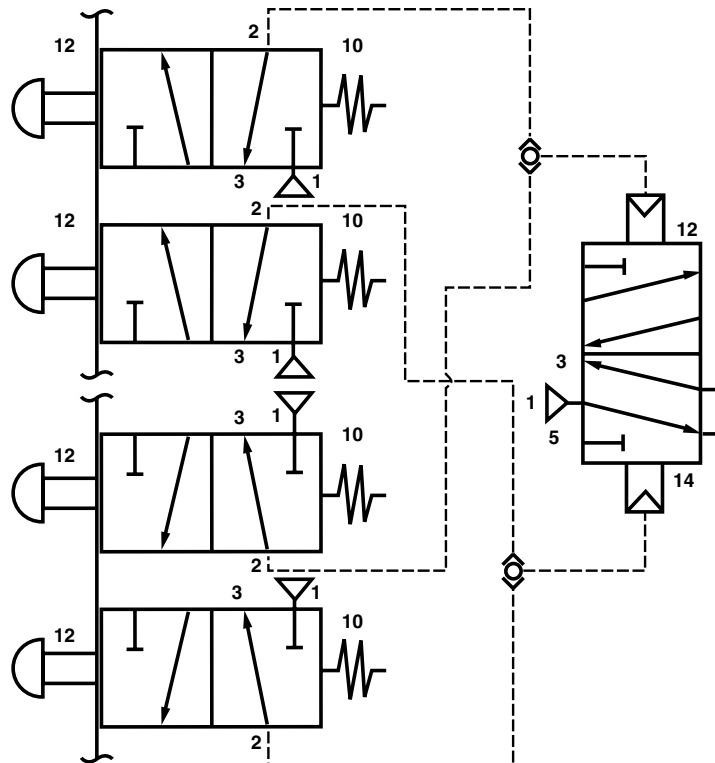
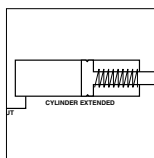
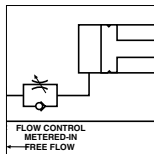
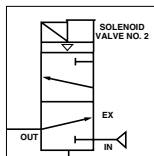


# SIMPLIFIED VALVE CIRCUIT GUIDE



## A GUIDE TO UNDERSTANDING PNEUMATIC DIRECTIONAL CONTROL VALVES



## Compressed Air Valves

Directional control valves start, stop or change the direction of flow in compressed air applications. Many manufacturing companies apply compressed air as the power to operate tools and equipment which are used to make the products they offer. To understand the different applications of compressed air and how valves are used, one must first have a knowledge of the kinds and types of valves used by industries.

Valves are designed for different applications and a factory may use several different types of valves with each being suited for a particular job. These designs fall into the following categories: spool – bonded and lapped; poppet; a combination of spool and poppet; sliding seal; rotary and diaphragm.

The two types of spool (bonded and lapped) and the poppet are the most common designs in use. Of these, Norgren makes valves using the packed and bonded spools and the poppet design.

Bonded spool valves use an elastomer to seal against pressure. Bonded spools allow practically no leakage, can be used in three-position applications, and the standard valve goes through a blocked center, which prevents blowby from the exhaust ports when changing from one flow pattern to another.. Spool valves are tolerant of dirt and compressor varnish and when lubricated properly, will cycle for millions of operations.

Poppet valves use a large poppet seal and operate much the same way as a home water faucet. The seal surface moves perpendicular to the valve area and pushes against an annular ridge for positive sealing. Poppet valves are fast, rugged, and known for their ability to operate under adverse conditions.

Spool valves are available in 3-way and 4-way configurations. A 3-way spool valve can be used as a 2-way valve by blocking one port. Poppet valves are made in 2-way, 3-way, and 4-way configurations.

## Valve Operation

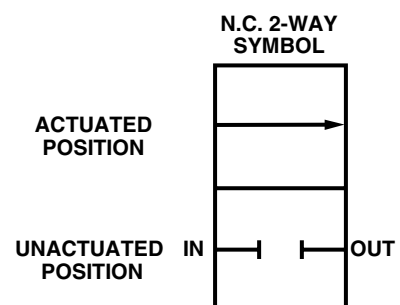
### Two Way Valves

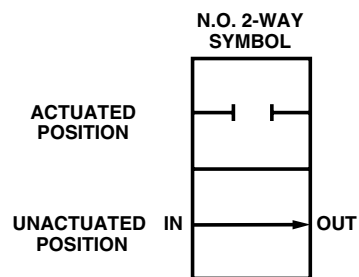
Two-way valves turn air on and off in applications such as shop air, branch airlines, supply pressure to systems, and supply air to tools, motors and similar equipment. Two-way valves can also be used as vent valves.

### Poppet Valve, 2-Way, 2-Port

Normally closed 2-way valves block inlet flow when in the unactuated position. Inlet flow is passing when actuated.

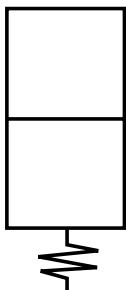
**Note:** Valve symbols always show the unactuated position in the lower block.



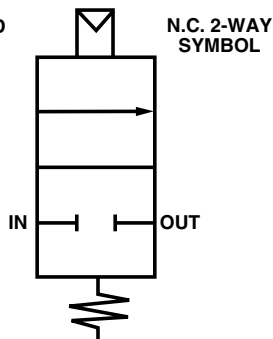


N.O. 2-WAY  
SYMBOL

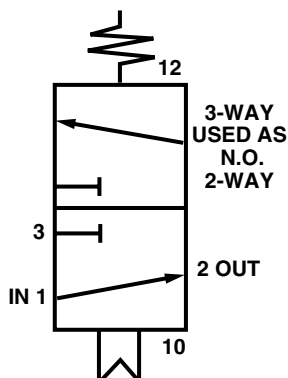
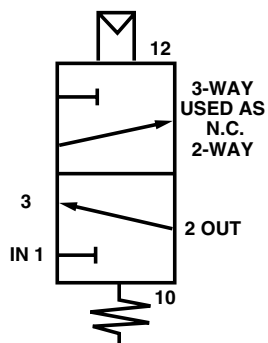
SPRING  
RETURN  
SYMBOL



SIMPLIFIED  
AIR PILOT  
SYMBOL



N.C. 2-WAY  
SYMBOL



## Compressed Air Valves, cont.

**Normally open** 2-way valves pass inlet flow when unactuated and block flow when actuated. Normally open valves can be applied to safety applications which require cooling flow, etc. when actuated. Normally held off cooling flow would come on in event of failure.

## Spring Return

Added to valve symbol. The spring returns the valve to its normal, unactuated position.

## Air Operator

Simplified air operator added to the valve symbol. When the valve is actuated, the flow path shown in the upper block replaces the flow path in the lower block.

## Spool Valve, 3-Way, 3-Port, Used as a N.C. 2-Way, 2-Port

To use a 3-way spool valve as a 2-way normally closed valve, plug port 3 and connect the inlet to port 1 and the outlet to port 2

## Spool Valve, 3-Way, 3-Port, Used as a N.O. 2-Way, 2-Port

**Except:** The normally open, 2-way configuration is not possible with the 3-way  $\frac{1}{8}$ " Nugget solenoid operated valve. This valve does not have provisions for "Normally Open" solenoid operated valves.

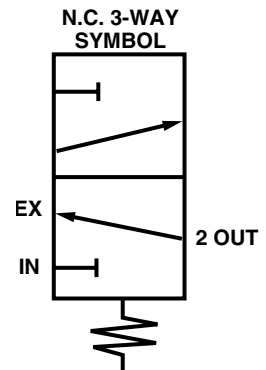
## Three-way Valves

Three-way valves are the same as 2-way valves with the addition of a third port for exhausting downstream air. Three-way valves are available in a normally open or normally closed operating configurations. These valves are used to control single acting or spring return cylinders and any load which must be pressurized and alternately exhausted. These valves can also pilot other air operated valves.

### Poppet and Spool Valves, 3-Way, 3-Port

#### Normally Closed 3-Way Valves

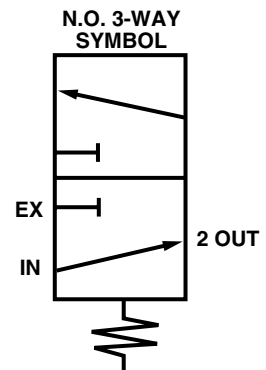
When unactuated, block inlet flow and connect the outlet port to the exhaust port. When actuated, the inlet port is connected to the outlet port and the exhaust port is blocked.



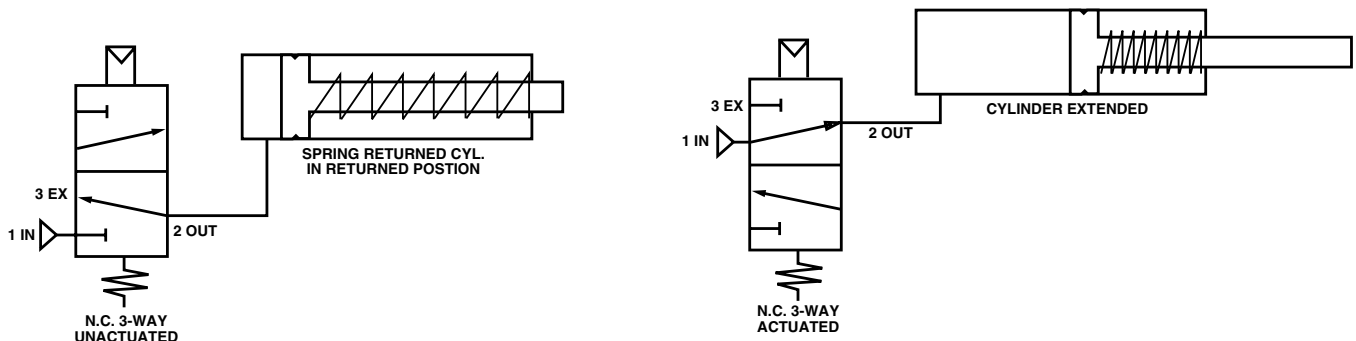
#### Normally Open 3-Way Valves

When unactuated, pass inlet flow to the outlet and block the exhaust port. When actuated, inlet flow is blocked and the outlet port is connected to the exhaust port.

**Except:** The normally open configuration is not possible with the 3-way 1/8" Nugget solenoid operated valve. This valve does not have provisions for an external pilot supply which is required for "Normally Open" solenoid operated valves.

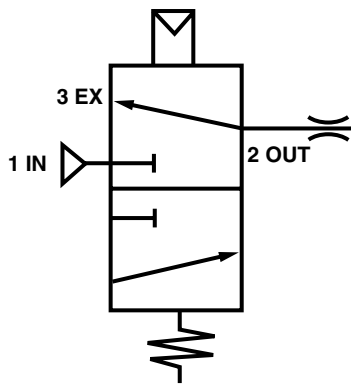


Three-way valve applied to a spring return cylinder.



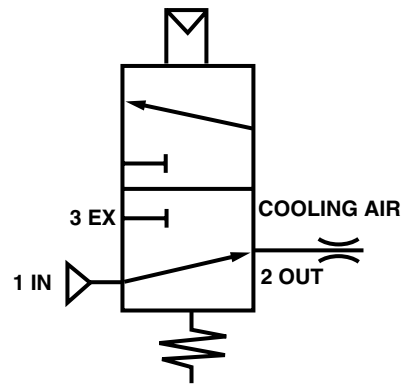
## Three-Way Valves, cont.

Three-way valve applied to a cooling air supply



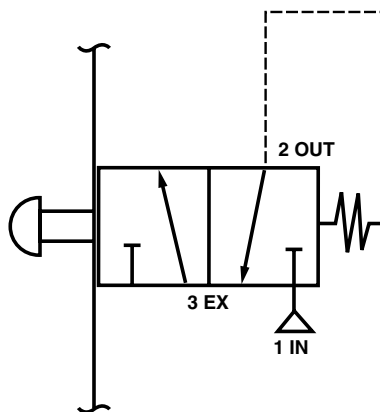
N.O. 3-way Actuated  
(Cooling air held off)

**Note:** A normally open 2-way poppet valve can also be used in place of the normally open 3-way above.

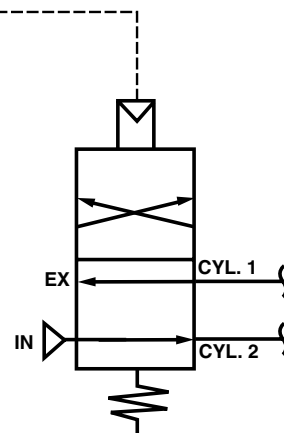


N.O. 3-way unactuated  
(Upon loss of pilot signal,  
valve supplies cooling air.)

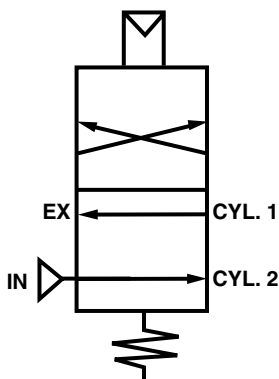
Three-way valves can be used as a remote air pilot for larger valves.



