Van de Graaff Generator Instructions - VDGPSUB

Caution:

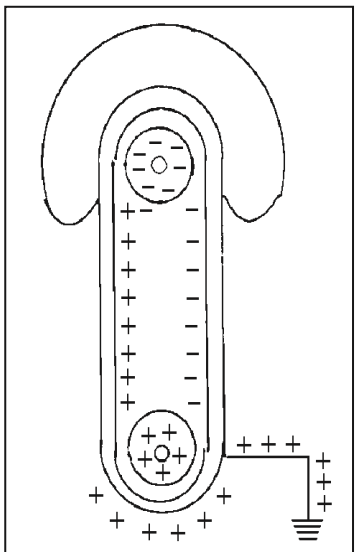
People with cardiac pacemakers or other such electronic medical implants or devices should never operate the generator or come in contact with it. Discharge of static electricity could cause the electronic device to be damaged or to malfunction.

Introduction:

The Van de Graaff generator deposits a very large amount of negative electrical charge on the metal dome (globe). This massive volume of negative electrical charge produces a spectacular display of "lightning" and other phenomena.

When two insulators are rubbed together, one loses electrons to the other and becomes electrically positive by acquiring positive electrical charges. The other insulator, having gained ex-cess electrons (negative electrical charges) becomes electrically negative. These charges are static be-cause they do not move on their own. When you walk on a carpet in a dry room with dry feet you deposit a large amount of electrical charge on your body; the impact is felt when you touch a door knob. Electrical charges can also be induced on a neighbouring insulator or conductor by a process known as induction. In the case of a flat insulator, the opposite side acquires opposite electrical charge by induction

The generator uses a nylon pulley at the lower end of the machine, attached to an electric motor. A rubber belt passes over the pulley. As the pulley turns, rubbing occurs; the pulley acquires positive charges while the inside surface of the rubber belt (near the plastic pulley) acquires an equal amount of negative charge. The outside surface of the rubber belt acquires an equal amount of positive charge by induction. An electrode, in the form of a comb or brush, is provided to drain away these positive charges from the outside surface of the rubber belt to the "ground."



Schematic shows negative charges carried upward from pulley to collector sphere.

A similar comb (electrode) is provided at the upper end where it will provide a path for negative charges to be taken to the collector dome. The plastic pulley retains the positive charges that it acquired.

Negative charges stay on the inside surface of the belt and travel upwards as the belt moves up. At the top, it runs over a PVC pulley which picks up these negative charges and retains them. Free electrons from the PVC pulley flow on the electron-deficient belt and are carried down to the plastic pulley. As the belt keeps running, more charges are deposited on both pulleys, resulting in heavy build-up of charges on each. Soon this build-up reaches ionization intensity in the vicinity of the two comb assemblies and a large number of positive and negative charges are generated.

The negative charges are transferred to the collector dome by the up-per comb and the positive charges are drained to the **ground** by the lower comb. The belt plays an important role in transporting positive charges from upper to lower comb and negative charges (on other half of the belt) from lower to upper comb.

Once on the metallic collector dome, the positive charges spread out due to **electrostatic repulsion** and become uniformly distributed because of the dome's spherical shape. The build-up of negative charge on the dome continues until ionization intensity is reached. This is the **equilibrium state** and limits the quantity of charge that the generator can place on its dome. It is measured in **volts.** Once this limit is reached (400,000V), the air between dome and lower housing gets ionized and creates a discharge with a spark. The discharge causes the potential to fall below the ionization intensity but is brought up to the limit again in seconds, and another similar discharge occurs. The process continues as long as the generator is running.

