



## 09 - Choosing /sizing a cylinder and valve

- Pipe flow resistance
- Valve sizing
- Cylinder sizing

## PIPE FLOW RESISTENCE

### Flow rate Qn

Flow rate is calculated as the volume at normal conditions ( atmospheric pressure, 20° C temperature) in relation to time.

The measurement unit is the normal litre per minute (NI/min)

The normal litre is the specific quantity of compressed air, and corresponds to the volume that it would fill at atmospheric pressure

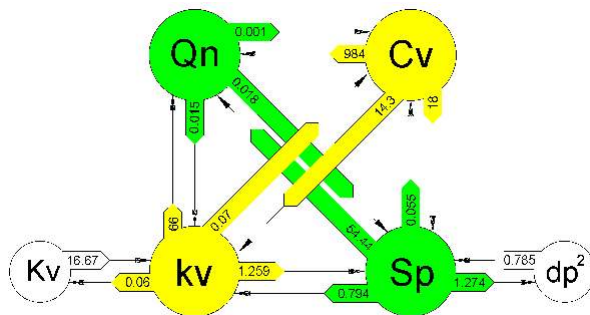
Flow rate is measured with standardised measuring equipment and, as previously explained, defines parameters such as:

$k_v$  ( l/min ) measured with water  $\Delta P = 1$  bar

$K_v$  ( m<sup>3</sup>/ora ) measured with water  $\Delta P = 1$  bar

$C_v$  ( USA gallons/min ) measured with water  $\Delta P = 1$  psi (0,07 bar)

The chart below shows some of the conversion coefficients (see also pag. IX)



<b>Qn</b>	Nominal flow rate	NI/min
<b>kv</b>		l/min
<b>Kv</b>	Hydraulic coefficient	m <sup>3</sup> /hours
<b>Cv</b>		USA gallons/min
<b>Sp</b>	Nominal inner section area	mm <sup>2</sup>
<b>dp<sup>2</sup></b>	Nominal diameter <sup>2</sup>	mm <sup>2</sup>

\* to calculate the diameter dp (mm<sup>2</sup>) square root of dp<sup>2</sup>

### Pipes flow resistance

The C factor (l/sec) indicates the pipe flow capacity and is the ratio between the maximum flow rate and absolute pressure (ISO 6358). The flow capacity progressively decreases with increasing pipe length, due to the air friction on the pipe inner surface increasing the pressure drop. Therefore the longer the pipe the smaller the flow rate.

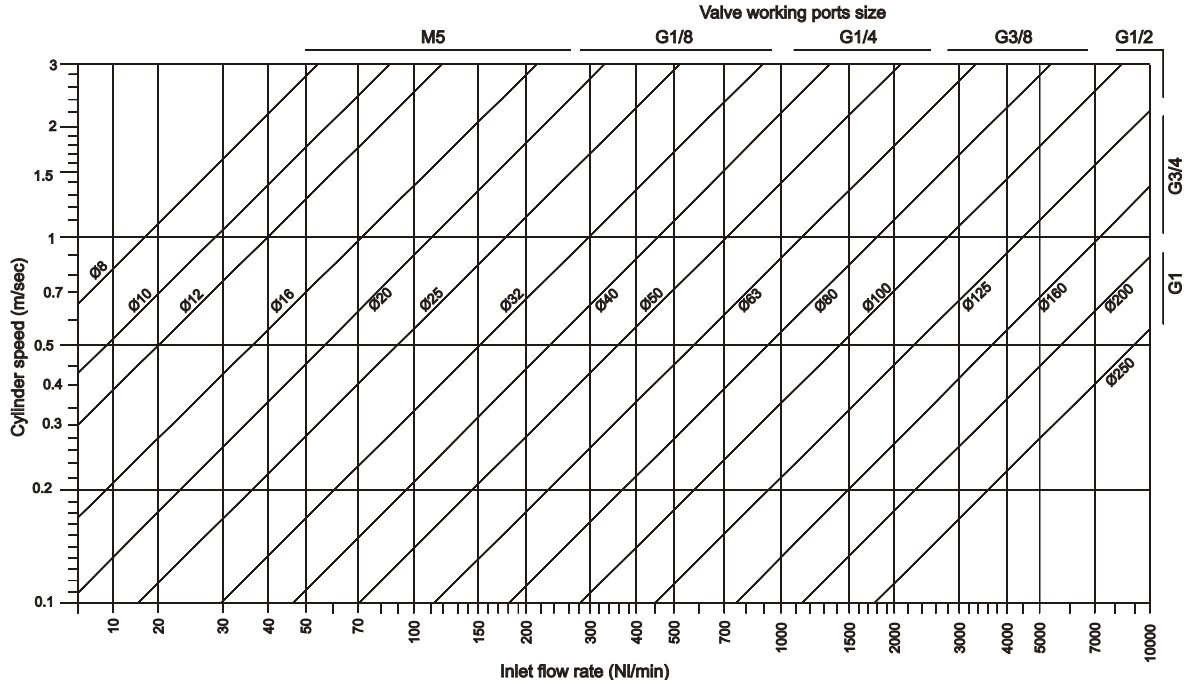
The chart below shows the flow rate characteristics of different pipe sizes (i/d and o/d) in function of the length. Values in NI/min.

