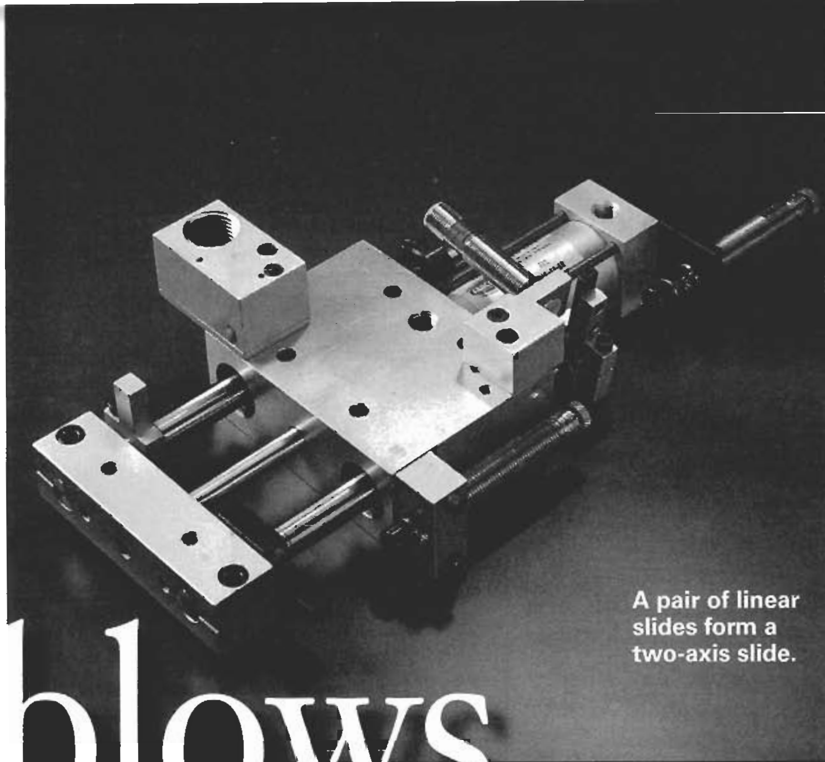
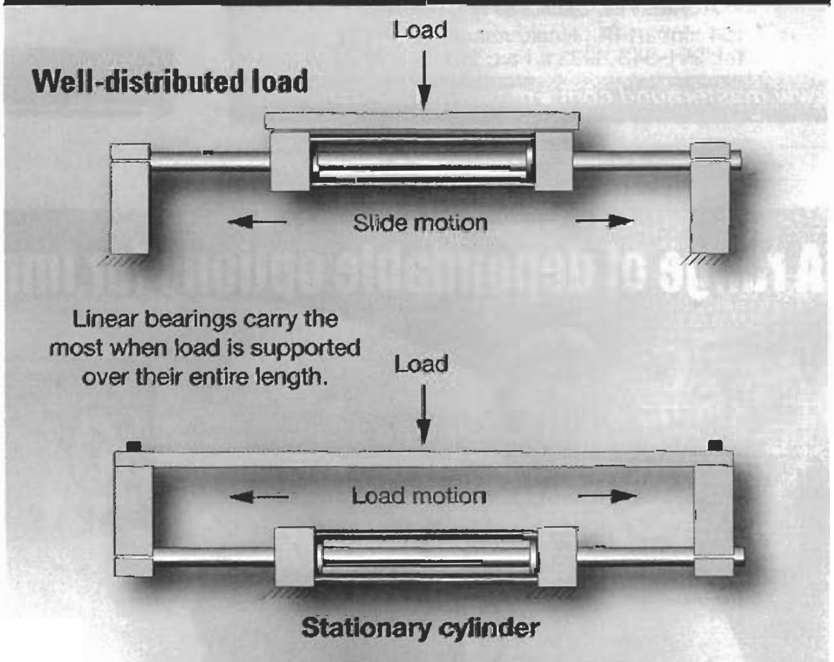
Learn how to balance pneumatic power with the load capacities of supports for automated assembly equipment.

Steady as she blows



A pair of linear slides form a two-axis slide.

Doug Mills
Chief Engineer
Fabco-Air Inc.
Gainesville, Fla.



Top: A carriage load is attached to a mounting plate on the reciprocating slide. Bottom: A stationary slide with a (carriage) load plate is attached to reciprocating guide shafts.

