

Van de Graaff Generator

Instruction Manual for
Van de Graaff Generator – EL-VANDEGR

**HOME SCIENCE TOOLS**
THE GATEWAY TO DISCOVERY

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Welcome to an exciting world of discovery with your new Van de Graaff generator! This unique device is designed to produce electric current at exceptionally high voltages yet low, safe-to-use amperage. This makes your Van de Graaff generator an excellent tool for learning about and experimenting with electric fields and electric forces.

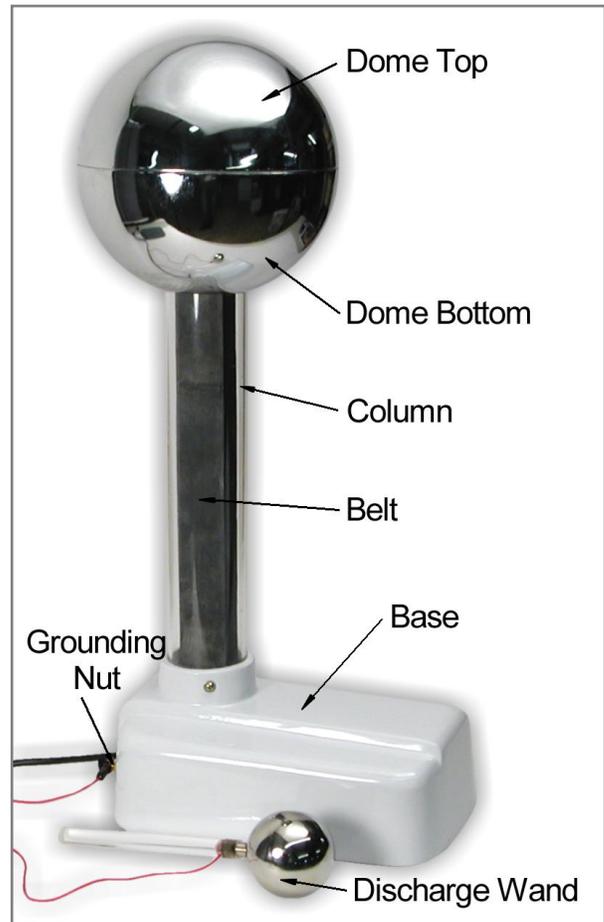
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Assembly, Safety, and Use

Unpacking and Assembly

Your Van de Graaff generator arrives in three pieces: 1) the fully assembled main unit, 2) the top half of the dome, and 3) the discharge wand. Carefully unpack all three pieces from the shipping carton. Set the main unit on a sturdy wood or plastic (not metal) table. Fit the top half of the dome on to the lower half of the dome (which is already attached to the main unit). Connect the red grounding wire from the discharge wand to the grounding terminal on the back of the main unit base. Do this by loosening the black plastic grounding nut on the grounding terminal, sliding



the pronged connector on the end of the red wire onto the terminal, and then retightening the black nut to complete the connection.

Safety

This generator produces up to 200,000 volts of electricity! When used properly, it is safe even though it produces such high voltage. The reason it is safe is because the current flow produced is very low--usually around 200 milliamps. Please read through the entire instruction manual before using your generator for the first time and follow all instructions carefully. Follow these safety instructions each time you use your generator.

WARNING!

The discharge of electricity produced by this generator can trigger a heart attack in individuals with heart disease (either diagnosed or undiagnosed). This generator may also cause cardiac pacemakers or electrical implant devices to malfunction or fail. Individuals with these conditions should not operate or come in contact with this generator under any circumstances.

CAUTION!

Electronic devices such as computers, stereos, televisions, and microwaves can also be damaged by static electricity. Operate your generator well away from these types of devices. We recommend that you operate your generator in a room that does not contain these devices.

