Comparison of two different methods for calibration of Cole type Pitot tubes

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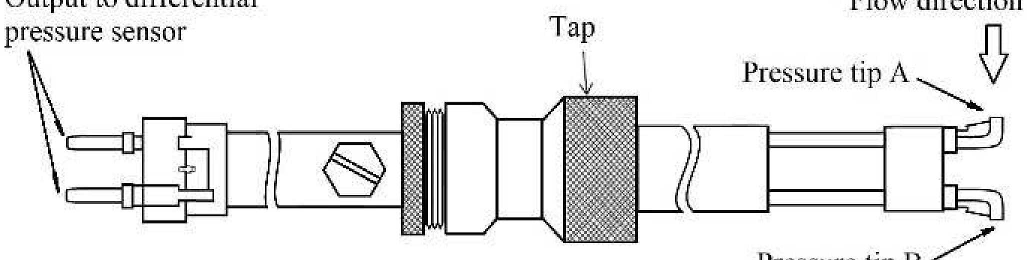
Presentation outline

1. Introduction
2. Effects of instrument calibration
3. Methodology of study
4. Results… so far
5. Conclusions

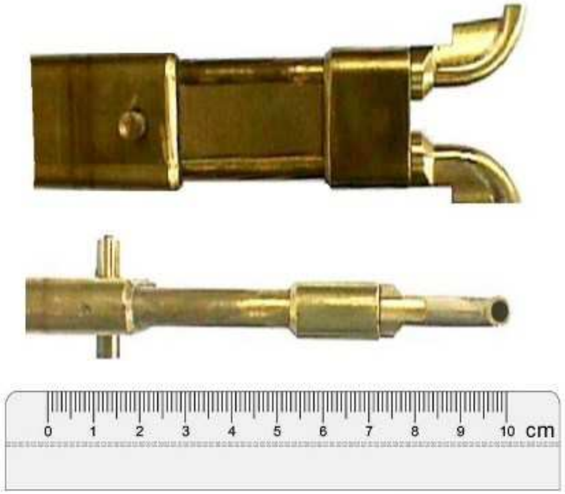
Introduction

Overview of the Cole type Pitot tube (Pitot-Cole tube)

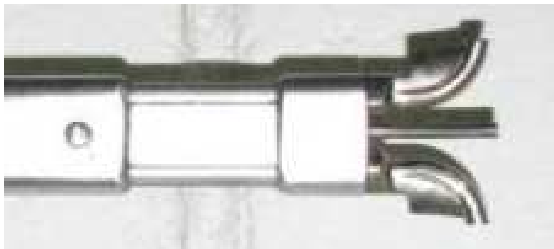


As proposed by Edward S. Cole around 1896

Without central safety pin



With central safety pin – Modified



Introduction

Advantages of the Pitot-Cole tube:

- Used for calibration of large water flow meters
- Reliable instrument
- Easy to use on-site
- Versatile for a wide range of pipe diameters
- Provides accurate measurements, as long as it is properly calibrated
- It can be used to calibrate large water flow meters under operating conditions – no need for lab calibration or flow interruption

Introduction

Disadvantages of Pitot-Cole tube:

- It needs to be inserted in the flow
- It interferes in the flow velocity profile...
- Difficulty to measure differential pressure at low Reynolds numbers

Introduction

Pitot-Cole tube principle of operation:

$$V_0 = C_d \sqrt{\frac{2\Delta P}{\rho}}$$

- V_0 is the velocity of the fluid
- ΔP is the differential pressure
- ρ is the fluid density
- C_d is the calibration coefficient

Pitot-Cole tube calibration

Literature review – calibration coefficient

- First experiments run by Cole [1] and Hubbard [2] – mean C_d of 0.869

  [1] Cole, E. S., & Cole, E. S.. “Pitot Tubes in Large Pipes”. *Transactions of A.S.M.E.*, *61*, 465–475, 1939.
  [2] Hubbard, C. W.. “Investigation of Errors of Pitot Tubes”. *Transactions of A.S.M.E.*, *61*, 477–506, 1939.

