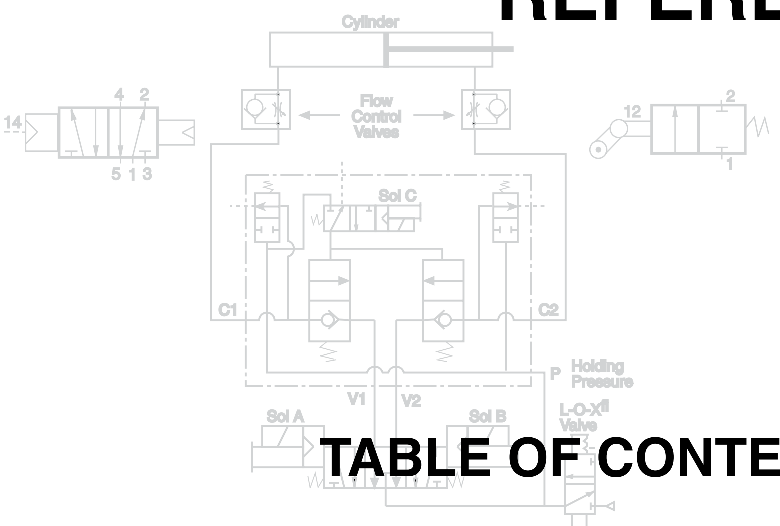
ROSS CONTROLS®

PNEUMATIC REFERENCE DATA



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Bulletin 371C

Pneumatics is the study of the mechanical properties of gases. In industrial applications the gas involved is most commonly compressed air. The mechanical properties with which we are most concerned are *pressure, volume* and *temperature.* The relationships between these properties, and the meanings of some basic pneumatic terminology are discussed below.

Force and Pressure. Consider the diagram of the cylinders below.

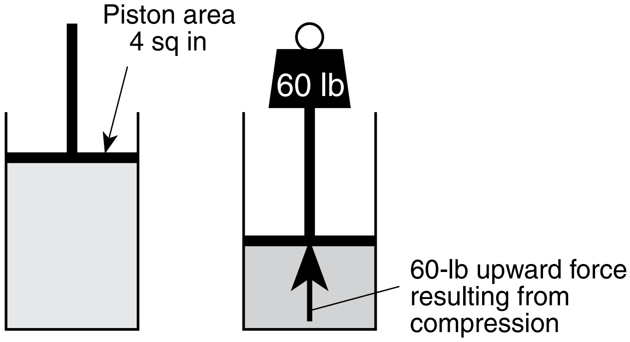


Figure 1

When the force of 60 pounds is applied to the piston, the air in the cylinder is compressed. This compression continues until the upward force on the piston is the same as the downward force, that is, until the forces are in equilibrium.

The force on each square inch of the piston is:

$$\frac{\text{force on piston}}{\text{area of piston}} = \frac{60\text{ lb}}{4\text{ in}^2} = 15\text{ lb per in}^2\text{ (psi)}$$

This *force per unit area* is called *pressure.* The terms *force* and *pressure* must not be confused. Force is expressed in units such as *pounds, tons, kilograms, etc.,* while pressure is expressed as *pounds per square inch, tons per square mile, kilograms per square meter, etc.*

In general terms, then:

$$\textbf{pressure} = \frac{\text{force}}{\text{area}}$$

Conversely, the force exerted on or by an area is:

$$\textbf{force} = \text{pressure x area}$$

Pascal's Law. Pressure applied to a confined fluid is transmitted undiminished in all directions. In the discussion of Figure 1 we learned that the force applied to the piston produces a pressure of 15 psi (pounds per square inch). Pascal's Law simply says that a pressure of 15 psi is applied to all surfaces containing the air, i.e., the walls and bottom of the cylinder as well as the piston surface itself.

Atmospheric Pressure. The pressure produced on the earth's surface by the weight of the air surrounding the earth was measured by the 17th-century scientist, Evangelista Torricelli. He filled a 36-inch glass tube (sealed at one end) with mercury, and placed his finger over the open end of the tube. He then stood the tube on end in a dish of mercury and removed his finger. Some mercury flowed from the tube into the dish, but a column of mercury 30 inches tall remained in the tube. The pressure of the atmosphere, he reasoned, is sufficient to support a column of mercury 30 inches high. More refined tests have shown this *atmospheric pressure* to be equal to 14.69 pounds per square inch.

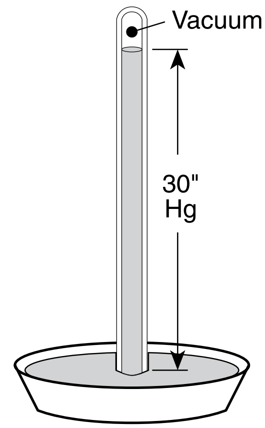


Figure 2

Gauge Pressure. Atmospheric pressure is a part of our everyday environment. We don't notice the pressure on us, and it is convenient to think of atmospheric pressure as "zero" pressure. So we measure pressure starting at this zero point, and a pressure so measured is called *gauge pressure.* A common abbreviation for gauge pressure measurements is *psig* (pounds per square inch gauge).

Absolute Pressure. When dealing with the effects of pressure on gases it is necessary to consider the total pressure on the gas. We can no longer ignore the effect of atmospheric pressure as we do when we measure gauge pressure. This total pressure acting on a gas is called *absolute pressure.*

$$\textbf{absolute pressure} = \text{gauge pressure} + 14.69$$

You will recognize 14.69 as the pounds-per-square-inch measure of atmospheric pressure.

To distinguish absolute pressure from gauge pressure measurements, we use units such as *psia* (pounds per square inch absolute).

Absolute Temperature. Absolute temperature is based on a theoretical "lowest" temperature. This lowest temperature is the zero point for the two absolute temperature scales in common use, the Rankine scale and the Kelvin scale.

The Rankine scale is based on the Fahrenheit degree.

$$\textbf{Rankine temperature} = \text{Fahrenheit temperature} + 459.67$$

Thus, 0°F = 459.67°R, although for most practical applications it is taken as 460°R.

The Kelvin scale of absolute temperature is based on the Celsius degree.

Kelvin temperature
= Celsius temperature + 273.16

Thus, 0°C = 273.16°K. Again, for most practical purposes it is taken as 273°K.