Panel mounted 3-way control valve



Power Valve



## Four-Way Valves

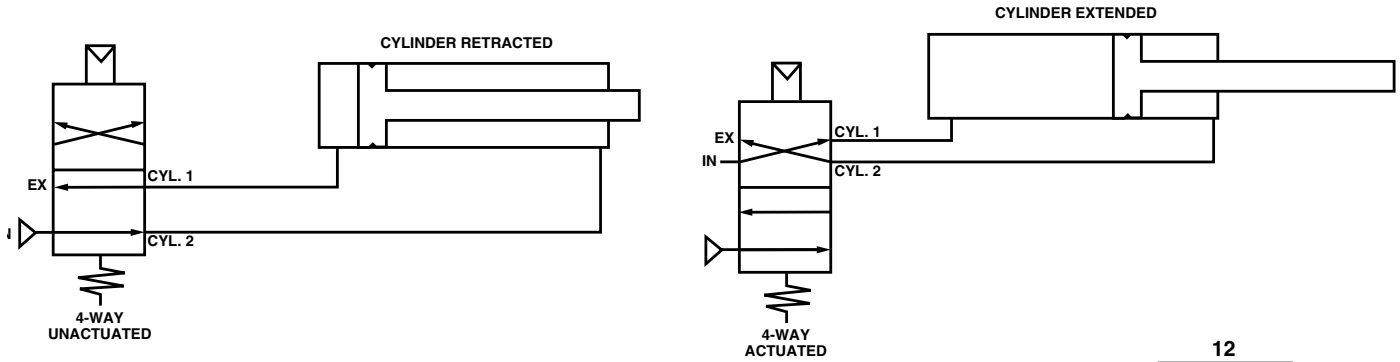
Four-way valves use two 3-way valve functions operated at the same time, one normally closed and one normally open. These valves have two outlet ports that alternate between being pressurized and exhausted. Four-way valves are used to operate double acting air cylinders, control bi-directional air motors and in air circuitry. Also two single acting cylinders can be operated with one 4-way valve.

### Poppet Valves, 4-Way, 4-Port

The flow paths for an unactuated valve are inlet to cylinder 2 and cylinder 1 to exhaust. When actuated, the inlet is connected to cylinder 1 and cylinder 2 is connected to exhaust. Four-way poppet valves have one exhaust port which is shared by all cylinder ports.

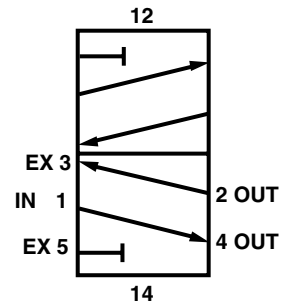
## Four-Way Valves, cont.

A 4-way Poppet valve applied to a double acting air cylinder

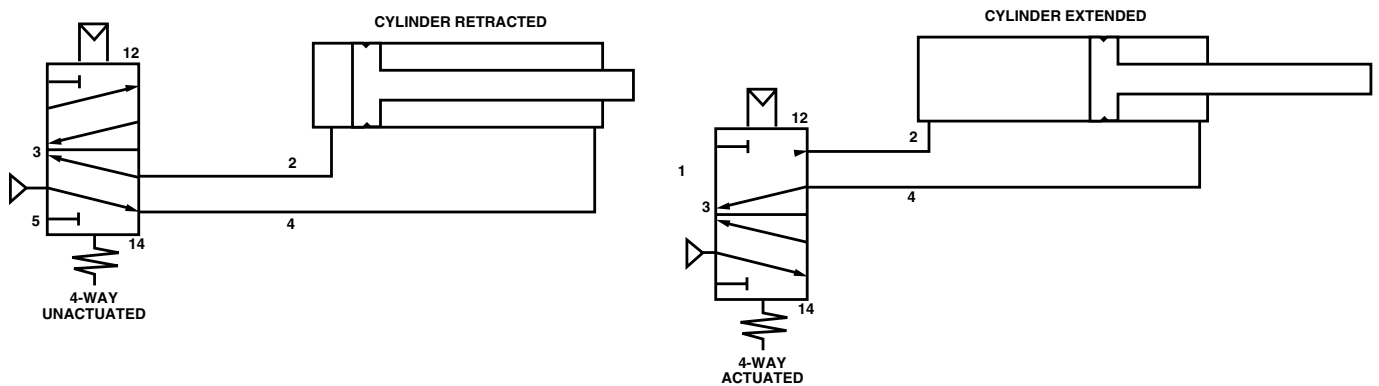


## Spool Valves, 4-Way, 5-Port

The 4-way spool valve can be controlled by using two operators, one on each end or by a spring return and a single operator. The flow path when actuated at the 14 end of the valve is from port 1 to port 4 and from port 2 to port 3. Port 5 is blocked. When the valve is actuated from the 12 end, the flow path is from port 1 to port 2 and from port 4 to port 5. Port 3 is blocked. Each cylinder port has a separate exhaust port.



Three-way valve applied to a spring return cylinder

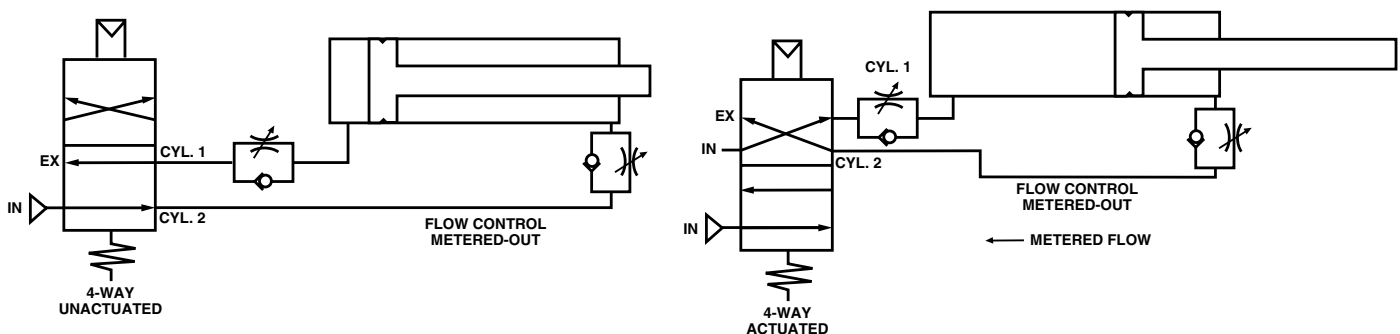


## Cylinder Speed Control

Cylinder speed control requirements are defined by the load being moved or work done on extension. Speed control on cylinder extension stroke, metered exhaust air-metered out.

### Speed control on cylinder extension — metered out (Poppet valves)

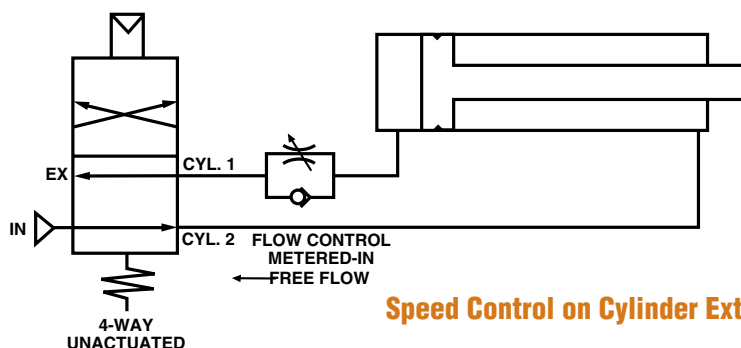
Install the flow control device at the rod end of the cylinder with the free flow arrow toward the cylinder. When the valve is actuated, pressure is applied to the blank end of the cylinder. Air being exhausted from the rod end cannot go through the check valve and must flow through the needle valve of the flow control before being exhausted by the valve. The cylinder is being extended against a cushion of air that is slowly being bled to atmosphere.



## Four-Way Valves, cont.

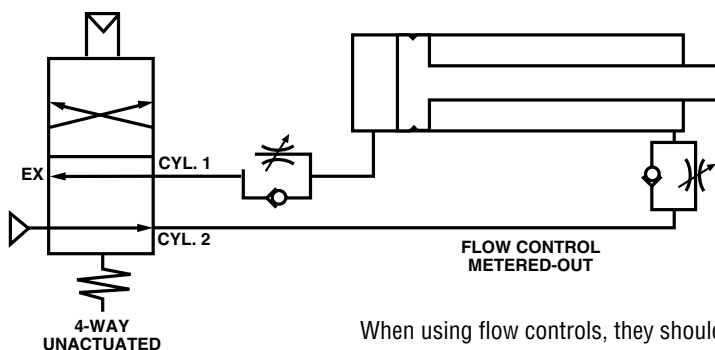
### Speed Control on Cylinder Extension—Metered-In

Install the flow control at the blank end of the cylinder with the free flow arrow away from the cylinder. When the valve is actuated, the rod end of the cylinder is exhausted and pressure is metered-in at the blank end. Cylinder speed depends on the load or work done on extension. Although not as stable as metered-out, this method is used in circuits using sequence valves and pressure switches.

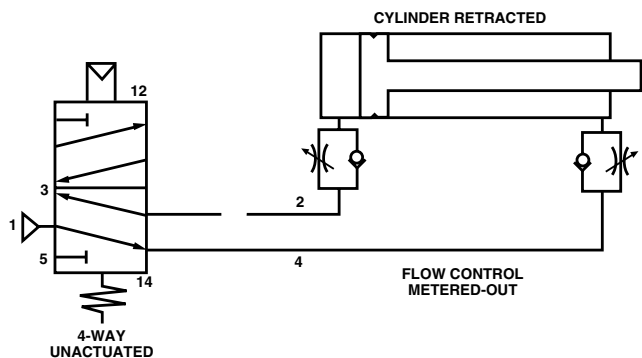


### Speed Control on Cylinder Extension and Retraction—Metered-Out

Install a flow control at each end of the cylinder with the free flow arrow toward the cylinder. When the cylinder is extended or retracted, it will be doing so against a cushion of air being slowly bled to the atmosphere. Extension and retraction speed can be controlled by adjusting the flow control needle valves.

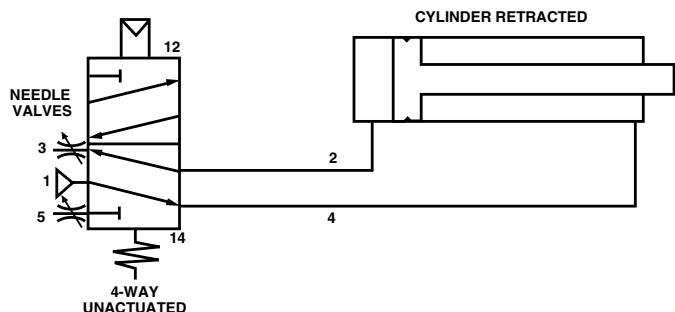


When using flow controls, they should be mounted in the cylinder ports or as close to the cylinder as possible. Flow controls **MUST** be mounted between the cylinder and the valve when using a poppet valve, except for the multi-directional 3-way selector valve (C1012/48).



### Flow Controls When Used with Spool Valves

When flow controls are used with spool valves, the connections and location can be the same as when used with poppet valves.

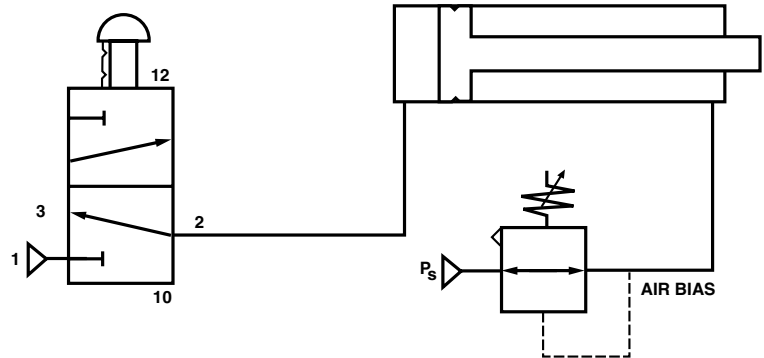


An alternate method of cylinder speed control is to use a needle valve in one or both exhaust ports of the spool valve. This method eliminates the need for a check valve in each flow control.

## Valve Applications

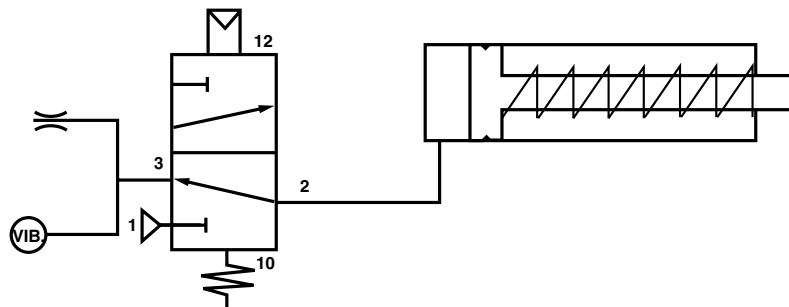
### Air-Spring Returned Cylinder (Spool Valve Shown)

A double acting cylinder can be extended using a manual, push-pull 3-way valve and retracted with a constant bias air pressure. The regulator supplying the bias pressure must be a relieving type and can be set at 10 to 20% of the pressure being applied to the blank end of the cylinder. This circuit can be used with clamping fixtures and anywhere a cylinder can be retracted at a low pressure.



