PNEUMATICS 101

With Paul Jameson

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Why Pneumatics?

Haunters, and especially home haunters, generally enjoy building props. Everyone knows the coolest props are usually the ones that MOVE! Home Haunters also have a tendency to use whatever is laying around the house to make their props work, rotisserie motors, windshield wiper motors, things like that. The problem with these is they are good for rotary mechanisms and smooth back and forth motions, but we want something scary! We want something powerful that moves quickly! One of the easiest ways to do this is using pneumatics.

My Story

Although I'm only 25 I've been building pneumatic props for 12 years or so now. It all started at a friend's house where we had decided to scare trick or treaters and set up a cemetery scene. One of my friends actually had a leaf blower with an aluminum covered cardboard blade on it to make it look like a chainsaw (which surprisingly scared a lot of people). There was a conveniently located hole in the yard to access some type of underground plumbing. This was to be a grave, and I was a zombie, leaping from the grave lunging at people passing by on the sidewalk. There were black lights in the hole with me, as my costume was black light sensitive. Anyway, it started to rain, and throughout the night I kept receiving shocks from our awesome lamp cords and black lights in the hole. The next year I decided to put some sort of mechanical device in the hole to jump up and scare people, so no actors needed to be in the hole in case it rained. A quick trip to the internet showed me some techniques for ghetto-rigging pop- up monsters using door-closers and washer solenoids. Those first props I built were simple, and probably fairly dangerous. Most of them did not work through the whole night the next Halloween, except for one I had constructed in an hour using duct tape. But the scares I produced, and the speed and power of the pneumatic system had me hooked. Each year my prop building skills got more technical and of higher quality. Now I can animate almost anything I want!

Pneumatics Theory

The theory behind pneumatics is very simple. A COMPRESSOR takes a lot of air and squeezes it into a small space, creating a lot of potential energy, in the form of pressurized air. The pressurized air travels through the system trying to be released and equalize with the pressure of the atmosphere. It will always travel from a higher pressure area to a lower pressure area. When you open a VALVE (or spring a leak), that gives the system a chance to equalize itself, and the air will move from a higher pressure region to a lower pressure region. You can harness this moving air to do your bidding using ACTUATORS. When the air starts moving it is converted back into kinetic energy. These actuators can take the form of a piston, a rotating actuator, an air motor, blower nozzle, or many other types of devices.

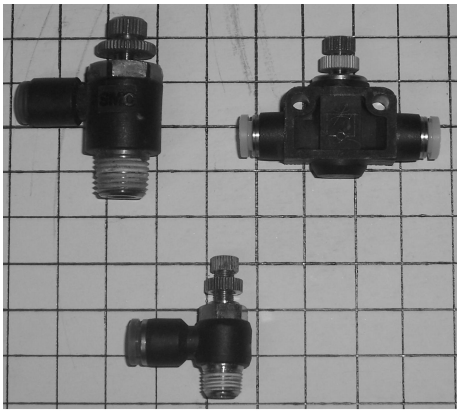
Parts of a Pneumatic System

1. AIR COMPRESSOR- The job of the compressor is to take air from the environment and pressurize it. This creates a high amount of potential energy. The Compressor usually has a TANK which stores the pressurized air. Most compressors have a pressure monitor for the tank and a pressure monitor for an attached regulator. A small 1 hp air compressor will do well for a small yard haunt with only 2 or 3 props run randomly, but if you're like me with many air props running constantly, you'll need a larger compressor. Your compressor should not need to run at a higher pressure than 120psi (all my props run at 90 psi or lower).

