Precautionary measures against condensation in a pneumatic system

(Phenomena, process, prediction and preventive measures)

In a pneumatic system, temperature drops may cause internal condensation under certain piping and operating conditions, leading to malfunction and reduced life time due to deterioration and the washing out of grease. This brochure provides useful information on countermeasures and preventive actions to be taken in this regard.

SMC

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Contents

Information in this catalog is based on researches conducted by SMC.
Condensation is affected by various factors, such as the quality of air, circuit configuration, characteristics of equipment, operating conditions and environmental elements.
Therefore, condensation judgment and the limit of piping length tend to involve a certain degree of errors and shall be presented here as guidelines.

1. Condensation phenomena

● What is condensation in a pneumatic system?

In a pneumatic system, waterdrops sometimes form inside piping, affecting operation and the life of equipment. For this reason, compressed air is usually dehumidified with an air dryer before being supplied to the system.
However, due to increasing demand for smaller, faster equipment, even the use of dehumidified air may result in condensation and consequent failure when a small actuator is used. Photo 1 shows condensation occurring inside a piping, and Photo 2 shows the dripping of condensation in a cylinder.

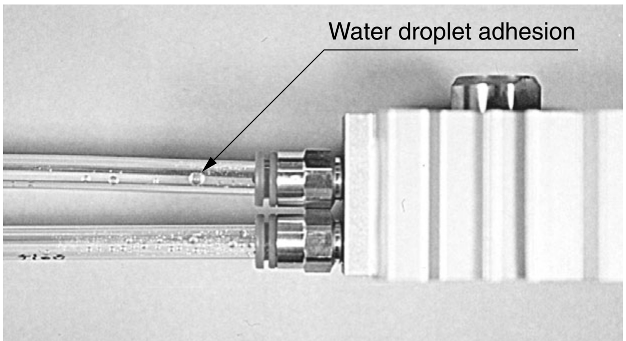


Photo 1 Condensation inside tube

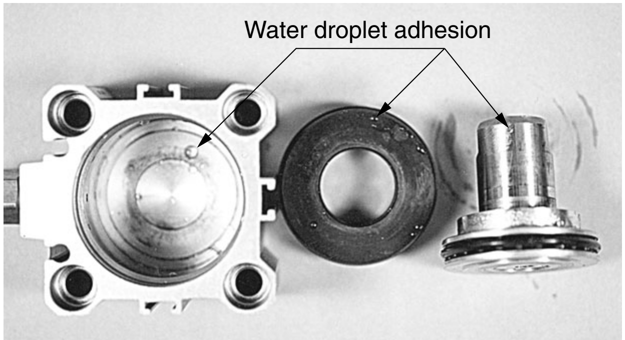
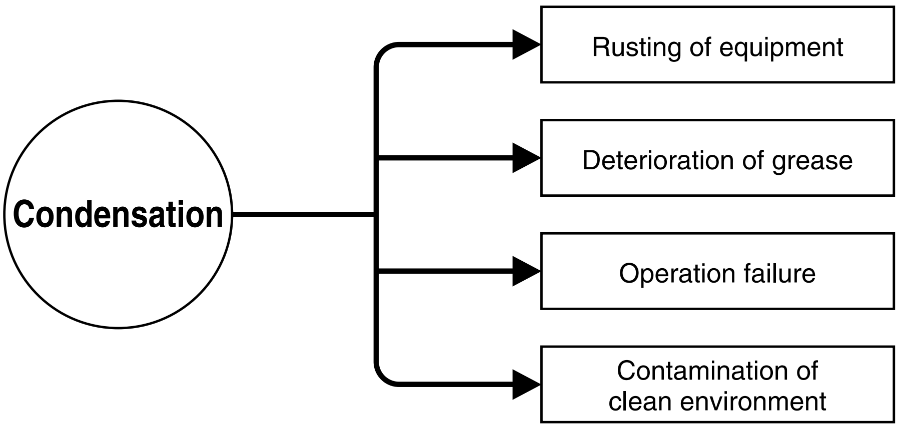


Photo 2 Dripping of condensation in a cylinder

● What kind of problems can it bring about?



2. Process of condensation

The following is an example of a small cylinder drive system illustrating a condition under which condensation occurs inside a piping.

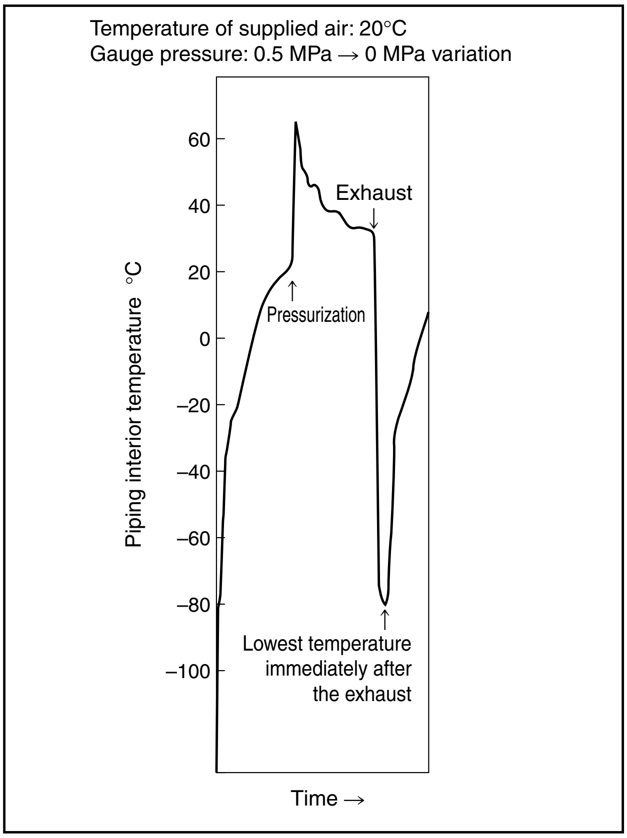
2-1 Adiabatic expansion

When air is discharged from the piping between the cylinder and a solenoid valve, the temperature drops due to adiabatic expansion.
Assume the gauge pressure of supply air to be Ps [MPa] and temperature to be Ts [°C]. The temperature after adiabatic expansion Tl is obtained as follows;