Perfect Gas Laws. The relationships between pressure, volume, and temperature are expressed in three basic "laws" which we will discuss below. These laws apply to an ideal gas, but are also remarkably accurate for the mixture of gases making up our air.

In applying these laws it is important to remember that only absolute values of pressure and temperature may be used.

Boyle's Law. This law expresses the relationship between pressure and volume when *temperature is held constant.* According to this law, the volume of the gas in a container is inversely proportional to the *absolute pressure* on the gas, i.e.,

$$P_1V_1 = P_2V_2$$

Let us apply this law to find the volume of the gas in the cylinder below after compression.

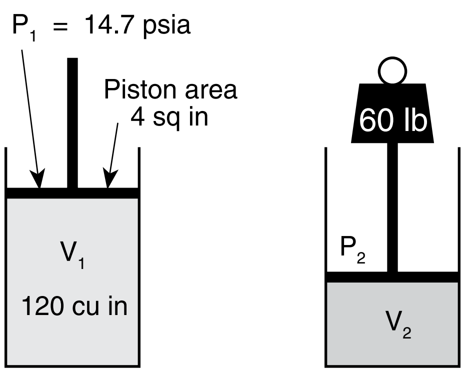


Figure 3

The pressure acting on the cylinder at the left is simply atmospheric pressure. The absolute pressure on the cylinder after it is compressed is:

$$P_2 = (60 \div 4) + 14.7 = 29.7 \text{ psia}$$

With this information we can use Boyle's Law to find the compressed volume.

$$14.7 \times 120 = 29.7 \times V_2$$

$$V_2 = 14.7 \times 120 \div 29.7$$

$$= 59.4 \text{ cubic inches}$$

When a gas is compressed it gets warmer, so the above calculation would be correct only after the compressed gas has been allowed to cool to the temperature it had before compression.

Charles' Law. This law expresses the relationship between volume and temperature when *pressure is held constant.* According to this law, the volume of the gas in an expandable container is directly proportional to the absolute temperature of the gas, i.e.,

$$V_1T_2 = V_2T_1$$

Let us take the cylinder in Figure 3 and specify that the temperature of the gas is 60°F. If we apply heat to the container, as depicted in Figure 4 below, so that the temperature of the gas is raised to 100°F, what will be the new volume of the gas. Note that the load on the piston does not change, and therefore the pressure on the gas is constant as required by Charles' Law.

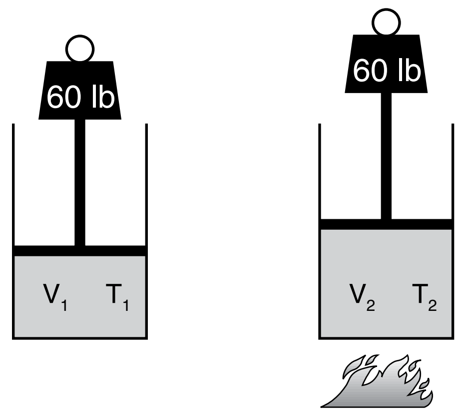


Figure 4

The absolute temperatures are:

$$T_1 = 60°F + 460F° = 520°R$$

$$T_2 = 100°F + 460F° = 560°R$$

The volume of the compressed gas as we determined it from Figure 3 is V_1 = 59.4 cubic inches. When we apply Charles' Law to this information we have:

$$59.4 \times 560 = V_2 \times 520$$

$$V_2 = 59.4 \times 560 \div 520$$

$$= 64.0 \text{ cubic inches}$$

Gay-Lussac's Law. The third gas law states that if the volume of a gas is held constant (i.e., confined in a rigid container) the absolute pressure of the gas is directly proportional to its absolute temperature. Thus,

$$P_1T_2 = P_2T_1$$

A closed container when heated builds up considerable internal pressure, and can lead to an explosion of the container. This is Gay-Lussac's Law at work!

General Gas Law. In practical applications all three of the variables — pressure, volume, temperature — may change. The three gas laws we have discussed can be consolidated into a single general law which provides for changes in all three variables. This general law is simply:

$$P_1V_1T_2 = P_2V_2T_1$$

Let us apply this general law to the following problem.

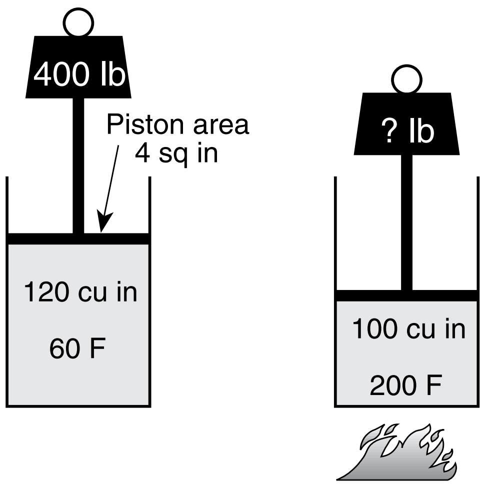


Figure 5

Initially, the force on the cylinder's piston is 400 lb. This compresses the gas in the cylinder to a volume of 120 cubic inches at a temperature of 60°F. If the gas in the cylinder is heated to 200°F, what force must be on the piston to compress the gas further to a volume of 100 cubic inches?

Because the piston has an area of 4 square inches, the *absolute* pressure on the gas initially is:

$$P_1 = (400 \div 4) + 14.7 = 114.7 \text{ psia},$$

and the *absolute* temperatures are:

$$T_1 = 60 + 460 = 520°R$$

$$T_2 = 200 + 460 = 660°R.$$

In order to determine the force that must be on the piston in order to compress the heated gas to 100 cubic inches, we must first find the value of P_2. To do this we apply the general gas law, $P_1V_1T_2 = P_2V_2T_1$.

$$114.7 \times 120 \times 660 = P_2 \times 100 \times 520$$

$$P_2 = (114.7 \times 120 \times 660) \div (100 \times 520)$$

$$= 174.7 \text{ psia}$$

P_2 in terms of the force F acting on the piston is:

$$P_2 = (F \div 4) + 14.7$$

Then we have,

$$174.7 = (F \div 4) + 14.7$$

$$F \div 4 = 174.7 - 14.7 = 160 \text{ psig}$$

$$F = 160 \times 4 = 640 \text{ lb.}$$

Standard Air and Free Air. In the United States the volume of air is most commonly measured by the cubic foot. Of course the actual amount of air in a cubic foot depends on factors such as pressure and temperature, so it has become necessary to define a *standard cubic foot (scf)* of air. For most industrial applications this is a cubic foot of air at a pressure of one atmosphere (14.69 psia), a temperature of 68°F, and a relative humidity of 36 per cent. The weight of a standard cubic foot of air is 0.0762 lb; 1 lb of standard air occupies 13.1 cubic feet.

