Measurement of air flow rates in ducts by velocity measurements: an overview

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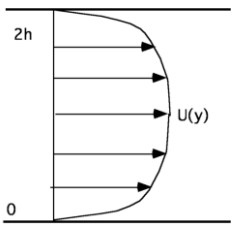
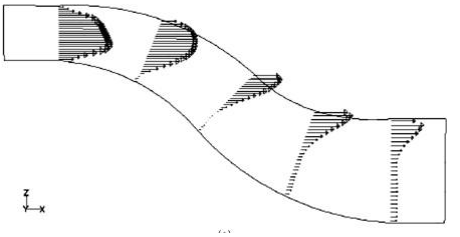
Context

- **Evaluation of air flow in duct by velocity measurements**
  - Measurement of local velocity(ies)
  - Representative value of the mean velocity from the shape of the velocity profile





Measurement of local velocity(ies)

- **Pitot tube (Prandtl tube)**
  - Measurement of a differential pressure
  - Velocity range depends on pressure range
  - V_{min} > ~ 3 m/s

$$V = k \times \sqrt{\frac{2 \times \Delta P}{\rho}}$$

Measurement of local velocity(ies)

- **Thermal anemometer**
  - Sensitive to pressure and temperature conditions
  - Fragile
  - V_{min} > ~ 0.1-0.3 m/s

Measurement of local velocity(ies)

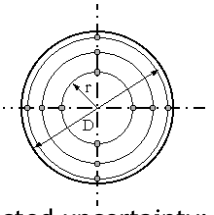
- **Vane anemometer**
  - Small size (∅ ≈ 16 mm)
  - Start threshold
  - V_{min} > ~ 1 m/s

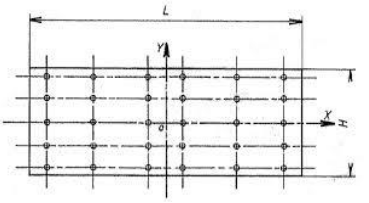
Measurement of local velocity(ies) in ducts

- **Measurement in the duct**
  - On several diameters
  - At different positions

Position of the measurement points

- **ISO 3966 (circular & rectangular ducts), "reference method"**
  - Turbulent flow
    - For any disturbances : 20D/5D (80D/20D)





  - Expected uncertainty: 2% flow rate
- **EN 12599, Pr EN 16211, NF X 10-113 (ISO 7145)**

On site measurement

- **ISO 3966**
  - Time consuming method
  - Straight lengths not always available
  - Low uncertainty not always needed
- **Question: what would be the method uncertainty if**
  - Another method is used
  - A lower number of local velocities is measured
  - The distance from the disturbances is smaller

Circular ducts (Bonthoux *et al.*)

- **Experimental conditions**
  - DN 200 (Re ≈ 200000)
  - 2 x 10 points + 1 point at the center

Circular ducts (Bonthoux *et al.*)

- **Experimental conditions**
  - DN 200 (Re ≈ 200000)
  - 2 x 10 points + 1 point at the center
  - Different disturbances
    - ☞ At 1D, 4D, 10D, 45D

Straight pipe inlet	
Elbow	
2 co-planar	
2 non-co-planar elbows	
Y junction	
Y junction with reducer	
Open damper	
Closed damper (flap at 30 °)	

Circular ducts (Bonthoux *et al.*)

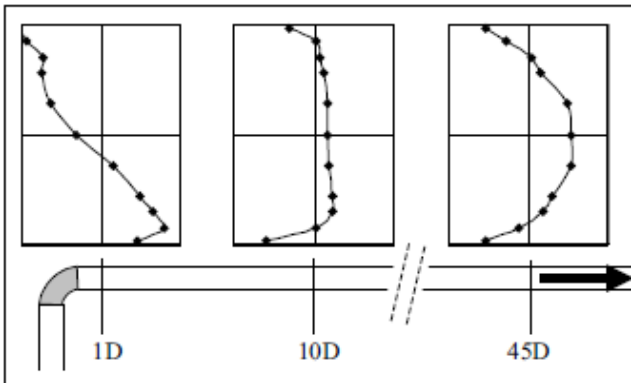


Figure 2. Profile of velocity U/Ud for an elbow (velocity axis covers a U/Ud from 0.7 to 1.3).