$$Tl = (Ts+273) \times \left(\frac{0.1}{Ps+0.1}\right)^{0.286} - 273$$

When the air at 27°C and 0.5 MPa undergoes adiabatic expansion to atmospheric pressure, theoretically the temperature will drop to nearly –93°C. Actual temperature measurements inside the piping in the right chart show that the temperature dropped to approximately –80°C.

Results of temperature measurement inside the piping

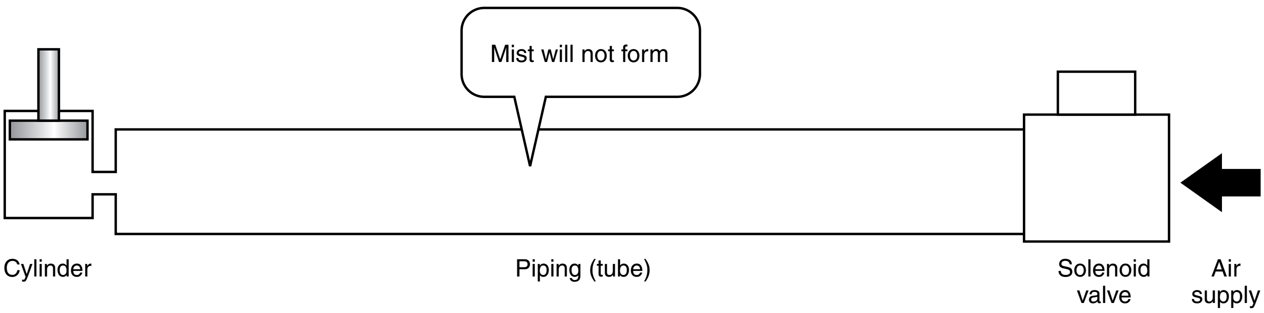


2-2 Process of condensation

① Air supply

[No mist formation]

A solenoid valve opens and compressed air instantly enters the piping which is in a state of low pressure. When this happens, the original air in the piping is compressed, causing the temperature to rise and so no mist will form.



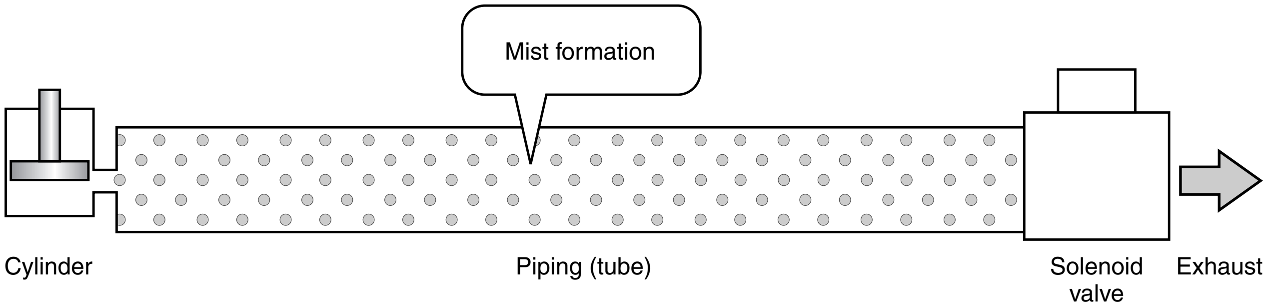
Note) Most piping is usually long, with a larger volume than the cylinder volume.
Therefore, the piping is larger than the cylinder in the above figure.

② Exhaust

[Temperature drop → Mist formation]

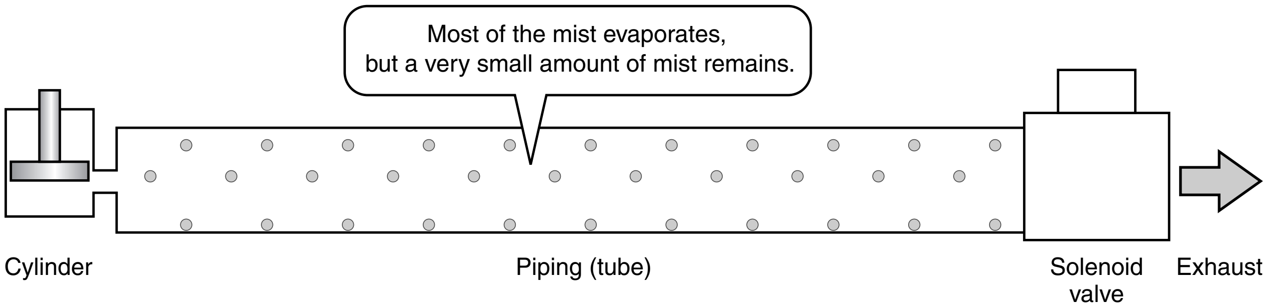
The solenoid valve is switched and air inside the piping is instantly released. Then, the pressure inside the piping is reduced suddenly (adiabatic expansion), causing the temperature to drop.

