**CYLINDERS**

**The core** of pneumatics is the pneumatic cylinder. There are other types of pneumatic devices, but the cylinder is the most commonly used for animation. A pneumatic cylinder consists of an outer tube with a metal rod inside. The cylinder has one or two air connections for the flow of air into and out of the internal air chamber. When air is forced into the cylinder it either pushes the metal rod in or out.

The linear movement of that rod is used for mechanical movement. It can be used to push something or to pull something. The force cylinders can generate make them useful for leveraged props, where the short throw of the cylinder can be used to generate a much large movement through a series of linkages. More about that later.

Two basic factors for a pneumatic cylinder is its length ( or throw) and its diameter. The length of the rod, or more specifically how much it moves when pressure is applied, is a key factor in selecting the right cylinder for an application. The diameter of the tube directly relates to how much force can be generated with a given air pressure. The larger the diameter, the more force that can be generated.

Calculating the force of a pneumatic cylinder is fairly straightforward. To calculate how many pounds of force a cylinder will have, use the following formula:

Air Pressure per Square Inch (PSI) x Area of cylinder = Force

So, 40 PSI in a 1" diameter cylinder would look like this:

40 x .78539 = 31.4 pounds or force

To calculate the area of a circle, use the formula 3.14 x 1/2 diameter x 1/2 diameter (pi x radius^2) or for a simple rough estimate, multiply the diameter by the diameter and the result by .78

**Types of Cylinders**

Single Rod - a cylinder with just one rod.

Single-acting - a cylinder with one air connection. Air is forced in to push the rod. To return the rod to its original position, remove the air pressure, and either gravity or a spring push it back. This type of cylinder is typically used as a full extension or no extension device, it is not used to move to an "in between" position.

Double-acting - a cylinder with two air connections. Air is forced into one end of the cylinder to move the rod and then air is forced into the other connection to return the rod to the original position. This type of cylinder can also be used to rapidly move the rod (or prop) back and forth. It can also be used to achieve a position between full extension and zero extension.

Spring Return - Single acting cylinders sometimes have a spring return to return the rod to its starting position. It has little force and can move little more than the rod itself in most cases.

**Other Considerations**

Cylinders also have various diameter push rods. Generally, this isn't a big concern, but you may have an application that mates more easily with a certain size rod. The rod has a threaded end for making connections or threading a nut to secure it in place. the only other factor for consideration of the rod diameter is if you are dealing with large forces, then you want a rod capable of supporting that force. A small rod on a 1" cylinder with 150 psi could damage the rod. While you probably won't need such high PSI, it just illustrates the point to choose the proper cylinder for the application.

The air connection fittings to a cylinder also vary. Generally 1/4" connections are ideal unless you need to move high volumes of air, such as in an air cannon. try to stick to one fitting size to simplify your work. If you find a deal on cylinders with a the wrong fitting size, that is fine, you can always work around with extra fittings.

Lastly, connecting your cylinder in place is the final consideration. The rod is threaded and so can be bolted together with a prop or a variety of connectors can be screwed onto it and those attached to the prop. The other end of the cylinder also has a variety of connection options. Some have a nut allowing the cylinder to be bolted in place while other have other types of connectors allowing for pivoting.

Pneumatic cylinders are primarily used in industrial applications and so a great variety of options and features are available that are not relevant to the typical builder of special effects. Most of these features increase the price of the cylinder but have little other bearing on your project and so can be ignored. The bare bones cylinder is what most prop builders will need. A good source for cheap cylinders is Ebay. Finding a very specific cylinder is difficult and you may be forced to pay full price through a retailer, such as Grainger.

VALVES

**The control** of pneumatic cylinders is achieved through a solenoid valve. Pneumatic solenoid valves are electrically activated to stop and start the flow of air, similar to a faucet stopping and starting the flow of water. These valves can offer more features than just "on" or "off" but we'll get into that later.

The most basic electric solenoid valve uses electricity to move a plunger in or out of an opening to stop or start the flow of air. A valve can be normally open (NO) or normally closed (NC). When closed, no air flows. When current is supplied to the solenoid, the valve opens and remains open until the current stops, then the valve closes again.

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| Solenoid vale - Click to enlarge |

As the air flows from the compressor (or a tank of compressed air) through the valve and into the pneumatic cylinder the rod is actuated (pushed or pulled) as a result of the pressurized air. When the valve closes, the flow of air to the cylinder stops. What happens next depends on the type of valve and on the type of cylinder.

