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Crack flow. A power law estimation technique.

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Synopsis

A set of diagrams for estimating flow coefficients and exponents in the power law flow equation for cracks are presented. The diagrams are primarily intended for those who perform infiltration calculations by hand or by using a computer program for single and multi zone infiltration and ventilation calculations.

The error introduced by the estimation technique is compensated for by means of a correction coefficient with a specific value in different pressure difference intervals. A computer program performing the calculations behind the diagrams is available for public use.

1. Introduction

For many purposes a power law approach is useful in order to describe the flow behaviour of a crack or an air gap. Many multizone infiltration and ventilation computer programs require a power law description of the flow characteristics of a crack. However, hitherto no simple ways have existed for predicting the flow coefficient and exponent in the power law by means of calculation for a given flow geometry.

2. A power law estimation technique for cracks

The power law flow equation reads:

$$q_v = a * (\text{delta } p)^b$$

where:

q_v = volumetric air flow rate, m3/s
a = flow coefficient, m3/(s*Pa^b)
delta p = pressure difference, Pa
b = flow exponent, -

The estimation of the coefficient a and the exponent b is made by means of running a computer program - PET - designed for this application. In the program the full hydraulic equations for duct flow, entrance-, exit-and bend effects are calculated. As these flow equations are not explicit in solving the air flow rate as a function of the pressure difference a numerical curve fit procedure gives a power law curve fit for a number of calculated corresponding values of pressure difference and air flow rate. The fitted values of the air flow rate is compared to the exact hydraulic solution for each pressure difference. Thus a correction factor is calculated. This factor is depending on the pressure difference.

The calculations have been made for different crack widths between 0.5 and 10 mm. The bredth of the crack is always 1.00 m and the length in flow direction varies between 0 and 500 mm. For some cases a 90 deg bend is included too. The pressure difference interval chosen is 1 to 50 Pa which in most cases should be applicable for practical use.

The computer program performing the calculations behind the diagrams is available for public use by contacting the author.

