

350kv Van De Graaff Generator

By Higgs Boson in Workshop > Science  68 604  142  53



This is a Van de Graaff Generator that I designed and built for use with many electrostatic experiments. I attempted to make a vdg about a year ago, but the design was very poor and the project ultimately failed. I still really wanted to make one though so recently I decided to go back to the drawing board and

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A brief note on safety

A Van de Graaff Generator is capable of generating extremely high voltages, but it is very safe due to the very low current, and quick dissipation of the arcs. For almost all people, the vdg will not adversely affect you in any way (I can't say the same for your sensitive electronics), but if you have a bad heart, it would be a good idea to steer clear of a Van de Graaff generator.

IF you like this instructable, be sure to vote for it in the Make to Learn Youth contest and other contests!

Judges see step 10 for contest information.

higgsboson39



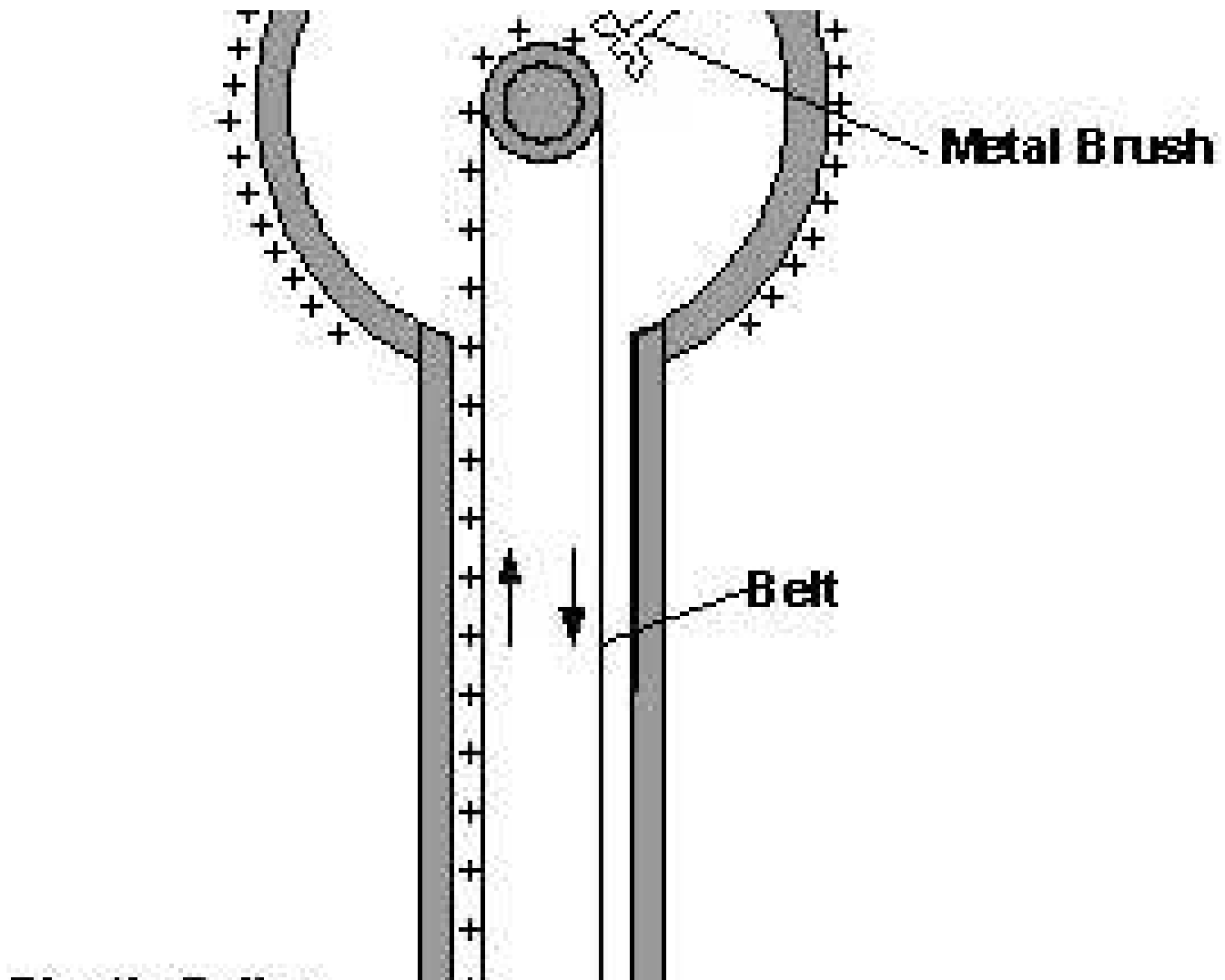
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Step 1: How It Works



What good is any project if you don't know any of the theory behind it?