## VALVE SIZING

The choice of the correct size valve is essential in order to ensure that the cylinder to be controlled will perform as expected. It is therefore necessary to know the cycle time to be achieved and to calculate the coefficient T which will be used as multiplier for the air consumption value previously calculated. The result of this equation, expressed in NI/min and multiplied by a safety factor of 1.2, corresponds to the minimum flow rate needed (at standard conditions 6 bar supply and 5 bar on the consumption connection) to operate the cylinder at the required rate.

$$T = \frac{60}{\text{Cycle time}} \quad Q_n = T \times \text{Consumption}$$

It is also important to ensure that the pipes used to connect the valve to the air supply and to the cylinder do not affect the flow rate in any way. The pipe inner bore must therefore be at least 1.5 times the diameter of the valve nominal orifice size. The choice of the fittings is also very important, the inner bore must be equal or greater than the pipe I/D. The diagram below shows the flow rate required to operate different size cylinders at varying speeds and also the valve connection sizes.



## CYLINDER SIZING

In order to properly size a cylinder it is necessary to consider the following parameters:

**Force generated** : calculated in function of the piston area and of the pressure that acts upon it.

$$F = \text{area} \times \text{pressure} \quad (\text{daN}) = (\text{cm}^2) \times (\text{bar})$$

The value is theoretical and needs to be reduced by approximately 10-15% in order to compensate for the effects of friction. We must also consider that the force generated during the return stroke (traction) is lower, as the area on which the pressure acts is reduced by the presence of the rod.

**Weight of the load** : the force generated by the cylinder must be sufficient to move the load in the desired direction within the specified time (cycle time). The load ratio (RdC) must not exceed 70%.

$$\frac{\text{Needed force (load weight)}}{\text{Available force (generated)}} \times 100 = \text{RdC}$$

## LOAD POSITION

**Vertical lift** (pull upwards): the real force generated by the cylinder must be sufficient to counterbalance the load and to accelerate it

Example:

Weight to be lifted 120Kg

Working pressure 6 bar

Load ratio 70%

Using the load ratio equation it is possible to calculate the force needed to lift the load:

$$\text{Available force} = \frac{\text{Load}}{\text{RdC}} \times 100 \quad \text{the result is } 171,4 \text{ daN}$$

A 63 bore cylinder which generates a theoretical force of 187 daN is suitable for the application.

A similar load ratio allows, using unidirectional flow regulators, good speed control.

When the speed is below 20mm/sec. It is difficult to properly control the movement.

The load ratio must be reduced to 50% on slow speed applications. In these conditions, or where constant movement is required, the use of a hydraulic speed control unit is recommended.

On applications where the load is moving downwards, thereby increasing the force generated by the actuator, it is usually necessary to use flow regulators.

**Horizontal or inclined movement:** If the load is supported and the working position is horizontal, it is necessary to multiply the needed force by the coefficient of friction.

The coefficient of friction  $\mu$  varies according to the material.

For example considering  $\mu = 0.4$

Weight to be moved 120Kg

Pressure 6 bar

Load ratio 70%

Solving the load ratio equation it is possible to calculate the available force:

$$\text{Available force} = \frac{\text{Load}}{\text{RdC}} \times 100 \times \mu \quad \text{which, in the above conditions is } 68,57 \text{ daN}$$

