Can pneumatics support extreme engineering?

Components operate at wide temperature ranges for trains, construction vehicles, agricultural equipment & implements and semi-trucks.

Bill Service
Marketing Manager
Pneumatic Division North America
Parker Hannifin Corporation

****

Pneumatic industrial valves work in a variety of applications to control the operation of pneumatic actuators, including cylinders, clutches, rotary actuators and air bags. However, using valves for applications in low-temperature environments, such as found in transportation applications, can pose special challenges from both a manufacturer and OEM perspective. To understand why, let's first look into what goes into a valve manufacturer's thought process in designing a standard valve. This will help further in the understanding of valve design for applications where a standard product isn't – "good enough."

The world of standard pneumatic directional control valves

A basic valve is typically manufactured with a metal or plastic body containing a sliding spool or disk. Actuated by a solenoid, air pilot or manual operator, the spool shifts to provide air flow from one communication port(s) to another. Standard valves have general design characteristics to meet factory automation and heavy industrial applications, which have a large variation in standard performance requirements.

In general, pneumatic valve manufactures build valves with common features that meet or exceed OEM customer expectations for performance and quality. For performance, manufacturers consider size and flow expectations for the valve package size. They also take into account response time, cycle life, and leakage. Response time is literally how long the valve takes to shift position. Response times typically vary between 5 milliseconds to 40 milliseconds. Cycle life is how many cycles the valve can operate over its lifetime, with the number of cycles typically ranging from 20 million to 40 million. This assumes the use of proper filtration, such as 5 to 40 micron, so the valve and actuator receives clean, dry air. Previously, OEM designers basically relied on manufacturers spool technologies as a general rule to determine performance and cycle life. Today, valves from the major suppliers operate for tens of millions of cycles in non-lube systems. When in reality, a majority of applications typically don't require a cycle life of 20 million cycles. In fact, from the OEMs point of view, the life of the valve usually exceeds the manufacturer's warranty.

For standard valves, basic temperature specifications are often considered to be in the range of 14 degrees F (-10 degrees C) to 122 degrees F (50 degrees C), with pressures ranging from vacuum to 145 psi (10 bar). Valve manufacturers choose from a combination of internal designs containing seals, spools, lubrication, solenoid components and connections based on these temperature ranges. Once the basics are designed and tested, the manufacturer improves design characteristics to limit the overall leakage factor of the valve. Unless the valve is specifically designed to be bubble tight — that is, with no leakage of pressurized air — the valve will typically have some amount of leakage factor.

Valves have different spool designs, including spools that use an O-ring for a seal, spools over-molded with a rubber seal, and metal lapped spool and sleeve construction that exactly match the bore. Sealing surfaces and general construction can often be altered to improve the leakage factor. Standard valve leakage can vary by manufacturer, but typically is under 10 cc/minute. Valves are tested for leakage during factory assembly at ambient temperature. Note that some standard valves, such as Parker's Viking Xtreme, can be used in critical applications such as suspension control on semi-trucks. These valves also include a unique solenoid for operation in intrinsically safe applications.

How valves for transportation applications work

Pneumatic values used in "extreme" transportation applications require a different mindset for both the manufacturer and the OEM design engineer. These valves might be engineered differently or they might need a different spool design, better sealing material or different type of lube. The two major considerations for these valves are pressure and temperature.

Temperature is important in braking applications on railcars because they can encounter ambient temperatures as low as -40 degrees F (-40 degrees C). Standard valves contain lubricant that become less viscous as the temperature decreases, and therefore, become sluggish or not able to properly shift position. As such, these valves require the use of a special lubricant.

Additionally, at lower temperatures, sealing materials become increasingly hard and brittle. Normal manufacturing imperfections affecting the surface finish on the sealing surfaces and O-rings have a greater effect and can cause valve leakage. With a standard valve operating under typical pressures and temperatures, the hardness factor remains fairly constant. At lower temperatures, sealing materials get harder and harder, which basically means the valve will ultimately leak. Different seals have their own coefficients of expansion and physical properties that let the seal either operate or remain static and maintain an acceptable level of sealing. Many valves use special compounds including the use of fluorocarbon.