Well it just so happens that the Van de Graaff generator works on a very simple principle. I'm sure you are all familiar with what happens when you walk on carpet with rubber shoes on a very dry day. Your hair stands up, and you are able to send electricity arcing through the air to the dismay of anyone

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your body does not have the capacity to hold anymore charge, or you get too close to something that has a difference in potential and all the charge suddenly leaks from your body through a path of ionized air.

A Van de graaff generator takes advantage of triboelectric transfer by using a belt on two rollers to carry a charge from a metal comb to another metal comb where the charge gets transferred to a metal sphere.

In construction, the vdg is extremely simple, but the principle that it works on is far more complex. For example, these generators do not have their belt rub on the rollers as rubber shoes do on floors. The triboelectric transfer occurs simply through contact not friction. This does mean however, that the type materials that the vdg belt comes in contact with on the rollers is crucial to operation. To be effective the materials of the two rollers should be on opposite ends of the triboelectric series, and the belt should be made from a material that falls somewhere in between them in the series. Triboelectric series is nothing more than a list of materials ordered by their triboelectric effect, or the way they exchange charges with other materials. Since the vdg relies on this affect if the two rollers are triboelectrically identical no charge can be built up. In fact, the orientation of the rollers is what determines the polarity of the output. In my case I used teflon for the bottom roller and aluminium for the top so I got a positive output. Swapping the rollers would give me a negative output.

The rollers and belts are only part of the story though. If you look at the diagram above you can see that two metal combs or brushes are used on the

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better to think about an example. Imagine a vdg with a positive output. as the belt comes down from the top roller to the bottom roller, it is carrying electrons from the top brush. As it approaches the bottom brush, the charge is sufficient to ionize the air between the brush and the belt and the electrons move to ground. as the belt continues along, it is triboelectrically charged by the bottom roller to be positive. As it goes across the top roller it begins to pull electrons from the top sphere, leaving unpaired protons, and therefore positively charging the top sphere.

The top sphere of the machine itself is actually highly important to the output of the vdg for many reasons. For example, with the above parameters there is no reason why a vdg couldn't continue building up a charge forever, that is if it wasn't for the fact that for one thing there are only so many unpaired protons that could be left on the sphere, and because any kind of small imperfection or point on the sphere would begin to cause corona discharge, where the charge literally leaks off the sphere and into the air causing a large amount of losses. That being said, The bigger, rounder and smoother the sphere on the top of the vdg, the higher the output it is capable of reaching.

I certainly haven't covered everything, and there is a lot more going on in the operation of vdg's, but hopefully now you understand the basics of how they work.

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Step 2: Making the Rollers



The first part of the machine that I actually constructed was the rollers. As I mentioned earlier, I constructed this with only off the shelf parts. The goal was to be able to make everything fit together like a puzzle with as little actual fabrication as possible, and I feel this part of machine accomplished those goals nicely.

You will need:

- two bed rollers
- a 1/4 20 threaded rod
- 8 1/4 20 nuts
- 4 skate bearings
- teflon tape
- aluminium tape
- degreaser
- you will also need a hack saw, and one (or preferably two) pair of pliers.