Demonstrations:

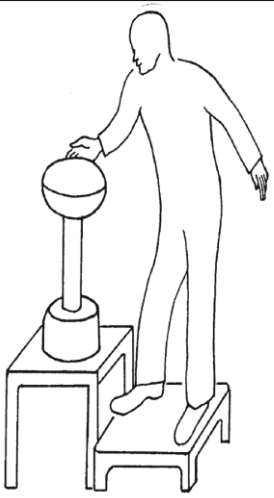
(1) Hair Raising:

Approaching a running generator can be a hair raising experience. This is because the charges are transferred to your body and, specifically, to the hair. Due to electrostatic repulsion between similar charges, every hair tends to get as far away from every other hair as possible. This "raises" hair and can be felt on head, arms and all over the body.

For best results **you need two people and a plastic footstool.** Stand on the footstool and place one hand palm down on the globe of the Van de Graaff before your helper turns on the generator. Keep your hand on the globe, with your other hand at your side taking care not to touch anything else, the entire time the machine is running. Shake your hair lightly to loosen the strands; wait 2 minutes.

You should now feel each individual strand start to lift. Have your helper angle a mirror (taking care not to get too close to you!) so you can see the results. Fine, light, long hair works best. Make sure you do not remove your hand from the globe, touch anyone or step down from the footstool while the machine is running. If you do, you will feel a mild shock. This is because, by doing so, you have completed the electrical connection and grounded yourself. (The footstool serves as an insulator.) The static electricity, instead of remaining on your body, passes to earth. You feel the results.

This experiment works best on days when **humidity** is **low**. Water vapour drains static charge. If you do demonstrate on high-humidity days, dry the inside of column and globe with a hair dryer immediately before experimenting.



To raise hair, stand on footstool or other plastic (nonconducting) platform to insulate yourself.

(2) Electric Wind:

Charge distribution on the collector dome is isotropic because the dome is predominantly spherical in shape. The distribution will not be isotropic for irregularly or asymmetrically shaped objects.

This is because narrower parts always carry much greater concentration of charges than broader parts. The effect is maximum for pointed objects like thin rods or large needles.

Try attaching a conductor in the form of a sturdy, light, thin metallic rod six to eight inches long (for instance, a darning needle) on the body of the collector dome, radially outwards. Use tape or clay to attach. The concentration of charges at the tip of the needle will be so intense that it will ionize air in its neighbourhood. Positive ions will rush towards the collector dome and neutralize their charges. Negative ions, however, move away (due to electrostatic repulsion) from the generator and do not get neutralized. As the generator is continuously running, it keeps supplying more and more negative ions at a fast speed. The ions running away form a wind called "electric wind" which blows away (radially outward) from the generator. By attaching the conductor or needle, you have created an electric wind.

Generate Statics.

The wind is strong enough for its effects to be experienced as far away as 10 feet from the generator. It may not deflect a flame that far away but will certainly impart statics to your clothing which would cling to your body; or to a paper that would cling to your hand or to the wall.

Turn a vane.

Place a vane, such as a child's pinwheel, in front of the conductor. It will turn in the direction of the wind. See for yourself what the wind direction is and see if you can form some idea of how strong the wind is. Try a vane that is slightly stiff and requires a stronger wind to turn it.

Spin a spinner.

Make a small spinner using aluminium foil " across with 4 - 6 blades. Use a sharp pin to act as axis for spinner and mount the pin on a wooden or plastic stick. Try placing 2 beads on each side to localize the spinner. When brought near the conductor, the electric wind will spin it.

Deflect a Flame.

Bring a lighted candle near the conductor. The flame is deflected away from the generator in the same manner as an air draft.

Rotate the collector dome.

Show how an actual (electric) wind can be created by ionized air molecules running away from the pointed conductor.

The ionized molecules move away from the sharp or rounded end of the conductor in great numbers and at great speeds. This, according to **Bernoulli's Principle**, produces a low-pressure region in front of the tip of the conductor. The rear end of the conductor (attached to the dome) remains at normal pressure. This sets up a pressure difference near the conductor. By using it, you can rotate the dome.