1. Operate this generator only under adult supervision. This generator is not a toy!
2. Plug the generator into a standard grounded (3-prong) 110 volt outlet.
3. Do not operate the generator in a wet or damp location. Do not operate outdoors.
4. Check for loose or defective wires before operating the generator. Replace if necessary.
5. Unplug the generator before performing adjustments or maintenance. Never remove the base cover plate unless the generator is unplugged. A dangerous electrical shock hazard exists whenever the base cover plate is removed.
6. The electrical shock you receive from normal contact with the generator is not harmful, although it can be uncomfortable, startling, and occasionally even painful. The static shock you get from this generator is similar to, although much stronger than, the one you might get from touching a metal door knob after walking over carpet on a dry day.
7. You can get a small static shock when you unplug the electrical cord. To prevent this, touch the grounded discharge wand to the dome several times until all static electricity is dissipated. Then unplug the cord.
8. Even after your generator has been unplugged, the charge that has built up on it can still shock you. You can avoid getting shocked by touching the discharge wand to the dome before approaching it with your hand. Any charge that is left on the dome will be transferred to the wand instead of to your hand.
9. The switch on the base of the generator is not an On/Off power switch for the unit, but rather a switch for a 25-watt drying lamp in the base used for drying the unit when the humidity is high. Keep the wand in contact with the dome while switching

the power on or off. Use it only as needed and only while the unit is running.

Operating the Generator

The generator is simple to operate. Place the unit on a plastic or wooden table. Attach the red wire from the discharge wand to the grounding terminal using the black plastic nut. Make sure the drying lamp switch is "Off". Plug in the power cord to a grounded 110 volt outlet and the generator belt will begin to rotate (there is no on/off power switch). Within 30 seconds the dome will become charged. Move the discharge wand toward the dome until you get a spark. When the discharge wand is close to the dome the sparks are short and frequent (about one spark per second). As you move the discharge wand further from the dome, the sparks become longer and less frequent. Unplug the generator to turn it off.

When operating properly under the right conditions, your generator will consistently produce 1-2" sparks every second and 5-6" sparks every 3-5 seconds. Under ideal conditions 8-12" sparks can be produced. However, there are several variables that affect the performance of your generator including air humidity, cleanliness of the rollers and belt, and adjustments on the generator. Carefully read the **Maintenance** and **Troubleshooting** sections if your generator is not performing fully.

Specifications

- Input voltage: 110 volts
- Input power: 70 watts
- Discharge voltage: up to 200,000 volts
- Spark Length: 5-6" easily, up to 8-12"
- Dome diameter: 20 cm
- Discharge ball diameter: 6 cm
- Upper Roller: Nylon
- Lower Roller: ABS plastic

Operation

Introduction to Electric Fields

Most objects have an equal positive (+) and negative (-) electrical charge, which makes them electrically neutral. Objects acquire an electrical charge by collecting or giving up electrons. Electrons are subatomic particles with a negative charge that are a normal part of all matter. An object that collects electrons develops a negative

charge while an object that gives up electrons develops a positive charge.

Any electrically charged object produces an electric field which attracts oppositely charged objects (e.g. a positively charged object attracts negatively charged objects) and repels similar charged objects (e.g. a positively charged object repels other positively charged objects).

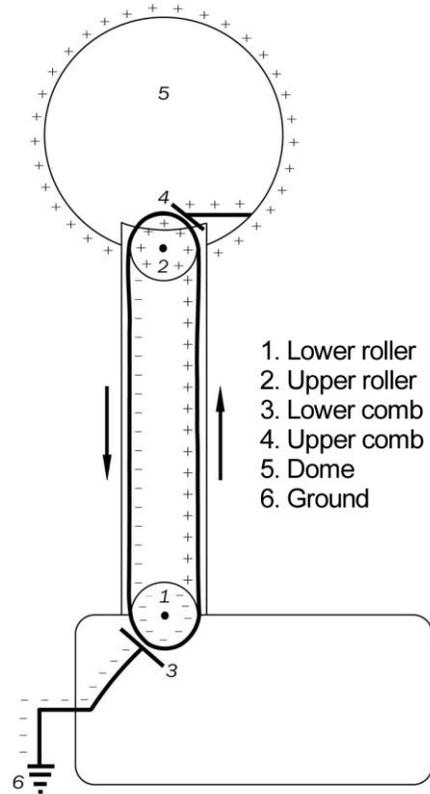
You can demonstrate this with a small balloon on a dry day. Rub the balloon on the hair of your lower arm. As you do, the balloon collects electrons from your arm and becomes negatively charged. At the same time the hair on your arm gives up electrons and becomes positively charged. Now bring the balloon to within 1-2" of your arm. What happens? The hair stands straight up toward the balloon. The electric field of the negative charged balloon attracts the positive charged hair on your arm!