- Recommended physical simulation of disturbances for large pipes of operational conditions – unpractical for calibration

- Closer methods: towing tank and closed conduits

- Alternative method used at IPT: wind tunnel

- Good agreements for $Re/L > 5 \times 10^5$ with towing tank and closed conduits experiments

Effects of instrument calibration

Literature review – calibration coefficient

- Individual and periodic calibration of Pitot-Cole tubes is needed [1]. Up to 5 % in C_d variation along time are reported.

[1] Espirito Santo, G., & Sanchez, J. G.. "Calibração De Tubos De Pitot Tipo Cole", *20º Congresso Brasileiro de Engenharia Sanitária e Ambiental*, 2096–2105, 1999.

- Differences in C_d values for each tip of the tube

- According to Buscarini et al.[2], a fixed value of C_d can impact in up to 1.5 % in flow measurement uncertainty.

[5] Buscarini, I. D. O., Barsaglini, A. C., Jabardo, P. J. S., Taira, N. M., & Nader, G.. "Impact of Pitot tube calibration on the uncertainty of water flow rate measurement". *Journal of Physics: Conference Series*, *648*, 2015.

Effects of instrument calibration

- Figures presented clearly show the importance of accurate C_d values, attained individually and for each tip of the tube

- To ensure calibration, easy and reliable methods must be developed

- In this work, two methods are compared

Methodology of study

- Set of four Pitot-Cole tubes:
  - Two with central pin
  - Two without central pin
  - Tips A and B were tested – equivalent to 8 different instruments

- Results were established as function of dimensionless Reynolds numbers divided by unitary diameter (Re/L)

- C_d calculated for various Re/L by two methods:
  - Wind tunnel: 20 velocities
  - Towing tank: 17 velocities

  ⟩ Same range of Re/L

Re/L	V air [m/s]	V water [m/s]
1,00E+05	1,7	0,1
2,00E+05	3,3	0,2
3,00E+05	5,0	0,3
4,00E+05	6,6	0,4
5,00E+05	8,3	0,5
6,00E+05	9,9	0,6
7,00E+05	11,6	0,7
8,00E+05	13,2	0,8
9,00E+05	14,9	0,9
1,00E+06	16,5	1,0
1,10E+06	18,2	1,1
1,20E+06	19,9	1,2
1,30E+06	21,5	1,3
1,40E+06	23,2	1,4
1,50E+06	24,8	1,5
1,60E+06	26,5	1,6
1,70E+06	28,1	1,7
1,80E+06	29,8	1,8
1,90E+06	31,4	1,9
2,00E+06	33,1	2,0
2,10E+06	34,7	2,1
2,20E+06	36,4	2,2
2,30E+06	38,1	2,3

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Methodology of study

Wind tunnel experiments

- Prefered method at IPT for calibration

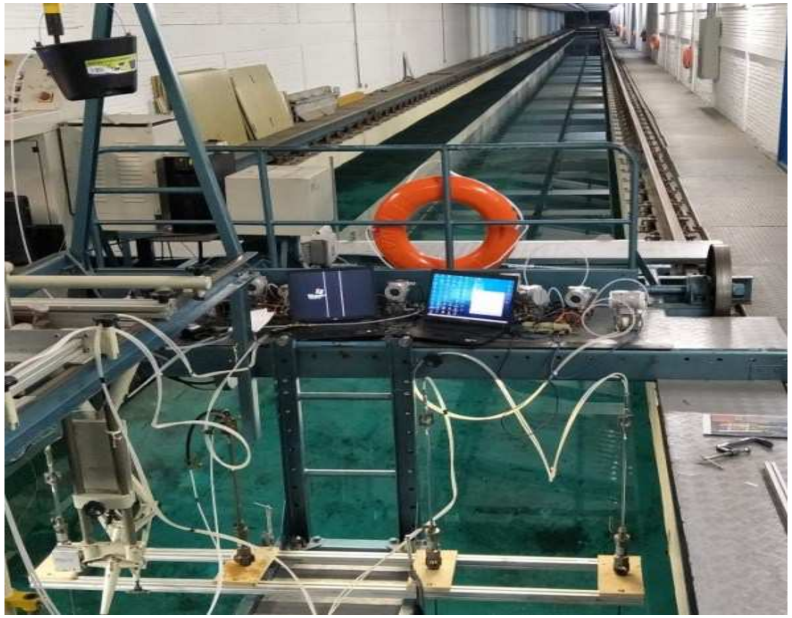
- C_d is calculated as a relation between measurements from a standard static Pitot tube and those from Pitot-Cole tube