Attach two identical sharp or rounded conductors tangentially (not radially) to the dome along the seam on opposite sides and in opposite directions. Conductors can be attached with clay or tape. Observe how pressure differences near these conductors exert torques on the dome which begin to rotate slowly but steadily. The dome rotates as long as the generator is running. The mass of the dome is substantial. The fact, therefore, that the dome will rotate solely due to the electric wind that is generated is a testimony to the strength of that electric wind.

The Electric Wind.

In this experiment you bring the wind to the candle instead of bringing the candle to the generator to observe its effect on the flame. Prepare a large darning needle by securely attaching a well-insulated copper wire in the needle's eye. Attach the other end of the wire to the collector dome with transparent tape. Carry the needle as far as the wire will allow you to carry it. Place it near a candle and watch the electric wind (emanating from the needle's tip) deflect the flame or turn a vane or rotate a spinner.

(3) Lightning:

Lightning, an awesome natural phenomenon, is an electrical discharge between clouds and the ground. Create it in miniature with a Van de Graaff generator due to the build-up of negative electrical charges on the dome.

Bring a rounded object (metallic, for best results, such as a mixing bowl or juice can which matches the height of the Van de Graaff) near the dome. You may wish to wear a glove or use a dry towel to hold the objects as you approach the dome to minimize the likelihood of receiving a shock. The discharge that occurs between rounded object and collector dome is accompanied by a crackling sound and can be made brighter and more frequent by bringing the rounded object closer (from 2" to /2" away.) If you withdraw the rounded object, the discharges become feeble and less frequent and may be seen only in a darkened room.

If the dome has accumulated full charge and you do not induce lightning, a discharge will automatically occur between dome and base. You should hear intermittent crackling sounds and see feeble sparks in darkness.

With larger generators such as the 0-285, the lightning effect is greatly enhanced.

(4) St. Elmo's Fire:

There are three types of electrical discharges from clouds to the earth.

Point Discharge.

No visible light or sound. These are the bulk of discharge between clouds and ground.

Corona Discharge.

It is accompanied by visible light but no audible sound. This is known as St. Elmo's Fire.

Lightning Discharge.

This is accompanied by blinding light and deafening sound.

You can create St. Elmo's using a drinking straw or small plastic strip. Tape the needle to one end of the straw, hold the straw by the other end and press it lightly against the dome. (The object, of course, is to resist a shock as your hand approaches the dome.)

A small but significant glow or "fire" appears at the tip of the needle.

St. Elmo's Fire can also be created by attaching a 3' long electrical wire (not solid, but stranded) to the eye of a sewing needle. As the strands are passed across the eye, fold and twist them with pliers to join the needle solidly to the wire's end. Connect the other end of this wire to the ground connector on the base of your Van de Graaff. (This procedure will not work if your receptacle has only two flat holes.) Now tie the needle perpendicularly to one end of a drinking straw using cord or tape. Hold the far end of the straw and bring the needle close to the dome to watch the "fire" glow.

With this method, you can study the effect of distance on the glow. The glow will be stronger in the vicinity of the dome. As distance increases, the glow dims.

Determine the "firing distance" - the distance over which the glow is visible.

(5) <u>Lighting</u>:

You can light a variety of light emitting devices with your Van de Graaff - incandescent (filament) light bulbs, fluorescent tubes or lamps, gas filled tubes, old radio tubes, even tiny neon tubes. For best results, do these experiments in a darkened room or at night.

Bring your bulb toward the dome as the generator is operating. You may wish to make a non-conducting holder for the light bulb to avoid receiving a shock as you approach the dome. The outside glass surface nearest the dome acquires positive charge by induction. The charge builds up on the glass surface to discharge intensity. As discharge occurs, positive charges rush through the entire bulb, lighting it up for the duration of the discharge.