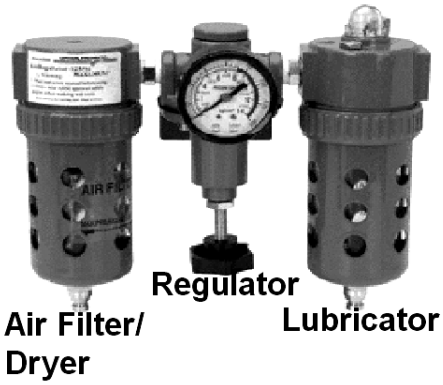
2. AIR LINES- Pipes, hoses or tubes (or any combination of the 3) which distribute the pressurized air from its origin at the compressor to the different actuators in the props. Air lines can be branched out or split using a "T" or a manifold.
3. REGULATOR- A Regulator controls the pressure at which the air is released downstream of the regulator. For example if the tank of your compressor is at 120psi and you have a small prop that only needs 40 psi to operate, the 120 psi might break it! So you would use a regulator inline somewhere and set it to 40 psi. from the regulator to the prop, the air pressure would then climb to 40 psi but not higher. Your system should have a regulator at the compressor to control the pressure in the air lines and a regulator at or inside every prop, set to whichever psi that prop uses, so that you can remove the prop, and install it into any system. This will prevent that prop from getting damaged by higher air pressures, because it will allready have regulator in it. Set your regulators as low as possible to get the power you need for your prop.

4. VALVES- Valves control the distribution of the pressurized air, either blocking it, restricting it, or letting it pass through one or more different pathways. Valves control air flow to the ACTUATORS downstream from them.
5. ACTUATORS- convert the moving air into some other form of mechanical energy. These include CYLINDERS (for pushing or pulling), rotary actuators (strong rotary forces), AIR MOTORS (driving a rotary shaft very quickly), NOZZLE (directs stream of air) or any number of devices. These devices are generally attached to your prop's frame or armature and are actually responsible for the prop's motion.

6. FLOW CONTROLS- Flow controls control the speed of the air traveling through the line. They DO NOT control pressure. Flow controls are usually installed in a prop between the valve and the actuator. They usually control speed in ONE DIRECTION only so you can control your up and down motions separately. This also means you will most likely need 2 of these for each actuator.



7. FILTER DRIER and LUBRICATION unit. These units are optional but if used can increase the reliability and life of your props. The filter/dryer unit removes condensed moisture from the pressurized air before it reaches your props, and also filters out small particles of dirt or metal that may be present in the air lines that could damage your actuators or valves. The lubrication unit dispenses small amounts of lubricant into the air lines to keep props running smoothly. ONLY USE SPECIAL KINDS OF OIL MADE FOR AIR LINES. If you use petroleum-based oil it will swell rubber seals and o-rings in your actuators, valves, and regulators and make them not work anymore.



8. CONNECTORS/FITTINGS- Connectors connect the components to each other and to air lines. There are many different types of connectors including threaded, push-lock, hose and barb, and quick disconnect. It is important to note when using quick disconnect fittings the female side has a valve inside that stops the air from rushing out when disconnected, so the female side should be on the upstream side of the connection, flowing into the male end. Quick disconnects are also used for air tools and this is a good connector to use where your prop hooks up to the air lines. Put the male end on your prop.
9. RESERVE TANK- This is an extra tank used to hold the pressurized air. As air travels thought air lines it slows down due to friction. If you have a prop that uses a lot of air quickly, put a reserve tank inline close to (or inside of) the prop. This makes the prop more reliable and predictable. It might also be helpful to put a check valve (one way valve) so air cannot travel back upstream from the reserve tank. If you put a reserve tank in a prop downstream of the prop's REGULATOR you will have a very precisely volumed and pressured amount of air that will keep the motions of your prop VERY reliable regardless of fluctuations in the line pressure.

Pneumatic Cylinders

Of the many different actuators one might use in a pneumatic system (including cylinders, rotary actuators, sliding actuators, air driven motors, nozzles that blow air or spit water, inflatable objects) the one most used in haunting is the cylinder. Due to moisture in the line it is preferable to use stainless steel cylinders. Try to avoid using objects not purpose built for this, such as bicycle pumps or door closers as these items give inconsistent results and could be dangerous if misused.

