10 Fluid Power Lessons You Don't Learn in School

By Charles J. Murray, Senior Technical Editor
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Completing engineering school doesn't make you an expert - at least in fluid power. Here's some of the most common fluid power mistakes most courses never cover, and how to avoid them.

Face it: If you were educated in a four-year mechanical engineering curriculum, you probably didn't learn much about fluid power. American universities typically teach fluid mechanics, fluid dynamics, and thermodynamics. But they seldom delve deeply into the subjects of hydraulics or pneumatics as a power medium.

That's why most design engineers in this country learn their fluid power on the job. And it's why they sometimes make mistakes they could easily avoid if the theoretical underpinnings of the subject were more readily available.

"You may have left school with a mechanical engineering degree, but that does not mean you have a good grasp of fluid power," notes an engineer from a major fluid power supply company. Fortunately, many hydraulic and pneumatic component suppliers offer training classes for design engineers. Parker Hannifin, Vickers, Mannesmann Rexroth, Festo and others teach the basics of hydraulics and pneumatics. "Most of these classes offer 95% of the material that design engineers need," notes Don Caputo, marketing manger for Parker Hannifin's Hydraulic Valve Division. "We want to get the word out to customers, many of whom are engineers, who never had this material in school."

For those who can't immediately attend such programs, Design News offers a compilation of some of the most common mistakes in fluid power design. The mistakes cover a broad range, from problems with pneumatic tubing to errors in hydraulic force calculation. Some may seem elementary. But suppliers agree on one point: Avoiding them in your projects will not only cut time and save money, it will eliminate countless headaches.

HYDRAULICS

Mistake #1: *Failure to recognize maximum flow*

You're designing a hydraulic actuator that will operate at a prescribed speed. To accomplish that, you calculate that the cylinder needs a flow rate of 10 gallons per minute (gpm). So you size your hydraulic system for 10 gpm, right?

Not necessarily. Many applications call for the return stroke to be faster than the power stroke. In the application described above, it's not uncommon for the return stroke to need a flow rate of 20 gpm.

If, however, the return lines and filters are sized for 10 gpm, then the user has a problem. The system builds up heat. Undersized filters fail to properly clean the hydraulic fluid. Leaks result.

Remedy: ***Consider the return rate***

Remember, the flow rate needed for cylinder extension is not always the system's fastest flow rate.

"Typically, the user wants to extend the cylinder with a great deal of control," Caputo says. "But on the way back, they're not doing any work, so they want the cylinder to get back as fast as it can." In most applications, Caputo says, the return rate is twice that of the extension flow rate.

Mistake #2: ***Undersized piping***

After selecting a hydraulic motor, engineers often look at the motor's port sizes before choosing their piping. If the motor's port sizes are, say, three-quarters of an inch, then they choose three-quarter-inch fittings and three-quarter-inch outer diameter piping.

Determining pressure drop in a length of pipe

$$P = \frac{hQ}{18{,}300d4}$$

Where P = pressure drop/ft of pipe
h = viscosity (ssv)
Q = flow
d = ID of pipe

That's a mistake. Too often, such snap decisions result in undersized piping. And undersized piping, in turn, causes larger pressure drops and more heat generation than the system is designed for.

Remedy: ***Check ID, flow velocity, pressure drop***

A designer who quickly sizes piping simply by looking at the motor's port risks making several mistakes. First, a three-quarter-inch outer diameter is too small. Why? Because a three-quarter-inch OD may have an inner diameter of as little as half an inch. Second, selection of piping requires more thoughtful consideration. Designers must consider velocity of flow through the pipe and pressure drop per foot of pipe (see equations above and below). Experts say that pressure drop can be important, especially in systems using long sections of piping. They also recommend that designers maintain flow velocities with certain parameters. Exceeding those parameters may cause turbulence in the flow, which can affect the Reynolds number of the fluid.

