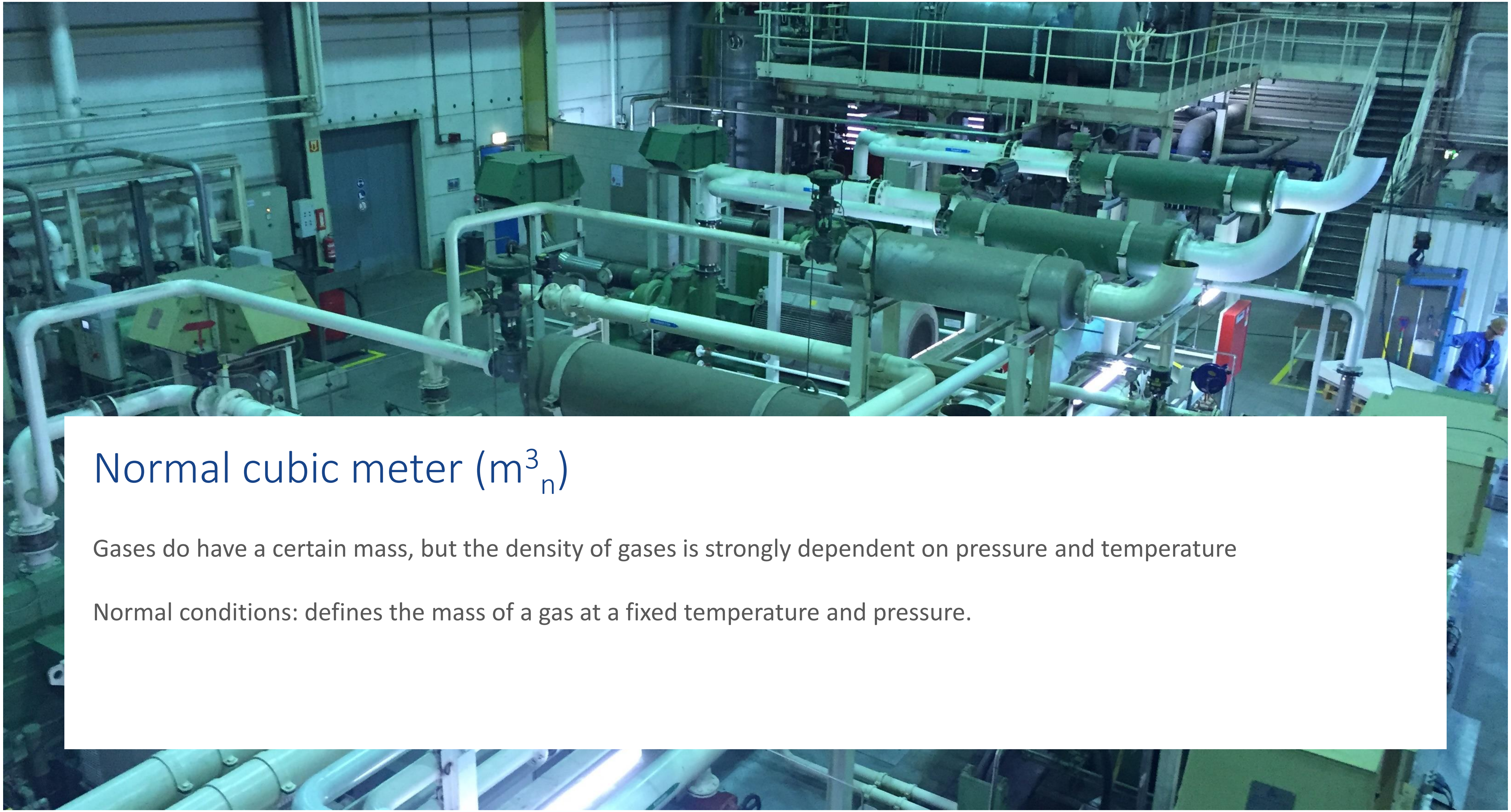
Introduction to Flow measurement

VPInstruments



Normal cubic meter (m^3_n)

Gases do have a certain mass, but the density of gases is strongly dependent on pressure and temperature

Normal conditions: defines the mass of a gas at a fixed temperature and pressure.

Normal cubic meter (m^3_n)

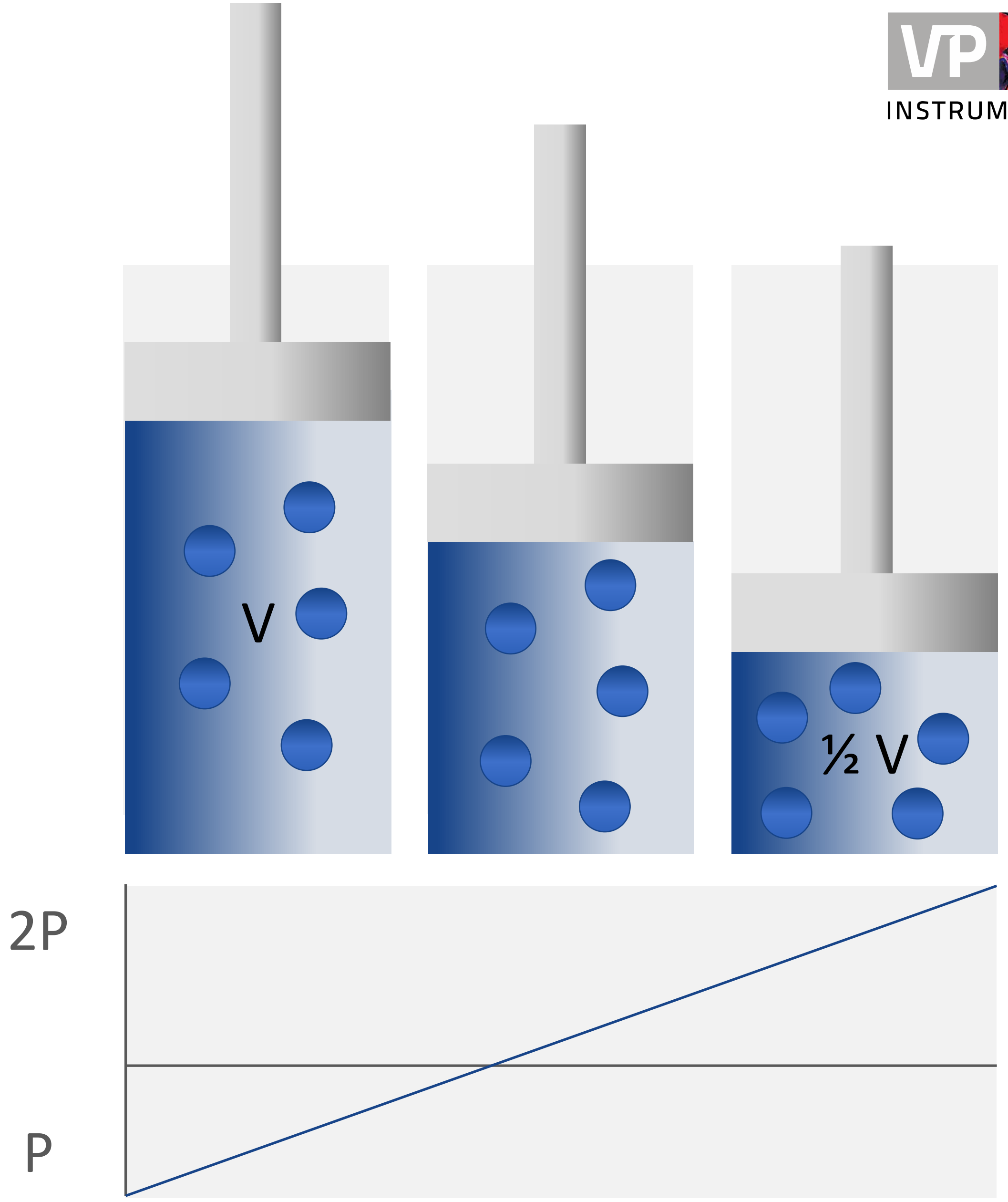
- Volume: $1m^3$
- Temperature: 0°C
- Pressure: 1013,25 mbar
- Relative humidity: 0%
- Mass: 1293 gram

m^3_n

The ideal gas law

Pressure * Volume / Temperature = Constant

$$\frac{(P*V)}{T} = n_m * R$$



Normal conditions may vary

Other common normal conditions:

- **20˚C reference (FAD):** See ISO 1217
- **15˚ reference:** See DIN 1533
- **CAGI:** 68 F, 14.5 PSIA, 0% water vapor pressure

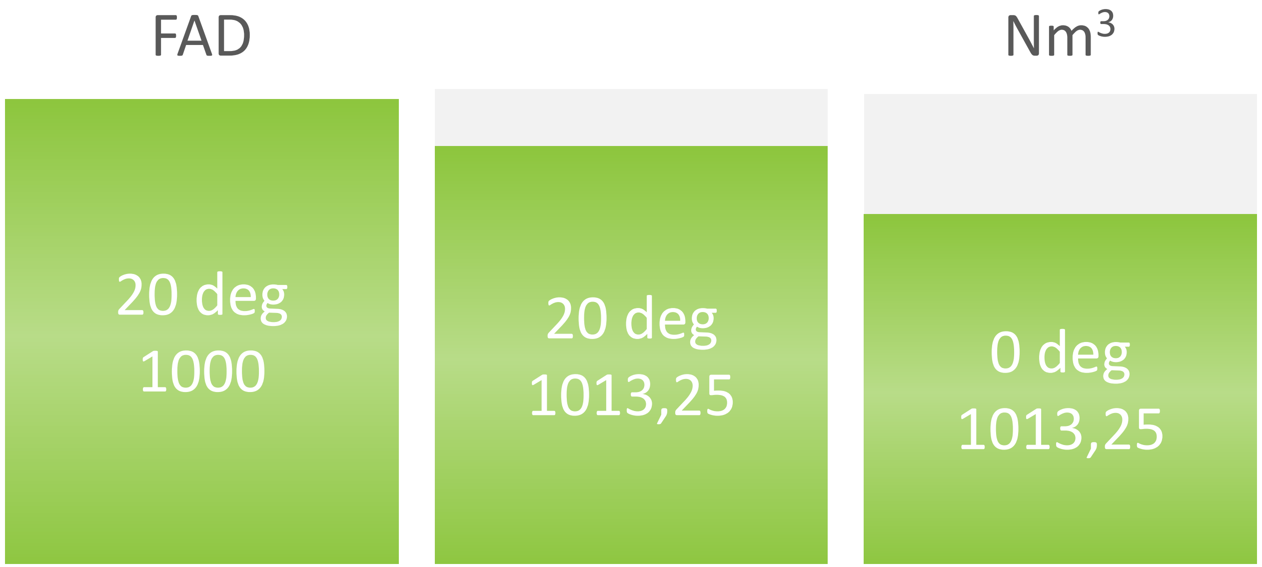
$$Nm^3/hr = V * (TN / T) * (P / PN)$$

From FAD to normal cubic meter

INSTRUMENTS

$100\ m^3/hr\ FAD * 273,16/(273,16+20) * 1000/1013,25 = 91,95\ Nm^3/hr$

FAD/Nm^3 factor = 1,0874 → 8,7% difference when comparing numbers



Thermabridge™ technology

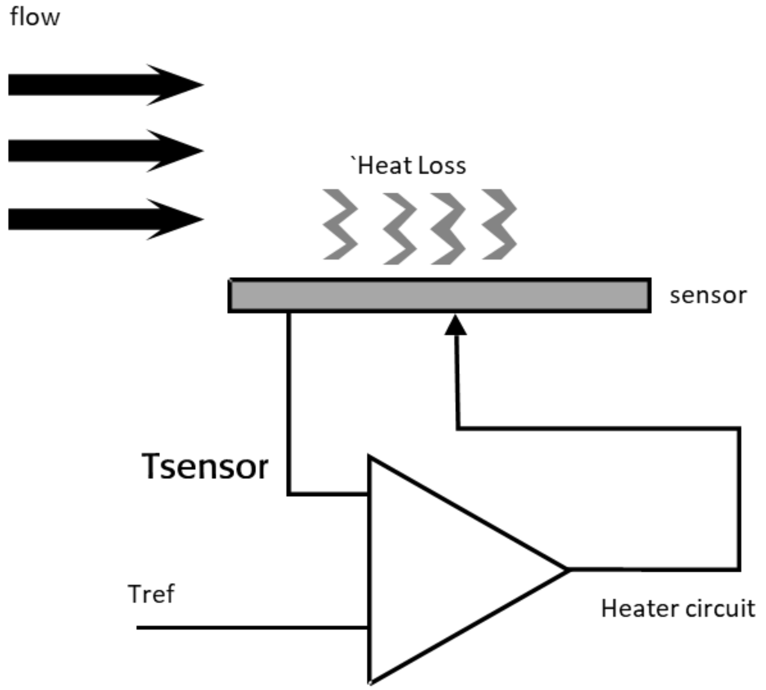
Core technology of the VPFlowScope®

Thermabridge™ technology

Vout = k ∗ λ ∗ **ρ ∗ v** ∗ (Ts−Tg)

- Vout = output voltage
- k = sensor (geometrical) constant
- λ = thermal conductivity of the gas
- ρ = density of the gas
- v = actual velocity in in m / sec
- Ts = sensor temperature
- Tg = gas temperature

Working principle



ρ * v: mass flow

Normal meter per second

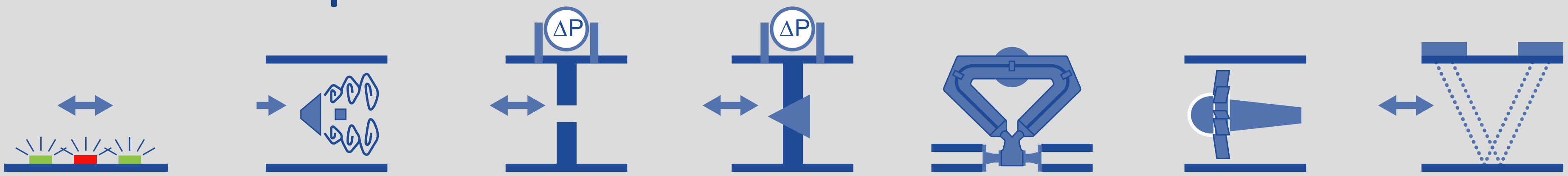
Thermal mass flow: velocity in Normal meter per second

Rule of thumb:

"Actual velocity times absolute pressure" (forget temperature)

Example: 8 m/sec∗ 7 bar abs ~ 56 m_n/sec

Principles compared



	Thermal	Vortex	DP – Orifice plate	DP – Cone meter	Coriolis	Turbine/ rotary displacement	Clamp on ultrasonic
Mass flow	Yes	Optional	Optional	Optional	Yes	Optional	Optional
Meter run	20D	15D	15D	5D	0D	10D	20D
Pressure loss	Low	Medium/high	high	high	Low	Low	Low
Dirty air	Fouling	OK	Clogging	Clogging	Internal fouling	Faillure	OK
Wet Air	Spikes	OK, spikes	OK	OK, orientation	Yes, but affects reading	Faillure	Spikes
Range	1:250	1:10	1:10	1:10	1:100	1:100	1:100
Accuracy	2%	2%	2%	2%	0.5 .. 1%	0.5…1 %	1%
Purchase price	$	$	$	$	$$$$	$$	$$$
Maintenance	Medium	Low	Medium	Medium	Low	High	Low

Value of mass flow and 3-in-1

We believe in: Pressure ∗ Flow = Voltage ∗ Current – Energy!

