Vacuum generator selection guide

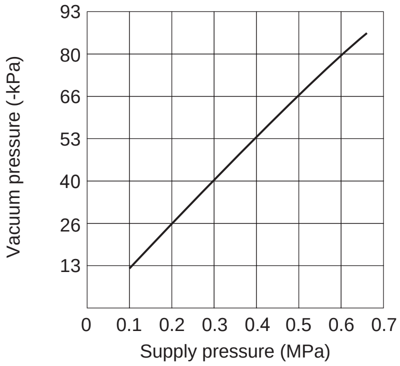
There are basically three types of CKD vacuum generator according to performance: H: high vacuum, L: large flow (efficiency emphasized), E: low supply pressure, high vacuum. Select according to the condition of use.

- Deciding between H (high vacuum) and E (low supply pressure high vacuum)
  If high vacuum is required and supply pressure of 0.5 MPa can be secured, use H. If it cannot be secured or in order to conserve consumed air, use E at 0.35 to 0.4 MPa.

- Deciding between H (high vacuum) and L (large flow type (efficiency emphasized))
  Use H when high vacuum is required and L to adjust the vacuum pressure, setting the desired vacuum pressure by adjusting the supply pressure with a regulator or the like.
  The vacuum pressure characteristics of L are essentially proportional to the supply pressure, and are set as shown in Fig. 1 between 0.2 to 0.6 MPa. Although differences of -5% to +15% with respect to the target value will occur, the vacuum pressure can be set based on the supply pressure.

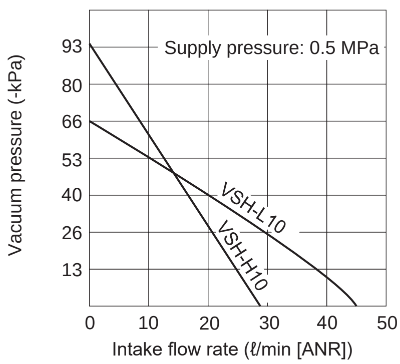
- When the pad does not make complete contact
  If the workpiece cannot adhere completely to the suction pad, the criterion for deciding between H or L comes down to the degree of vacuum pressure in the vacuum system. Fig. 2 Vacuum pressure - intake flow rate shows that H is preferable at vacuum pressure -53 kPa or greater, and L at -40 kPa or less.

L achieved vacuum characteristics



(Fig. 1)

Vacuum pressure - Intake flow rate for VSH-H10 and VSH-L10



(Fig. 2)

Other precautions

- Valve used
  When using a solenoid valve or the like, be sure to allow a sufficient flow rate.
  (Use a valve with effective cross-sectional area three times or greater than the cross-sectional area of the nozzle.)

- Vacuum piping
  The piping resistance in vacuum is surprisingly large. Shorten the vacuum piping as much as possible and use a large inner diameter. Excessive piping resistance may cause malfunction, especially when a vacuum switch or the like is used. Also, ejector intake flow rate will decrease, which may result in performance degradation due to insufficient flow rate.

- Supply side piping
  Pay attention to air supply side piping as well. Be sure to perform piping so that the prescribed pressure is secured at the ejector input.

Vacuum

■ Vacuum

Pressure higher than atmospheric pressure is generally referred to as "positive pressure" and pressure lower than atmospheric pressure is called "vacuum" or "negative pressure".

Vacuum pressure

The word pressure refers to two different things.
- Absolute pressure: Pressure based on a perfect vacuum state
- Gauge pressure: Pressure based on atmospheric pressure

If the vacuum pressure is not very high, it is commonly expressed by gauge pressure.
For high vacuum close to perfect vacuum, at standard atmospheric pressure, perfect vacuum is defined as -101.3 kPa, but since the atmospheric pressure is always fluctuating, the perfect vacuum pressure may become unclear and cannot be shown with gauge pressure. For this reason, high vacuum is commonly expressed with absolute pressure.
CKD's vacuum generator is in the low vacuum range and shows the vacuum pressure in gauge pressure.

Atmospheric pressure and vacuum pressure

Air has weight, as it is "matter". On earth, anything with mass will be affected by gravity. This includes the atmosphere, which causes a force (weight) that pushes on the ground surface. This is atmospheric pressure, which is force generated by the weight of the atmosphere per unit area.
Atmospheric pressure varies according to elevation. It is also constantly fluctuating due to weather conditions.
In other words, when using gauge pressure, there will be dispersion in the atmospheric pressure according to elevation and weather conditions, so even if the same vacuum pressure is applied, the value indicated by the gauge will be different depending on these factors. For this reason, correction values converted to standard atmospheric pressure are used for gauge pressure values.
Standard atmospheric pressure is expressed as a value based on atmospheric pressure at 0 m above sea level.
The conversion method is as follows:

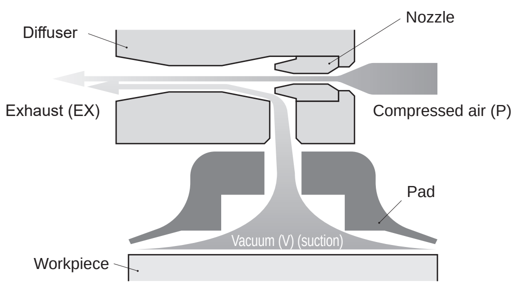
Standard atmospheric pressure converted value (-kPa) =
1013.25 (hPa)/atmospheric pressure (hPa) at measurement location x measured achieved vacuum pressure (-kPa)

Principles of the vacuum generator

■ The vacuum generator is a device that generates vacuum by feeding compressed air.

■ Compressed air is restricted by the nozzle, discharged at high speed and fed into the diffuser. When jetted at high speed, the pressure drops and vacuum is generated, for use in transporting workpieces.

■ In order to obtain a high speed jet and high degree of vacuum, structures called nozzle and diffuser are constructed, with shapes and sizes determining the achieved vacuum pressure, intake flow rate and consumption flow rate.



Vacuum component display units

■ Vacuum component parameters

The following three parameters are used as performance indicators for vacuum components.
- Achieved vacuum pressure ... Vacuum pressure in vacuum circuit (unit: -kPa)
- Intake flow rate ... Flow rate in vacuum circuit (unit: ℓ/min (ANR))
- Consumption flow rate ... Flow rate of supply air (unit: ℓ/min (ANR))

■ Pressure parameters

kPa	MPa	bar	kgf/cm^2	mmHg
1	1x10^{-3}	1x10^{-2}	1.01972x10^{-2}	7.50062
1x10^3	1	1x10	1.01972x10	7.50062x10^3
1x10^2	1x10^{-1}	1	1.01972	7.50062x10^2
9.80665x10	9.80665x10^{-2}	9.80665x10^{-1}	1	7.35559x10^2
1.33322x10^{-1}	1.33322x10^{-4}	1.33322x10^{-3}	1.35951x10^{-3}	1

■ Force parameters

N	kgf
1	1.01972x10^{-1}
9.80665	1

Vacuum system components

Vacuum components selection method

When suctioning and conveying workpieces by vacuum, select the suction pad, vacuum generator and vacuum switching valve according to the following Vacuum component selection method. The Vacuum component selection method here is only a guideline for selecting equipment. In actual use, be sure to evaluate the actual device, check the precautions for selection and confirm that the equipment is problem-free.

