

FLOWMETERS

A BASIC GUIDE AND SOURCE-BOOK FOR USERS

Alan T. J. Hayward

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First published 1979 by
THE MACMILLAN PRESS LTD
London and Basingstoke
Associated companies in Delhi Dublin
Hong Kong Johannesburg Lagos Melbourne
New York Singapore and Tokyo

Typeset by
Reproduction Drawings Ltd, Sutton, Surrey
Printed in Great Britain by
Unwin Brothers Limited, The Gresham Press
Old Woking, Surrey

British Library Cataloguing in Publication Data

Hayward, A T J

Flowmeters.

1. Flow meters

I. Title

532'.053

TC177

ISBN 0-333-21920-1

This book is sold subject to the standard conditions of the Net Book Agreement

FLOWMETERS

By the Same Author

INSTRUMENTATION

Repeatability and Accuracy, Mechanical Engineering Press, 1977

SCIENCE AND RELIGION

God Is—A Scientist Shows Why it Makes Sense to Believe in God, Marshall, Morgan and Scott, 1978

God's Truth—A Scientist Shows Why it Makes Sense to Believe the Bible, Marshall, Morgan and Scott, 1973

Planet Earth's Last Hope—The Christian Answer to the Environmental Crisis, Marshall, Morgan and Scott, 1973

To Peggy

Who has given me —

— thirty years of happy married life

— two fine children

— and her loyal support while I have struggled through the production of half a dozen books (although only another author's wife will be able to appreciate what that means!)

Preface

My main aim in this book has been to tell the man in the works office, who probably has an overflowing in-tray and a harassed look on his face, almost everything he really needs to know about fluid flowmeters. What I have tried to do is to state in simple language:

- (1) just enough about every important kind of flowmeter to help him decide which is—and, perhaps more significantly, which is not—suitable for use in any combination of circumstances he is likely to come across;
- (2) how to use flowmeters to their best advantage, thus saving both time and money, and what to do when their performance falls off;
- (3) the best places to obtain further information on any particular aspect of flow metering.

With any luck this means that the book will tell him the answer to 90 per cent of his questions, and will advise him where to find an answer to nine out of the remaining ten. That leaves one question in a hundred which, in all probability, simply cannot be answered by anyone at present—otherwise there would be no justification for all those fellows beaver away in research laboratories.

The plan of the book is quite simple and can be seen at a glance from the detailed table of contents. This should enable the reader to find his way about in it easily. Although the book is intended for straightforward reading there is a detailed index at the end and a flowmeter selection table in Chapter 9, which should make things easy for the enquirer with no time to spare who wants to use the book as a work of reference.

To keep the book small it has been necessary to cut out nearly all the frills. Above all else a user wants to know exactly what a flowmeter will do, and to a limited extent he is interested to see how it does it. However, he is unlikely to enthuse about the finer points of theory and the long, contorted trail of engineering evolution which lies behind today's model.

So I have taken all the mathematical proofs for granted and resolutely refused to explore any fascinating but profitless blind-alleys. Likewise, the bibliography at the end of the book is not designed to show how much (or how little!) the author

has read: it is there to point the way to the relatively few books, standard specifications and original papers of first-rate importance.

There has been no attempt to mention every individual flowmeter on the market, of which there are certainly hundreds and possibly thousands; that would have been rather pointless, and quite impossible in a short book. Instead, I have tried to describe every class of flowmeter which, in my opinion, it is well worth a mechanical or chemical engineer's while to know about—and that has still necessitated describing several dozen basic types. (Civil engineers may feel disappointed that there is no mention of weirs and flumes and other structures used to measure the flow of rivers and open channels. I am sorry about this omission, but there are two good reasons for it: opinions differ on whether these can properly be classed as flowmeters and I have used up my whole ration of space, anyway.)

However, I may well have failed to meet even this limited objective. New flowmeters are coming on the market almost every year and one or two valuable devices could easily have been overlooked. If so, it may be possible to rectify the omissions in a future edition or reprint. Should you have a pet flowmeter which to your great disappointment has not been mentioned, do please send me some information about it. Obviously I cannot promise to adopt every suggestion sent to me, but they will all be considered carefully.

