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Pressure losses caused by obstructions in ducts and pipes

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THE PREPARATION OF THIS DATA ITEM

The work of the permanent professional staff of the Engineering Sciences Data Unit on this particular Item was monitored and guided by the Internal Flow Panel which had the following constitution:

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The Internal Flow Panel has benefited from the participation of members from several engineering disciplines. In particular, Dr G. Hobson has been appointed to represent the interests of mechanical engineering as the nominee of the Institution of Mechanical Engineers and Mr B. Payne has been appointed to represent the interests of chemical engineering as the nominee of the Institution of Chemical Engineers.

The work on this Item was carried out in the Internal Flow and Physical Properties Group of the Engineering Sciences Data Unit under the supervision of Mr R. Partington and the initial construction of the Item was undertaken by Mr C.J.T. Clarke, until recently Group Head of the Internal Flow and Physical Properties Group. The member of staff who undertook the technical work involved in the initial assessment of the available information and the subsequent development of the Item was

Mr B.C. Freeman — Senior Engineer.

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PRESSURE LOSSES CAUSED BY OBSTRUCTIONS IN DUCTS AND PIPES

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PRESSURE LOSSES CAUSED BY OBSTRUCTIONS IN DUCTS AND PIPES

1. NOTATION AND UNITS

		<i>SI Units</i>
A	cross-sectional area of empty duct or pipe	m^2
a	along-flow dimension of body	m
b	across-flow dimension of body, see also H	m
C_{Df}	drag coefficient relating to unconfined flow (free air) and to frontal area, S , of body	–
d	diameter of circular cylinder or sphere	m
H	largest across-flow dimension of isolated body or dimension of body normal to mounting wall, see Tables 6.1 and 6.2	m
H_d	duct dimension in same direction as H	m
k	velocity profile correction ratio, $(V_{ref}^2/V)^2$	–
m	wake expansion factor used in Equation (3.2)	–
Δp	total-pressure loss	$\text{Pa (N/m}^2\text{)}$
Q	volume flow rate through pipe or duct	m^3/s
Re	Reynolds number of body in duct, $Re = \rho Vd/\mu$ or $\rho Vb/\mu$	–
Re_f	Reynolds number relating to unconfined flow, $Re_f = Re\sqrt{\beta}$	–
S	frontal area of body	m^2
V	mean velocity in empty duct or pipe, $V = Q/A$	m/s
V_{ref}	reference velocity for C_{Df} (see Appendix A)	m/s
β	blockage correction factor	–
μ	dynamic viscosity	N s/m^2
ρ	density	kg/m^3

2. INTRODUCTION

The pressure loss caused by a body obstructing a duct or pipe can be estimated from a knowledge of the drag force on the body. However, the presence of the duct or pipe walls confines the flow around the body and increases the drag force on it above the value applicable to unconfined flow or "free-air" conditions, which is the value that is usually known. This Item gives values of a correction factor β (based on wind-tunnel blockage correction data from Derivation 8), and "free-air" drag coefficients (based on data from Derivations 1 to 7) from which the pressure loss can be estimated for a range of body shapes as shown in Tables 6.1 and 6.2. The drag force on the body can also be estimated if required.

The Item is applicable for incompressible flow of gases, and for liquid flow in which cavitation does not occur, at Reynolds numbers, Re_f , greater than about 10^3 . The uncertainty in the accuracy of pressure losses estimated using this Item cannot be quantified. However, except at low blockage ratios ($S/A < 0.05$) it will be greater than for pressure-loss data derived from direct pressure difference measurements in duct or pipe flows, such as the data presented in other Items in the Internal Flow Sub-series. Some of the factors contributing to the uncertainty and their contribution to blockage effects are briefly discussed in Appendix A.

3. CALCULATION OF PRESSURE LOSS

From a momentum balance, the additional pressure loss in a duct or pipe caused by an obstruction having a "free-air" drag coefficient C_{Df} is given by

$$\Delta p = \frac{1}{2} \rho V^2 k (S/A) \beta C_{Df}, \quad (3.1)$$

where β is a blockage correction factor given, for the body shapes considered in this Item, by

$$\beta = 1/(1 - mS/A), \quad (3.2)$$

and k is a velocity profile correction factor allowing for differences between the mean velocity, V , and the drag-coefficient reference velocity, V_{ref} . Values of m , the wake expansion factor, based on data from Derivation 8 and values of C_{Df} based on data from Derivations 1 to 7 may be found from Table 6.1 or Table 6.2. The value of k varies from 1.0 for uniform flow to about 1.2 for fully-developed duct flow (see Appendix A).

The overall pressure loss in the duct or pipe is given by the sum of Δp from Equation (3.1) and the friction loss (estimated for fully-developed flow) in the length of duct or pipe concerned.

The drag force¹ on the obstruction is given by

$$\text{drag force} = \frac{1}{2} \rho V_{ref}^2 \beta C_{Df} S = \frac{1}{2} \rho V^2 \beta C_{Df} S, \quad (3.3)$$

where βC_{Df} represents the confined-flow drag coefficient.

¹ In addition to the steady, mean, drag force given by Equation (3.3), fluctuating forces may arise, leading to vibration of the obstruction. This problem is outside the scope of this Data Item but some guidance is given by Data Items in the Wind Engineering Sub-series.

The applicability of pressure losses and drag forces calculated by this method becomes increasingly uncertain as $m S/A$ increases above about 0.5 and the method should not be used for values of $m S/A$ greater than about 0.8. The data apply for all values of Reynolds number, $Re_f (= Re \sqrt{\beta})$, greater than about 10^3 for sharp-edged bodies but strictly only up to about 10^5 for rounded bodies. For Reynolds numbers above 10^5 , use of the values of m and C_{Df} given in the Tables will overestimate pressure losses and drag for rounded bodies.