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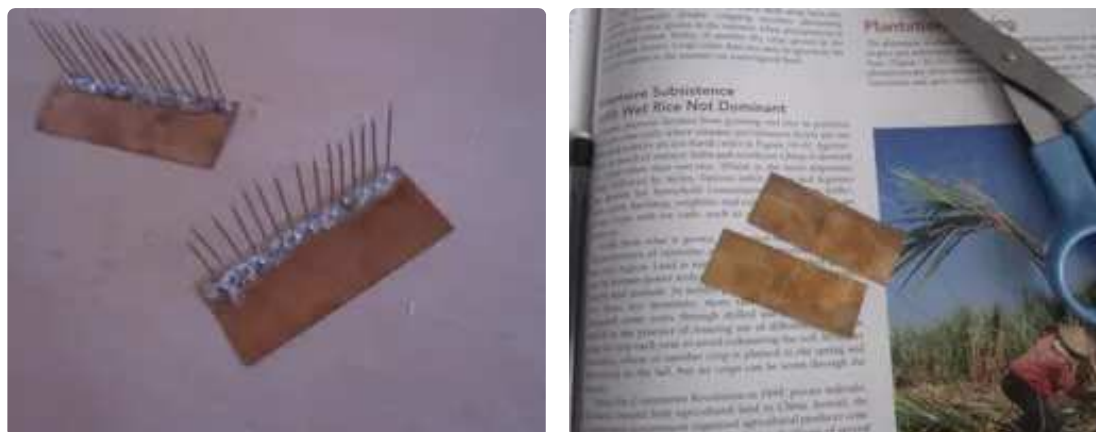
it with a hack saw to remove the plastic part (which is all I needed from the be roller). Next I cut a length of the threaded rod about 3 3/4 inches long, and another length about 6-7 inches long. The longer piece of the rod is for the bottom and the shorter for the top, but other than the length of the rod, the rollers are made in exactly the same way. I secured the roller on the rod with a nut on either end, and placed a bearing after it had been cleaned off with the degreaser on either end securing it with more nuts on each end. I then covered the roller with the longer rod with teflon tape and the other with aluminium tape. This made a roller that was very easy to turn, and was a very good length for the 3" PVC I chose to act as a body for the vdg.

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Step 3: Making the Brushes



Making the brushes is extremely straight forward. I would even say that I took a more complicated approach. The simplest thing to do would to just fan out some stranded wire and place it near the belt, but like the way my brushes turned out better. What's important to keep in mind, is that the more pointy the ends on the brush the better, and that the brushes do not actually touch the belt. It is best to keep each about 1/8 of an inch away from the belt.

You will need:

- two pieces of sheet copper (I used two pieces 1/2" by 2")
- 28-32 strait pins
- solder
- you will also need a hammer, some scrap wood, and a soldering iron

To make the brushes I simply measured and marked the copper at 1/8" intervals on one of the long sides. I then used a hammer and a spare straight

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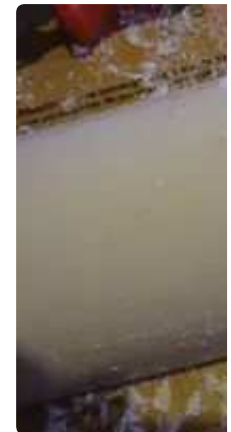
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Step 4: Preparing the PVC Body



This is by far the most labor intensive parts of the whole build, and involved a lot of drilling and filing, so be prepared to work.

You will need:

- one two foot length of 3" diameter PVC
- one 3" toilet flange
- one wire coat hanger
- You will also need a drill, drill bits, a hack saw, some files, pliers, and snips.

The info. for the belt I wanted to use said that is was 18 inches when fully installed (in the vdg it was meant for) so I decided to make the rollers 16 inches apart so the belt would be stretched about 18 in. with the diameter of the rollers. I also knew that I wanted the bottom holes to drilled 2" from the bottom of the PVC to allow space for the flange at the bottom, and to raise it enough for the drive system.

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end I just traced one end of the PVC to a piece of paper and busted out the ol' compass and straight edge to find the mid-line (or diameter if you want to be technical) of the PVC. once I had one end marked I used a piece of wood as a straight edge and drew a line up the PVC to act as a guide line for where I would make my mark for the top holes. If the rollers aren't aligned properly, it is likely they will have difficulty spinning, or the belt will continuously move off the roller.

Once I had my marks, I began drilling. Unfortunately I only had a 3/4" and 1" saw bit as viable options for PVC, and the 1" was too big for my bearings, and the 3/4" was too small. eventually I decided to use the 3/4" one and just file out the holes to get them to the right size. You want the holes to be just barely (but only barely) big enough to let the bearing slide through. This will make installing the belt (and the roller for that matter) much, much easier. once I had my holes the right size I used a hack saw to cut the top part of the PVC off, leaving half of the top holes left in the PVC (if that doesn't make sense look at the picture) to fit the top roller. I also drilled a hole with the 1" pin perpendicular to the bottom roller (and a little below the other two holes) just so that I could see what I was doing when positioning the bottom brush later on.

Once I had all the filing and cutting done I cleaned the hole thing with some Windex to get all the dust and shavings off of it, and pushed the toilet flange onto the bottom. It was a tight fit so no cement was needed.

To get the sphere to stay on the top but not touch the top roller I cut a piece of

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Step 5: Installing the Belt



This is pretty straight forward, you just want to get the belt on both rollers, about in the middle. Some things to keep in mind are, make sure your hands are clean and dry, also make sure the rollers have little to no dust on them and are very dry.