Vacuum component selection method

1 Selecting the pad
- ① How to determine the suction force
- ② How to calculate the pad diameter from the suspension load of the workpiece
- ③ Selecting the pad shape
- ④ Selecting the pad material
- ⑤ Note on model No. selection

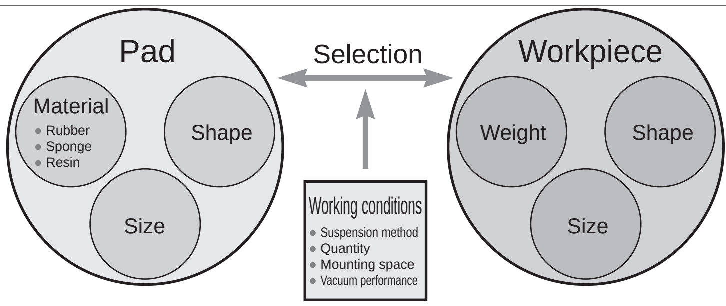
2 Selecting the vacuum generator/vacuum switching valve
- ① Various working conditions
- ② Selection procedure
- ③ Note on model No. selection

Technical data

1 ▶ Selecting the pad

Three main items (pad, workpiece and use conditions) are involved in selecting pads as shown on the right. Understand these well when selecting pads.

The pad size (diameter) is obtained by calculating the suction force of the pad.



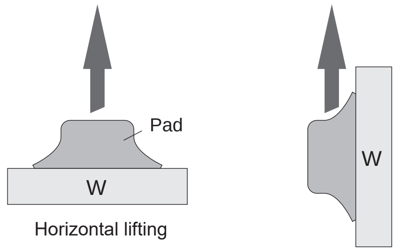
① How to determine the suction force

● How to calculate from the formula

The suction force of the suction pad can be calculated by assigning values to the following formula.

$$W = \frac{CxP}{101} \times 10.13 \times f$$

W: Suction force (N), C: Pad area (cm^2), P: Vacuum pressure (-kPa)
f: Safety factor (horizontal lifting: 1/4 or greater, vertical lifting: 1/8 or greater)



* The basic suspension method is horizontal.

● Selecting from the theoretical suction force table

The theoretical suction force of the suction pad can be obtained from the following table.
However, safety ratios are not included in the values in the following table. Take the safety factor into account when obtaining the suction force.
Suction force (N) = theoretical suction force (N)/f (safety factor)

1 Theoretical suction force table (suction force = $\frac{CxP}{101}$ x 10.13)

■ For circular pad

Unit: N

Pad diameter (ømm)	0.7	1	1.5	2	3	4	6	8	10	15	20	25	30	35	40	50	60	70	80	100	150	200
Suction area (cm^2)	0.004	0.008	0.018	0.031	0.071	0.126	0.283	0.502	0.785	1.766	3.14	4.906	7.065	9.616	12.56	19.63	28.26	38.47	50.24	78.5	176.6	314
Vacuum pressure (kPa) -85	0.034	0.068	0.153	0.264	0.604	1.07	2.41	4.27	6.67	15.01	26.7	41.7	60.05	81.74	106.8	166.9	240.2	327	427	667.3	1501	2669
-80	0.032	0.064	0.144	0.248	0.568	1.01	2.26	4.016	6.28	14.13	25.1	39.25	56.52	76.93	100.5	157	226.1	307.8	401.9	628	1413	2512
-75	0.03	0.06	0.135	0.233	0.533	0.945	2.12	3.765	5.89	13.25	23.6	36.8	52.99	72.12	94.2	147.2	212	288.5	376.8	588.8	1325	2355
-70	0.028	0.056	0.126	0.217	0.497	0.882	1.98	3.514	5.5	12.36	22	34.34	49.46	67.31	87.92	137.4	197.8	269.3	351.7	549.5	1236	2198
-65	0.026	0.052	0.117	0.202	0.462	0.819	1.84	3.263	5.1	11.48	20.4	31.89	45.92	62.5	81.64	127.6	183.7	250.1	326.6	510.3	1148	2041
-60	0.024	0.048	0.108	0.186	0.426	0.756	1.7	3.012	4.71	10.6	18.8	29.44	42.39	57.7	75.36	117.8	169.6	230.8	301.4	471	1060	1884
-55	0.022	0.044	0.099	0.171	0.391	0.693	1.56	2.761	4.32	9.713	17.3	26.98	38.86	52.89	69.08	108	155.4	211.6	276.3	431.8	971.3	1727
-50	0.02	0.04	0.09	0.155	0.355	0.63	1.42	2.51	3.93	8.83	15.7	24.53	35.33	48.08	62.8	98.15	141.3	192.4	251.2	392.5	883	1570
-45	0.018	0.036	0.081	0.14	0.32	0.567	1.27	2.259	3.53	7.95	14.1	22.08	31.79	43.27	56.52	88.34	127.2	173.1	226.1	353.3	794.7	1413
-40	0.016	0.032	0.072	0.124	0.284	0.504	1.13	2.008	3.14	7.064	12.6	19.62	28.26	38.46	50.24	78.52	113	153.9	201	314	706.4	1256

■ For oval pad

Unit: N

Pad diameter (ømm)	4x10	4x20	4x30	5x10	5x20	5x30	6x10	6x20	6x30	8x20	8x30
Suction area (cm^2)	0.365	0.765	1.165	0.446	0.946	1.446	0.522	1.122	1.722	1.462	2.262
Vacuum pressure (kPa) -85	3.103	6.503	9.903	3.791	8.041	12.29	4.437	9.537	14.64	12.43	19.23
-80	2.92	6.12	9.32	3.568	7.568	11.57	4.176	8.976	13.78	11.7	18.1
-75	2.738	5.738	8.738	3.345	7.095	10.85	3.915	8.415	12.92	10.97	16.97
-70	2.555	5.355	8.155	3.122	6.622	10.12	3.654	7.854	12.05	10.23	15.83
-65	2.373	4.973	7.573	2.899	6.149	9.399	3.393	7.293	11.19	9.503	14.7
-60	2.19	4.59	6.99	2.676	5.676	8.676	3.132	6.732	10.33	8.772	13.57
-55	2.008	4.208	6.408	2.453	5.203	7.953	2.871	6.171	9.471	8.041	12.44
-50	1.825	3.825	5.825	2.23	4.73	7.23	2.61	5.61	8.61	7.31	11.31
-45	1.643	3.443	5.243	2.007	4.257	6.507	2.349	5.049	7.749	6.579	10.18
-40	1.46	3.06	4.66	1.784	3.784	5.784	2.088	4.488	6.888	5.848	9.048

Vacuum components selection method

1 ▶ Selecting the pad

② How to calculate the pad diameter from the suspension load of the workpiece

● How to calculate from the formula

The vacuum pad diameter can be calculated from the required suction force.