Electrical current flows when oppositely charged objects are connected together with a good conductor like a copper wire. Electrons flow from the negative charged object to the positive charged object. Electrical current can also flow from an object with very high negative charge to a second object that is less negatively charged. If the difference in electric charge is great enough, the current can even flow through a poor conductor like air. This is what happens when lightning strikes the earth. Clouds with a very strong negative charge are insulated from the earth by air. As the negative charge on the cloud builds, it finally overcomes the insulating barrier of the air, and current flows in the form of lightning from the cloud to the earth.

How the Van de Graaff Generator Works

The generator has a rubber belt that runs vertically (up and down) between two rollers. The lower roller is ABS plastic and the upper roller is nylon. A metal bar or "comb" is attached close to but not touching the belt at each roller. The belt assembly is enclosed in a clear plastic column that connects and insulates the base and dome. An electric motor in the base of the generator rotates the bottom roller which makes the belt turn on the rollers.

The simplest way to think of a Van de Graaff generator is as an electric charge separator. As the motor turns, it moves the rubber belt which rubs against the rollers. As the belt rubs over the ABS lower roller (1), a negative charge develops (electrons collect) on the lower roller and a positive charge is produced on the part of the belt



moving up. This is because rubber is higher in the triboelectric series than ABS and therefore rubber develops a positive charge while ABS develops a negative charge when the two are rubbed together. The positively charged rubber belt then rubs over the nylon upper roller (2), which develops a positive charge on the upper roller and a negative charge is produced on the part of the belt moving down. In this case, nylon is higher in the triboelectric series than rubber. (Learn more about the triboelectric series on the internet.)

As the generator continues to operate, electrons build on the lower roller increasing the negative charge. Then these electrons are transferred from the lower roller to the lower comb (3) and directed to the ground connection (6). At the same time, the positive charge building on the upper roller begins to attract electrons from the steel dome (5) through the upper comb (4). As this occurs, the dome builds a strong positive charge and these electrons are transferred onto the belt going to the lower roller. The positive charges continue to build on the dome and spread out uniformly, because like charges repel. With all other variables equal, the larger the dome the greater the positive charge it is able to hold. In simple terms, we can say the generator pulls electrons from the dome and moves them through

the bottom of the generator to an electrical ground, as illustrated above.

Eventually, the charge on the dome reaches an equilibrium state where the positive charged dome begins to pull electrons from the air. That is why you hear a crackling sound in the air around your generator as it operates. The positive charge on the dome builds until it overcomes the resistance of electron movement in the air. This causes a sudden transfer of electrons to the dome accompanied by a crackling sound. The electric potential of the positive charged dome at this point is measured in volts.

Many factors affect how much voltage your generator can produce, such as air humidity and particle buildup on the dome. The moisture in humid air makes the air a better conductor, which increases the electron flow from the air to the dome. This prevents the dome from building high voltages. Dust and dirt particles on the dome create distinct points that help break the resistance to electron flow between the air and the dome. This results in a "leaking" of neutralizing electrons from the air to the dome and limits voltage potential of the dome.

The first Van de Graaff generator was invented in 1931 by an American physicist named Robert Jemison Van de Graaff. He called the machine an electrostatic accelerator. This type of generator is able to produce extremely high voltages – some today can produce up to 20 million volts of static electricity! For history, information, and images of Van de Graaff's first large scale generator, visit this site from the Boston Museum of Science:

<http://www.mos.org/sln/toe/history.html>

Experiments & Demonstrations

Experiment 1 – Lightning

You can create sparks, or "lightning," using the discharge wand that came with your generator. Attach the red wire from the discharge wand to the grounding terminal with the black grounding nut. Plug in the generator on and let it run for one or two minutes. Holding the plastic handle of the discharge wand, slowly move the ball towards the dome. Depending on humidity conditions, you should see a large, bright blue spark when the wand is anywhere from one to six inches away from the dome. The sparks that can be made are very quick like lightning. When the spark is produced, you should also hear a loud crack or

pop. This demonstrates a lightning electrical discharge which is accompanied by a bright flash and loud cracking sound. It is spectacular in a dark room!

