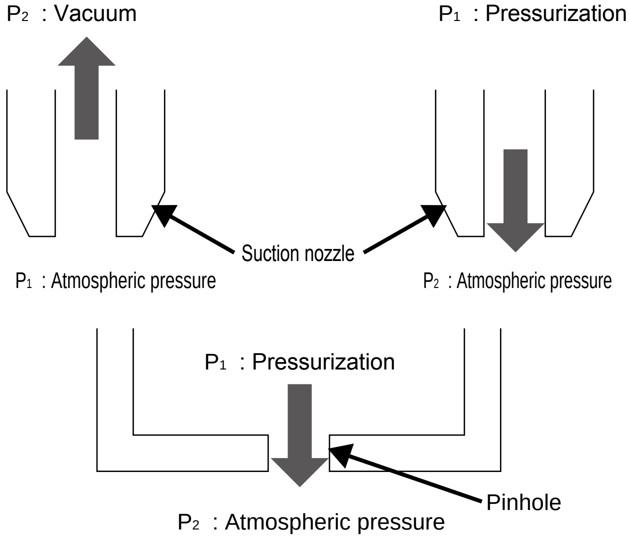
1 Flow rate sensor selection method

Use as a guideline for selection of the flow rate range when using the flow rate sensor for suction nozzle suction/release confirmation or leakage inspection.

The flow rate can be calculated using the effective cross-sectional area of nozzle (pinhole) and the pressure difference inside and outside the nozzle.



● For $P_1 \geq 1.89P_2$ (acoustic velocity)

$$Q=113.2 \times S \times P_1$$

● For $P_1 < 1.89P_2$ (subsonic velocity)

$$Q=226.4 \times S \times \sqrt{P_2(P_1-P_2)}$$

Q : Flow rate L/min
P_1 : Primary side absolute pressure MPa
P_2 : Secondary side absolute pressure MPa
S : Effective cross-sectional area of nozzle (pinhole) mm^2

■ Example of calculation

The calculated value of flow rate when the nozzle diameter is ø0.1 to 2 and P_2 is varied is shown in the figure below.

	P_1 (MPa) Abs. press	P_1 (MPa) Gauge press	P_2 (MPa) Abs. press	P_2 (MPa) Gauge press	Acoustic/ subsonic velocity	Calculated flow rate value (L/min) ø0.1	ø0.2	ø0.3	ø0.4	ø0.5	ø0.7	ø1	ø1.5	ø2
Vacuum	0.1013	0	0.0313	-0.07	Acoustic velocity	0.090	0.360	0.810	1.440	2.250	4.411	9.002	20.254	36.007
	0.1013	0	0.0413	-0.06	Acoustic velocity	0.090	0.360	0.810	1.440	2.250	4.411	9.002	20.254	36.007
	0.1013	0	0.0513	-0.05	Acoustic velocity	0.090	0.360	0.810	1.440	2.250	4.411	9.002	20.254	36.007
	0.1013	0	0.0613	-0.04	Subsonic velocity	0.088	0.352	0.792	1.408	2.200	4.312	8.800	19.801	35.202
	0.1013	0	0.0713	-0.03	Subsonic velocity	0.082	0.329	0.740	1.315	2.055	4.028	8.220	18.494	32.878
	0.1013	0	0.0813	-0.02	Subsonic velocity	0.072	0.287	0.645	1.147	1.792	3.512	7.166	16.125	28.666
	0.1013	0	0.0913	-0.01	Subsonic velocity	0.054	0.215	0.483	0.859	1.343	2.631	5.370	12.083	21.480
Blow (leakage inspection)	0.1113	0.01	0.1013	0	Subsonic velocity	0.057	0.226	0.509	0.905	1.414	2.772	5.657	12.727	22.626
	0.1213	0.02	0.1013	0	Subsonic velocity	0.080	0.320	0.720	1.280	2.000	3.920	8.000	15.679	31.998
	0.1413	0.04	0.1013	0	Subsonic velocity	0.113	0.453	1.018	1.810	2.828	5.543	11.313	17.999	45.252
	0.1613	0.06	0.1013	0	Subsonic velocity	0.139	0.554	1.247	2.217	3.464	6.789	13.856	24.454	55.423
	0.1813	0.08	0.1013	0	Subsonic velocity	0.160	0.640	1.440	2.560	4.000	7.840	15.999	31.175	63.996
	0.2013	0.1	0.1013	0	Acoustic velocity	0.179	0.716	1.610	2.862	4.472	8.765	17.888	35.998	71.552
	0.3013	0.2	0.1013	0	Acoustic velocity	0.268	1.071	2.410	4.284	6.694	13.119	26.774	60.242	107.096
	0.4013	0.3	0.1013	0	Acoustic velocity	0.357	1.426	3.209	5.706	8.915	17.474	35.660	80.236	142.641
	0.5013	0.4	0.1013	0	Acoustic velocity	0.445	1.782	4.009	7.127	11.137	21.828	44.547	100.230	178.186
	0.6013	0.5	0.1013	0	Acoustic velocity	0.534	2.137	4.809	8.549	13.358	26.182	53.433	120.224	213.731

