Air Cylinders' Drive System

Full Stroke Time & Stroke End Velocity

How to Read the Graph

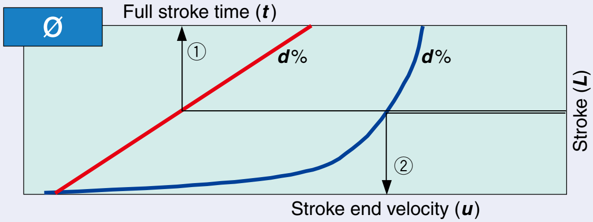
This graph shows the full stroke time and stroke end velocity when a cylinder drive system is composed of the most suitable equipment.
As the graph shown below, various load ratio and full stroke time which corresponds to stroke and terminal velocity are indicated for every cylinder bore size.

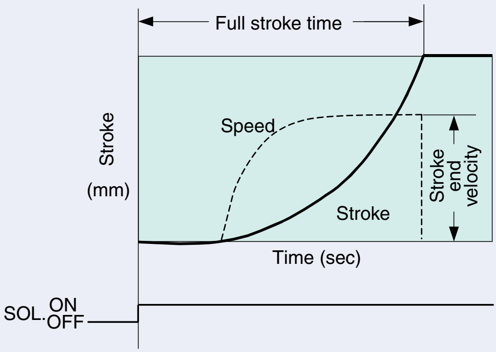
Conditions

Pressure		0.5 MPa
Piping length	**1 m**	Series CJ2, Series CM2, Series CQ2
	2 m	Series MB, Series CQ2
	3 m	Series CS1, Series CS2
Cylinder orientation		Vertically upward
Speed controller		Meter-out, connected with cylinder directly, needle fully opened
Load factor		((Load mass x 9.8)/Theoretical output) x 100%

Example

When the cylinder bore size is ø, its stroke is ***L***, and load ratio is ***d***%, full stroke time ***t*** is obtainted, as an arrow mark ①, by reading the value on the abscissa over the point at which the ordinate ***L*** hits the full stroke line (red line) of ***d***%. Terminal velocity ***u*** is obtained, as an arrow mark ②, by reading the value on the abscissa below the point at which the ordinate ***L*** hits the terminal velocity line (blue line) of ***d***%.





Glossary of Terms: Cylinder's Motion Characteristics

(1) Piston start-up time
It is the time between the solenoid valve is energized (de-energized) and the piston (rod) of a cylinder starts traveling. The accurate judgement is done by the start-up of acceleration curve.

(2) Full stroke time
It is the time between the solenoid valve is energized (de-energized) and the piston (rod) of a cylinder is reached at the stroke end.

(3) 90% force time
It is the time between the solenoid valve is energized (de-energized) and the cylinder output is reached at 90% of the theoretical output.

(4) Mean velocity
Values which devided stroke by "full stroke time". In the sequence or diaphragm, it is used as a substituting expression for "full stroke time".

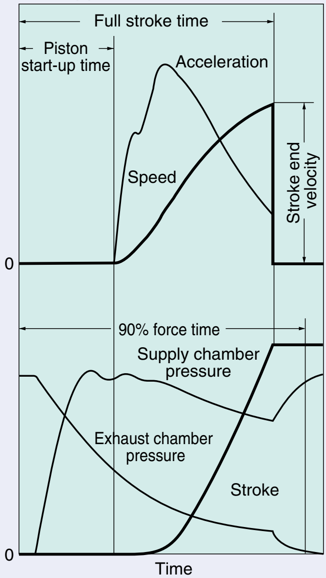
(5) Max. velocity
It is the maximum values of the piston velocity which occurs during the stroke. In the case of Graph (1), it will be the same values as "stroke end velocity". Like Graph (2), when lurching or stick-slipping occurs, it shows substantially larger values.

(6) Stroke end velocity
It is the piston velocity when the piston (rod) of a cylinder is reached at the stroke end. In the case of a cylinder with adjustable cushion, it says the piston velocity at the cushion entrance. It is used for judging the cushion capability and selecting the buffer mechanism.

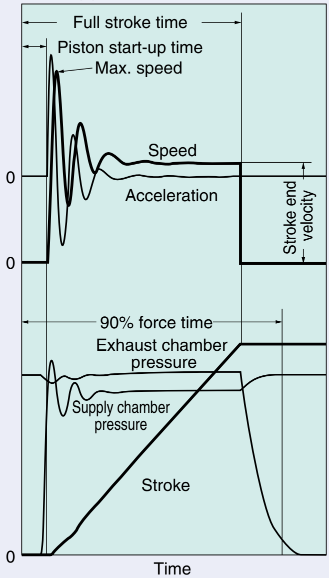
(7) Impact velocity
It is the piston velocity when the piston (rod) of a cylinder is collided with the external stopper at the stroke end or arbitrary position.
(Reference)
Balancing velocity: If a cylinder having enough longer stroke is driven by meter-out, the latter half of a stroke will be in an uniform motion. Regardless of the supply pressure or a load, the piston speed for this time will be dependent only on the effective area ***S*** [mm^2] of the exhaust circuit and the piston area ***A*** [mm^2] . Balancing velocity = 1.9 x 10^5 x (***S***/***A***) [mm/s] is estimated with this formula.

Note) These definitions are harmonized with SMC "Model Selection Software".