- Flow, Pressure, Temperature combined
- ISO 11011 (e.g. must measure pressure on multiple locations)
- Difference between supply and demand
- How to detect cause of a pressure drop if you dont measure?
- Internal accounting: 7 bar is more expensive than 6 bar
- Flow & temperature to identify issues with compressed air driers and (water) cooled compressors

Velocity to mass flow

Check the inner pipe diameter
Area $A = \pi * 0.25 * D^2$

Wrong entry of D → big deviation

Example:

V = 60mn/sec

D: 50 mm → Q = 0,117 m^3_n / sec

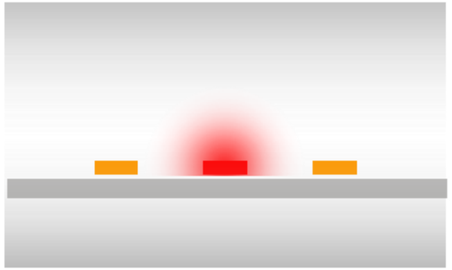
D: 54 mm → Q = 0,137 m^3_n / sec

Difference: 17%

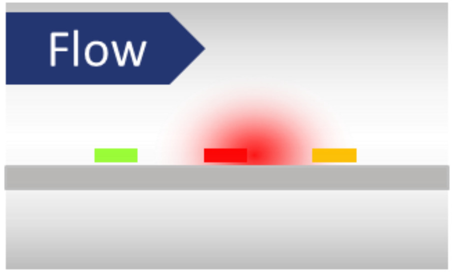
True diameter	Measured error	Measured diameter	% of error
50	3	53	12.36
100	3	103	6.09
200	3	203	3.02
300	3	303	2.01

Sensing direction

No flow
Everything in balance.



Flow from left
The left part is cooled down; the right part of the bridge is heated up.



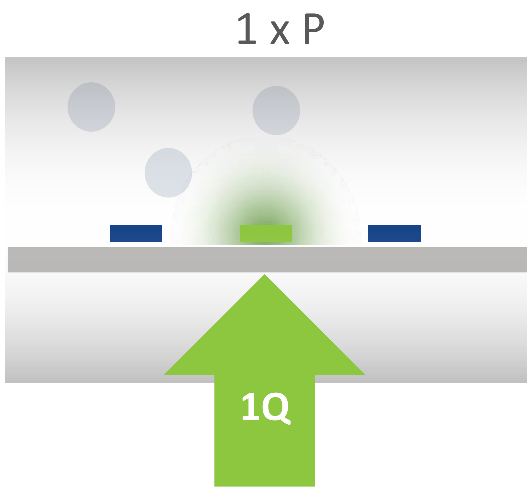
Flow from right
Vice versa! Now the left part is heated up and the right part is cooled down.

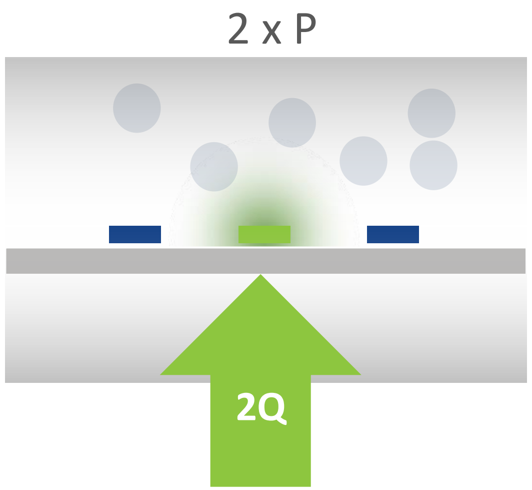
Thermal mass flow = pressure independent

Why? The sensor counts molecules:

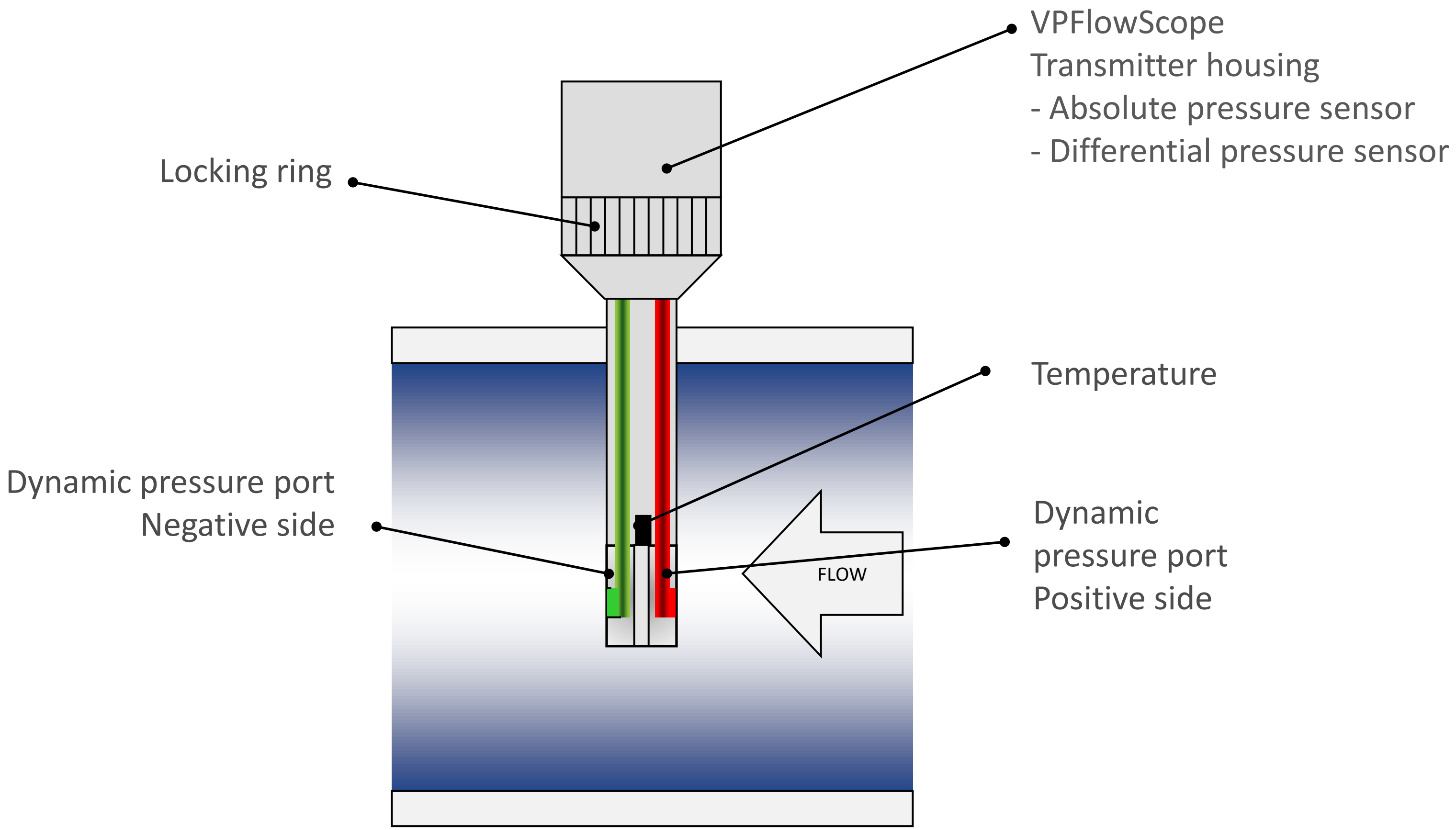
More pressure = denser air* = more molecules = more heat loss*