Leamington Spa, 1979

A.T.J.H

Acknowledgements

When I began writing this book I had the good fortune to be working in the Flow Measurement Division of Britain's National Engineering Laboratory—an organisation which is justly proud of its reputation as the 'flow measurement centre for Europe'. I am grateful to the Director of NEL for allowing me to publish the book, and for permission to reproduce a number of illustrations from NEL publications.

On a more personal level, I am deeply indebted to a number of friends who read the first draft of those chapters where they felt most at home and suggested a great many improvements. In particular, I am grateful to Dr E A Spencer, the Head of Flow Measurement Division, NEL, who gave me much useful information as well as commenting upon the full text of the first draft. Mr R S Medlock, the former Technical Director of the George Kent Group, also gave most generously of his time to work through the complete text. Helpful comments were made on portions of the first draft by Professor R C Baker, Dr T J S Brain, Mr B C Ferguson, Mr R W F Gould, Mr P Harrison, Dr J J Hunter, Mr K I Jespersen, Dr F C Kinghorn, Mr L M Macdonald, Dr W C Pursley and Mr R W W Scott.

Finally, I must express my gratitude to two other friends and former colleagues: Mr A M Nicolson who edited the text and gave a great deal of useful advice on the preparation of the illustrations, and Mrs Bessie Pollock who traced all the line diagrams and graphs.

Notation

A	Cross-sectional area of pipe
B	Magnetic flux density
C	Coefficient of discharge of a flowmeter, ($=Q_T/Q_I$) or other dimensionless calibration coefficient
c	Concentration of one substance in another
c_p	Specific heat capacity at constant pressure
D	Diameter of pipe
d	Diameter of a constriction—for example, the throat of a venturi tube
F	Meter factor ($=V_T/V_I$)
f	Frequency
g	Acceleration of gravity
H	Power supplied in the form of heat; or, height
H_n	Hodgson number
K	' K -factor' ($=n/V_T$)
K_n	Nominal K -factor
L	Length
M	Mass
m	Area ratio ($=A_2/A_1$ where A_2 and A_1 are throat and upstream cross-sections, respectively)
n	Meter pulse count
P	Pressure
δP	Pressure difference
Q	Flowrate
Q_I	Indicated flowrate
Q_M	Mass flowrate ($=dM/dt$)
Q_T	'True' flowrate (as measured by a calibration standard)
Q_V	Volumetric flowrate ($=dV/dt$)
q	One-pulse volume ($=1/K$)
R	Radius
Re_D	Reynolds number (based on pipe diameter) ($=\rho\bar{v}D/\eta$)
Re_d	Reynolds number (based on meter throat diameter)

T	Temperature
t	Time
U	Voltage
V	Volume
V_I	Indicated volume
V_s	Specific volume ($= V/M$)
V_T	'True' volume (as measured by a calibration standard)
v	Velocity at a point
v_I	Indicated velocity
v_T	'True' velocity (as measured by a calibration standard)
\bar{v}	Mean velocity over a cross-section
Y	Flowmeter readout
β	Thermal expansion coefficient ($= \{1/V_s\} \{dV_s/dT\}$); or, diameter ratio ($= d/D$)
γ	Shear strain
$\dot{\gamma}$	Rate of shear strain
Δ	Meter correction ($= \{V_T - V_I\}/V_I$)
ϵ	Expansibility factor
η	Viscosity ($= \tau/\dot{\gamma}$)
κ	Compressibility ($= -\{1/V_s\} \{dV_s/dP\}$)
ν	Kinematic viscosity ($= \eta/\rho$)
ρ	Density
τ	Shear stress

Contents

<i>Preface</i>	xvi
<i>Acknowledgements</i>	xviii
<i>Notation</i>	xix
1 Basic Principles of Fluid Flow	1
1.1 Some Important Properties of Fluids	1
1.1.1 Density and specific volume	1
1.1.2 Thermal expansion coefficient	1
1.1.3 Compressibility	2
1.1.4 Viscosity	2
1.1.5 Air solubility of liquids	4
1.1.6 Humidity in gases	5
1.2 Some Important Principles of Pipe Flow	5
1.2.1 Reynolds number	5
1.2.2 Laminar and turbulent flow	6
1.2.3 Velocity profile	7
1.2.4 Rotation and swirl	7
1.2.5 Continuity and Bernoulli's equation	8
1.2.6 Velocity head	8
1.2.7 Cavitation	9
1.2.8 Double-block-and-bleed valve systems	9
Reference	10
2 Basic Principles of Flow Measurement	11
2.1 What Do You Want to Measure?	11
2.1.1 Point velocity measurement	11