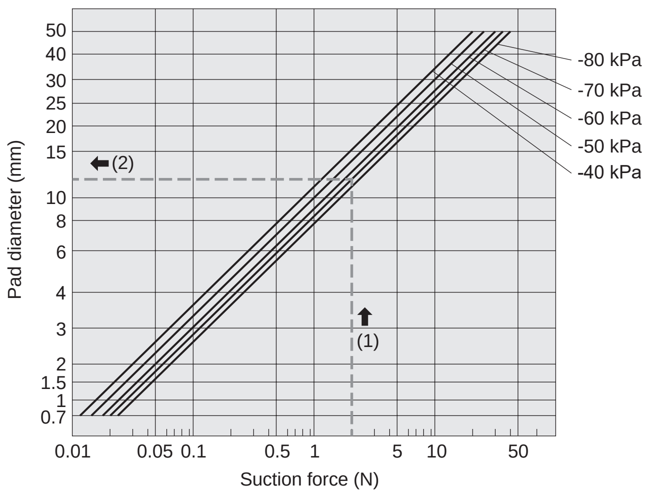
$$D = \sqrt{\frac{4}{3.14} \times \frac{1}{P} \times \frac{W}{n} \times \frac{1}{f} \times 1000}$$

D: Pad diameter (mm), n: Pad quantity for workpiece, W: Suction force (N), P: Vacuum pressure (-kPa), f: Safety factor (horizontal suspension: 1/4 or greater, vertical suspension: 1/8 or greater)

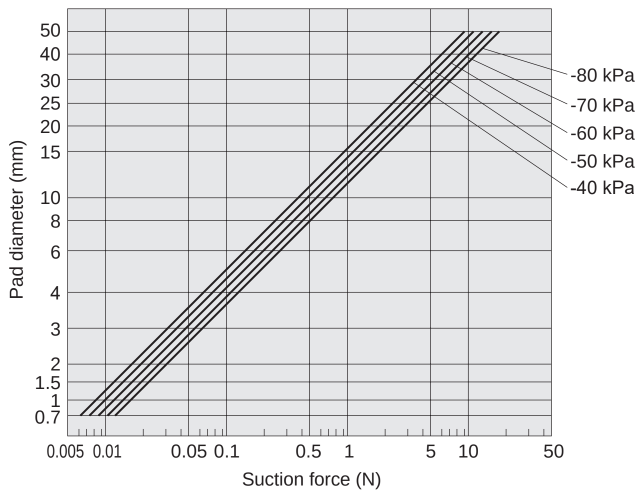
● Selecting from selection graph

The suction pad diameter can be obtained from the following table based on the suspension method (vertical or horizontal) to be used and required suction force per vacuum pad.

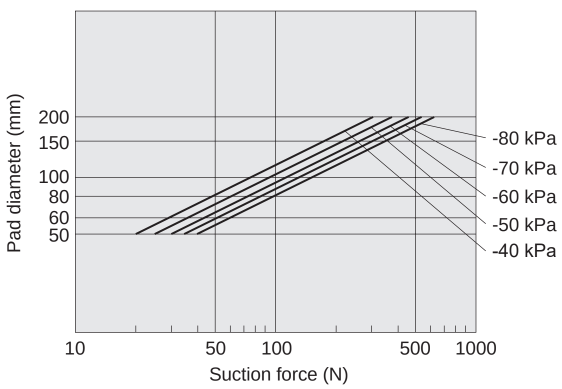
Selection graph 1-1 Graph of pad diameter selection by suction force
Horizontal suspension (ø2 to ø50)



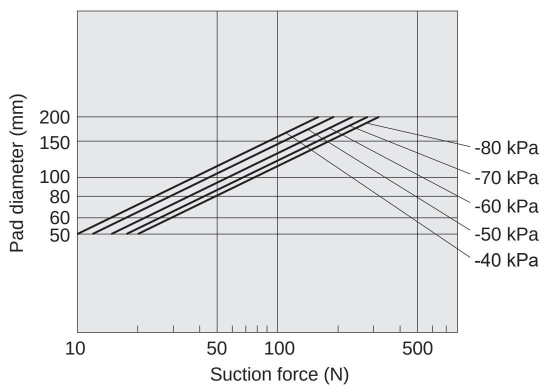
Selection graph 2-1 Graph of pad diameter selection by suction force
Vertical suspension (ø2 to ø50)



Selection graph 1-2 Graph of pad diameter selection by suction force
Horizontal suspension (ø50 to ø200)



Selection graph 2-2 Graph of pad diameter selection by suction force
Vertical suspension (ø50 to ø200)



Example (selecting pad diameter)

When the weight of the workpiece is 8 N:

- Number of pads: 4
- Vacuum pressure: -70 kPa
- Suspension method: Horizontal

Obtain the vacuum pad diameter.

Using the formula

$$D = \sqrt{\frac{4}{3.14} \times \frac{1}{P} \times \frac{W}{n} \times \frac{1}{f} \times 1000} = \sqrt{\frac{4}{3.14} \times \frac{1}{70} \times \frac{8}{4} \times 4 \times 1000} = 12.06$$

Therefore, select a pad of ø15 mm or greater.

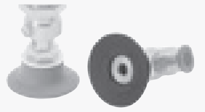
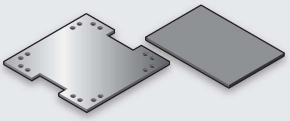
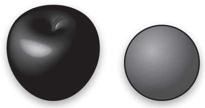
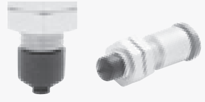
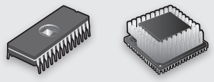
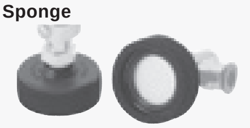
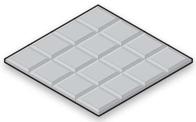
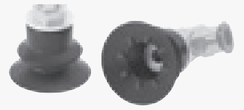
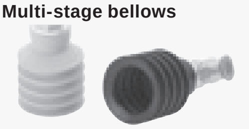
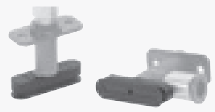
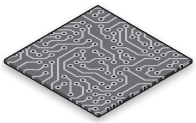
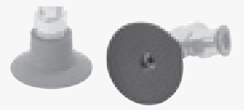
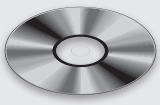
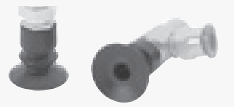
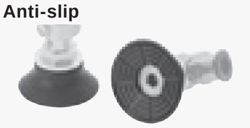
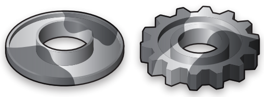
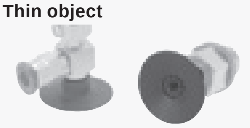
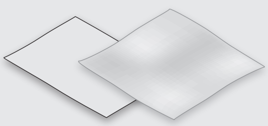
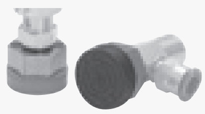
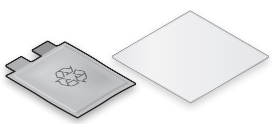
Using the selection graph

Conditions show that the suction force per pad is 2N (8N/4 pieces = 2N).
As the suspension method is horizontal (selection graph 1) and vacuum pressure is -70 kPa (horizontal axis of selection graph), we see that the pad diameter is equivalent to ø12 mm. Therefore, select a pad of diameter ø15 mm or greater. (Selection graph 1 ① → ② order)

Vacuum system components

③ Selecting the pad shape

Select the shape of the pad according to the shape and material of the workpiece. If you need to perform suction tests on the sample, consult the nearest CKD Sales Office.