* : linear with pressure





Differential pressure technology



Flow range is critical

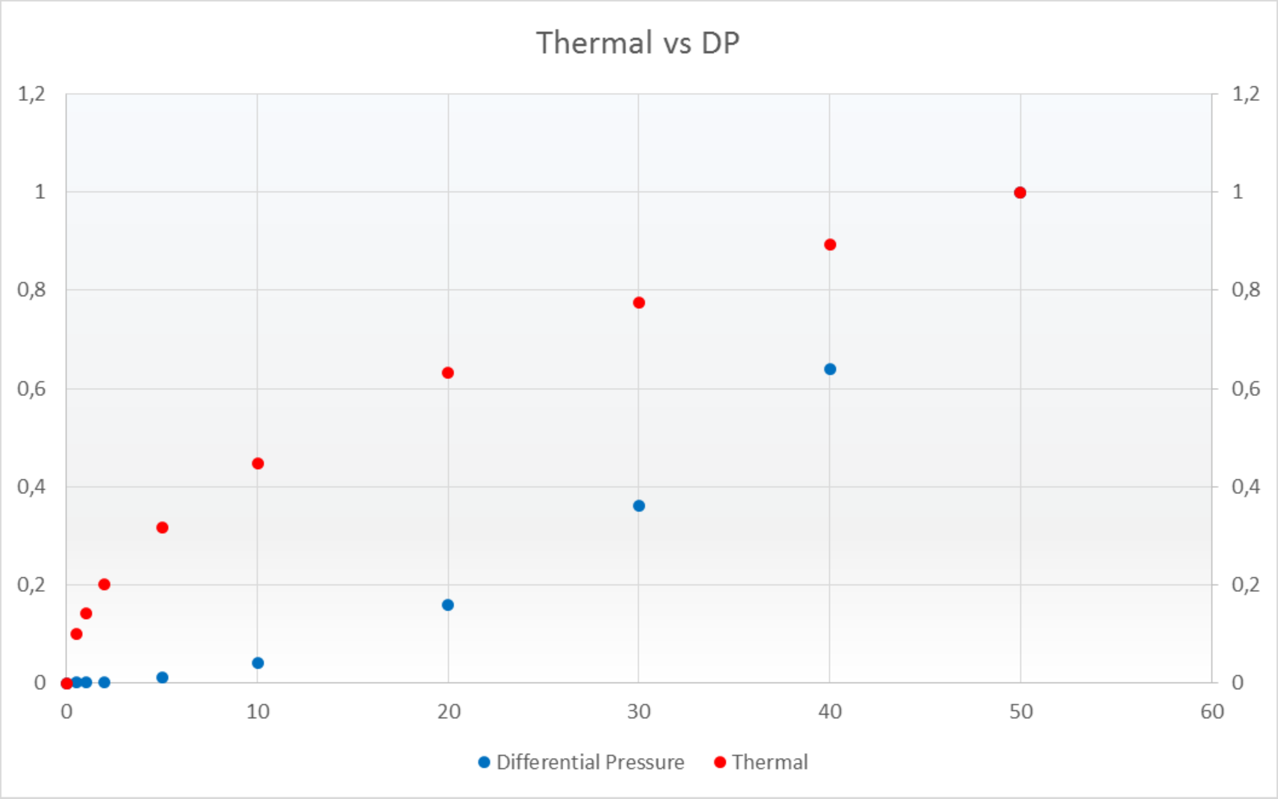
Thermal vs DP technology: 1:300 range vs 1:10 (1:5) range

Thermal:

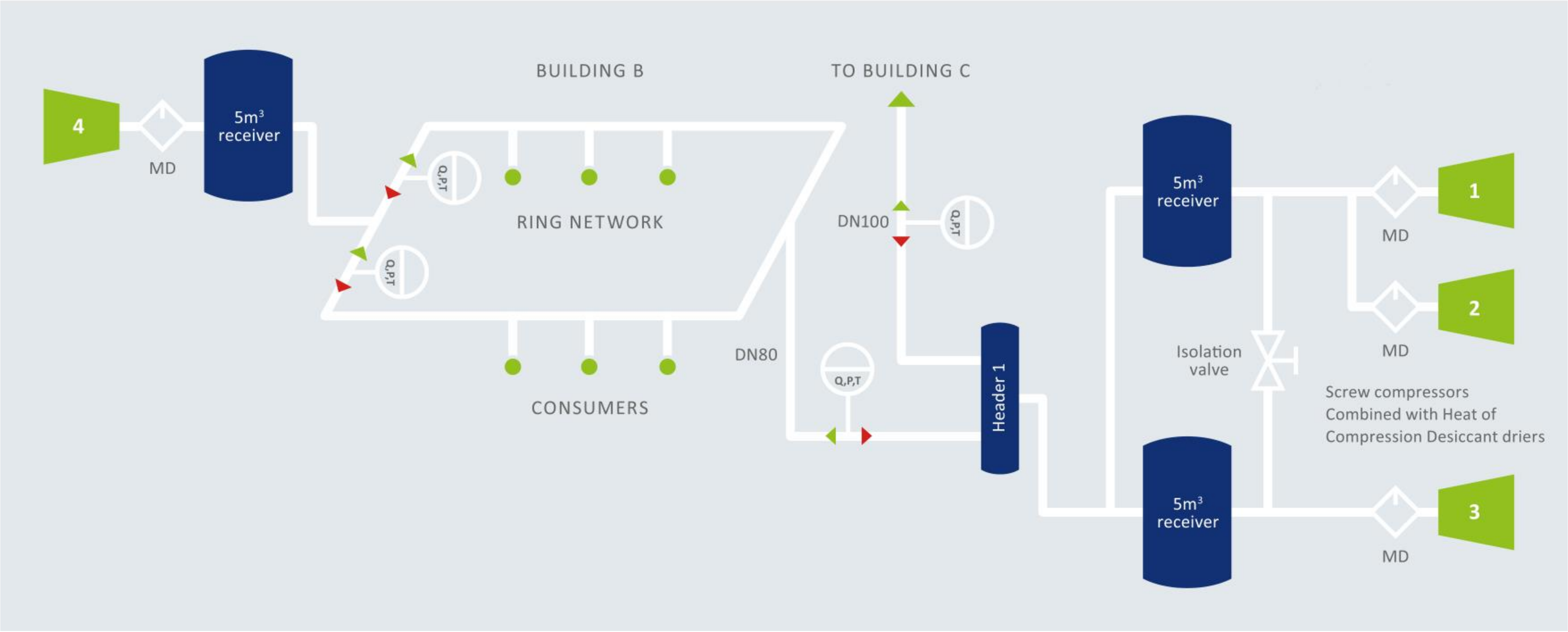
- From leakages to high flow
- Dry air only
- Temp range up to ~60°C

DP:

- Only medium to high flow rates
  - Not suitable for leakage/low flows
- Wet air and dry air
- Temp range up to ~150°C (or higher)