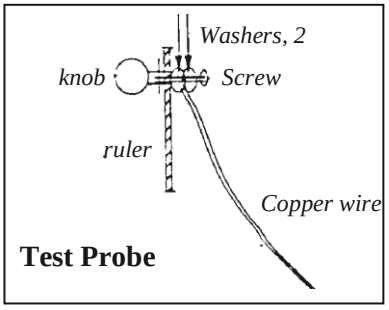
Experiment with distances between bulb and dome. The bulb will light even when 2' away from the dome. Here, discharges will be stronger but the intervals between them will be longer. The light bulb will also glow more brightly. When you bring the bulb nearer, the discharges are more frequent but the light is dimmer. The bulb touches the dome, the light may be continuous (or flickering) but the intensity is low. Household (incandescent) bulbs will glow with purple light. Other gas-filled tubes will glow with the characteristic lights of the respective gases.

More Demonstrations:

These experiments require a few simple devices made from common materials.

(1) <u>Test Probe</u>

This can be made out of a spherical metal object, about 2 " in diameter, threaded, such as for a cabinet. Drill a hole in a ruler near one end for a screw. Take a piece of well-insulated copper connecting wire, 2-3' long, bare one end and fold it around the screw loosely. Fix the knob on the ruler with the wire attached to the probe in between two washers, using a solderless crimp terminal. Bare the other end of the wire and ground it by connecting it to the ground connection on the base.

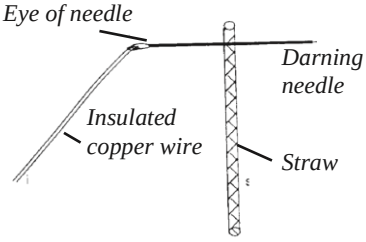


Test Probe

(2) <u>Neon Bulb Probe</u> Mount a small neon bulb (i.e. Ne_2) on a plastic ruler. Turn the two lead wires at right angles, with one protruding from the ruler by 1 ". Solder an insulated copper wire to the other end and ground it by connecting it to the ground connection on the generator base.

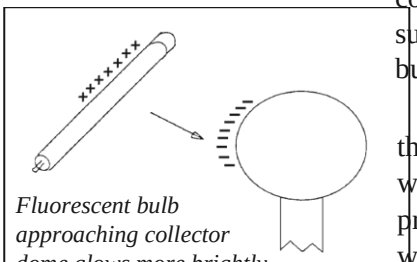
(3) <u>Moveable Electrode</u>

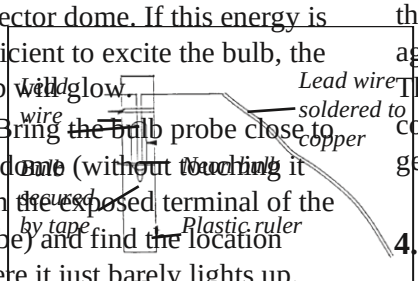
Take a piece of well-insulated stranded copper connecting wire about 3' long. Bare a length of 2" on each end. Pass the strands at one end through the eye of a darning needle about 6" long. Twist the wire using a pair of nose pliers until the needle is solidly connected to the wire. Solder the copper parts (optional). Attach the needle to a plastic rod such as a drinking straw by passing the needle right through the straw near one end. Or, use a 6" plastic or wooden ruler, attaching the needle with cord or tape. Do not ground this wire. **(4) <u>Cylindrical Box</u>**



Movable Electrode

Roll a piece of clear, strong plastic sheet into a cylinder or tube about 6" tall and attach 2 metal caps (such as lids of peanut butter jars) to the ends. Glue one cap to the tube but do not glue the other.





Neon Bulb Probe

Use this box to carry foam pieces painted with conductive paint. Connect the upper and lower electrodes to the generator.

Experiments:

1. Effective spark distance of the generator

For best results, do in a dark room.

