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PROPORTIONAL VALVE OVERCOMES LIMITATIONS

Application of proportional pneumatic controls has been hampered by inconsistent valve performance, which prompted development of a new valve that overcomes these limitations.

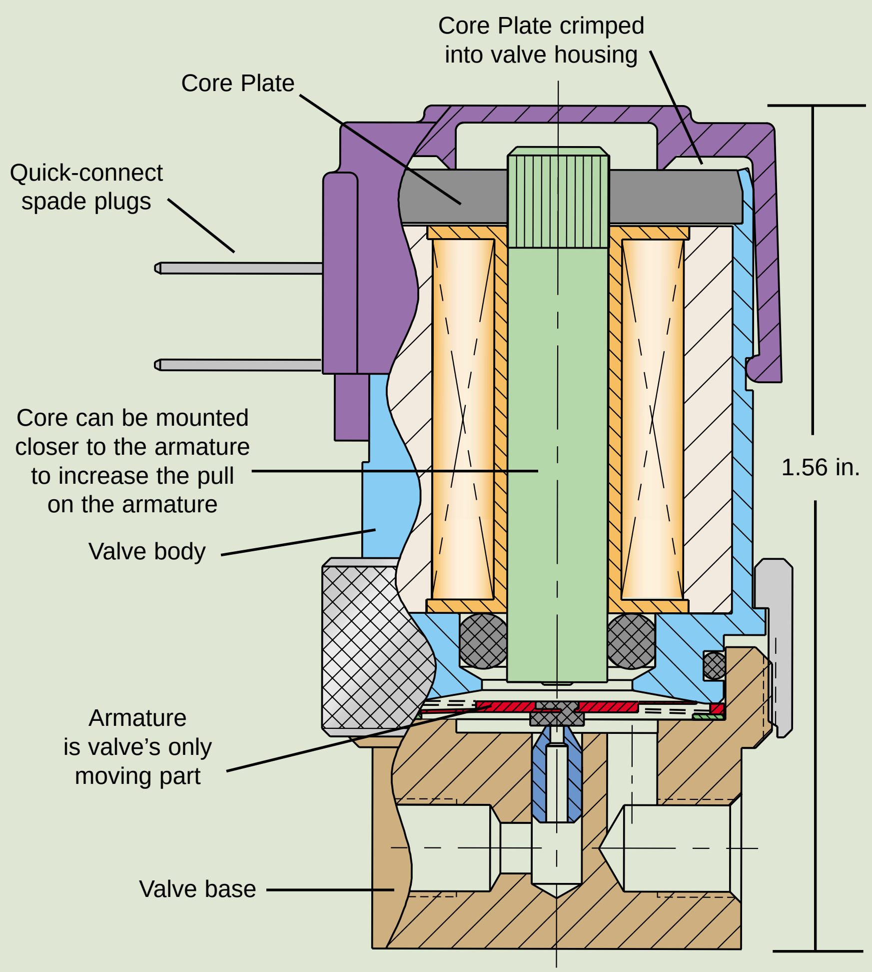
Since 1974, Clippard Instrument Laboratory has produced their EV series valve, which combines simple design, low power consumption, fast operation, and long life (applications have exceeded 3 billion cycles with a single valve). The heart of that valve is its armature, which is the only moving part. Dubbed the spider, because of its flexing legs, it has helped make the EV valve reliable and versatile enough to be used in thousands of applications.

Now, the spider has again provided the spark for a new product series. By re-engineering the (now) conventional spider element, an engineering team at Clippard added another dimension to the valve—variable output flow that is proportional to input current. The result is the new EVP valve.

What's out there

When considering the existing state of proportional control in analytical machines, mass flow controllers, and medical