When operating properly, in low humidity, your generator can consistently produce 1-2" sparks every second and 4-5" sparks every 3-5 seconds. Sparks of up to 8-12" can be produced under ideal conditions. If the air is dry enough, and you let your generator run for a few minutes without discharging the dome, you can get "lightning" from the dome to the base, a full 12".

Experiment producing sparks with other objects. Try the flat of your hand or finger tips. You will discover that flat or round objects produce larger and more distinct sparks than thin or more pointed objects.

Experiment 2 – Raising Hair

To raise your hair (or someone else's!) you will need a wooden chair or plastic step stool (it must be non-metal) that is sturdy enough to stand on and that will insulate you from the ground. If you don't insulate yourself, your hair won't be raised and you will receive an electrical shock instead. To raise your own hair, you will need someone to plug in the generator for you. While standing on the plastic stool with the generator unplugged, place one hand on top of the dome with your other hand at your side. Have your helper plug in the generator. Make sure you do not touch anything else while it is running.

Depending on the humidity in the room and in your generator, it might take two to five minutes before your hair begins to stand on end. Being in contact with the running generator causes the positive charges built up in the storage dome to be transferred to your body. Once those charges are on your body, they will try to get as far away from each other as possible (like charges repel) causing the hair on your head to stand on end.

You can try this experiment with different people who have different hair length or hair fineness. Or try it with people standing on different insulating objects. Which conditions produce the best results? Form a hypothesis or guess as to why particular conditions produce better results and then design an experiment to test your hypothesis.

Experiment 3 – Floating Objects

Because of the amount of positive charge that accumulates on the outside of the dome, some objects in this experiment may be attracted

to the dome at first. Once some of its positive charge is transferred to the objects, they are then forced away from the dome because both surfaces have the same charge, which causes them to move as far away from each other as possible.

Place a small disposable aluminum pie or tart pan on top of the storage dome before plugging in the generator. When you plug it in, the pan should acquire the same charge as the dome, which will cause it to be repelled away from the dome! Try a stack of two or more pie pans and watch them lift off one at a time. You may have better success using a looped piece of tape or some sticky tack to attach the bottom pan to the top of the dome. You can also try this experiment by making pans from aluminum foil shaped around the bottom of a bowl. Make sure the top edges of the aluminum foil bowls are smooth as possible because all sharp edges or points will dissipate charge from the dome of your generator.

Another floating object experiment can be done with a small plastic or styrofoam bowl. Tape or stick the bowl to the dome. Then put a handful of dry cereal (puffed wheat or Rice Krispies work well) into the bowl. Plug in the generator and let it run for awhile. Once a positive charge builds up on the kernels of cereal they will fly out of the bowl and away from the dome. The kernels may fly out one at a time or many all at once. If the kernels do not begin flying out of the bowl within a few minutes, try reducing the charge on the dome by bringing the discharge wand near, and then waiting a few more minutes. Again, this demonstrates like charges repel and electric fields produce forces that can act on objects with mass. Experiment with other objects to see what will be repelled and what will stay.

You can also blow some bubbles towards your generator while it is running. When the bubbles come near the dome, they begin to develop a positive charge as well. As the bubbles become positively charged they are repelled from the dome and move away rapidly!

Experiment 4 – Deflecting a Flame

Your Van de Graaff generator can create an electrical wind that is powerful enough to deflect the flame of a candle and turn a toy windmill or propeller. To create a wind, attach a long, thin metal rod or needle (a darning needle or dissection pin will work well) to the side of the generator dome, near its middle, with the sharp end pointing out. Use modeling clay or a piece of

tape, making sure that the metal touches the dome. Plug in your generator, light a candle, and hold it in front of the point. The flame should lean away from the generator. To see how far the effect of the wind extends, slowly move the candle away from the generator until the flame is no longer deflected.

Experiment 5 – St. Elmo's Fire

Push a straight pin, needle, or opened up paperclip through the end of a plastic drinking straw so that the metal needle is at a 90° angle to the straw. Use this device as a point conductor. Plug in your generator and turn out the lights. Holding the end of the straw, slowly move one pointed end of the needle towards the surface of the dome while the other end of the needle is pointed away from the dome at a 90° angle. As the metal gets near the dome (usually 1-3"), a faint steady glow should appear at the tip of the needle and a stronger, larger glow will appear between the other end of the needle and the dome. This electrical discharge is called St. Elmo's fire and demonstrates how a pointed object produces a corona discharge in a strong electric field. A corona discharge produces light but no sound.