Graph (1)



Graph (2)

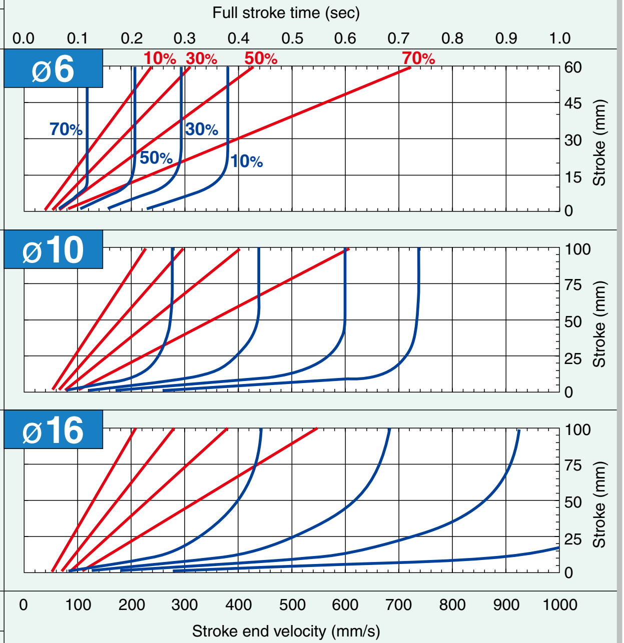


Air Cylinders' Drive System

Full Stroke Time & Stroke End Velocity

Series CJ2/Bore size: ø6, ø10, ø16

Applicable model				
Silencer	Tubing	Solenoid valve (2 position)	Speed controller	Bore size
AN120-M5 AN120-M3	TU0425	**SY3120-M5** **SYJ3120-M3** **VQD1121-M5**	AS1201F-M5-04 AS1200-M5	ø6
AN120-M5	TU0425	**SY3120-M5** **SYJ512□-M5** **VQZ1120-M5**	AS1201F-M5-04 AS1200-M5	ø10
AN120-M5	TU0425	**SY3120-M5** **SYJ512□-M5** **VQZ1120-M5**	AS1201F-M5-04 AS1200-M5	ø16



For details corresponding to each various condition, make the use of "Model Selection Software" on SMC website for your decision.

How to Read the Graph

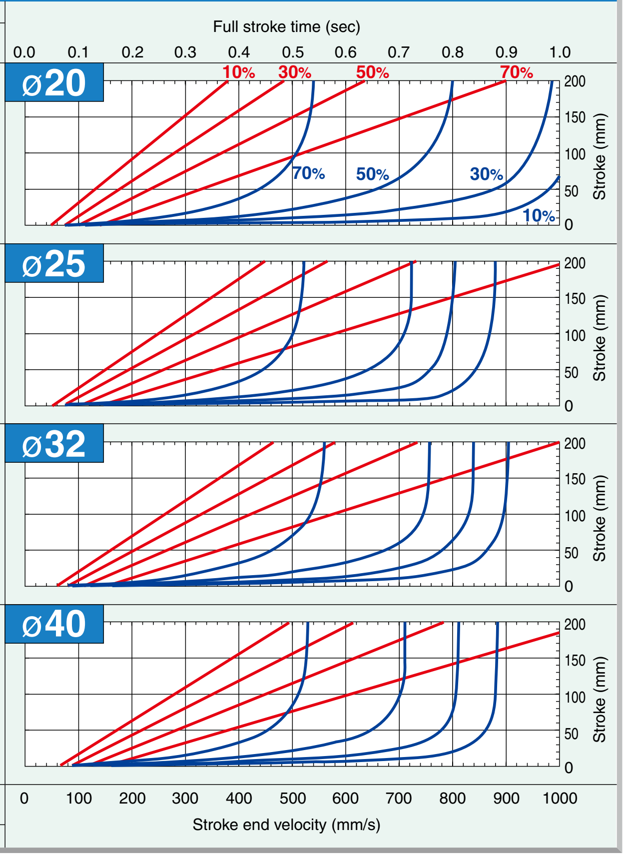
This graph shows the full stroke time and stroke end velocity when a cylinder drive system is composed of the most suitable equipment.
As the graph shown at right, various load ratio and full stroke time which corresponds to stroke and terminal velocity are indicated for every cylinder bore size.

Conditions

Pressure	0.5 MPa
Piping length	1 m
Cylinder orientation	Vertically upward
Speed controller	Meter-out, connected with cylinder directly, needle fully opened
Load factor	((Load mass x 9.8)/Theoretical output) x 100%

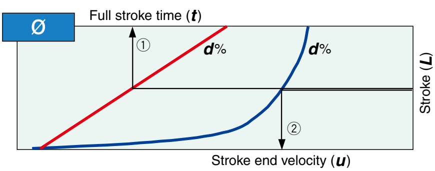
Series CM2/Bore size: ø20, ø25, ø32, ø40

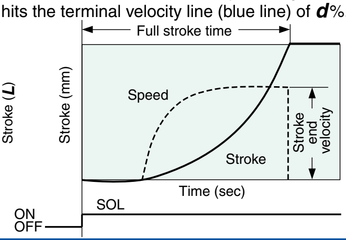
Applicable model				
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller	Bore size
AN120-M5	TU0425	**SY3120-M5** **SYJ5120-M5** **VQ1160-M5**	AS2201F-01-04 AS2200-01	ø20
AN120-M5	TU0425	**SY3120-M5** **SYJ5120-M5** **VQ1160-M5**	AS2201F-01-04 AS2200-01	ø25
ANB1-01 AN101-01	TU0604	**SY5120-01** **SX5120-01**	AS2201F-01-06 AS2200-01	ø32
ANB1-01 AN101-01	TU0604	**SY5120-01** **SX5120-01**	AS2201F-02-06 AS2200-02	ø40
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller	
Applicable model				



For details corresponding to each various condition, make the use of "Model Selection Software" on SMC website for your decision.

