Project #1606-TRP

Laboratory Testing of Flat Oval Transitions to Determine Loss Coefficients

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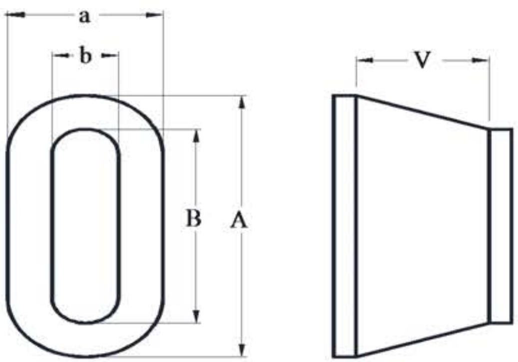
Objective

To experimentally determine the total pressure loss coefficients for flat oval transition fittings, and update the *ASHRAE Duct Fitting Database* (2009) with the test findings.

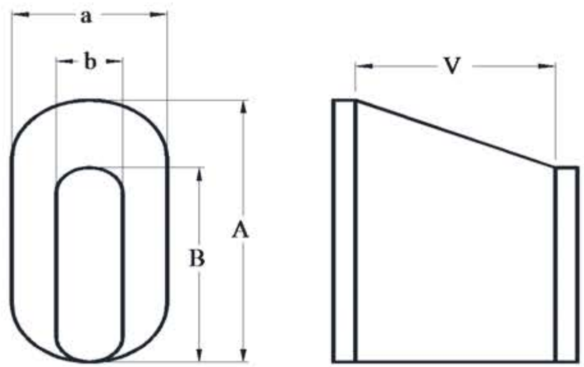
Value to ASHRAE

More reliable data and/or a large database of fitting loss coefficients will help ASHRAE members and others to better design ductwork for their clients, enabling more accurate pressure drop calculations and less safety factor. This will allow fans to be sized properly, reducing energy consumption and wasted material. It should also generate an increase in sales for the ASHRAE Duct Fitting Database.

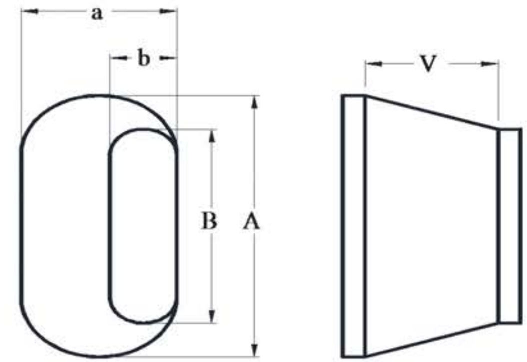
Transition Arrangements



Concentric
Arrangement 1



Eccentric
Arrangement 2



Eccentric
Arrangement 3

Test Fittings (Converging)

Arrangement and Geometry	Upstream Fitting Sizes A×a, in. (Aspect Ratio, A/a)	Downstream Fitting Sizes B×b, in. (Aspect Ratio, B/b)	V, in.
Arrangement 1 Concentric	33×6 (5.50)	28×6 (4.67)	12
		15×4 (3.75)	12
	31×14 (2.21)	28×12 (2.33)	12
		26×10 (2.60)	12
		23×10 (2.30)	12
		23×6 (3.83)	12
	23×10 (2.30)	14×6 (2.33)	12
	23×6 (3.83)	15×4 (3.75)	12
Arrangement 2 Eccentric	33×6 (5.50)	28×6 (4.67)	18
		15×4 (3.75)	18
	31×14 (2.21)	28×12 (2.33)	18
		26×10 (2.60)	18
		23×10 (2.30)	18
		23×6 (3.83)	18
	23×10 (2.30)	14×6 (2.33)	18
	23×6 (3.83)	15×4 (3.75)	18
Arrangement 3 Eccentric	33×6 (5.50)	15×4 (3.75)	12
	31×14 (2.21)	28×12 (2.33)	12
		26×10 (2.60)	12
		23×10 (2.30)	12
		23×6 (3.83)	12
	23×10 (2.30)	14×6 (2.33)	12
	23×6 (3.83)	15×4 (3.75)	12