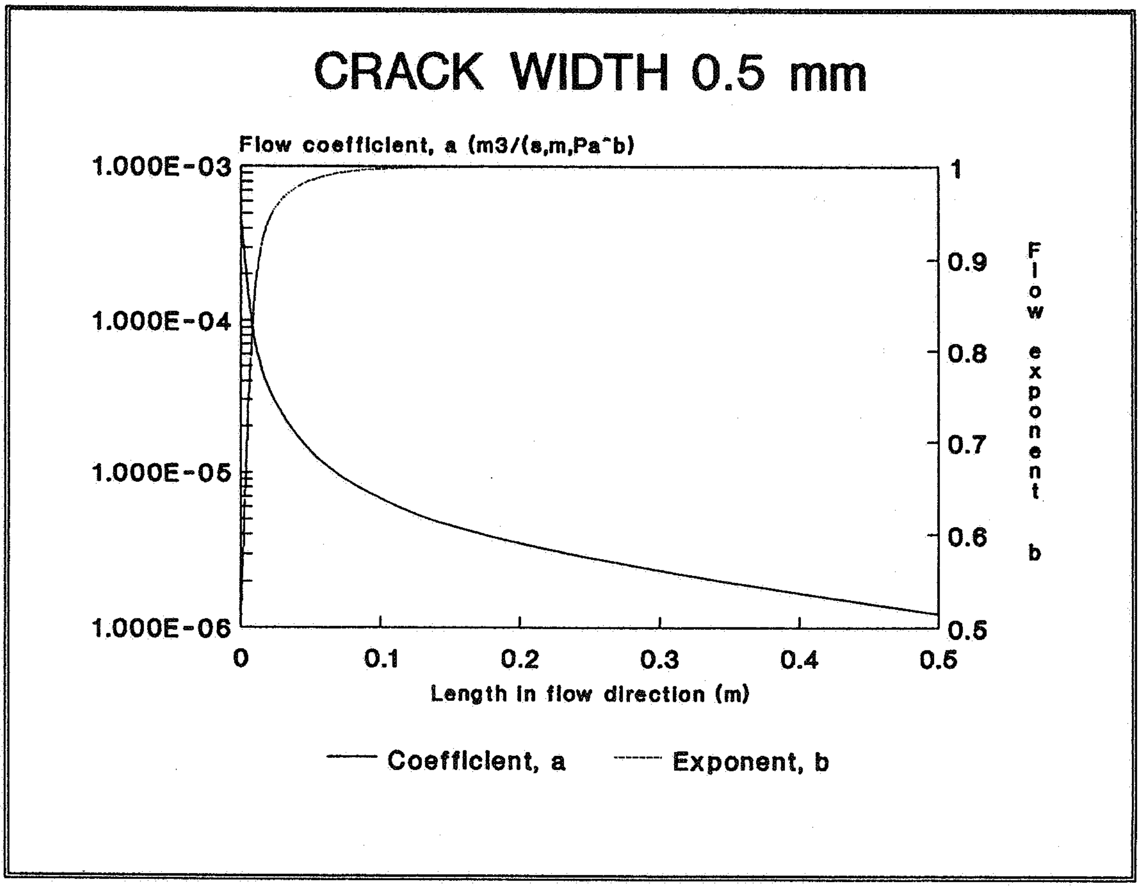
3. Results

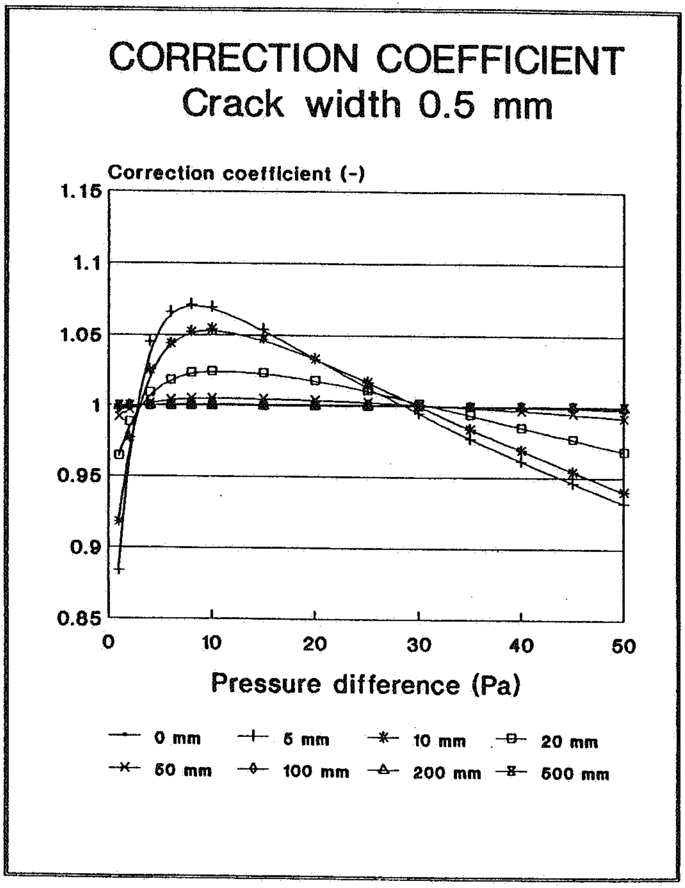
The calculations for each crack width are summarized in two diagrams, the first one showing the variation in the flow coefficient and exponent for different lengts in flow direction and the second one showing the different values a correction coefficient takes for different pressure differences. Each flow length has its own curve.

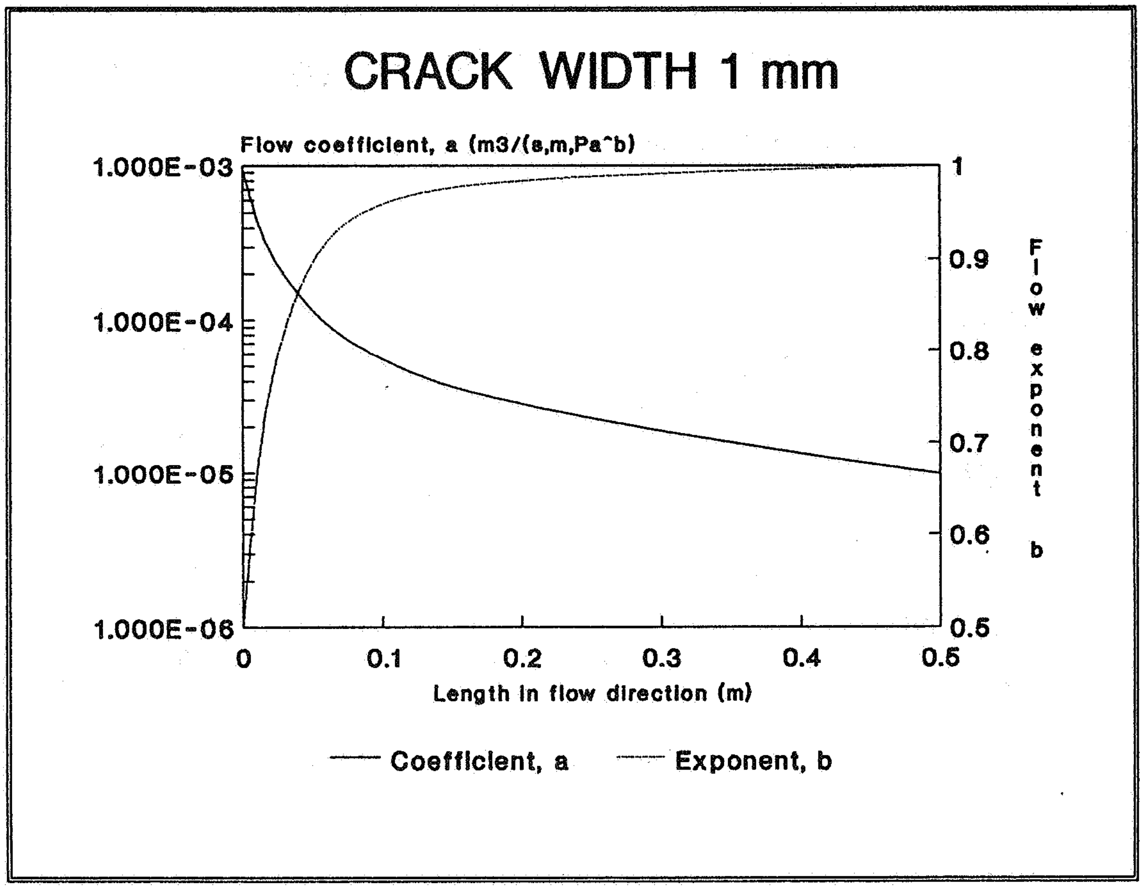
The air flow rate is eventually calculated as:

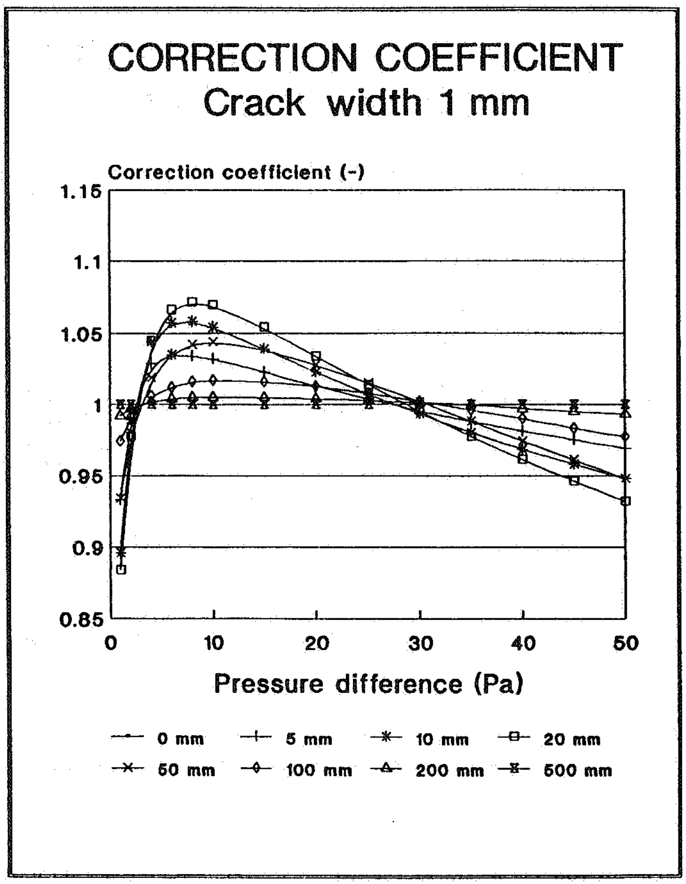
$$q_v = \text{correction coefficient} * a * (\text{delta p})^b$$