Pneumatic linear slides combine air power with mechanical guides to move workloads with precision. They're useful on everything from simple pressing operations to demanding multi-axis robotics. Packaged pneumatic actuators are particularly cost-effective: Free CAD files of the units can be inserted directly into larger design files, and build time and related costs are reduced. Incorporating off-the-shelf slide components can simplify maintenance and even machine manuals and parts lists. What's more, equipment designers can now choose from a wide array of linear slide models.

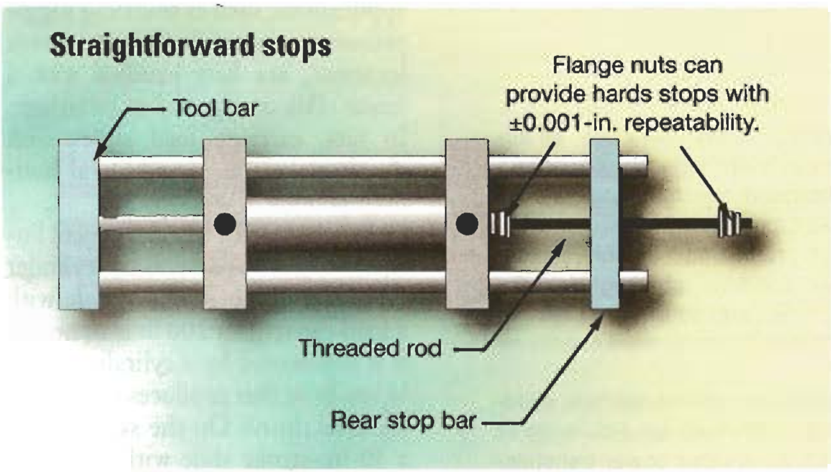
But if you're not developing a custom unit, how do you ensure that an off-the-shelf solution will still perform well on your machine? Several factors determine the best design: Force required determines air cylinder bore size, and required load capacity determines the proper size and bearing type of a slide's guide. Depending on stroke, or total linear distance traveled, guide stiffness will be a factor. And if operating speed — cycles or inches per second — is high, utilizing engineering data for each model series is paramount. Let's now examine each of these factors more closely.

Force

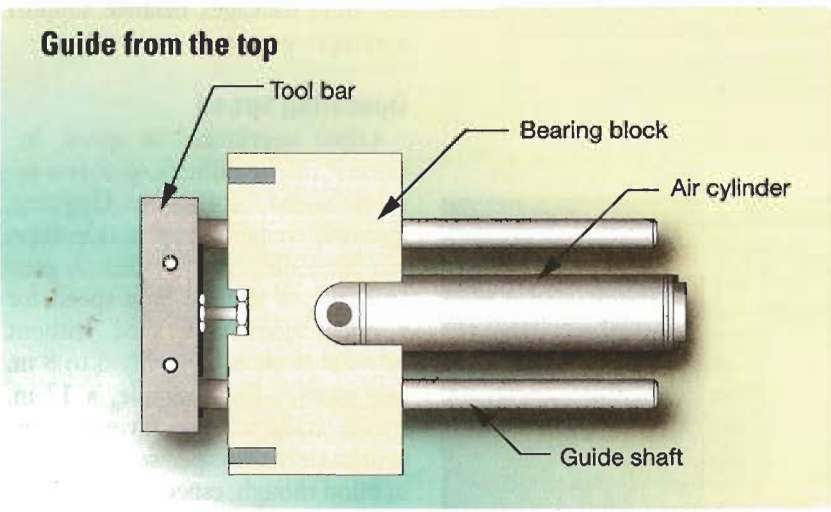
Linear slide cylinder bores are determined with:

Force = psi x Area

Called the *power factor*, many slide models have a different value for their extend stroke than for retraction. That's because the factor



Mechanical stop options include clamp collars or threaded stop nut/bolt arrangements.



Some linear slides include guide mechanisms with bearing blocks and guideshafts attached to a common tool bar. This is a setup useful for pressing applications.

accounts for area lost by the piston rod. So, if your application involves pressing, as in an assembly operation, consider the possibility that more force may be required than initially expected. To meet the demand, one option is to size the cylinder to a larger bore, and regulate it to a lower supply pressure. Then when more output force is needed, pressure can be increased.

