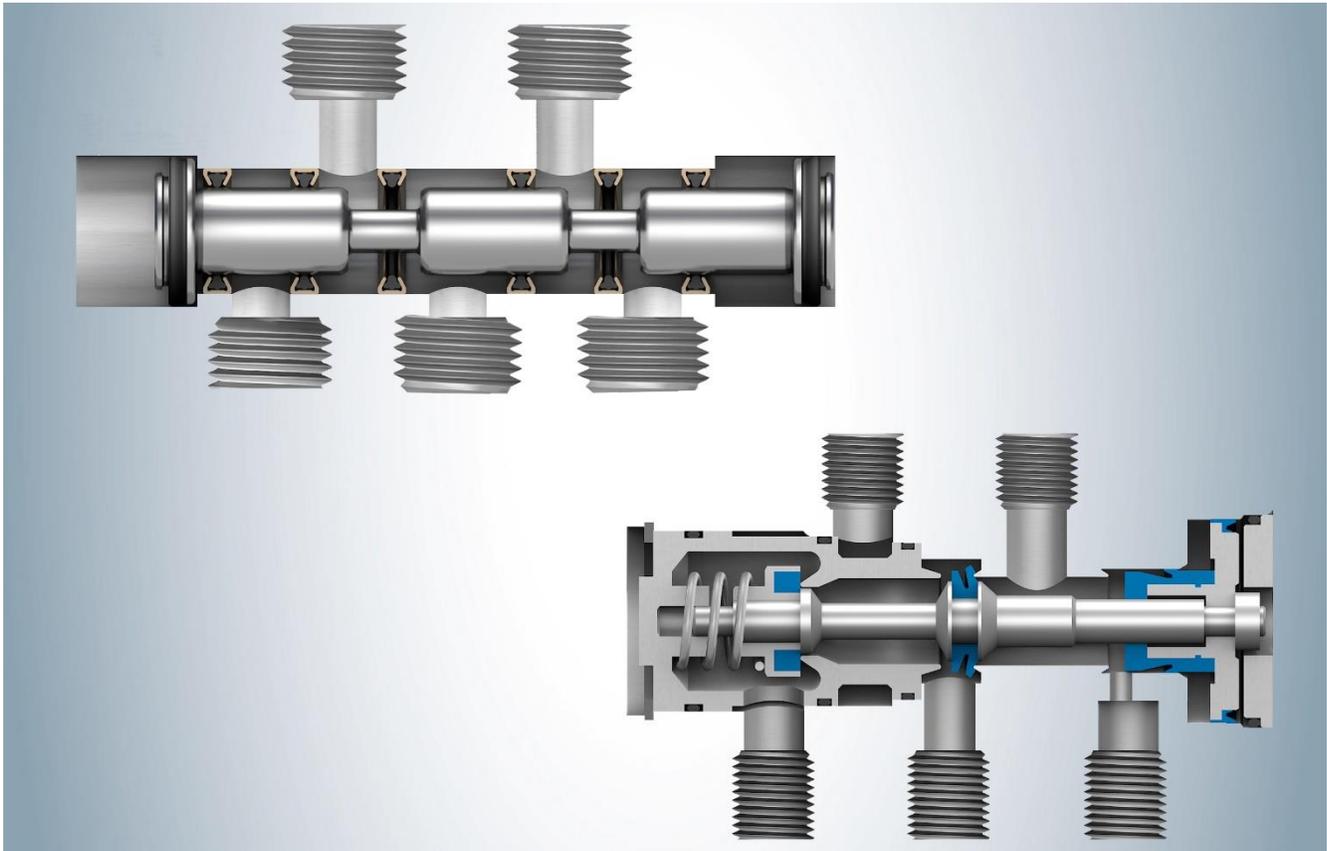


# Piston spool valves and poppet valves

## - A technical comparison of available solenoid valves

### White Paper



This whitepaper includes information on:

- An introduction to valve technologies
- Poppet valves, piston spool valves and the cartridge principle – what you need to know
- Which valve type suits you best? A valve selection aid

# Executive Summary

## Why should you choose your valves carefully?

The increasing demands placed on valve technology in recent years has led to a formidable extension of the range of available technologies and valve types, models, and properties.