Any sharp point on the surface of the dome will produce a corona or point discharge that leaks the generator's electric field into the surrounding air. This leakage is most prevalent where the two halves of the dome join and it prevents the generator from reaching its full voltage potential. Experiment with sealing the two dome halves with electrical tape to see if you can reduce this leakage and increase the spark potential of your generator.

Other Experiments

You can find many other experiments to do with your generator by conducting a search on the internet for "Van de Graaff." The possibilities are endless!

Cleaning & Maintenance

Your Van de Graaff generator requires periodic maintenance to keep it functioning properly. Follow the steps below to help ensure that your generator continues to work for many years. Be careful of the dangerous electrical shock potential when performing maintenance--unplug the power cord whenever doing maintenance.

1. Check the belt and rollers for buildup of dirt, grit, or grease after every few hours

of operation. Follow the belt removal procedure and the roller and belt cleaning procedure any time you notice a buildup or if your generator is not performing properly. You may have to scrub the rollers to remove grease.

2. Clean the exterior parts of the generator before use with a soft cloth dampened with a little soapy water.
3. Periodically clean the inside of the plastic column with a soft cloth dampened with soapy water. Do this only with the belt and rollers removed. Do not use alcohol or solvents that could damage the plastic.
4. Remove the belt before storing the generator for extended periods of time (i.e. several months). This will keep the belt from losing its elasticity.
5. Check the belt for wear periodically. Replace worn or damaged belts.
6. Store the generator in a clean dry place to prevent dust accumulation or humidity absorption.

1. Remove/Replace the Belt

Follow this procedure to remove or replace the belt. Reinstall the belt by performing these steps in reverse.

1. Unplug the generator.
2. Remove the top of the dome.
3. Remove the base cover plate by removing the four screws and washers.
4. Slide the belt off the open end of the lower roller.
5. Lift the top roller assembly off the brass brackets. Slide the belt off the top roller assembly.

2. Clean the Belt and Rollers

Dust, dirt, and grease will collect on the belt and rollers over time. Remember, these components are electrically charged during operation and therefore act as magnets to dust and grease particles in the air. Dirt or grease between the rollers and belt will interfere with the transfer of electrons from the dome to ground, preventing a charge buildup on the dome. Follow this procedure for cleaning these parts and retuning your generator to peak performance.

1. Remove the top of the dome.

2. Pull the belt back from the upper roller and look for dirt buildup on the roller. If you see dirt on the roller it is time for cleaning.
3. Remove the belt following the above procedure.
4. Scrub the top and bottom rollers using a soft cloth wetted with rubbing alcohol. You may have to scrub hard and keep using a clean section of the cloth to remove all the dirt and grease. **Do not use detergents or other solvents to clean the rollers as they may damage or interfere with the electrical operation of these parts.**
5. Scrub the inside and outside of the belt using a clean cloth wetted with soapy water. This is done easily by laying a section of the belt on a clean surface and rubbing the belt in strokes. You may have to rub toward the edges to remove any tiny particles on the belt that interfere with electron transfer. Rinse the belt well with water and then thoroughly dry it with a soft cloth. Finally, remove any residual water on the surface of the belt by drying for a few minutes with a hair dryer.
6. Wipe any excess grease off the upper roller shaft and spacers. Be careful not to get grease on the belt or surface of the rollers--it will interfere with the generator performance.
7. Replace the belt and rollers. Center the belt and adjust the belt tension if necessary. Adjust the combs if necessary.

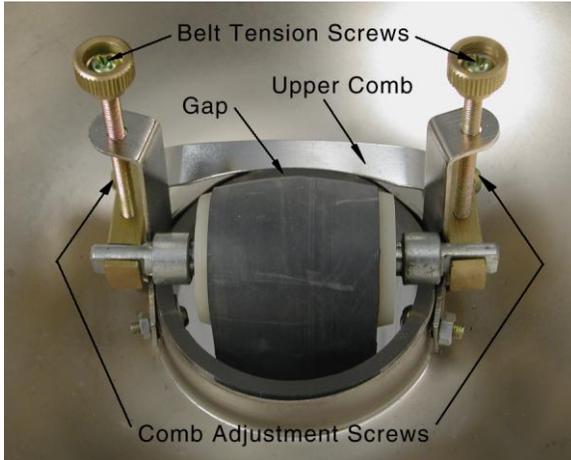
3. Center the Belt and Rollers

Follow these steps to center the belt within the column so that it properly carries electric charges up and down the column. Complete this procedure anytime the belt looks off center or when you replace the belt.