Circular ducts (Bonthoux *et al.*)

- **Maximum measured error (whatever the disturbance is)**

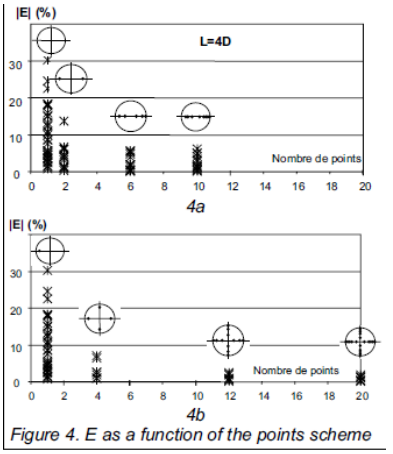


Figure 4. E as a function of the points scheme

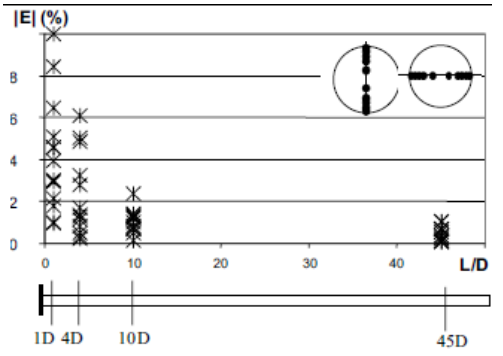
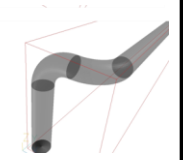


Figure 3. E as a function of L/D

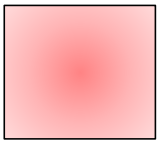
RECTANGULAR DUCTS (Caré *et al.*)

- **Disturbances**
  - 1 elbow
  - 2 coplanar elbows
  - 2 non coplanar elbows

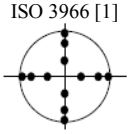
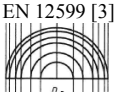
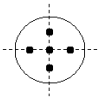




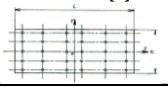
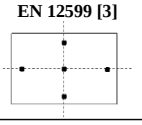
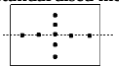
- **Rectangular ducts shape**
  - Shape factor (Length/Width) < or > 4




Expected maximum method uncertainty Circular duct

Exploration scheme	Number of diameters	Expected method uncertainty (%) L/D : Upstream distance from disturbances		
		4	10	45
ISO 3966 [1] 	2	6	3	2
	1	7	7	2
EN 12599 [3] 	2	2	3	2
	1	6	5	1
Non standardised method 	2	10	8	8
	1	15	9	9

Expected maximum method uncertainty Rectangular duct (Length/Width < 4)

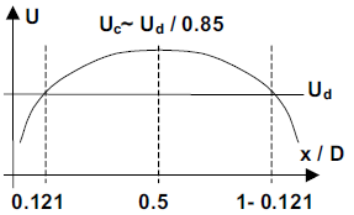
Exploration scheme	Number of traverses (points)	Expected method uncertainty (%) L/D : Upstream distance from disturbances		
		5	10	45
ISO 3966 [1] 	5 (25)	5	3	1
	1 (5)	39	9	8
EN 12599 [3] 	2 (6)	11	10	8
	1 (3)	38	26	19
Non standardised method 	2 (9)	14	16	10
	1 (5)	62	25	17

Expected maximum method uncertainty

- **To achieve an acceptable measurement uncertainty**
  - Circular duct: 5%
  - Rectangular duct: 10%
- **It is necessary to**
  - Choose a suitable method
  - Measure away from disturbances and/or Increase number of measurement points
- **… Time consuming**

Circular ducts (Caillou *et al.*)

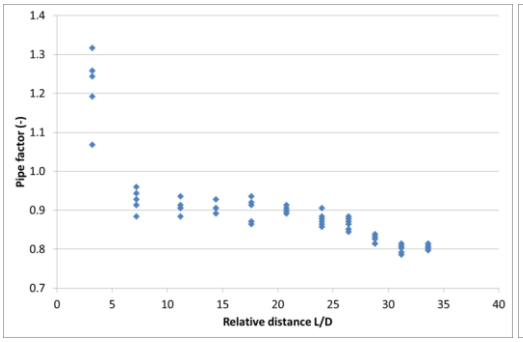
- **One measurement in the middle of the cross-section**
  - ISO 7145
  - Simple,
  - The result must be corrected with the “pipe factor” coefficient



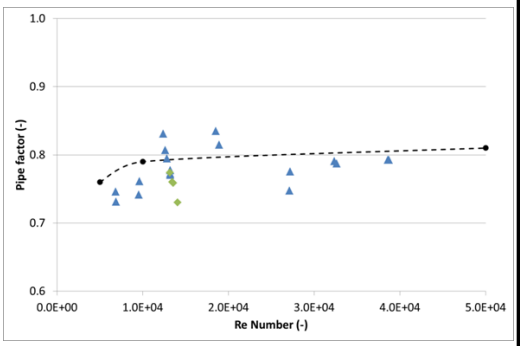
Velocity at
- centre: Uc
- flow: Ud

Circular ducts (Caillou *et al.*)

Pipe factor vs relative distance from an elbow



Pipe factor vs Reynolds number



Conclusion

- **Evaluation of flow rate in duct by velocity profile**
  - Compromise between Time & Method uncertainty
    - Circular & Rectangular ducts
  - Additional components of uncertainty
    - Instrument uncertainty
    - Knowledge of the inside duct section
    - Uncertainty of the positioning of the instrument inside the duct
    - Measurement procedure and expertise

Thank you for your attention

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