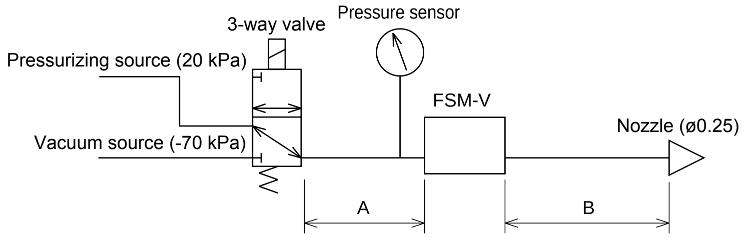
(CAUTION)

- When there is a leakage in the piping, etc., the actual flow rate becomes larger than the calculated value. When selecting the flow rate, consider the amount of leakage in the piping.
- When there is a portion narrower than the suction nozzle diameter in the middle of the piping, the flow rate may be reduced to lower than the calculated value.
  In addition, suction confirmation, etc., may become impossible.
- The effective cross-sectional area is just a guideline. When the nozzle is long and thin, the effective cross-sectional area becomes smaller than the opening area.
- The response time is determined by the inner volume of the piping from the flow rate sensor to suction nozzle (pinhole). For high-speed detection, reduce the inner volume of the piping as much as possible by installing a flow rate sensor near the suction nozzle, etc.

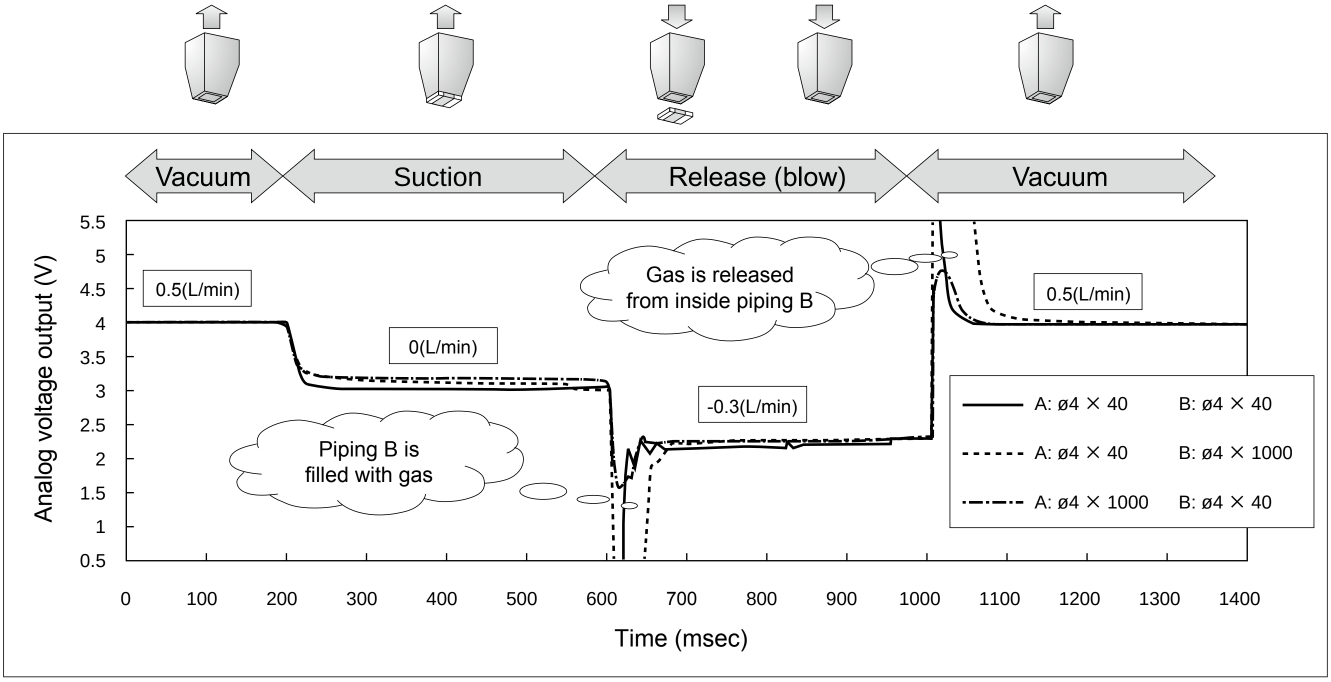
Suction confirmation

1 Response time

The response time at suction confirmation is determined by inner volume of the piping or exhaust capacity of the vacuum pump, etc. For example, with piping as in the figure at right, the response time piping dependency is as in the figure below. This result demonstrates that it is effective to reduce the inner volume of the piping from sensor to suction nozzle as small as possible in order to decrease the response time.