Another method of increasing slide output is to utilize a tandem cylinder or power-boosting cylinder auxiliaries. Lifting applications are good candidates for this approach; they require that the slide have at least twice the output force as the weight to be lifted. Underpowered slides that just barely lift loads operate poorly, with a slow, jerky, and uncontrolled motion.

In contrast, many applications require very little force. Here, a common mistake is to ignore bore size. A better approach: Select a slide with a bore size that provides a sufficient volume of air to operate with a smooth, controlled motion, and avoid excessively large bores that waste air (and energy) needlessly.

Precision and capacity

A slide must support its workload over the length of the linear motion, with the precision required by the application. After all, a linear slide carrying a paddle that knocks boxes off of a conveyor does not need the same degree of precision as a parts placer on an assembly machine. Engineering data pertaining to slide load capacity will generally indicate safe loading in pounds, as well as predicted toolbar deflection, or bending, in thousandths of an inch.

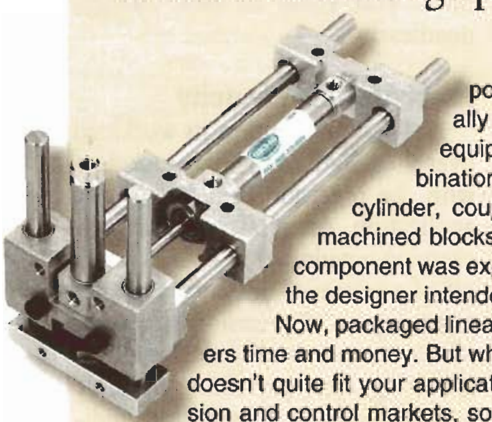
In one of the most common linear slide arrangements, two or more shafts serve as the guiding mechanism, while workloads are attached to the reciprocating toolbar — producing an overhung load. In this arrangement, load capacity is ultimately determined by:

- the guideshaft's resistance to deflection, and
- the linear bearing's ability to support that load.

Although overhung workloads produce undesirable loading on the leading edge of the linear bearing, most bearings have a much higher load rating than that of the guideshafts to resist deflection. In fact, a slide with linear ball bearings may be rated for, say, 20 lb with 0.005-in. deflection in an overhung load situation, even though the four bearings may have a combined load rating of several hundred pounds. Bearing over-capacity ensures precision and long life even in overhung loading situations.

Even so, the fact remains that linear bearings, whether ball or sleeve-type bearings, support the most load when that load is applied over their entire length — a distribution commonly known as *carriage load*. Heavy

A little something special

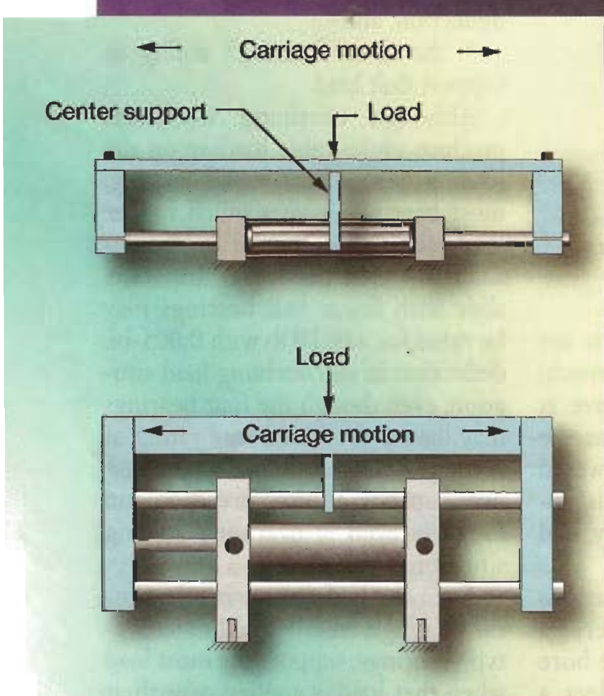


Not that many years ago, all air-powered linear slides were individually designed and fabricated by the equipment builder, who used a combination of purchased components: air cylinder, coupler, bearings, shafting, custom-machined blocks, plates, and so on. This custom component was expensive, but performed exactly as the designer intended.