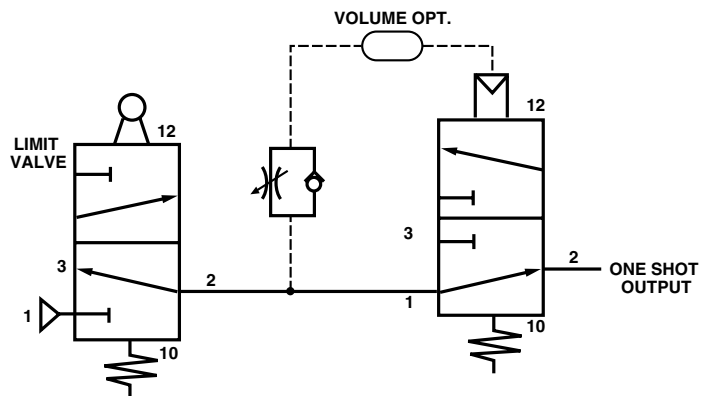
### Tapped Exhaust (Spool Valve Shown)

The air exhausted from cylinder retraction can be used to do secondary work such as operating a vibrator or to clean or eject parts.



### One Shot Output (Spool Valves Shown)

The one shot circuit is used to shorten long signals which may still be actuating a valve when it is necessary to reset the same valve. The circuit output appears as soon as the limit valve is actuated and after a delay (determined by volume and restrictor setting) the output is shut off.

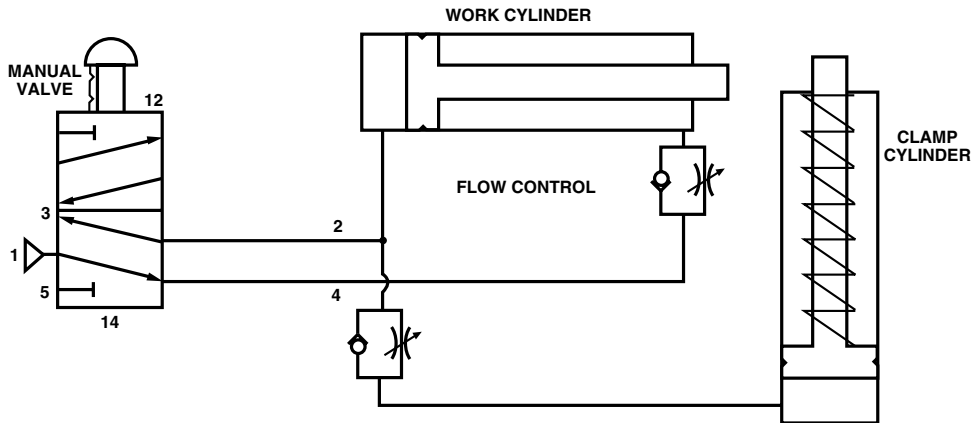




## Valve Applications, cont.

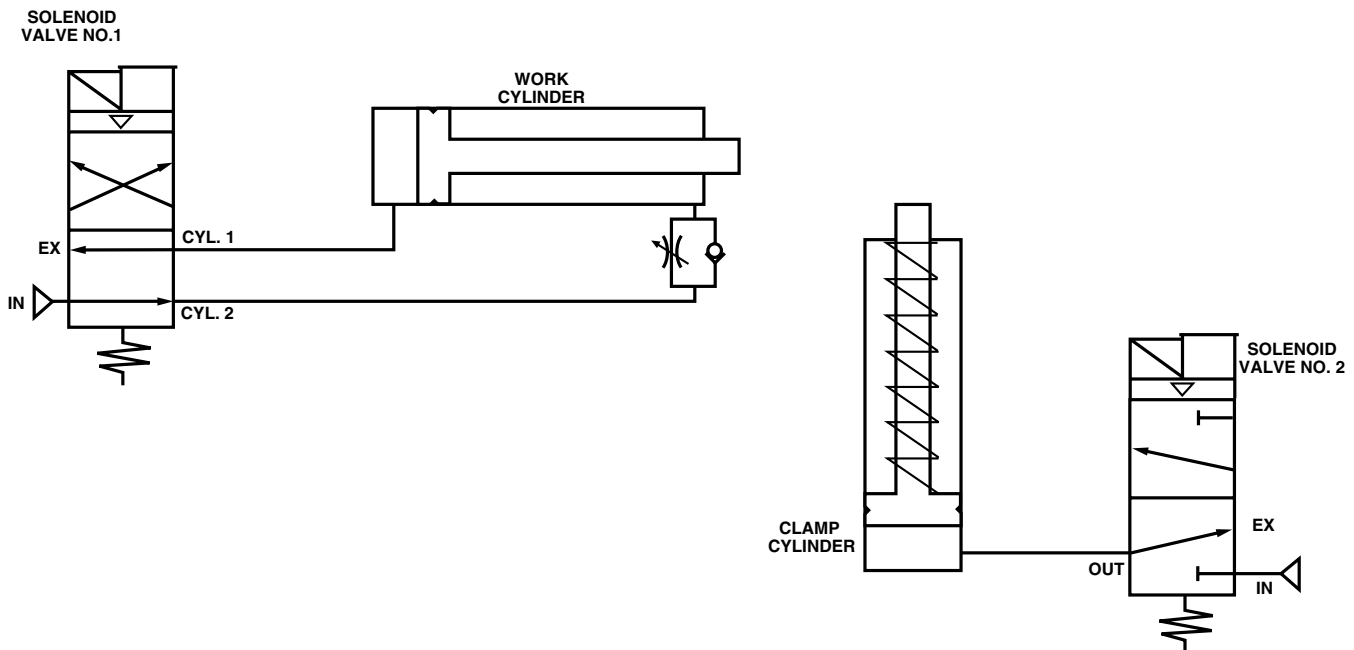
### Air Clamp and Work Cylinder Controlled by One Valve (Spool Valve Shown)

The flow control delays the extension of the work cylinder until the clamp cylinder is in place. The clamp cylinder force is limited to the work cylinder load until the work cylinder is fully extended. When the manual valve is reset, the work cylinder will return before the clamp cylinder is released.



### Air Clamp and Work Cylinder Controlled by Two Valves (Poppet Valves Shown)

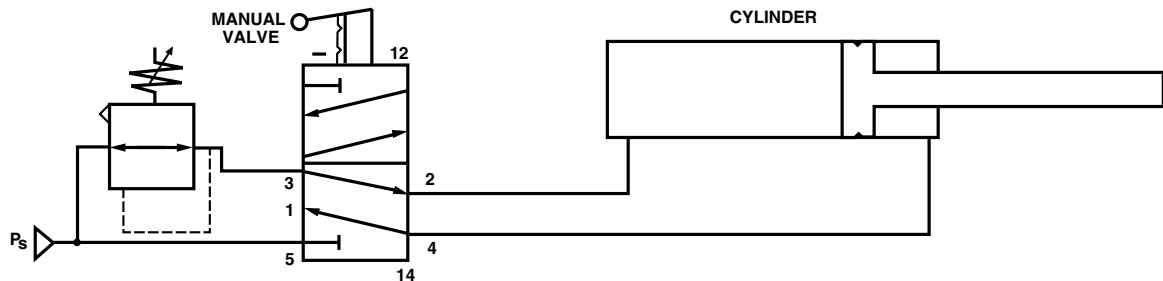
The solenoid valves are energized at the same time. The clamp cylinder is extended and goes to full clamp force. The work cylinder extension rate is controlled by the flow control. The advantage of this circuit is that separate control of the two valves is possible if desired.



## Valve Applications, cont.

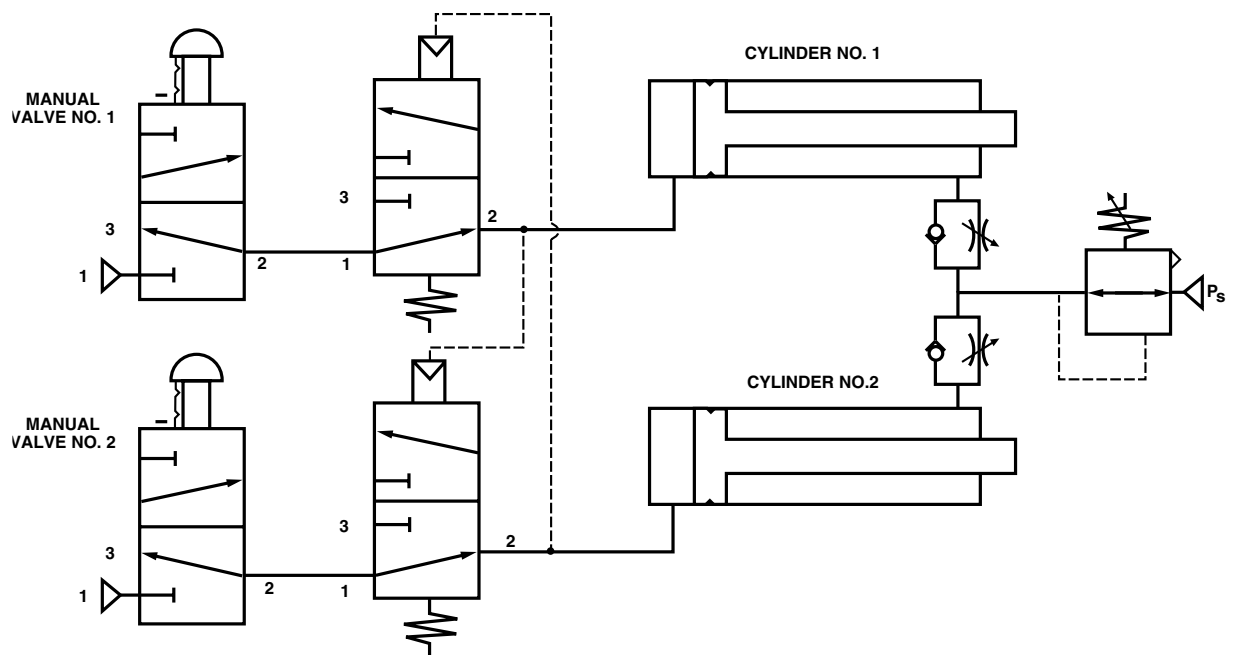
### Air Clamp, Controlled Force (Spool Valve Shown)

Cylinder clamping force can be controlled by a separate regulator when used with a dual pressure valve. (Port 1 becomes exhaust).



### Interlock Circuit (Spool Valves Shown)

The cylinders can be either air spring or spring return. The cylinders are interlocked with the pressure extending one cylinder, disabling the other cylinder circuit. One cannot be extended as long as pressure is applied to the other.

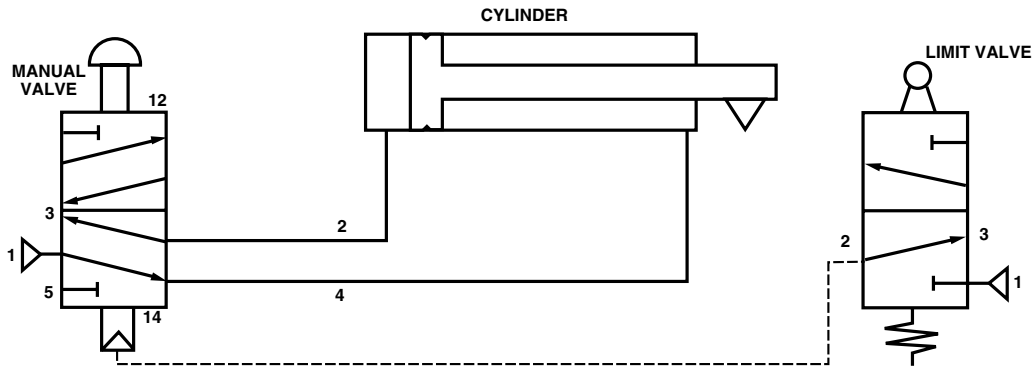


\* Regulator relief flow must be sufficient to accommodate the cylinder speed.  
Flow controls will allow variations of cylinder extension speed.

## Valve Applications, cont.

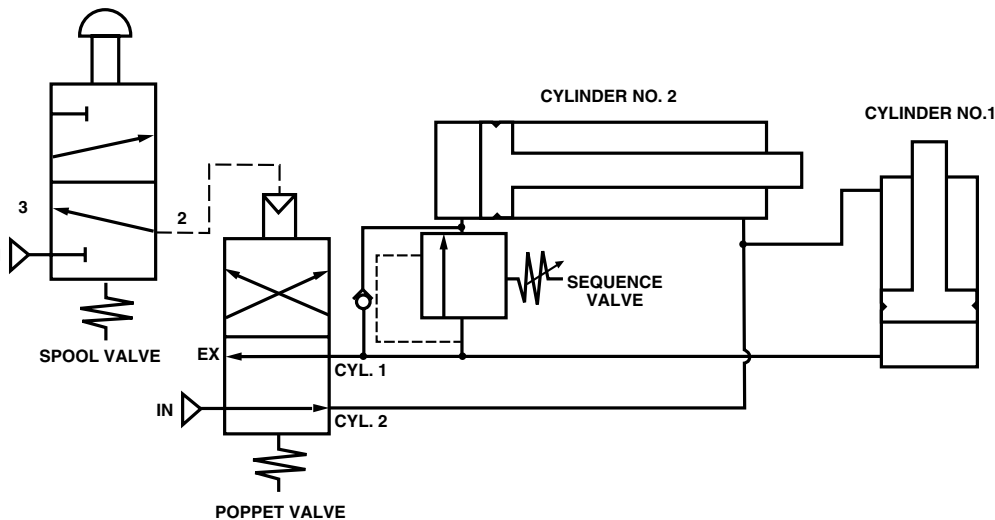
### Cylinder Extends, Retracts Automatically (Spool Valve Shown)

Operation of the manual valve causes the cylinder to extend, actuating the limit valve which resets the manual valve retracting the cylinder.