2.1.2	Mean pipe velocity measurement	11
2.1.3	Volumetric flowrate measurement	12
2.1.4	Total volume measurement	12
2.1.5	Mass flowrate measurement	12
2.1.6	Total mass measurement	13
2.2	Characteristic Curves	13
2.2.1	Linear and non-linear flowmeters	13
2.2.2	Use of a flowmeter performance index	13
2.2.3	Coefficient of discharge	14
2.2.4	Meter correction	15
2.2.5	Meter factor	15
2.2.6	<i>K</i> -factor	15
2.3	Properties of Measuring Instruments	16
2.3.1	Discrimination	16
2.3.2	Repeatability	18
2.3.3	Accuracy	18
2.3.4	Effective range and rangeability	18
2.3.5	Linearity	19
	References	19
3	Differential Pressure Meters	20
3.1	Introduction	20
3.1.1	Advantages	20
3.1.2	Disadvantages	20
3.1.3	Basic principles	21
3.1.4	Selecting a differential pressure meter	22
3.2	Venturi Tubes	22
3.3	Orifice Plates	24
3.3.1	General principle	24
3.3.2	Concentric orifice plates	25
3.3.3	Eccentric and chord orifice plates	26
3.3.4	Integral orifice plates	26
3.3.5	Orifice plates with bypass flowmeters	26
3.4	Nozzles	27
3.4.1	Nozzles as differential pressure meters	27
3.4.2	Sonic nozzles for gas flow	27
3.5	Proprietary Low-loss Differential Pressure Meters	28
3.6	Points to Watch When Using	29
3.7	Where to Learn More	30
	References	31

4 Other Flowrate Meters Utilising Pressure Difference	33
4.1 Drag-plate, or Target, Flowmeters	33
4.1.1 How they work	33
4.1.2 Advantages	34
4.1.3 Disadvantages	34
4.1.4 When to use them	35
4.2 Rotameters	35
4.2.1 How they work	35
4.2.2 Advantages and disadvantages of the transparent-tube type	36
4.2.3 Advantages and disadvantages of the metal-tube type	37
4.2.4 When to use them	37
4.3 Spring-loaded Variable-aperture Flowmeters	37
4.3.1 How they work	37
4.3.2 Advantages	39
4.3.3 Disadvantages	40
4.3.4 Points to watch when buying	40
4.4 Other Types of Variable-aperture Flowmeter	40
4.5 Laminar Flowmeters	40
4.5.1 How they work	40
4.5.2 Advantages	41
4.5.3 Disadvantages	42
4.6 Where to Learn More	42
References	42
5 Rotating Mechanical Meters	44
5.1 Positive Displacement Meters for Liquids	44
5.1.1 How they work	44
5.1.2 Performance characteristics	46
5.1.3 Advantages	47
5.1.4 Disadvantages	47
5.1.5 Points to watch when buying and using	48
5.2 Positive Displacement Meters for Gases	48
5.2.1 How they work	48
5.2.2 The Roots meter	48
5.2.3 The CVM meter	49
5.2.4 Diaphragm meters	50
5.2.5 Wet gas meters	51
5.2.6 Servo-driven meters	52
5.3 Turbine Meters for Liquids	52
5.3.1 How they work	52

