LOSSES IN FLOWMETERING DEVICES

CONTENTS

	Page
1. NOTATION AND UNITS	1
2. INTRODUCTION	3
3. CALCULATION OF PRESSURE LOSS	3
4. METER CLASSIFICATION	4
4.1 Volumetric Flowmeters	4
4.1.1 Differential pressure devices	4
4.1.2 Variable area devices	4
4.1.3 Inferential meters	5
4.1.4 Displacement meters	5
4.2 Mass Flowmeters	5
4.3 Other Types of Flowmeter	6
4.4 Sources of Further General Information	6
5. PRESSURE LOSS CHARACTERISTICS	7
6. REFERENCES	9
7. EXAMPLES	10
8. TABLES	13
9. PRESSURE LOSS MEASUREMENT	19
FIGURES 1-6	20-25

PRESSURE LOSSES IN FLOWMETERING DEVICES

1. NOTATION AND UNITS

Any coherent set of units may be used. Two such sets are indicated below.

		SI	British fps
A	internal cross-sectional area of meter entry	m^2	ft^2
C_K	meter pressure-loss coefficient (see Equation (5.1))	–	–
D	nominal internal diameter of meter entry	m	ft
g	local acceleration due to gravity*	m/s^2	ft/s^2
h	flowmetering pressure difference [†] (see Sketch 9.1)	m	ft
Δh	loss of head of flowing fluid due to meter (corresponding to pressure loss Δp)	m	ft
M	mass flow rate through meter	kg/s	lb/s
m	area ratio = (minimum cross-sectional area in meter)/(meter entry area)	–	–
p	static pressure (absolute)	N/m^2	pdl/ft^2
Δp	pressure loss due to meter [†] (see Sketch 9.1)	N/m^2	pdl/ft^2
Q	volume flow rate = M/ρ	m^3/s	ft^3/s
Re_D	Reynolds number based on meter entry diameter [‡] = VD/ν	–	–
V	mean velocity = Q/A	m/s	ft/s
μ	dynamic viscosity**	N s/m^2	pdl s/ft^2
ν	kinematic viscosity = μ/ρ	m^2/s	ft^2/s
ρ	density	kg/m^3	lb/ft^3

* For the purposes of this Item the difference between the local gravitational acceleration and the standard value is not significant and g may be taken as 9.81 m/s^2 or 32.2 ft/s^2 .

[†] The British Standard, B.S. 1042 (Reference 2), defines a pressure difference, h , across differential pressure devices. This is measured between standardised points on or close to the device and is used only for flowmetering purposes. It is not the same as the pressure loss (Δp) referred to in this Item. Sketch 9.1 shows a typical example of the measurement of the pressure difference, h .

[‡] For differential pressure devices, B.S. 1042 uses a Reynolds number based on the minimum internal diameter of the device.

** The symbol η is often used to denote dynamic viscosity.

Issued October 1966 – 25 pages
Reprinted at Amendment C – March 2007

Suffixes

<i>a</i>	value at mid-range flow rate
<i>G</i>	gross value (see Sketch 9.1)
<i>N</i>	net value (see Sketch 9.1)

Conversion factors

Pressure:	$1 \text{ pdl/ft}^2 = 215.8 \times 10^{-6} \text{ lbf/in}^2 = 1.488 \text{ N/m}^2$
Flow rate:	$1 \text{ UKgal/min} = 1.201 \text{ USgal/min} = 2.676 \times 10^{-3} \text{ ft}^3/\text{s} = 75.77 \times 10^{-6} \text{ m}^3/\text{s}$
Kinematic viscosity:	$1 \text{ cSt} = 1 \times 10^{-6} \text{ m}^2/\text{s} = 10.76 \times 10^{-6} \text{ ft}^2/\text{s}$
Dynamic viscosity:	$1 \text{ cP} = 1 \times 10^{-3} \text{ N s/m}^2 = 671.97 \times 10^{-6} \text{ pdl s/ft}^2$
Density:	$1 \text{ lb/ft}^3 = 16.02 \text{ kg/m}^3$

2. INTRODUCTION

This Item gives approximate pressure loss information for a wide range of flowmeters operating under turbulent flow conditions. It is assumed that any flow disturbing elements in the pipe line (e.g. valves, bends, area changes) are sufficiently far from the meter to have no appreciable effect on its pressure loss. The data are based on information supplied by manufacturers of flowmeters and on the British Standard, B.S. 1042, Part 1, 1964 on flow measurement.