To understand why pressure is important, consider the case of an OEM customer that tests a valve at -45 degrees F and notes that it properly shifts at this temperature. But it's also important for the customer to know the valve's leakage at that temperature and the inlet pressure when it shifted. Valves typically have a minimum operating pressure of about 40 psi to ensure proper operation in extreme environment. Most vehicles would have adequate compressed air reserves to overcome any leakage in this case. But the vehicle may require an elevated inlet pressure, in some cases 80 or 90 psi, so the leakage through the valve does not affect the valve reliability.

Another factor in extreme applications is when the valve is used as different times for multiple functions which can make leakage a main consideration. For example, a street sweeper with a large rotary brush that rotates as the vehicle travels must adjust the rotary brush up or down according to the terrain. When the vehicle is sweeping, the valve works continually. However, when the operator parks the sweeper for days, the air supply reservoir remains pressurized and the control valves remain static for long periods of time. It's important the valve doesn't leak because any leakage can potentially drain the system. Typically, pressure is desired and is a requirement at startup for immediate operation.

Other examples include heavy-duty mass transit buses which have kneeling modules that include pneumatic poppet valves to inflate and exhaust air bags attached to the vehicle axles. This causes the bus to "kneel" or lower so passengers can more easily get on or off. These pneumatic components encounter drastic temperature swings in the Northern and Southern regions of the country during the seasonal changes in temperature. The pneumatic systems must be reliable, have repeatable response times and have the least amount of leakage possible. So, at initial start-up, the driver does not have to wait several minutes for the system to achieve operational pressure.

Designing an "extreme" valve

A valve manufacturer can take two basic approaches to designing valves that can withstand extreme temperatures and pressures. When cost is a major consideration, the company must further develop something it has already created, perhaps even modifying a standard valve to withstand harsher environments. Because of the nature of extreme applications, there is not as much production volume as found in common applications. An example here might be an OEM designer needing a valve that will operate on a one-off prototype. Examples might include farm implements, construction & forestry equipment.

A better approach to follow, if possible, often comes from starting from scratch. This eliminates the need for a compromise in terms of cost, design or anything else. Of course, this approach might necessitate special tooling and parts.

Drawing a line between a standard and a custom or extreme valve really depends on the specifications from the customer. Should an OEM designer need a valve that will work at -60 degrees F, it might be possible to use a standard valve and simply modify it for use in that temperature. But what if the OEM has space restrictions precluding the use of a standard valve body? Each of the performance criteria will lead the manufacturer down a narrower path of what technology it can adapt, or whether the project must start from a clean sheet of paper.

Specifying a pneumatic valve for low temperatures is also not an obvious process. Russian rail companies use a guideline that defines climate regions around the world and gives a statistical measure of how cold a region gets within so many years. The guide might say, for instance, in far northern climates, temperatures can reach -70 F for one day out of every 15 years. The railcar OEM might then perform a risk analysis based on that to determine the design specification, answering questions such as, "Does the valve have to work successfully at that temperature?" Alternatively, "Does the valve just have to withstand that temperature because when it warms up, the valve will then work again?"

Overall, few OEMs — even rail companies — can correctly specify how a pneumatic valve should work at low temperatures. Instead, the OEM designer usually relies on the valve manufacturer to know what valve will work in settings of -40 degrees F or below. Additionally, consider this: When a valve leaks at -40 degrees, is it really a critical loss of air pressure? Or, is the main concern whether or not the valve continues to shift? Therefore, in general, a train manufacturer would likely specify an extreme pneumatic device to ensure an acceptable level of performance in all conditions. Additionally, OEMs should not jump to conclusions by simply using catalog specifications for general operating parameters and assume that the same specification holds true in extreme environments like that found at -40 F. That's a common mistake.

Need more information on this topic?

Call or e-mail Parker’s Pneumatic Division at 877-321-4PDN or pdnapps@parker.com.