Cylinder Bore (Diameter)

One of the most important things about choosing the proper cylinder for an application is the cylinder diameter or bore size. Bore size determines the force applied to the prop from the cylinder (how hard the cylinder will push). The amount of force a cylinder produces can be found in this manner. Take half the diameter of the cylinder and square it. Then multiply it by PI (~3.14). This will give you the area of the face of the cylinder. Then multiply that number by the air pressure in PSI. That will give you the theoretical force of the cylinder.

Let's try it with this example. We will be using a 1.5" diameter cylinder (common to haunting). So first he take half the diameter (1.5"/2 = .75") and square it (.75 x .75 = 0.5625). Then we multiply this number by PI (~3.14) and get our area for the cylinder face (0.5625 x 3.14) and get about 1.766. Now whatever pressure we apply to our 1.5" diameter cylinder, the pressure (measured in PSI) multiplied by 1.766 will be our force in pounds. If we use 100PSI of pressure, we should get 176.6 pound push from the cylinder. If we use 50PSI, we will get 88.3 pounds of force from the cylinder. Note that actual force delivered from a cylinder is slightly less than the theoretical force of the cylinder. Also if using a 2-way cylinder the pulling force will be slightly less than the pushing force due to decreased face surface area on the pulling side because of the cylinder rod.

Actual Cylinder Push Force at Varied Pressures

	5/8" Bore	¾" Bore	1-1/16" Bore	1-1/2" bore	2" Bore	2-1/2" Bore
@ 30 PSI	8 lb.	11 lb.	18 lb.	48 lb.	87 lb.	137 lb.
@ 60 PSI	16 lb.	23 lb.	36 lb.	97 lb.	174 lb.	275lb.
@ 90 PSI	25 lb.	35 lb.	54 lb.	145 lb.	261 lb.	413 lb.

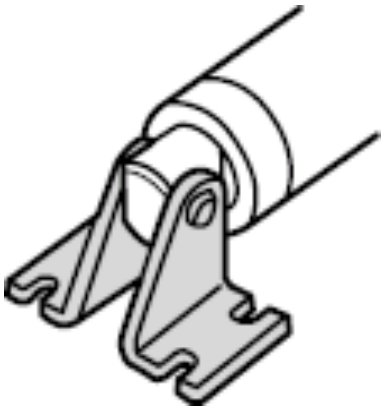
Cylinder ports

When choosing a cylinder make note of the size and location of the threaded ports on the cylinder and make sure your fittings are the same size.

Cylinder Mounts

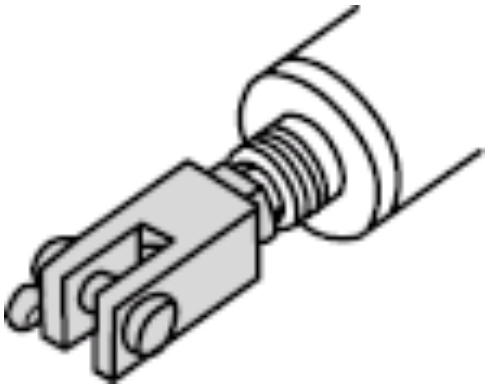
The way cylinders are mounted is important in the way the cylinder is used. For most haunting purposes (moving levers on armatures, etc.) you would probably want to use REAR PIVOT MOUNT cylinders. These mount on a pin or pivot in the rear of the cylinder. Either you can use brackets on either side of the pin to mount the cylinder or knock the pin out and run a bolt through the pivot-hole. The rod end of the cylinder is threaded and for pivot mounting you would either use a rod clevis or possibly a rod end if you needed a bit of a wiggle.

Another type of mounting is the NOSE-MOUNT. This cylinder has a threaded front end and is firmly mounted through a plate or bracket so the rod sticks straight out. This is useful if you want something to pop out of a wall or straight up or down, like a drop-portrait.