Pad shape		Recommended workpiece		Features
Standard	Standard 		Ideal for flat workpieces (hard and inflexible)	• Compatible with a wide variety of pad sizes (18 types, ø1 to ø200) and pad materials (8 types) as standard
Standard	Deep 		Ideal for spherical workpieces (apples, balls, etc.)	• The deep inner pad makes it ideal for workpieces with spherical surfaces or protrusions
Standard	Compact 		Ideal for semiconductor components	• Small diameter sizes of ø0.7, ø1.0 and ø1.5 are available for compatibility with compact semiconductor parts • 10 types of pad materials are available, corresponding to various environmental conditions
Sponge 			Ideal for workpieces such as building outer wall materials, small stones and shells	• New lineup of silicone rubber sponges suitable for food-related workpieces is available
Bellows 			Ideal for retort-packs and bags containing food, etc.	• Usable when the spring buffer cannot be attached or when the workpiece is tilted • Now available: a new retrofitting resin attachment (for bellows) ideal for workpieces which must not have suction traces
Multi-stage bellows 				
Oval 			Ideal for long workpieces like substrates, round bars and semiconductor parts	• Small sizes (2 x 4, 3.5 x 7) that correspond to workpieces with small suction surfaces available
Soft 			Ideal for taking out molded parts or easily damaged workpieces	• Pad is flexible and can suction paper, etc.
Soft bellows 				• Pad is flexible and can suction paper, etc. • Usable when the spring buffer cannot be attached or when the workpiece is tilted
Anti-slip 			Ideal for workpieces with oil adhered such as press parts	• Grip grooves are provided on the pad suction surface to prevent slippage when transporting oily iron plates
Thin object 			Ideal for thin workpieces such as copy paper and vinyl	• Thin pad lips improve adhesion to workpieces, allowing use on thin workpieces and reducing overlap suction • Since the pad surface is flat, it causes fewer wrinkles
Flat 			Ideal for thin workpieces such as sheets and vinyl	• The workpiece suction surface is flattened to reduce deformation/wrinkling of the workpiece during suction
Suction mark prevention 			Ideal for liquid crystal glass, painting process and semiconductor manufacturing equipment, etc.	• Resin pad reduces suction marks • The holder is equipped as standard with a flexible mechanism for better adaptability to the workpiece

Technical data

Vacuum components selection method

1 ▶ Selecting the pad

④ Selecting the pad material

Select suitable materials according to usage conditions, used fluids and atmosphere. For the main characteristics, refer to the table below.

■ Pad material list

	Pad material															
	Rubber material													Resin material		
	Nitrile rubber	Silicone rubber	Urethane rubber	Fluoro rubber	Chloroprene rubber	Fluorosilicone rubber	HNBR	EPDM	Static dissipative silicone rubber	Conductive rubber (low resistance)	Conductive NBR (low resistance)	NBR compatible with Food Sanitation Act	Oil-resistant NBR	PEEK	POM	Conductive PEEK
	N	S	U	F	Blank	FS	HN	EP	SE	E	NE	G	NH	K	M	KE
High-temperature usage limits	110°C	180°C	60°C	230°C	80°C	180°C	140°C	150°C	180°C	100°C	110°C	110°C	110°C	250°C	95°C	250°C
Low-temperature usage limits	-30°C	-40°C	-20°C	-10°C	-45°C	-50°C	-30°C	-40°C	-40°C	-50°C	-30°C	-30°C	-30°C	-50°C	-60°C	-50°C
Weather resistance	△	◎	○	○	○	○	○	◎	◎	○	△	△	△	◎	○	◎
Ozone resistance	×	◎	◎	◎	○	◎	○	◎	◎	×	△	×	×	-	-	-
Acid resistance	△	○	×	◎	△	○	△	◎	○	△	△	△	△	◎	×	◎
Alkali resistance	○	◎	×	×	◎	◎	○	◎	◎	○	○	○	○	◎	○	◎
Oil resistance (Gasoline/light oil)	◎	△	◎	◎	×	△	◎	×	△	×	◎	◎	◎	-	-	-
Oil resistance (Benzene/toluene)	△	△	△	◎	△	△	×	×	△	×	△	△	△	-	-	-
Self-lubrication	-	-	-	-	-	-	-	-	-	-	-	-	-	○	○	○
Abrasion resistance	-	-	-	-	-	-	-	-	-	-	-	-	-	◎	○	◎
Volume resistance ratio	-	-	-	-	-	-	-	-	10^5 Ω·cm or less	200 Ω·cm or less	200 Ω·cm or less	-	-	-	-	10^5 to 10^6 Ω·cm

Reading the rating ⇒ ◎: Ideal, ○: Suitable, △: Good, x: Unsuitable

■ Main application classification by pad material/shape

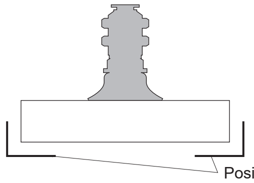
		Recommended workpieces, environments, etc.															
		Cardboard	Plywood	Iron plate	Food-related	Semiconductor	Molded products	Thin object	Chemical atmospheres	High temperature workpieces	Low ozone environments	Light resistance, ozone resistance required	Moist atmospheres	Uneven surfaces	Packaging machine	Electronic device parts	Liquid crystal manufacturing equipment
Pad material / Rubber material	Nitrile rubber	○	○	○	○								○		○		
Pad material / Rubber material	Silicone rubber				○	○	○	○		○	○		○		○		
Pad material / Rubber material	Urethane rubber	○	○	○							○				○		
Pad material / Rubber material	Fluoro rubber					○			○	○	○		○		○		
Pad material / Rubber material	Chloroprene rubber (sponge)				○								○	○			
Pad material / Rubber material	Fluorosilicone rubber						○			○	○		○		○		
Pad material / Rubber material	HNBR	○	○	○	○						○		○				
Pad material / Rubber material	EPDM										○	○	○				
Pad material / Rubber material	Static dissipative silicone rubber				○	○	○	○		○			○		○	○	
Pad material / Rubber material	Conductive rubber (low resistance)					○										○	
Pad material / Rubber material	Conductive NBR (low resistance)	○	○	○	○								○		○	○	
Pad material / Rubber material	NBR compatible with Food Sanitation Act	○	○	○	○								○				
Pad material / Rubber material	Oil-resistant NBR	○	○	○	○								○		○		
Pad material / Resin material	PEEK					○							○				○
Pad material / Resin material	POM										○		○		○		
Pad material / Resin material	Conductive PEEK					○							○			○	○
Pad shape	Standard / Standard	○	○	○		○			○	○						○	
Pad shape	Standard / Deep				○	○			○	○							
Pad shape	Standard / Compact					○			○	○	○	○	○			○	
Pad shape	Sponge				○	○								○			
Pad shape	Bellows	○	○	○	○	○			○	○	○	○	○			○	
Pad shape	Multi-stage bellows	○	○	○	○	○			○	○	○	○	○				
Pad shape	Oval	○	○	○	○	○			○	○						○	
Pad shape	Soft					○	○									○	
Pad shape	Soft bellows	○	○	○		○	○				○	○	○				
Pad shape	Anti-slip	○	○	○	○	○	○		○	○							
Pad shape	For thin objects	○	○	○	○	○	○	○	○	○					○		
Pad shape	Flat				○	○		○	○	○					○		
Pad shape	Suction mark prevention					○									○	○	○

Vacuum system components

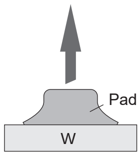
⑤ Note on model No. selection

CAUTION 1. Notes on selecting suction pads

- If the suctioned object (workpiece) is at risk of falling off, be sure to provide a preventive measure for safety.



- Consider horizontal suspension the basic method and select with a sufficient safety factor.



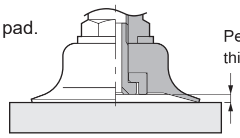
Horizontal lifting

- Calculate the suction force with consideration of not only the weight of the workpiece but the acceleration and impact as well.
- When setting the pad diameter, number of pads and suction position, be sure to fully understand the suction force in the catalog and select with a sufficient margin.
- Depending on the operating environment and usability, select the pad material with reference to the selection method in the catalog.
- The suitable pad shape (type) depends on the suctioned object and its shape, so read the Selection method carefully before selection.

