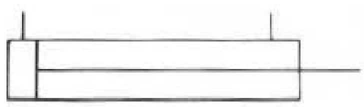
Pneumatic Actuators

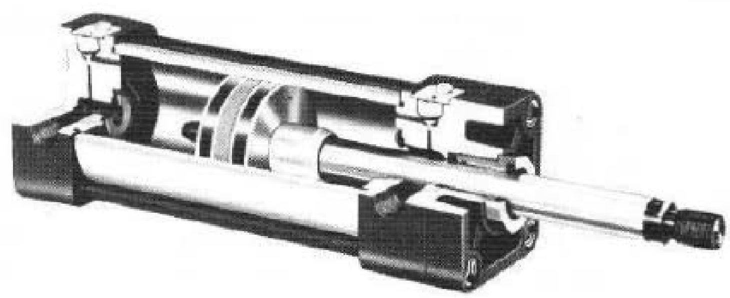
Pneumatic systems make use of actuators in a fashion similar to that of hydraulic systems. However, because air is the fluid medium rather than hydraulic oil, pressures are lower, and hence pneumatic actuators are of lighter construction. For example, air cylinders make extensive use of aluminum and other nonferrous alloys to reduce weight, improve heat transfer characteristics, and minimize corrosive action of air.

Pneumatic cylinders

Figure illustrates the internal construction features of a typical double-acting pneumatic cylinder. The piston uses wear-compensating, pressure-energized U-cup seals to provide low-friction sealing and smooth chatter-free movement of this 200-psi pressure-rated cylinder. The end plates use ribbed aluminum alloy to provide strength while minimizing weight. Self-aligning Buna-N seals provide a positive leakproof cushion with check valve action, which reverts to free flow upon cylinder reversal. The cushion adjustment, which uses a tapered self-locking needle at each end, provides positive control over the stroke, which can be as large as 20 in.



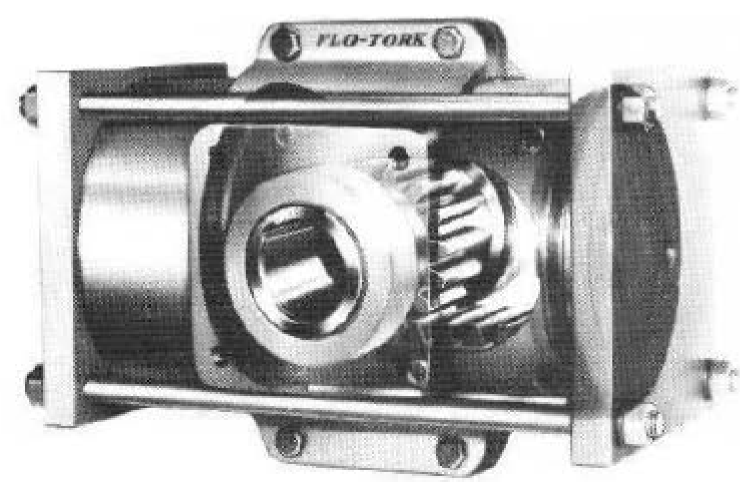
ANSI SYMBOL



Pneumatic Rotary Actuators

Oscillatory air motors

In Figure, we see a pneumatic actuator, which is available in five basic models to provide a range of torque outputs from 100 to 10.000 lb.in. using 100-psi air. Standard rotations are 94°, 184°, and 364°. The cylinder heads at each end serve as positive internal stops for the enclosed floating pistons. The linear motion of the piston is modified into rotary motion by a rack and pinion made of hardened steel for durability.