**2-Port 2-Way Valve**

There are many valve configurations, but the most basic is a 2-port, 2-way valve. The valve has a port "IN" and a port "OUT". Pressurized air flows from the compressor through the valve to the device being controlled. When the valve opens, air flows. When the valve closes, the air flow stops. Now here is the problem with that, if the air flow stops and the valve is closed, where does the air in the cylinder go? The answer is nowhere, it is trapped in the cylinder and air supply tube. Unless it is vented somewhere, the cylinder will remain in its "actuated" position. That is why this type of valve is used for things like air cannons where the compressed air is vented to the atmosphere.

**3-Port 3-Way Valve**

In order for the rod to retract when the air flow stops, the air must be able to vent to somewhere. That is where a 3-port, 3-way valve comes in. The is an "IN" port, there is an "OUT" and there is an "EXHAUST" port. When the valve goes from open to closed, the "OUT" port is switched from connecting with the "IN" port to connecting with the "EXHAUST" port. So when the valve is closed, the air can escape to the atmosphere through the exhaust port. The shortcoming with this is that cylinders rely on gravity to return to the resting position (although many cylinders have a return spring, they don't have the strength to move the prop).

**4-Port 4-Way Valve**

So what if you are using a Double-Acting Cylinder that needs pressure to actuate and reverse pressure to retract? You need a valve that sends air pressure in one direction when the prop is in the resting state and to switch the flow of air to to actuate the cylinder. A 4-port, 4-way valve has an "IN" port, 2 "OUT" ports that switch depending on whether current is flowing or not and then an "EXHAUST" port for the two "OUT" ports to vent to.

**5-Port 4-Way Valve**

What why would I need another port? Air goes in or out and it all vents, what else is there? Well, let's say you have a double-acting cylinder, and let's say your prop is moving too fast when it pops up. So fast that the prop flies right off the end of the rod. You need to slow the flow of air to reduce the speed of the pop up. If you place an in-line valve to slow the rate of flow, that will slow the pop up, but it will also slow the exhaust and the return of the prop. In order to have the prop pop up at one speed and retract at a different speed, you must be able to control the air lines individually and thus they must exhaust separately and that calls for one extra port.

So in practice, if you want something to pop up and gravity will return it to its at resting position, then a 3-port, 3-way valve will do. If you want to make something jump back and forth, then a 4-port, 4-way valve will do the trick, and if you want to precisely control the rate of movement in both directions then a 5-port, 4-way valve is required. I buy only 5-port valves because they can do all the work and so they are the most versatile. They cost a little more, but from project to project I never know what I'll need, so having the most versatile in-stock is convenient.

If you use a 5-port valve for a strict on-off application, you will actually have to plug the first "OUT" port or air will blast while it is in the resting position.

These valves usually go for about $28-$35 (in 2009). You might be able to find them on EBay for less, but make sure you are getting exactly what you need.

Valves are available in AC line voltage or various DC voltages. Whatever is most convenient for you, whether connecting to a battery, a controller or to house current, select whatever is easiest for you to use.

To learn about how to trigger the solenoid valve and how to connect the whole prop control system together, read our "[Set-Up](http://diy-fx.com/pneumatics/set-up.php)" article in the pneumatics section.

CONNECTORS

**Connecting** together cylinders with valves and air supply requires the use of specialized connectors and air supply hoses. It isn't to complicated, but it can be frustrating when you are putting it all together if you didn't purchase just the right connectors.

In the old days, barbed connectors were used to connect hoses to the valves and cylinders. However, a much easier connector is the new standard, quick-connect connectors allow you to slip the hose right into the connection point within almost no effort and to disconnect the hose by simply depressing the quick-connect collar and pulling out the hose.

The connectors will screw into cylinders and into valves. They are available in various sizes, so make sure you select ones that match your devices. To ensure that no air pressure is lost, it is best to wrap the threads in a couple turns of teflon tape. Teflon tape pretty much guarantees an air tight connection. If you waste air, the compressor will run more, making more distracting noise. Also, if you are operating a lot of equipment, wasted air can really add up and result in underpowered props.

The three most common connectors are simple straight connectors, elbows and flow regulators. I prefer elbows because I don't like the air hose to stick out 90 degrees to the cylinders and valves, most of the time. Fittings cost about $1.50 to $2.50, so stock up on a few extra, it is really frustrating to run short at the last minute.