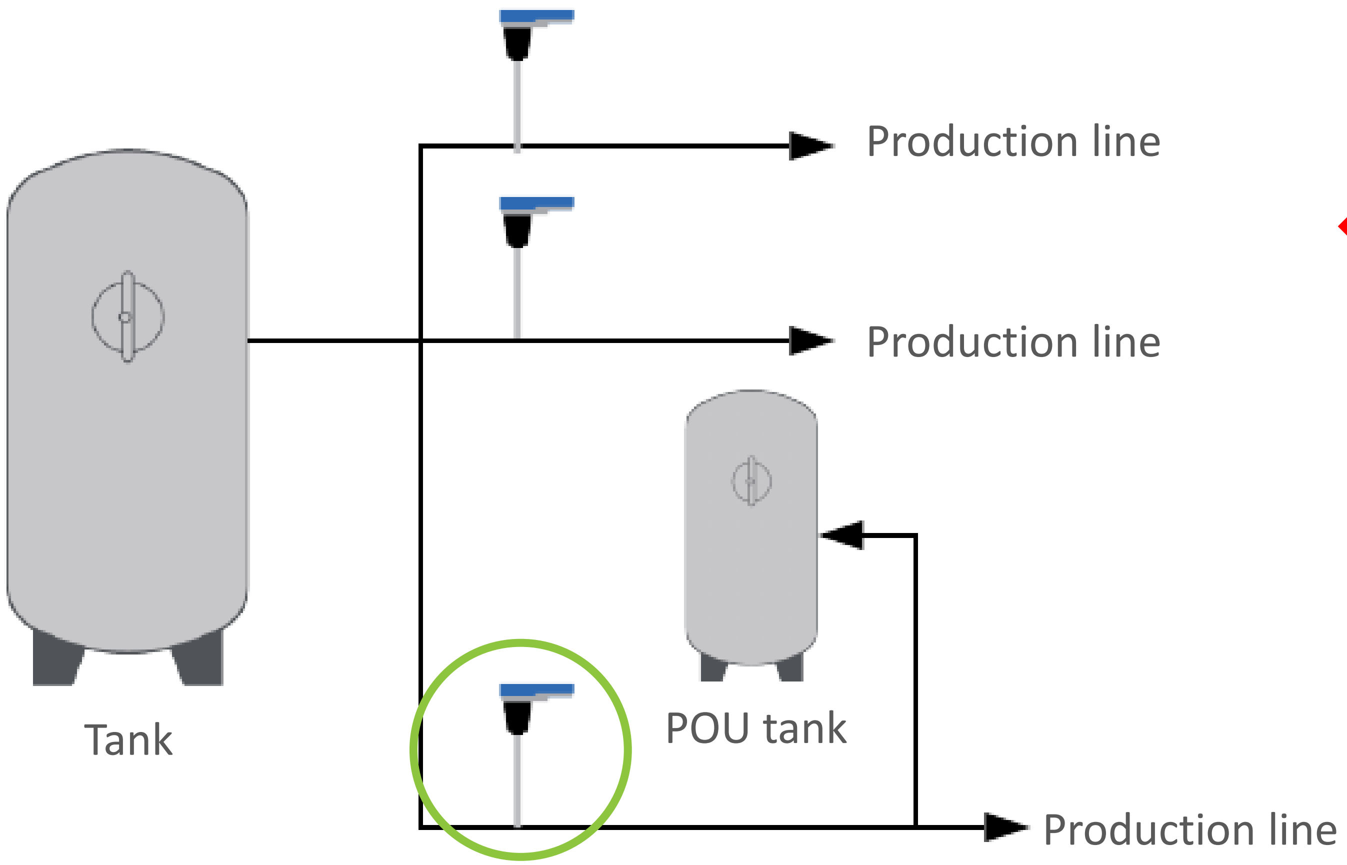


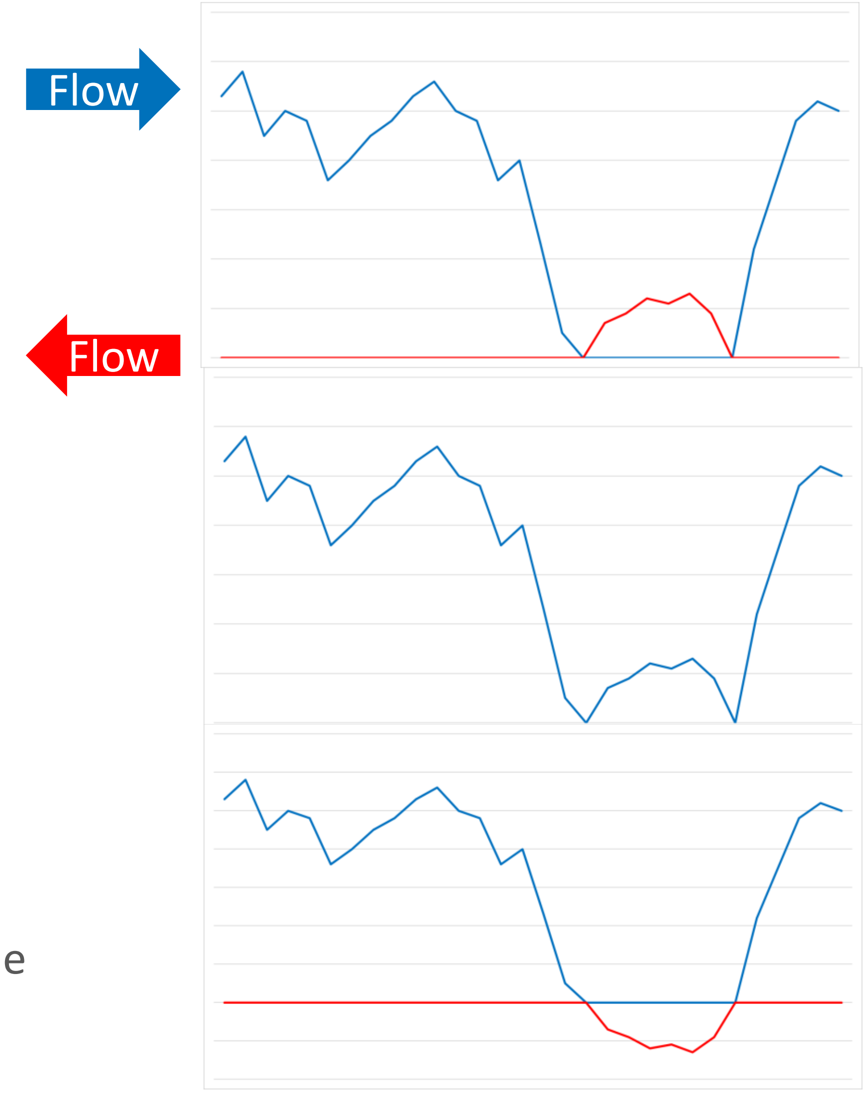
Bi-directional flow: air can go both ways!



Importance of bi-directional flow measurement

Demand side (reverse flow)





$+1002\ m_n^3$

$+941\ m_n^3$
$-\ 61\ m_n^3$

$+880\ m_n^3$

Bi-directional flow examples

- Ring networks
- Multiple compressor rooms
- Complex (old) compressed air networks
- Large receiver tanks
- Non return valves in compressors
- Leaking drains and seals

Extremely useful information for audits and permanent installations.

Turbulent vs laminar flow

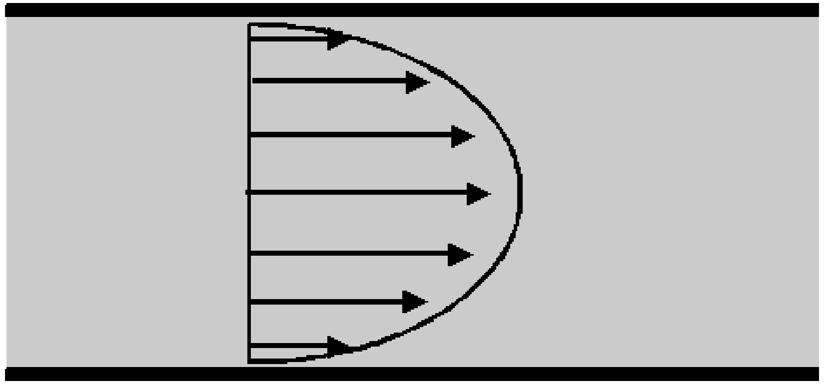
Reynolds number

$$\frac{\rho * v * D}{\eta} = \frac{density * velocity * tubediameter}{dynamic\ viscosity}$$