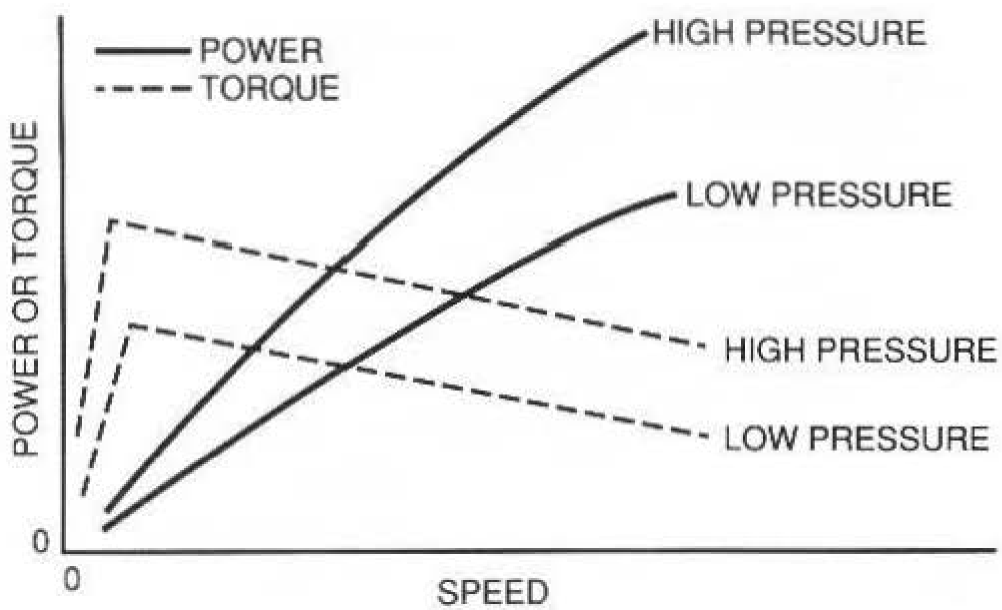


Rotary air motors

Rotary air motors can be utilized to provide a smooth source of power. They are not susceptible to overload damage and can be stalled for long periods of time without any heat problems. They can be started and stopped very quickly and with pressure regulation and metering of flow can provide infinitely variable torque and speed.

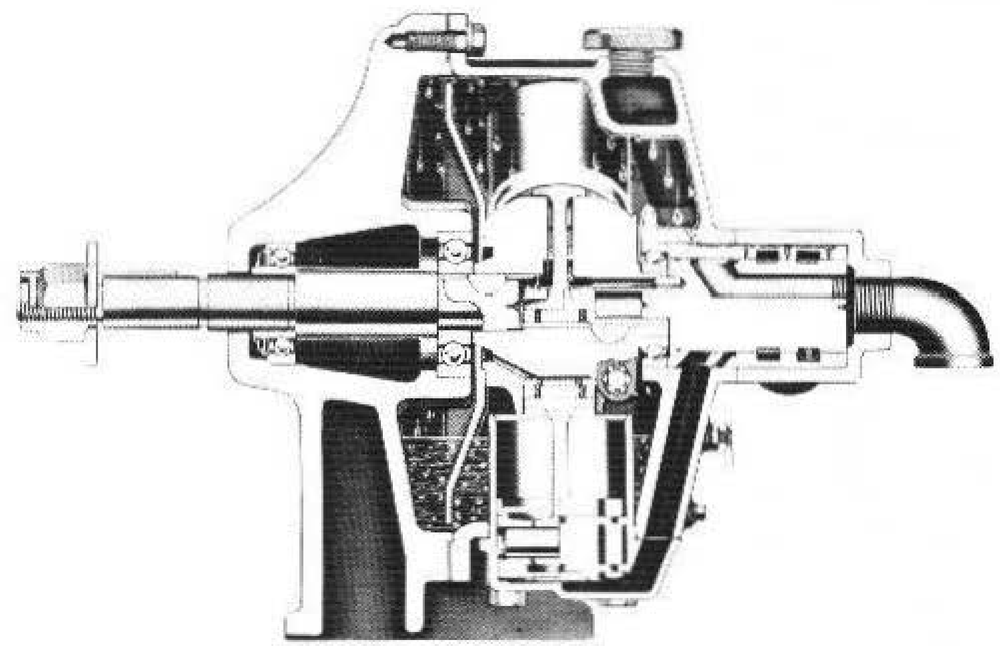
The equations for determining the output torque and power for air motors are identical to those used for hydraulic motors. However, because air is compressible, the accuracy of these equations is not as good for air motors as for hydraulic motors. For example, the speed of an air motor decreases significantly as the load torque increases. In addition, the air-consumption rate (scfm) increases at the same air motor speed with increased pressure.