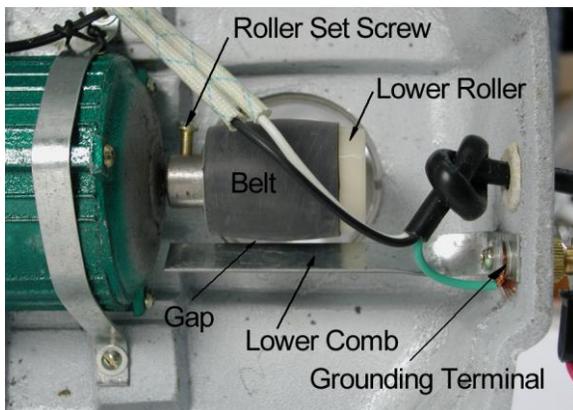
1. Remove the top of the dome.
2. Remove the base cover plate by removing the four screws and washers.
3. Operate the generator, being careful of the 110 volt shock hazard.
4. Observe the position of the belt on the top roller. The top roller should be centered above the top of the column and the belt should be riding on the center of the roller.

Rub marks on the column indicate that the belt has not been centered.

5. If the roller or belt is not centered, turn one of the belt tension screws as necessary to get it centered. A little experimentation here will allow you to quickly master this adjustment.



6. When the belt and top roller are centered, the generator will operate smoothly and the belt will not touch the sides of the column.
7. Now unplug the generator and set it on its side so you can observe the lower roller operation.
8. If the belt is not centered in the bottom of the column, you will need to move the lower roller on the motor shaft. Don't be concerned whether the belt is centered on the lower roller, only that it is centered in the column.



9. Unplug the generator and loosen the set screw that holds the lower roller on the

motor shaft. Reposition the lower roller and tighten the set screw.

10. Plug in the generator on and check to see if the belt is centered in the column again. Repeat step 9 as necessary.
11. Your generator is now ready for use. Reinstall the base cover plate and the top of the dome.

4. Adjust Belt Tension

Follow this procedure anytime you replace the belt or if the belt begins to slip on the rollers. It is normal for the belt to stretch a little over extended use. Your Van de Graaff generator is designed with belt tension screws to take out slack from stretching and extend the life of the belt while still operating at high voltages.

Caution: Do not put too much tension on the belt or it will put undue stress on the motor bearing and reduce its life. Operate your generator with the belt as loose as possible as long as it does not slip or flop around on the rollers.

1. Remove the top of the dome.
2. Tighten the belt tension screws each the same amount until the belt no longer slips on the roller.
3. Follow the procedure for centering the belt and top roller to make sure your generator functions properly.
4. Replace the top of the dome.

5. Adjust the Combs

The combs located near the top and bottom rollers may affect the charge buildup on the dome. These combs must be adjusted to within 1/8" to 1/4" from the belt to produce optimal charge buildup. The lower comb especially may come out of adjustment as it is attached to the grounding terminal.

1. Remove the top of the dome.
2. Remove the base cover plate by removing the four screws and washers.
3. Inspect the upper comb. Position it so the gap between the belt and comb is between 1/8" and 1/4". The gap should be fairly uniform the entire width of the belt. You may have to loosen the comb adjustment screws to do this.
4. Set the generator on its side so you can observe the lower comb.

5. Inspect the lower comb. If necessary, the lower comb can be rotated toward or away from the belt and roller by first loosening the brass grounding nut. Position it so the gap between the belt and lower comb is between 1/8" and 1/4". You may also need to twist the lower comb slightly with a pair of pliers if necessary to align the comb parallel to the lower roller.
6. After making adjustments, rotate the belt by hand to make sure no part of the belt touches the combs. Note that there is variability in the thickness of the belt and some wobble of the rollers as they rotate. Make sure you rotate the belt at least one full revolution as you check for rubbing.
7. Replace the base cover plate.