In actual practice one seldom encounters standard air, but is dealing with "free" air, that is, the air that we encounter in everyday experience. Fortunately, unless we are on a mountaintop or working near a blast furnace, free air is close enough to standard air so that we do not have to make corrections for the small differences.

Compressed Air. The flow of air through a valve or any part of a pneumatic system is usually measured in *standard cubic feet per minute (scfm).* Often it is necessary to know what this volume of air is when compressed. Boyle's law solves the problem easily.

For example, if the air flow through a valve is 50 scfm, what is the actual volume of the air if the pressure is 100 psig? Remembering that Boyle's law requires that we use absolute pressures, we have:

$$14.7 \times 50 = (100 + 14.7) \times V$$

where V is the volume of the compressed air, we obtain:

$$V = (14.7 \times 50) \div (100 + 14.7)$$

$$V = 6.4 \text{ cubic feet per minute.}$$

Conversely, we could ask for the pressure required to fill an automobile tire with 2 cubic feet of free air if the tire has a volume of 0.5 cubic foot. Again, from Boyle's law we obtain:

$$14.7 \times 2 = (P + 14.7) \times 0.5$$

where P is the *gauge* pressure required to fill the tire.

$$P + 14.7 = (14.7 \times 2) \div 0.5$$

$$P + 14.7 = 58.8$$

$$P = 44.1 \text{ psig.}$$

GLOSSARY OF USEFUL TERMS

Absolute Pressure: The sum of atmospheric pressure and gauge pressure. Designated as psia (pounds per square inch absolute).

Air Receiver: A container in which air is stored under pressure as a source of pneumatic power.

Ambient Temperature: The temperature of the immediate environment.

Atmospheric Pressure: The pressure exerted by the atmosphere. At sea level this pressure is 14.69 pounds per square inch absolute.

Bar: A unit of pressure measurement equal to 10^5 newtons per square meter or 14.50 pounds per square inch.

Celsius, Degree: A unit of temperature measurement abbreviated °C. Celsius temperatures are calculated from Fahrenheit temperatures by the following formula:

$$C = \frac{5(F - 32)}{9}$$

Closed Center: Pertains to three-position valves; all ports are closed when the valve is in the center position.

Detent: A device for retaining movable parts in one or more fixed positions; usually a spring-loaded device fitting into a depression. Positions of parts are changed by exerting sufficient force to overcome the detent spring, or by releasing the detent.

Directional Control Valve: A valve whose function is to direct or prevent flow through selected passages.

Flow Rate: The volume or weight of a fluid passing through a conductor per unit of time. For pneumatic systems, flow rate is most often expressed as standard cubic feet per minute (scfm).

Fluid: A liquid or a gas.

Fahrenheit, Degree: A unit of temperature measurement abbreviated °F. Fahrenheit temperatures are calculated from Celsius temperatures by the following formula:

$$F = 1.8C + 32$$

Four-Way Valve: Now designated as a 4/2 valve; a four-port, two position valve.

Free Air: Air at atmospheric pressure.

Gauge Pressure: Pressure above or below atmospheric pressure. Designated as psig (pounds per square inch gauge).

Holding Power: Amount of electric power required to maintain solenoid in its actuated position.

Impulse Signal: A briefly applied pneumatic or electric signal; a momentary signal.

Inrush Power: Amount of electric power required during time solenoid plunger is moving.

Media: The fluids used in a fluid power system. In a pneumatic system they are gases such as air, nitrogen, or various inert gases.

Media Temperature: The temperature of the fluid within a valve or other device.

Micron: A measurement equal to one-millionth of a meter or about 0.00004 inch.

Momentary Signal: A briefly applied pneumatic or electric signal; an impulse signal.

Normally Closed: A term used to describe a valve which blocks the flow of supply air when the valve is not actuated.

Normally Open: A term used to describe a valve which allows supply air to flow only when the valve is not actuated.

Open Center: Pertains to three-position valves; outlet ports are connected to exhaust when valve is in the center position.

Pressure: A measure of force per unit area; often expressed as pounds per square inch (psi) or bar.

Pressure Range: The range of inlet pressures with which a device can operate satisfactorily.

Signal: A fluid or electric command to the valve actuator causing the valve to change position.

Silencer: A device used to reduce the sound level produced by an exhausting gas.

Standard Air: Air at a temperature of 68°F, a pressure of 14.69 pounds per square inch absolute (psia), and a relative humidity of 36 per cent (0.0750 pounds per cubic foot). In gas industries the temperature of standard air is usually specified as 60°F.

Three-Way Valve: Now designated as a 3/2 valve; a three-port, two-position valve.

Two-Way Valve: Now designated as a 2/2 valve; a two-port, two-position valve. Also know as a straightway valve.

Vacuum: Pressure less than atmospheric pressure.

VALVE RESPONSE TIME

Most pneumatic applications call for a valve to be used to control the repeated filling and exhausting of a device (cylinder, clutch, etc.) having a certain volume. The time required to fill or exhaust this volume is called the *valve response time.* The time to fill a volume is usually different from the time to exhaust the volume. Both times can be found by using the following formula:

Valve Response Time = M + (F • V)

This formula gives the time in milliseconds (msec = 0.001 sec) required to fill the volume V to 90% of supply pressure *or* to exhaust the volume V to 10% of supply pressure. M and F are *average response constants,* and their values for each valve are found in the ROSS master catalog. V is the number of cubic inches in the volume to be filled or exhausted.

What is the constant M?
When a valve is energized it takes a number of milliseconds for the valve to shift and allow a steady flow of air to be established at the outlet port. In like manner, when the valve is de-energized it takes a number of milliseconds for the valve to shift and cut off the flow of outlet air and establish the flow of exhaust air. These valve "movement" times are designated by M in the above formula.