Figure shows speed-vs.-torque and speed-vs.-power curves for air motors at high- and low pressure levels. These types of performance curves are determined from actual test data. Observe that the starting torque (torque produced under load at zero speed) is lower than the running torque. As a result, higher inlet pressure (as controlled by a pressured regulator) may be required to start driving a large load torque.

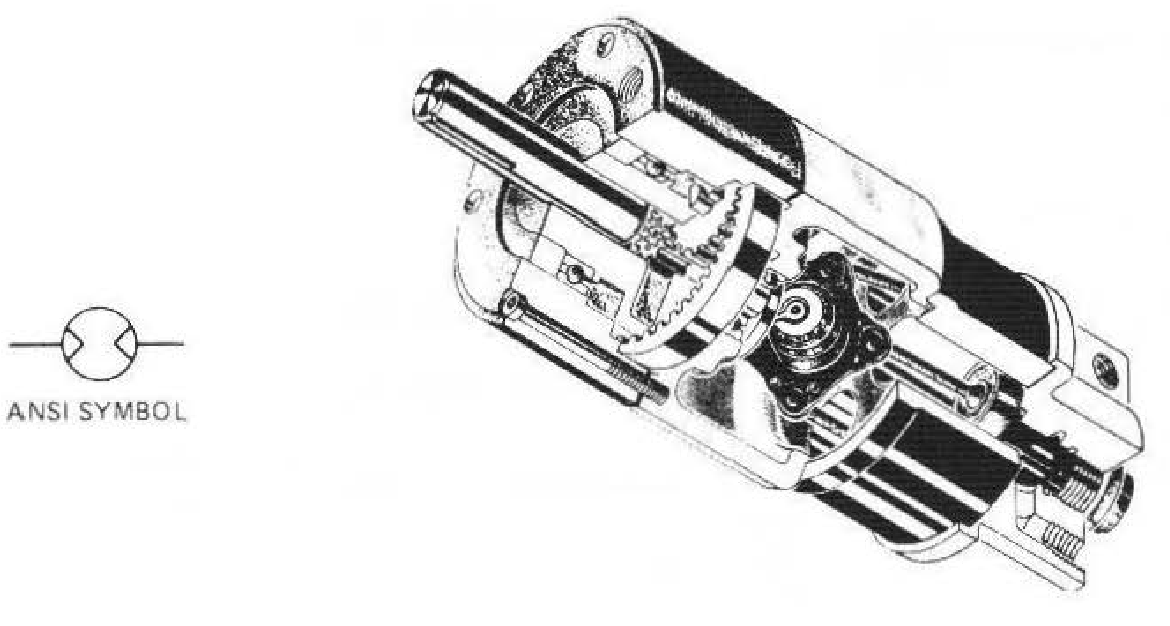


Power-speed and torque-speed curves for a typical air motor.

Figure shows a radial piston air motor. The five-cylinder piston design provides even torque at all speeds due to overlap of the five power impulses occurring during each revolution of the motor. At least two pistons are on the power stroke at all times. The smooth overlapping power flow and accurate balancing make these motors vibrationless at all speeds. This smooth operation is especially noticeable at low speeds when the flywheel action is negligible. This air motor has relatively little exhaust noise, and this can be further reduced by use of an exhaust muffler. It is suitable for continuous operation using 100-psi air pressure and can deliver up to 15 hp.



In Figure, we see an axial piston air motor, which can deliver up to 3 hp using 100-psi air. The power pulses for these five-piston axial design motors are the same as those for the radial piston design. At least two pistons are on the power stroke at all times, providing even torque at all speeds.



Pneumatic actuators are used to drive a variety of power tools for performing useful work. The air requirements of these tools in terms of flow rate and pressure depend on the application involved. Figure gives the air flow requirements in scfm and standard m^3/min for a number of average-size pneumatic too is designed to operate at a nominal pressure of 100 psig (687 "Pa gage).

EXAMPLE

A single-acting pneumatic cylinder with a 1.75-in. piston diameter and 6-in. stroke drives a power tool using 100 psig air at 80°F. If the cylinder reciprocates at 30 cycles/min. determine the air-consumption rate in scfm (cfm of air at standard atmospheric conditions of 14.7 psia and 68°F).

