4-tube “2-in-1” Coriolis design with two independent measuring tube pairs

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Introduction

- Coriolis mass flow meters are most commonly one or two tubes
- 4-tube coriolis meters have been around for many years
- What is the advantage of 2 systems in one?

“2 in 1” 4 tube design

- Promass Q 300/500
  - 4 tube version available from DN150 to DN250 (6” to 10”)
- Consists of two independent tube pairs: inner pair and outer pair
- Each pair has its own driver, sensors and couplers
- This provides two independent flow and density values
- Each pair has different working frequencies

Reducing measurement uncertainty

The statistic theory has shown that for a total measurement equally divided by two sub-measurements of two independent measuring devices, the measurement uncertainty caused by random errors is reduced by a factor of $\sqrt{2}$ for the combined total measurement [1].

[1] NIST TN 1297: "*Appendix A. Law of Propagation of Uncertainty*", 2019.

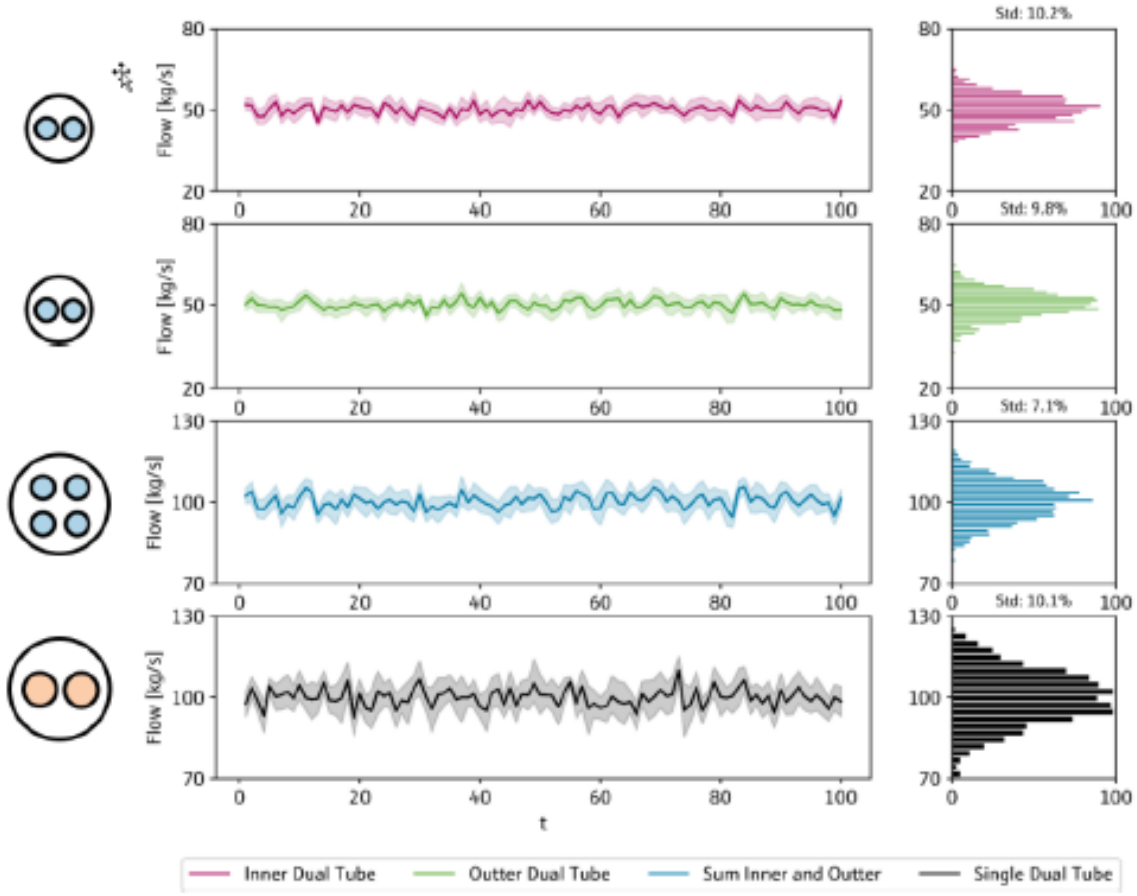


Figure 7: Comparison of repeatability between a conventional dual-tube meter and a "2 in 1" 4-tube meter of the same size (red and green: small inner and outer dual-tube meters; blue: combined "2 in 1" 4-tube meter; black: conventional dual-tube meter).