Test Fittings (Diverging)

Arrangement and Geometry	Upstream Fitting Sizes A×a, in. (Aspect Ratio, A/a)	Downstream Fitting Sizes B×b, in. (Aspect Ratio, B/b)	V, in.
Arrangement 1 Concentric	28×6 (4.67) 15×4 (3.75)	33×6 (5.50)	12 12
	28×12 (2.33) 26×10 (2.60) 23×10 (2.30) 23×6 (3.83)	31×14 (2.21)	12 12 12 12
	14×6 (2.33)	23×10 (2.20)	12
	15×4 (3.75)	23×6 (3.83)	12
Arrangement 2 Eccentric	28×6 (4.67) 15×4 (3.75)	33×6 (5.50)	18 18
	28×12 (2.33) 26×10 (2.60) 23×10 (2.30) 23×6 (3.83)	31×14 (2.21)	18 18 18 18
	14×6 (2.33)	23×10 (2.30)	18
	15×4 (3.75)	23×6 (3.83)	18
Arrangement 3 Eccentric	15×4 (3.75)	33×6 (5.50)	12
	28×12 (2.33) 26×10 (2.60) 23×10 (2.30) 23×6 (3.83)	31×14 (2.21)	12 12 12 12
	14×6 (2.33)	23×10 (2.30)	12
	15×4 (3.75)	23×6 (3.83)	12