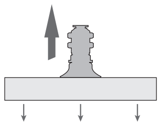
CAUTION 2. Notes for the use conditions of the suction pad

- When two or more pads are piped to a single vacuum source in a vacuum circuit, if one pad suffers suction failure (leakage), there is a danger that the other pads may be detached due to a decrease in vacuum pressure.
  As countermeasures, 1. Position locking valve
  2. Needle valve
  3. Vacuum switching valve
  can be used effectively.
  Also, when using a vacuum pump, a chamber (tank) can be effective aside from the 3 items above.

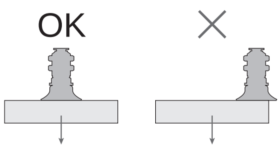
- When suctioning a workpiece, do not apply excessive impact or load to the suction pad.
  It may cause a drastic decrease in the durability of the suction pad.
  As a guideline, we recommend the deformation range of the lip or a setting in which it touches lightly.



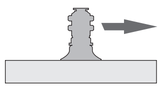
- The suction position of the workpiece by suction pad should be set so that moment will not be generated.



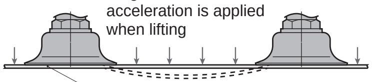
- Mount so that the suction pad does not protrude from the workpiece.
  Degradation of the degree of vacuum may cause the workpiece to fall.



- Reduce the acceleration of the lateral movement of the workpiece as much as possible.
  Depending on the friction coefficient of the workpiece, it may slip sideways.

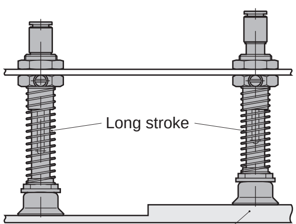


- When using a large, thin workpiece such as a glass plate or mounting substrate, be sure to consider the placement and moving acceleration of the suction pads.
  The workpiece may be deformed or damaged due to the position of the suction pad and acceleration.



- In environments where the workpiece may fall, please use an aid such as a position locking guide.

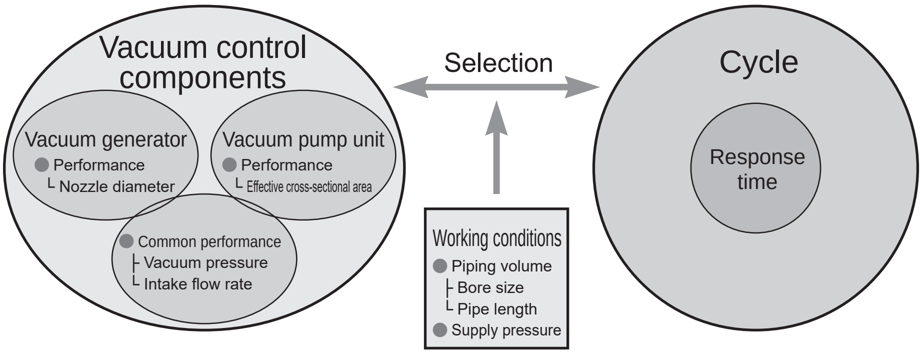
- The spring holder or long stroke type holder is suitable for the suction of objects with irregular height, those with steps, or those prone to damage due to external force.



Vacuum components selection method

2 ▶ Selecting the vacuum generator/vacuum switching valve

Three main items (vacuum control equipment, cycle and use condition) are involved in selecting the vacuum generator/vacuum pump compatible unit as shown on the right.
Understand these well when selecting vacuum generators/ vacuum switching valves.



① Various working conditions

A Vacuum piping volume

● How to calculate from the formula

The piping volume of the vacuum system can be calculated by assigning values to the following formula.

Piping volume

$$V = \frac{3.14}{4} D^2 \times L \times \frac{1}{1000}$$

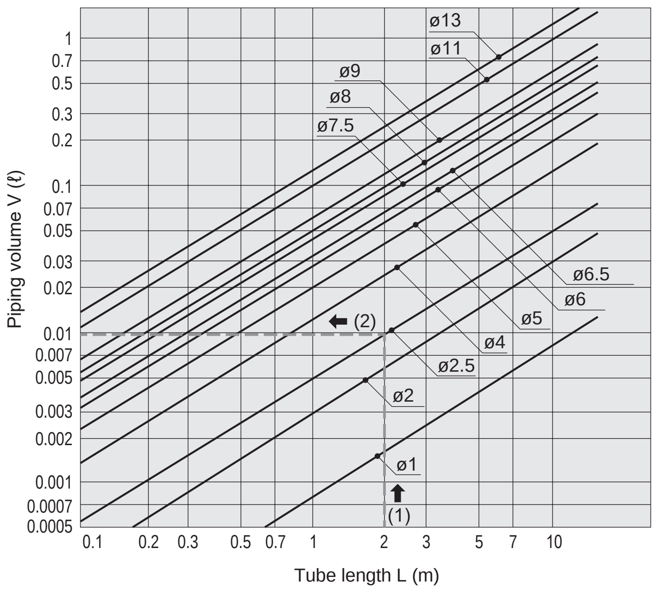
D: Piping bore size (mm)
L: Length from vacuum generator and switching valve to pad (m)
V: Piping volume from vacuum generator and switching valve to pad (ℓ)

● Selecting from selection graph

■ Obtain the piping volume of the vacuum system tube

Piping volume can be obtained from the table below.

Selection graph 3 Piping volume by tube inner diameter



Example

▶ When obtaining the volume of tubes with inner diameter of 2.5 mm (ø4 mm O.D.) and length of 2 m.

Using the formula

$$V = \frac{3.14}{4} D^2 \times L \times \frac{1}{1000} = \frac{3.14}{4} \times 2.5^2 \times 2 \times \frac{1}{1000} = 0.0098 \approx 0.01(\ell)$$

Using the selection graph

From the intersection of the horizontal tube with length 2 m and tube with inner diameter ø2.5 mm (ø4 mm O.D.), extend the piping to the left and obtain the piping volume ≈ 0.01 ℓ on the vertical axis.
Piping volume ≈ 0.01 ℓ

B Information on vacuum control components

Representative performance (information) of the vacuum control components (vacuum generator/vacuum pump compatible unit) is listed here. (For more information, refer to the ejector characteristics in this catalog.)

● For vacuum generator (VSH, VSU, VSB, VSC)

Vacuum characteristics list

Nozzle diameter (mm)	High vacuum: H		Large flow rate: L		Low supply pressure high vacuum: E	
	Vacuum pressure (kPa)	Intake flow rate (ℓ/min (ANR))	Vacuum pressure (kPa)	Intake flow rate (ℓ/min (ANR))	Vacuum pressure (kPa)	Intake flow rate (ℓ/min (ANR))
0.3	-90	2	-66	3 to 4	-88	1
0.4	-90	4	-66	7 to 7.5	-90	2
0.5	-90	7	-66	12	-90	3
0.7	-93 to -92	12.5 to 13	-66	22 to 26	-92 to -90	10 to 10.5
1	-93	28	-66	42	-92	21
1.2	-93	38	-	-	-92	27
1.5	-93	63	-66	95	-92	42
2	-93	110	-66	180	-92	84

*1. The supply pressure is high vacuum (H)/large flow (L): 0.5 MPa and low supply pressure high vacuum (E): 0.35 MPa.
*2. For vacuum generators other than the above, refer to the catalog text.