5.3.2	Advantages	55
5.3.3	Disadvantages	55
5.3.4	Points to watch when buying	56
5.3.5'	Points to watch when using	56
5.4	Turbine Meters for Gases	56
5.4.1	How they work	56
5.4.2	Advantages and disadvantages	58
5.4.3	When to use them	58
5.5	Miniature Pelton Wheel Meters	58
5.5.1	How they work	58
5.5.2	When to use them	59
5.6	Mass-produced Total-volume Rotary Meters	59
5.7	Some Other Rotary Flowmeters	60
5.7.1	Constrained-vortex meters	60
5.7.2	The 'Hoverflo'	60
5.7.3	The angled propeller meter	61
5.8	Bypass Meters	62
5.8.1	How they work	62
5.8.2	Some practical designs	63
5.8.3	Advantages and disadvantages	64
5.9	Metering Pumps	65
5.9.1	How they work	65
5.9.2	When to use them	65
5.10	Where to Learn More	65
	References	66
6	Other Volumetric Flowmeters	68
6.1	Electromagnetic Flowmeters	68
6.1.1	How they work	68
6.1.2	Advantages	70
6.1.3	Disadvantages	71
6.1.4	Points to watch when buying	72
6.1.5	Points to watch when using	72
6.2	Ultrasonic Flowmeters	73
6.2.1	Introduction	73
6.2.2	The single-path diagonal-beam meter	73
6.2.3	The multi-chordal diagonal-beam meter	74
6.2.4	The cross-correlation ultrasonic meter	75
6.2.5	The Doppler-effect ultrasonic meter	76
6.2.6	Built-in, or clamped-on?	77
6.2.7	Which type for which job?	78

6.3	Vortex-shedding Meters	78
6.3.1	How they work	78
6.3.2	Advantages and disadvantages	80
6.3.3	Points to watch when buying	80
6.4	Some Other Non-mechanical Oscillatory Flowmeters	81
6.4.1	Fluidic flowmeters	81
6.4.2	The 'Swirlmeter'	83
6.5	Tracer Flowmeters	83
6.5.1	How they work	83
6.5.2	The nuclear-magnetic-resonance meter	84
6.5.3	Thermal flowmeters	85
6.6	Flow Indicators	86
6.7	Where to Learn More	86
	References	87
7	Fluid Velocity Measuring Instruments and Insertion Meters	88
7.1	Introduction	88
7.2	Pitot Tubes	89
7.2.1	How they work	89
7.2.2	Advantages	91
7.2.3	Disadvantages	91
7.2.4	When to use them	91
7.3	Propeller-type Current Meters and Vane Anemometers	92
7.3.1	How they work	92
7.3.2	Advantages	93
7.3.3	Disadvantages	94
7.4	Hot-resistor Anemometers	94
7.4.1	How they work	94
7.4.2	Advantages and disadvantages	96
7.4.3	Points to watch when buying and using	96
7.5	Another Type of Hot-wire Anemometer	96
7.6	Some Other Non-mechanical Fluid Velocity Meters	97
7.6.1	Introduction	97
7.6.2	Electromagnetic velocity meters	97
7.6.3	Ultrasonic velocity meters	97
7.6.4	The jet-deflection fluidic velocity meter	98
7.6.5	The 'Ionflo' ion-deflection velocity meter	99
7.6.6	Vortex-shedding velocity meters	99
7.7	Laser-Doppler Velocity Meters	100
7.7.1	How they work	100
7.7.2	Advantages	100
7.7.3	Disadvantages	101

7.8	Insertion Meters	101
7.8.1	The three-quarter-radius meter	101
7.8.2	The ‘Annubar’	102
7.9	Velocity–area Integration Techniques	103
7.9.1	The mathematical principles	103
7.9.2	The experimental techniques	104
7.10	Where to Learn More	105
	References	106
8	Special Problems in Flow Metering	108
8.1	Mass Flow Measurement	108
8.1.1	Angular-momentum meters	108
8.1.2	The ‘Wheatstone bridge’ meter	109
8.1.3	The thermal mass flowmeter	110
8.1.4	Inferential methods of measuring mass flow	111
8.1.5	Which method for which job?	112
8.2	The Measurement of Pulsating Flow	112
8.2.1	Introduction	112
8.2.2	Types of error caused by pulsating flow	112
8.2.3	The Hodgson number	114
8.2.4	What to do about pulsating flow	115
8.3	The Measurement of Two-phase Flow	116
8.4	Metering Cryogenic Liquids	117
8.5	Metering Corrosive Fluids	118
8.6	Metering Potable Liquids	118
8.7	Very Wide Range of Flowrates	119
8.8	Where to Learn More	119
	References	119
9	Choosing the Right Flowmeter for the Job	121
9.1	Introduction	121
9.2	Cost-consciousness in Flowmeter Selection	121
9.3	A Flowmeter Selection Table	123
10	Pitfalls, and How To Avoid Them	126
10.1	Bad Installation Conditions	126
10.1.1	The extent of the problem	126
10.1.2	Disturbances on the downstream side	129
10.1.3	Rules for avoiding installation errors	130