If the atmospheric dew point of the supply air is T_t (°C), and the temperature drop of the air T_l (°C) after adiabatic expansion falls below this value ($T_l < T_t$), then mist formation occurs.



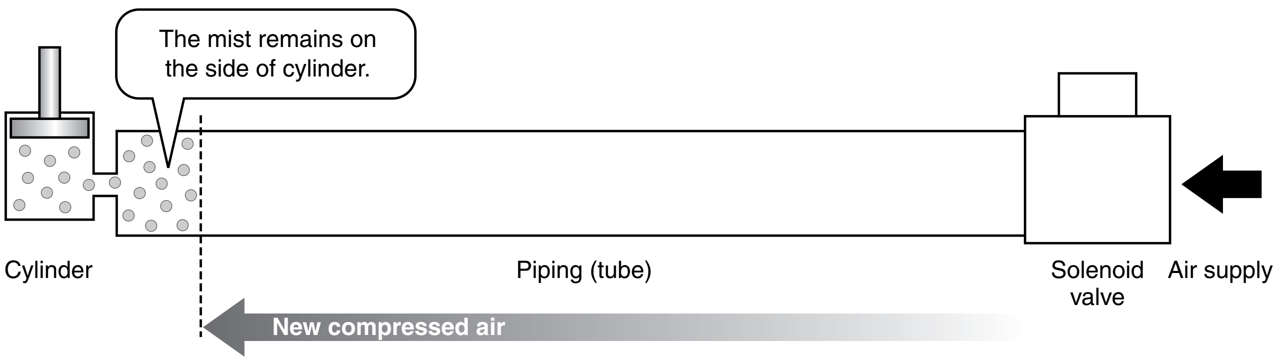
[Mist evaporation and small amount of residual mist]

Most of the mist is discharged through evaporation by the surrounding heat. However, a small amount of residual mist tends to adhere to the inner wall of the piping.



③ Air supply

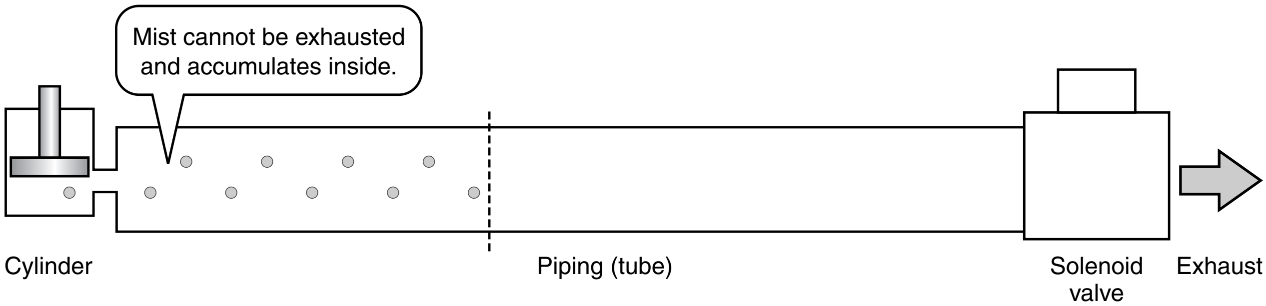
The solenoid valve is switched and new compressed air is supplied, so the residual mist in condition ② remains on the side of the cylinder.



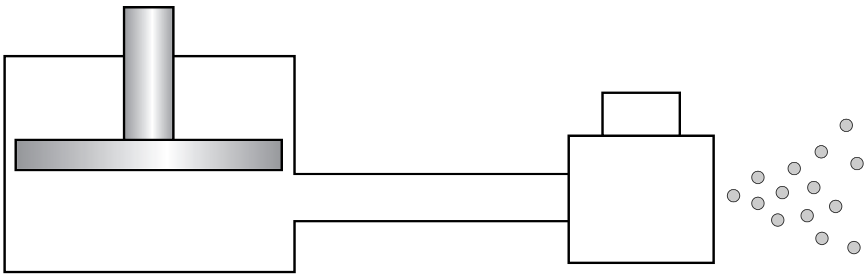
④ Exhaust

[Volume of the piping is large (long piping) → Mist accumulation]

When the cylinder is small and the piping is long (that is, the volume of the piping is larger than that of the cylinder), air inside the cylinder cannot be exhausted at the time of release and remains inside the piping.



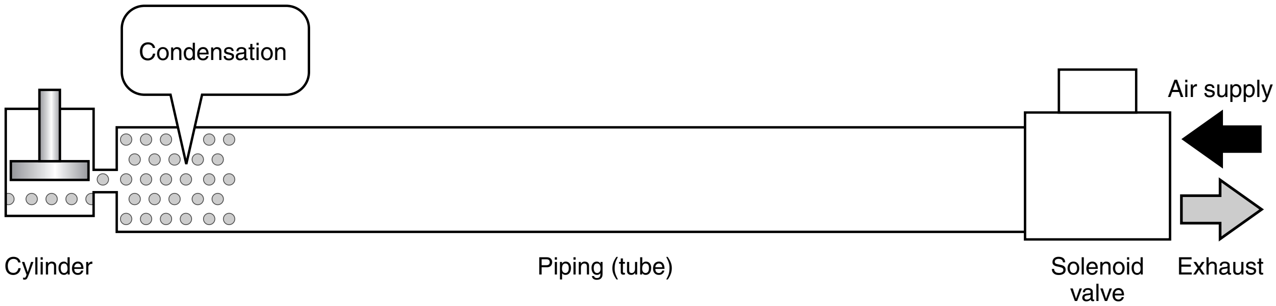
If the volume of the piping is smaller than the volume of the cylinder, the mist will be exhausted with the exhausted air as shown in the figure below, and the mist will not accumulate inside the piping.