$$C_d = C_{Standard}\sqrt{\frac{\Delta P_{Standard}}{\Delta P_{Cole}}}$$

Methodology of study

Towing tank experiments

- Conventional method, although more expensive and time consuming



- C_d is calculated as a relation between imposed velocity and those obtained from Pitot-Cole tube measurements

$$C_d = \frac{V_{Carriage}}{V_{Cole}}$$

Methodology of study

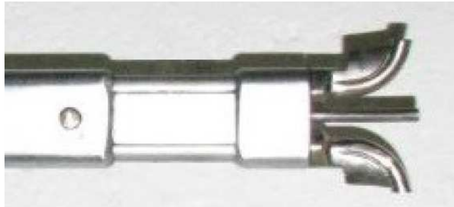
- Main *focus* on reducing uncertainty for extreme values of Re/L

- Sample regarded as two sets of Pitot-Cole tubes:
  - Four with central pin
  - Four without central pin

- The limit of $Re/L = 5 \times 10^5$ mentioned by Espirito Santo [1] is evaluated, since their sample was scarce and ranges were more limited

[1] Espirito Santo, G., & Sanchez, J. G.. “Calibração De Tubos De Pitot Tipo Cole”, *20º Congresso Brasileiro de Engenharia Sanitária e Ambiental*, 2096–2105, 1999.

