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Flow of liquids. Pressure losses across orifice plates, perforated plates and thick orifice plates in ducts

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THE PREPARATION OF THIS DATA ITEM

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FLOW OF LIQUIDS PRESSURE LOSSES ACROSS ORIFICE PLATES, PERFORATED PLATES AND THICK ORIFICE PLATES IN DUCTS

CONTENTS

	Page
1. NOTATION AND UNITS	1
2. INTRODUCTION	3
2.1 Non-circular Ducts and Openings	4
3. SOME GENERAL FEATURES OF THE FLOW THROUGH ORIFICES	5
3.1 The Effect of Orifice Thickness/Diameter Ratio under Incompressible Flow Conditions	5
3.2 The Effect of Reynolds Number	5
4. DEFINITION AND CALCULATION OF PRESSURE LOSSES	7
4.1 Definition of Pressure Loss	7
4.2 Calculation of Pressure Loss	8
5. RANGES OF APPLICABILITY OF PRESSURE-LOSS COEFFICIENT DATA	9
6. EXAMPLE	10
7. REFERENCES AND DERIVATION	11
7.1 References	11
7.2 Derivation	11
APPENDIX A	17

ESDU 81039 C 2007

FLOW OF LIQUIDS

Pressure losses across orifice plates, perforated plates and thick orifice plates in ducts

1. NOTATION AND UNITS

		<i>SI Unit</i>
A	cross-sectional area	m^2
A_f	total area of openings in plate	m^2
A_u	cross-sectional area of duct in which plate is placed	m^2
a	speed of sound in fluid	m/s
D	diameter of circular duct or equivalent diameter of non-circular duct ($4A_u$ / perimeter)	m
d	diameter or equivalent diameter of orifice (diameter of inner surface of orifice) or of one hole in perforated plates	m
K_i	pressure-loss coefficient for incompressible flow, based on upstream kinetic pressure, $\frac{1}{2}\rho_1 V_1^2$	–
K'_i	pressure-loss coefficient for incompressible flow, based on kinetic pressure at entry to orifice, $\frac{1}{2}\rho_2 V_2^2$ ($K'_i = \alpha^2 K_i$)	–
K_0	value of K_i corresponding to $t/d = 0$	–
K'_0	value of K'_i corresponding to $t/d = 0$ ($K'_0 = \alpha^2 K_0$)	–
$K_{0.8}$	value of K_i corresponding to $t/d = 0.8$	–
$K'_{0.8}$	value of K'_i corresponding to $t/d = 0.8$ ($K'_{0.8} = \alpha^2 K_{0.8}$)	–
m	rate of mass flow through duct	kg/s
p	static pressure	N/m^2
Δp_s	static-pressure drop due to plate (see Sketch 4.1)	N/m^2
p_t	total pressure	N/m^2
Δp_t	total-pressure loss due to plate	N/m^2
R	gas constant	J/kg K
Re_d	Reynolds number based on hole diameter and mean velocity at entry to holes, $V_1 d / \alpha \nu_1$	–
t	thickness of plate (see Sketch 2.1)	m

Issued November 1981 - 18 pages
 Reprinted with Amendment C – March 2007
 This page Amendment A

V	mean velocity, $m/\rho A$	m/s
α	porosity or area ratio, A_f/A_u	–
γ	ratio of specific heat capacity at constant pressure to that at constant volume	–
λ_a	correction factor for effect of plate thickness for $t/d < 0.8$ ($\lambda_a = K_i/K_0 = K'_i/K'_0$)	–
λ_b	correction factor for effect of plate thickness for $t/d \geq 0.8$ ($\lambda_b = K_i/K_{0.8} = K'_i/K'_{0.8}$)	–
μ	dynamic viscosity of fluid	N s/m ²
ν	kinematic viscosity of fluid, μ/ρ	m ² /s
ρ	density of fluid	kg/m ³

Subscripts

a	refers to correction factor for effect of plate thickness for $t/d < 0.8$	} See Sketch 4.1
b	refers to correction factor for effect of plate thickness for $t/d \geq 0.8$	
d	refers to Reynolds number based on hole diameter	
i	refers to incompressible flow conditions	
m	refers to pressures measured in regions of fully-developed flow	
s	refers to static-pressure	
t	refers to total-pressure	}
u	refers to duct area	
0	refers to incompressible flow loss coefficient when $t/d = 0$	
0.8	refers to incompressible flow loss coefficient when $t/d = 0.8$	
1	refers to conditions at station upstream of orifice in region of fully-developed flow	}
2	refers to conditions at entry to orifice	
3	refers to conditions at station downstream of recovery plane	

Superscripts

$'$	refers to pressure-loss coefficient based on kinetic pressure, $\frac{1}{2}\rho_2 V_2^2$, at entry to orifice
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2. INTRODUCTION