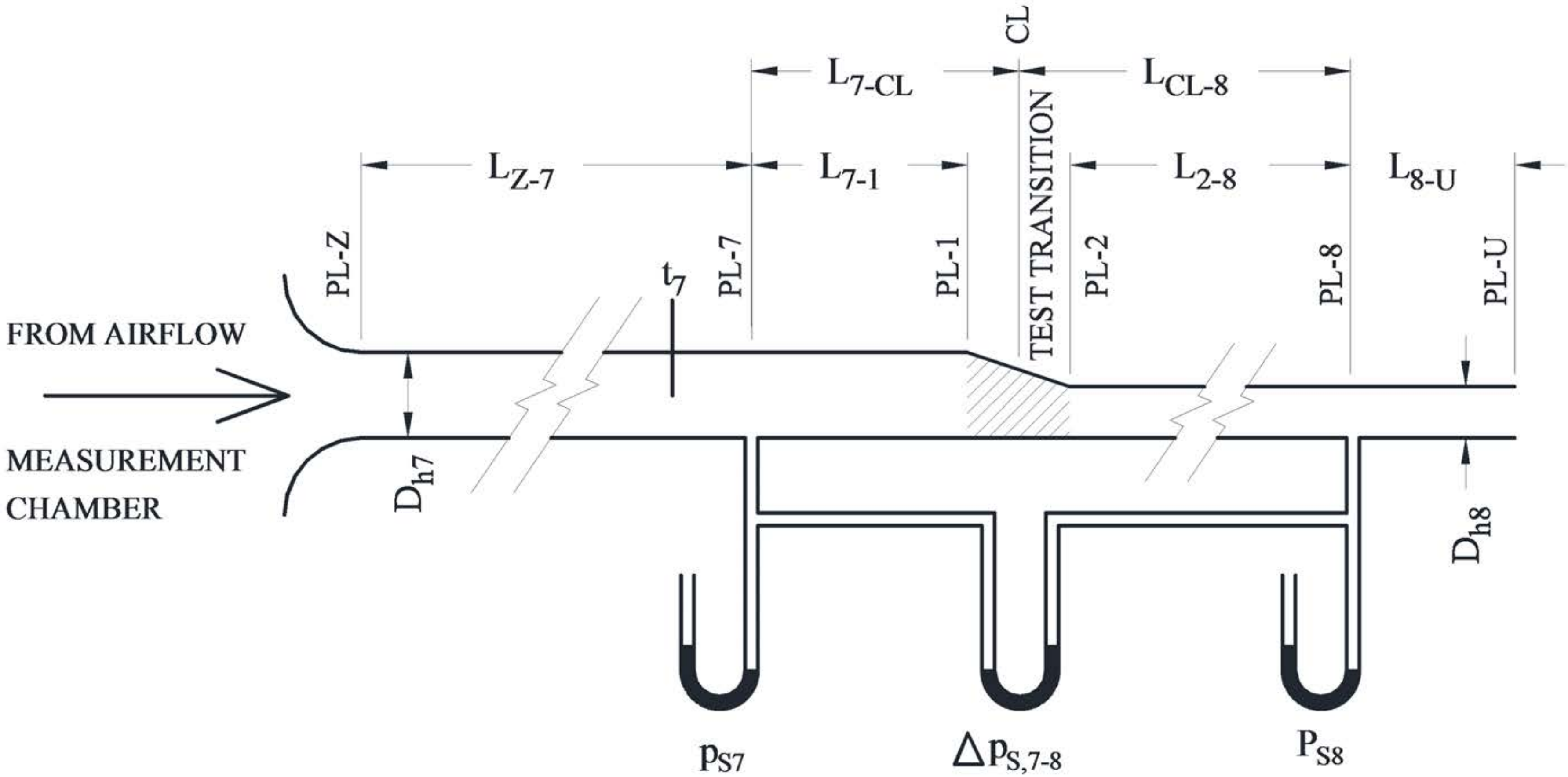
Airflow Measurement Chamber

- In accordance with ANSI/ ASHRAE 51-07/ANSI/AMCA 210-07
- Chamber cross sectional area: 7.53 m^2 (81 ft^2)
- Supply fan: 37 kW (50 Hp) inline centrifugal with VFD for speed control
- Maximum airflow rate: 68,000 m^3/hr (40,000 cfm)
- Flow nozzles: 203.2mm (8”) dia. – qty. 16 and 152.4mm (6”), 101.6mm (4”), 76.2mm (3”), 50.8mm (2”) one each

Instrumentation

Parameter	Uncertainty	Instrument
Dry Bulb Temperature (t_o)	0.5°C (1°F)	Oakton 37210-series Assman psychrometer
Wet Bulb Temperature (t'_o)	0.5°C (1°F)	Oakton 37210-series Assman psychrometer
Chamber Temperature (t_5)	0.2°C (0.4°F)	Thermocouple
Test Section Temperature (t_7)	0.2°C (0.4°F)	Thermocouple
Chamber Static Pressure (p_{s5})	2.5 Pa (0.01 in. water)	Incline manometer
Pressure Drop Across Nozzle ($\Delta p_{s,5\text{-}6}$)	1 Pa (0.004 in. water)	Omega transducer
Pressure Drop Across Test Fitting ($\Delta p_{s,7\text{-}8}$)	1.7 Pa (0.007 in. water)	Setra 239 transducer
Test Section Static Pressure (p_{s7})	2.5 Pa (0.01 in. water)	Incline manometer
Barometric Pressure (p_b)	0.25 mm Hg (0.01 in. Hg)	Mercury barometer