Example When the cylinder bore size is **ø**, its stroke is ***L***, and load ratio is ***d***%, full stroke time ***t*** is obtainted, as an arrow mark ①, by reading the value on the abscissa over the point at which the ordinate ***L*** hits the full stroke line (red line) of ***d***%. Terminal velocity ***u*** is obtained, as an arrow mark ②, by reading the value on the abscissa below the point at which the ordinate ***L*** hits the terminal velocity line (blue line) of ***d***%.



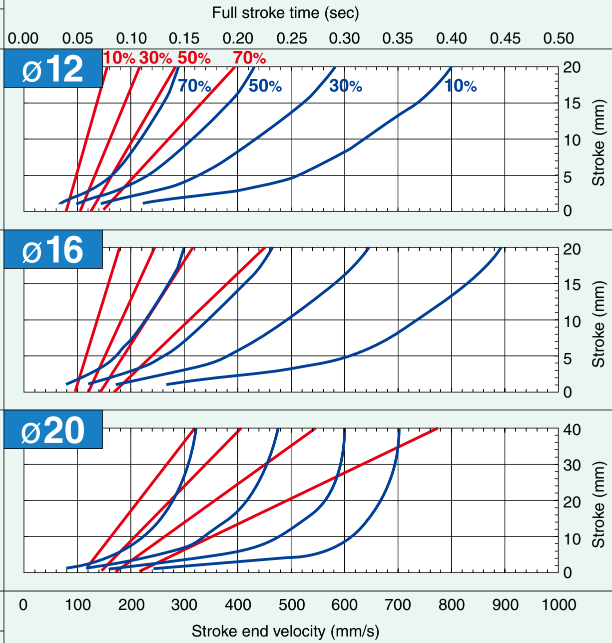


Air Cylinders' Drive System

Full Stroke Time & Stroke End Velocity

Series CQ2/Bore size: ø12, ø16, ø20

Applicable model				
Silencer	**Tubing**	**Solenoid valve (2 position)**	**Speed controller**	**Bore size**
AN120-M5	TU0425	SY3120-M5 SYJ5120-M5 VQ1160-M5	AS1201F-M5-04 AS1200-M5	ø12
AN120-M5	TU0425	SY3120-M5 SYJ5120-M5 VQ1160-M5	AS1201F-M5-04 AS1200-M5	ø16
AN120-M5	TU0425	SY3120-M5 SYJ5120-M5 VQ1160-M5	AS1201F-M5-04 AS1200-M5	ø20



For details corresponding to each various condition, make the use of "Model Selection Software" on SMC website for your decision.

How to Read the Graph

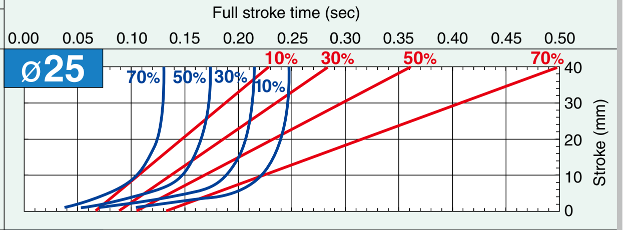
This graph shows the full stroke time and stroke end velocity when a cylinder drive system is composed of the most suitable equipment.
As the graph shown at right, various load ratio and full stroke time which corresponds to stroke and terminal velocity are indicated for every cylinder bore size.

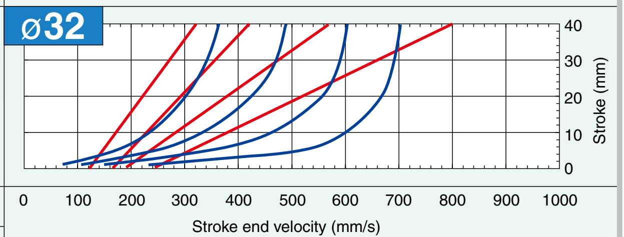
Conditions

Pressure	0.5 MPa
Piping length	1 m
Cylinder orientation	Vertically upward
Speed controller	Meter-out, connected with cylinder directly, needle fully opened
Load factor	((Load mass x 9.8)/Theoretical output) x 100%

Series CQ2/Bore size: ø25, ø32

Applicable model			
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller
AN120-M5	TU0425	**SY3120-M5** **SYJ5120-M5** **VQ1160-M5**	AS1201F-M5-04 AS1200-M5
AN120-M5	TU0604	**SY3120-M5** **SYJ5120-M5** **VQ1160-M5**	AS2201F-01-06 AS2200-01





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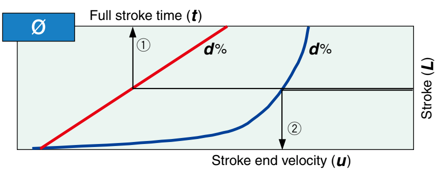
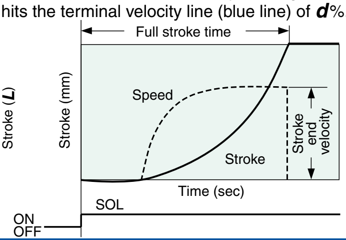
Example When the cylinder bore size is **ø**, its stroke is ***L***, and load ratio is ***d***%, full stroke time ***t*** is obtainted, as an arrow mark ①, by reading the value on the abscissa over the point at which the ordinate ***L*** hits the full stroke line (red line) of ***d***%. Terminal velocity ***u*** is obtained, as an arrow mark ②, by reading the value on the abscissa below the point at which the ordinate ***L*** hits the terminal velocity line (blue line) of ***d***%.