What is the constant F?
After the valve has shifted and air flow to fill the volume V is established, the air flows rapidly at first, then flows at a reducing rate as pressure builds up in the volume V. In exhausting the volume V, air flows rapidly at first, then at a reducing rate as the pressure falls in the volume V. In either case the *average flow rate* is represented in the above formula by F. It is the average number of milliseconds required to fill or exhaust one cubic inch of the volume V. The product F • V, then, is the number of milliseconds required to fill or exhaust the entire volume V after the valve has shifted.

The F values for each valve are found in the ROSS master catalog, and they are generally different for the filling and exhausting functions. The response time tables list the F values under the headings "In-Out" and "Out-Exh." Clearly the values under the In-Out heading are to be used when a volume is being filled, and the values under the Out-Exh heading are used when a volume is being exhausted.

Use of the valve response time formula is illustrated by the following problems.

Problem A: How long will it take to fill a 100-cubic-inch chamber to 90% of supply pressure using an ISO size 2 metal spool valve with single solenoid control?

Solution A: Average response constants for this valve are found in the ROSS master catalog.
For the size 2 series W60 (metal spool) valve the values are M = 41 and F = 1.5. The F value of 2.4 is for the exhaust paths and so is not needed for this problem.

Putting these M and F values into the valve response time formula we have:

Average Response Time = 41 + (1.5)(100)

= 41 + 150

= 191 msec

The volume of 100 cubic inches would be filled to 90% of supply pressure in 191 milliseconds, or less than 2/10 of a second.

Problem B: What Series 27, normally closed, 3/2 valve is needed to fill a 1000-cubic-inch volume to 90% of supply pressure in less than 1/2 second (500 msec)?

Solution B: Put the given data into the basic formula:

500 = M + (F • 1000)

Now we must find the values of M and F that make the right-hand side of the equation *less* than 500 msec. We can shorten our work by noting that the dominant quantity in the formula is F • 1000. Therefore we must find a value of F that will make F • 1000 less than 500, i.e., F must be less than 0.5.

In the ROSS master catalog we find the response time constants for Series 27, 3/2, normally closed valves. The first F value that is less than 0.5 is 0.43. The M value is 11.

Putting these values into the basic formula we obtain:

Average Response Time = 11 + (0.43)(1000)

= 11 + 430

= 441 msec

We see that the valve to be selected is the larger of the two 1/2-inch valves. In the ROSS master catalog we identify this valve as model number 2773B4001.

The flow coefficient (C_v) of a pneumatic device is a measure of the device's ability to pass air. The amount of air that can flow through various valves, for example, is in direct proportion to the sizes of their flow coefficients, for given inlet and outlet pressures.

Air flow through a valve (or other device) is measured in the laboratory under carefully controlled conditions. From this measurement plus measurements of the inlet and outlet pressures, the flow coefficient can be determined. The relationship between these factors at a temperature of 68°F (20°C) is expressed in the following formula:

$$Q = 0.98\, C_v \sqrt{\Delta P(P_2 + 14.7)}$$

where

- Q = air flow in standard cubic feet per minute (scfm)
- C_v = flow coefficient
- P_1 = inlet pressure (psig)
- P_2 = outlet pressure (psig)
- ΔP = pressure drop across valve (psi) = $P_1 - P_2$

Knowing the flow coefficient and the inlet and outlet pressures, the flow through a valve can be determined using this formula.

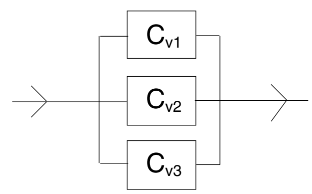
A simpler way, however, to determine air flow is to use the graph on the page 9. This graph is based on the above formula when $C_v = 1$. Since air flow is proportional to C_v, this graph can be used for any C_v value; simply multiply the air flow rate given on the graph by the new C_v value.

Example: Given a supply pressure of 125 psig, a pressure drop of 7 psi, and a valve with a C_v of 4.2, find the rate of air flow through the valve.

From the 7 psi pressure drop value at the bottom of the graph, move upward to the supply pressure line for 125 psig. From this point move to the left and read the air flow rate: 30 scfm. Since this is the air flow rate for $C_v = 1$, multiply by 4.2 to obtain the air flow rate for the valve in this example. 30 x 4.2 = **126 scfm.**

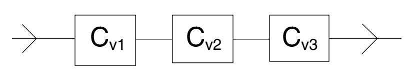
Determining the C_v Required of a Valve Operating a Cylinder: The charts on pages 10 and 11 can be used to determine the valve C_v required to operate cylinders of various sizes. The chart on page 10 shows the displaced volume of cylinders with various strokes and diameters. Knowing the volume of the cylinder and the number of strokes per minute the cylinder must make, the chart on page 11 can be used to determine the minimum C_v that the operating valve must have.

Parallel Connection of Pneumatic Components: If several pneumatic components are connected in parallel, the flow coefficient of the combination is simply the sum of the flow coefficients of the several units.
For example:



$$\text{Combined } C_v = C_{v1} + C_{v2} + C_{v3}$$

Series Connection of Pneumatic Components: If several pneumatic components are connected in series, the flow coefficient of the combination is a little more complicated. For example:



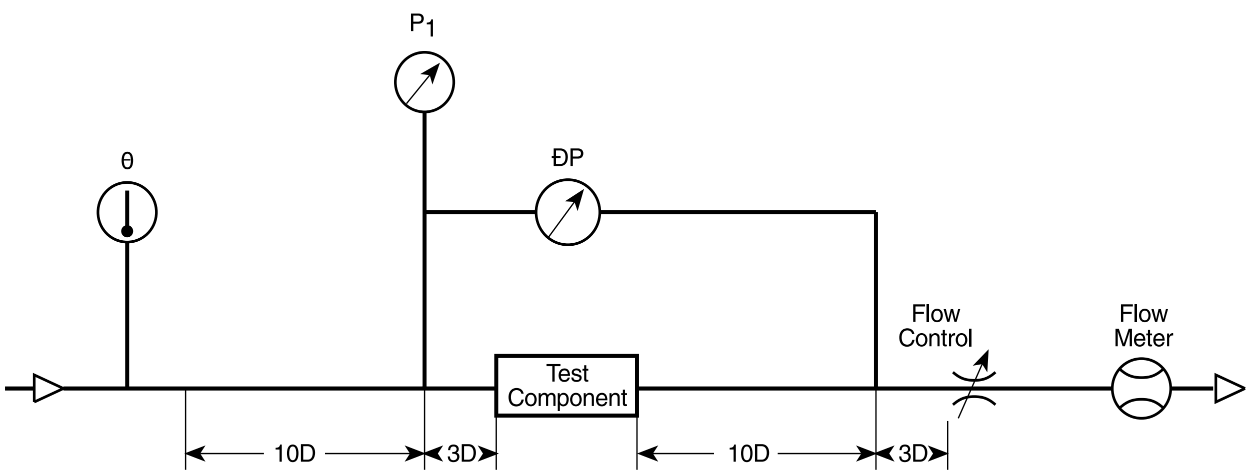
$$\text{Combined } C_v\text{:}\quad \frac{1}{(C_v)^2} = \frac{1}{(C_{v1})^2} + \frac{1}{(C_{v2})^2} + \frac{1}{(C_{v3})^2}$$

Using C_v values must always be tempered with good judgement. Flow coefficients are determined in the laboratory under steady flow conditions, a state that exists only part of the time in an industrial pneumatic system. Some allowance must be made for the valve response time required to establish steady flow conditions. (See discussion of Valve Response Time on page 2.) The use of C_v values is just one area in which the experience and judgement of the pneumatic designer become important.

STANDARDIZED TESTING

The illustration below shows a standardized test set-up established by the American National Standards Institute. ROSS engineering practice calls for strict adherence to the new testing standards established by ANSI.

The adoption of the new ANSI testing standards by the pneumatics industry will be a major step forward in eliminating the confusion about C_v ratings which has sometimes existed. Acceptable variations in instrumentation and test hookup can still yield variations up to 15 per cent in C_v values. However, this will still represent a major improvement over the extreme variations which have sometimes existed in the past.