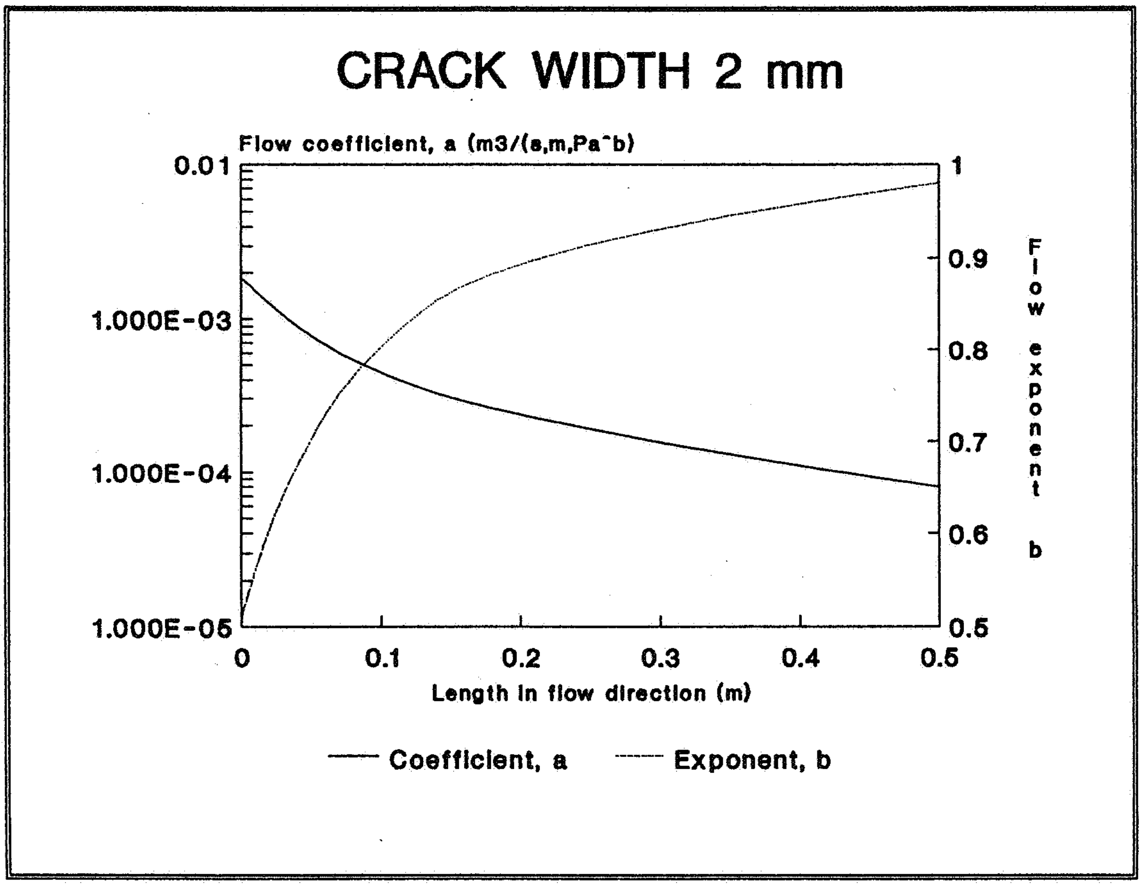
If the demands on the degree of accuracy of the calculated flow rate is less than e.g. ten percent, no correction coefficient needs to be applied at all. For many applications this is sufficient depending on the fact that other factors are determined with (far) less accuracy, by no means less the crack width.


CRACK WIDTH 0.5 mm
Flow coefficient, a (m3/(s,m,Pa^b)
1.000E-03
1.000E-04
1.000E-05
1.000E-06
1
0.9
0.8
0.7
0.6
0.5
Flow exponent b
0
0.1
0.2
0.3
0.4
0.5
Length in flow direction (m)
Coefficient, a
Exponent, b

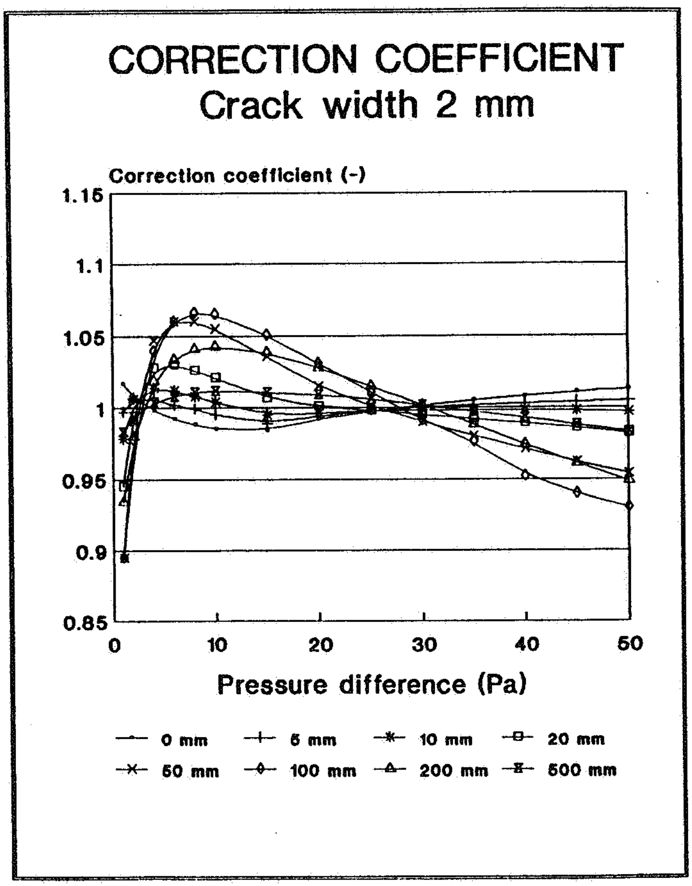

CORRECTION COEFFICIENT
Crack width 0.5 mm
Correction coefficient (-)
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
Pressure difference (Pa)
0 mm
5 mm
10 mm
20 mm
50 mm
100 mm
200 mm
500 mm