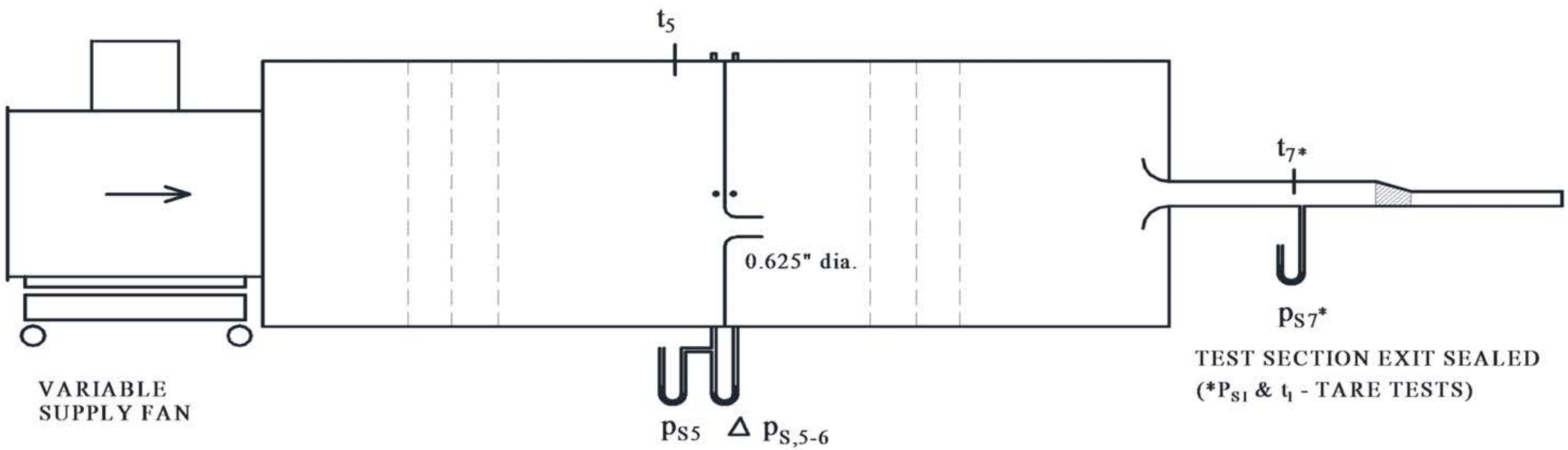
Test Setups



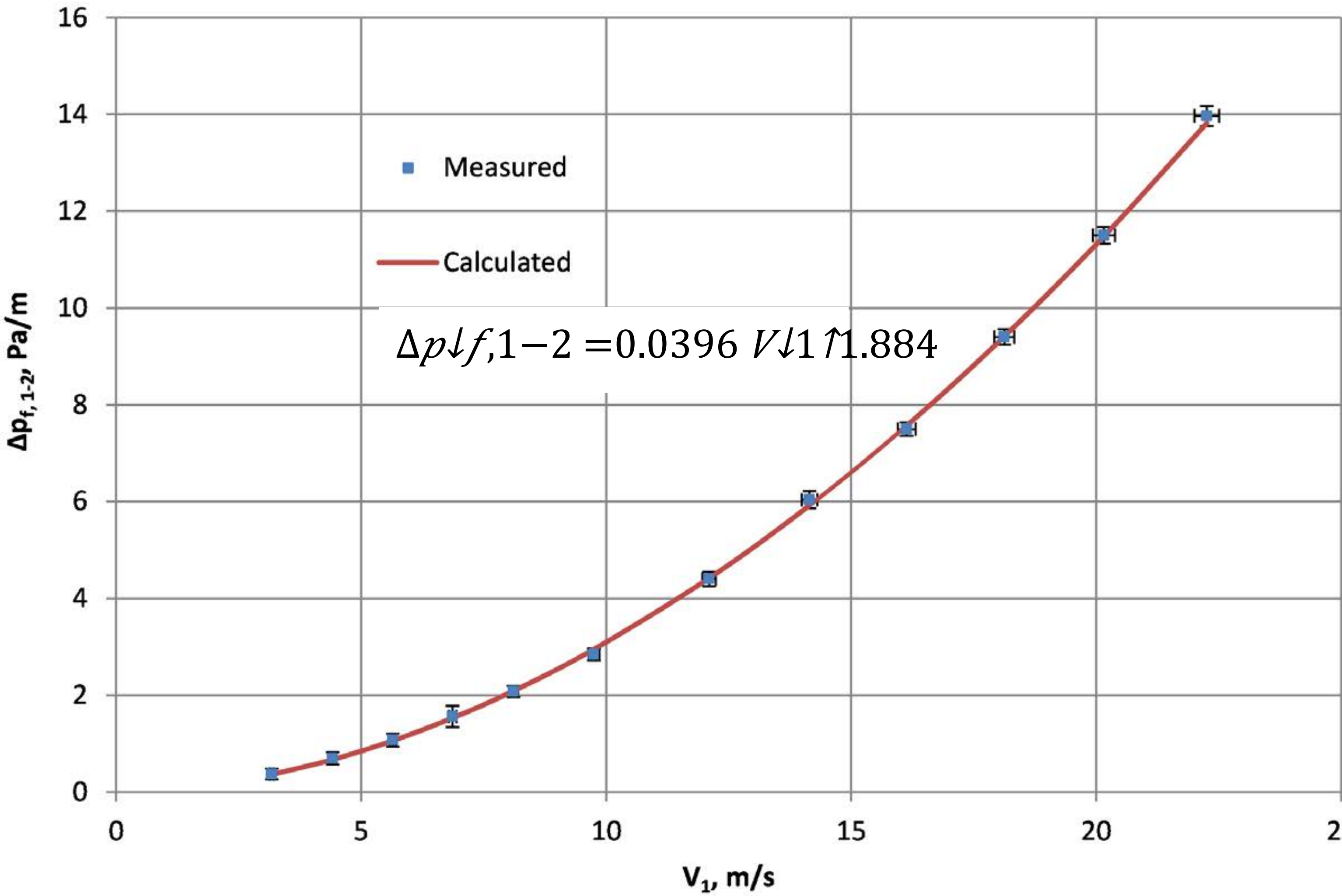
CL
L7-CL
LCL-8
LZ-7
L7-1
L2-8
L8-U
PL-Z
PL-7
PL-1
TEST TRANSITION
PL-2
PL-8
PL-U
t7
FROM AIRFLOW
MEASUREMENT
CHAMBER
Dh7
Dh8
pS7
Δps,7-8
PS8