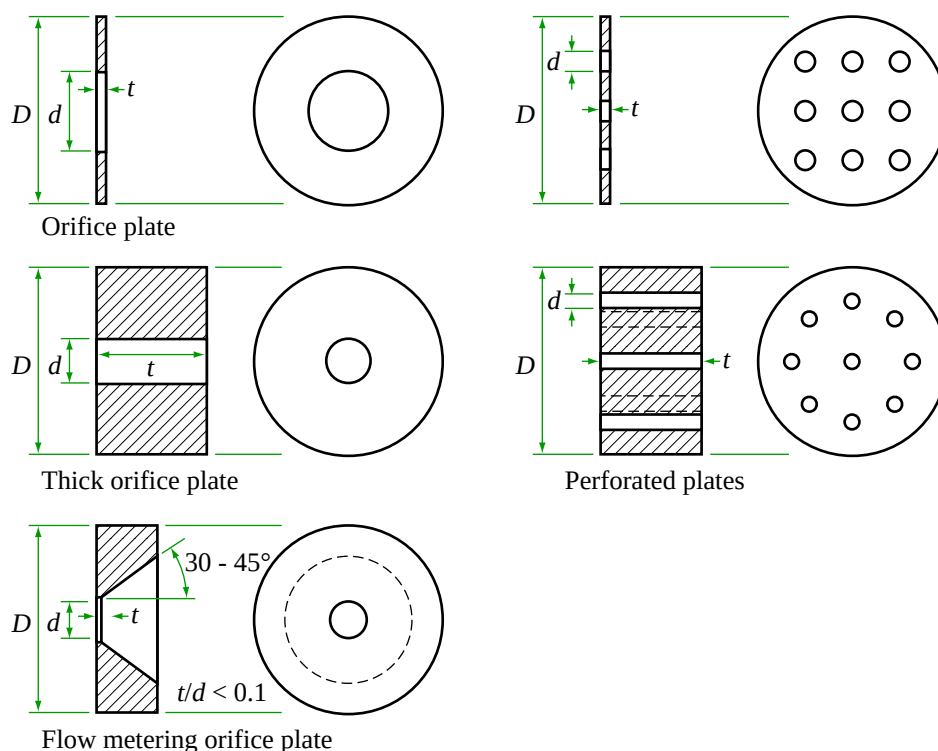
This Data Item provides total- and static-pressure loss coefficients for the calculation of the pressure drop in liquids flowing through sharp-edged orifice plates, perforated plates and thick orifice plates installed in ducts of constant area.

The method for calculating incompressible flow pressure-loss coefficients is outlined in Section 4.2.

The method for calculating pressure losses for compressible flow, appropriate for the flow of gases*, is given in ESDU 82009.

The data in this Item are applicable under the following conditions:

- (i) flow of liquids;
- (ii) fully-developed flow in regions upstream and downstream of the orifice;
- (iii) Reynolds numbers, Re_d , greater than about 10^4 (see Section 3.2);
- (iv) components having sharp edges free from any chamfering or rounding since such edge profiles can considerably reduce the values of the pressure-loss coefficients. The presence of burrs would also affect the pressure loss;



Sketch 2.1 Typical components

* For the flow of gases, it is necessary to use compressible flow values even at low upstream Mach numbers since, although the upstream Mach number in the duct may be low, the Mach number in the smaller orifice area will be higher and the flow may be approaching conditions where compressibility effects are significant.

- (v) thin and thick orifices. Separate correlations are provided for $t/d < 0.8$ and $t/d \geq 0.8$, corresponding to separated flow and reattached flow respectively under incompressible flow conditions. For incompressible flow conditions, the flow may be either separated or reattached for $0.6 < t/d < 1.0$ and it is uncertain as to which correlation will be appropriate*. The use of orifices in this thickness range should be avoided in design as flow fluctuation, vibration and noise may occur;
- (vi) symmetrical systems with single and multiple circular openings in circular ducts. Sketch 2.1 illustrates examples of typical components (see Section 2.1 for notes on non-circular ducts and openings).

2.1 Non-circular Ducts and Openings

Some data for perforated plates with square holes are given in Derivation 10 and some data for perforated plates in rectangular-sectioned ducts were included in the correlation in Derivation 12. No systematic departures from the correlations presented here were found in these cases, but the available data only cover values of α up to about 0.6. For high values, $\alpha > 0.8$ say, the effects of the system geometry are likely to become more significant and application of the data to components not shown in Sketch 2.1 will be less reliable, and should be made with caution.

* For values of t/d in the range of $0.6 < t/d < 1.0$, the loss coefficient, K_l , may be obtained from either the separated or reattached flow correlations. For separated flow, the curve given in Figure 3 can be extrapolated to $t/d = 1.0$ and for reattached flow, Equation (5.1) can be used to find K_l when $0.6 < t/d < 0.8$.