The most commonly used are poppet valves and piston spool valves. Nowadays, there is a much wider choice of valve technologies to successfully plan a project.

However, choosing the right parts for the application at hand requires comprehensive knowledge and an accurate appraisal by the consulting engineer or technician.

This White Paper is intended to offer you a brief overview.

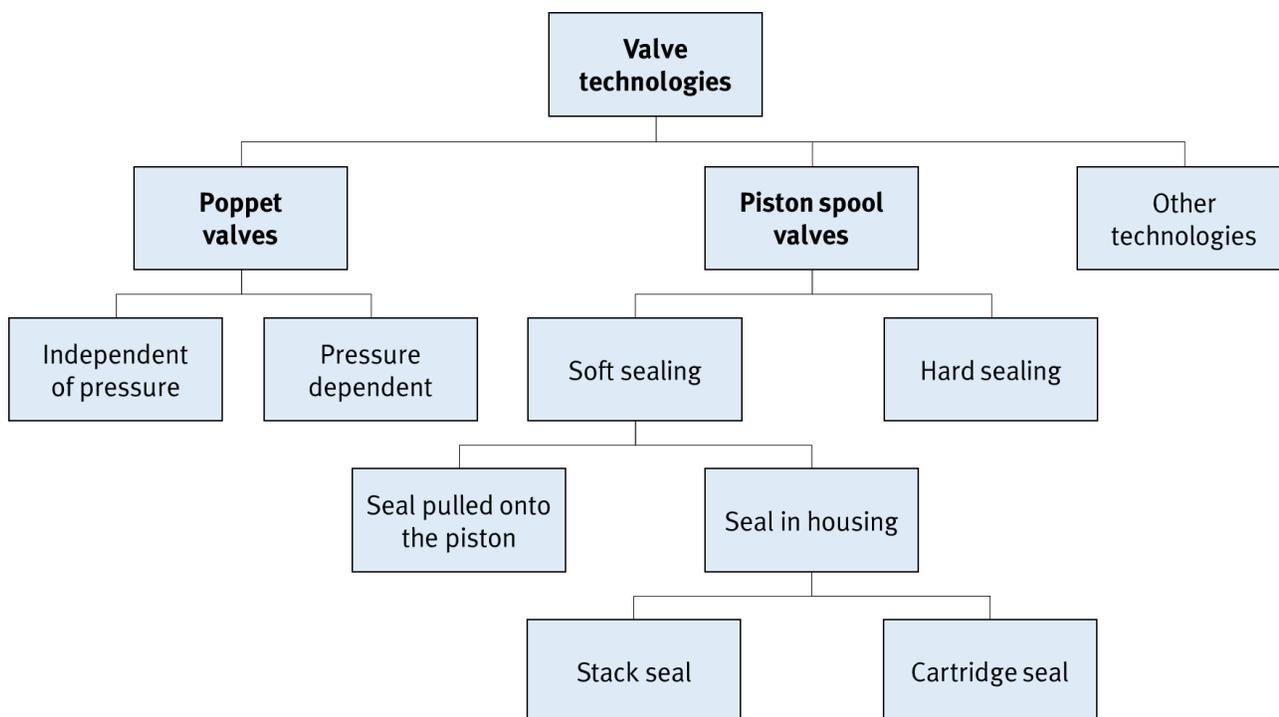


Figure 1: Examples of valve technologies

## Introduction

Poppet valves and piston spool valves are the most commonly used valves for controlling compressed air. Flat slide valves, rotary slide valves, piezo valves and other technologies tend not to be used as often. The chart in Figure 1 offers an example of how the two common technologies can be subdivided. Among the piston spool valves, the valves with a cartridge seal are particularly interesting. This type of valve has lower leakage values and offers significantly higher operating pressures.

