Tech Sheet #SV 503

Key Considerations for Sizing and Selection of Solenoid Valves

Proper Sizing of Solenoid Valves

Proper sizing of solenoid valves will result in optimum flow and performance, increased fluid control system life, as well as reduced maintenance costs and down time.

The solenoid valves addressed in this tech sheet include direct fluid control two way on/off valves, three-way fluid flow/diverter valves as well as three- and four-way pilot valves typically used to pilot larger valves, actuators, and cylinders.

Improper Sizing of Solenoid Valves

The following describes common issues resulting from improper solenoid valve sizing:

Oversized Solenoid Valve

System designs that specify a valve that is too large, or oversized, for the intended pressure and flow rate can result in numerous problems that can be avoided if the valve is sized properly.

The C_v flow factor is the most commonly used tool to size a solenoid valve. This is a fixed value for the valve that the manufacturer should provide in their specifications. Using this value helps a fluid system designer select the appropriate solenoid valve by taking into account the important relationship between flow rate and operating pressure differential (ΔP), especially in piloted piston or diaphragm solenoid valves where minimum operating differentials are required to achieve full shift of the valve (and thus full flow).

In addition to other factors, knowing the pipe size and flow rate the system requires (for example, from the output of the selected pump or known flow source) allows one to check a certain valve's C_v to determine if the required minimum operating pressure differential (ΔP) can be maintained. If the calculation does not show a proper minimum OPD across the pilot, then the valve will not shift properly; therefore, a valve with a different C_v must be selected.

Example: Consider a system utilizing water flowing at 30 GPM in a one-inch pipe with a maximum inlet of 100 psi and the outlet open to atmosphere. If on/off automatic valve control is necessary, a two-way on/off piloted solenoid valve would be used. A direct-acting two-way solenoid valve is likely not available for such a high-pressure inlet when combined with a one inch or larger pipe size.

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At first, it seems obvious to select a 100 psi rated valve with a one-inch NPT pipe size to meet the needs of the 100 psi system. However, it is not good practice to select a valve with a pressure rating at or near the system pressure rating. The valve's pressure rating is its maximum, and the system is already at the valve limit. In this case, it would be wise to select a valve with a (maximum) pressure rating that is higher than the system pressure rating. In this case a 125,150 or even 200 psi rated valve is better suited.

With $C_v = Q * \sqrt{(SG/\Delta P)}$

Q = flow in gpm
SG = specific gravity of the liquid (1 for water)
ΔP = minimum operating pressure differential (assume 5 psi minimum OPD needed for the valve of choice)

$C_v = 30 * \sqrt{(1/5)} = 13.4$, so selecting a valve with a Cv no larger than about 13 should work.

Here is an example of selecting a valve with a published C_v of 30 (higher than recommended above):

Rearranging the formula, $\Delta P = SG*(Q/C_v)^2 = 1*(30/30)^2 = 1$ psi, which is inadequate since the valve needs 5 psi to shift. The valve with a C_v of 30 is oversized because it has too much flow through it to maintain a minimum pressure drop of 5 psi to open and stay open properly.

Even if a zero minimum differential pilot valve is selected, the valve will open but the piston or diaphragm will likely have issues remaining open resulting in chatter and/or inconsistent flow.

So, the maximum C_v for the valve should be 13.

Undersized Solenoid Valve

A system designed to use an undersized valve will cause the main orifice flow to be inadequate to provide the overall system flow with the design system pressure. The system pressure may need to be increased to compensate for the too low C_v which causes additional issues such as exceeding the piping and system components' maximum specification ratings, higher pump output and system strain.

Using Improperly Sized Valves to Power Pneumatic Cylinders and Actuators

The following are other issues that may occur with an undersized or oversized valve when using to power pneumatic cylinders and actuators:

- An undersized valve may cause the actuator to move in a choppy, erratic manner.
- Using a smaller valve to lower the flow so the cylinder moves more slowly results in the cylinder moving erratically throughout the stroke. The cylinder speed should be controlled by restricting the exhaust flow using speed controls.

- Using an oversized valve can also result in the cylinder slamming at the end of stroke.

Using the proper size solenoid valve with proper flow within the system's fixed parameters will avoid these issues.

Properly Sized Piping/Tubing into Inlet/Outlet/Cylinder/Exhaust Ports

It is important to properly size the piping and tubing for solenoid valves, especially on piloted three- and four-way solenoid valves. These types of valves will not shift properly if the flow is restricted by undersized piping. It is not recommended to use an adapter from the smaller piping/tubing to the larger NPT pipe connection of the valve. Refer to table below.