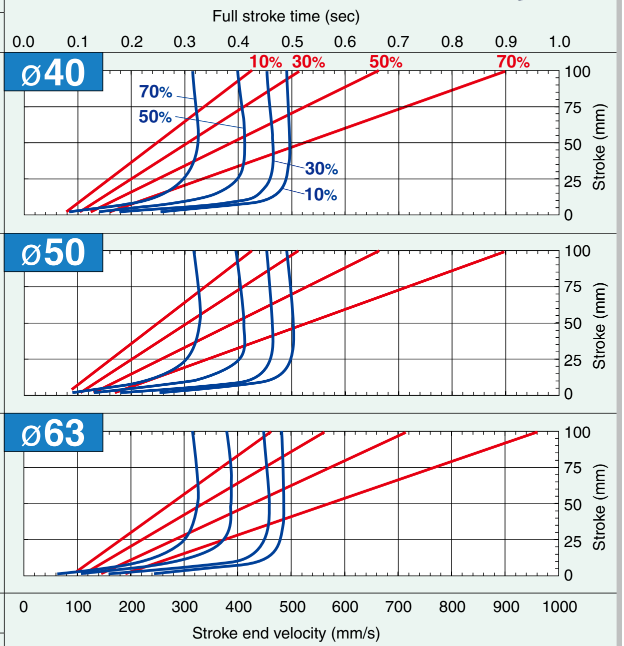


Air Cylinders’ Drive System

Full Stroke Time & Stroke End Velocity

Series CQ2/Bore size: ø40, ø50, ø63

Applicable model			
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller
AN101-01	TU0604	**SY5120-01**	AS2201F-01-06 AS2200-01
AN101-01	TU0604	**SY5120-01**	AS2201F-02-06 AS2200-02
AN101-01	TU0805	**SY5120-01**	AS3201F-02-08 AS3000-02



For details corresponding to each various condition, make the use of “Model Selection Software” on SMC website for your decision.

How to Read the Graph

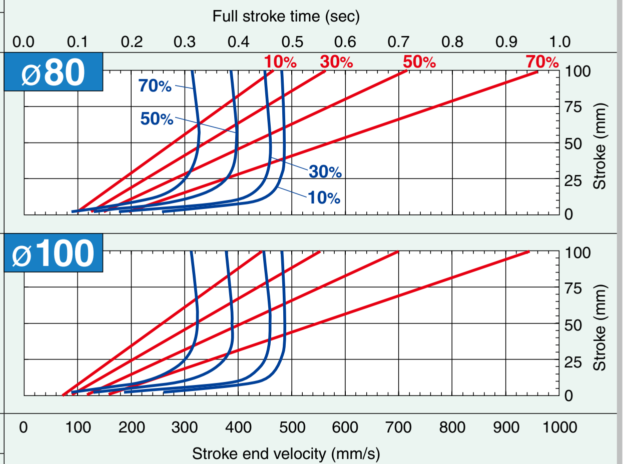
This graph shows the full stroke time and stroke end velocity when a cylinder drive system is composed of the most suitable equipment.
As the graph shown at right, various load ratio and full stroke time which corresponds to stroke and terminal velocity are indicated for every cylinder bore size.

Conditions

Pressure	0.5 MPa
Piping length	2 m
Cylinder orientation	Vertically upward
Speed controller	Meter-out, connected with cylinder directly, needle fully opened
Load factor	((Load mass x 9.8)/Theoretical output) x 100%

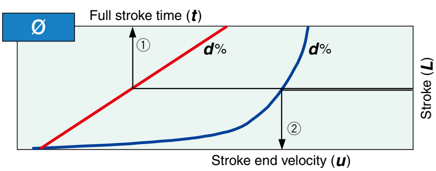
Series CQ2/Bore size: ø80, ø100

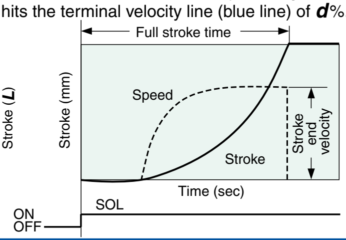
Applicable model			
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller
AN110-01 AN101-01	TU1065	**SY7120-02** **SX7120-01**	AS4000-03
ANB1-03 AN30-03	TU1208	**VFS41□□-03** **VFR41□□-03**	AS5000-03 AS420-03



For details corresponding to each various condition, make the use of "Model Selection Software" on SMC website for your decision.

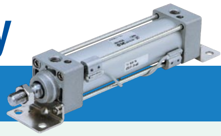
Example When the cylinder bore size is **ø**, its stroke is ***L***, and load ratio is ***d***%, full stroke time ***t*** is obtainted, as an arrow mark ①, by reading the value on the abscissa over the point at which the ordinate ***L*** hits the full stroke line (red line) of ***d***%. Terminal velocity ***u*** is obtained, as an arrow mark ②, by reading the value on the abscissa below the point at which the ordinate ***L*** hits the terminal velocity line (blue line) of ***d***%.