### Sequence Circuit, Cylinders Extend in Succession, Two Valves (Spool and Poppet Valves Shown)

Cylinder number 1 extends when the manual valve is actuated. When the pressure builds up to overcome the set pressure of the sequence valve (relief valve), cylinder number 2 extends.

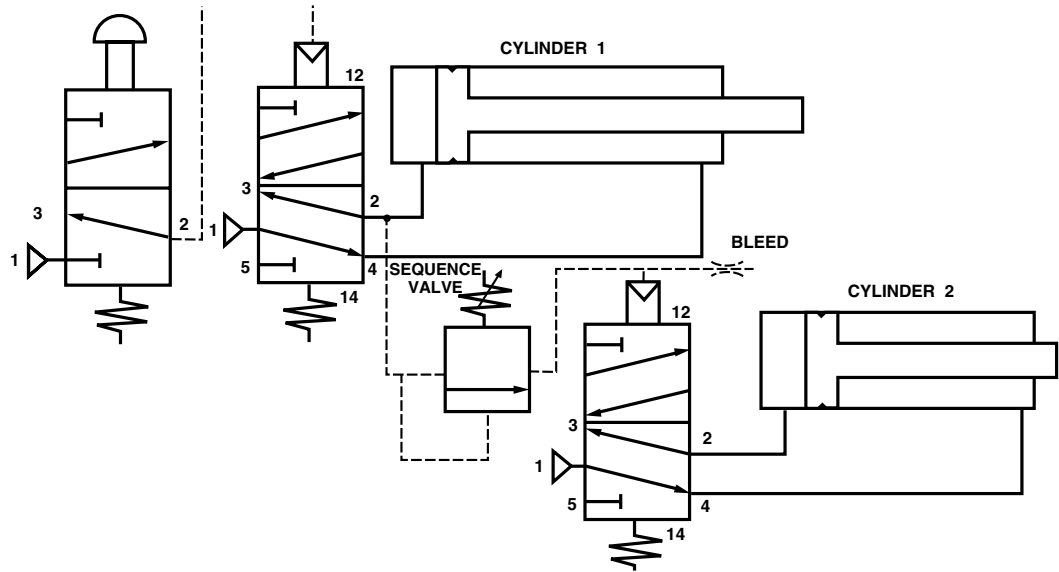


## Valve Applications, cont.

### Sequence Circuit, Cylinders Extend in Succession, Three Valves (Spool Valves Shown)

The sequence valve can be adjusted to allow the second cylinder to extend after cylinder number 1 has extended fully and the pressure has built up. Cylinder number 2 pressure is independent of cylinder number 1 pressure, the force generated by cylinder number 2 is not dependent on cylinder number 1.

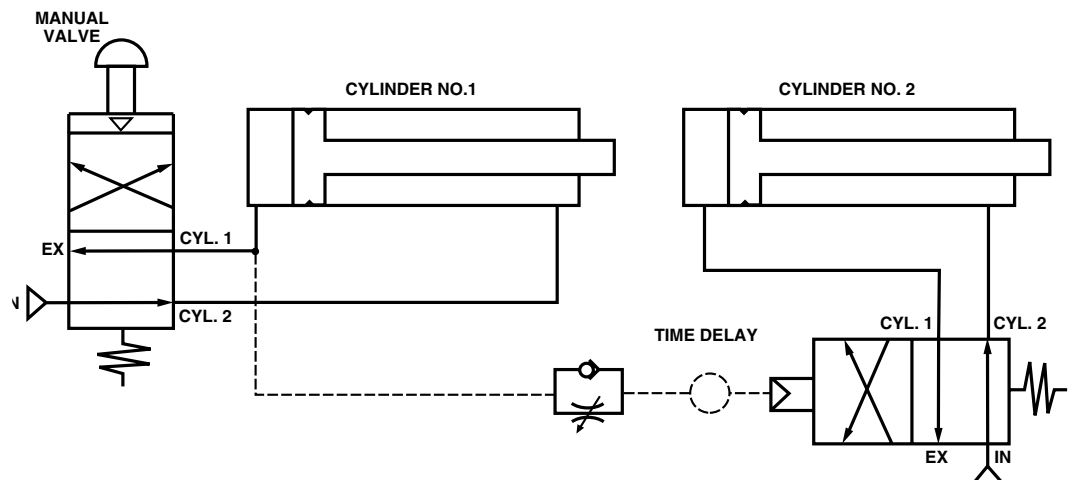
**Note:** A bleed must be provided as shown to exhaust pilot air.



This circuit is not suitable for use with Poppet valves because of crossover during shifting.

### Time Based, Cylinders Extend in Succession (Poppet Valves Shown)

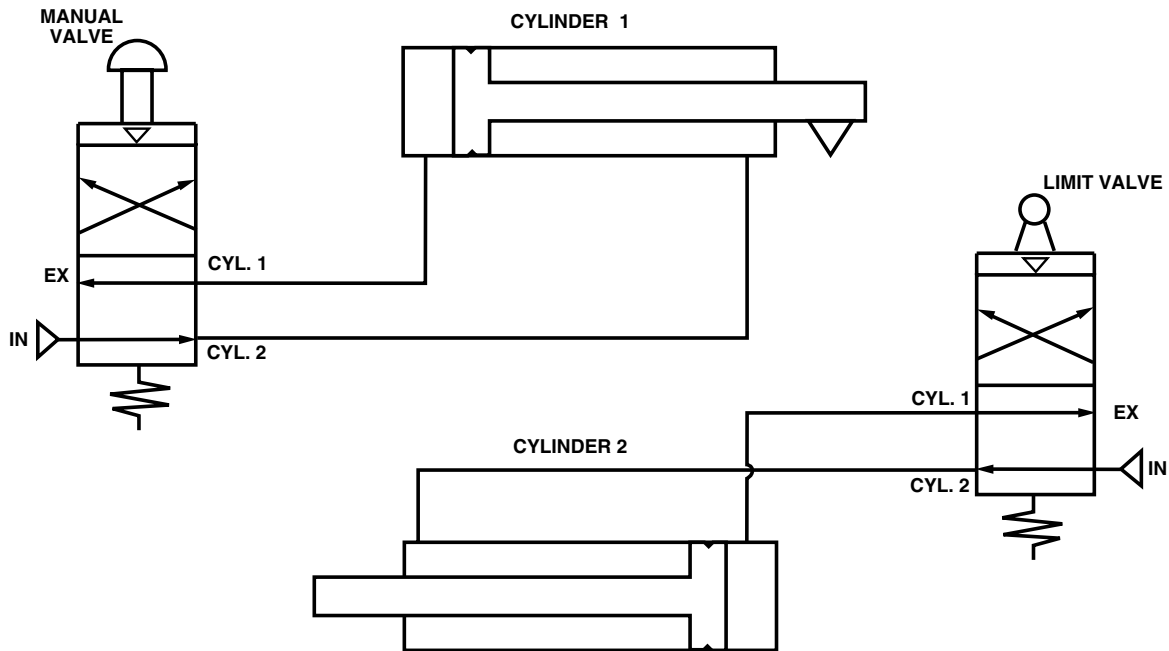
Cylinder number 2 extends only after a time delay, which starts when cylinder number 1 is extended.



## Valve Applications, cont.

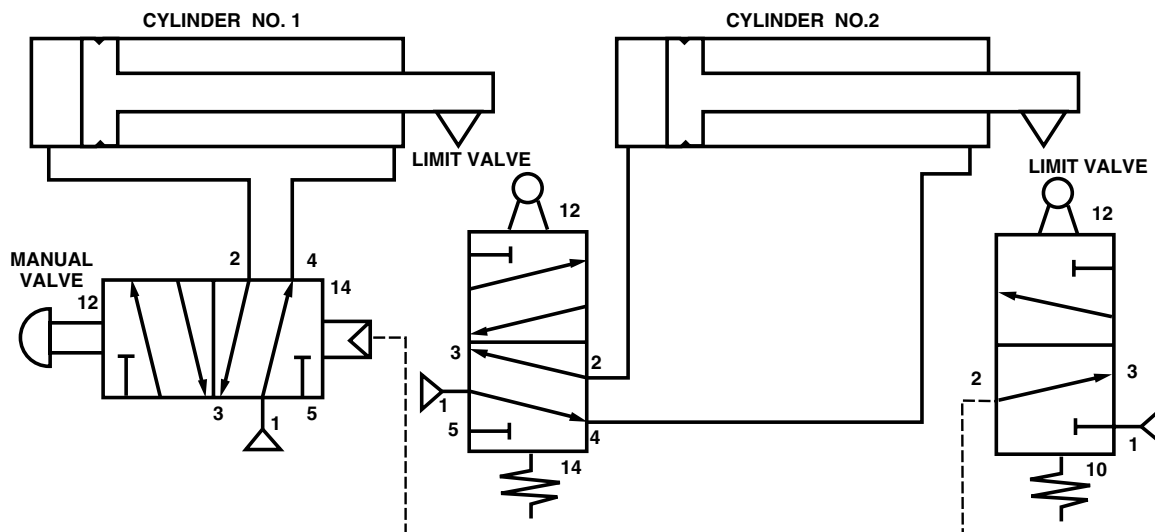
### Event Based, Cylinders Extend in Succession (Poppet Valves Shown)

Cylinder number 2 extends only after cylinder number 1 has reached a predetermined stroke (limit valve). Cylinders will retract almost simultaneously when the manual valve is released.



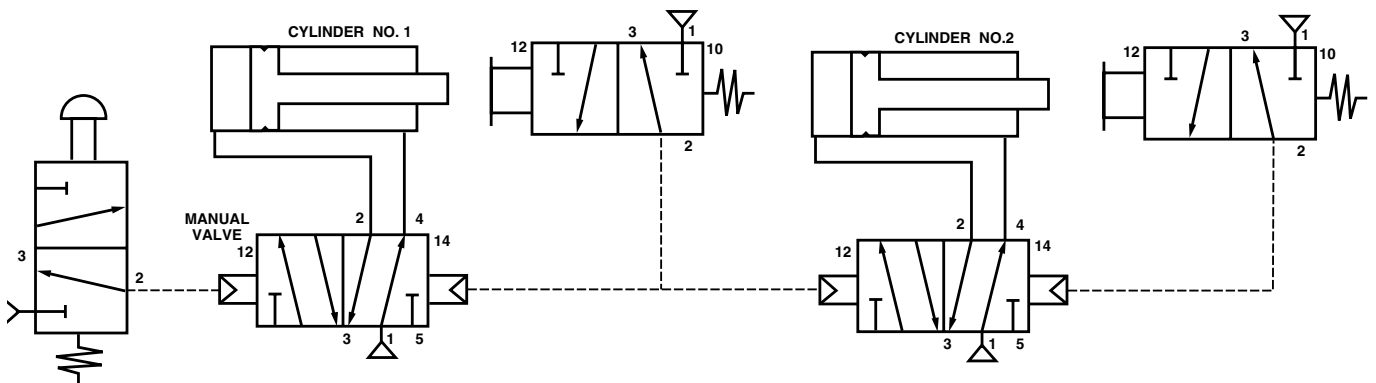
### Event Based, Cylinders Extend, Retract Automatically (Spool Valves Shown)

This circuit, when manually initiated, will cause the two cylinders to extend in sequence, then retract automatically. The manual valve will be returned to its original position in the process.



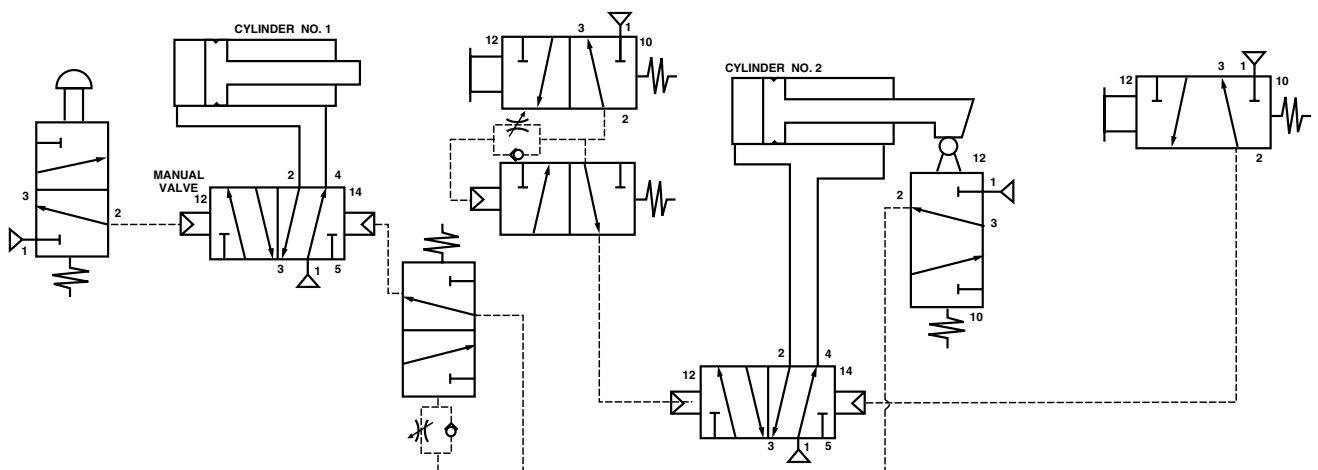
### Event Based, Cylinders Extend and Retract in Succession (Spool Valves Shown)

Cylinder number 1 extends when the manual valve is actuated, cylinder number 1 retracts and cylinder number 2 extends. Cylinder number 2 retracts.



