Pneumatic Signal Line Lag and Response Time

Transport delay and time constant of a pneumatic signal line feeding a receiver volume, with laminar tube flow, and the 63 % and 98 % response times.

Method: Lumped laminar-flow RC model of a pneumatic line

Input parameters

Unit system: SI

Parameter	Value	Unit
Tube length	100.00	m
Tube inside diameter	4.0000	mm
Receiver (terminal) volume	0.10000	L
Mean signal pressure (absolute)	1.6000	bar
Air temperature	20.000	°C
Air viscosity	181.00	µP

Calculated results

Parameter	Value	Unit
Transport delay	0.29134	s
Time constant	1.3113	s
63 % response time	1.6026	s
98 % response time	5.5365	s
Line volume	1.2566	L

Notes for this case

• Lumped model: a pressure wave arrives after L/c (speed of sound); the line then fills like an RC circuit, with laminar (Hagen–Poiseuille) resistance 128µL/(πd⁴) and isothermal capacitance V/p̄, using the receiver volume plus half the line volume. τ grows with length squared (since line volume grows with L too), so lines beyond about 100 m need boosters. A first-order approximation of a distributed line; it is less accurate for very long lines with small receivers.

Formula and method

$$\theta = \frac{L}{c}, \quad \tau = \frac{128 \mu L}{\pi d^4} \frac{V_r + V_{line}/2}{\bar{p}}$$

Variables

L	Tube length	m
d	Tube inside diameter	m
V_r	Receiver (terminal) volume	m³
$\bar{p}$	Mean signal pressure (absolute)	Pa
T	Air temperature	K
μ	Air viscosity	Pa·s
θ	Transport delay	s
τ	Time constant	s
t_{63}	63 % response time	s
t_{98}	98 % response time	s
V_{line}	Line volume	m³

Method and standards

Pneumatic lag.

Assumptions and limits

- Laminar flow; isothermal; small signal change; lumped capacitance.

References

Lumped laminar-flow RC model of a pneumatic line

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/instrumentation/signals-calibration/pneumatic-signal-line-lag

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.