Test Setups

Leakage Checks



Duct Tare Pressure Loss Test Result



Note: Error bars represent the confidence interval of the measured data points at a confidence level of 95%.

Duct Tare Pressure Loss Test Results (P = 95%)

$$\Delta p_{f,1-2} = a_1 V_1^{b_1}$$

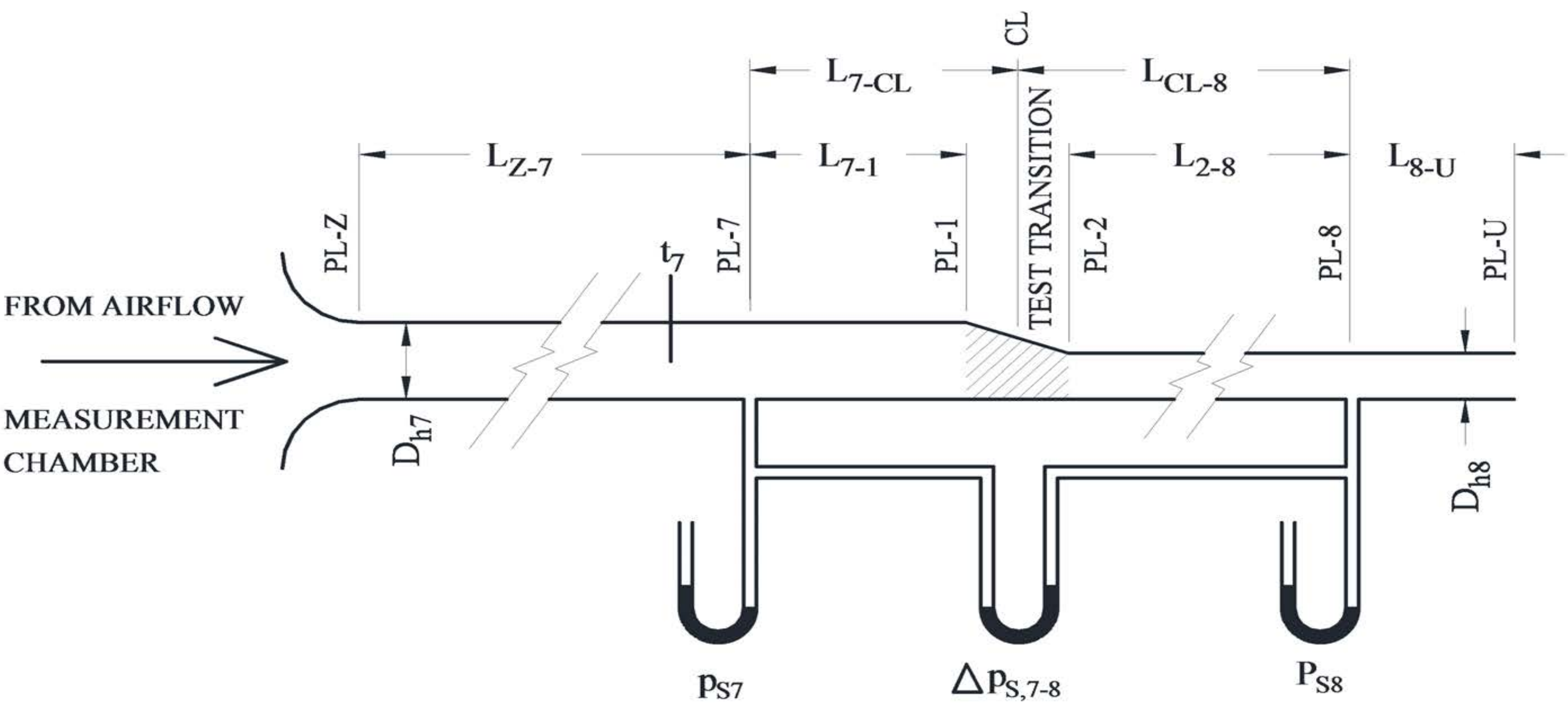
Duct Nominal Size (A × a) (in.)	a_1		b_1
	SI	I-P	
31×14	$0.324{\downarrow}-0.075{\uparrow}+0.098$	$(1.092E-06){\downarrow}-6.04E-07{\uparrow}+1.352E-06$	1.116±0.103
28×12	$0.0268{\downarrow}-0.0025{\uparrow}+0.0028$	$(1.327E-09){\downarrow}-3.34E-10{\uparrow}+4.46E-10$	1.915±0.036
26×10	$0.0176{\downarrow}-0.0077{\uparrow}+0.0135$	$(7.20E-10){\downarrow}-5.86E-10{\uparrow}+3.151E-09$	1.952±0.211
23×10	$0.0396{\downarrow}-0.0038{\uparrow}+0.0042$	$(2.310E-09){\downarrow}-5.96E-10{\uparrow}+8.03E-10$	1.884±0.037
33×6	$0.0642{\downarrow}-0.0054{\uparrow}+0.0059$	$(4.517E-09){\downarrow}-1.054E-09{\uparrow}+1.374E-09$	1.849±0.034