⑤ Air supply — Repeated exhaust

[Condensation]

As the cylinder cycles, the mist accumulating near the cylinder increases, finally resulting in formation of large waterdrops and condensation.



From observation of the above, one can see that condensation is largely influenced by the volume of the cylinder and piping.

The volume ratio Kv, which is the ratio of the volume of compressed air inside the cylinder converted into the volume at atmospheric pressure to the volume of the piping, is defined as follows:

$$Kv = \frac{Vt}{Vc} \times \frac{0.1}{Ps + 0.1}$$

Vt : Volume of the piping [cm^3]
Vc : Volume of the cylinder [cm^3]
Ps : Gage pressure of air supply [MPa]

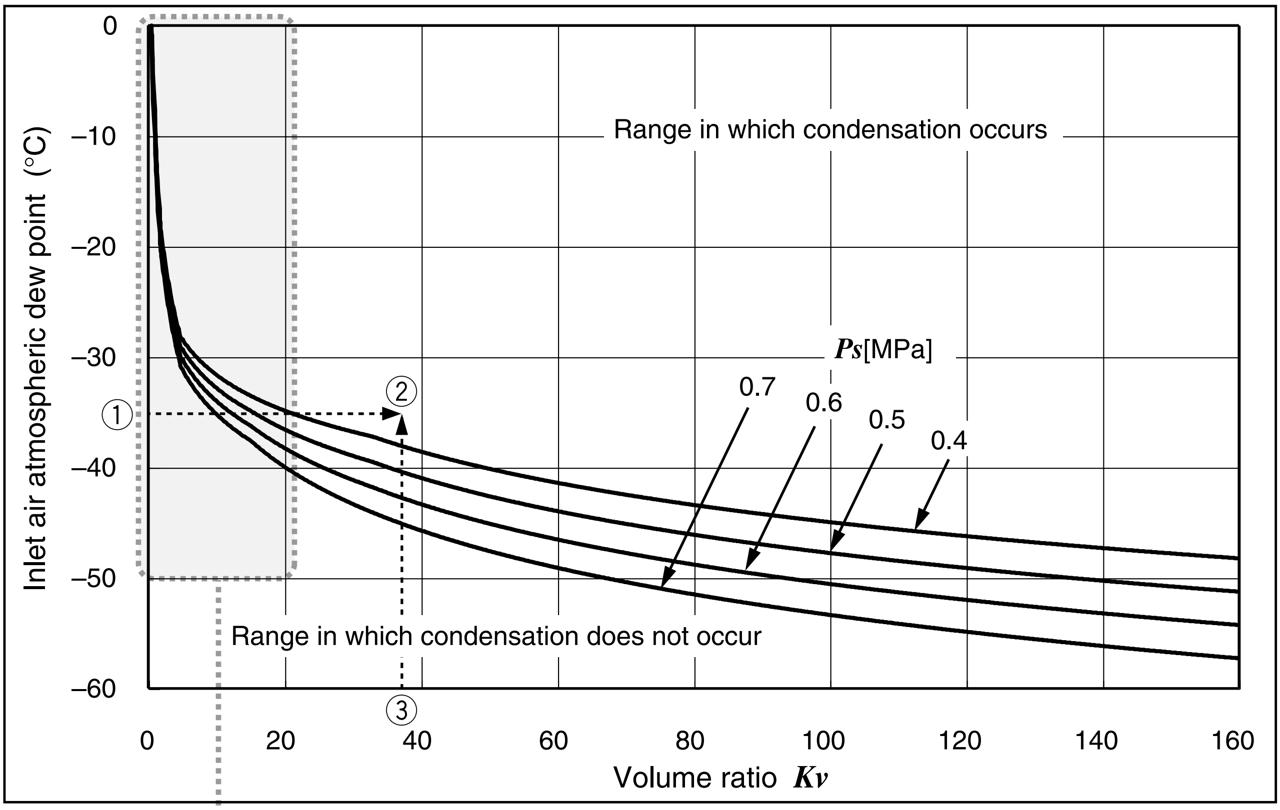
If $Kv > 1$, there is a large possibility of condensation. Kv can be reduced if Vt is made smaller by cutting down the piping length. Accordingly probability of condensation decreases.