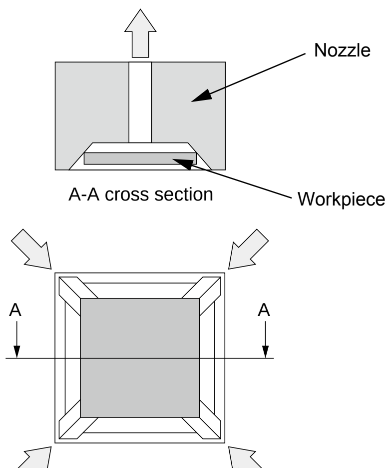
Test piping



Response piping dependency

2 When using the collet nozzle

The collet nozzle is commonly used when you do not want the workpiece to be suctioned to contact the nozzle directly. The inside of the collet nozzle is pyramid-shaped, with a structure that creates gaps at the four corners when the workpiece is contacted, generating leaks during suction. If the effective cross-sectional area of the piping (including valves and fittings, etc.) compared to the clearance between the collet nozzle and workpiece is small, the flow rate is determined by the effective cross-sectional area of the piping, and accordingly the flow rate difference between when suctioned and when not suctioned becomes small. In this instance, secure suction confirmation is enabled by making the effective cross-sectional area of the piping as large as possible, larger than the clearance between the collet nozzle and workpiece.



Collet nozzle

F.R.L.
F.R.
F (Filtr)
R (Reg)
L (Lub)
Drain Separ
Mech Press SW
Res press exh valve
SlowStart
Anti-bac/Bac-remove Filt
Film Resist FR
Oil-ProhR
Med Press FR
No Cu/ PTFE FRL
Outdrs FRL
Adapter Joiner
Press Gauge
CompFRL
LgFRL
PrecsR
VacF/R
Clean FR
ElecPneuR
AirBoost
Speed Ctrl
Silncr
CheckV/ other
Fit/Tube
Nozzle
Air Unit
PrecsCompn
Electro Press SW
ContactSW
AirSens
PresSW Cool
Air Flo Sens/Ctrl
WaterRtSens
TotAirSys (Total Air)
TotAirSys (Gamma)
Gas generator
RefrDry
DesicDry
HiPolymDry
MainFiltr
Dischrg etc
Ending

Leakage inspection (*1)

1 Calculation method of amount of leakage

When switching over from the pressure gauge calculation method, use the calculation for the amount of leakage.

$$Q=V\times\frac{\Delta P}{1.013\times10^{5}}\times\frac{60}{T}$$

Q: Amount of leakage (mL/min)   ΔP: Differential pressure (Pa)   V: Inner volume of workpiece (mL)   T: Detection time (s)

Example) When a differential pressure of 20 Pa is generated in 5 seconds of detection time for a workpiece of inner volume of 500 mL, the amount of leakage is

$$Q=500\times\frac{20}{1.013\times10^{5}}\times\frac{60}{5}\approx 1.18\ \text{(mL/min)}$$

2 Ratio of amount of leakage between gas and liquid

Use this as a guideline during pneumatic leakage inspection of liquid workpieces.
Note that this formula is derived from the Hagen-Poiseuille equation with the condition that the pinhole is a circular pipe and has a smooth surface. Pinholes caused by poor welding, etc., may not always be applicable to the theoretical equation.

$$\frac{Ql}{Qa}=\frac{\eta a}{\eta l}\times\frac{101.3\times Pl}{(101.3+Pa/2)\times Pa}$$

Qa : Air leakage (mL/s)
Ql : Liquid leakage (mL/s)
ηa : Air viscosity (Pa·s)
ηl : Liquid viscosity (Pa·s)
Pa : Air test pressure (kPa)
Pl : Liquid test pressure (kPa)

● Viscosity coefficient (Pa·s x 10^{-3})

Temperature	Air (ηa)	Water (ηl)	Brake oil (ηl)
20°C	0.0181	1.00	26
50°C	0.0195	0.55	10
70°C	0.0204	0.40	7

● Ratio of air (20°C) and liquid leakage amount

Liquid		ηl, Pa·s	Pneumatics pressure Pa	Liquid pressure Pl	Ql/Qa
Water	20°C	0.001	0.4 MPa	0.4 MPa	0.006
Brake oil	50°C	0.01	0.4 MPa	0.4 MPa	0.0006
Brake oil	50°C	0.01	0.4 MPa	15 MPa	0.02

Example) When inspecting a workpiece with water leakage of 0.1 mL/min. (test pressure of 0.4 MPa) with air (test pressure 0.4 MPa), leakage Qa is as follows:

from $\frac{QL}{Qa}=0.006$ $Qa=\frac{0.1}{0.006}\approx 16.7\ \text{(mL/min)}$