6. Clean the Column and Dome

Whenever you clean the belt and roller it is also a good idea to clean the plastic column and metal dome. Dust and other particles will collect in the column over time. If the belt is misaligned, it can rub on the inside of the column and produce plastic dust from this rubbing. These particles can get on the belt and interfere with the performance of your generator.

Clean the column by rubbing a soft cloth slightly dampened with soapy water up and down the length of the inside column several times. Repeat with a dry soft cloth. Blow dry with a hair dryer if necessary.

Dust and grease buildup on the dome can create discharge points that leak voltage into the surrounding air. This prevents the generator from reaching its full voltage potential. Clean the dome with a clean soft cloth dampened with slightly soapy water. Dry it thoroughly.

7. Compensate for High Air Humidity

As the humidity increases, the plastic parts of the Van de Graaff generator (rollers and column), which are designed to work as insulators, begin to conduct small amounts of current. Because a Van de Graaff generator produces very high voltage and very low amperage, it takes little conductivity to prevent the generator from working well or not at all. Moisture in the air also dissipates the electric charge before it can build up on the dome. The performance of your generator may begin to fall off as the air increases above 60% relative humidity and perhaps not work at all above 80-90% relative humidity.

You can easily determine if the humidity is too high by rubbing a balloon on the hair of your arm. Then, move the balloon away and back again toward the hair on your arm. If the hair stands up as the balloon approaches, the air is dry enough for the generator to work. If the hair does not stand up as the balloon approaches, then the humidity is too high for the generator to work well.

If the air is humid, you can dry it out using the 25-watt drying lamp located in the base of the unit. Flip the switch on the back or the base to the "On" position while the unit is running. Leave it on for 10-15 minutes and see if the heat from the bulb will adequately reduce the humidity in the interior of the generator. You may need to operate the drying lamp longer in higher humidity situations. This drying lamp is not designed to run continuously. Turn it on only when the unit is running and only as needed.

Note that your generator may not perform well in a very high humidity environment, even with the drying lamp operating.

8. Replace the Drying Lamp Bulb

After awhile the 25-watt drying lamp bulb will burn out. The bulb is accessed by removing the base cover. Replace the drying lamp bulb with a standard 25-watt household tungsten light bulb.

9. Lubricate Bearings

Apply a drop of household oil to the motor shaft and the upper roller shaft once per year. **Caution: Do not get oil on the belt or roller surfaces.** Oil on these surfaces may greatly reduce the performance of your generator.

Warranty

Home Science Tools warrants this instrument against defects in materials and workmanship for one year from the date of purchase. This warranty does not cover belts or damage due to misuse, abuse, alterations, or accident. Return your generator freight prepaid for warranty service to Home Science Tools, or the repair facility we designate. We will repair or replace your generator at no charge and return it freight prepaid to you. Please call 1-800-860-6272 to arrange warranty service before returning this instrument.

Home Science Tools
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Troubleshooting

Your Van de Graaf generator is capable of producing an electric potential of 200,000 volts and sparks consistently 5-6" long. When operating properly it will consistently produce 1-2" sparks every second and 5-6" sparks every 3-5 seconds. There are a number of variables that can affect both the amount of voltage produced and the corresponding spark length. If your generator is not operating at this level, then work through this troubleshooting table.

Problem	Check These Conditions	Try These Solutions	Page
Belt does not turn.	Cord not plugged in.	Plug the cord into an appropriate 110 volt grounded outlet.	3
	Belt tension (motor only hums).	Loosen belt tension.	8
Generator does not produce large sparks.	Air humidity.	Turn on the switch on the back of the base for several minutes while the unit is running. This switches on a 25 watt bulb located in the base used to reduce the humidity inside the device.	9
	Dirty belt or rollers.	Clean belt and rollers.	7
	Dirty dome or column.	Clean dome and column.	9
Generator is noisy with rubbing sound.	Incorrect comb adjustment.	Adjust upper and lower combs.	8
	Position of belt and rollers.	Center the belt and rollers to prevent rubbing on the column.	7
	Belt tension (vibrates against column).	Adjust belt to proper tension.	8
	Upper roller bearing or motor bearing is noisy.	Lubricate upper roller bearing and motor bearing with a drop of household oil.	9

This page is intentionally blank. It is a good place to record results from your experiments.