

Pneumatic Safety Systems and Cylinder Speed Control

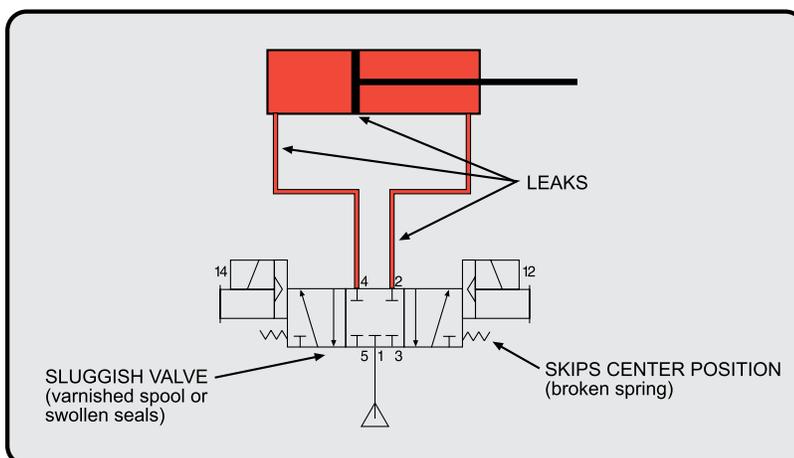
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The advancements in automation systems have led to tremendous increases in productivity for manufacturers. Machine controls utilizing sensing and verification of the product and position sensing of machine components allows for higher speeds of equipment and improvements in quality. Improvements in safety have also been achieved, greatly reducing the instances where operators are required to interact with the equipment during operation. However, automated machines are not autonomous. Material deviations or component malfunctions still require an operator to investigate and alleviate the situation. Because of this, operators and maintenance personnel must access potentially hazardous areas in the machine for functions such as clearing jams and other routine production related issues. These production related issues must of course be done in a safe manner; advancements in safety control systems are helping to make this possible.

Industry-accepted best practices for machine safety system design involve the completion of a risk assessment that looks at the tasks involved, foreseeable misuse, and component malfunction. The safety system should not cause damage or premature wearing of components. This damage could be caused by stop commands occurring at any point in the machine cycle or the reapplication of pneumatic energy causing rapid movement of components. Premature wear causes greater man-machine interaction due to it leading to a greater frequency of malfunctions and maintenance related activities.

Pneumatic safety, in the past, consisted of a few primary components to stop and control motion. It was very common to use closed center valves in order to hold cylinders in place. This would trap pressure on both sides of the cylinder and generally leads to the desired effect. But this approach ignores three primary issues; slow or sticking valves, testing of the center position which is dependent on spring functions, and the effects of leakage when using spool valves. All three of these issues can result in potentially hazardous motion.

Slow valve response allows for motion to continue longer than anticipated. In normal operation a 5/3 Closed center valve may shift from one side to the other without the center position being used except during a safety event. An untested center position may result in a valve simply shifting as in normal operation. A closed center valve traps pressure on both sides. Greater leakage on one side would result in movement and if the cylinder is vertical a closed center valve maintains pressure on the top side of the cylinder adding force to the potentially hazardous condition.

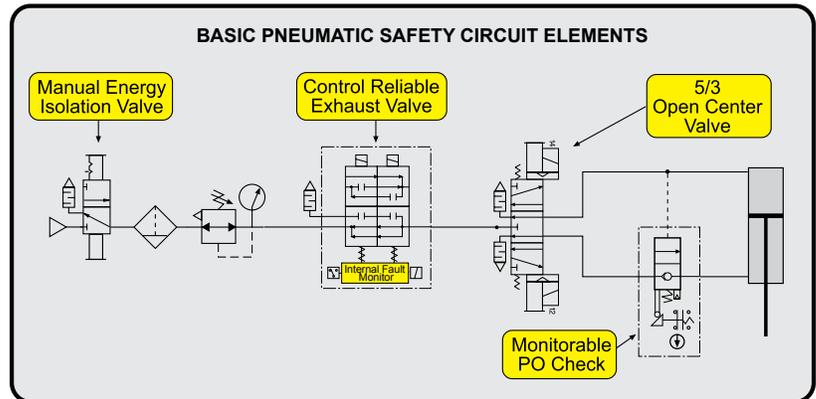


A sluggish valve might take longer to achieve the center position, thus, causing an increase in stopping time. Also, if the center position is only used for safety stops, it may not be tested regularly to make sure the valve will actually go to the center position when both solenoids are turned off. (What if a spring breaks in the valve?) Also, leaks in either cylinder line or in the cylinder piston seal can cause an unbalanced pressure condition in the cylinder allowing unexpected movement.