### Event Based, Cylinders Extend and Retract, Cylinder Number 1 Brackets Cylinder Number 2 (Spool Valves Shown)

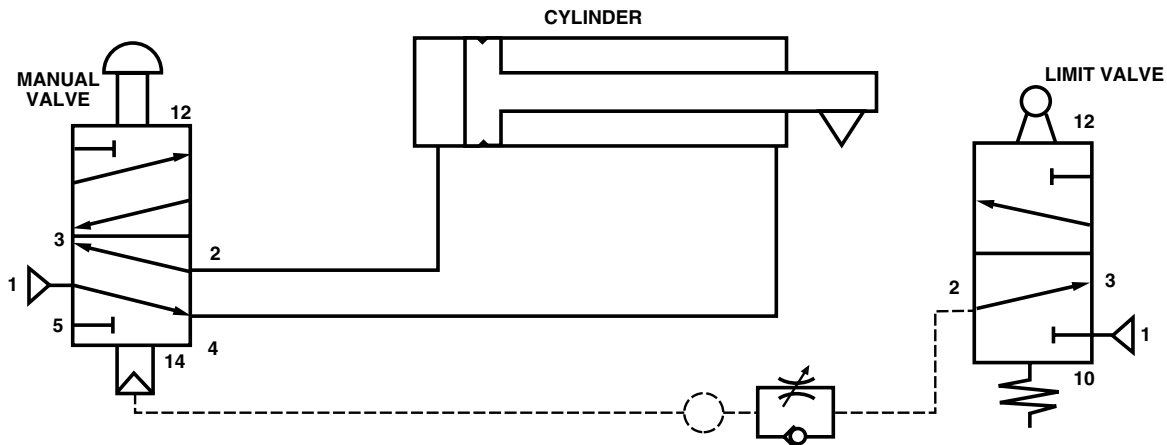
Cylinder number 1 extends when the manual valve is actuated. Cylinder number 2 extends, then retracts, finally cylinder number 1 retracts.



## Valve Applications, cont.

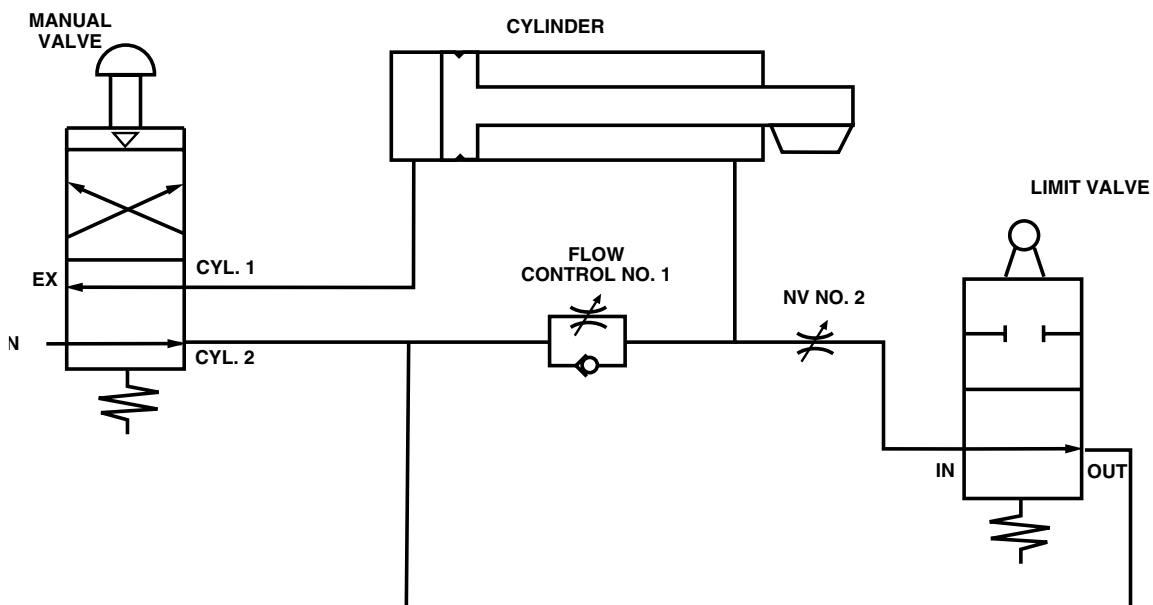
### Cylinder Extends, Dwells before Retracting (Spool Valves Shown)

The cylinder will extend and dwell before being automatically retracted. The volume will extend the dwell time and also improve repeatability by allowing more flow and less critical adjustment of the flow control.



### Cylinder Deceleration Circuit (Poppet Valve Shown)

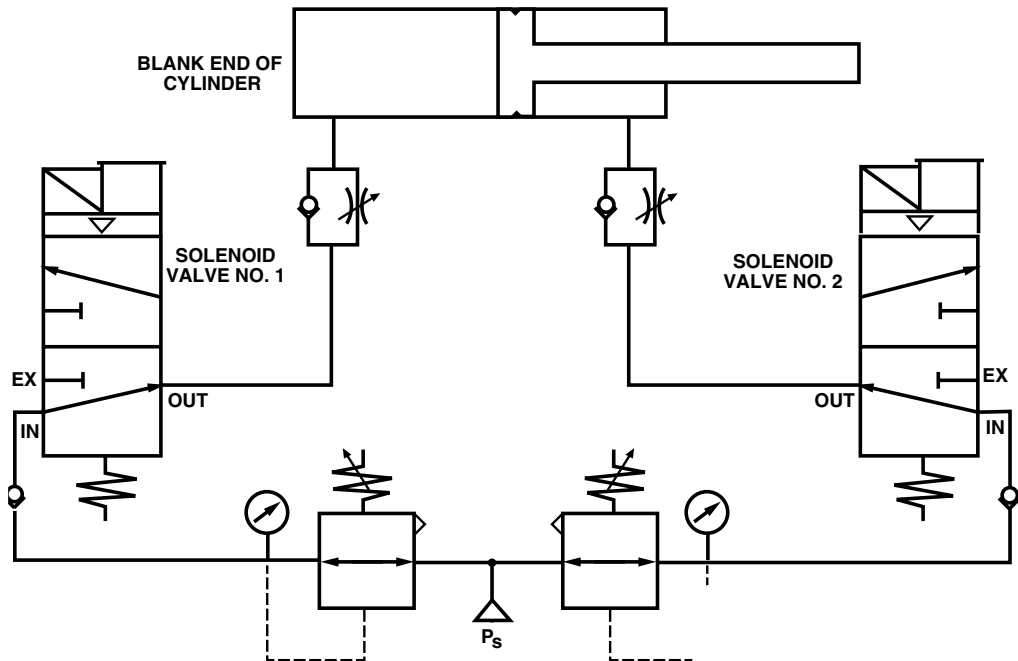
Cylinder velocity will be reduced when a predetermined position has been reached. Needle valve number 2 will be removed from the circuit when the limit valve is actuated by the cylinder rod, leaving flow control number 1 to control cylinder speed. This circuit will prevent damage to cylinders due to stopping of high momentum loads.



## Valve Applications, cont.

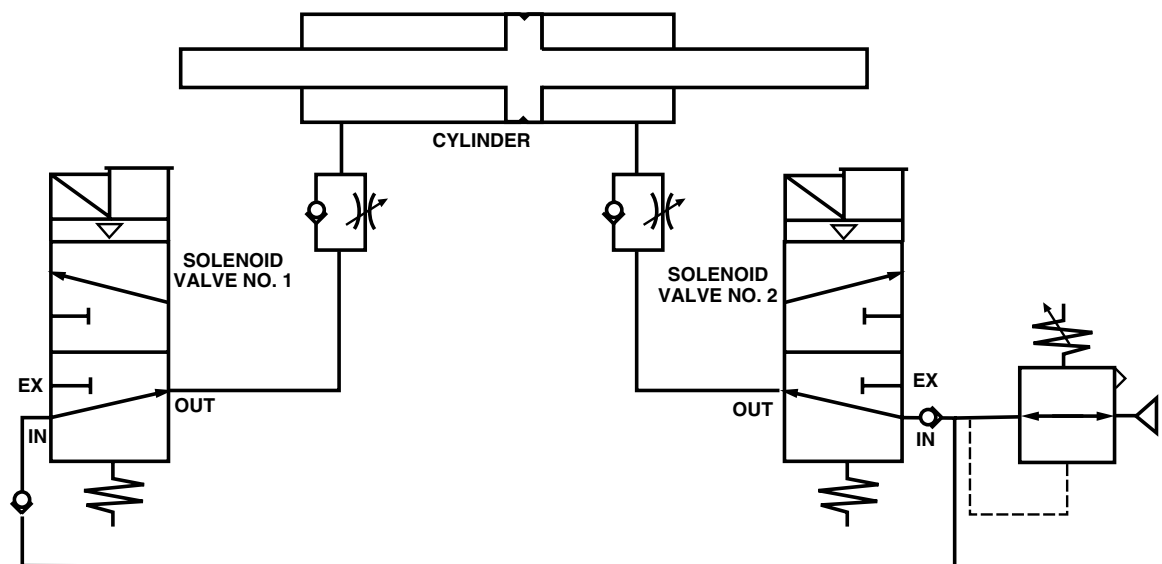
### Cylinder Positioning Circuit (Poppet Valves Shown)

Cylinder position is controlled by exhausting the cylinder end of the desired direction of travel. Regulator number 2 must be set at a higher pressure than regulator number 1 to balance the larger area of the blank end of the cylinder.



### Cylinder Positioning Circuit, Double Rod End Cylinder (Poppet Valve Shown)

Cylinder position is controlled by the same method as a single rod end cylinder, except the second regulator is not required. Piston area will be equal in a double rod end cylinder.

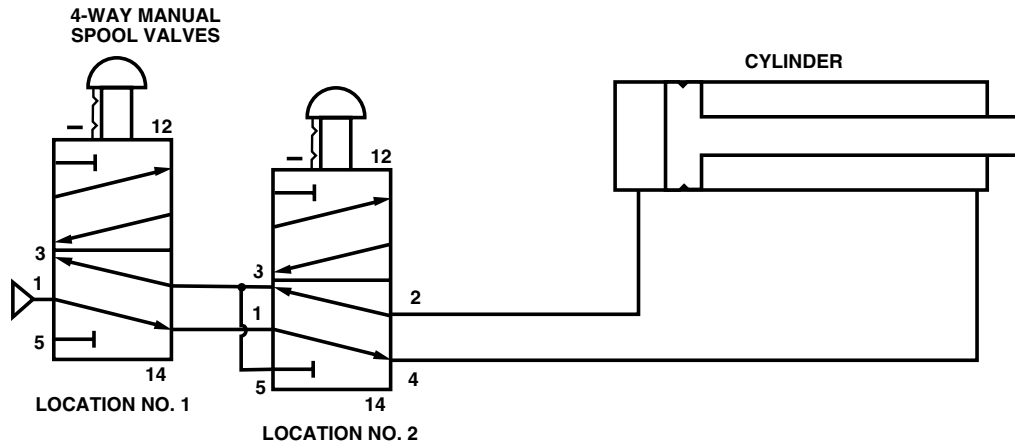




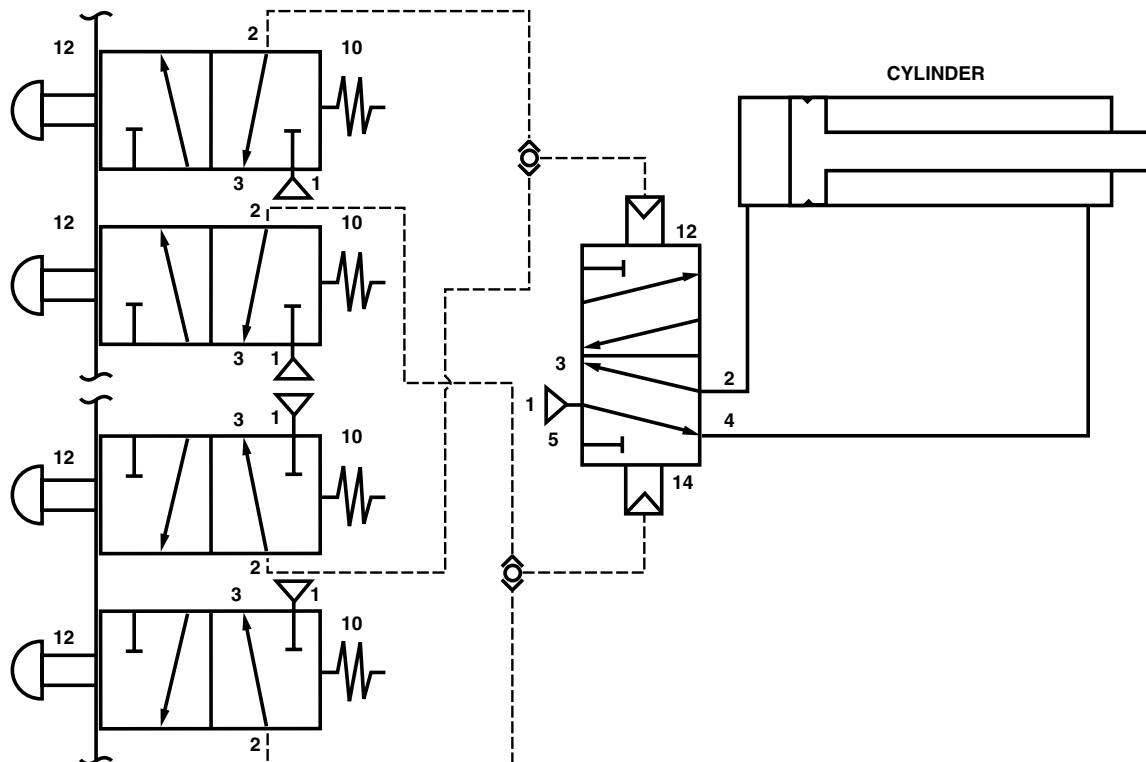
## Valve Applications, cont.