Results



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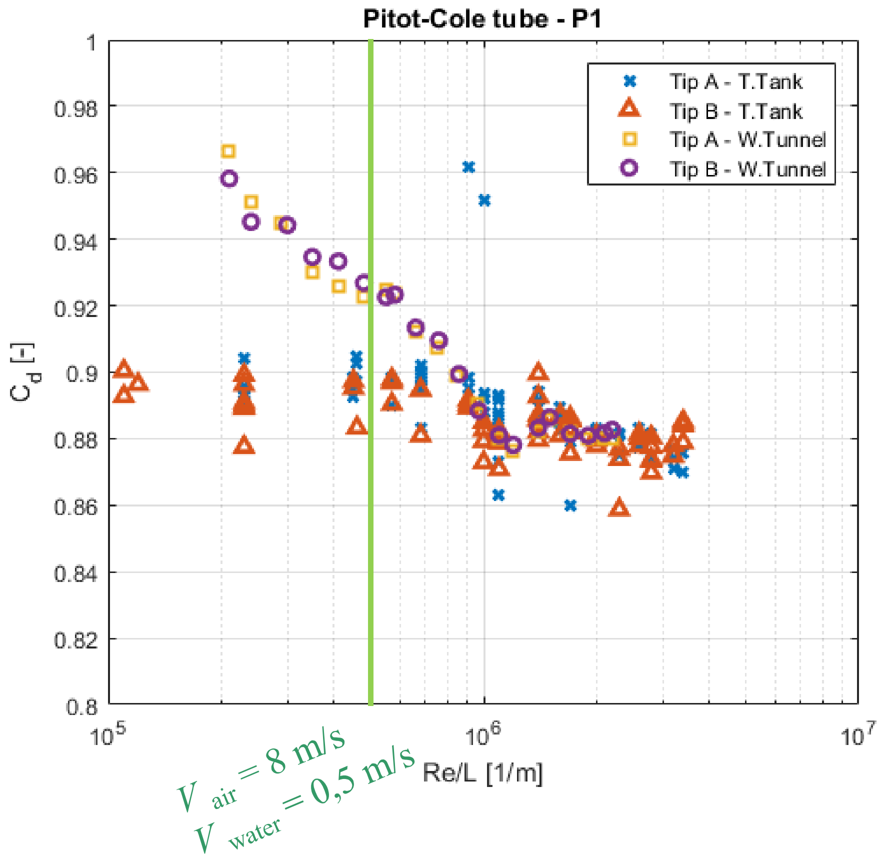
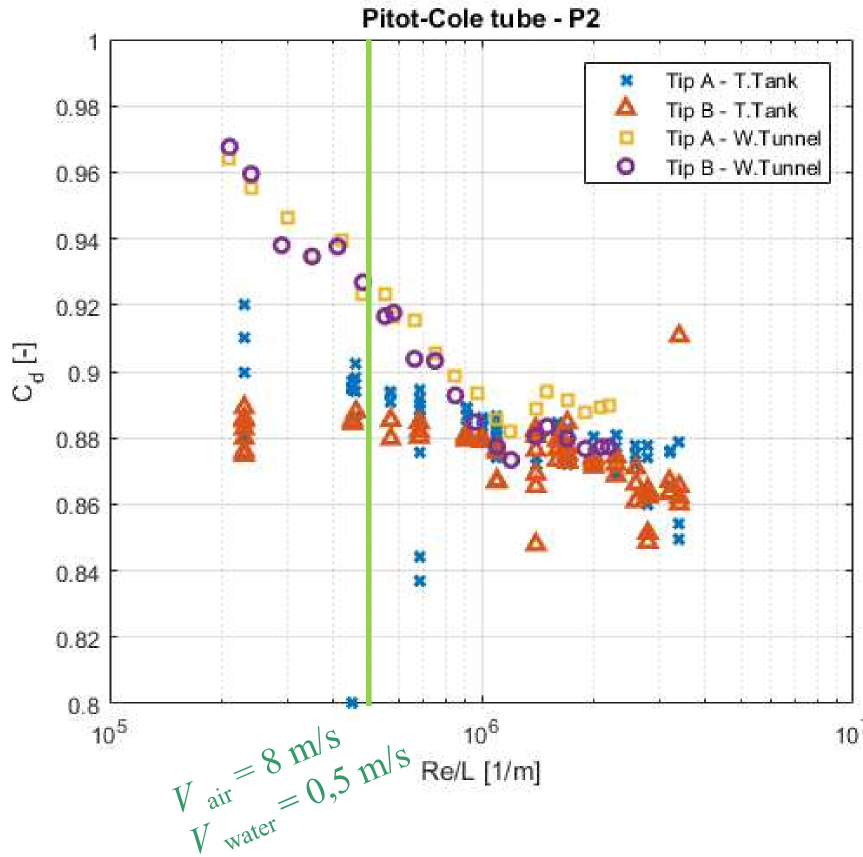
Pitot-Cole **with** central pin (P1 and P2):