The information is presented in the form of a non-dimensional pressure loss coefficient plotted against nominal meter size or, for differential pressure devices, against meter area ratio. For differential pressure devices the data given here are accurate to within a few per cent but for inferential and displacement meters it is possible to give only approximate data. There are two principal reasons for this difference. The first arises because there is no standardisation of inferential and displacement meters, and there is, in general, a lack of geometrical similarity between meters of different sizes and from different manufacturers. The second reason arises from fluid dynamic considerations. Sketch 9.1 shows how the presence of a meter may considerably affect the axial pressure distribution in a pipe line. Close to the meter variations around the perimeter of the pipe may also occur. The data given here for differential pressure devices are based on measurements at standardised positions which are in regions of fully-developed flow. For inferential and displacement meters no standard procedures for pressure loss measurement exist and variations in the positioning of the pressure tapings are a probable source of scatter of the data for these meters.

It is emphasised that the question of metering accuracy is quite different from the question of the accuracy of the pressure loss data quoted in this Item. The accuracy of metering is not considered here.

3. CALCULATION OF PRESSURE LOSS

Figures 1, 3 and 5 present values of the pressure loss coefficient, C_K , for a number of flowmeters. Figures 4 and 6 allow the effect of variation in Reynolds number to be taken into account where necessary. Table 8.1 indicates the appropriate figures to be used for each meter.

When C_K has been found the pressure loss Δp is given by

$$\Delta p = C_K \times \frac{1}{2} \rho V^2. \quad (3.1)$$

The corresponding head loss, $\Delta h (= \Delta p / \rho g)$, in terms of fluid flowing is given by

$$\Delta h = C_K \times \frac{V^2}{2g}. \quad (3.2)$$

If SI units are used, the pressure loss is given directly in N/m^2 and the head loss in metres of fluid flowing. When foot-pound-second units are used, Δp is given in pdl/ft^2 and Δh in feet. Δp may be converted to lbf/in^2 by using the conversion factor from Section 1. The head loss may be expressed in terms of head of water by multiplying the value obtained from Equation (3.2) by the specific gravity of the fluid flowing.

For examples of these calculations see Section 7. Section 9 provides information on pressure loss measurement.

4. METER CLASSIFICATION

This section gives the main groups into which flowmeters may be classified. Table 8.1 describes various individual types of meter within each main group.

4.1 Volumetric Flowmeters

4.1.1 Differential pressure devices

Devices of the orifice plate, venturi tube and nozzle type are among the most widely used of flowmeters. They are normally manufactured to standard specifications, of which British Standard 1042, Part 1, 1964 is most common in UK practice. Some examples of these meters are given in Table 8.1 (Section 1.1) and some pressure loss coefficient data are given in Figures 1 and 2. See also ESDU 81039 and 82009 for more detailed information on pressure losses through orifice plates.

4.1.2 Variable area devices

The most common type of variable area meter takes the form of a free float in a tapered tube. The float is always of greater density than the fluid flowing and the tapered tube is mounted with its axis vertical and with the larger bore at the top. The meter inlet is at the bottom.

The apparent weight of the float is supported by the pressure difference caused by the fluid flowing through the annular space between the rim of the float and the wall of the tube. Since the apparent weight of the float depends only on the float density and the fluid density, the theoretical pressure drop across the float is constant over the working flow range of the meter. The constant pressure difference is maintained by the float rising and increasing the annular area for flow at the increased flow rates.

Since the tapered tube has to be maintained with its axis vertical, pressure loss in addition to that across the float may be incurred as a result of changes in the pipework necessary to accommodate the meter. Inlet and outlet connection losses may also be present. The overall pressure loss is also influenced by any pressure recovery which may occur downstream of the float.