CRACK WIDTH 1 mm
Flow coefficient, a (m3/(s,m,Pa^b)
1.000E-03
1.000E-04
1.000E-05
1.000E-06
1
0.9
0.8
0.7
0.6
0.5
Flow exponent b
0
0.1
0.2
0.3
0.4
0.5
Length in flow direction (m)
Coefficient, a
Exponent, b

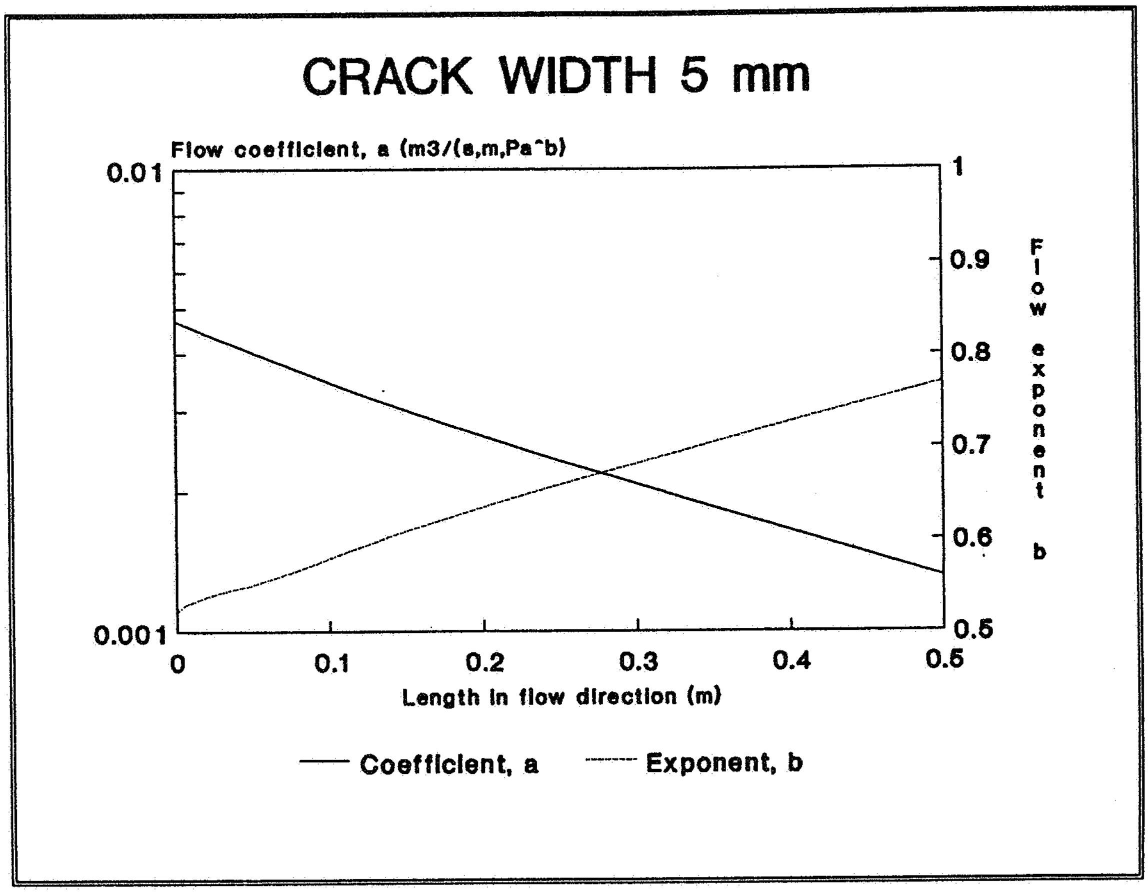

CORRECTION COEFFICIENT
Crack width 1 mm
Correction coefficient (-)
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
Pressure difference (Pa)
0 mm
5 mm
10 mm
20 mm
50 mm
100 mm
200 mm
500 mm