Connecting your entire rig to a compressor requires a transition from compressor hoses to the connectors used in your air distribution system. Generally, you should be able to find a reducing adapter fitting in the plumbing department to make the step down to the smaller size. Be sure to have a sample of all your fittings with you in order to make sure everything fits as expected while you are still at the store.

When connecting everything together, it is important to use teflon tape on the threaded joints. If you don't seal the connections, you will have a slow steady air loss. While you may be able to spare some lost air, it will cause your compressor to cycle on more frequently. A few leaks across several connections can quickly deplete air supply, so save yourself the trouble and make all threaded connections tight by wrapping them with teflon tape.

**SETUP**

**Animating**a prop with an air cylinder (pneumatic cylinder) requires several pieces to make it happen. First of all you need a pneumatic cylinder to cause the actual movement, a valve to stop and start the flow of air, tubing to connect all the pieces together, fittings to join the tubing to the components, an air supply and finally a trigger to control the device. An auxiliary air storage tank is optional.

Before positioning your equipment in place or connecting the cylinder to a prop, connect together the pieces of your system to test for proper function.

**Caution:** Once connected to pressurized air, the cylinder rod may actuate very rapidly and unexpectedly. Always place the cylinder so that the rod is directed away from people. The rod should be pointed into open air so that it cannot harm anyone or push against an object forcing the cylinder backward toward you. Always start testing with minimal air pressure. Always operate a prop with the minimum pressure needed to get the job done and no more.

Typically the air supply does not need to be near the prop. If you are using a compressor, the noise may detract from the operation of your prop and it is desirable to separate the two. The compressor can be connected to control valve, a splitter or an auxiliary storage tank with standard air hose and quick connect fittings. This is preferable to use of the tubing we'll use later because these hoses are more durable than the tubing and can withstand more punishment. If you will be driving multiple props from one compressor, it is a good idea to add in auxiliary storage tanks to ensure adequate air supply during peak demand.

A small compressor should be able to provide more than enough air supply for one or two cylinders. However, if you are driving those cylinders continuously or you have more cylinders, your compressor may be taxed to keep up with demand. It is always a good idea to double check all your fittings from end to end to make sure you don't have any air leaks. Even small leaks can add up. All hoses and quick connect connectors should be be tightly connected together and gas rated teflon tape should applied to all male fittings to get air tight seals.

With your air supply hose connected to your compressor (but with no pressure) you can connect the air supply to the valve and the tubing between the valve and the cylinder. Use of push connector fittings are a vast improvement over the old barb fittings. Each push connector fitting should have gas rated teflon tape wrapped onto the male threads before the fitting is screwed into the valve and cylinders. Tighten the fittings by hand and then give them a quarter to full turn with a wrench to seal them tightly.

Depending upon the valve and cylinder you use, the number of connections will vary. If you are using the most versatile, 5-port, 4-way valve, you will start by connecting the air supply to the "In" port. One of the ports will be "Normally Open" or "NO" and one will be "Normally Closed" or "NC". If you have a double-acting cylinder, then you will use both of these ports. The "NC" port is the port that opens when you electrically trigger the solenoid valve. When the valve opens, your prop will be actuated. Connect this port to the side of your cylinder that should receive pressure to actuate the prop. Connect the other port to the side of cylinder that should return the prop to the "resting" position.

If you are using the push-to-connect fittings, then making the connections is very simple. Cut your tubing with a razor knife to length, plus a little slack to prevent pinching. Insert the tubing to the push fitting on the cylinder and to the valve.

The valve has two exhaust ports. You don't need to do anything with these ports, however, you can add a flow control or a muffler. The muffler is used to reduce the noise from venting air. The flow control allows you to adjust the rate of exhaust and thus slow the movement of the prop.

If you do not use one of the output ports, it will need to be capped, otherwise air will blast out while the valve is directing the flow path through that port.

Finally, the solenoid valve needs a trigger. Valves are available for different voltage sources, be sure to connect it to the proper power source for the solenoid. You can connect the valve to a manual switch, such as a simple on-off light switch, a momentary switch such as a push button or it can be triggered with various sensors. A pressure mat makes an electrical connection when someone steps on the mat. When someone steps near the prop and stands on the pressure mat, the circuit is made, the valve is energized and the prop is actuated. Similar sensors include motion sensors, infra-red sensors and light-beam sensors. For automated props, you can connect the valve to a variety of "key banger" controllers that will record and play back a sequence of on-off signals to actuate the prop in a preset way on demand.