### Cylinder Controlled from Two Locations (Spool Valves Shown)

In the following circuit, operation of either valve will cause the cylinder to travel to its other position. Valve operation consists of shifting the valve to its other position.

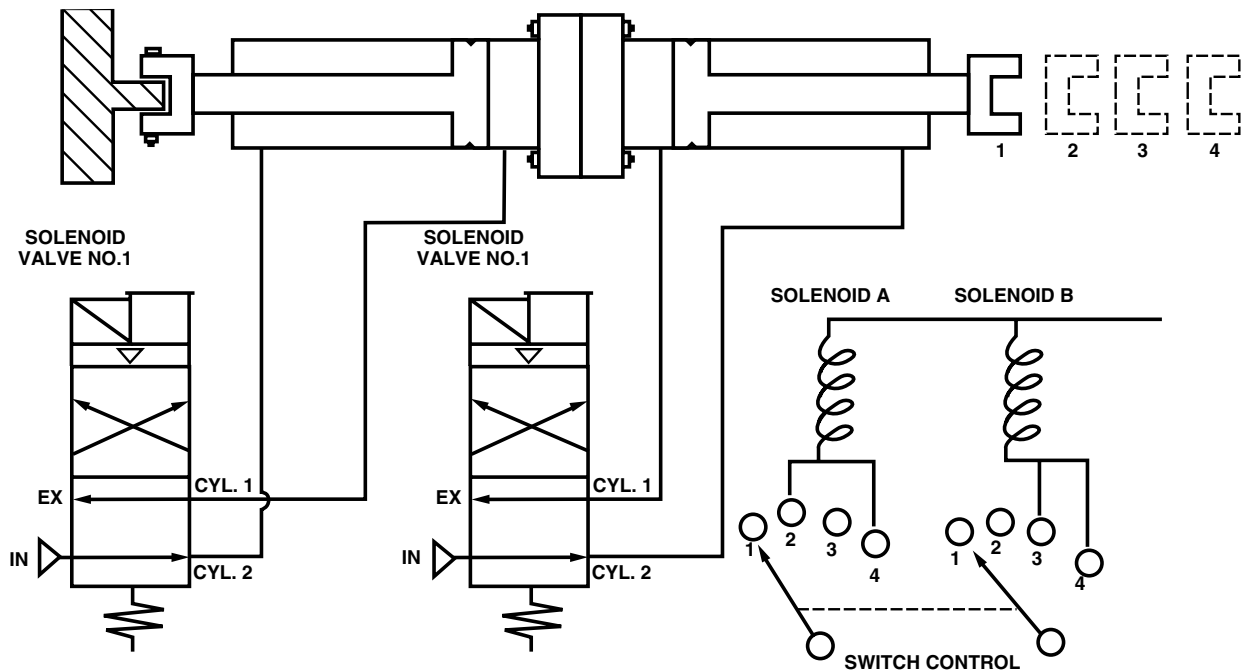


In the following circuit, two sets of manual valves control the cylinder extension and retraction from two locations.



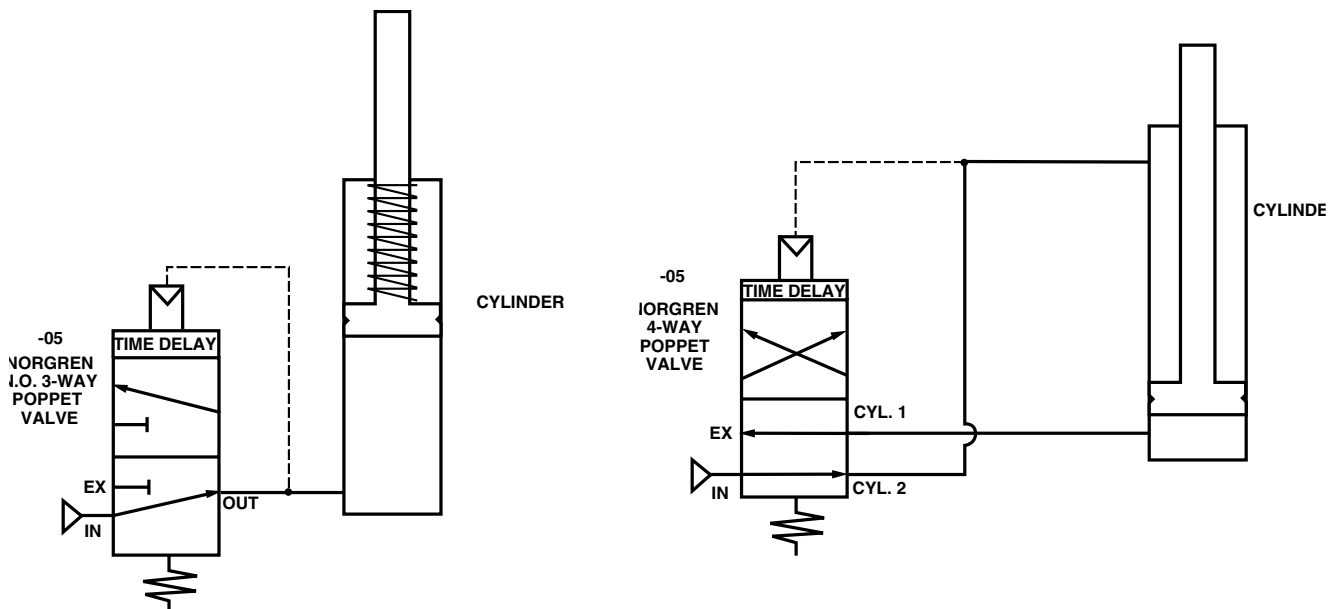
## Positive Cylinder Positioning “Four Positions” (Poppet Valves Shown)

The two solenoid valves are controlled in four different combinations by a double wafer electrical switch to give four distinct positions.



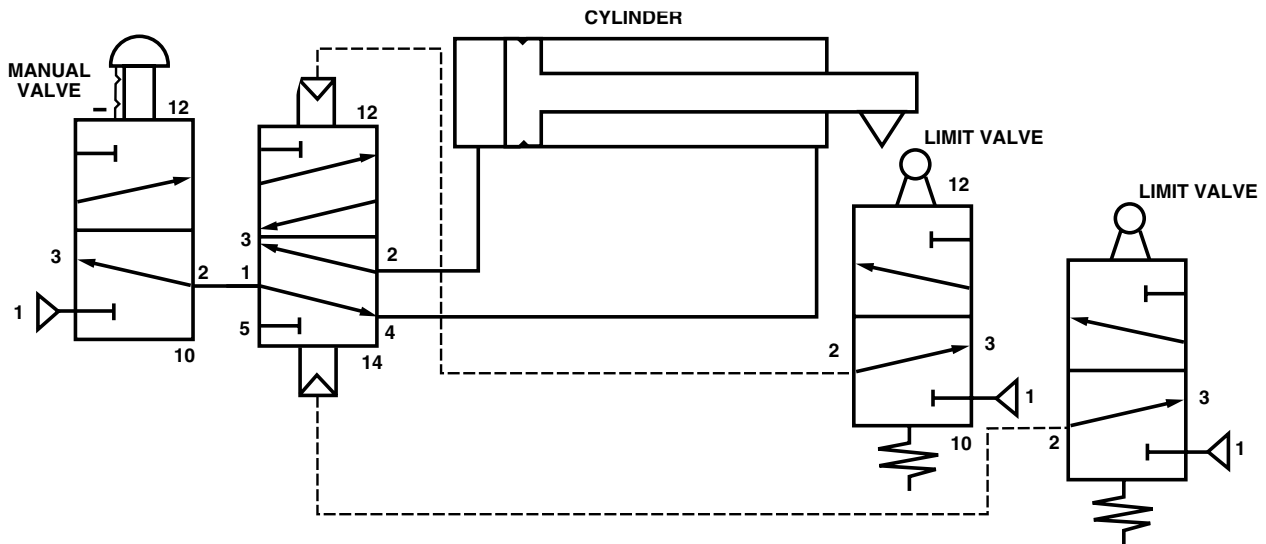
## Continuously Cycling Cylinder, Time Based (Poppet Valves Shown)

The use of Norgren -05 time delay with a normally open 3-way or 4-way poppet valve per the following diagrams will produce a continuously cycling cylinder, adjustable up to one minute in each direction. Cycle frequency and dwell time can be adjusted individually. Shut-off valves are used upstream of either valve to control start and stop function .



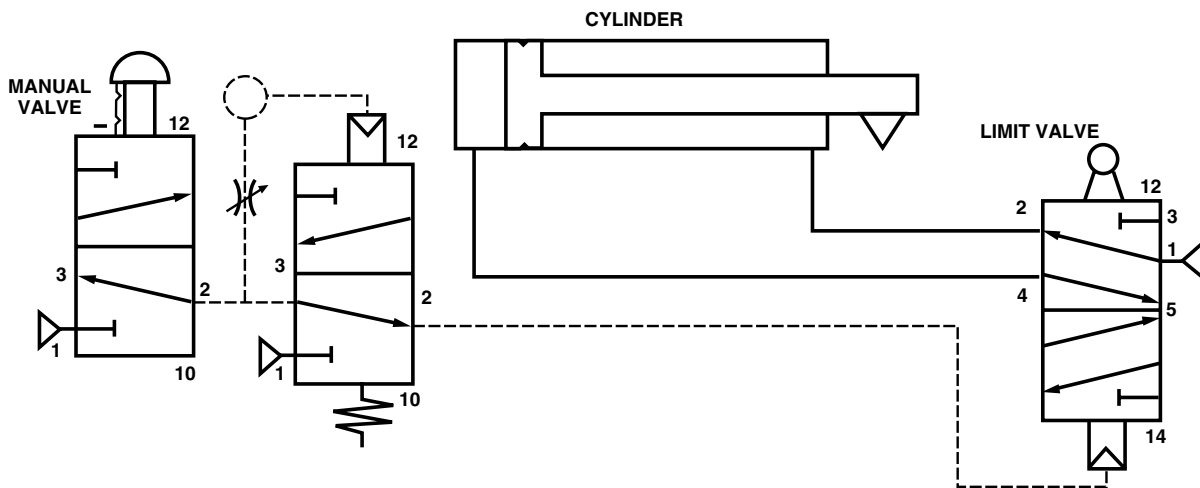
### Continuously Cycling Cylinder, Event Based (Spool Valves Shown)

When the manual valve is actuated, the cylinder will extend and then reverse direction continuously each time it reaches either limit. Returning the manual valve to its normal position will stop the cylinder.