● For vacuum pump compatible units

Valve effective cross-sectional area list for vacuum pump compatible switching valve

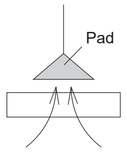
Type	Effective cross-sectional area (mm^2)		
	Vacuum supply solenoid valve		
VSJP	PV port size	ø4 mm	3.5
		ø6 mm	5
VSXP	PV port size	ø4 mm	3.5
		ø6 mm	4.5
VSXP-T	PV port size	ø4 mm	3
		ø6 mm	3.6
VSZPM	4.5		
VSQP	16.5		
VSNP	0.9		

① Various working conditions

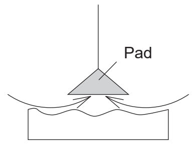
C Consideration when there is leakage

If leakage occurs between the pad and workpiece, it needs to be taken into account when quantifying the response time and selecting the vacuum control components.
If there is leakage, the vacuum pressure will inevitably decrease, which also needs to be taken into account.

Even in actual use, depending on the workpiece, leakage may occur, causing the vacuum pressure to decrease.
When selecting a vacuum generator and vacuum switching valve, it is necessary to take the amount of leakage into account.



Ventilated workpiece



Workpiece with rough surface

The following describes two methods, "How to calculate the amount of leakage when the effective cross-sectional area of the workpiece is known" and "How to calculate the amount of leakage by suction test".

● How to calculate the amount of leakage when the effective cross-sectional area of the workpiece is known

If the effective cross-sectional area (S_L) of the workpiece and opening of the suction pad is known, the amount of leakage can be calculated by the following formula.

Amount of leakage $Q_L = 11.1 \times S_L$

Q_L: Amount of leakage (ℓ/min (ANR))
S_L: Clearance between the workpiece and pad, and effective cross-sectional area of the opening of the workpiece (mm²)

From the calculated leakage amount and flow rate characteristic diagrams of the vacuum generator and vacuum pump, it is possible to predict how much the value will drop using the gauge pressure.

Example

When using the vacuum generator (VSC-E12) to obtain the vacuum pressure that can be secured when the effective cross-sectional area of the workpiece and opening of suction pad is 0.4 mm².

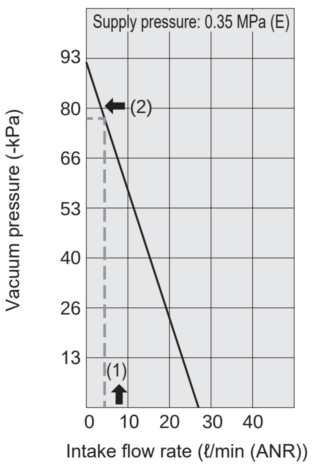
Point

Since the effective cross-sectional area of the workpiece and opening of the suction pad is known, the amount of leakage is calculated from the formula.
$Q_L = 11.1 \times S_L = 11.1 \times 0.4 = 4.4$ ℓ/min (ANR)
The actual vacuum pressure is calculated from the flow characteristics of the vacuum generator.

Answer

With the above formula for leakage amount,
$Q_L = 11.1 \times S_L = 11.1 \times 0.4 = 4.4$ ℓ/min (ANR)
From the flow characteristics of VSC-E12 (right figure), it can be predicted that a vacuum pressure of -77 kPa can be obtained if there is leakage of 4.4 ℓ/min (ANR).

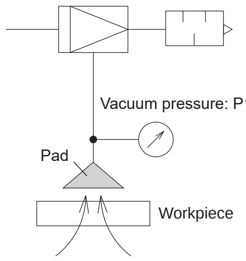
Flow characteristics



* Although the vacuum pressure for VSC-E12 is -92 to -90 kPa in the catalog, it can be seen that the actual vacuum pressure drops to -77 kPa due to the effective cross-sectional area of the workpiece and opening of the suction pad, so be sure to select the vacuum components in consideration of this effective sectional area.

● How to calculate the amount of leakage by suction test

If you do not know the effective cross-sectional area of the workpiece and opening of the suction pad, perform a test with the actual device and measure the amount of leakage as shown in the figure below.



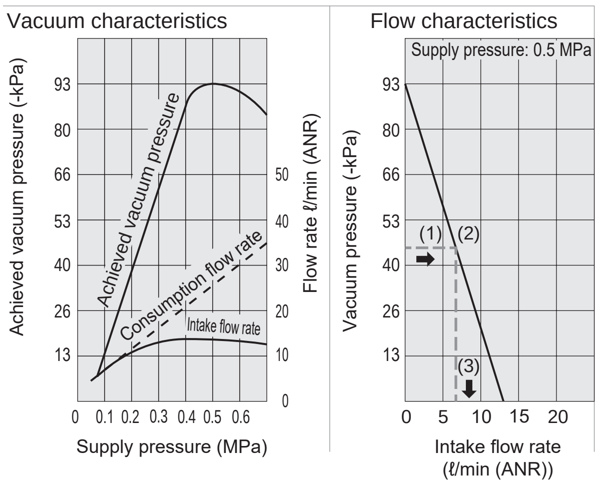
Example

When suctioning a leaky workpiece with a vacuum generator (VSB-H07) at the supply pressure of 0.5 MPa, the vacuum gauge pressure showed -45 kPa. Calculate the amount of leakage from this workpiece.

Answer

From the flow characteristics of the vacuum generator VSB-H07, it is found that the intake flow rate for -45 kPa is about 7 ℓ/min (ANR).
(in order of (1) → (2) → (3))
Amount of leakage ≈ 7 ℓ/min (ANR)

VSB-H07



* Regarding the flow characteristics of vacuum generators other than VSB-H07, refer to the characteristics of each product in the catalog.

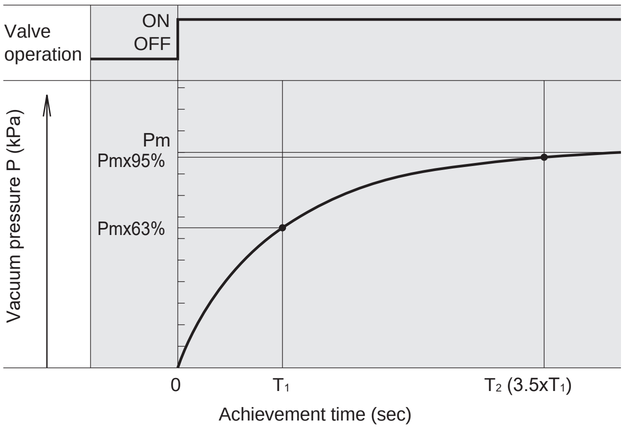
Vacuum components selection method

2 ▶ Selecting the vacuum generator/vacuum switching valve

② Selection procedure

A Obtaining response time (when there is no leakage)

When the vacuum control components and use conditions are clear, the approximate response time (reference value) can be quantified.



P_m: Final vacuum pressure, T_1: Time to reach 63% of final vacuum pressure P_m
T_2: Time to reach 95% of final vacuum pressure P_m

● How to calculate from the formula

Suction response time T_1 and T_2 can be calculated from the following formula.