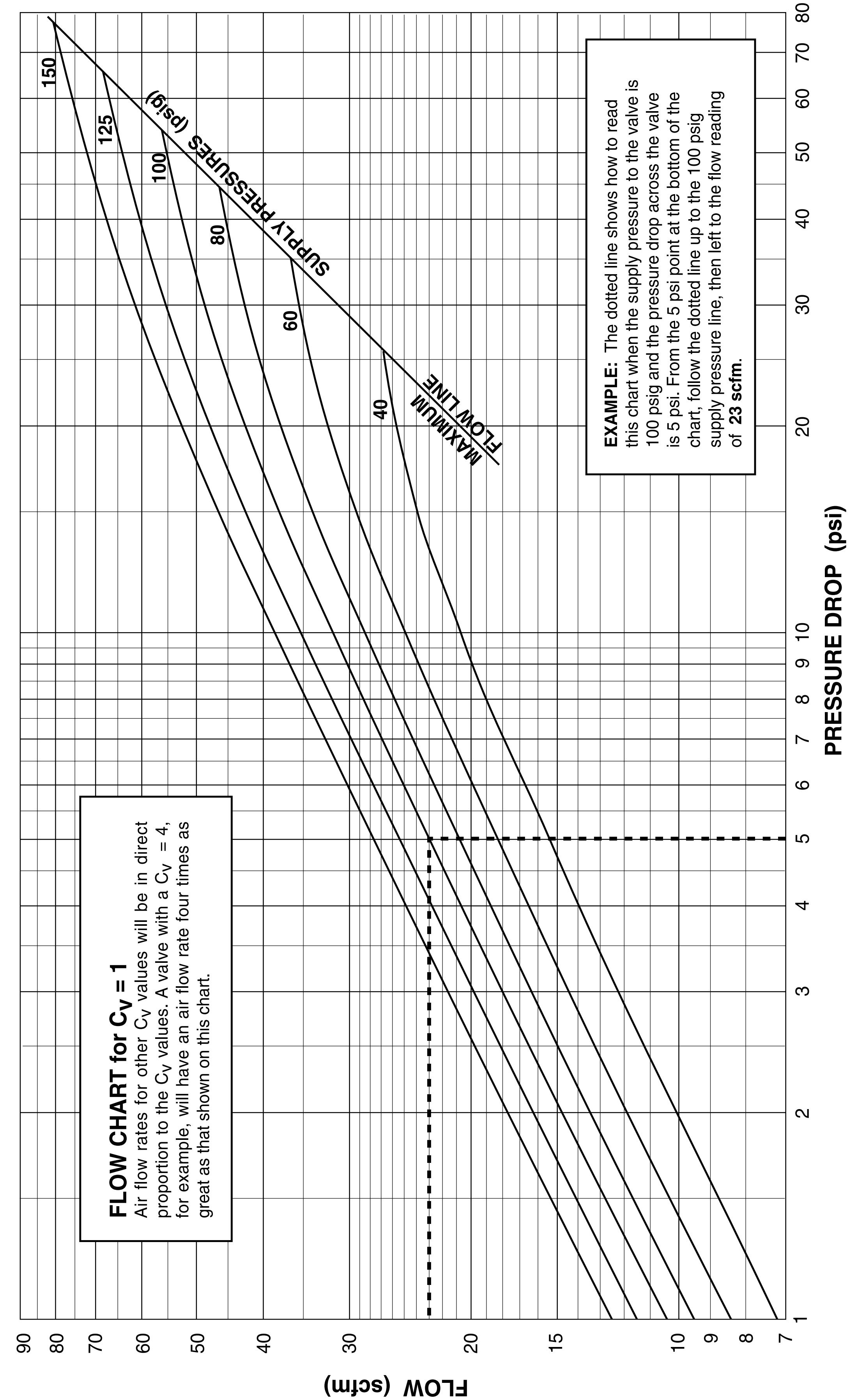
0 = upstream temperature

P_1 = pressure at upstream tap

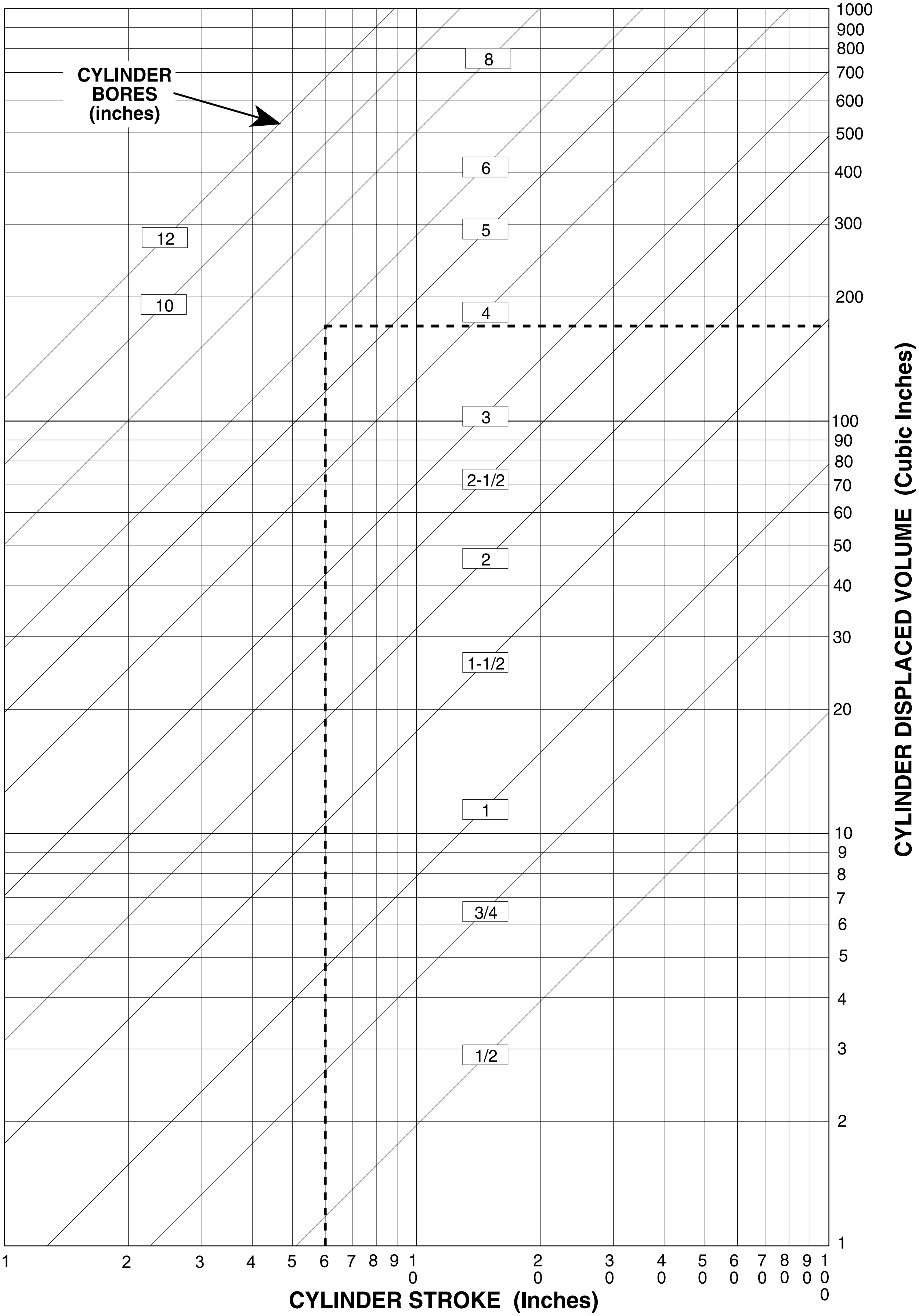
ΔP = pressure drop

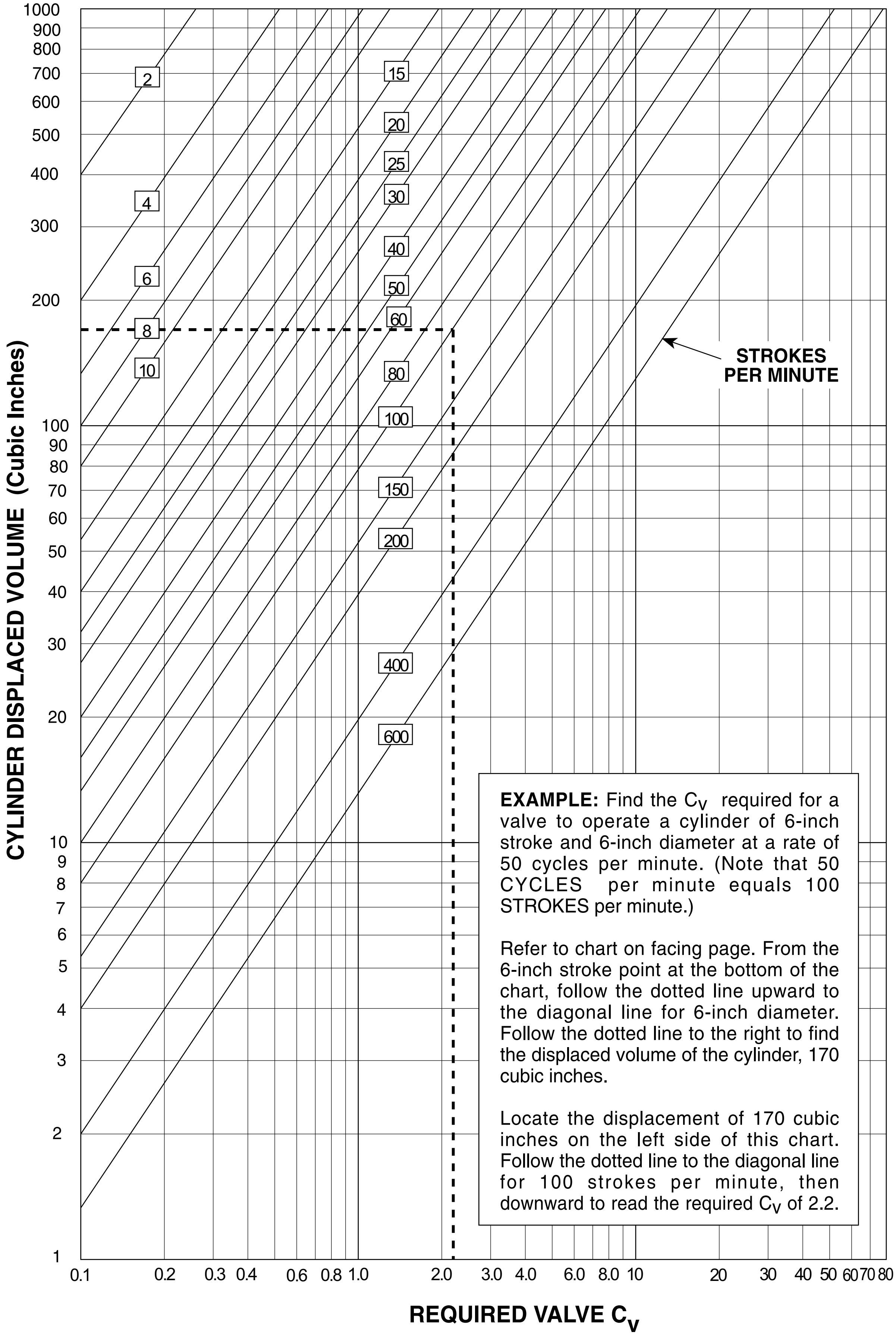
D = inside diameter of conductor

FLOW CHART FOR $C_v = 1$



CILYNDER VOLUME





EXAMPLE: Find the C_V required for a valve to operate a cylinder of 6-inch stroke and 6-inch diameter at a rate of 50 cycles per minute. (Note that 50 CYCLES per minute equals 100 STROKES per minute.)

Refer to chart on facing page. From the 6-inch stroke point at the bottom of the chart, follow the dotted line upward to the diagonal line for 6-inch diameter. Follow the dotted line to the right to find the displaced volume of the cylinder, 170 cubic inches.

Locate the displacement of 170 cubic inches on the left side of this chart. Follow the dotted line to the diagonal line for 100 strokes per minute, then downward to read the required C_V of 2.2.

PNEUMATIC SYMBOLS

FLUID CONDUCTORS

Working Line

Exhaust Line or Control Line

Lines Crossing

Lines Connected

Mechanical Connection
(Shaft, Rod, etc.)

Fixed Restriction

Variable Restriction

Flexible Line

Plugged Port

Direction of Flow

ENERGY SOURCES

Pneumatic
(Any fluid power source)

Compressor
(Fixed displacement)

Vacuum Pump
(Fixed displacement)

Accumulator

VALVES

Single Square
(Unit for controlling flow. Contains information on porting and flow paths.)

One Flow Path

Two Closed Ports

Two Flow Paths or

Two Flow Paths & One Closed Port

Two Flow Paths with Cross Connection

One By-pass Flow Path & Two Closed Ports

Two External Ports

2-Position Envelope

3-Position Envelope

Two Distinct Positions & One Transitory (center) Position

2/2 Valve
2 Ports, 2 Positions

3/2 Valve
3 Ports, 2 Positions

VALVES (cont.)

4/2 Valve
4 Ports, 2 Positions

5/2 Valve
5 Ports, 2 Positions

4/3 Valve
4 Ports,
3 Positions

5/3 Valve
5 Ports,
3 Positions

FLUID CONDITIONERS

Basic Envelope
(Filters and lubricators)

Filter
(Manual drain)

Filter
(Automatic drain)

Lubricator
(Less drain)

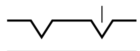