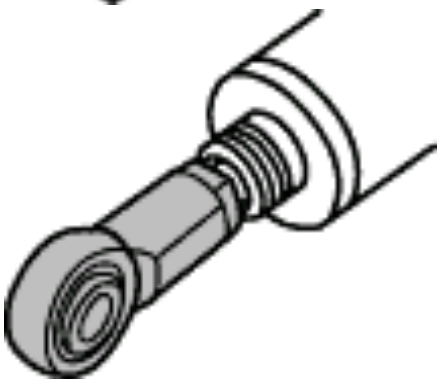


Rear pivot mounted cylinders with pivot brackets for when cylinders need to pivot

Nose Mounted cylinder using a Foot Bracket when cylinders need to stay locked in place



Rod Clevis



Rod End

Valve Types

At first the wide array of valves can be confusing. There are manually operated valves, electric solenoid valves, pilot operated and pilot-solenoid operated valves. Some valves have 2 solenoids, and come in different sizes, pressures, and voltages.

For haunting purposes I usually get a 4-way, direct acting solenoid valve. When you apply electrical current to the wires it opens the valve pretty much instantly. I like 4 way valves because you can run double acting cylinders (that push AND pull) or you can plug up 1 or more ports and use it as a 2 or 3 way valve as well (and it usually doesn't cost more than a 2 or 3 way valve).

Make sure the valve you buy is rated for the pressures you want to use (for haunting usually in the 10-120psi range).

Also make sure the ports are the right size for your application (the ports are usually threaded, make sure the thread size matches your fitting). Occasionally, you will come across a valve with integral push to connect fittings. Make sure these match your tubing size.

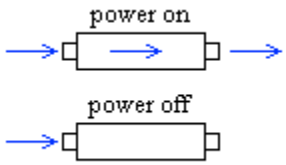
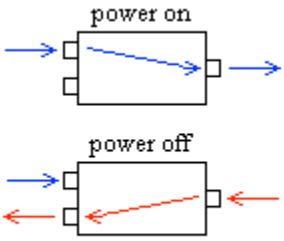
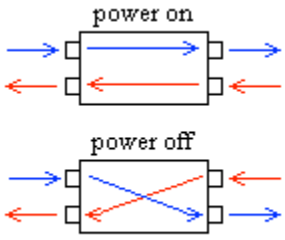
Use a valve with larger ports and higher flow when you need to move more air quicker (like when you use a really big actuator) and don't forget to get larger size fittings and hoses to match.

Probably the most important decision you need to make is whether you want to use a valve that uses low voltage DC current, or high voltage AC current.

If you are going to be activating the valve manually using a switch or button, it is easier to wire the 110VAC solenoid (make sure your switch is also rated for 110VAC current).

If you are going to activate the valve with a circuit board, haunt controller, or sensor, you usually would then use a low voltage solenoid, as most of the prop controllers like the Prop-1 use DC outputs.

Just make sure the voltage of the solenoid on your valve matches the current it will be hooked up with to activate the valve.

	**A two-way valve** has two ports. When power is applied, the pressure flows from one port to the other. With power off, the flow ceases. [Assuming a normally-closed valve, which is almost always the case.]
	**A three-way valve** has three ports. When power is on, one of the ports is connected to the common port (which leads to the actuator), and pressure flows through to extend the pneumatic cylinder. When power is off, the other port is connected to the common port, and pressure is exhausted to reset the cylinder.
	**A four-way valve** has four or 5 ports (it may have 2 exhaust ports). With power on, one set of ports is connected straight through to the other set of ports. (one side is directing air towards the actuator, the other side is venting exhaust from that actuator). With power off, the connection is reversed.

Don't forget you can use a 4 way valve as a 3 or 2 way valve if you plug up 1 or 2 of the ports. You can use a 3 way valve as a 2 way valve if you plug up 1 of the ports.

Types of air lines (hoses, tubes and pipes)

Commercial Air Hoses

These rubber, PVC, or vinyl hoses often have webbing between the layers of material for strength. They are often rated to 300psi and often have threaded connectors on each end. They are generally fairly abrasion and crush resistant and are good to use to move air from the compressor around to all the different points it might be used. Either use the threaded connectors on the end or cut them to length and use a hose barb and ring clamp to connect these. Air hoses are usually measured from the **inside diameter**.