Test data

Improved repeatability can be achieved by combining the measurements from the individual tube pairs

4-tube meter: 6”

Indicated flow [ton/h]	Deviation [%]	Repeatability [%]
16.42	-0.011	0.003
25.70	-0.005	0.010
43.06	0.008	0.003
72.30	0.024	0.005
119.81	0.027	0.001
189.68	0.018	0.002
307.70	-0.005	0.005
506.74	0.003	0.013

Table 2.1: Proving result at Euroloop for a 6" 4-tube meter with 20 cSt oil (Certificate number EH.200918.0838.12.1.A.R1).

4-tube meter: 10”

Indicated flow [ton/h]	Deviation [%]	Repeatability [%]
50.81	-0.078	0.008
78.52	-0.001	0.016
127.57	0.023	0.007
213.80	0.037	0.003
341.28	0.027	0.003
556.32	-0.004	0.001
896.87	-0.026	0.011
1453.86	-0.022	0.002

Table 2.2: Proving result at Euroloop for a 10" 4-tube meter with 20 cSt oil (Certificate number EH.200914.1406.12.2.A.R1).

Enhanced stability

- A stable zero-point is critical for accurate measurement
- It’s very important to decouple the tubes from the environment
  - The tube diameter, housing stiffness and mechanical connections all contribute to the zero-point stability
- Smaller tube mass = smaller residual force on housing
  - This leads to better zero-point stability
- Testing on TÜV SÜD’s EPAT rig proved the zero-point deviations of the individual measurement pairs were subject to random deviations and can be combined to mitigate each other, reducing the overall zero-point deviation

Test data

- The “2 in 1” meter design provides a “cancelling effect” and achieves a more stable zero point

Test No.	Fluid/Process condition	Zero Point of outer tube pair	Zero Point of inner tube pair	Zero Point of “2 in 1” meter
1	Velocite (40 cSt)	0.2	0.0	0.2
2	Aztec (600 cSt)	-0.8	1.1	0.3
3	EPAT (20°C, 5 barg)	0.7	-0.5	0.2
4	EPAT (20°C, 45 barg)	1.2	-0.5	0.7
5	EPAT (80°C, 45 barg)	0.7	-0.5	0.2
6	EPAT (80°C, 25 barg)	0.2	-0.5	-0.5
7	EPAT (80°C, 5 barg)	-0.8	0.0	-0.8
8	EPAT (40°C, 45 barg)	-0.3	0.5	0.2
9	EPAT (40°C, 25 barg)	-0.3	0.5	0.2
10	EPAT (40°C, 5 barg)	-0.8	0.0	-0.8
Exp. unc.		**0.67**	**0.68**	**0.53**