3. Condensation assessment

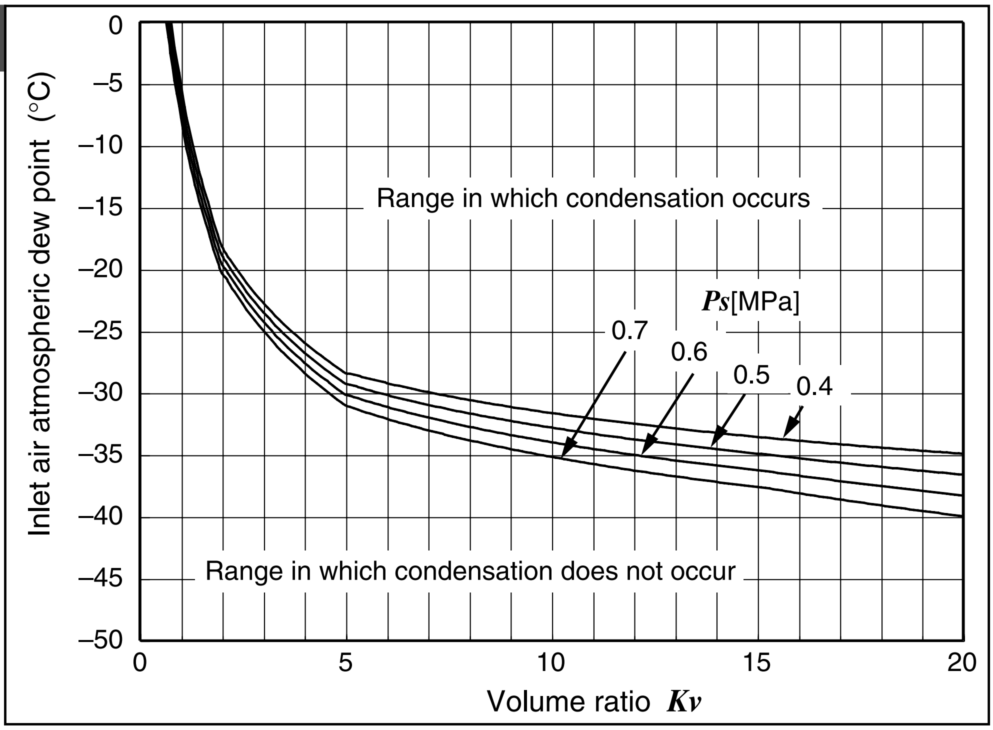
The probability of condensation is influenced mainly by the volume ratio, humidity and pressure of the supply air, etc. The following chart and program are provided for assessing more specific cases.

3-1 Condensation assessment chart

[Condition]
Switching intervals of solenoid valve: ON 1 sec, OFF 1 sec.
Piping tube material: Polyurethane



Enlarged chart



How to use the chart (Refer to page 5)

(1) Find the atmospheric dew point of inlet air ①.

When the humidity of inlet air can be considered as relative humidity or a pressure dew point, the atmospheric dew point can be found according to the humidity conversion chart in “Humidity and conversion” page 10 of the supplement.

(2) Find the volume ratio Kv ③.

Find the volume ratio from the following equation for a volume ratio.

$$Kv = \frac{Vt}{Vc} \times \frac{0.1}{Ps+0.1}$$

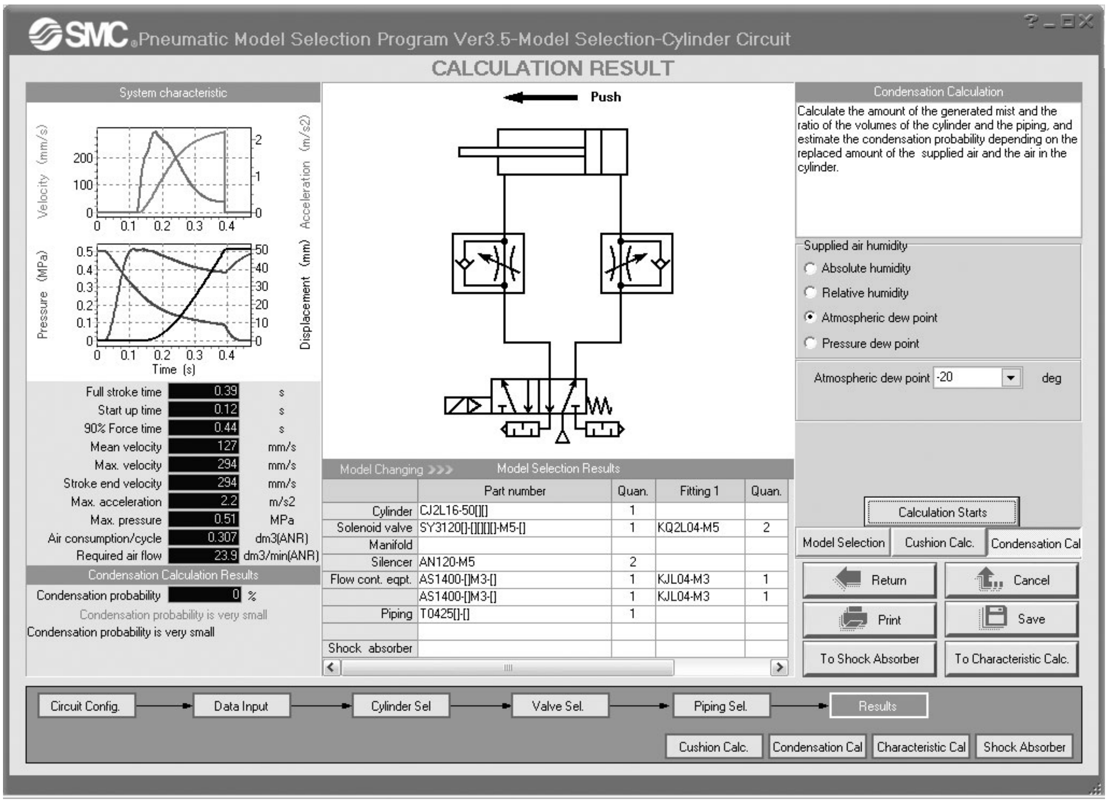
Vt :	Volume inside the piping [cm^3]
Vc :	Cylinder volume [cm^3]
Ps :	Gage pressure of supplied air [MPa]

(3) Assess the probability of condensation.