You will need:

- latex rubber belt (<http://www.scientificsonline.com/replacement-wand-for-winso-van-de-graaff-generator.html>)
- PVC from step 4
- Rollers from step 2
- you will also need a pair of pliers and a string

Unfortunately, the bottom roller I put together previously had to come apart for this step, since the roller was too big to fit through the bottom hole I drilled in the PVC. Although this is probably a good thing, it makes installing the belt

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and then put the threaded rod (which still has two nuts and a bearing on it) through a hole in the PVC and then through the roller. I put a nut back on the other side of the roller, followed by the bearing and another nut. I placed the bearings in their respective holes in the PVC, and then added a little hot glue so they wouldn't wander around (you could also use something like locktight, so long as you can break the bond later).

I used the string to pull the other end of the belt through the PVC and put the other top roller through it. Since the top roller doesn't have to go through any holes I could leave it intact. once the belt was over the top roller, I placed the bearings for the top roller in their respective halfcircles at the top of the PVC. The tension of the belt is enough to hold the top roller in place (most of the time), so no glue had to be added. I checked to make sure the belt was not twisted or stretched too much, and that the rollers could roll easily.

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Step 6: Making the Base



To make my base I decided to use a rather large piece of plywood, so I would have extra space to add future experiments to the same board that had the VDG (see the last step). I supported it by some 1x1's so that screws or bolts I put through the wood would not touch the ground/table/floor. Dimensions for this are not critical, and you can make it to be whatever size you think is best.

You will need:

- One 1' by 4' piece of sturdy plywood
- 3' of 1by1 wood
- Wood screws
- You will also need a drill, drill bits, and wood saw of some kind

At Home Depot I found a nice piece of 2' by 4' plywood, and asked them to cut it down the middle so I would have two 1' by 4' pieces to act as a base in this project and in future projects. I also cut three 1' pieces of 1x1 I had sitting

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a half inch from the ends and at exactly 2' down. The holes were 4" from the edge of the wood. I used these holes to screw the three pieces of 1x1's onto the base to support it.

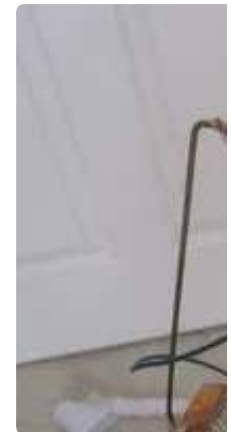
You can make any sized base out of whatever material, that suits your needs.

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Step 7: Positioning the Brushes



This step is important to the operation of the Van de Graaff generator. If the brushes are too far away or touching the belt, the machine will not work. Other than that though it is not very critical.

You will need:

- The brushes from step 3
- Some wire
- the PVC/ VDG body
- Some scrap wood + screws
- You will also need a drill, soldering iron, and hot glue gun + glue

To position the bottom brush I started by screwing together some small pieces of scrap wood to make a platform a couple inches tall. I put the brush on top of it and put the VDG body over it. There wasn't really an exact science to this, I just kind of eyeballed it through the the third hole I drilled on the bottom until it

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the brush, and ran it under the flange prior to screwing it down.

For the top brush, I simply put the brush against the coat-hanger wire top part, and hot glued it so it was a good position and distance from the belt. After soldering I wire to the brush, I stripped the other end of the wire from the brush, and twisted around the top part of the coat-hanger wire. I was going to solder it there, but it worked fine without soldering.

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Step 8: The Drive System



The drive system includes the motor, and its coupling to the bottom brush. How you do this will depend on the motor you have, but the way I did it should work for almost all motors.

You will need:

- A motor with decent torque and speed (look on ebay, amazon, craigslist, surplus stores)
- a mounting bracket or "L" bracket/ some sheet metal
- screws that fit the mounting on your motor
- some scrap wood
- a 3 prong plug
- Some wire
- A somewhat large pulley
- A somewhat small pulley
- Two 1/4 20 nuts

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I got a surplus AC motor on an online surplus store for under ten dollars. It had really good torque, but only 1800 RPM at no load. I've seen a lot of VDG's where the motor is directly coupled to the bottom roller, but since my motor was so slow I figured I might as well try to make it go faster. I would do this by putting a rather large pulley on the motor's shaft, and a smaller pulley on the bottom roller. The two pulleys would be attached by a belt, and the ratio of the circumferences would determine how much the speed is stepped up. This works basically the same way as gears on a bike, big gear at the pedals and small gear at the wheel means there is greater speed but requires more torque.

