When the going gets tough, look to fluid power.

Hydraulic and pneumatic control systems both have a place in industrial automation equipment. Their capabilities overlap to a certain extent, but each offers specific benefits.

- Hydraulics are the choice when an application requires extreme forces or torques, beyond the capabilities of pneumatics.
- Pneumatics can provide the needed performance at the best price.

In the end, the choice usually comes down to performance factors such as force, precision, speed, durability and, of course, cost.

Corrosion-resistant, stainless-steel cylinders are ideal for washdown applications. They are designed specifically to reduce sharp edges and corners and provide a smooth transition from end cap to cylinder body. Rod wipers keep out contaminants and pressure-activated seals are wear compensating for long life.

Repairable cylinders can be disassembled to replace seals and other internal components and extend life. These durable cylinders are generally used in rugged, heavy-duty applications.
Fluid-power advantages

Fluid-power devices also hold some distinct advantages. Fluid-power cylinders and motors are compact, powerful devices that have a higher force-to-size ratio than electric drives. So they can transmit more power from the same envelope or the same power from a smaller envelope. This is especially significant where weight is a concern, say on aircraft or mobile equipment, or when space on a machine is limited.

Fluid-power systems also offer engineers more design flexibility, because the actuators can be located away from the pump or compressor. One pump or compressor can power multiple cylinders and actuators. Thus, most designs using fluid power take less space and are not restricted by orientation.

Another big advantage is safety, hydraulic and pneumatic actuators can be used in volatile atmospheres and other hazardous areas without the need for an explosion-proof housing.

By their nature, fluid-power devices handle adverse environments well. Dust and dirt have little effect on fluid-power equipment, provided the air or hydraulic fluid sees proper filtration. Likewise, they readily withstand wet, humid, and aggressive washdown conditions and, with certain precautions, can even operate under water. They also routinely tolerate high temperatures and frequent starts and stops.

Selecting cylinders

By far, the most widely used type of fluid-power actuator is the cylinder. They generate force and motion on a vast range of OEM equipment, for instance to push, pull, lift, rotate, or clamp products.

Wide acceptance comes in large part because cylinders are simple, economical, durable, and easy-to-install. They can produce thousands of pounds of force over a broad range of velocities; cycle at high speeds without overheating; and stall without internal damage. They come in literally thousands of styles, sizes, and configurations. This variety makes more-innovative equipment possible.

The basic, rod-style industrial cylinders function in two ways. Double-acting cylinders use pressure to power both the extend and retract strokes, making them ideal for pushing and pulling loads. Single-acting versions supply pressure to only one side of the piston; a spring or gravity powers the return stroke.

They come in various designs. Repairable cylinders can be disassembled to replace seals and other internal components and extend life. These durable cylinders are generally used in rugged, heavy-duty hydraulic and pneumatic applications.

Sealed-for-life or “disposable” pneumatic cylinders have end caps mechanically crimped to the tube. Internal components are prelubed prior to assembly. Although they are less expensive to manufacture than comparable repairable cylinders, they cannot be taken apart to repair without destroying the housing. These cylinders are usually used in lighter-duty applications.

Compact cylinders fit into smaller spaces where only a short stroke is required. They are used in lighter-duty applications due to the small bearing surface on which the rod slides. They mainly come in single-acting versions.

Sizing considerations

A key selection criterion is how much force a cylinder generates. A general rule-of-thumb is that for vertical and high-friction applications, the required force should be twice the load to be moved. In some cases additional force is necessary to compensate for friction.

Designers can calculate cylinder force by multiplying the effective piston area by the working pressure. The effective area for push force is the cylinder bore. For pull, it’s the bore area less the cross-sectional area of the piston rod. Thus, theoretical push force is:

\[ F = \pi \left( \frac{D}{4} \right)^2 P \]

where \( F \) is force, lb; \( D \) is cylinder diameter.
to determine rod column strength and suggest design modifications.

As one can see, for a seemingly simple device there are a number of considerations when sizing cylinders. For that reason, cylinders may be the most overspecified component in the average fluid-power system. An oversized cylinder has a healthy extra margin of force that can override a bit of misalignment, binding, or overload. But a larger-than-necessary cylinder also increases cost, air and energy consumption, along with size and weight, and can slow actuation time.

Fortunately, leading manufacturers offer online configuration tools and energy-saving calculators that help designers size components to precisely meet application requirements. This online sizing software, such as Bimba’s version – available at www.bimba.com – simplifies the selection process, ensures accuracy, and lets engineers find the right cylinder for a job and test it with different application variables.

Calculating a cylinder’s air consumption is often necessary on fast-cycling equipment to ensure enough supply air is available. This should include not only the volume the piston displaces, but also the unswept volume from end-cover cavities, cylinder ports, connecting tubing, and valves. The unswept portion is likely to be a small percentage of the total and will vary with the installation.

Extending cylinder life

While fluid-power cylinders are rugged and built for rapid cycling and long life – even under less-than-ideal conditions – they’re not indestructible. Here are some tips to help ensure trouble-free operation.

**Mounting.** It’s said that more cylinders are ruined by improper mounting than by any other type of abuse. Poor mounting produces excessive side loads on the rods that can prematurely wear the seals, bend the rods, or bind the load. An important design consideration is to keep cylinder thrust as close as possible to the centerline of the piston rod and free from misalignment or off-center loads.

Cylinders with fixed or pivot mounts that absorb force on the centerline are considered best for straight-line force transfer. Thrust or tension forces are distributed uniformly about the cylinder and bearing side loading is minimized.