Along came a spider

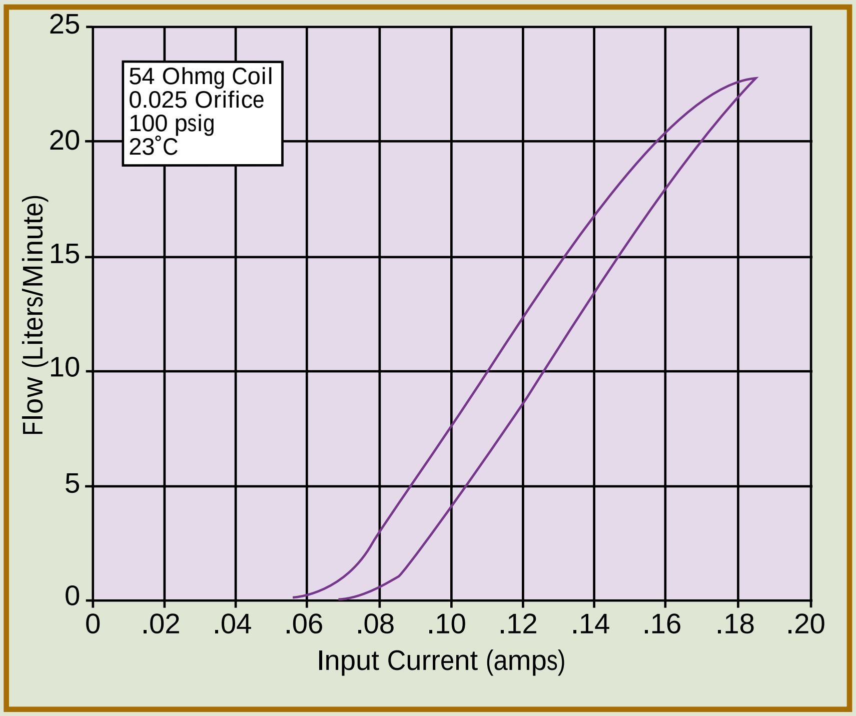


Redesigning a spider-shaped armature allowed Clippard to develop a proportional valve with low hysteresis, plus consistent maximum flow and gain from one valve to another.

applications, Clippard found that existing valves can exhibit hysteresis as high as 15%. This can present serious limitations to both open- and closed-loop control systems. Second, variation in the maximum flow from one valve to another can cause problems. And third, variation in gain typically found in the current generation of valves can cause similar problems.

The gain of a proportional valve is the rate of flow change to valve input current. Differences in the gain of a given valve can cause the performance envelope to be quite large, putting the burden on the OEM to make their equipment adapt to the limitations of high hysteresis, maximum flow variation, and non-uniform gain.

A lot to gain



Near linear gain of the EVP valve and low hysteresis make it especially well suited to closed loop control applications.

A need for change

To improve all three of these characteristics, Clippard's efforts focused on redesigning the spider element—and the sloped ramp it acts upon. Designers found that one of the characteristics of the original EV valve, its factory-adjustable core, proved to have a decisive advantage in achieving their goals. They found that adjusting the magnetic field could compensate for the limitations imposed by mechanical tolerances.

As a result, the valve has an improved maximum flow variation—as little as ±10%—and also has more consistent gain. These two improvements result in better controllability. Furthermore, the valve's low mass element, materials of construction, and virtual absence of friction combine to produce high response, long life, and hysteresis of less than 10%. And even though the valve is intended to control flow, adding a pressure sensor and comparator circuit produces a low-cost electronic pressure controller.

Causes and effects

The main cause of gain variation from one valve to another is the mechanical and geometric tolerances that occur in manufacturing processes. Most manufacturers use a chemically-etched or stamped flat spring to resist plunger or armature movement. The spring, in conjunction with the surface it makes contact with, creates the proportionality between flow rate and valve coil current. Increasing electrical current applied to the armature subjects it to a magnetic field, which creates a magnetic force on the armature that pulls on it. The flat spring resists this travel until the magnetic force on the armature equals the force that the flat spring subjects on the armature.

Although the flat spring is the critical component in maintaining consistent gains from valve to valve, typical tolerances for flat springs can cause substantial changes in spring rate. For example, the spring rate of flat springs is inversely proportional to the thickness of the material it is made of to the third power. This means if thickness tolerance varies by 5%, a spring rate fluctuation of 35% could exist. Therefore, large swings in gains can exist from only slight variations in flat spring thickness.

Another limitation in the current valves is maintaining a relatively constant linear gain over the entire flow range of a valve. As seen in the illustration, the valve gain has an S shaped gain curve, rather than a consistently linear one. Also, the hysteresis of the valve is 15% of the full current to the valve. This can cause major problems when using this valve in a closed-loop control system.

Adjustability it the key

This design makes it very easy to control the amount of the magnetic field strength the armature is subjected to. By simply press-fitting the core closer to the armature this will increase the magnetic field which creates more force or pull on the armature.

The adjustment of the magnetic field compensates for the mechanical tolerance problems that all proportional valve manufacturers must contend with. Therefore, even with varying spring rates and mechanical part tolerances, the valve can create a consistent gain relationship between flow rate and electrical current to the valve. Clippard can also maintain the same tight tolerances on maximum flow that it presently has on the standard EV series valves. This tolerance is ±10% of maximum flow or better.

The consistent valve gains will greatly improve closed-loop control systems that need precise control at ramp up and ramp down. The predictability of gain will allow for improved PID algorithm control and less chance of instability or inconsistencies.