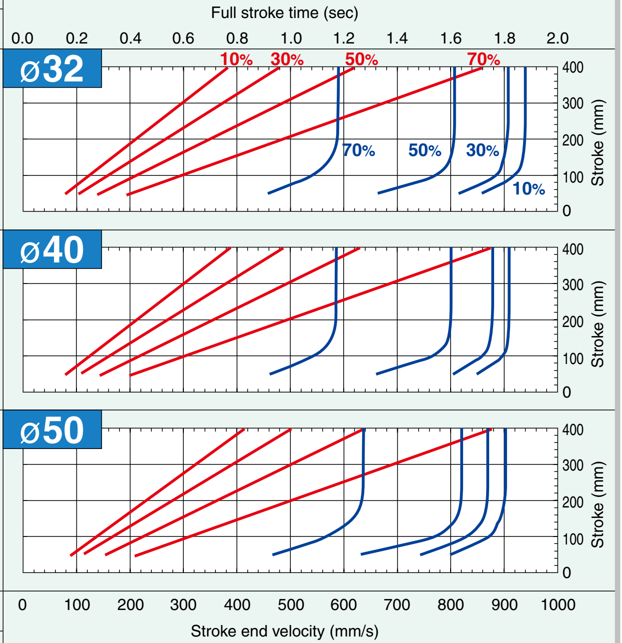
Air Cylinders’ Drive System

Full Stroke Time & Stroke End Velocity



Series MB/Bore size ø32, ø40, ø50

Applicable model			
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller
ANB1-01 AN101-01	TU0604	**SY5120-01** **SX5120-01**	AS2201F-01-06 AS2200-01
ANB1-01 AN101-01	TU0604	**SY5120-01** **SX5120-01**	AS2201F-02-06 AS2200-02
ANB1-01 AN101-01	TU0805	**SY5120-01** **SX5120-01**	AS3201F-02-08 AS3000-02



For details corresponding to each various condition, make the use of “Model Selection Software” on SMC website for your decision.

How to Read the Graph

This graph shows the full stroke time and stroke end velocity when a cylinder drive system is composed of the most suitable equipment.
As the graph shown at right, various load ratio and full stroke time which corresponds to stroke and terminal velocity are indicated for every cylinder bore size.

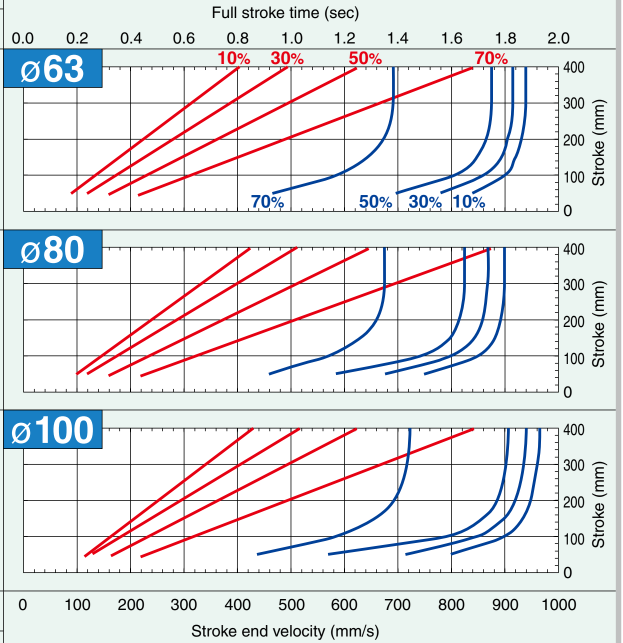
Conditions

Pressure	0.5 MPa
Piping length	2 m
Cylinder orientation	Vertically upward
Speed controller	Meter-out, connected with cylinder directly, needle fully opened
Load factor	((Load mass x 9.8)/Theoretical output) x 100%

Series MB/Bore size: ø63, ø80, ø100

Silencer	Tubing	Solenoid valve (2 position)	Speed controller
AN110-01 AN101-01	TU1065	**SY7120-02** **SX7120-02**	AS4000-03
ANB1-02 AN20-02	TU1065	**VFS31□□-02** **VFR31□□-02**	AS5000-02 AS420-02
ANB1-03 AN30-03	TU1208	**VFS41□□-03** **VFR41□□-03**	AS5000-03 AS420-03

Applicable model



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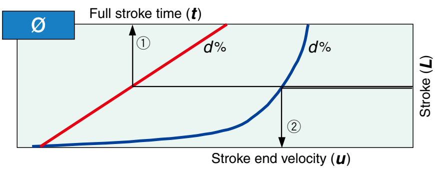
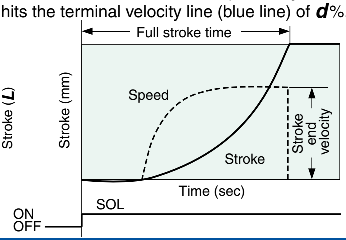
Example When the cylinder bore size is **ø**, its stroke is ***L***, and load ratio is ***d***%, full stroke time ***t*** is obtainted, as an arrow mark ①, by reading the value on the abscissa over the point at which the ordinate ***L*** hits the full stroke line (red line) of ***d***%. Terminal velocity ***u*** is obtained, as an arrow mark ②, by reading the value on the abscissa below the point at which the ordinate ***L*** hits the terminal velocity line (blue line) of ***d***%.