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Results

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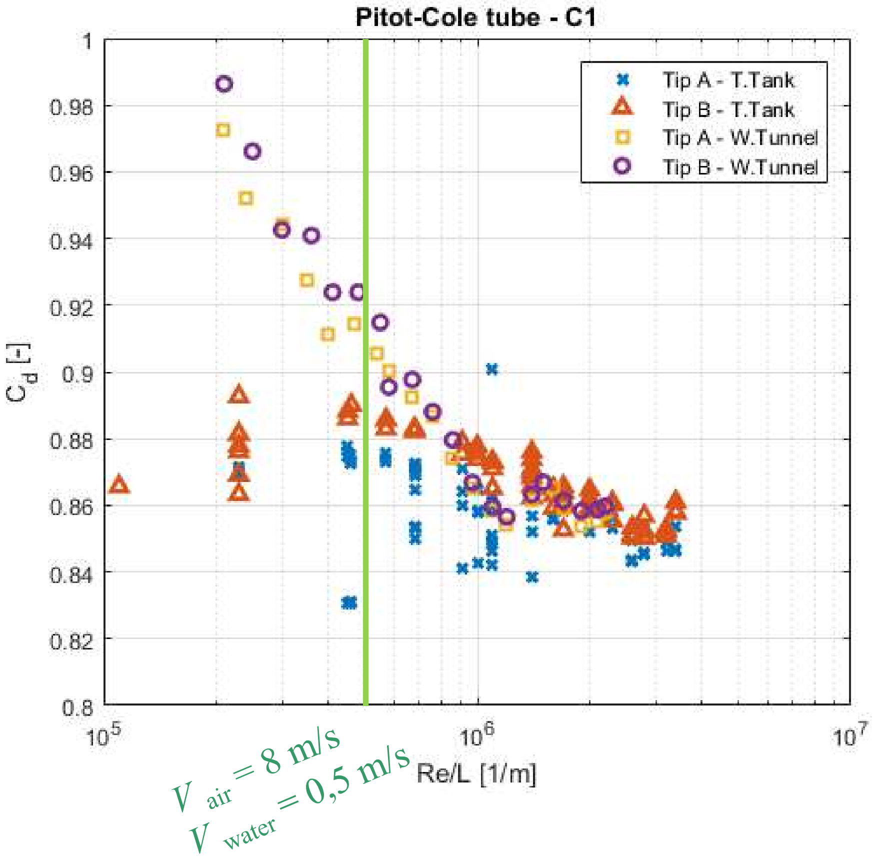
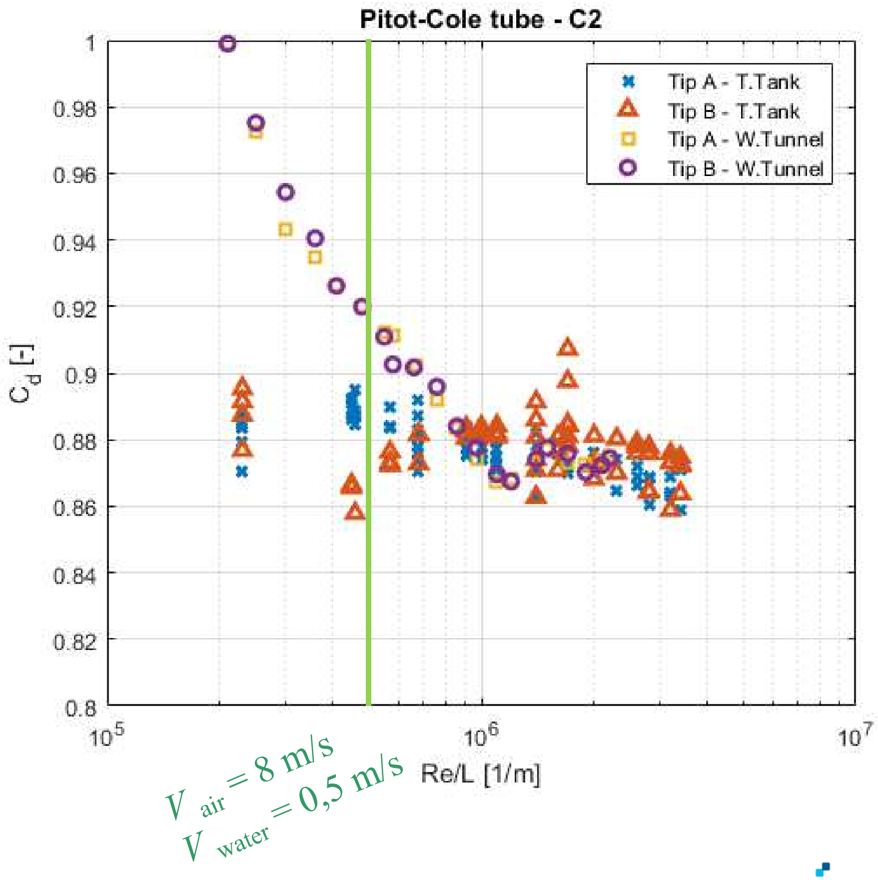
Pitot-Cole **without** central pin (C1 and C2):





