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Flow through a sudden enlargement of area in a duct

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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 Fluid Mechanics Steering Group which had the following constitution:

Chairman	
Mr W.F. Wiles	— Rolls-Royce (1971) Ltd, Hucknall
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Mr E.C. Firman	— Central Electricity Research Laboratories
Mr B.H. Fisher	— Consulting Structural Engineer
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The Steering Group has benefited from the participation of members from several engineering disciplines. In particular, Mr B.H. Fisher has been appointed to represent the interests of structural engineering as the nominee of the Institution of Structural Engineers, Mr E.C. Firman has been appointed to represent the interests of mechanical engineering as the nominee of the Institution of Mechanical Engineers and Dr J.M. Ilsley has been appointed to represent the interests of chemical engineering as the nominee of the Institution of Chemical Engineers.

The Item was accepted for inclusion in the Aerodynamics Sub-series by the Aerodynamics Committee which had the following constitution:

Chairman	
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Prof. D.W. Holder	— University of Oxford
Mr W.F. Wiles	— Rolls-Royce (1971) Ltd, Hucknall
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FLOW THROUGH A SUDDEN ENLARGEMENT OF AREA IN A DUCT

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FLOW THROUGH A SUDDEN ENLARGEMENT OF AREA IN A DUCT

1. NOTATION AND UNITS

Three coherent systems of units are given below.

		SI	British	
A	cross-sectional area of duct	m ²	ft ²	ft ²
a	speed of sound in a flowing gas	m/s	ft/s	ft/s
a_t	speed of sound in a gas brought to rest isentropically	m/s	ft/s	ft/s
D	diameter of circular duct	m	ft	ft
K_s	static-pressure drop coefficient, $\Delta p_s / (\frac{1}{2} \rho_1 V_1^2)$	—	—	—
K_t	total-pressure loss coefficient, $\Delta p_t / (\frac{1}{2} \rho_1 V_1^2)$	—	—	—
M	mean Mach number, V/a	—	—	—
m	mass flow rate	kg/s	lb/s	slug/s
p	static pressure	N/m ²	pdl/ft ²	lbf/ft ²
Δp_s	static-pressure drop	N/m ²	pdl/ft ²	lbf/ft ²
p_t	total pressure	N/m ²	pdl/ft ²	lbf/ft ²
Δp_t	total-pressure loss	N/m ²	pdl/ft ²	lbf/ft ²
R	gas constant	J/kg K	ft pdl/lb°R	ft lbf/slug K
Re	Reynolds number, $V_1 D_1 / \nu_1$	—	—	—
T_t	total temperature of fluid	K	°R	K
V	mean velocity in duct, $m/\rho A$	m/s	ft/s	ft/s
v	local velocity	m/s	ft/s	ft/s
α	momentum factor*, see Equation (3.4)	—	—	—
β	kinetic energy factor*, see Equation (3.5)	—	—	—
γ	ratio of specific heat capacity at constant pressure to that at constant volume	—	—	—

For footnotes see end of Notation Section.

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ϕ	area ratio of enlargement, A_1/A_2	—	—	—
ρ	density of fluid	kg/m ³	lb/ft ³	slug/ft ³
ν	kinematic viscosity of fluid, μ/ρ	m ² /s	ft ² /s	ft ² /s
μ	dynamic viscosity of fluid	N s/m ²	pdl s/ft ²	lbf s/ft ²

* Note that in later Data Items and elsewhere the symbol α is frequently used for kinetic energy factor and β for momentum factor.

Suffixes

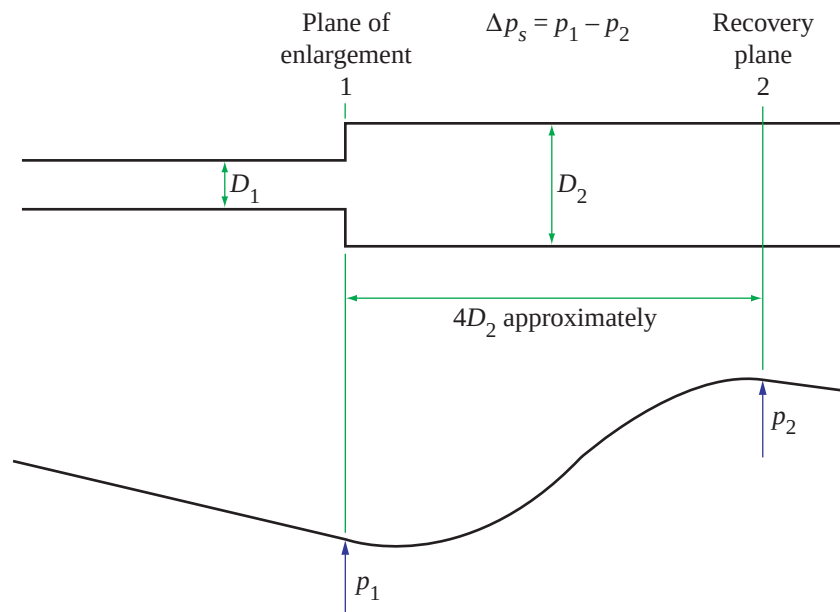
- 1 refers to conditions in small pipe at plane of enlargement of area
- 2 refers to conditions at position of maximum pressure recovery downstream of enlargement
- i* indicates value for incompressible flow conditions

2. INTRODUCTION

This Data Item gives information on the pressure changes occurring in the flow of fluids along a duct with a sudden enlargement of area. The data for incompressible flow are presented in non-dimensional form as total- and static-pressure loss coefficients in Figures 1 and 2 (uniform flow) and in Figure 3 (non-uniform flow). For uniform compressible flows the downstream Mach number, total-pressure loss coefficient and static-pressure ratio are given in Figures 4 to 6.

The values given represent the overall changes between the plane of the enlargement and the recovery plane (see Sketch 2.1) and are therefore strictly applicable only to sudden enlargements with that length of duct downstream. However, for values of the area ratio, ϕ , near to 0 or near to 1, this restriction may be relaxed and the data applied to shorter ducts.

For a fluid flowing along a duct with a sudden enlargement of area a loss of total pressure occurs but the static pressure rises. Sketch 2.1 shows a typical static pressure distribution along a duct with a sudden enlargement of area. The recovery plane occurs at about $4D_2$ downstream of the enlargement⁶.



Sketch 2.1 Typical static pressure distribution along a duct with a sudden enlargement of area