Lubricator
(Manual drain)

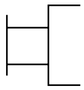
Air Dryer

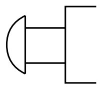
Pressure Regulator
(Adjustable, self-relieving)

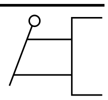
Pressure Regulator
(Adjustable, non-relieving)

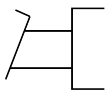
ACTUATORS and CONTROLS

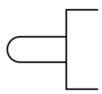
Detent – 2 Position
Vertical line indicates flow position.


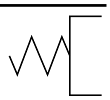
Muscular Control


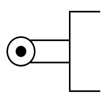
Push-button


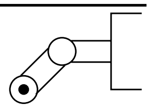
Lever


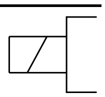
Pedal or Treadle


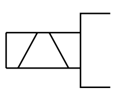
Plunger or Position Indicator Pin


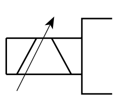
Spring


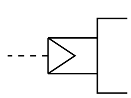
Roller


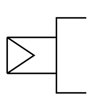
Roller - One way


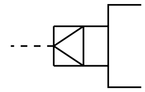
Solenoid
Single winding


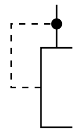
Solenoid
Two opposite windings


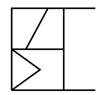
Variable Solenoid
Two opposite windings


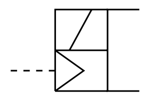
Pilot Pressure
External


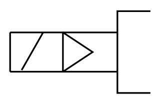
Pilot Pressure
Internal


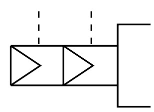
Release of Internal Pilot Pressure


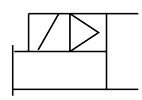
Interior Control Path


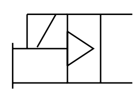
Solenoid or Internal Pilot


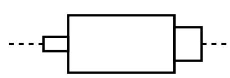
Solenoid or External Pilot


Solenoid plus Internal Pilot


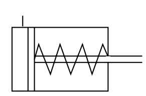
Two External Pilots


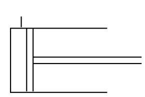
Solenoid & Pilot or Manual Override


Solenoid & Pilot or Manual Override and Pilot


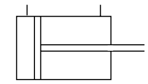
Differential Pressure


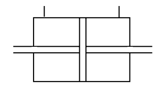
ENERGY CONVERSION

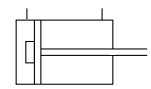
Cylinder
Spring return


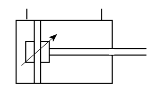
Cylinder
Unspecified return


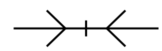
ENERGY CONVERSION (cont.)