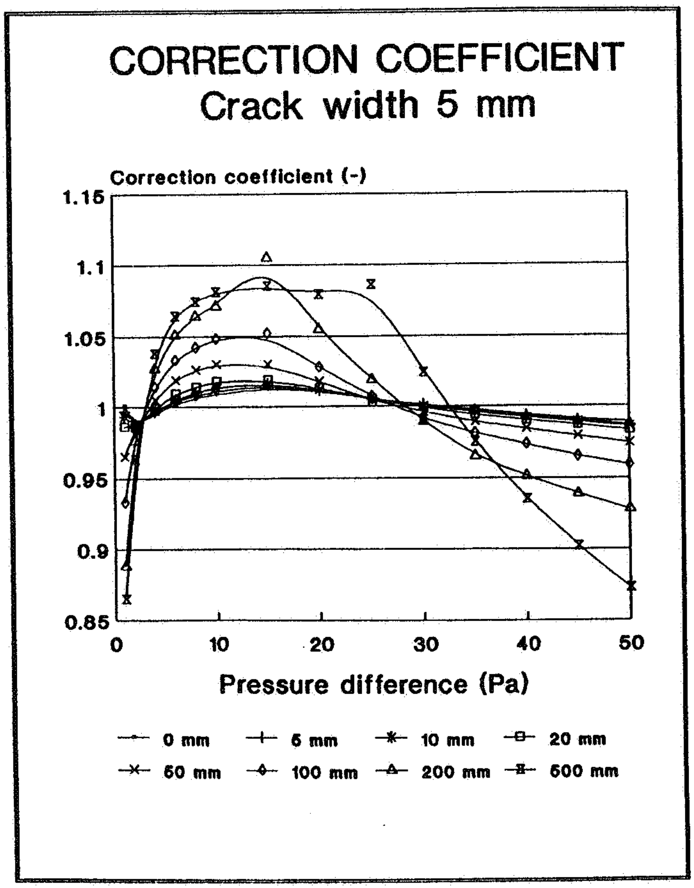
CRACK WIDTH 2 mm
Flow coefficient, a (m3/(s,m,Pa^b)
0.01
1.000E-03
1.000E-04
1.000E-05
1
0.9
0.8
0.7
0.6
0.5
Flow exponent b
0
0.1
0.2
0.3
0.4
0.5
Length in flow direction (m)
Coefficient, a
Exponent, b



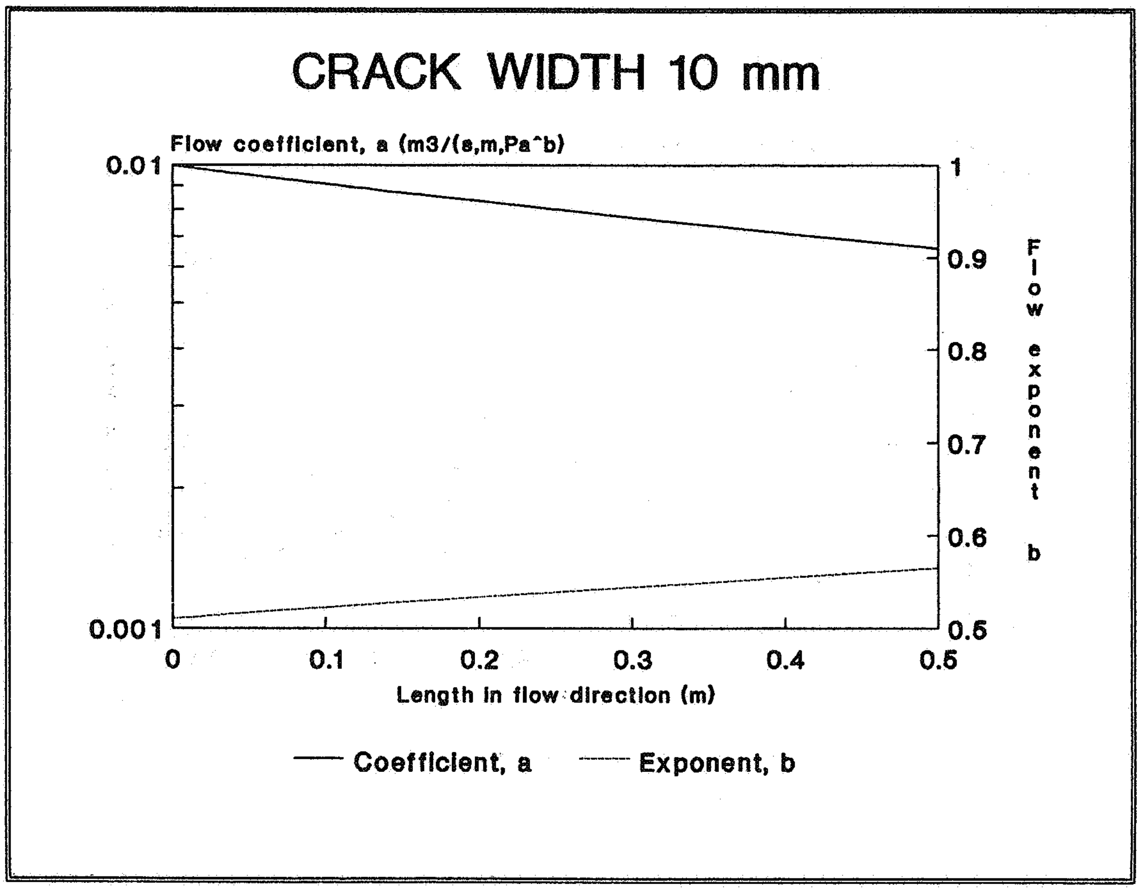
CORRECTION COEFFICIENT
Crack width 2 mm
Correction coefficient (-)
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
Pressure difference (Pa)
0 mm
5 mm
10 mm
20 mm
50 mm
100 mm
200 mm
500 mm