To prepare the pulleys I had to use a hack saw to cut another pin holding the pulleys to their main mounting hardware, in almost exactly the same way I had to cut through the pin on the bed roller in step 2. Once the pulleys were off, I found the metal bearing surface on the small pulley was too small for the bottom roller, so I bore it out with a 1/4" bit on my drill press. I then put it on the long amount of the threaded rod sticking out on the bottom roller with a nut on either side of the pulley.

I found an "L" bracket at home depot that worked well for my motor , but if you can't find anything you can try to make your own with some thick sheet metal. I also found that 4mm screws fit in the screw holes on the front face of my motor. I drilled some holes on the bracket so it would line up with the holes on my motor. I then screwed the bracket onto the base on the other side of the L bracket before attaching the motor with the 4mm screws through the holes I

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shaft of the motor.

To wire the motor, I followed the wiring diagram that came with it. It was capacitor start and included a 5 uf 660v capacitor, or as I like to call it, "The big-ass capacitor." Wiring was straight forward following the diagram, the only thing I changed was adding the wire coming off of the bottom brush to the ground going to the motor. Despite what many have said, Mains ground has worked fine as a ground for the bottom brush. I soldered all the connections to the three prong plug, and insulated them with wire nuts (unconventional, but effective).

I tried to make a belt to couple the motor to the bottom roller out of part of a bike inner tube, but it failed miserably. Surprisingly, simple rubber bands worked spectacularly as a belt, so I ended up using them.

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Step 9: The Top Sphere



This is a very critical part of the VDG in operation. It's size and smoothness can quite possibly be responsible more for the final output of the generator than any other part of the machine, so It is imperative that you eliminate all sharp points and edges from the sphere, and that you keep it smooth as possible. Other than that, any metal spherical object can work on the top.

You will need:

- Two stainless steel mixing bowls (the larger the better)
- Electrical tape
- Thin clear vinyl tubing
- you will also need tin snips, and a hammer.

This step is pretty straight forward. I bought two stainless steel mixing bowls (at Target I believe) that were about 8" in diameter. To get the sphere to fit over the body I had to cut out the bottom of one of the bowls. I initially drilled

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roller is inside the top sphere). This left a lot of sharp edges on the bowl, so I covered the edge with electrical tape. You can also use thin vinyl tubing split down the middle to cover sharp edges (this is what I did with the rim on the bowls). The electrical tape isn't to insulate, it is simply to cover the sharp edges and make them smoother (electrical tape is conductive at these voltages). The next step was to put the bowls together. I did this by putting the bowls on top of each other to make a sphere, and then electrical taping them like that. I tried to make a dent in the top of the sphere (bulging on the outside) to allow for a spot for the coat hanger wire to fit into to keep the sphere from sliding around. I only partially succeeded, but it still worked rather well. In the future I hope to replace this sphere with a larger, smoother garden gazing sphere.

Put the sphere over your VDG, and you're done. That's all there is to it. You can plug it in and watch the sparks fly!