Non-repairable pneumatic cylinders are an economical choice for many applications. End caps are mechanically crimped to the tube, with internal components prelubed prior to assembly.
Side-mounted cylinders do not absorb forces along their centerlines. They produce a turning moment under load that tends to rotate the cylinder about its mounting bolts. If the cylinder is not well secured to the machine and the load is not well guided, side load will be applied to the rod gland and piston bearings. To avoid this problem, ensure side-mounted cylinders have a stroke length at least as long as the bore size and machine frame members are strong enough to resist bending.

Sometimes, even properly mounted cylinders face side loading of the rods. If offset loads cannot be avoided, guided cylinders have guide rods and guide blocks mounted parallel to the piston rod, or dual piston rods. They provide precise, controlled linear motion, especially when the unit is subject to high side loads, and reduce rod and piston bending and uneven seal wear.

**Filtration.** Reliability is one of the strongest reasons to use fluid power, and proper filtration is the key to maximizing reliability and longevity. Air exiting a compressor can carry condensed water, oil carryover from the compressor, and solid impurities from internal wear and scale and rust within pipeline. The contaminants can cause problems at every point of use, and should be removed by installing suitable filters.

Likewise, hydraulic fluid will become contaminated over time with water, dust and dirt ingestion, and wear particles from moving parts within the system. Thus, installing and maintaining the proper hydraulic filters for a given system is a must. High temperatures and extreme pressures or operating conditions can also degrade the fluid itself, so testing the fluid on a regular basis is also recommended.

**Seals.** Cylinders are exposed to a vast range of temperatures, pressures, fluids, and environments that all affect seal performance and life. Fortunately, many seal designs and materials are available to meet most any application requirement. Typical seals range from inexpensive O-rings for low-pressure applications to low-friction U-cups and other pressure-energized seals.

Common materials include Buna N rubber for pneumatics and many hydraulic cylinders. It’s good for temperatures up to 200°F with air, mineral oil, and water glycol. When synthetic fluid or high heat is encountered, Viton seals are often a better bet. Viton works at temperatures of 400° to 450°F with air and most any hydraulic fluid. Many other seal materials such as Neoprene and Teflon are also available.

**Lubrication.** Hydraulic cylinders are, by their nature, self-lubricating. Most pneumatic cylinders are assembled with a coating of grease on the bore of the barrel and seals for service with nonlubricated air. If the compressed air supply is clean and dry, the grease will give the seals a long life without adding oil through an airline lubricator. However, contaminated air will gradually compromise the original grease lubricant and shorten seal life. Lubricated air will extend the life of the cylinder, but it will also wash out the original lubrication. So once lubricated air is introduced, it must always be used, and the lubricator should be regularly checked and maintained.

**Cushions.** Cylinders that move at high speed need some sort of deceleration method to keep them from slamming when they reach end of stroke. Otherwise, the impact loads can quickly destroy the cylinder or machine. In most cases, standard cushions built into cylinders work well by taking advantage of air’s compressibility or controlling airflow exiting the cylinder. If the cylinder sees high forces, or changing loads and speeds, external shock absorbers are another option.

**Rod covers.** Consider protecting exposed rods from abrasion and corrosion that could damage the rod surface and, in turn, the rod seal. In especially dirty environments, protect the rod with a cover such as a rod boot or bellows.

**Custom Designs**

It’s no secret that some of the biggest fluid-power manufacturers offer literally thousands of different kinds of cylinders. But that can carry a “take-it-or-leave-it” attitude: If one doesn’t fit your
application, you have to redesign your machine or downgrade performance.

Other manufacturers have a different mindset, more willing to tailor basic lines of products to precisely fit a customer’s needs. They’ve set up their engineering and manufacturing operations to offer application assistance and streamline production prototypes for quick delivery at little or no additional cost over off-the-shelf parts.

Engineers may equate custom with expensive. But the results are often better performance, reliability, and uptime, as well as lower overall equipment and operating costs. Consider custom units when standard catalog components cannot give the requisite level of performance, complex motion control is needed, or equipment design constraints dictate special configurations. Sometimes it involves combining standard or modified components in a novel configuration, other times it means inventing something completely new.

Engineers have a lot of leeway in tweaking a cylinder to best fit an application. Considerations include:

- **Port sizes and locations** can be adjusted in custom designs.

- **Dimensions.** NFPA and ISO have established standards for many cylinder dimensions, but many models also have unique dimensions.

- **Mounting configuration.** A special rigid or articulated mounting ensures a cylinder securely attaches to a machine and can execute the specific movements an application requires.

**Materials.** The operating environment is the major factor that governs material choice. Cylinders are typically made of steel, aluminum, stainless steel, brass, or engineered plastics, along with protective coatings, plating, paint, or anodized finishes.

**Seal materials.** Cylinder manufacturers use a variety of methods to seal the piston and rod. Designers can specify alternative seal materials for applications that operate in extreme high or low ambient temperatures or are exposed to caustic chemicals or radiation.

**Combo units.** Sometimes it’s simpler for OEMs to specify cylinders, valves, filters, regulators, wiring, and other components as a single, factory built and tested package. It ensures the components are properly sized and assembled, and simplifies and speeds installation.

When considering a custom design, first find a manufacturer that will work closely with you throughout the process; present fresh ideas and suggest workable alternatives when necessary; have a dedication to quality solutions executed with quick delivery; and take a strong interest in the outcome of the final project.

A suitable manufacturer also adheres to established industry-wide quality control standards when applicable — including ISO 9001 certification, which provides a uniform framework for quality assurance that is recognized worldwide.