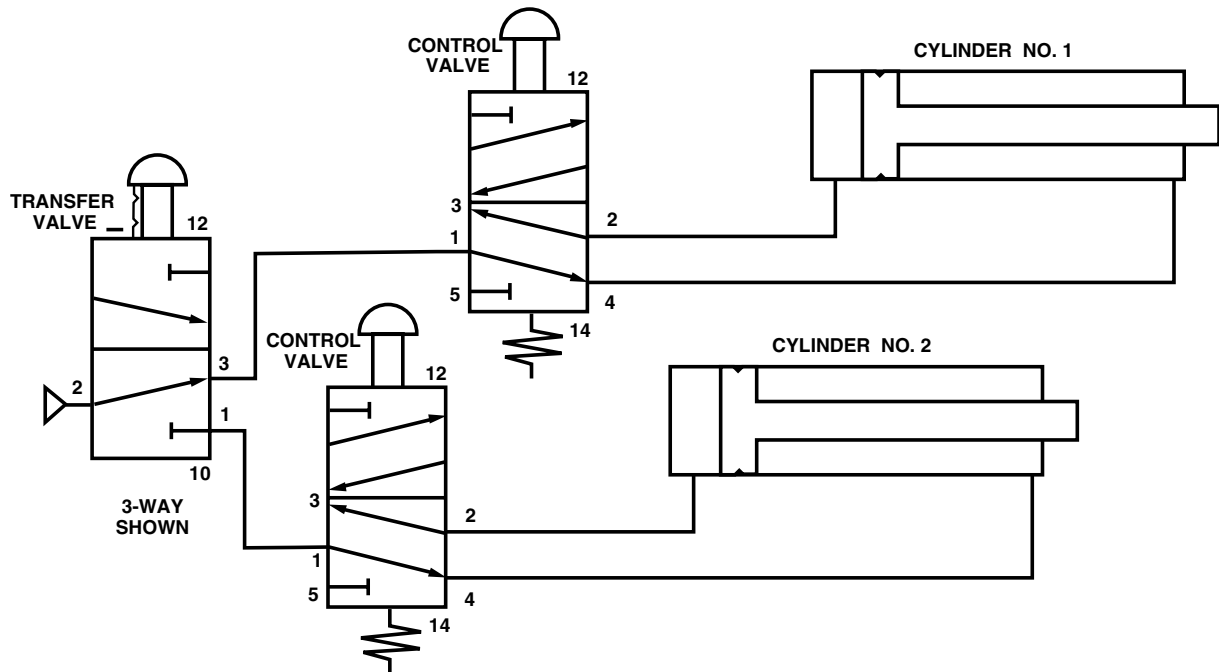
### One Cycle Cylinder Operation with a Short or Long Manual Start Signal (Spool Valves Shown)

This circuit will cause the cylinder to cycle once, regardless of how long the manual start signal is applied. The manual valve has to be released before another cycle can be started.



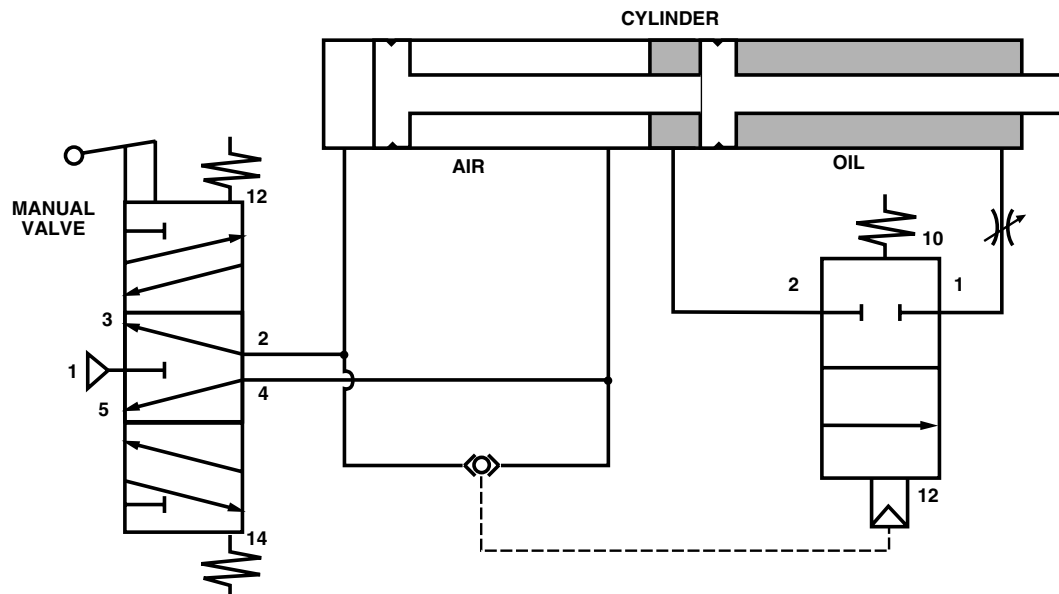
### Cylinder Control Transfer (Spool Valve Shown)

This circuit allows only one cylinder to be operative at a time. Use of a 3-way valve for transfer control causes the cylinders to remain in their last position when control has been transferred (pressure is not exhausted). The use of a 4-way valve for transfer control will cause the cylinder to be free floating when control has been transferred (pressure is exhausted).



### Cylinder Feed Rate Control with Positive Lock in any Cylinder Position (Spool Valves Shown) (Air Over Oil Cylinder)

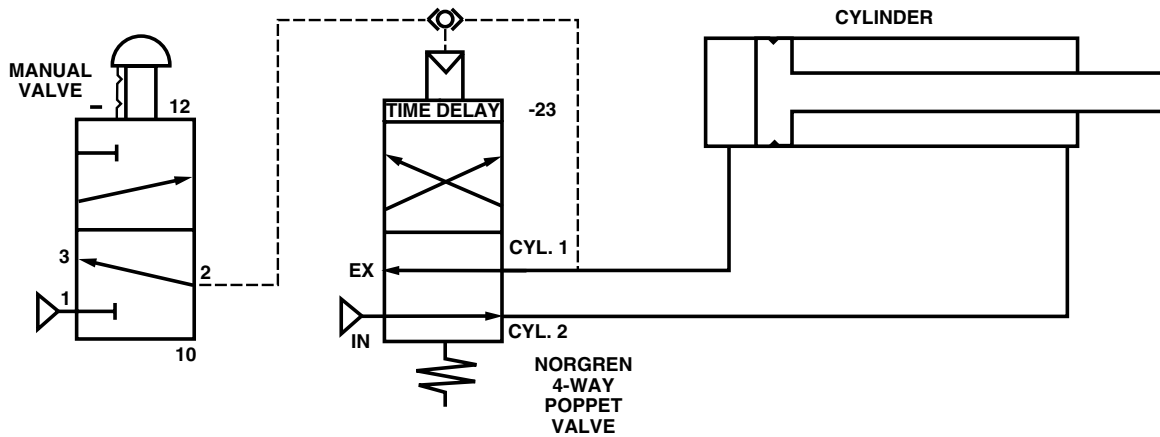
This circuit provides a constant cylinder feed rate for both directions of travel. In addition, the cylinder will lock in position when the manual valve is centered. Air provides the force to move the cylinder; oil, with its feature of non-compressibility, is used to give smooth cylinder motion.



### Cylinder Control-One Cycle, Starts of First Operation (Poppet Valves Shown)

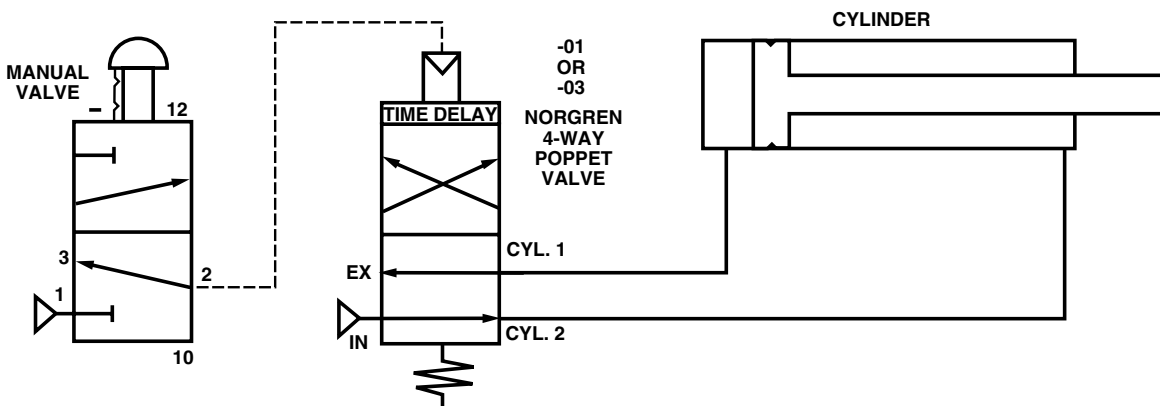
The cylinder will cycle once regardless of multiple start signals or how long the manual valve is actuated. Time of cylinder cycle adjustment is up to one minute.

Circuit consists of a Norgren 4-way valve with a -23 time delay and a shuttle valve.



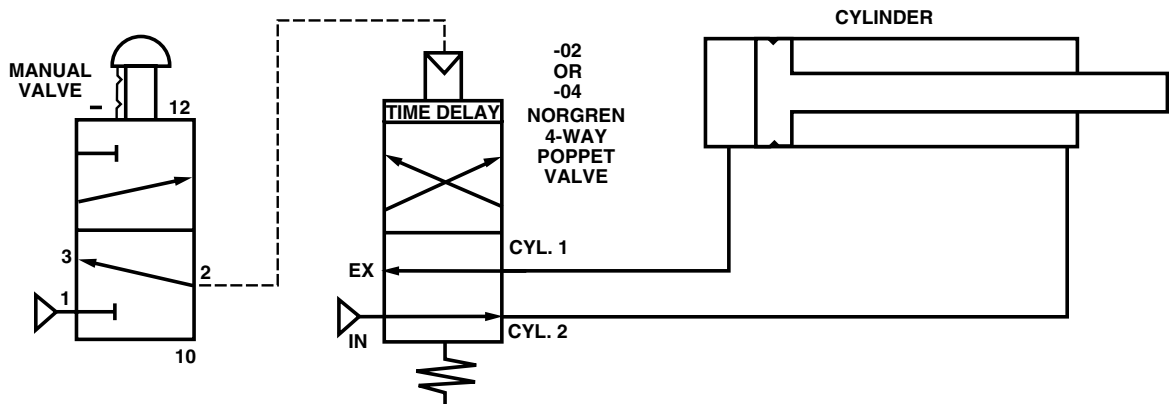
### Time Delay on Extension of Cylinder (Poppet and Spool Valves Shown)

The cylinder extension can be delayed up to one minute after the manual valve has been actuated by using a Norgren T.D.O. (-"01"=0-5 seconds, or "03" = 0-60 seconds) time delay and a 4-way valve.



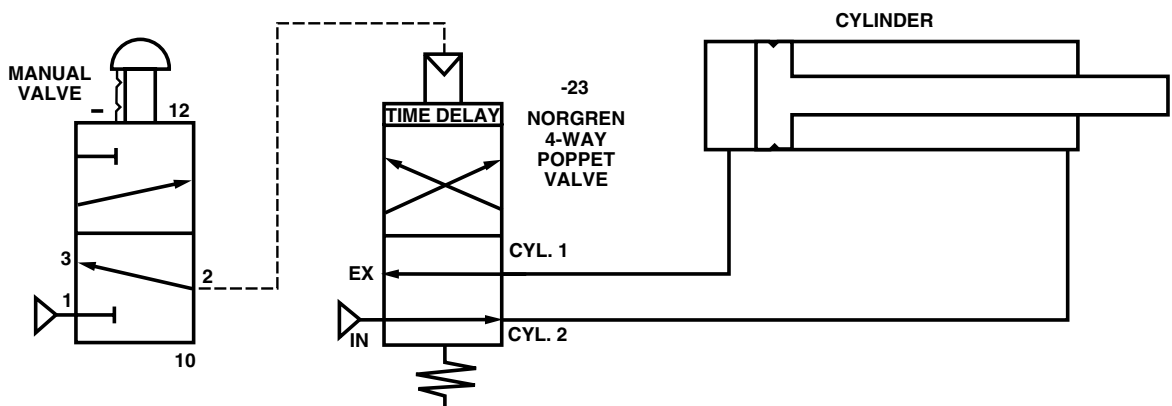
## Time Delay on Retraction of Cylinder (Spool and Poppet Valves Shown)

The cylinder retraction can be delayed up to one minute after the manual valve has been deactuated by using a Norgren T.D.R. (-"02 = 0-5 seconds, or -"04 = 0-60 seconds) time delay and a 4-way valve.



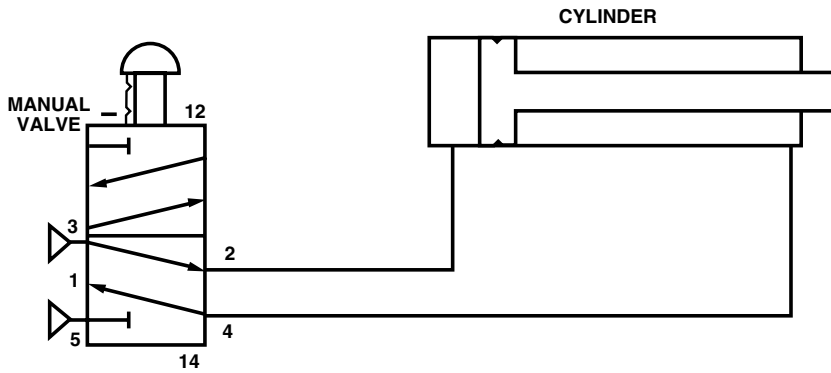
## Cylinder Cycles Once with Long Signal to Valve (One-Shot) (Spool and Poppet Valves Shown)

The cylinder will complete one cycle when a long signal has been applied to the power valve by using a Norgren -23 time delay and a 4-way valve. This circuit is for pulse shortening. Use circuit on top of page 20 for pulse stretching.