Extend lines from ① to ② and from ③ to ② to find the intersection ②. Depending on the range corresponding to the intersection ②, the probability of condensation will be assessed.

3-2 Condensation assessment program

A condensation assessment function is implemented in “Pneumatic Model Selection Program Ver. 3.5 or later” by SMC. Conduct the condensation calculation on the result screen of model selection and calculation of special characteristics, then the probability of condensation will be displayed upon entering the humidity of the air.



4. Countermeasures against condensation

Based on the above-mentioned condensation example, the following preventive measures can be implemented.

● Countermeasures against air quality

Compressed air containing a large amount of moisture condenses easily and may cause the pneumatic equipment to malfunction. Therefore, it is recommended to install an air dryer before pneumatic equipment, based on the results of the Condensation Assessment Chart or the SMC Model Selection Software. For selecting the air dryer, refer to the SMC Pneumatic Energy Saving Program.

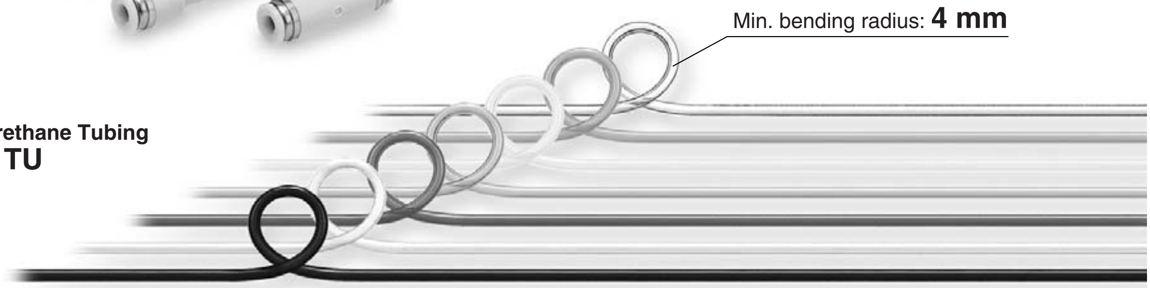
● Countermeasures against volume of piping

Minimize the piping volume by shortening the piping between the SUP/EXH valve and actuator, and by considering the piping size. (The smallest tubing ø2 is available.)

ø2 One-touch Mini
Series KJ

ø2 Miniature Fittings
Series M

ø2 Polyurethane Tubing
Series TU



● Countermeasures against piping materials

Internal condensation is caused by adiabatic cooling after adiabatic expansion, so select a piping material with high thermal conductivity such as copper tubing.

● Countermeasures against operating pressure

Minimize the operating pressure since internal condensation can be easily caused when the piping volume is large and the operating pressure is high. Please confirm the range of the graph and calculate the actual operating conditions as it is possible to reverse the conditions that easily cause internal condensation when the Kv value is low and when within the range of an increase in the graph.

● Countermeasures against air supply and exhaust

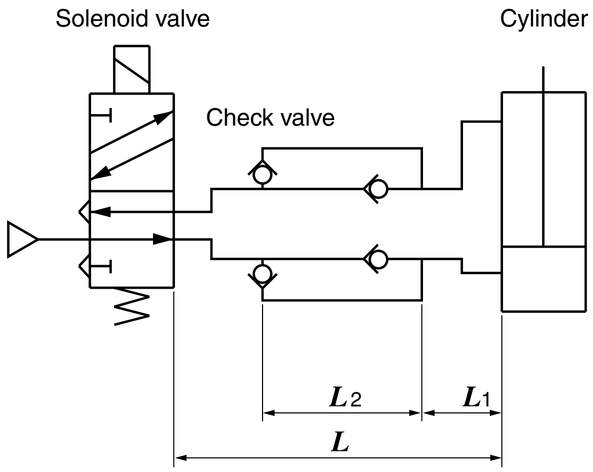
It may be necessary to separate the SUP/EXH passage or to raise the exhaust speed in the piping. The following are typical examples:

① By-pass circuit method

Sufficient exchange of air can be achieved by providing one-way air supply and exhaust circuits with check valves and by-pass piping.

By-pass piping installation position L_1: it should be smaller than $\frac{Vc}{Sp} \times \frac{Ps+0.1}{0.1}$
and be installed as close to the cylinder as possible.

Length of by-pass piping L_2: approx. 20% of the total length of L



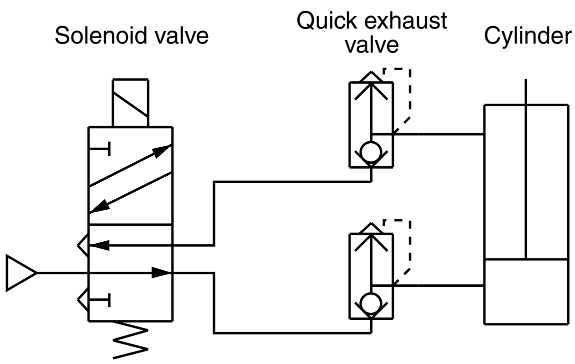
Vc : Cylinder volume [cm^3]
Ps : Supply pressure [MPa]
Sp : Piping cross-sectional area [mm^2]

Check Valve
with One-touch Fitting
Series AKH

Straight type

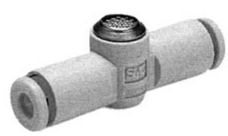
② Quick exhaust valve method

Install quick exhaust valves close to the cylinder to exhaust air inside the cylinder directly to the atmosphere.



