



Guide to the flow relationships and statistical methods used in the Data Items on two-phase flow pressure gradients in straight pipes

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The Fluid Mechanics Steering Group, which first met in April 1970, has the co-operation of many engineers and scientist in industry, research establishments and universities from whom much assistance and information is being received.

GUIDE TO THE FLOW RELATIONSHIPS AND STATISTICAL METHODS USED IN THE DATA ITEMS ON TWO-PHASE FLOW PRESSURE GRADIENTS IN STRAIGHT PIPES

CONTENTS

	Page
1. NOTATION AND UNITS	1
2. INTRODUCTION	3
3. TWO-PHASE FLOW PATTERNS	4
3.1 Flow Patterns in Vertically-Upwards Flowing Mixtures	4
3.2 Patterns in Non-Vertically-Upwards Flowing Mixtures	5
4. FLOW VARIABLES	6
4.1 Variables Affecting Two-Phase Flow	6
4.2 Representation of Pressure Gradient in Two-Phase Flow	9
4.2.1 Representation of the frictional component	9
4.2.2 Representation of the gravitational component	9
4.2.3 Representation of the momentum-change component	10
4.3 Calculation of Finite Changes in Pressure	11
5. ILLUSTRATION OF THE STATISTICAL METHODS EMPLOYED IN ESDU 76018 AND 77016	11
6. REFERENCES	13

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1. NOTATION AND UNITS

The notation is compatible with the notations used in the two-phase flow Data Items and it is recommended that the SI system of units should be employed.

		SI
C	confidence level	—
D	pipe inside diameter	m
$\bar{E}$	mean correction factor within selected batch of N data points given by $\bar{E} = 10^{\bar{e}}$	—
ΔE	uncertainty factor within selected batch of N data points given by $\Delta E = 10^{\Delta e}$	—
e	logarithmic error ratio defined by $\log_{10}$ (measured value of velocity ratio/calculated value)	—
$\bar{e}$	mean value of e within selected batch of N points given by $\bar{e} = \sum_{1}^N e/N$	—
Δe	tolerance on $\bar{e}$ appropriate to specified confidence and probability	—
G	mass velocity of whole mixture = $4(\dot{m}_G + \dot{m}_L)/(\pi D^2)$	kg/s m ²
g	acceleration due to gravity (= 9.81 m/s ²)	m/s ²
$\dot{m}_G$	mass flow rate of gas or vapour component of mixture	kg/s
$\dot{m}_L$	mass flow rate of liquid component of mixture	kg/s
N	number of data points within selected batch	—
P	probability	—
dp/dz	pressure gradient	Pa/m (N/m ³)
dp_a/dz	component of pressure gradient due to momentum change	Pa/m (N/m ³)
dp_f/dz	component of pressure gradient due to friction	Pa/m (N/m ³)

dp_g/dz	component of pressure gradient due to gravity	Pa/m (N/m ³)
s	standard deviation within selected batch of N data points defined by $s = \left[\sum_{1}^N (\bar{e} - e)^2 / N \right]^{1/2}$	—
VR	ratio of the mean gas (or vapour) velocity to the mean liquid velocity $= \frac{\beta}{1-\beta} \frac{1-\alpha}{\alpha}$	—
x	mass quality of gas or vapour component defined by $x = \dot{m}_G / (\dot{m}_G + \dot{m}_L)$	—
α	void fraction, time-averaged proportion of pipe cross-sectional area occupied by gas (or vapour) phase	—
β	gas (or vapour) volume flow fraction which can be expressed as $\beta = 1 / \left(1 + \frac{1-x}{x} \frac{\rho_G}{\rho_L} \right)$	—
γ	interfacial tension	N/m
ε	equivalent sand roughness height	m
θ	angle of pipe inclination relative to horizontal, positive for uphill flow	degree
μ_G	dynamic viscosity of gas (or vapour) phase	N s/m ²
μ_L	dynamic viscosity of liquid phase	N s/m ²
$\bar{\rho}$	time-averaged density of mixture	kg/m ³
ρ_G	density of gas (or vapour) phase	kg/m ³
ρ_L	density of liquid phase	kg/m ³
ϕ_S^2	two-phase multiplier defined in Section 4.2.1	—

2. INTRODUCTION

Despite the large amount of work done on the subject of two-phase flow (in response to its immense technological importance), the most sophisticated of today's generalised design methods are unable to give reliable predictions of its complicated behaviour. The complexity results, in part, from the large number of variables that can influence two-phase flow and, because it has not been possible to include all of these in design methods, uncertainty inevitably exists.

This Guide fulfils two requirements: firstly, in Sections 3 and 4, to provide the non-specialist with background information on the principles for calculating pressure gradients in two-phase flow and, secondly, in Section 5, to give guidance on the statistical methods employed in certain Data Items^{1,2}. These allow quantitative assessments to be made of the accuracy in predicting pressure gradients that are calculated by some of the best of the published empirical correlations for pressure gradient.