Determination of the Fitting Loss Coefficient

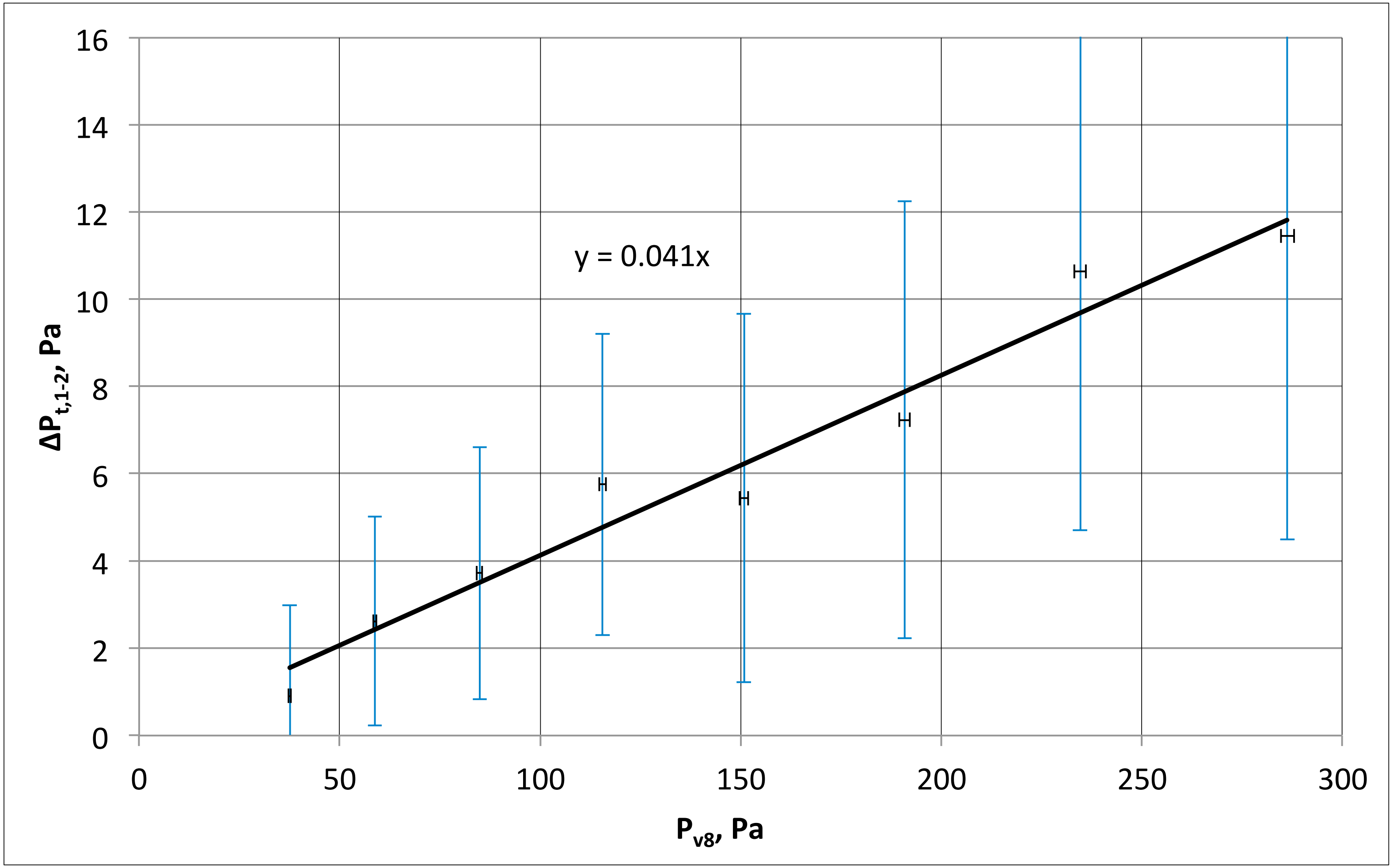
C was determined as the slope of a linear regression of p_{v8} vs. $\Delta p_{t,1\text{-}2}$, forcing the straight line through the zero-zero intercept.

$\Delta p_{t,1\text{-}2}$ was the zero-length total pressure loss of a test fitting, and calculated by:

$$\Delta p_{t,1-2} = \Delta p_{s,7-8} + (p_{v7} - p_{v8}) - \left(L_{7-\mathrm{CL}} \Delta p_{f,7-1} + L_{\mathrm{CL}-8} \Delta p_{f,2-8}\right)$$



Test A1-1-4 results (typical)



Error bars represent the confidence interval of the measured data points at a 95% confidence level.