Quick Exhaust Valve
with One-touch Fittings
Series AQ240F/340F

With exhaust port fitting



With silencer

5. Supplement

● Dew point

Air contains a small amount of water in the form of vapor, the content of which is restricted by an upper limit that depends on the temperature of the air. If it is exceeded, extra vapor will condense in the form of waterdrops. This upper limit of content is called the dew point, which is represented with "g" as the amount of vapor in 1 m^3.

Table of dew points (unit: g/m^3)

Temperatures in 10°C increments	Temperatures in 1°C increments: 0	1	2	3	4	5	6	7	8	9
90	420.1	433.6	446.5	464.3	480.8	496.6	414.3	532.0	550.3	569.7
80	290.8	301.7	313.3	325.3	337.2	349.9	362.5	375.9	389.7	404.9
70	197.0	204.9	213.4	222.1	231.1	240.2	249.6	259.4	269.7	280.0
60	129.8	135.6	141.5	147.6	153.9	160.5	167.3	174.2	181.6	189.0
50	82.9	86.9	90.9	96.2	99.6	104.2	108.9	114.0	119.1	124.4
40	51.0	53.6	56.4	59.2	62.2	65.3	68.5	71.8	75.3	78.9
30	30.3	32.0	33.8	35.6	37.5	39.5	41.6	43.6	46.1	48.5
20	17.3	18.3	19.4	20.6	21.8	23.0	24.3	25.7	27.2	28.7
10	9.40	10.0	10.6	11.3	12.1	12.8	13.6	14.5	15.4	16.3
0	4.85	5.19	5.66	5.95	6.35	6.80	7.26	7.75	6.27	8.82
−0	4.85	4.52	4.22	3.93	3.66	3.40	3.16	2.94	2.73	2.54
−10	2.25	2.18	2.02	1.87	1.73	1.60	1.48	1.36	1.26	1.16
−20	1.067	0.982	0.903	0.829	0.761	0.696	0.640	0.556	0.536	0.490
−30	0.448	0.409	0.373	0.340	0.309	0.261	0.255	0.232	0.210	0.190
−40	0.172	0.156	0.141	0.127	0.114	0.103	0.093	0.063	0.075	0.067
−50	0.060	0.064	0.049	0.043	0.038	0.034	0.030	0.027	0.024	0.021
−60	0.019	0.017	0.015	0.013	0.011	0.0099	0.0087	0.0076	0.0067	0.0058

How to see the saturation state steam table

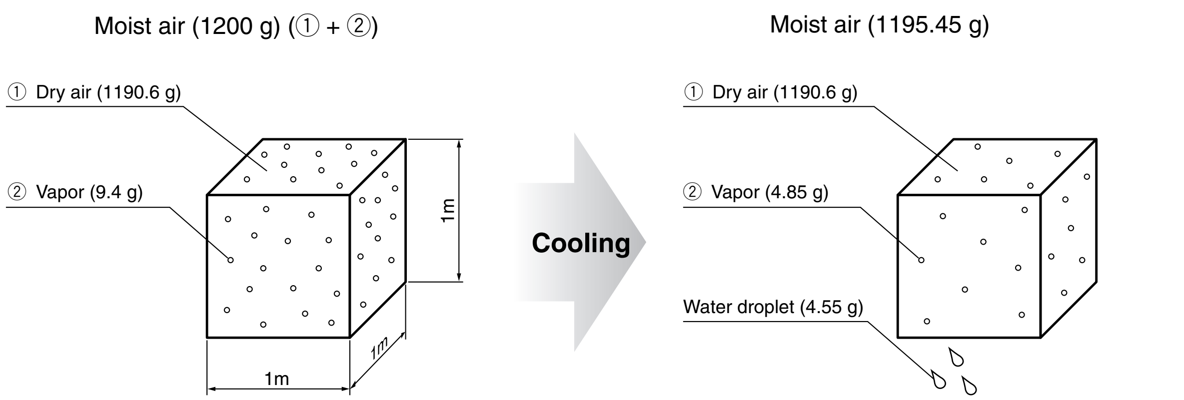
The table presents temperatures in 10°C increments in each column and in 1°C increments in each row.

[Example] Find the dew points at 32°C.

Example 32°C (Temperatures in 10°C increments)	Temperatures in 1°C increments: 0	1	2	3	
40					
30			33.8		
20					

33.8 g/m^3 is selected according to the above explanation of the table.

For example, assume 1 m^3 of air contains 9.4 g of vapor. At 20°C, the amount of saturated vapor is 17.3 g/m^3. Water takes the form of vapor. If the air is cooled to a temperature of 0°C, the amount of saturated vapor is reduced to 4.85 g/m^3. Consequently, 4.55 g (9.4 g − 4.85 g =) of extra vapor condenses.