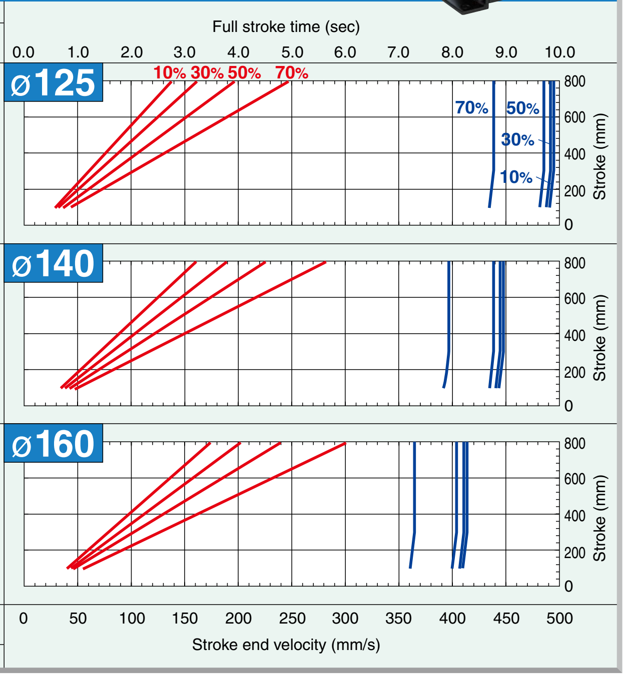


Air Cylinders' Drive System

Full Stroke Time & Stroke End Velocity

Series CS1, CS2/Bore size: ø125, ø140, ø160

Applicable model			
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller
ANB1-03 AN30-03	SGP10A	**VFR3100-03** **VEX3320-03**	AS420-02 AS5000-02
ANB1-03 AN30-03	SGP10A	**VFR3100-03** **VEX3320-03**	AS420-03 AS5000-03
ANB1-04 AN40-04	SGP10A	**VFR4100-04** **VEX3320-04**	AS420-03



For details corresponding to each various condition, make the use of "Model Selection Software" on SMC website for your decision.

How to Read the Graph

This graph shows the full stroke time and stroke end velocity when a cylinder drive system is composed of the most suitable equipment.
As the graph shown at right, various load ratio and full stroke time which corresponds to stroke and terminal velocity are indicated for every cylinder bore size.

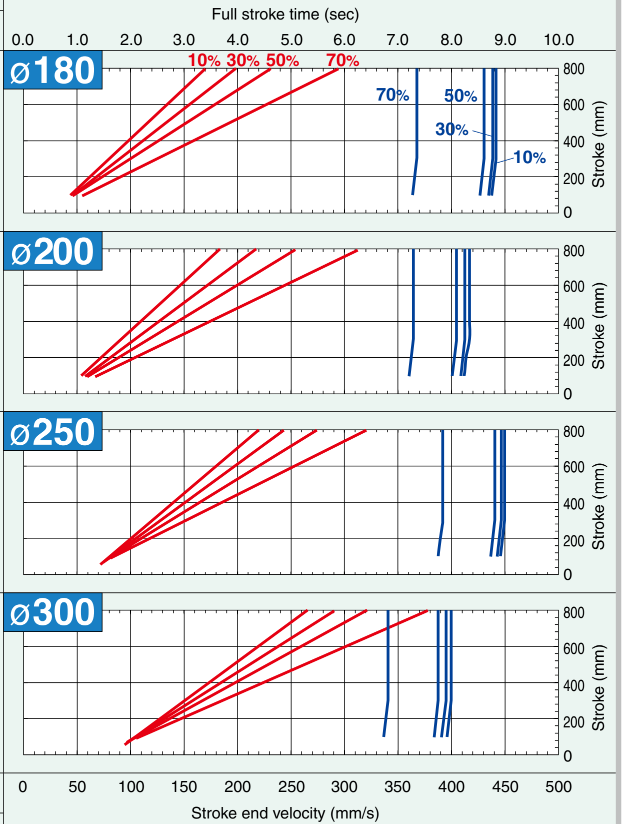
Conditions

Pressure	0.5 MPa
Piping length	3 m
Cylinder orientation	Vertically upward
Speed controller	Meter-out, connected with cylinder directly, needle fully opened
Load factor	((Load mass x 9.8)/Theoretical output) x 100%

SMC

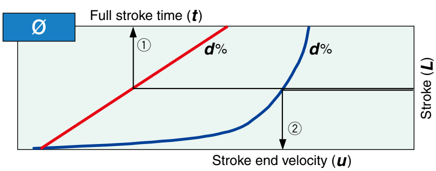
Series CS1/Bore size: ø180, ø200, ø250, ø300

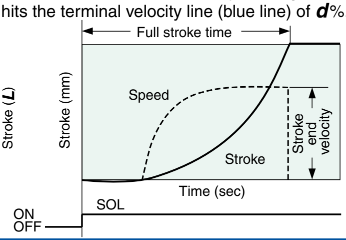
Applicable model				
Silencer	Tubing	**Solenoid valve (2 position)**	Speed controller	Bore size
ANB1-04 AN40-04	SGP15A	**VEX3500-04** **VP3145-03**	AS420-03	ø180
ANB1-04 AN40-04	SGP15A	**VEX3500-04** **VP3145-03**	AS420-04	ø200
ANB1-06 AN500-06	SGP20A	**VEX3500-06** **VP3145-04**	AS600-10	ø250
ANB1-10 AN600-10	SGP20A	**VEX3500-10** **VP3145-06**	AS600-10	ø300



For details corresponding to each various condition, make the use of "Model Selection Software" on SMC website for your decision.

Example When the cylinder bore size is **ø**, its stroke is ***L***, and load ratio is ***d***%, full stroke time ***t*** is obtainted, as an arrow mark ①, by reading the value on the abscissa over the point at which the ordinate ***L*** hits the full stroke line (red line) of ***d***%. Terminal velocity ***u*** is obtained, as an arrow mark ②, by reading the value on the abscissa below the point at which the ordinate ***L*** hits the terminal velocity line (blue line) of ***d***%.