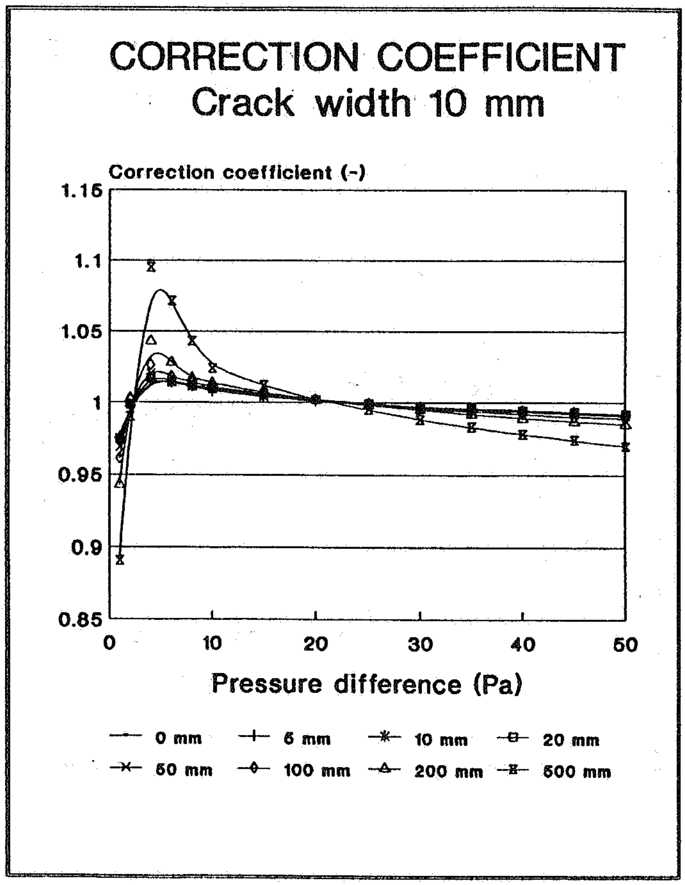
CRACK WIDTH 5 mm
Flow coefficient, a (m3/(s,m,Pa^b)
0.01
0.001
0
0.1
0.2
0.3
0.4
0.5
1
0.9
0.8
0.7
0.6
0.5
Flow exponent b
Length in flow direction (m)
Coefficient, a
Exponent, b



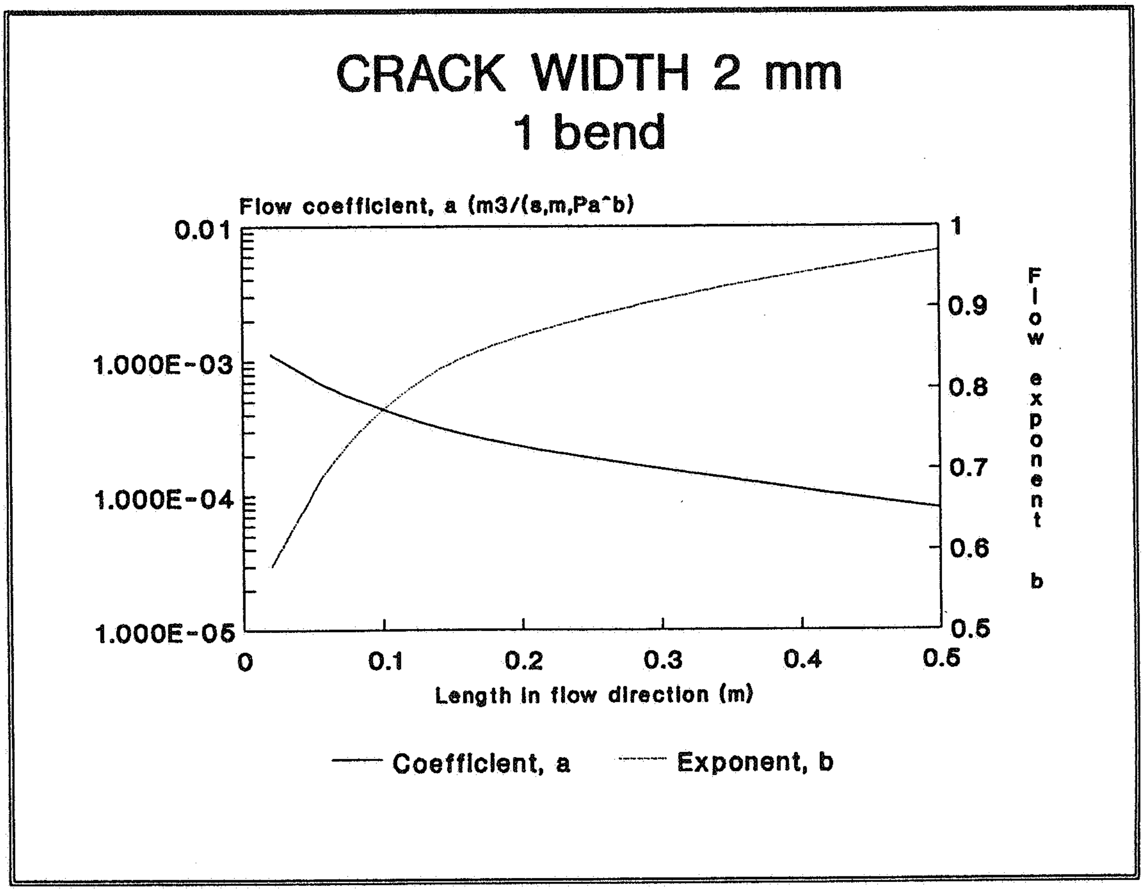
CORRECTION COEFFICIENT
Crack width 5 mm
Correction coefficient (-)
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
Pressure difference (Pa)
0 mm
5 mm
10 mm
20 mm
50 mm
100 mm
200 mm
500 mm