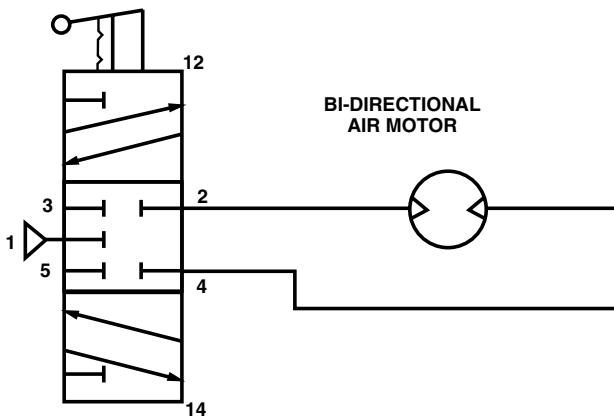
### Dual Pressure System (Spool Valve Shown)

A dual pressure system using a 5-port spool valve can be used to extend a cylinder with one pressure level and retract the cylinder using a second (normally lower) pressure. Cost savings of the differences in the air pressures used can be realized using this circuit. Port 1 becomes a common exhaust.

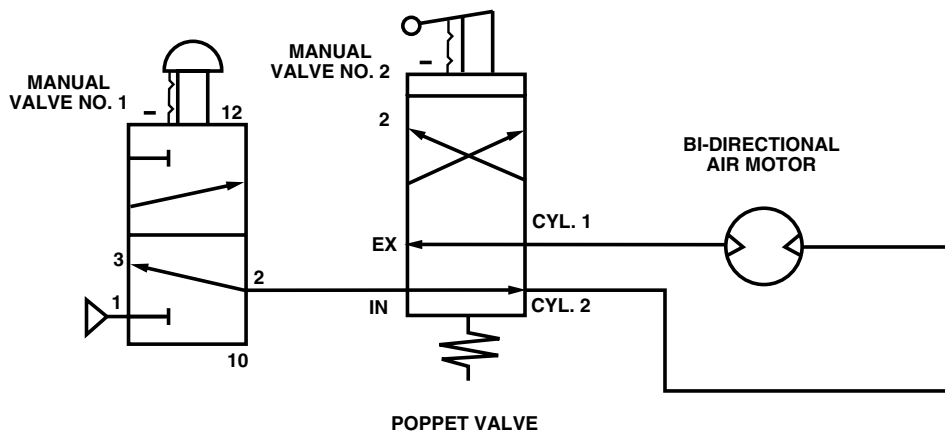


### Bi-Directional Air Motor Control (Spool Valves Shown)

A bi-directional motor can be controlled to run in either direction by using a 4-way 3-position spool valve.

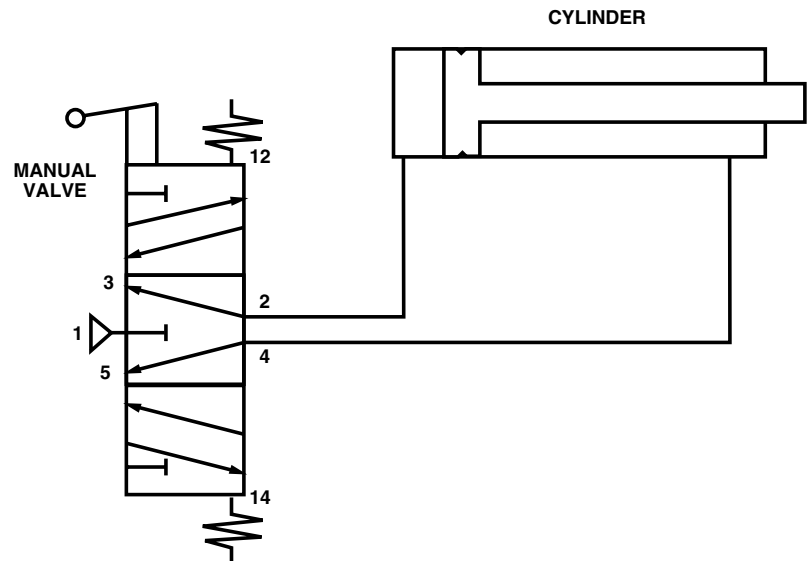


If a 4-way poppet valve is used, a second valve is required for on-off control of the air motor.



## Cylinder Float (Spool Valve Shown)

The cylinder can be made to float in any position of its travel when the valve is in its center position.



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# SAFELY APPLYING 3-POSITION AIR VALVES

A great deal of confusion exists regarding the application of 3-position valves with double acting pneumatic cylinders for emergency stop and jog-type cylinder applications. Many times, the designer is asked to provide these actions when they are not necessary and without realizing the additional complexity and cost required.

Each 3 position application should be examined closely for the following:

- Is there a requirement to stop the cylinder in mid-stroke?
- Is jogging of the cylinder, extend or retract, required?
- Is emergency stop of the cylinder, during extend or retract, absolutely necessary?

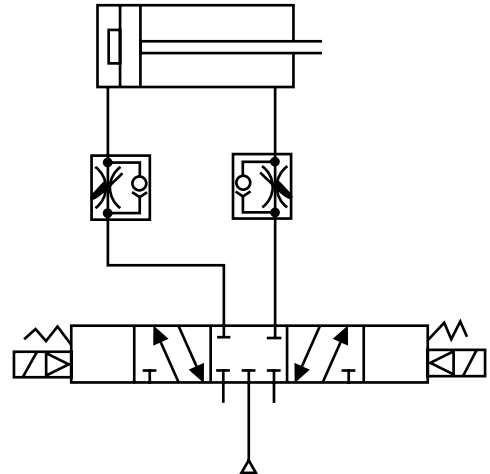
Improper applications of 3-position air valves to satisfy the above applications may, during start-up or repair, create additional safety hazards. The purpose of this discussion is to point out those hazards.

## 1. 3-POSITION - All Ports Blocked

This valve is frequently used to stop or jog an air cylinder in mid-stroke.

Be aware of the following:

- In the center position, air is trapped in the cylinder. Fitting, cylinder seal, or valve leakage will allow the cylinder to drift.
- When air is exhausted by a lockout and exhaust valve, air may still be trapped in the cylinder. For example, a vertical cylinder supporting a load, when the cylinder is opened, the load may drop unexpectedly.
- During start-up, when the lockout and exhaust valve is opened, the blocked center condition does not allow air to return to the cylinder. When full pressure is applied to the valve, and the valve is actuated, the first stroke of the cylinder may be at high speed due to the lack of air in the cylinder. This uncontrolled start-up can cause internal damage to the cylinder as well as the machine.

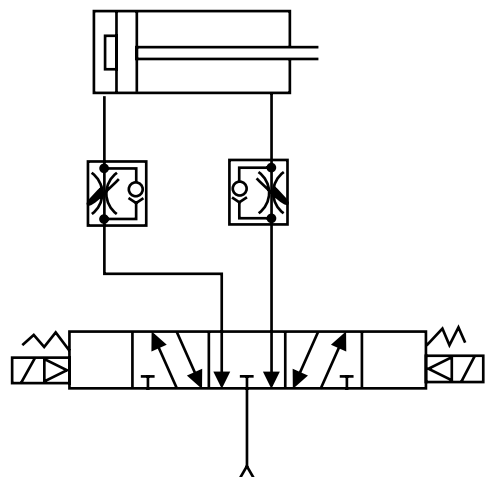


In the first two cases, the actions occur when least expected.

When it is necessary to provide jog or emergency stop, the following circuit is suggested.

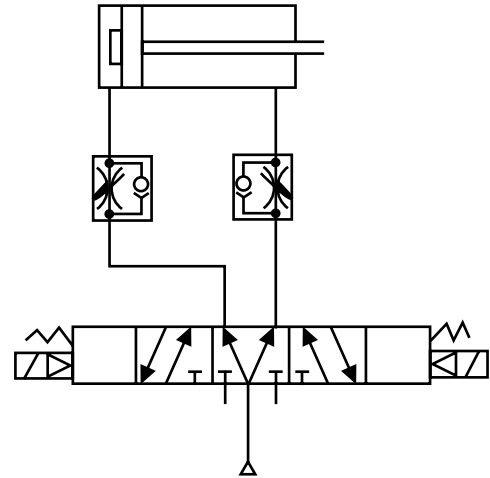
## 2. 3-POSITION Cylinder Ports Open to Exhaust (Single Pressure)

- The exhausted cylinder condition does not allow the cylinder to hold position against external loads.
- If the cylinder is moved from its normal extend or retract position, actuating the valve will cause rapid cylinder movement due to a lack of air in the cylinder (uncontrolled start-up).



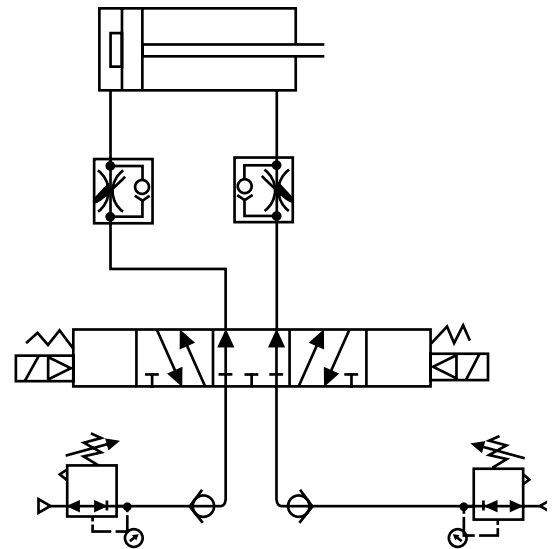
### 3. 3-POSITION - Inlet Open to Cylinder Ports

- a) Equal pressure supplied to both sides of the piston creates an unequal force, due to rod area differential, which causes the cylinders to extend. Many times a regulator will be installed in the blind end cylinder line to drop the blind end pressure and equalize the force (we all know this would be an improper application of a regulator). The application of full-line pressure to this regulator during normal cylinder cycling leads to premature regulator failures.
- b) Cannot be used to support vertical loads.



### 4. 3-POSITION Cylinder Ports Open to Exhaust (Dual Pressure Applied)

- a) This circuit provides the system with make-up pressure to overcome fitting, valve, and rod seal leakage.
- b) Check valves provide back pressure to the cylinder to help hold against external loads. The check valve also protects the regulators against sudden inertial loads
- c) Independent pressure regulator allows adjustment for piston differential and vertical loads.
- d) During start-up, when the lockout and exhaust valve is opened, air is supplied to both ends of the cylinder to prevent run-away condition when the valve is first actuated.



### CAUTION

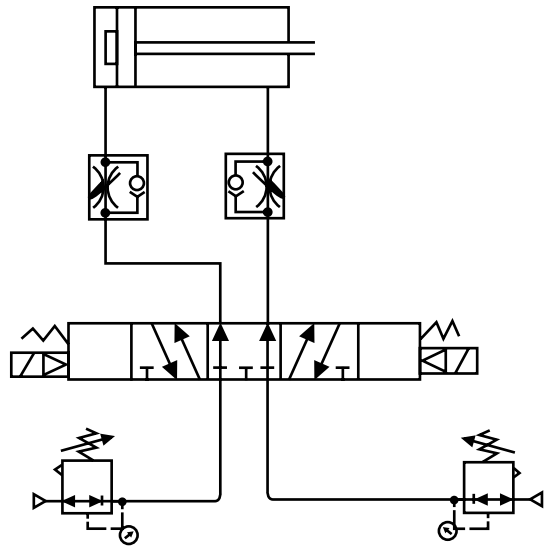
When air is exhausted by a lockout and exhaust valve, air may still be trapped in the cylinder. A vertical cylinder supporting a load may unexpectedly drop when the cylinder line is opened or disconnected. Applications requiring this method of control may not be incorporated into manifold assemblies. They must be piped as individually mounted valves.

### 5. 3-POSITION - Cylinder Ports Open to Exhaust (Dual Pressure Applied)

- a) This circuit provides system pressure to overcome filling, valve, and rod seal leakage.
- b) Regulator may adjust to compensate for piston differential area to provide jog or emergency stop control.
- c) When air is exhausted by a lockout and exhaust valve, all air is vented with no trapped air.
- e) During start-up, when the lockout and exhaust valves are opened, air is supplied to both ends of the cylinder to prevent an uncontrolled start-up when the valve is first actuated.

#### NOTE

Not recommended for vertical cylinders supporting heavy loads. Some drift of the cylinder may occur when centering the valve due to relieving regulators.



#### SUMMARY

Evaluation should be made to determine the need for a 3-position valve.

- Many times during emergencies or loss of electrical power, a spring return, 2-position valve may be used where no pinch point exists or an action is guarded and the cylinder may return to its normal position.
- 2-position, detented valves are normally used on clamps, etc., to maintain the cylinder position during loss of electrical power. They may be energized during the forward stroke to return to the normal position during emergencies, provided guards are present and no pinch points exist.
- 3-position valves should be held energized except during jog or emergency stop conditions. This maintains full pressure on one end of the cylinder to provide full force and prevent drifting.
- Cylinders, controlled by 3-position valves, must not have leaky piston seals. Leaky seals allow the air to bypass the piston, causing the cylinder to drift.
- Regulators should not be installed between the valve and the cylinder.
- When in doubt, circuit #4 with regulators and check valves provides the best alternative.
- Air cylinders cannot be depended upon to hold location in mid-position during manufacturing operations. A method of positive location control must be used.