Solenoid Valves Flow Characteristics
(How to indicate flow characteristics)

1. Indication of flow characteristics

Indication of the flow characteristics in specifications for equipment such as solenoid valve, etc. is depending on “Table (1)”.

Table (1) Indication of Flow Characteristics

Corresponding equipment	Indication by international standard	Other indications	Standards conforming to
Equipment for pneumatics	C, b		ISO 6358: 1989 JIS B 8390: 2000
		S	JIS B 8390: 2000 Equipment: JIS B 8373, 8374, 8379, 8381
		Cv	ANSI/(NFPA)T3.21.3: 1990

2. Equipment for pneumatics

2.1 Indication according to the international standards

(1) Standards conforming to

ISO 6358: 1989 : Pneumatic fluid power—Components using compressible fluids—Determination of flow-rate characteristics

JIS B 8390: 2000 : Pneumatic fluid power—Components using compressible fluids—How to test flow-rate characteristics

(2) Definition of flow characteristics

Flow rate characteristics are indicated by the comparison between sonic conductance C and critical pressure ratio b.

Sonic conductance C : Values which devide the passing mass flow rate of an equipment in a choked flow condition by the product of the upstream absolute pressure and the density in the standard condition.

Critical pressure ratio b : It is the pressure ratio which will turn to the choke flow (downstream pressure/upstream pressure) when it is smaller than this values. (critical pressure ratio)

Choked flow : It is the flow which upstream pressure is higher than the downstream pressure and it is being reached the sonic speed in a certain part of an equipment. Gaseous mass flow rate is in proportion to the upstream pressure, and not dependent on the downstream pressure. (choked flow)

Subsonic flow : Flow in more than the critical pressure ratio.

Standard condition : Air in the state of temperature 20°C, absolute pressure 0.1 MPa (= 100 kPa = 1 bar), relative humidity 65%. It is stipulated by adding the abbreviation (ANR) after the unit depicting air volume. (standard reference atmosphere) Standard conforming to: ISO 8778: 1990 Pneumatic fluid power—Standard reference atmosphere, JIS B 8393: 2000: Pneumatic fluid power—Standard reference atmosphere

(3) Formula of flow rate

It can be indicated by the practical unit as following.

When

$$\frac{P_2 + 0.1}{P_1 + 0.1} \leq b, \textbf{ choked flow}$$

$$Q = 600 \times C(P_1 + 0.1)\sqrt{\frac{293}{273 + t}} \quad \cdots\cdots (1)$$

When

$$\frac{P_2 + 0.1}{P_1 + 0.1} > b, \textbf{ subsonic flow}$$

$$Q = 600 \times C\,(P_1 + 0.1)\sqrt{1 - \left[\frac{\frac{P_2 + 0.1}{P_1 + 0.1} - b}{1 - b}\right]^2}\sqrt{\frac{293}{273 + t}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Q : Air flow rate [dm³/min (ANR)], dm³ (Cubic decimeter) of SI unit are also allowed to described by L (liter). 1 dm³ = 1 L.

C : Sonic conductance [dm³/(s·bar)]

b : Critical pressure ratio [-]

P_1 : Upstream pressure [MPa]

P_2 : Downstream pressure [MPa]

t : Temperature [°C]

Note) Formula of subsonic flow is the elliptic analogous curve.

Flow characteristics curve is indicated in Graph (1). For details, make the use of SMC's "Energy Saving Program".

Example)

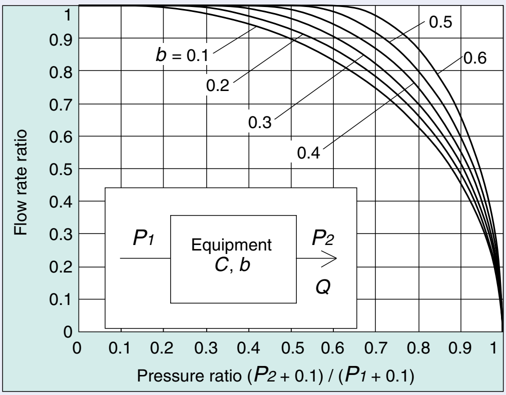
Obtain the air flow rate for P_1 = 0.4 [MPa], P_2 = 0.3 [MPa], t = 20 [°C] when a solenoid valve is performed in C = 2 [dm³/(s·bar)] and b = 0.3.

According to formula 1, the maximum flow rate = $600 \times 2 \times (0.4 + 0.1) \times \sqrt{\frac{293}{273 + 20}}$ = 600 [dm³/min (ANR)]

$$\text{Pressure ratio} = \frac{0.3 + 0.1}{0.4 + 0.1} = 0.8$$

Based on Graph (1) it is going to be 0.7 if it is read by the pressure ratio as 0.8 and the flow ratio to be b = 0.3.

Hence, flow rate = Max. flow x flow ratio = 600 x 0.7 = 420 [dm³/min (ANR)].



Graph (1) Flow characteristics line

Solenoid Valves Flow Characteristics
(How to indicate flow characteristics)

2.1 Indication by international standards

(4) How to test

By piping the equipment on test with the test circuit as shown in figure (1), while maintaining the upstream pressure to a certain value which does not go down below 0.3 MPa, measure the maximum flow rate to be saturated in the first place. Then next, measure this flow at the point of 80%, 60%, 40%, 20% flow and the upstream pressure and downstream pressure. And from this maximum flow rate, figure out the sonic conductance C. Also, substitute the other each data for the subsonic flow formula to figure out b and then obtain the critical pressure ratio b from that average.