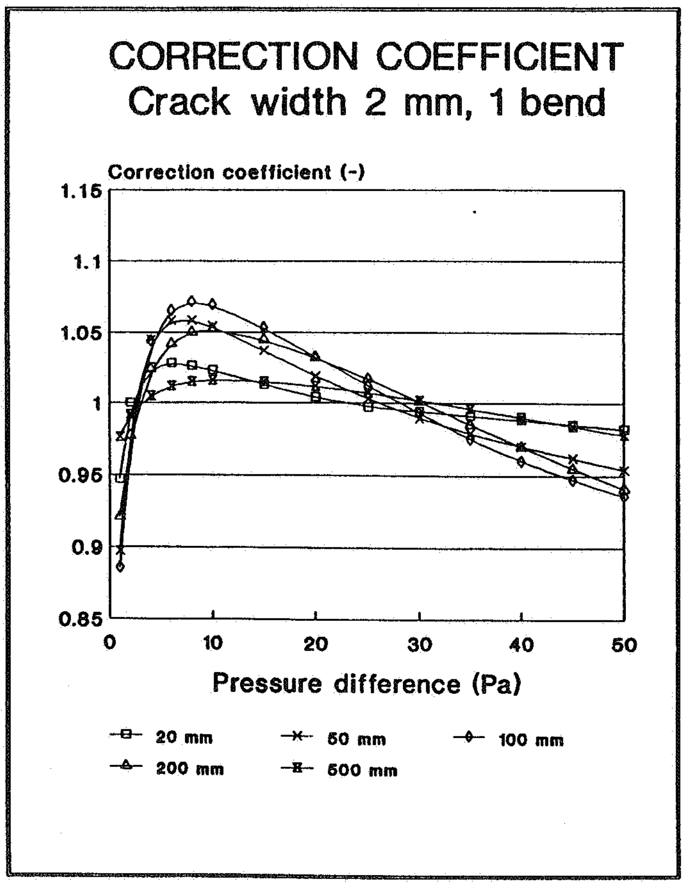


CRACK WIDTH 10 mm
Flow coefficient, a (m3/(s,m,Pa^b)
0.01
0.001
1
0.9
0.8
0.7
0.6
0.5
Flow exponent b
0
0.1
0.2
0.3
0.4
0.5
Length in flow direction (m)
Coefficient, a
Exponent, b



CORRECTION COEFFICIENT
Crack width 10 mm
Correction coefficient (-)
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
Pressure difference (Pa)
0 mm
5 mm
10 mm
20 mm
50 mm
100 mm
200 mm
500 mm


CRACK WIDTH 2 mm
1 bend
Flow coefficient, a (m3/(s,m,Pa^b)
0.01
1.000E-03
1.000E-04
1.000E-05
0
0.1
0.2
0.3
0.4
0.5
Length in flow direction (m)
1
0.9
0.8
0.7
0.6
0.5
Flow exponent b
Coefficient, a
Exponent, b


CORRECTION COEFFICIENT
Crack width 2 mm, 1 bend
Correction coefficient (-)
1.15
1.1
1.05
1
0.95
0.9
0.85
0
10
20
30
40
50
Pressure difference (Pa)
20 mm
50 mm
100 mm
200 mm
500 mm