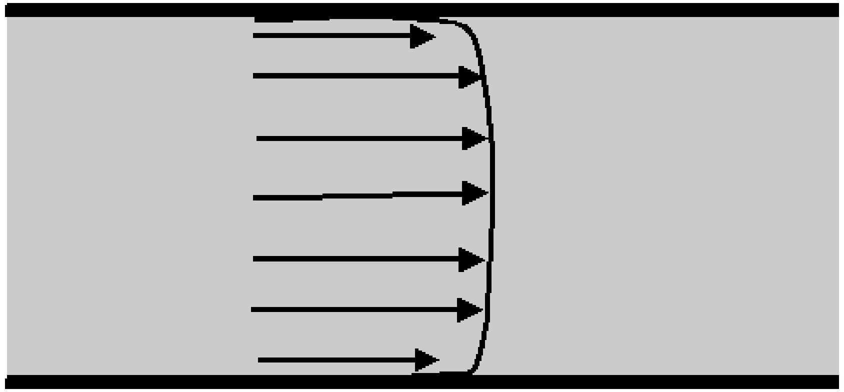
Air dynamic viscosity = $17{,}1 * 10^{-6}$, which is very small compared to water or syrup

- Compressed air lines: Flow is always turbulent!
- Turbulent: Velocity profile is nearly flat: Less sensitive for insertion depth

Laminar flow profile



Turbulent profile



Flow meter selection

Know the basics: Process data

Key to correct measurements and to prevent damage to your flow meter

- Type of gas
- Flow range
- Humidity (dry/saturated)
- (Inner) Diameter
- Pressure
- Temperature range

Model selection

In-line meters: 0.5, 1, 2 inch

Flow range leads direct to model,

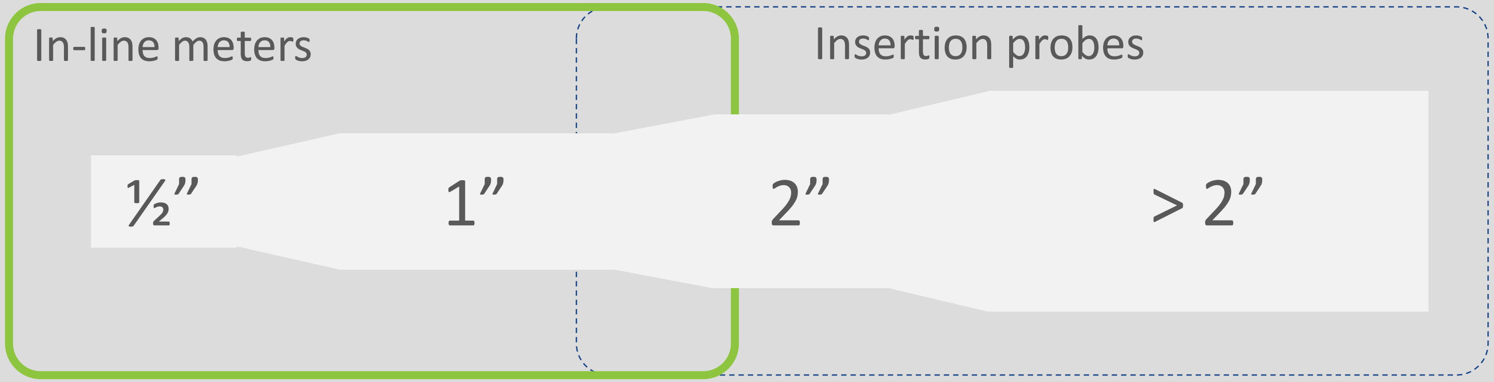
Check the diameter to ensure quick mechanical installation.

Insertion probes: 2 inch and up

The (normalized) velocity range needs to be calculated from the flow range to determine the right model.

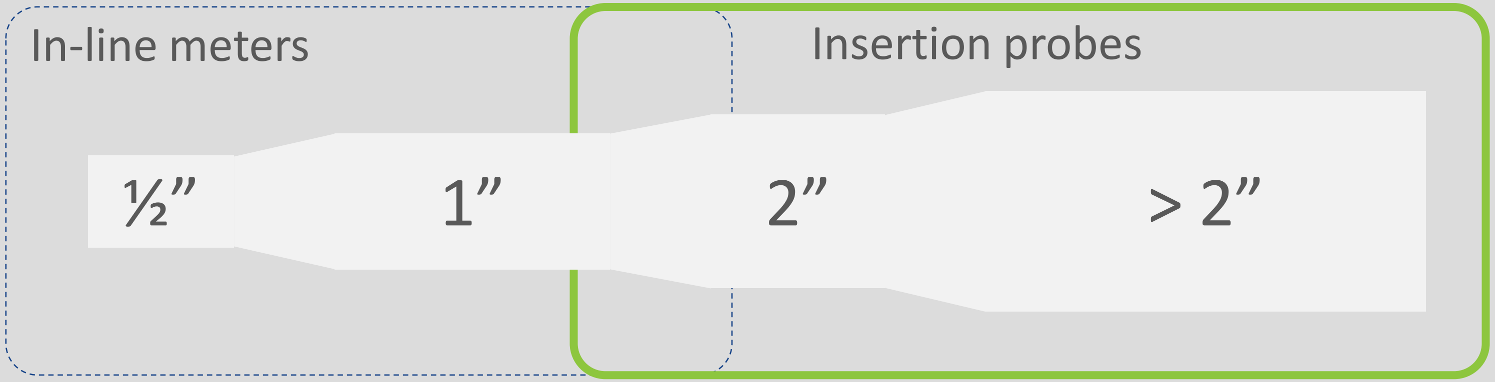
Normalized velocity = mass flow [m^3_n/hr] / [3600] / tuber area

Flow ranges



Size (inch)	Min flow m^3_n/hr	Max flow m^3_n/hr	Min flow SCFM	Max flow SCFM
½ inch	0,32	80	0.19	50
1 inch	0,88	250	0,52	150
2 inch	3,53	1000	2,06	600