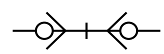
Cylinder Double Acting
Single rod


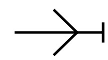
Cylinder Double Acting
Double rod


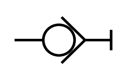
Cylinder Double Acting
Single fixed cushion


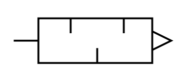
Cylinder Double Acting
Two adjustable cushions


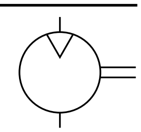
Quick Acting Coupling


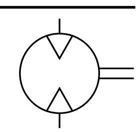
Quick Acting Coupling – With mechanically opened non-return valve


Quick Acting Coupling – Not coupled, with open end


Quick Acting Coupling – Not coupled; closed by free non-return valve


Silencer


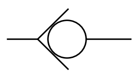
Air Motor
One directional flow


Air Motor
Two directional flows


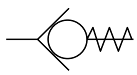
PNEUMATIC SYMBOLS – PORT IDENTIFICATION

SPECIAL PURPOSE VALVES

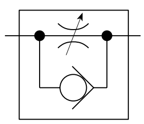
Check Valve
Non-return



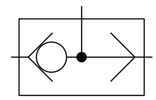
Check Valve
Spring loaded



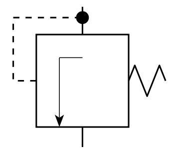
Flow Control Valve



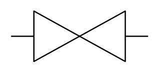
Shuttle Valve



Sequence Valve

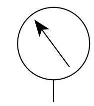


Shutoff Valve

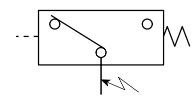


MEASURING INSTRUMENTS and SWITCHES

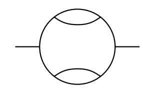
Pressure Gauge



Pressure Actuated Electric Switch



Flow Gauge



PORT IDENTIFICATION

The port markings on ROSS valves are the same as those shown on the valve symbols in ROSS literature. Main ports are identified by numbers, except for SAE valves which continue to use letters for identification.

Older valves may not have numerical port markings. The correspondence between the older markings and the current numerical markings is shown below.

Current Port Marking	Previous Port Marking
1	IN, P
2	OUT 1, OUT A, CYL 1, CYL A
3	EXH, EA, R
4	OUT 2, OUT B, CYL 2, CYL B
5	EXH, EB, S
12	CA
14	CB

Main Port Identification. Numbers 1 through 5 are used for main port identification as follows:

- **1** Normal inlet port.
- **2** Normal outlet port.
- **2 & 4** Normal outlet ports where two are provided.
- **3** Normal exhaust port.
- **3 & 5** Normal exhaust ports where two are provided.

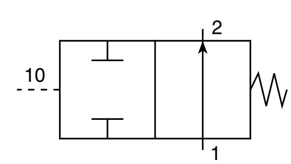
Pilot Control Identification. The following numbers are used on symbols for pilot control or control port identification. When an electrical or pneumatic signal is applied to the control or port, the following conditions result:

- **10** Inlet 1 is closed.
- **12** Inlet 1 is connected to outlet 2.
- **14** Inlet 1 is connected to outlet 4.

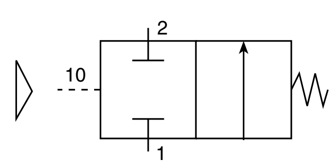
Use of some of the above controls are shown in the following examples.

Example 1. 2/2 (2 port, 2 position) normally open, spring return valve.

Valve not actuated.



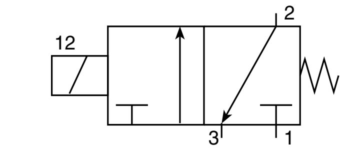
Valve actuated by pneumatic signal applied to port 10.



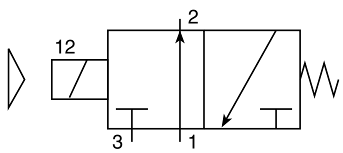
PORT IDENTIFICATION – CONVERSION FACTORS

Example 2. 3/2 (3 port, 2 position) normally closed, spring return valve.

Valve not actuated.

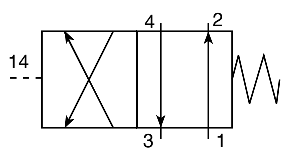


Valve actuated by electrical signal applied to control 12.

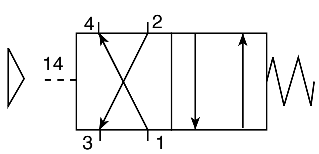


Example 3. 4/2 (4 port, 2 position) spring return valve.

Valve not actuated.

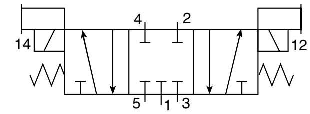


Valve actuated by pneumatic signal applied to control 14.

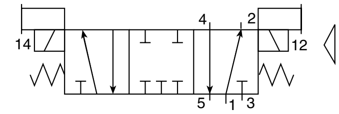


Example 4. 5/3 (5 port, 3 position) closed center, spring centered valve.

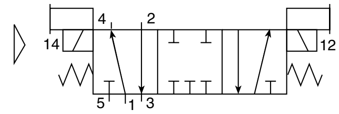
Valve in non-actuated center position.



Valve actuated by electrical signal applied to control 12.



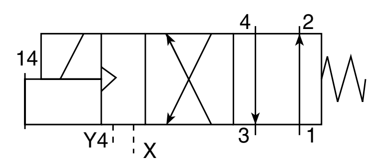
Valve actuated by electrical signal applied to control 14.



Auxiliary Ports for Pilot Operators

Port	Function
X X1	External pilot supply port
Y2 Y3 Y4	Exhaust port for solenoid pilot

Example:



CONVERSION FACTORS

U.S. to Metric Conversion

From	To	Multiply By
inches	millimeters	25.40
feet	meters	0.3048
miles	kilometers	1.609
square feet	square meters	0.09290
cubic feet	cubic meters	0.02832
cubic feet	liters	28.32
gallon	liters	3.785
pounds	kilograms	0.4536
lb/in^2 (psi)	bar	0.06895
ft^3/min	liters/second (l/s)	0.4718

Metric to U.S. Conversion

From	To	Multiply By
millimeters	inches	0.03937
meters	feet	3.281
kilometers	miles	0.6214
square meters	square feet	10.76
cubic meters	cubic feet	35.30
liters	cubic feet	0.03531
liters	gallons	0.2642
kilograms	pounds	2.205
bar	lb/in^2	14.50
liters/second (l/s)	ft^3/min	2.120

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