Recommended Tubing IDs When Plumbing 3- & 4-Way Pilot-Operated Valves

NPT Pipe Size (inches)	Pipe O.D. (inches)	Pipe I.D. Sch 40 (inches)	Pipe I.D. Sch 80 (inches)	Recommended Tubing I.D. (inches)
1/8	0.405	0.269	0.215	1/4 (0.250)
1/4	0.540	0.364	0.302	11/32 (0.344)
3/8	0.675	0.493	0.423	15/32 (0.469)
1/2	0.840	0.622	0.546	5/8 (0.625)
3/4	1.050	0.824	0.742	3/4 (0.750)
1	1.315	1.049	0.957	1 (1.000)

Failure of Three- and Four-way Internally Pilot-Operated Valves to Shift

One of the most common problems end users may experience is the failure to shift or the partial shift of three- and four-way internally pilot-operated valves. As designed, most internally pilot-operated valves require a pressure differential between 5-20 psid across a diaphragm or piston to accomplish shifting. This generally translates into the requirement for a specific pressure differential between the inlet (pressure) and exhaust ports.

It is important to remember, since it is the pressure differential that is doing the work of moving the valve's diaphragm or piston, that the critical time for maintaining the required pressure differential is during the valve's shifting cycle. The most frequent symptom of the "failure to shift" condition is a continuous flow to exhaust and, in the case of a four-way valve, to both "cylinder" connections. The "starvation" of the valve resulting in this condition can generally be attributed to an inability of the system to maintain the required flow, either due to an inadequate pressure source (e.g. undersized compressor) or a restriction in the supply piping.

The following items should be considered when evaluating if potential restrictions are a concern:

1. When attempting to operate numerous valves from a common pressure source, does the condition tend to become more common as more valves in the system are operated

simultaneously? Do the valves that are the furthest from the pressure source tend to exhibit the failure to shift problem more than those valves closest to the pressure source?

2. Typical examples of when there is a restriction in the piping, either in supply piping or in the piping from the exhaust connection, include:

   A. **Undersized piping or tubing**. Piping should be full-sized. If copper tubing is used, the ID of the tubing should be at least as large as the valve pipe size.

   B. **Speed control valves installed in the pressure or exhaust lines**. If speed control valves are required for the system, they should be installed in the "cylinder" lines only.

   C. **Regulators installed in the supply piping**. Even if the orifice in the regulator is adequate, the response time of the regulator may be such that it does not respond fast enough to the sudden decrease in the downstream pressure to enable it to keep the valve adequately supplied with the required flow during its shifting cycle.

   D. **Mufflers**. Mufflers, if used in the exhaust port piping, should be of the non-restrictive type, and should be checked regularly for clogs.

To confirm that a restriction is the cause of the malfunction, install a pressure gauge in the pressure line to the valve as close to the valve inlet as possible, and observe the gauge while the valve shifts. A dramatic drop in the pressure will typically be indicative of a restriction.

Occasionally, where the system flow is marginal, a reservoir or accumulator between the restriction and the valve inlet will help. However, other than elimination of the source of the restriction, there is little that can be done short of replacing the pilot operated valve with a direct-acting type valve that requires no minimum operating pressure differential or downsizing the valve to meet the system pressure and flow capabilities.

Water hammer
In liquid applications, improper valve sizing can contribute to water hammer. “Water hammer” is the result of a pressure surge that propagates through a piping system when the flow of a fluid is forced to change direction or stop abruptly.

Viscosity
In certain applications, fluid viscosity should be considered in valve sizing calculations as viscosity of the fluid affects flow through the valve. Ignoring viscosity may result in using an undersized valve.

Seat Erosion
Other common problems that are a result of improper sizing include seat erosion and wire drawing. This type of premature seat erosion in solenoid valves used on liquids generally occurs in one of two ways:

1. General uniform erosion of the main valve internal orifice seating surface.
2. Wire drawing which creates gouges or grooves, cutting deeply into the main valve internal orifice seating surface.

General seat erosion normally occurs in valves which are open continuously and are subjected to nearly continuous flow over the seat. Under normal operating conditions, this process can take a lifetime to occur. However, a phenomenon known as dezincification, which occurs in brass valves, can greatly accelerate this type of erosion process.

Brass is an alloy containing copper and zinc. Dezincification is the leaching out of the zinc from the surface of the alloy, leaving a weak, porous copper layer. This soft layer is then much more easily eroded by the action of the flow through the valve.