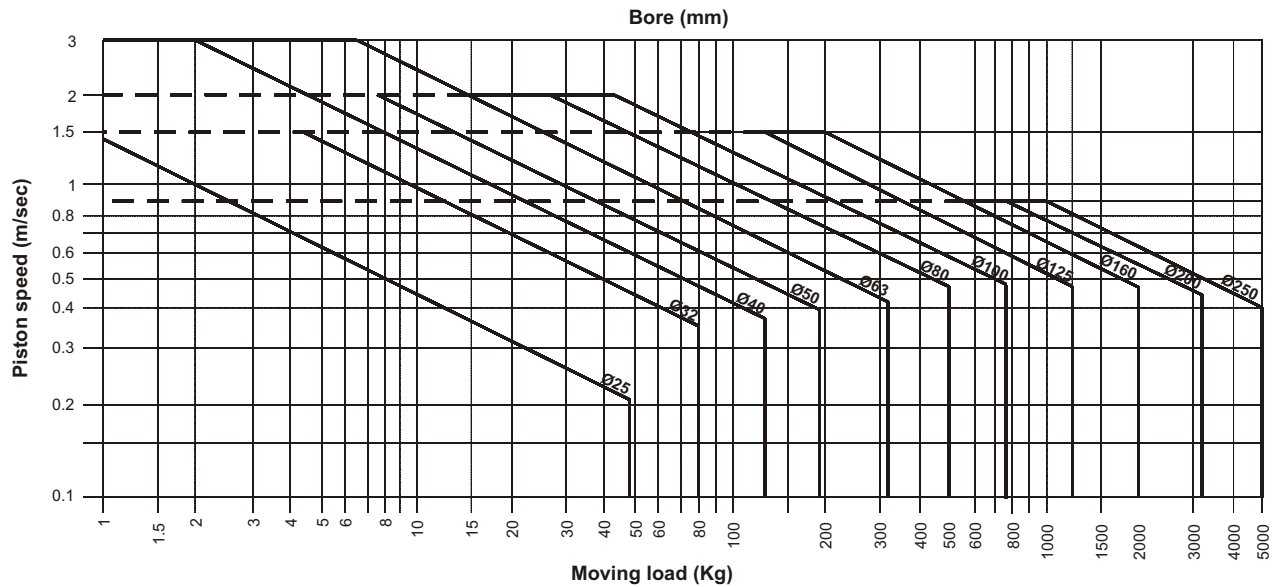
A  $\varnothing 40$  bore cylinder that generates a theoretical force of 75.4 daN is suitable for the application.

In cases of inclined application the required force increases according to the angle.

Also in these conditions it is necessary to multiply the needed force by a coefficient of friction.

## End of stroke cushioning

The air cushion damping function is to absorb the kinetic energy in order to prevent end of stroke impacts which could damage the unit. Once the cylinder has been chosen, based on the parameters previously described, it is necessary to verify its capacity to absorb the kinetic energy. Using the chart below it is possible to verify, for each diameter and combination of speed/load, the suitability of the cylinder. The pressure value considered is 6 bar.



## Axial load

Is a load that is applied axially to the rod tip. Under the action of axial load the rod can flex. The amount of flexion depends on the following factors:

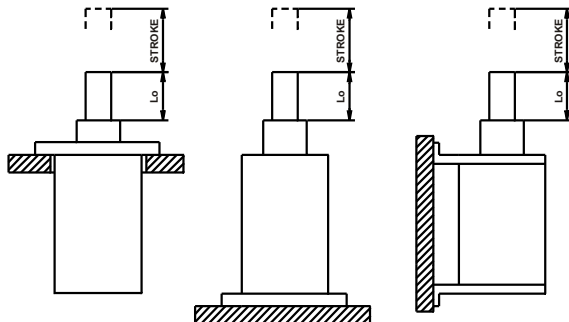
- load applied
- rod size and length
- mountings used to hold the cylinder in position.

The worst case scenario is when the cylinder is fixed at both ends; on all other conditions the load allowed can be up to 50% greater.

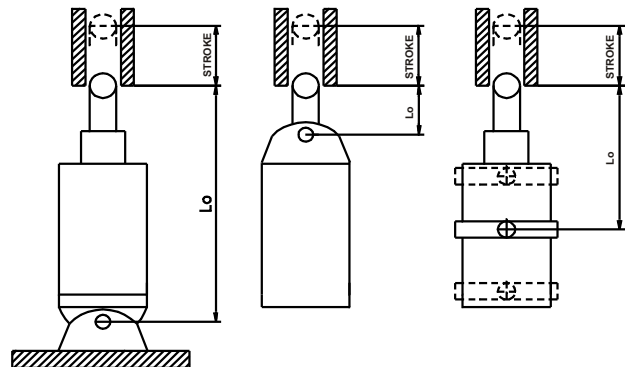
The dimension to be considered is::

$$L_{tot} = L_o + \text{stroke}$$

CASE "A"



CASE "B"



# Choosing/sizing a cylinder and valve



The below chart shows the values relative to the ISO 1552 series cylinders considering the out stroke movement and a supply pressure of 6 bar. The acceptable value for each diameters are those found below each size line.