This led to the use of electrically operated dump valves used in conjunction with 5/3 open center valves or 5/2 spring return valves. Dump valves are generally 3/2 normally closed valves used to “dump” the air pressure from the downstream portion of the system. Because these dump valves are now being used as part of the safety system, they should also meet the same safety category requirements (or performance level) as the rest of the safety system. This configuration of dump valve and directional valve removes all pneumatic energy from the system so that even a malfunctioning valve would not result in continued motion due to pneumatic energy. Should there be concerns due to the speed and load requiring a more responsive and immobile stop, then pilot operated check valves would be used where required. With this arrangement the air supply is removed from both cylinder lines and the pilot operated check(s) holds the cylinder in place by trapping pressure in the cylinder. With vertical cylinder arrangements where gravity is a factor it is usually only necessary to trap the pressure on the bottom end of the cylinder as opposed to trapping pressure on each end with horizontally oriented cylinders.

This use of a 3/2 control reliable electrically operated exhaust valve, 5/2 spring return or 5/3 open center cylinder valves, and pilot operated checks is the most effective safety circuit used in automated equipment. The end result is a safer machine that can be stopped at any point in its cycle, whether there are cylinders fully extended, fully retracted, or in a mid-position. There may be air trapped in one end and no air at the opposite end of the cylinder.

There are two primary reasons to stop the machine. The first is production related and the other is for maintenance purposes. Production related issues must utilize a risk assessment to ensure a safe state is reached and maintained to complete the required task. Maintenance issues will require lockout and steps must be taken to mechanically block the machine from moving and release any trapped pressure that had been selectively trapped for the purposes of affecting a safe stop.



The next step after the work is completed is to safely re-energize the machine. The re-application of air is an event that should not cause unexpected motion or cause what is otherwise avoidable damage to the machine. The old saw is, “When in doubt meter out.” By using a flow control to reduce air flow out of a cylinder you can control the speed of the cylinder no matter how fast air is added to the opposite side. This is especially true to prevent meter-in slip-stick issues caused by a combination of friction, flow, volume, and load. This meter out assumption goes away with safety systems that remove the primary air supply and the air from all or parts of the cylinder. In this case there is no air left in the cylinder to meter out which can result in a run-away cylinder when air is re-applied or during the first cycle of the valve and cylinder.

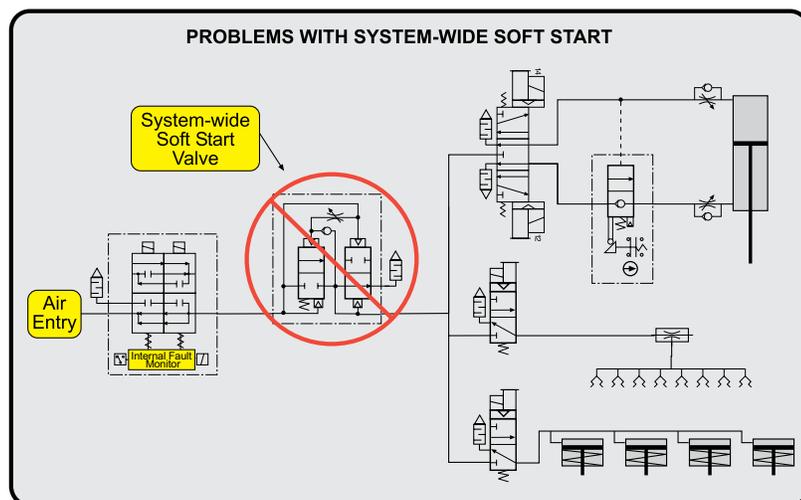
Another possible solution for this is to meter into the cylinder. By using a flow control to limit the air flow into the cylinder you can control the motion. This is practical for most applications except where friction, flow, volume, and load create a slip-stick issue. Also, if a vertical load is enough to overcome the break-away friction of the cylinder seals, then a metering-in device on the top end may not have the speed limiting effect desired as the force of gravity alone will cause the cylinder to fall unless air is present in the bottom end of the cylinder and a meter out device is used.

An alternative to metering-in is to meter the entire system as a whole when air pressure is first applied after a safety event or even a normal shut-down. This is known as a soft start because the air pressure rises slowly until an adjustable



2/2 EEZ-ON® Valve

preset point is reached before full line pressure is then supplied downstream to all components. Advantages are that the downstream components will move slowly into place and individual flow control components may not be required in all locations. There are devices available to soft start the whole system or just at the point-of-use. A soft start device coupled with meter-out flow controls at the actuators seems to be an ideal solution at first glance and can be in some cases.



System-wide soft start can be problematic. In this example circuit with solenoid pilot valves downstream, the valves must remain switched off at least until minimum operating pressure is reached, otherwise they may not shift properly. This also means that the cylinders will not start softly, but will immediately see full pressure when the valves are switched on.