Temperature 20°C
(Amount of saturated vapor 17.3 g/m^3)

Temperature 0°C
(Amount of saturated vapor 4.85 g/m^3)

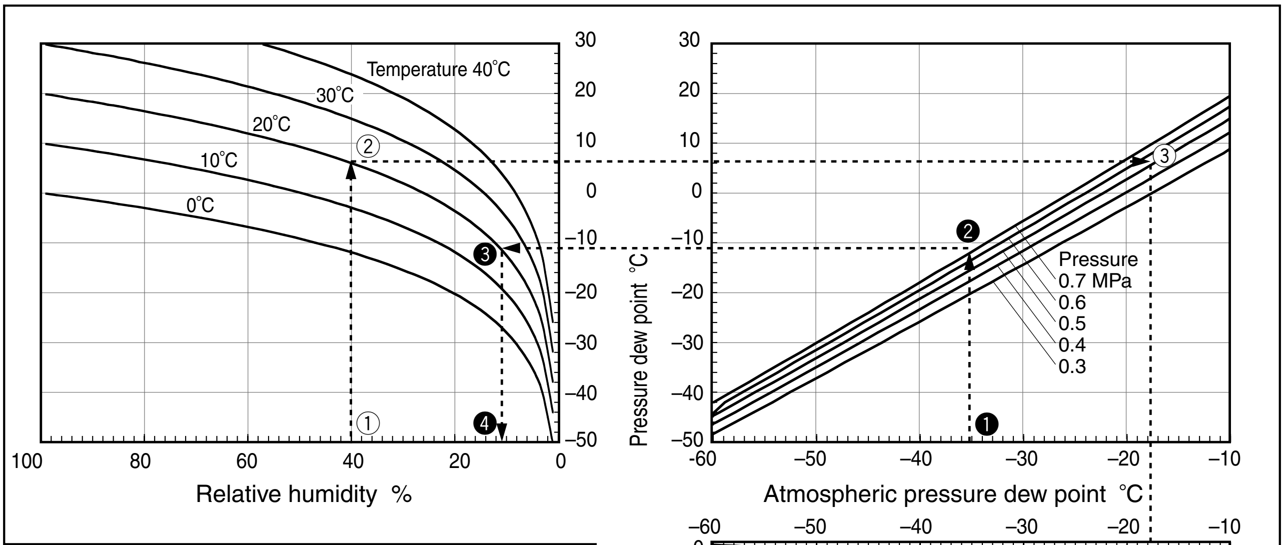
∗Calculation of condensation amount as in the above example can be performed easily by using "Model Selection Program" by SMC.

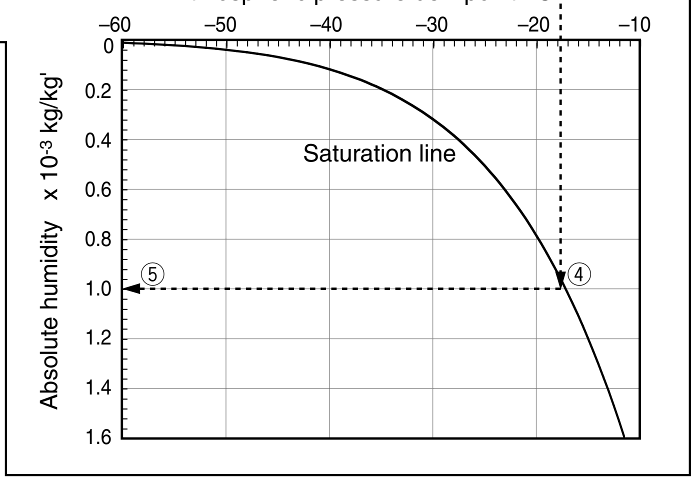
● Humidity and conversion

The content of vapor in air is represented by the humidity or dew point.

Absolute humidity : The mass ratio of vapor to dry air
Relative humidity : The mass ratio of vapor to amount of saturated vapor
Atmospheric pressure dew point
: Temperature at which vapor reaches saturation when air is cooled under atmospheric pressure.
Pressure dew point: Temperature at which vapor reaches saturation when air is cooled under fixed pressure.

Humidity conversion diagram





How to use the humidity conversion chart

Top-left chart: Used for conversion between relative humidity (abscissa) and the pressure dew point (ordinate) through the temperature line.

Top-right chart: Used for conversion between the pressure dew point (ordinate) and the atmospheric pressure dew point (abscissa) through the pressure line.

Bottom-right chart: Used for conversion between the atmospheric pressure dew point (abscissa) and absolute humidity (ordinate) through the saturation line.

[Example 1] The absolute humidity of compressed air of 0.5 MPa pressure, 20°C temperature and 40% relative humidity is found to be 0.001 pkg/ kg' through the steps ①→②→③→④→⑤.

[Example 2] The absolute humidity of compressed air of 0.7 MPa pressure, 20°C temperature and −35°C atmospheric pressure dew point is found to be 11% through steps ❶→❷→❸→❹.

∗ Conversion between humidity and dew point temperature as in the above example can be performed easily by using "Model Selection Program" by SMC.

● Air dryer dehumidification specifications

Product name	Series	Atmospheric pressure Note) dew point of outlet air [°C]
Refrigerated air dryer	Series IDU	−17
	Series IDF	−17
Heatless air dryer	Series ID	−30
	Series ID (Option: Low dew point)	−50
Membrane air dryer	Series IDG (−20°C specifications)	−20
	Series IDG (−15°C specifications)	−15
	Series IDG (−40°C specifications)	−40
	Series IDG (−60°C specifications)	−60

Note) The atmospheric pressure dew point of outlet air is that under rated conditions.

Refrigerated Air Dryer

Series IDF
Standard temperature air inlet type
Rated inlet air temperature: 35, 40°C

Series IDU
High temperature air inlet type
Rated inlet air temperature: 50, 55°C

Heatless Air Dryer

Series ID
Outlet air flow: 80 to 780 ℓ/min (ANR)

Membrane Air Dryer

Series IDG
Outlet air flow: 10 to 1000 ℓ/min (ANR)

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