Confidence Interval Calculations for Fitting Loss Coefficients

The standard error of *C*:

$$\sigma_C^2 = \frac{\sum\left(\Delta p_{t,1-2} - \Delta\hat{p}_{t,1-2}\right)^2}{n\sum\left(p_{v8} - \bar{p}_{v8}\right)^2}$$

The upper and lower bounds of a fitting's loss coefficient at the 95% confidence level:

$$C \pm t\sigma_C$$

Measured Loss Coefficients for the Converging Fittings (P = 95%)

Arrangement and Geometry	Upstream Nominal A × a, in.	Downstream Nominal B × b, in.	Loss Coefficient, C
1 (Concentric)	33×6	28×6 15×4	0.073±0.071 <0.020
	31×14	28×12 26×10 23×10 23×6	0.044±0.018 0.041±0.010 0.041±0.007 0.145±0.037
	23×10	14×6	0.111±0.015
	23×6	15×4	<0.020
2 (Eccentric)	33×6	28×6 15×4	0.072±0.056 <0.020
	31×14	28×12 26×10 23×10 23×6	0.022±0.014 0.073±0.011 0.043±0.011 0.121±0.027
	23×10	14×6	0.125±0.023
	23×6	15×4	<0.020
3 (Eccentric)	33×6	15×4	<0.020
	31×14	28×12 26×10 23×10 23×6	0.038±0.017 0.060±0.020 0.082±0.007 0.151±0.023
	23×10	14×6	0.120±0.024
	23×6	15×4	<0.020

Empirical Equation for Converging Fittings

$$C = 0.032 \times \ln\left(\frac{A \times a}{B \times b}\right) \times \left(\frac{A}{a}\right)^{1.58} \pm 0.035$$

where *A*, *a*, *B* and *b* were the actual (NOT nominal) sizes of the upstream and downstream oval flat ducts.

The standard error of the regression was 0.016. R^2 (the coefficient of determination) of the regression was 0.97. The differences of the loss coefficients between concentric and eccentric fittings were not statistically significant.

Measured Loss Coefficients for the Diverging Fittings (P = 95%)

Arrangement and Geometry	Upstream Nominal A × a, in.	Downstream Nominal B × b, in.	Loss Coefficient
1 (Concentric)	28×6	33×6	0.015±0.009
	15×4		8.410±0.238
	28×12	31×14	<0.020
	26×10		0.295±0.143
	23×10		0.313±0.201
	23×6		2.130±0.339
	14×6	23×10	2.993±0.092
	15×4	23×6	2.980±0.093
2 (Eccentric)	28×6	33×6	<0.020
	15×4		7.975±0.192
	28×12	31×14	0.024±0.149
	26×10		0.328±0.132
	23×10		0.293±0.214
	23×6		1.401±0.318
	14×6	23×10	2.811±0.074
	15×4	23×6	2.822±0.107
3 (Eccentric)	15×4	33×6	8.219±0.209
	28×12	31×14	<0.020
	26×10		0.420±0.186
	23×10		0.332±0.128
	23×6		2.531±0.147
	14×6	23×10	3.244±0.071
	15×4	23×6	2.924±0.061

Empirical Equation for Diverging Fittings

$$C = 0.684\left(\frac{A_{\mathrm{d}}}{A_{\mathrm{u}}} - 1\right)^{2.46}$$

$$A_{\mathrm{u}} = \frac{1}{4}\pi a^2 + a(A - a) \qquad A_{\mathrm{d}} = \frac{1}{4}\pi b^2 + b(B - b)$$

The upper bound: $$C + \varepsilon_2 = 0.958\left(\frac{A_d}{A_u} - 1\right)^{2.46}$$

The lower bound: $$C - \varepsilon_1 = 0.488\left(\frac{A_d}{A_u} - 1\right)^{2.46}$$

The standard error of the transformed linear regression was 0.457. R^2 of the transformed linear regression was 0.94. The differences of the loss coefficients between concentric and eccentric fittings were not statistically significant.

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