Flow ranges

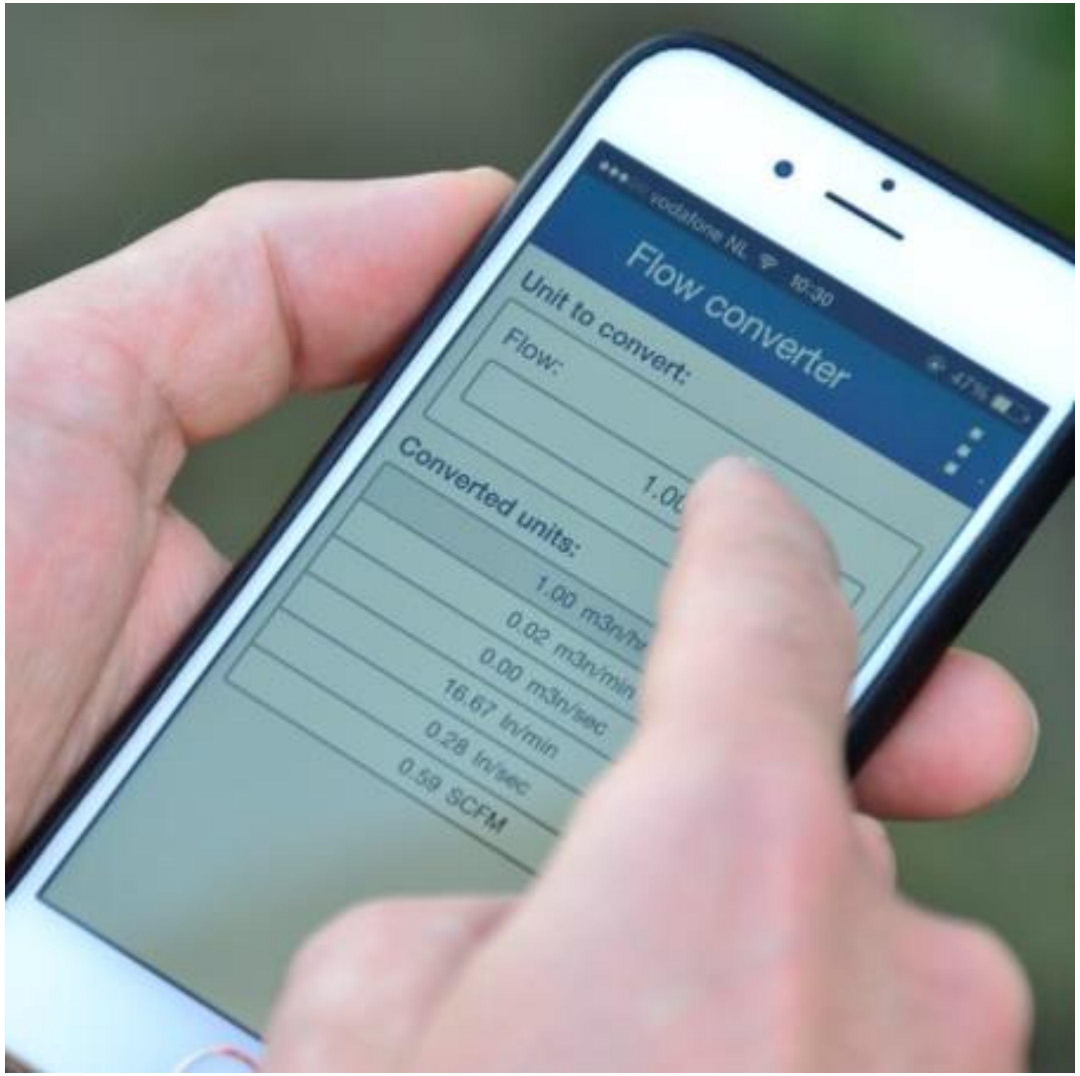


Thermal: Schedule 40 Standard Seamless Carbon Steel Pipe							
Size (inch)	DN	ID (inch)	ID (mm)	Min flow SCFM	Max flow SCFM	Min flow m^3_n/hr	Max flow m^3_n/hr
2	50	2,1	52,5	2,3	688	3,9	1,169
4	100	4,0	102,3	8,7	2,610	15	4,435
6	150	6,1	154,1	20	5,924	34	10,065
12	300	11,9	303,2	77	22,953	130	38,995
20	500	18,8	477,8	190	56,996	323	96,832

Not sure? Use VPCalculator

Use our calculator to determine which flow sensor you need.

See online Velocity Calculator
https://www.vpinstruments.com/selection-guide/velocity/



When creating a project quote

Gather enough information to be prepared

- P&ID (Process and Instrumentation Diagram)
- Plant map, to scale
- Pictures of installation points
- Use the on-line demand side table or Excel form
- Use bi-directional as default option

Flow meter installation

Read the manual…

- User manual
- VP Academy
- Instruction video
- This training
- Helpdesk “how to” articles

Check the direct environment

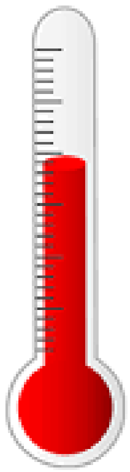
- Avoiding excessive external heat
- Protect against external water damage (IP)
- Eliminating excessive system condensate
- When having condensation in gas
  (100% condensation → VPS DP)
- Avoid corrosive atmosphere where possible
- Use the right cables and cable locations
- Eliminate mechanical vibration and potential danger

Check air quality

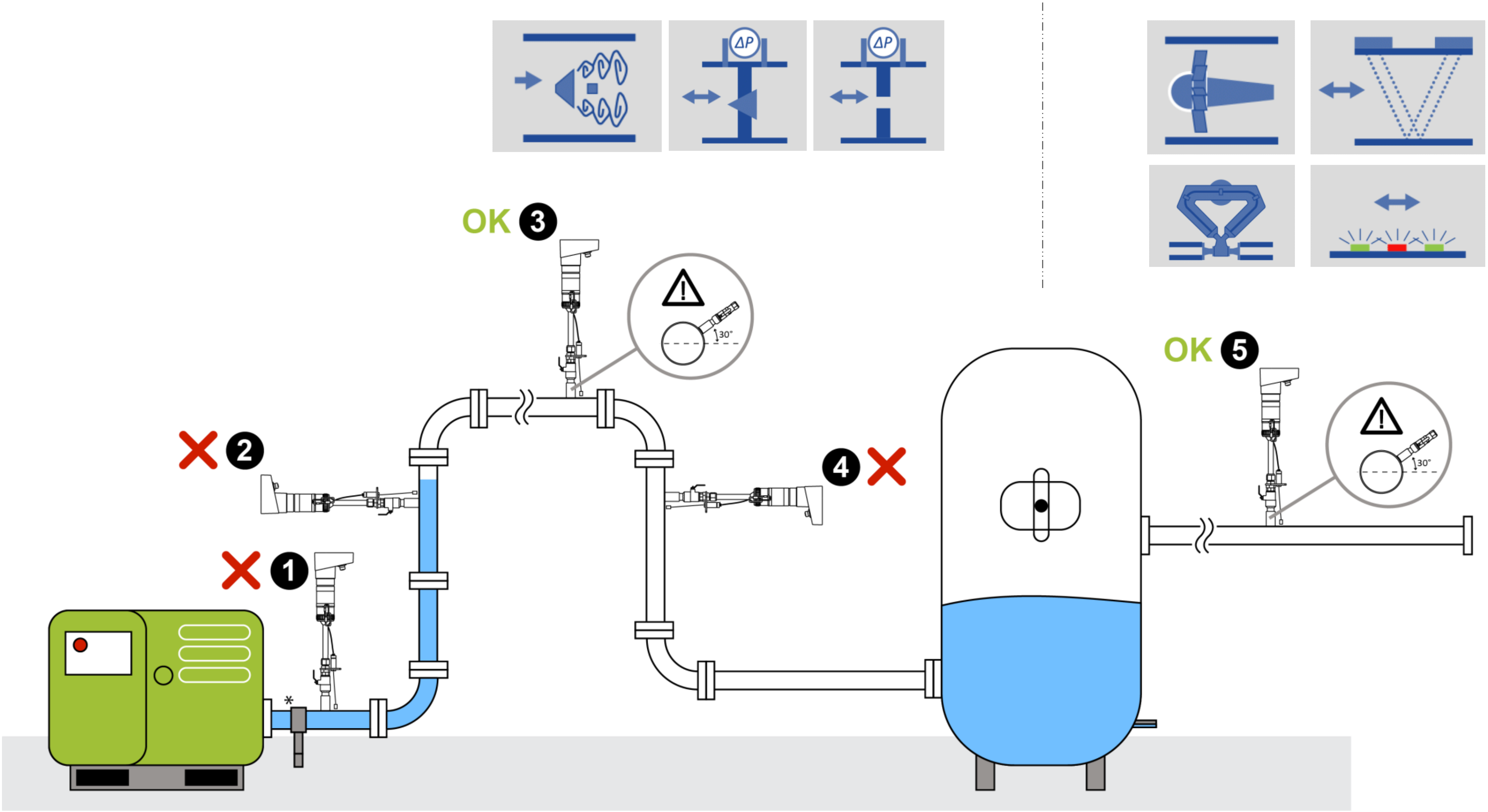
- Water
- Oil
- Drains
- Particles
    - (Cone strainer)

Check temperature

- Thermal mass: limited range: high temperature will cause sensor signal → 0
- Temperature fluctuations: lagging temperature compensation
- Coming from cold outside → inside (audits) : allow 1 hour acclimatization for best results.
- DP: high range, and reasonably fast response



Installation location: Avoid excess water



Piping not in scale

2. Find a straight pipe

General minimum rule:

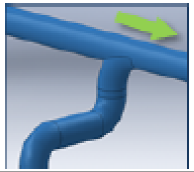
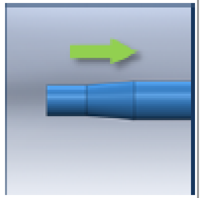
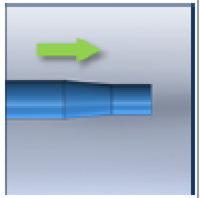
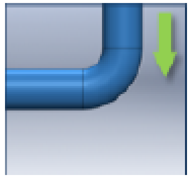
- 20*D upstream length (even 40*D preferred)
- 5*D downstream length (10*D preferred)

The longer the better

Without conditioners:

All other claimed shorter lengths are B.S.