Suction response time $T_1 = \frac{V \times 60}{Q}$

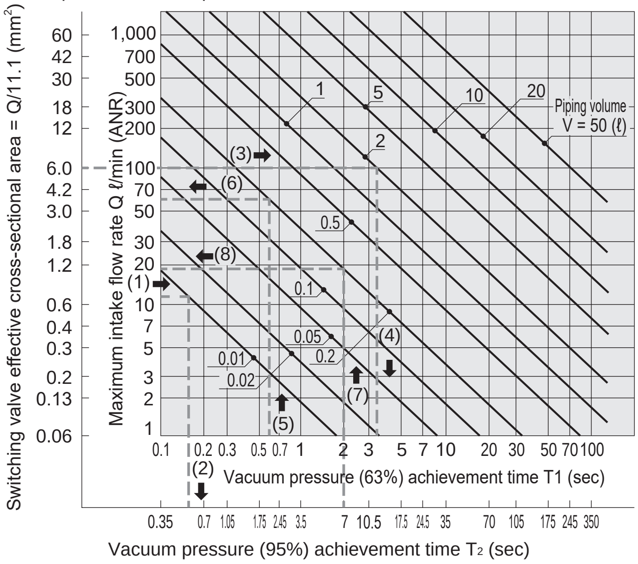
Suction response time $T_2 = 3.5 \times T_1$

T_1 : Time to reach 63% of final vacuum pressure P_m (sec)
T_2 : Time to reach 95% of final vacuum pressure P_m (sec)
V : Piping volume from vacuum generator and switching valve to pad (m)
Q : Average intake flow rate (ℓ/min (ANR))
Calculating the average intake flow rate
For vacuum generator ▶ Q = (1/3) x Vacuum generator maximum intake flow rate (ℓ/min (ANR))
For vacuum pump ▶ Q = (1/2) x 11.1 x Effective area of switching valve (mm^2)

● Obtaining from the selection graph

Suction response time T_1 and T_2 can be obtained from the following table.

Graph 4 Suction response time



* From the suction response time, it is possible to conversely obtain the size of the vacuum generator and switching valve of the vacuum pump system.

Example①

Obtain the suction response time when the pressure in the piping system with piping volume of 0.01 ℓ is made to reach the final vacuum pressure of -87 kPa using the maximum intake flow rate of 12 ℓ/min (ANR) in the vacuum generator (VSU-H07).

Point

Obtain the piping volume by referring to the formula on page 28 or selection graph 3.
-87 kPa ≈ -92 (kPa) x 95 (%)
From this, the suction response time T_2 in the above equation can be obtained.
In addition, the average intake flow rate is calculated from the list of vacuum characteristics on page 28:
Q = (1/3) x 12 = 1/3 x 12 = 4ℓ/min(ANR) is used.

Using the formula

$T_1 = \frac{V \times 60}{Q} = \frac{0.01 \times 60}{4} = 0.15$ (sec)

It can be seen from

$T_2 = 3.5 \times T_1 = 3.5 \times 0.15 = 0.525$(sec)

that the actual suction response time needs to be about 0.5 (sec).

Using the selection graph

The suction response time T_2 to reach 95% of the maximum vacuum pressure is obtained from the intersection point of the maximum suction flow rate of 12 ℓ/min (ANR) and the piping volume of 0.01 ℓ for the vacuum generator (VSU-H07). (Selection graph 4 (1) → (2) order)
$T_2 \approx 0.5$(sec)

Example②

Obtaining the suction response time when increasing the internal pressure up to 63% of the final vacuum pressure in a 2ℓ tank by using a valve with an effective cross-sectional area of 6 mm^2.

Using the formula

$T_1 = \frac{V \times 60}{1/2 \times 11.1 \times S} = \frac{2 \times 60}{1/2 \times 11.1 \times 6} = \frac{120}{33.3} = 3.6$ (sec)

Using the selection graph

Response time T_1 to reach 63% of the maximum vacuum pressure is obtained from the intersection point of the valve effective cross-sectional area 6 mm^2 and piping volume 2 ℓ.
(Selection graph 4 (3) → (4) order)
$T_1 \approx 3.5$(sec)

B Selecting the vacuum generator and vacuum pump compatible unit

When response time and usage conditions are clear, it is possible to select the optimal vacuum generator and vacuum pump compatible unit.

1. Size of vacuum generator and vacuum switching valve (when there is no leakage)

● Using the formula

a Average intake flow rate

$$Q = \frac{V \times 60}{T_1}$$

$T_2 = 3.5 \times T_1$

Q : Average intake flow rate (ℓ/min (ANR))
V : Piping volume (ℓ)
T_1 : Time (sec) to reach 63% of stable pressure P after suction
T_2 : Time (sec) to reach 95% of stable pressure P after suction

b Maximum intake flow rate (specification intake flow rate of vacuum components)
For vacuum generator ▶ Qmax = 3 x Q [ℓ/min (ANR)]
For vacuum pump ▶ Qmax = 2 x Q [ℓ/min (ANR)]

Point

■ For vacuum generator
It is necessary to select a vacuum generator with suction flow rate larger than Qmax in the formula above.

■ For vacuum switching valve

Effective cross-sectional area $S = \frac{Qmax}{11.1}$ (mm^2)

* It is necessary to select a switching valve larger than the effective cross-sectional area in the formula above.

● Method using the selection graph

a Tube volume
Calculate using "piping volume by tube inside diameter" in the selection graph 3 (Intro Page 28).

b Maximum intake flow rate Qmax
Calculate the required maximum intake flow rate Q from the suction response time (T_1, T_2) and tube volume from the selection graph 4 (Intro Page 30) "suction response time".

Point

■ For vacuum generator
It is necessary to select a vacuum generator with maximum intake flow rate larger than Q obtained from the graph.

■ For vacuum switching valve
It is necessary to select a vacuum switching valve larger than the effective cross-sectional area of the valve obtained from the graph.

Example

Selecting a vacuum generator to achieve vacuum pressure of -58 kPa in about 0.6 seconds using a tank with piping volume 0.2 ℓ. (0.5 MPa secured for supply pressure)

Point

-58 kPa = -93 (kPa) x 63 (%)
"H" is considered suitable when compared with our catalog value, given that the supply pressure of 0.5 MPa is likely to be secured.

Using the formula

■ a From the calculation formula of average intake flow rate

$$Q = \frac{V \times 60}{T_1} = \frac{0.2 \times 60}{0.6} = 20$$

■ b From the calculation formula of maximum intake flow rate
Qmax = 3 x Q = 3 x 20 = 60 ℓ/min(ANR)
From the above formula, we see that the suction flow rate of the vacuum generator should be 60 ℓ/min (ANR).

Using the selection graph

The maximum intake flow rate is obtained from the intersection point where the suction response time is 0.6 seconds and piping volume is 0.2 ℓ. (Selection graph 4 (5) → (6) order)
Q ≈ 60 ℓ/min(ANR)

* Since we already know that "H" is suitable from the above points, compared with the CKD catalog value, we see from the calculated value selection graph that the vacuum characteristics of H15 (intake flow rate: 63 ℓ/min (ANR)) are ideal.

Vacuum components selection method

2 ▶ Selecting the vacuum generator/vacuum switching valve

② Selection procedure

B Selecting the vacuum generator and vacuum pump compatible unit

2. Size of vacuum generator and vacuum switching valve (when there is leakage)

If there is leakage from the workpiece, the size of the necessary vacuum generator/vacuum switching valve can be calculated by adding the leakage amount to the maximum intake flow rate.

● Using the formula

a Average intake flow rate with leakage taken into account

$$Q = \frac{V \times 60}{T_1} + Q_L$$

$$T_2 = 3.5 \times T_1$$

Q : Average intake flow rate (ℓ/min (ANR))
V : Piping volume (ℓ)
T_1 : Time (sec) to reach 63% of stable pressure P after suction
T_2 : Time (sec) to reach 95% of stable pressure P after suction
Q_L : Amount of leakage during workpiece suction (ℓ/min (ANR))

b Maximum intake flow rate (specification intake flow rate of vacuum components)
For vacuum generator ▶ Qmax = 3 x Q [ℓ/min (ANR)]
For vacuum pump ▶ Qmax = 2 x Q [ℓ/min (ANR)]

Point
■ For vacuum generator
It is necessary to select a vacuum generator with suction flow rate larger than Qmax in the formula above.
■ For vacuum switching valve

$$\text{Effective cross-sectional area } S = \frac{Q_{max}}{11.1} \ (mm^2)$$

* It is necessary to select a switching valve with an effective cross-sectional area larger than S in the above formula.