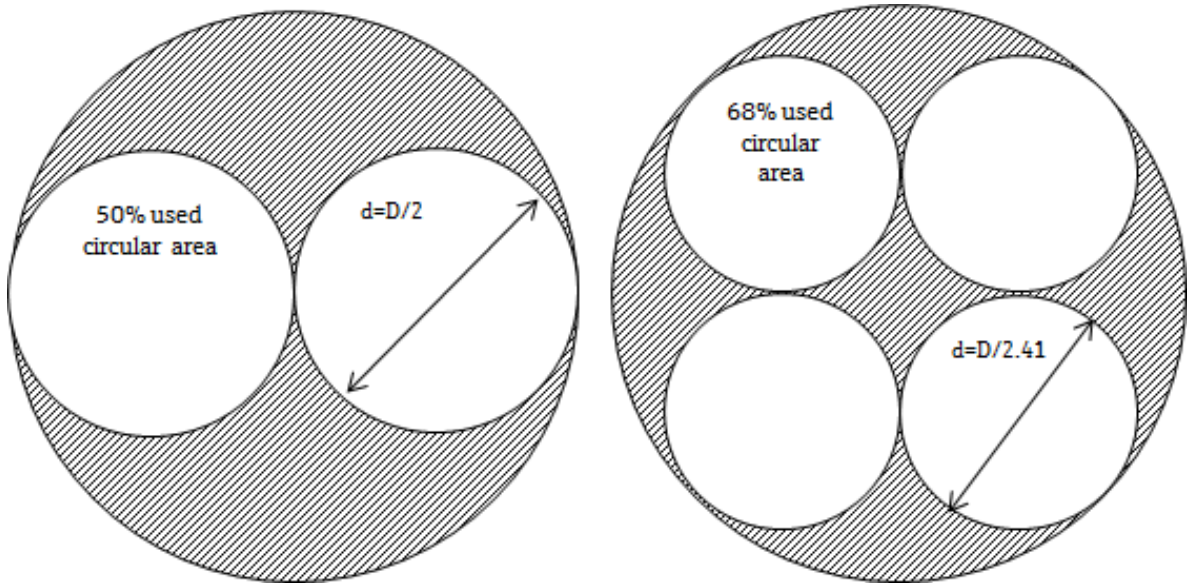
Table 1: Static Zero Point tests of a “2 in 1” 4-tube meter at NEL.

Reynolds number and pressure loss

- 25% increase in flow area for 4 tubes Vs 2 tubes
  - Reduced pressure loss for same flow rate
  - Faster on-/off-loading

- Smaller diameter tubes mean less deviation due to the Reynolds Number effect (for the same tube length)

- Smaller tube diameter results in a lower pressure effect



Enhanced process insights

- Individual density readings
  - Transient disturbances to volume flow calculations can be mitigated using the two independent density measurements
- Ratio of mass flow between tubes
  - Earlier build up detection due to different velocity profiles
- Temperature differential between tube pairs
  - Possible to detect temperature stratification

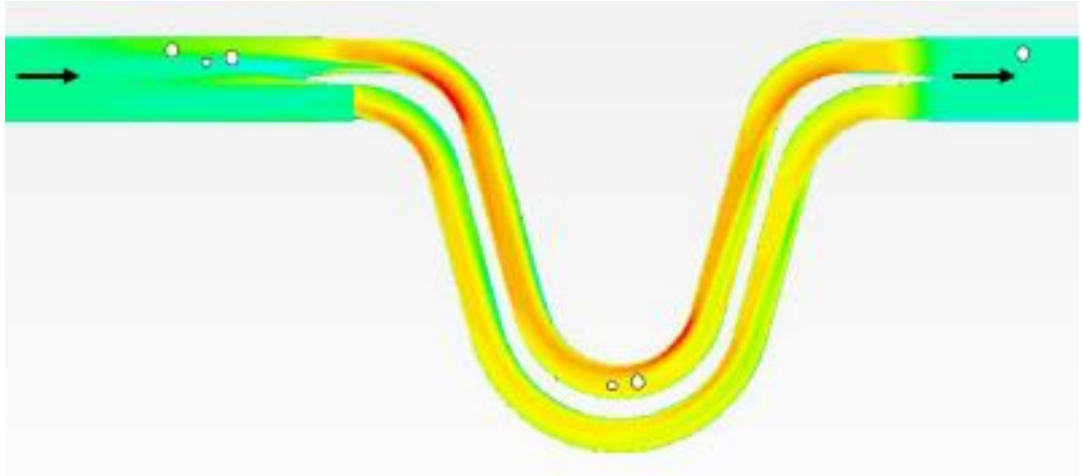


Figure 9: Transient bubbles flowing through a "2 in 1" 4-tube meter.