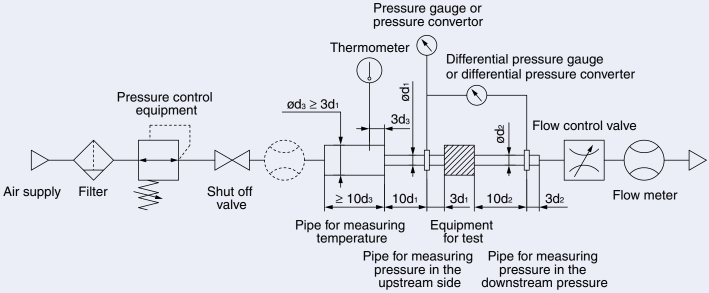


Fig. (1) Test circuit based on ISO6358, JIS B 8390.

2.2 Effective area S

(1) Standards conforming to

JIS B 8390: 2000: Pneumatic fluid power—Components using compressible fluids—Determination of flow-rate characteristics

Equipment standards: JIS B 8373: 2 port solenoid valve for pneumatics
JIS B 8374: 3 port solenoid valve for pneumatics
JIS B 8379: Silencer for pneumatics
JIS B 8381: Fittings of flexible joint for pneumatics

(2) Definition of flow characteristics

Effective area S: It is the cross-sectional area with having an ideal throttle without friction which was deduced by the calculation of the pressure changes inside air tank or without reduced flow when discharging the compressed air in a choked flow from an equipment attached to air tank. It is the same concept representing the "easy to run through" as sonic conductance C.

(3) Formula of flow rate

When $\frac{P_2 + 0.1}{P_1 + 0.1} \leq 0.5$, **choked flow**

$$Q = 120 \times S(P_1 + 0.1)\sqrt{\frac{293}{273 + t}} \quad \cdots\cdots (3)$$

When $\frac{P_2 + 0.1}{P_1 + 0.1} > 0.5$, **subsonic flow**

$$Q = 240 \times S\sqrt{(P_2 + 0.1)(P_1 - P_2)}\sqrt{\frac{293}{273 + t}} \quad \cdots\cdots (4)$$

Conversion with sonic conductance C:

$$S = 5.0 \times C \quad \cdots\cdots (5)$$

SMC

Q :Air flow rate[dm³/min(ANR)], dm³ (cubic decimeter) of SI unit is good to be described by L (liter), too. 1 dm³ = 1 L
S : Effective area [mm²]
P_1: Upstream pressure [MPa]
P_2: Downstream pressure [MPa]
t : Temperature [°C]

Note) Formula of subsonic flow (4) is only applicable when the critical pressure ratio b is the unknown equipment. In the formula by sonic conductance C (2), it is the same formula when b = 0.5.

(4) Test method

By piping an equipment for test with the test circuit shown in the figure (2), discharge air to the atmosphere until the pressure inside the air tank goes down to 0.25 MPa (0.2 MPa) from the air tank filled with compressed air of a certain pressure (0.5 MPa) which does not go down below 0.6 MPa. Measure the discharging time for this time and the residual pressure inside the air tank which had been left until it turned to be the normal values, and then figure out the effective area S by the following formula. The volume of air tank should be selected within the specified range by corresponding to the effective area of an equipment for test.

In the case of JIS B 8373, 8374, 8379, 8381, the pressure values are in the parenthesis and the coefficient of formula is 12.9.

$$S = 12.1 \frac{V}{t} \log_{10} \left(\frac{Ps + 0.1}{P + 0.1}\right) \sqrt{\frac{293}{T}} \quad \cdots\cdots (6)$$

S : Effective area [mm²]
V : Air tank capacity [dm³]
t : Discharging time [s]
Ps : Pressure inside air tank before discharging [MPa]
P : Residual pressure inside air tank after discharging [MPa]
T : Temperature inside air tank before discharging [K]

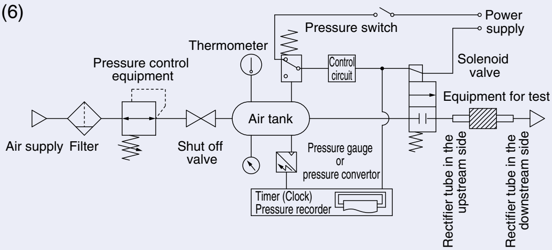


Fig. (2) Test circuit based on JIS B 8390

2.3 Flow coeffiecient *Cv* factor

The United States Standard ANSI/(NFPA)T3.21.3:1990: Pneumatic fluid power—Flow rating test procedure and reporting method—For fixed orifice components

defines the ***Cv*** factor of flow coefficient by the following formula based on the test conducted by the test circuit analogous to ISO 6358.

$$Cv = \frac{Q}{114.5 \sqrt{\frac{\Delta P (P_2 + Pa)}{T_1}}} \quad \cdots\cdots\cdots\cdots (7)$$

ΔP : Pressure drop between the static pressure tapping ports [bar]
P_1 : Pressure of the upstream tapping port [bar gauge]
P_2 : Pressure of the downstream tapping port [bar gauge]: $P_2 = P_1 - \Delta P$
Q : Flow rate [dm³/s standard condition]
Pa : Atmospheric pressure [bar absolute]
T_1 : Test conditions of the upstream absolute temperature [K]

Test condition is $P_1 + Pa = 6.5 \pm 0.2$ bar absolute, $T_1 = 297 \pm 5$K, 0.07 bar $\leq \Delta P \leq$ 0.14 bar.

This is the same concept as effective area A which ISO6358 stipulates as being applicable only when the pressure drop is smaller than the upstream pressure and the compression of air does not become a problem.