It’s based on physics, not technology

Picture	Description	Upstream length	Downstream length	Effect
	Complex feed-in situation (header)	40 * D[1]	10 * D[1]	Flow profile will be distorted
	Double elbow, multiple elbows following each other	40 * D[1]	10 * D[1]	Distorted profile + swirl
	Diameter change from small to large (gradual or instant)	40 * D[1]	5 *D[1]	Jet shaped flow
	Diameter change from large to small (gradual change, between 7 and 15 degrees)	10 * D[1]	5 * D[1]	Flattened flow profile
	Single elbow	30 * D[1]	10 * D[1]	Distorted flow profile

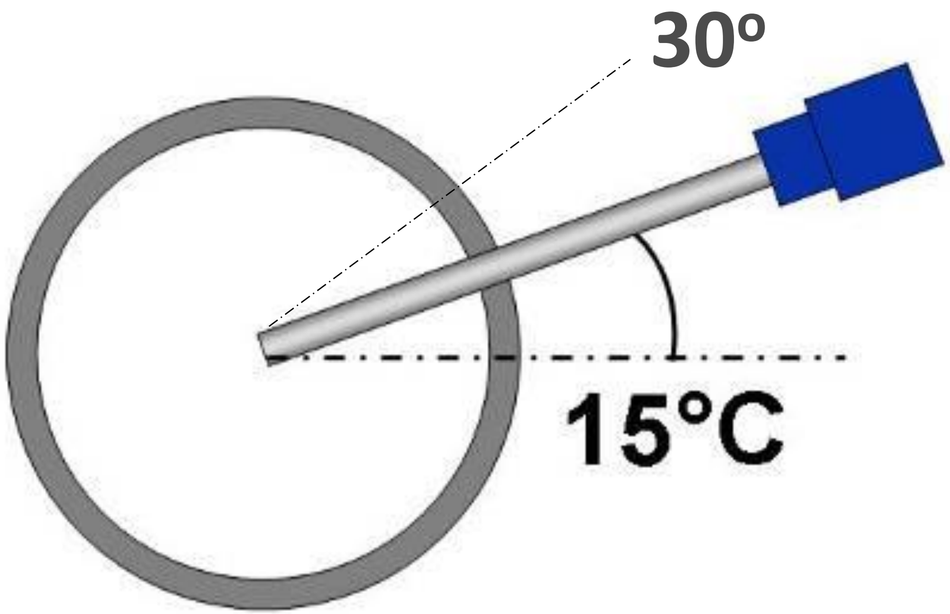
[1] = inner diameter

3. Use the best orientation

Take into account:

- Ease of wiring, maintenance, read out of and access to display
- Install at least at an angle of 15° upwards. ALWAYS if possible
- Piping table! Minimum up- and downstream length.

  Longer = better
- In case of doubt: Communicate with the end user

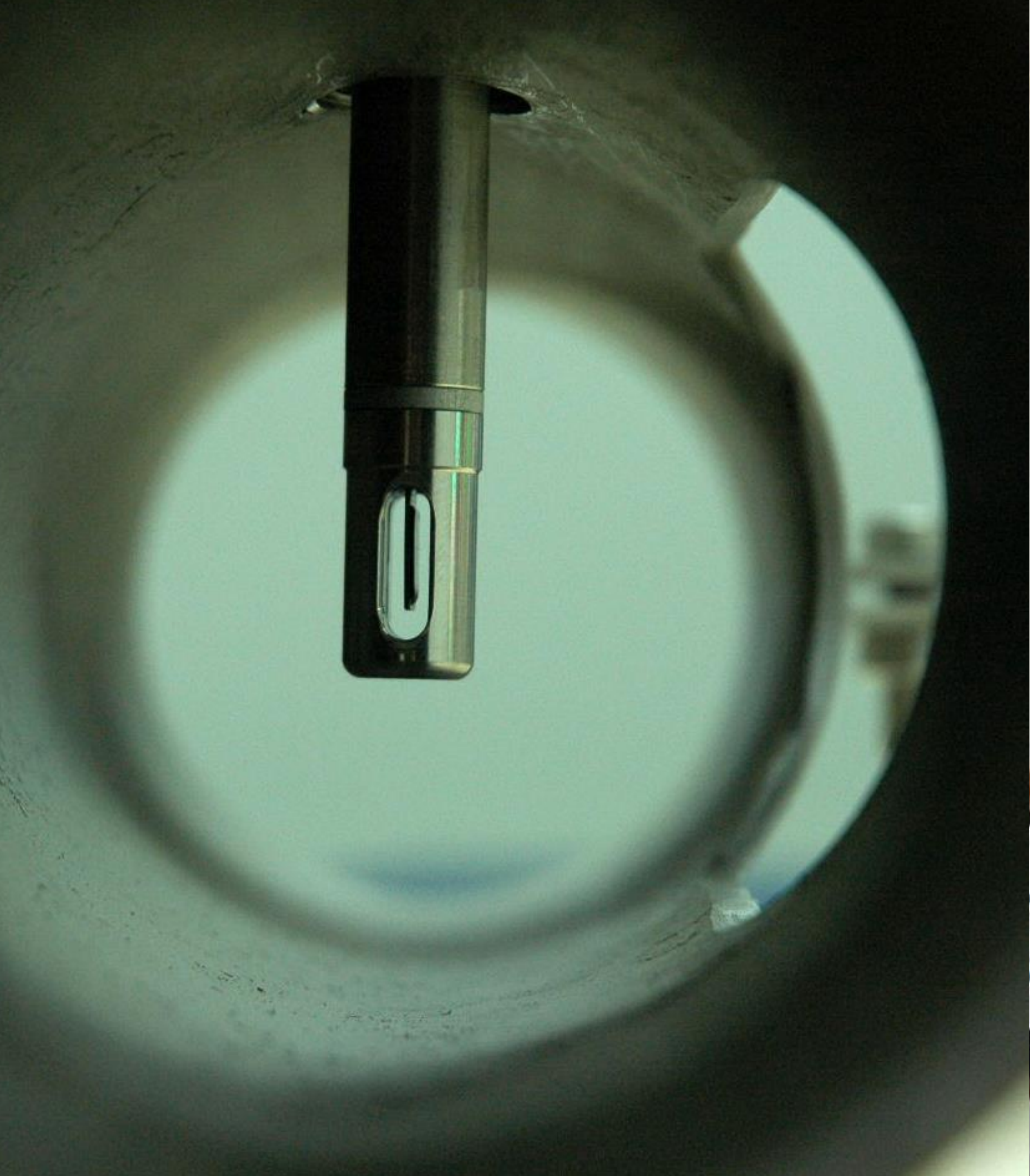


Recap

- Thermal mass : dry air
- Differential pressure : wet air
- In Line : 0,5, 1 and 2 inch
- Probes : > 2 inch
- Always check : Temperature, Pressure diameter and range
- Ring network : Bi – directional
- General : Use the checklist!

Things to avoid:

- Large and fast temperature swings
- Excessive condensate in the pipe
- Short meter runs



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THANK YOU!

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