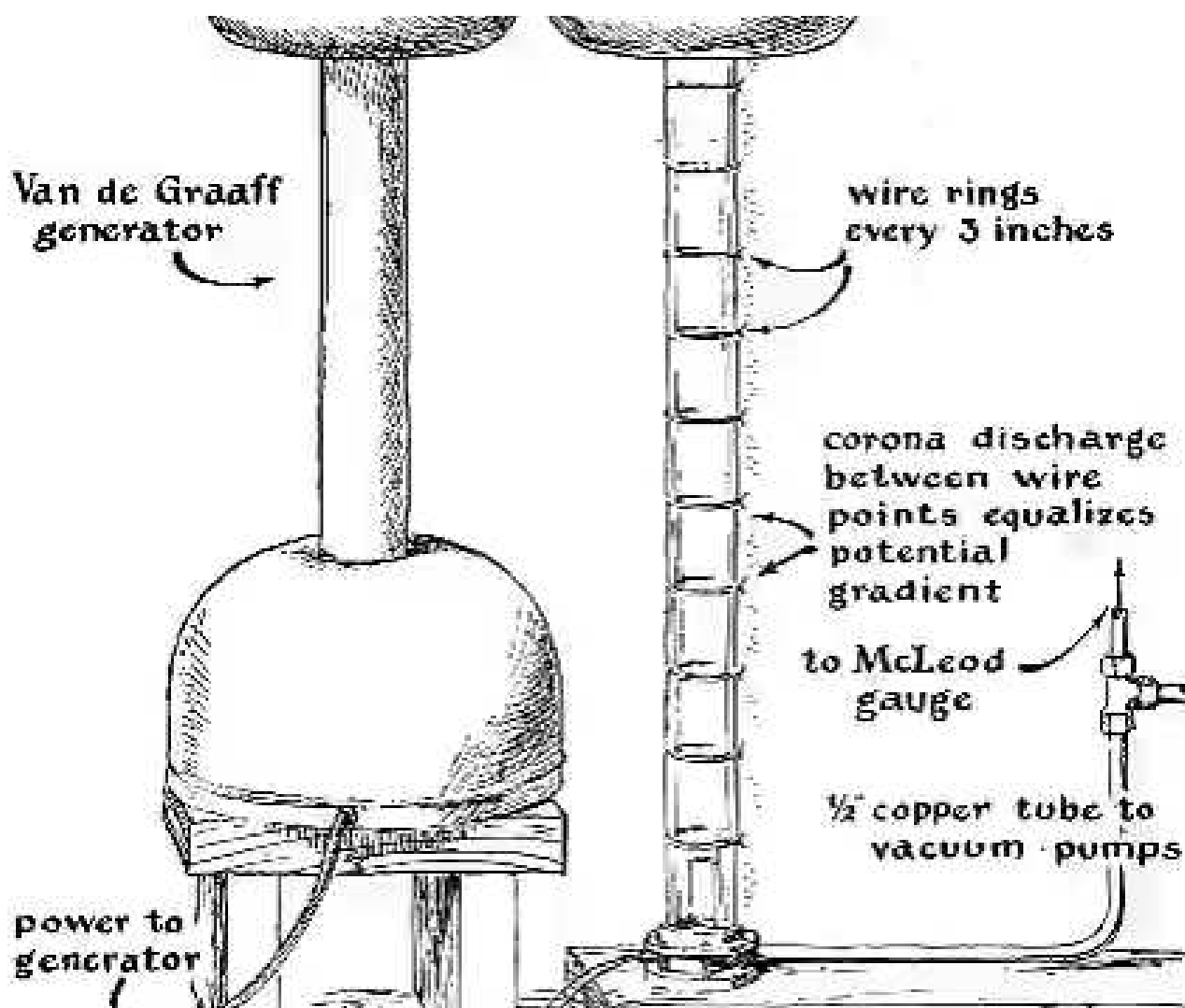
To improve the output of your VDG, simply run it in a very dark room, and carefully watch the sphere. Look for spots where you can see corona discharge, or a kind of purple glow on sharp points. If you see anything, cover that spot on the sphere with electrical tape. This will minimize your losses. If you live in a humid climate, you are going to have to dry out your VDG to get anything more than underwhelming. To do this simply take the top sphere off, and run the machine while blowing air from a hair dryer on the belt as it passes around the top roller.

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Step 10: Contests



The Make to Learn Youth Contest

What did I make?

I made a Van de Graaff Generator, a machine invented in the 30's for use in small electrostatic particle accelerators. The machine utilizes the triboelectric

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make use of. That includes a drill, hammer, screw drivers, files, a soldering iron, and some other things found in a pretty typical tool collection.

How did I make it?

I got the idea for this project actually from the purpose for which the machine was invented. I am highly interested in physics, and about a year ago I started researching particle accelerators when I saw that VDG's used to be used for them. After some more research, I was intrigued by their simplicity and effectiveness. I had made up my mind then that I wanted to build my own. I worked alone on this project, and the plans for it changed numerous times. My first attempt about a year ago failed completely, but even my second much more refined design faced quite a few design changes during the build.

Where did I make it?

Nearly all of the construction took place in my garage, but no part of it was constructed outside my house. Other than just for hobby, this connected with another thing I am doing. I am currently working with a professor at a local university on a science fair project involving electron beams, and this could possibly end up being the power supply, although it is less likely now than when I started building.

What did you learn?

I really had to step out of my comfort zone for this project. In the past I have

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experience, and an interesting challenge. I was surprised at how well it worked (especially after the way my first attempt a year ago failed), but I am pretty happy with the results and proud of how I pulled it off. If I had to do it again, I would probably try to use a CAD software to draw everything out prior to building to help construction go more smoothly.

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