The other option to this, in a permanent setting, would be to use solid metal pipe (like blackpipe) from the compressor to the points of use. Use thread sealer on the pipes.

Pneumatic Tubes

Pneumatic tubes will not take the traffic and abrasion that commercial air hoses will take. I use pneumatic tubes only to run short distances, or inside props between individual components.

Tube Type Comparison Chart

	Polyurethane	Nylon	Polyethelene	PVC
Max pressure	~140psi	~250psi	~120psi	~40psi
Working temperature	-40F - 140F	-60F – 200F	-50F – 150F	25F – 150 F
RESISTANCE TO				
Abrasion	Great	Good	Fair	Poor
Kinking	Great	Fair	Poor	Good
Moisture	Good	Good	Good	Good
UV radiation	Fair	Good	Poor	Poor
Fitting compatibility	Push connect + compression	Push connect + compression	Push connect + compression	Barbs
Pressure	Good	Great	Good	Poor
Clarity	Clear	Translucent	Translucent	Clear
Colors	Yes	Yes	No	No
Flexibility	Great	Fair	Fair	Good
cost	Most expensive	Moderate	Least expensive	moderate

COPPER TUBE

Also if your applications utilize more extreme heat or pressure or if your air line does not need to be flexible you might also consider using soft copper tube with compression fittings. The soft copper tube can also be used with the push-lock fittings.

Steel Braided Hoses

Use steel braided hoses when you need to hold extreme pressures and retain some flexibility.

Connector types

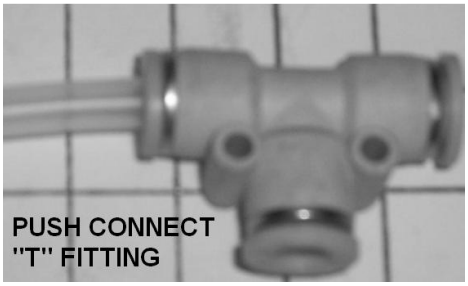
Threaded

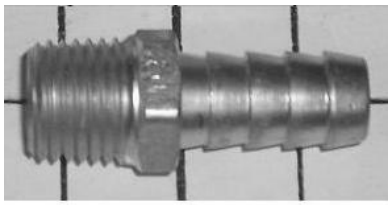
When using threaded connections (pipes, fittings, ports on manifolds and valves and actuators) remember that the fittings are measured by the INSIDE DIAMETER of the male end or the inside diameter of the pipe that would fit in the female end. For example a ¼ inch threaded port is actually roughly a half inch across, but if you put a threaded fitting or piece of pipe into it, the inside diameter of that pipe would be ¼ inch.

When using threaded connections use a thread sealer on the male threads before assembly to help against leaks. Use either rolls of Teflon tape or the stuff that comes in the tube (personally I like the tube stuff).

Push connect

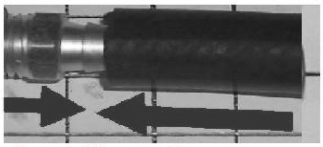
The simplest of all the connections. Simply cut the tube square on the end and firmly push the tube into the fitting all the way. When you pull on the tube it should be firmly stuck. To remove, push in the tip of the fitting and pull on the tube. When choosing the proper sized tube and fittings it is important to remember that unlike threaded fittings, tube connectors and push-connects are measured by the OUTSIDE diameter of the tube. If your tube's outer diameter is ¼", you will need ¼" push connect fittings.