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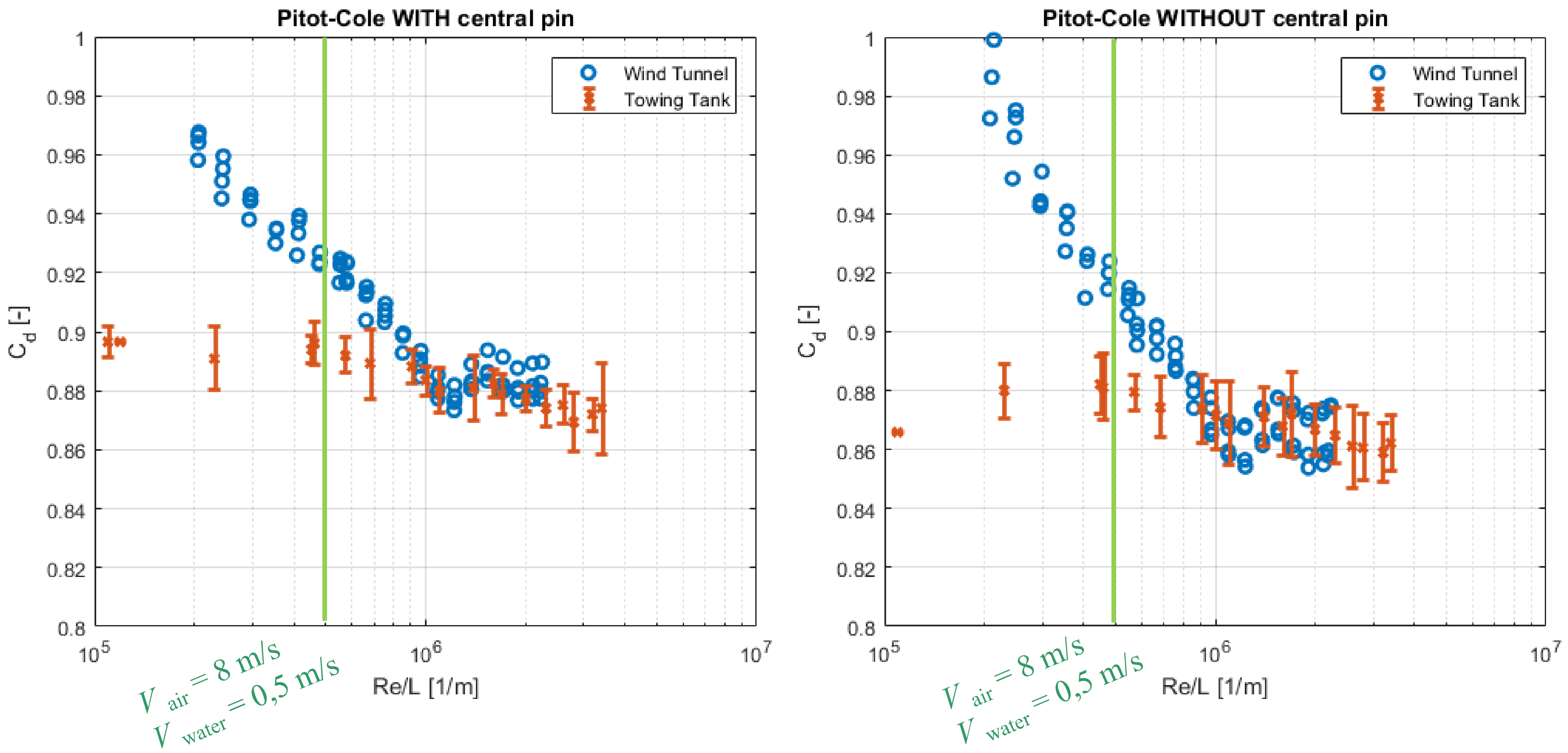
Conclusion

- Data grouped without differentiation of tips:



*Bars indicate standard deviation from the mean value of C_d

Conclusion

- Good agreement with previous studies for $5 \times 10^5 < Re/L < 2.5 \times 10^6$
- For $Re/L > 1.0 \times 10^6$, results indicate that a constant value of C_d can be employed individually for each tip of a Pitot-Cole tube.
- Care must be taken, since more study is needed, but towing tank constant value is recommended because of its independence from velocity profile.
- Comparison with experiments in closed conduits are necessary (and are in course...)
- Evaluation of viscous effects for low Reynolds numbers must be performed.
- Wind tunnel is a robust method for common velocities in water distribution systems: guarantees low uncertainty.

Thank you for your attention!