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Determining velocity of flow through a pipe

$$V = \frac{.3208(GPM)}{A}$$

Where V = flow velocity
GPM = gallons per minute of flow into the system
A = area inside the pipe (in^2)

Mistake #3: ***Reservoir size too small***
By dissipating heat, reservoirs in any hydraulic system play an important role. If the reservoir is undersized, however, it can't properly dissipate the heat. As a result, performance suffers and components wear out earlier. "A lot of users assume their reservoir is big enough without sitting down to calculate the heat dissipation," Caputo says. "If they would do some simple calculations, they might find that their system needs a bigger reservoir or even a heat exchanger."
Remedy: ***Calculate dissipation capabilities of the reservoir in horsepower***
In general, a 60-gallon tank will dissipate half a horsepower, given a 50° temperature differential between the oil in the reservoir and the air outside it. Compare that to your system's horsepower. Use a bigger reservoir or a heat exchanger, if necessary, depending on your packaging constraints.

Determining heat dissipation of a reservoir

$$HP = 0.001A\Delta T$$

Where HP = horsepower dissipated
A = surface area of reservoir (ft^2)
ΔT = temperature difference between oil in tank and air outside (deg F)
(1HP = 2544 BTU/hr)

Mistake #4: ***Proportional valves too big***
When selecting a directional valve, designers usually check their system's flow rate, open a catalog, and look for a valve with a corresponding rating.

So what's wrong with that? Nothing, if you're picking a directional valve. Proportional valves, however, are different. "Proportional and servo valves exhibit their control through a high pressure drop," notes Larry Schrader, director of motion control training for Parker Hannifin. The valve's flow rating, he says, is usually based on a specific pressure drop. Therefore, if your application's pressure drop is significantly different than the rated pressure drop of the valve, you'll probably select the wrong valve. Usually, Schrader says, engineers end up with an oversized proportional valve.

Sizing a proportional valve by flow rate

$$Q_R = Q_{OUT} \frac{\sqrt{\Delta P_R}}{\Delta P_A}$$

Where QR = valve's rated flow for your application
Q_{OUT} = output flow needed for application
ΔP_R = rated pressure drop of proportional valve
ΔP_A = actual pressure drop needed for application

If they do select an oversized valve, users are unlikely to get true proportional performance. In most cases, the valve will open all the way before it's supposed to, denying users the resolution that they seek.

Remedy: *Use pressure drop to determine flow rate*

Experts recommend that designers use this method to check the flow rating of their valve. In most cases, they say, the flow rating they obtain by this method will differ from the flow ratings in the catalog.

Mistake #5: *Specific gravity problems* In many cases, users want to replace conventional hydraulic oil with phosphate esters of water glycol fluids. That's fine, say experts, as long as you understand that hydraulic pumps can't lift those fluids as easily as they lift hydraulic oil. The reason: Conventional hydraulic oil has a specific gravity of about 0.85, while water glycol typically is about 1.0. Phosphate ester is even heavier at 1.1.

If design engineers don't make special accommodations for those heavier fluids, users soon notice that pumps make too much noise. Ultimately, cavitation of the pump occurs.

Remedy: *Put the reservoir higher than the pump*

Manufacturers call this "flooded suction." The pump doesn't need to work as hard to move the heavier fluid. If you're not sure about the specific gravity of the fluid you're using, call the pump's manufacturer to see if they require a flooded suction for that fluid.

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Mistake #6: *Force miscalculation*

If you know the loads, sizing a cylinder is easy. Unfortunately, knowing the loads can sometimes be difficult. Forces caused by friction and acceleration are more difficult to calculate, and are often overlooked. Worse, designers can't always foresee how the machine will be used. "For the design engineer, it's not always as easy as, 'I need to lift 50 pounds,'" says Jerry Scherzinger, senior support engineer for Bimba Manufacturing. "A lot of times the designer is coming up with a best estimate, and there are many factors involved in estimating that force." Too often", Scherzinger says, "The designer underestimates the force requirement, rather than overestimates it. As a result, the system doesn't move the load fast enough, or doesn't move it at all".