PNEUMATIC TOOL	scfm	STANDARD m^3/min
HOISTS	5	0.14
PAINT SPRAYERS	10	0.28
IMPACT WRENCHES	10	0.28
HAMMERS	20	0.57
GRINDERS	30	0.85
SANDERS	40	1.13
ROTARY DRILLS	60	1.70
PISTON DRILLS	80	2.36

Air requirement of various average-siza pneumatic tools designed for operation at 100 psig (687 kPa gage).

Solution The volume per minute (V_2) of 100 psig, 80°F air consumed by the cylinder is found first.

$$V_2\left(\frac{\text{ft}^3}{\text{min}}\right) = \text{displacement volume (ft}^3) \times \text{reciprocation rate}\left(\frac{\text{cycles}}{\text{min}}\right)$$

$$= \text{piston area (ft}^2) \times \text{piston stroke (ft)} \times \text{recip. rate}\left(\frac{\text{cycles}}{\text{min}}\right)$$

$$= \frac{\pi}{4}\left(\frac{1.75}{12}\right)^2 \times \frac{6}{12} \times 30 = 0.251\ \text{ft}^3/\text{min}$$

To obtain the volume per minute (V_1) of air (scfm) consumed by the cylinder, we use the general gas law (Eq. 10-6).

$$V_1 = V_2 \left(\frac{P_2}{P_1}\right)\left(\frac{T_1}{T_2}\right)$$

where

$$P_2 = 100 + 14.7 = 114.7 \text{ psia},$$

$$P_1 = P_{atm} = 14.7 \text{ psia},$$

$$T_2 = 80 + 460 = 540°\text{R},$$

$$T_1 = 68 + 460 = 528°\text{R}.$$

Substituting values yields

$$V_1 = 0.251 \left(\frac{114.7}{14.7}\right)\left(\frac{540}{528}\right) = 2.00 \text{ scfm}$$

If we ignore the temperature increase from standard atmospheric temperature (68°F) to the air temperature at the cylinder (80°F), the value of V_1 becomes

$$V_1 = 0.250 \left(\frac{114.7}{14.7}\right)\left(\frac{528}{528}\right) = 1.96 \text{ scfm}$$

Thus, ignoring the increase in air temperature results in only a 2% error $\left(\frac{2.00 - 1.96}{2.00} \times 100\%\right)$. However, if the air temperature had increased to a value of 180°F, for instance, the percent error would equal 21%.

EXAMPLE

For the pneumatic cylinder–driven power tool of Exercise 10-11, at what rate can reciprocation take place? The following equivalent metric data apply:

1. Piston diameter = 44.5 mm.
2. Piston stroke = 152 mm.
3. Air pressure and temperature (at the pneumatic cylinder) = 687 kPa gage and 27°C.
4. Available flow rate = 0.0555 standard m^3/min (cfm of air at standard atmospheric conditions of 101 kPa abs and 20°C).

Solution First, solve for V_2, which equals the volume per minute of air at 687 kPa gage and 27°C consumed by the cylinder:

$$V_2 = V_1\left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right)$$

where

$$P_2 = 687 + 101 = 788 \text{ kPa abs},$$

$$P_1 = P_{atm} = 101 \text{ kPa abs},$$

$$T_2 = 27 + 273 = 300 \text{ K},$$

$$T_1 = 20 + 273 = 293 \text{ K},$$

$$V_1 = 0.0555 \text{ standard m}^3/\text{min of air}.$$

Substituting values yields an answer for V_2:

$$V_2 = 0.0555\left(\frac{101}{788}\right)\left(\frac{300}{293}\right) = 0.00728 \text{ m}^3/\text{min}$$

Next, solve for the corresponding reciprocation rate.

$$V_2\left(\frac{\text{m}^3}{\text{min}}\right) = \text{area (m}^2) \times \text{stroke (m)} \times \text{recip. rate}\left(\frac{\text{cycles}}{\text{min}}\right)$$

$$0.00728 = \frac{\pi}{4}(0.0445)^2 \times 0.152 \times \text{recip. rate}\left(\frac{\text{cycles}}{\text{min}}\right)$$

$$\text{recip. rate} = 30 \text{ cycles/min}$$

As expected, the answer of 30 cycles/min equals the reciprocation rate given in Example 10-11, because the data in this example are the metric equivalents of the English data of Example 10-11.