The variables involved do not permit an analysis on the basis of a pressure loss coefficient versus meter diameter. A theoretical expression for the loss coefficient for the float takes the form

$$C_K = \frac{v_f(\rho_f - \rho)g}{\frac{1}{2}\rho V^2 A_f}, \quad (4.1)$$

where v_f and A_f are the volume and maximum cross-sectional area of the float, ρ_f , and ρ are the float and fluid densities (for hollow or composite floats ρ_f = total weight/total volume) and V is the flow velocity at the meter inlet.

The overall pressure loss coefficient is usually of the order of 1.25 to 2 times the value given by Equation (4.1).

As a guide, the overall loss may be as low as ¼ inch water gauge when metering small volumes of gas flow and up to some 4 lbf/in² when using a large meter, of the order of 8 inches bore, for metering large volumes of liquid flow. When a small pressure loss is important, a larger size meter with a lighter float is selected.

The majority of tapered tube and float meters used in industry use a glass tube, but metal tapered tubes are also widely used. Other forms of industrial significance are those employing a guided disc in a metal tapered tube, a hinged gate, or a variable orifice arrangement.

Some types of variable area meter are shown in Table 8.1 (Section 1.2).

4.1.3 Inferential meters

This type of meter infers flow rate from the measurements of another parameter of the flow. This is commonly the velocity imparted by the fluid to a movable element within the meter.

Individual types of inferential flowmeter are shown in Table 8.1 (Section 1.3) and pressure loss coefficient data are provided in Figure 3.

4.1.4 Displacement meters

This type of meter divides the flow into a series of "unit volumes" and counts the number of these passing through the meter.

Two subdivisions of displacement meters may be distinguished.

- (a) Meters in which the fluid flows through valved ports into the measuring chamber, usually characterised by sharp changes in flow direction and consequently high pressure loss (*e.g.* piston in cylinder meters).
- (b) Meters in which the measuring chamber is formed smoothly and continuously by moving elements (*e.g.* meshing rotor meters).

Individual types of displacement meter are shown in Table 8.1 (Section 1.4) and pressure loss coefficient data in Figure 5.

4.2 Mass Flowmeters

The mass flow rate of a fluid may be metered by measuring the angular momentum imparted to the fluid by some form of element rotated at constant speed. The angular momentum transferred to the fluid in unit time is then proportional to the mass flow rate. Meters working on this and similar principles are referred to as being of the true mass flow type.

In the inferential forms of mass flowmeter, a mass flow reading may be obtained by calibrating one of the foregoing volumetric meters for a particular fluid under specified conditions. In some cases automatic correction for temperature and pressure variations may be available.

In the case of the tapered tube variable area meter, if the float density is made equal to twice the average density of the metered fluid (which must be a liquid), a close approximation to a mass flow reading is obtained. For example, a 10 per cent variation of the liquid density from its average value produces only a 0.5 per cent error in mass flow reading.

This page Amendment B

4.3 Other Types of Flowmeter

Two special forms of flowmeter are the electromagnetic and ultrasonic meters. In both cases the bore of the meter can be the same as that of the pipe into which it is fitted, in which case the pressure loss is negligible.

In the shunt meter the flow rate in a large main pipe is inferred from the flow rate induced in a smaller line which generally by-passes an orifice in the main line. The flow measurement in the by-pass may employ any type of meter.

When the required range of flow rate measurement is very large, two sub-meters in parallel may be used, a small one for low flow rates and a larger one or both together for high rates. The sub-meters may be of inferential or displacement types. This type of meter, which may be described as a compound or combination meter, is distinguished from the shunt meter by the inclusion of a valve to direct the flow through the appropriate sub-meter.

The three-quarter radius flowmeter is also used in circular pipes. This consists essentially of a pitot tube at three-quarters of the radius from the axis of the pipe, together with wall static pressure tapings. For fully-developed turbulent flow the mean velocity occurs at approximately this point. The pressure loss, because it is determined by the obstruction caused by the pitot tube, is negligible except in very small pipes.

4.4 Sources of Further General Information

Further descriptive information is given in Table 8.1 and general information on flow measurement and flowmeters may be obtained from References 1 and 2 and from manufacturers' brochures.

This page Amendment B