● Method using the selection graph

a Tube volume
Calculate using "piping volume by tube inside diameter" in the selection graph 3 (Intro Page 28).

b Maximum intake flow rate Qmax
From the suction response time (T_1, T_2) and tube volume from selection graph 4 (Intro Page 30) "Suction response time", obtain the required maximum intake flow rate Q that does not include the leakage amount Q_L.

Maximum intake flow rate
For vacuum generator ▶ $Q_{max} = Q + (2 \times Q_L)$
For vacuum pump ▶ $Q_{max} = Q + (3 \times Q_L)$
Q : Maximum intake flow rate (ℓ/min (ANR)) obtained from selection graph 4 (Intro Page 30)
Q_L: Leakage amount (ℓ/min (ANR)) (Intro Page 29) Values taking into consideration leakage during workpiece suction

Point
■ For vacuum generator
It is necessary to select a vacuum generator with maximum intake flow rate larger than Q obtained from the graph.
■ For vacuum switching valve
It is necessary to select a vacuum switching valve larger than the effective cross-sectional area of the valve obtained from the graph.

Example
We want to satisfy the workpiece and opening of the vacuum pad of 4.4 ℓ/min (ANR) and piping volume of 0.2 ℓ. Time to achieve 95% of stable pressure Pm after suction: 7 sec.
Find out what type of vacuum generator to select.

Point
Refer to the example in "Extracting usage conditions" on Intro Page 28 for the piping volume and "When there is leakage" on Intro Page 29 for the amount of leakage after workpiece suction.

Using the formula
From $T_2 = 3.5 \times T_1$,

$$T_1 = \frac{T_2}{3.5} = \frac{7}{3.5} = 2 \text{ (sec)}$$

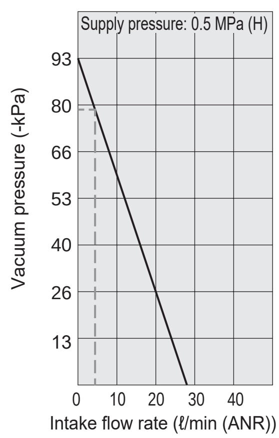
$$Q = \frac{V \times 60}{T_1} + Q_L = \frac{0.2 \times 60}{2} + 4.4 = 10.4 \text{ (ℓ/min(ANR))}$$

Therefore, the maximum intake flow rate is
Qmax = 3 x Q = 3 x 10.4 = 31.2 ℓ/min(ANR)
From the above formula, we see that it is reasonable to select a vacuum generator with intake flow rate of 31.2 ℓ/min (ANR) or greater.

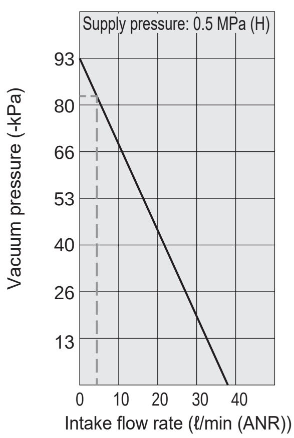
Using the selection graph
The maximum intake flow rate is obtained from the intersection point of the vacuum pressure (95%) achievement time of 7 sec and piping volume of 0.2 ℓ. (Selection graph 4 on Intro Page 30, in order of (7) → (8))
Q ≈ 20 ℓ/min(ANR)
Qmax = 20 + (3 x 4.4) = 33.2 ℓ/min(ANR)

[Supplement]
If a maximum intake flow rate of about 33 ℓ/min (ANR)) and supply pressure of 0.5 MPa can be secured, high vacuum (H) with nozzle diameter ø1 mm or ø1.2 mm will be suitable. However, as the maximum vacuum pressure will be -79 kPa for H10 and -83 kPa for H12 based on the leakage amount of 4.4 ℓ/min (ANR) of the workpiece and opening of the vacuum pad and flow characteristics in the figure below, it is necessary to select the vacuum components with consideration of the required maximum pressure.

Flow characteristics (for H10)



Flow characteristics (for H12)



Vacuum system components

③ Note on model No. selection

CAUTION 1. Notes on selecting vacuum components

- Be careful of vacuum pressure drop due to trouble with supply air and power supply.
- As there is a danger of the suctioned object falling due to decreased suction force, be sure to take safety measures.
- Remove drainage and dirt from the ejector supply air and use clean air. Do not lubricate using a lubricator. Impurities and oil contained in compressed air may cause malfunction or degrade performance.
- Supply pressure (catalog specification value) of the ejector is the value when the ejector is in operation. Consider the pressure drop and make sure the catalog specification value is achieved. If the specification value is not satisfied, the ejector will emit abnormal noise at a specific supply pressure and the performance will become unstable, which may affect the sensor and cause problems.
- Vacuum retention function type and check valve function type allow vacuum leakage, so take other safety measures if the vacuum state needs to be maintained for long periods.
- If energization to the valve continues for long periods, heat is generated from the coil. Heat generation may lead to shortened product service life, malfunction, etc. Also, heat risks causing burns and impacting peripheral devices.
- When the manifold specification is used, the combination of manifold stations and mounting units may degrade performance or affect other station vacuum ports.

CAUTION 2. Notes on selecting vacuum generator nozzle diameter

- With regard to the effective cross-sectional area on the ejector supply pressure side, carry out piping and equipment selection with 3 times the effective cross-sectional area of the nozzle diameter cross-sectional area as a guideline. If the supply flow rate is insufficient, it may cause the performance to degrade.

CAUTION 3. Notes on selecting vacuum line components

- Select related products according to the maximum flow rate of the vacuum source.

  Regarding the effective cross-sectional area of related products, calculate the total based on the calculation of
  S (effective cross-sectional area) = Qmax (maximum flow rate: ℓ/min (ANR)) / 11.1 (mm^2)
  when making a selection.
  Note: This approximate formula applies to vacuum lines, but not to positive pressure lines.

  For calculation with positive pressure lines, use the following formula.

  ■ MPa unit $P_1 > 1.89P_2$

  $$Q = 113 \times S \times P_1 \left(S = \frac{Q}{113 \times P_1} \right)$$

  ■ kgf/cm^2 unit $P_1 > 1.89P_2$

  $$Q = 11.1 \times S \times P_1 \left(S = \frac{Q}{11.1 \times P_1} \right)$$

  P_1: Primary side absolute pressure
  P_2: Secondary side absolute pressure

CAUTION 4. Notes on selecting the vacuum filter

- Never apply positive pressure for vacuum burst to the vacuum filter. Not an explosion-proof structure. Also, due to low pressure resistance, damage to the product body may cause injuries.

CAUTION 5. Notes on using vacuum equipment

- When operating the valve, make sure that the leakage current is 1 mA or less. Otherwise, there is a risk of malfunctions caused by leakage current.
- Do not apply pressures of 0.1 MPa or greater to the vacuum circuit side of the vacuum generator or vacuum pump unit. This risks causing damage to the body, as the vacuum component does not have an explosion-proof structure.
- When two or more pads are piped to a single ejector in a vacuum circuit, if one pad suffers suction failure (leakage), there is a danger that the workpiece may be detached due to decreased vacuum pressure.
- Do not use the product so as to block the exhaust port of the ejector or increase the exhaust resistance. It may prevent vacuum generation or cause the vacuum pressure to drop.