Dezincification can occur at various rates and is related to unusually high acid or oxidizer content of the fluid flowing through the valve. In water applications, chemicals which cause changes in the pH of the water can originate from natural mineral deposits, added chemicals, or dissolved gases, such as carbon dioxide. Oxidizers generally present themselves in the form of chlorine, fluorine, and bromine, which are commonly added as water purification elements. Dissolved oxygen can assist in the dezincification process as well.

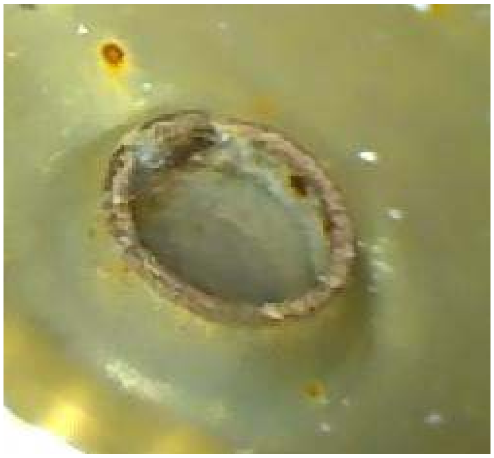
Dezincification can be identified by examination of the internal brass parts of a solenoid valve. These brass parts, when they are exposed to the medium, will appear coppery or pinkish in color in contrast to the brass color of the external portions of the valve. Mineral deposits can mask this effect.

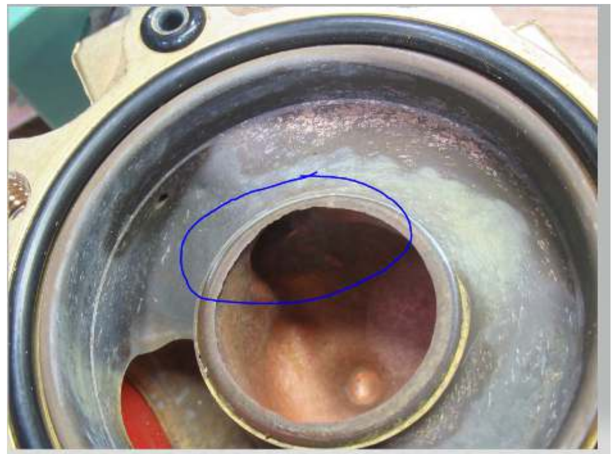
By performing routine maintenance in these fluid medium situations and polishing a small portion of the valve interior, the mineral deposits can be removed. This allows for easy identification and control of a possible dezincification problem.

Wire drawing is a form of seat erosion typified by gouges or grooves cut deeply into the valve seat. Typically, this condition is produced when a small piece of foreign matter is trapped, either temporarily or permanently, between the valve main orifice seat and sealing disc. This piece of foreign matter may cause a nick in the seat or disk, allowing a very small amount of leakage. However, the flow velocity through this leak path can be extremely high, producing a cutting effect on the seat. Again, this process may take a long time to severely damage the valve seat. Wire drawing can occur in valves made of stainless steel, bronze, and other materials. In brass valves, wire drawing can be greatly accelerated by dezincification.

To prevent wire drawing, suitable filters or strainers should be installed in the inlet piping to a valve, as close to the valve as possible, to prevent foreign matter from entering the valve and damaging the seat or sealing disk.

Once seat erosion has occurred, the valve or the orifice seat (if replaceable) will almost always have to be replaced. Consideration should be given to this problem when selecting a replacement valve. In the case of a large valve which has provided a substantial period of satisfactory service, simply replacing it with an identical or similar design may be the best solution, as alternative constructions may prove to be prohibitively expensive. Further, some valve manufacturers have special brass body valve constructions available with inserted stainless-steel seats, which provide increased durability. For smaller valves, the most economical solution is either replacing the entire valve body (if replaceable) or full replacement of the entire valve.





Examples of eroded valve seats exhibiting wire draw (left) and as result of dezincification (right)

Other Considerations for Fluid System Design and Sizing of Solenoid Valves

Internally pilot-operated three- and four-way valves are an economical, reliable source of control for cylinders, control valves, etc. They can operate with much smaller solenoids, both in physical size and in power consumption, than would a direct-acting valve with similar pressure and flow capabilities, thus reducing both initial and long-term operating costs.

Planning to eliminate potential problems during the system design, such as selection of a valve based on the flow required rather than the pipe size, and ensuring that the system pressure supply is adequate, will help to ensure a long, trouble-free life of the system.

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