Remedy: ***Oversize by 25%***

That's what Scherzinger recommends to account for frictional loads. If you suspect that the cylinder will be subjected to greater loads later on, you might even consider exceeding that 25% rule of thumb. The only downside to doing that is cost: Initial costs and operating costs can rise. In the long run, however, users usually find that a larger cylinder provides greater benefits. "Don't hesitate to oversize the cylinder," he says. "The advantages of oversizing outweigh the disadvantages."

Mistake #7: *Wrong valve for E-stop*

Emergency-stop situations demand that a pneumatic system come to a complete halt. Sometimes, however, a pneumatic valve is already shifted when power is cut off. Afterwards, that valve shifts back and the associated pneumatic cylinder moves. That scenario can take place when certain 5-way valves are used with double-acting cylinders. And the results, in some cases, can be damaging or even dangerous for personnel.

Remedy: ***Check with valve manufacturer first***

In most cases, users notice the problem before damage occurs. By that time, however, the valve has already been specified and installed. As a result, changing to the right valve can be time-consuming and costly. For that reason, experts say that engineers must be vigilant early in the design process. "They have to understand their machine and ask all of the 'what if?' questions," notes Daniel Sandoval, didactic training manager for Festo. "What if power is cut-off? What if the PLC goes bad? What if someone hits the E-stop? The solutions to these problems have to be dealt with in hardware. It's not permissible to remedy those problems in software." Because there are many different types and brands of valves, Sandoval says designers must consult with the valve manufacturer to learn how the valve will behave when power is cut off.

Mistake #8: ***High-speed undersizing***
High-velocity pneumatic applications require sufficient force and high flow rates. Unfortunately, system designers don't always provide both of those features. Too often, air cylinders are too small to provide the force needed for quick acceleration. And valves don't have the necessary flow rates to achieve high speed.
Remedy: ***Double the bore diameter of the chosen cylinder***
For speeds above 16 inches/second, if you're planning on selecting a one-inch cylinder, select a two-inch model instead. Also, pneumatics manufacturers say that designers must look carefully at the flow ratings of the valves they plan to use in high speed applications. Catalog ratings are usually sufficient, they say, but are too often ignored or misinterpreted.

Mistake #9: ***Failure to specify tough-enough construction***
Pneumatic-component manufacturers say they see them all the time: cylinders, working in tough, corrosive environments, unable to stand up to every day wear-and-tear. Before long, the cylinders draw in dirt, then fail to perform properly. In most cases, they say, the problem occurs because designers never foresee the breadth of application for their technology. "Sometimes a designer will design a system that's so good, three or four industries can use it," Scherzinger says. "All of a sudden, their equipment is in an application where they never expected it."
Remedy: ***Better materials***
If you suspect that your machine will be used in such applications as food or pharmaceutical processing, be prepared to improve the materials of construction of your cylinders. Stainless steel or anodized aluminum bodies resist corrosion more effectively, particularly in wash down environments. Also consider use of plastic end caps, wipers, scrapers or rod boots as a means of preventing ingress of dirt into the cylinder.

Mistake #10: ***Insufficient tubing*** Most designers are trained to think of a pneumatic system as a collection of pumps, cylinders, and valves. Somewhere in between those pumps, cylinders, and valves, however, lies an equally important component: tubing. Improperly designed tubing can cause disturbances in flow and pressure. Too often, it becomes the limiting factor in a pneumatic system.
Remedy: ***Pay attention***
Experts say that tubing mistakes fall into two categories: too long or too skinny. Long sections of tubing create unwanted pressure drops and skinny tubes cause valves to work improperly. Unfortunately, they say, designers can only remind themselves to be aware of the problems caused by improperly designed tubing. "When you look at a drawing, the tubing looks like a bunch of insignificant lines," Sandoval says. "But if you don't pay attention to it, it can cause a lot of trouble for you.

Slimebusters: Plastic end caps and stainless steel bodies, like those shown here, keep fluid power equipment operating even in aggressive environment applications.

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