Additionally, when items such as venturi type vacuum generators are present they will act like a leak in the system which could prevent the soft start valve from switching to full flow. Also, supplying the suction cups and clamping cylinders from the safety exhaust valve can cause an additional hazard of possibly dropping material when a safety stop or e-stop is initiated. A solution is to use point-of-use soft start and move the supply for the vacuum generator and clamping cylinders upstream of the safety exhaust valve.

The overall effect of a soft start device is entirely dependent upon the actuator valves, the position of the cylinders when stopped, and auxiliary devices such as flow controls and pilot operated checks. The first consideration is determining where air is removed or trapped during normal operation of the safety system. The second consideration is to determine where air is removed or trapped during a component malfunction as required by the risk assessment.

When pneumatic energy is re-applied (assuming no electrical signals have already been re-applied, especially with the use of direct solenoid valves) all actuators controlled by 5/2 spring return valves will move into their de-actuated position slowly and will also move at the proper speed when the valve is initially energized. The machine returns to its normal at rest condition in an orderly, safe fashion. If the spring return valve were to malfunction the cylinder may move in the wrong direction when air is re-applied but would do so at a reduced speed.

However, in many continuous process machines returning to an at-rest condition is not an option. Cylinders must stop in their location and remain there when pneumatic energy is re-applied. In these applications 5/3 open center valves with pilot operated checks are routinely used and system-wide soft start will have no affect whatsoever because the pressure was only built-up slowly to the valve which, at rest, blocks flow further downstream. Because of this the pneumatic supply to the actuator valves will be at full pressure (while the cylinder has no pressure on at least one end) when the valves are first actuated causing rapid initial motion; unless point-of-use soft start devices or meter-in flow controls are used.

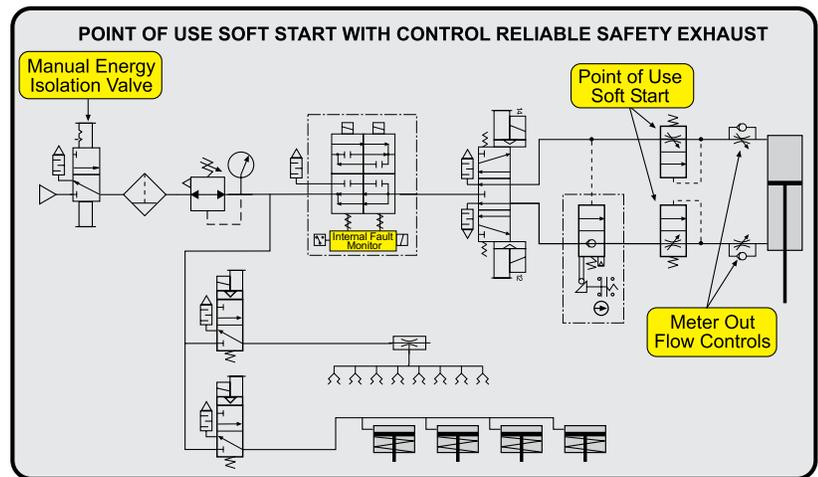


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The primary difference between a meter-in flow control and a point-of-use soft start is that the soft start allows full flow after a pre-set ramp-up pressure has been achieved. Also, we must not forget the problems with metering in; slip-stick cylinder motion can wreak havoc on machine processes. However, when utilizing point-of-use soft start devices, in conjunction with meter out flow controls, the re-application of pneumatic energy and cylinder speed is controlled while not inhibiting the normal, smooth cycling of the cylinder. The cylinder is controlled during every aspect of machine operation.

Another point to be made for not using system-wide soft start is that the design of these devices is to slowly bypass air downstream until a certain pressure is reached and then to open completely to allow full line pressure and flow through the valve. This bypass flow is usually limited, although adjustable, over the range of the limitation, and unfortunately pneumatic systems are generally plagued by leaks. Any system such as this that relies upon a build-up of pressure before fully opening will have an Achilles heel in that if the leaks downstream of the soft start valve are equal or greater than its bypass flow capability, the soft start valve will not open fully. Some machine processes such as blow-offs and vacuum generators constantly consume air, too. This consumption is virtually seen as a leak in a soft start system. In systems like this it is absolutely necessary to add in complexity for isolating the leaky areas of the system until after the soft start has completely opened for full flow or use point-of-use devices.

Even though applying a soft start device upstream of an entire machine circuit is often recommended, in many cases this is not the best solution. Whereas, utilizing point-of-use soft start in conjunction with flow controls limits the initial re-application of energy where needed and provides the most consistent solution for speed control for machines that must maintain position during a safety event and continue operation once the pneumatic energy is re-applied. This is especially true for safety systems that include the use of a control reliable dump valve along with a 5/3 open center directional valve to control cylinder operation.



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