### Poppet valves, piston spool valves and the cartridge principle - what you need to know

#### The poppet valve

The very simple construction and the option of using different sealing material often makes the poppet valves more inexpensive than the piston spool valves. For instance, a 5/2 poppet valve (see Figure 2) only requires 3 axial seals, but there are more advantages with this technology: the actuation strokes are small, which allows for shorter switching times. The axial sealing technology is resistant to contamination thanks to the self-cleaning effect as the air passes through the valve. Also, poppet valves do not require lubrication, which is an advantage in terms of chemical compatibility with lubricated compressed air.

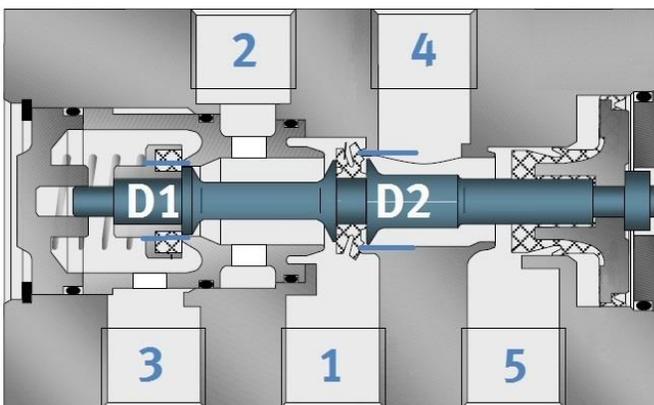


Figure 2: Pressure-dependent poppet valve

Figure 2 shows when the air flows through the valve from channel 1 to channel 2, the surface area  $D_2$  is larger than  $D_1$ . The supplied operating pressure acts on both surfaces resulting in the forces on the spool to be unbalanced. To increase actuation force to shift spool, pressure, depended poppet valves need to have larger pilot control components.

Blow-by or overlap is another common problem you can have with poppet valves. Depending on the design, it is possible during the movement of the spool supply pressure at port 1 can pass through port 2, port 4 and the exhaust ports at the same time. This results in unnecessary leakage and noise.

#### The piston spool valve

We know that the actuation forces in poppet valves are relatively large, they are much smaller in piston spool valves, because the valves do not have to be switched against any forces generated by the operating pressure. The problem with overlap is also easily solved, as can be seen in Figure 3.

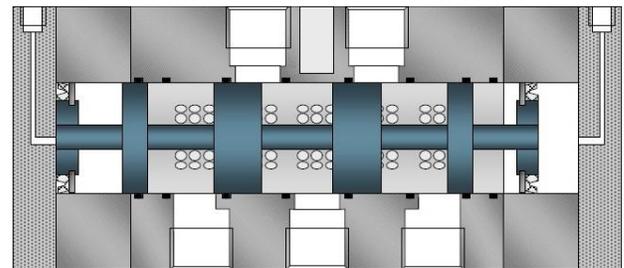
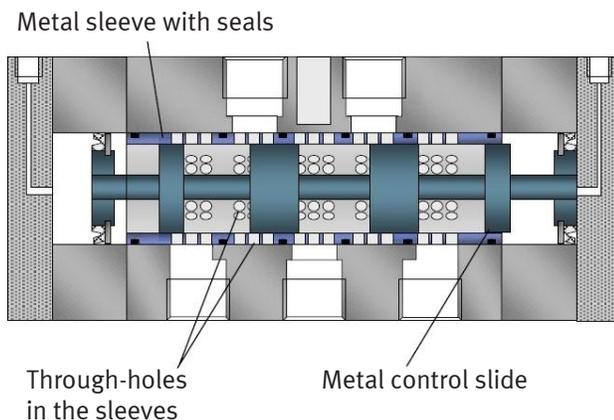


Figure 3: Piston spool valve

However, there are drawbacks with this valve type too. For example, the strokes for switching operating positions are longer than with poppet valves. These longer strokes and the requirement for several pistons mean that the piston spool valves typically must be longer. In terms of manufacturing, the piston spool valves are also more challenging, particularly when it comes to sealing technology. Two categories have evolved in this area:

- Category no. 1: Hard-sealing systems**

These sealing systems are more durable, but also more demanding. The durability is a result of the absence of soft rubber sealing elements in the piston spool valve. This means that valves using this sealing technology are immediately ready for full dynamic use after even longer periods of inactivity. In soft-sealing systems, there may be adhesive effects, which cause the sealing elements to wear out faster. The greatest challenge with the system is that the air gap surrounding the moving piston must not be larger than a few micrometers. The spool usually moves in a metal sleeve. The sleeve then works both as a seal and as a guide for the valve spool. It is crucial that the sleeve and the spool are made with the same material, since different materials have different thermal expansion coefficients. If this is not taken into consideration, greater leakage will occur, and even jamming of the spool. The combination of the sleeve and the spool therefore should comply with many technical specifications, since even the smallest deformation in the housing, e.g. due to tightening of screws, can damage sleeves and affect the life and leakage values of the valve.

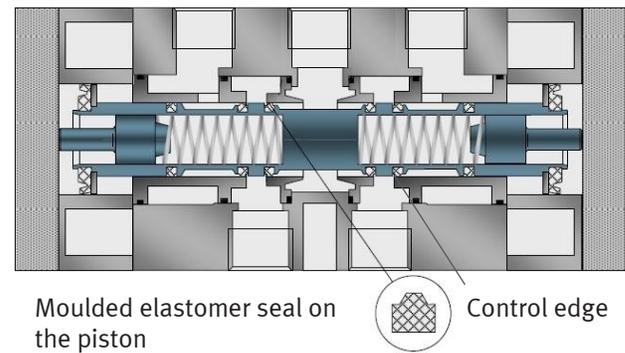


**Figure 4: Hard-sealing system**

In conclusion, hard-sealing systems are very robust and durable. The greatest drawback is that there is always a certain leakage with these systems because of the air gap. Furthermore, their flow capacity is lower than that of other valves with the same body dimensions.

- Category no. 2: Soft-sealing systems**

A technical alternative to hard-sealing systems is to use rubber gaskets (O-rings or moulded elastomer seals) on the piston.



**Figure 5: Soft-sealing system with gasket on the piston**

The problem with this alternative is that at higher pressures, the rubber seals may be worn down fast when in contact with the channel. The control channel edge, the spool seals, and piston guide need to be carefully designed to minimize friction to achieve long service life.

There is, however, yet another alternative. As illustrated in Figure 6, the seals can be mounted directly in the valve housing. This looks like a great option, but there are two disadvantages.

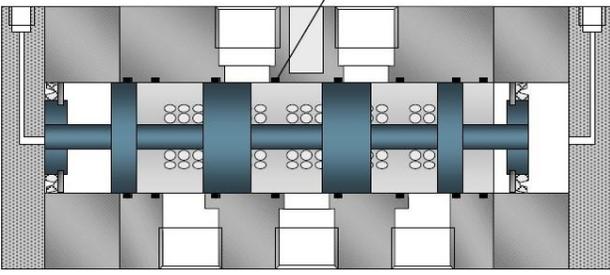


Figure 6: Soft-sealing system with seal in the housing

Firstly, the recesses required are difficult to produce and, secondly, the Bernoulli effect will cause the seal to be pulled out at a pressure of approx. 8 bar or higher. This again causes greater wear on the seal. Figure 7 shows the process in detail:

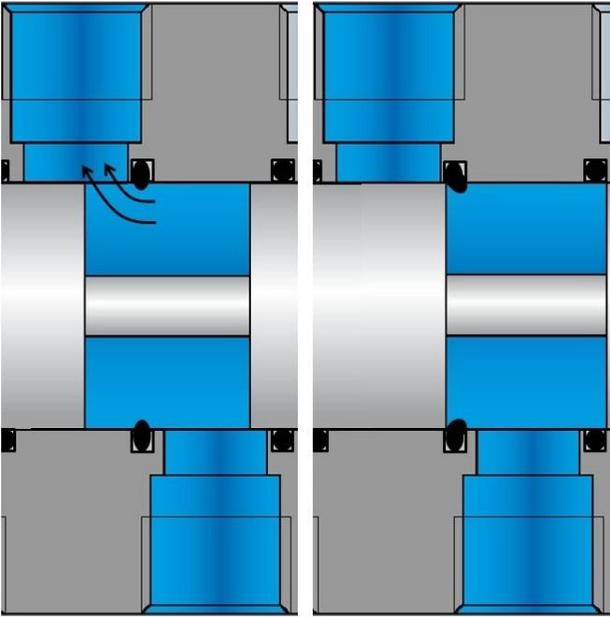


Figure 7: Increase seal wear due to the Bernoulli effect at a pressure of approximately 8 bar or higher.

1. The high pressure and the restriction of the channel produce a higher air flow rate through the valve.
2. The pressure in the valve is reduced due to the increasing air flow rate.
3. The greater static pressure on the groove base creates an imbalance of

forces on the seal forcing the seal to protrude more out of the groove.

4. When the spool switches positions, the seal friction forces are now higher resulting in premature wear.

- **The cartridge principle for piston spool valves**

One solution to the problem described in Figure 7 is to use moulded seals in metal cages. The seals are thus retained in recesses in the metal housing; the so-called cartridge principle (Figures 8 and 9).

The advantage with this solution is that the seal will not be pulled out of position even at an operating pressure of up to 16 bar, thanks to the special design of the metal cage holding the seal. This ensures a significantly longer service life. In addition, the improved sealing between the piston and the elastomer seal enables cartridge principle valves to be reliably used for vacuum applications.

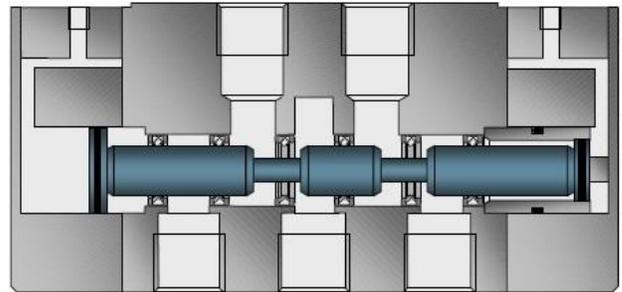


Figure 8: Piston spool valve with cartridge principle

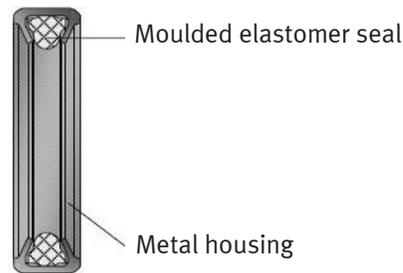


Figure 9: Cartridge seal

## Which valve type suits you best? A valve selection aid

Both valve types; piston spool valves and poppet valves, come with their advantages and disadvantages. However, if you are looking for a type of valve with low leakage values and the option of dual-pressure operation<sup>1</sup> with vacuum and ejector pulse, or if you require high operating pressures, the most suitable is probably a piston spool valve with cartridge sealing technology.

	Piston spool valve (seal on piston)	Piston spool valve with cartridge principle	Conventional poppet valve (pressure- dependent)
Relationship between valve size and flow	++	+++	+
High operating pressures up to 16 bar	Not available	+++	++
Vacuum operation	++/+++ <sup>2</sup>	+++	++
Reverse operation	++	+++	Not available
Resistance to “polluted air”	++	++	+++
Low leakage values	++	+++	+++
Switching time	++	++	+++
Lubricant compatibility <sup>3</sup>	+	+	+++

**Table 1: Valve selection aid**

+++ = Excellent  
 ++ = Good  
 + = Satisfactory

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1) Pressure-compensated poppet valves may also be used for dual-pressure operation.

2) Depending on the structural design.

3) If lubricants are used when working with compressed air, this will hardly affect the poppet valves, as their operation is usually “dry”. However, in piston spool valves, chemical processes involving the lubricant may occur in the valve.