PUSH CONNECT
"T" FITTING


HOSE BARB FITTING
With male threads

Hose Barb

These are usually used on the larger air hoses. These fit inside the hose and have teeth that grab the hose. For extra grip, use a ring-clamp around the hose at the hose barb

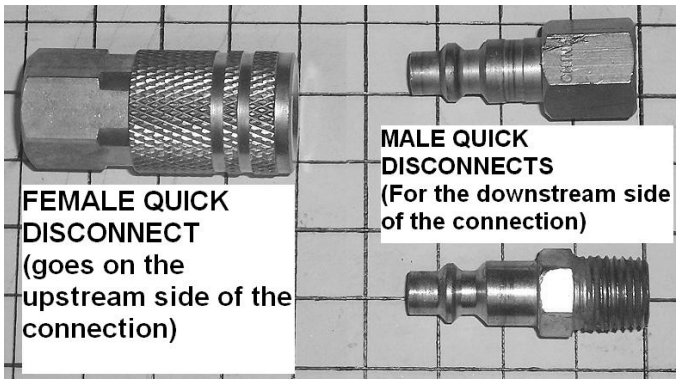

Push Hose Over
Hose-Barb And use a
Ring Clamp to tighten

Compression

Compression connections are used on the stronger tubes and copper tubes as well. As you turn the cap on a compression fitting it smashes the tube onto the fitting and seals it tight. These aren't often used in haunting, and are generally used for permanent, high-pressure applications. Compression fittings are measured by the outer diameter of the tube that they connect to.

Quick-Disconnect

Quick disconnects allow you do just that- quickly disconnect whatever you have attached to them. They are particularly useful on air hoses and things that can be interchanged, such as tools or props. Remember the FEMALE side of the quick disconnect goes on the upstream side, because it has an internal valve that closes when disconnected, keeping all the air from escaping from the system upstream and possibly causing dangerous whipping hoses. Quick disconnect sizes are the same as threaded sizes, they are measured from the inside diameter.


FEMALE QUICK
DISCONNECT
(goes on the
upstream side of the
connection)

MALE QUICK
DISCONNECTS
(For the downstream side
of the connection)

Complete Air System Build Up

At the Compressor

Your compressor should be able to generate enough pressurized air (measured in CFM- Cubic Feet per Minute) to operate all your props as often as you'd like and still be able to shut down to cool off occasionally (most available compressors you might get aren't made to run continuously and will overheat). If the motor runs continuously and the compressor can't keep up, get a compressor with a larger CFM rating. At the compressor you should have a regulator to regulate the pressure in the air lines, and either a quick disconnect fitting or a manual shutoff valve running to your output. Always make sure there is a way to turn all the air OFF from the compressor tank (quick disconnect or manual shutoff valve). That way if an air line gets loose and starts whipping around, you can shutoff the air supply.

At the Main Air Lines

From the manifold, shutoff valve, or quick disconnect located at the compressor, use air hoses (or possibly hard pipe, if in a permanent location) to run the pressurized air to all your props. It is up to you whether you should use a single hose and branch off of it or many separate hoses run directly from the compressor. Either way, when you get to the end of the hose where it will connect to the prop, use a female quick disconnect fitting. On the prop itself, have the air come in through a male quick disconnect fitting. This way, you can unplug the air lines from any prop if the prop malfunctions or needs work without having all the air escape from the system.

At the Props

Your props should have air entering through a quick disconnect and then into a regulator to control the pressure the individual prop needs to run. This way you can run all the different props, which need different pressures to work, off of a single high-pressure air source. The regulator at a prop is important and shouldn't be overlooked. Even when using professionally bought props that don't come with a regulator, you should still add one. Regulate the pressure of the prop as low as you can for it to still function properly. From the regulator you should direct the air into the valve or valves. There are many ways of doing this. The easiest is probably using push-to-connect fittings and tube. Then from the valve use more fittings and tube run to the air cylinder. This is the part where you use the flow controllers, to control the speed of the cylinder movement. I like to use the flow controls that mount on the cylinder itself, and take the place of the air cylinder fittings. By adjusting these you can control how quickly the cylinder moves up and down.

Once everything is in position, you can fire up your compressor and check for leaks. You can fix leaks using thread sealant. Leaks are bad because they give your props away, make the system less efficient, and make your compressor work harder.

ENJOY YOUR NEW PNEUMATIC SYSTEM AND
SCARE THE CRAP OUT OF EVERYONE!