Now, packaged linear slides are saving machine builders time and money. But what if an off-the-shelf slide product doesn't quite fit your application? As in other power-transmission and control markets, some manufacturers now sell "special" designs through their applications departments. The special designs are based on standard units, but with something as simple as a custom sensor, or custom mounting holes and dowels — or as complex as a new slide. The manufacturer makes these modifications to the unit before it is assembled, when alterations are easier to do. Then a special part number is assigned, for reference and reordering in the future.

Support adds load capacity

Carriage loads applied to guideshaft-style linear slides can cause shafts to deflect, or bend, especially on longer strokes. Rather than sizing up to a slide model with large-diameter guideshafts, you may be able to use a smaller model with the addition of the optional center support. Safe loading charts (usually included in slide literature) outline design considerations by predicting maximum deflections at various strokes and loads.



Here, optional center support members dramatically increase load-carrying capacity. By attaching the shaft support at the center, deflection can be reduced to less than 0.005 in., even on very heavy loads.

applications, such as shuttling toggle presses or rivet units between work locations, are best handled with a linear slide configured as a carriage. In fact, carriage load slides with short stroke can carry several hundred pounds of workload.

Another factor that influences linear slide load capacity is the cylinder bore and stroke. A linear slide with a load capacity of 200 lb is of no use if it is powered by a cylinder with a $^{1}/_{2}$-in. bore that produces only 10 or 15 lb of thrust. On the same token, a 30-in.-stroke slide with small $^{1}/_{4}$-in.-diameter guideshafts does not have sufficient strength to be of any practical value. Pre-engineered linear slide packages balance support and input power.

Operating speed

Often overlooked is speed, because it can be difficult to obtain accurate speed information. However, ignoring velocity and acceleration can have disastrous results. A general rule of thumb: Safe speed for a pneumatic linear slide without external stops is generally 6 to 8 in. per second. For example, a 12-in. stroke made in 2 sec averages approximately 6 in. per second. Keep in mind though, especially on shorter strokes, ignoring acceleration and deceleration can be very misleading. A 1.0-in. stroke in 0.16 seconds averages 6 in. per second. However, final speed is much higher than that, because a good portion of time is spent accelerating. What's more, high speeds make for severe impact forces when stopped suddenly at end of stroke.

Typically, slides are offered in 1.0-in. stroke increments. Designers generally specify a stroke slightly longer than the application requires, and then utilize optional adjustable stops; these hard stops repeat to within ±0.001 in. of stopping accuracy. Two systems are clamp collars or threaded stop nuts/bolts. If stopping accuracy is not an issue, urethane bumpers, either within the cylinder or not, can be used to cushion these forces. For a more precise cushioned stop, adjustable stops in conjunction with either hydraulic shock absorbers or optional internal cylinder air cushions can be employed.

Speed also affects which bearing type is most appropriate. High speeds are best accomplished with linear ball bearings, which can travel up to 100 in. per second. Ball bearings should be avoided with these designs, particularly in applications with short strokes and quickly reciprocating motions. The inertia of the ball circuit tends to make the balls skid in their tracks when direction is reversed suddenly.

Sensors

Options include toolbar and toolplate styles, bearing types, adjustable stops, shock pads, air cushions or hydraulic shock absorbers, and perhaps more importantly, sensors. Sensors are the interface between the linear slide and the electronic controller. Reed or Hall-effect switches are actuated by a magnetic piston band on the slide's air cylinder. Many slide models offer a proximity switch option operated by a moving target on the slide's motion. Other options are mechanical snap-action switches and air pilot switches, as well as LVDT linear transducers.

For more information, visit fabco-air.com or the Component Zone accessible from motionsystemdesign.com.

Brief linear slide history

Powered linear slides date back to the dawn of the Industrial Age, when leadscrews were added to early lathes, to power tool post carriages. Later, mechanical cams were developed to power slides and provide a programmed motion. For example, wooden gunstocks were mass-produced from master patterns with special machinery utilizing cam-operated linear slides.

Air cylinder and hydraulic slides evolved in the early twentieth century. Although reliable, their relay-logic control systems were complicated and lacked flexibility. Any change in sequencing required redesign and rewiring.

Today, programmable controllers control the sequencing of air-powered linear slides. This leap in technology has revolutionized modern industrial equipment. Costs and lead times are reduced, and small-volume consumer-product manufacturing can now be automated: The ability to easily reprogram means the flexibility to custom-tailor products.