When the grounded spherical test probe is brought near the dome, lightning discharges occur, accompanied by a crackling sound. You can enhance the effect by bringing the probe close to the dome. As it is moved farther away, the intensity of light and sound will diminish. To find the maximum effective distance at which visible light and audible sound occurs, move the probe back systematically until lightning can just barely be noticed. This is the effective spark distance of the generator. Repeat in different directions. -Expect equal effective distances on all sides. Look for any deviations.

2. Electric field intensity around the collector dome.

The grounded neon bulb draws energy from an electrostatic field such as the field around the collector dome. If this energy is sufficient to excite the bulb, the bulb will glow.

Bring the bulb probe close to the dome (without touching it with the exposed terminal of the probe) and find the location where it just barely lights up. Study the extent of the field by moving the bulb in all directions. You should expect the field to be symmetrical but you might wish to look for abnormalities or defects where the intensity diminishes.

3. Jumping balls in a box.

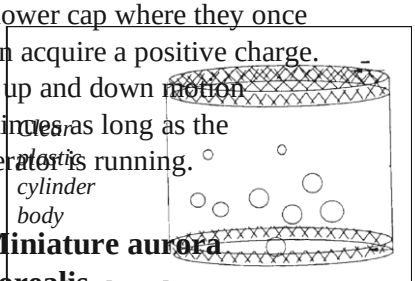
Cut small foam circles from foam packing material and cover them with electrically conductive material such as soot or graphite (from soft pencils). Or rub them against carbon paper.

Place conductive balls in the cylindrical box (described earlier). Connect the upper and lower electrodes (caps) of the box to the DOME and GROUND respectively, using well-insulated copper connecting wires. The two caps will become electrically charged.

At first the balls will be on the lower cap. Here they become charged positively and are repelled away toward the upper cap. The upper cap becomes negatively charged and attracts the balls.

The balls continue to move upward until they hit the upper cap. On impact, their positive charge is neutralized and they become negatively charged instead.

The balls now fall down to the lower cap where they once again acquire a positive charge. The up and down motion continues as long as the generator is running.



Cylindrical Box

4. Miniature aurora borealis

You Need: Pyrex flask Fill a Pyrex flask 1/3 full with water and heat until the water boils. When the flask is filled with steam, remove from your heater or burner and immediately cork. Allow to cool. As the steam settles and changes to water, a partial vacuum is created. It will be saturated with fine water vapour but there will be no air inside the flask. Do not handle the flask directly, even with gloves or plastic as you will not be protected against a build-up of charge. Use a tongs to bring the flask in contact with the dome. A greenish-pink glow should develop inside. This is a replica aurora borealis.

5. Electrostatic repulsion

Use metal streamers such as Christmas tinsel or graphite-coated pith balls*

placed in a bundle with one end tied together. Attach the tied end to the dome with tape and start your generator. All strands will be charged negatively and will stand erect, moving as far away from one another as possible. The effect is similar to HAIR RAISING and is a direct result of electrostatic repulsion.

You get the same effect if you use long, thin strands of paper coated with graphite from a soft lead pencil. Tape to the dome; start the generator; watch the strips repel each other.

6. Electrostatic spray painting

You Need: food colouring, spray atomizer The electrostatic field of the generator can be used to direct the fine mist of paint as it comes out of a sprayer nozzle. The particles in the mist are charged electrically which causes them to remain within the electrostatic field. This reduces the loss of paint from random scatter. The use of this technique in commercial spray painting requires only half the paint otherwise needed.

To test this feature of the electrostatic field, use a perfume atomizer. Fill an empty atomizer bottle with water coloured with food colouring. Spray the coloured water from the atomizer in the vicinity of the collector dome, tangentially across (not radially toward) the dome.

Notice how the spray gets trapped in the electrostatic field and bends toward the collector dome. The spray is localized and there is little waste.

Safety, Operation and Maintenance:

Safety: This generator is safe when used properly. As with all electrical appliances, follow these general safety rules.

. Plug the generator into a **grounded** (3-prong) 0 volt 50 Hz outlet only. (**10-086/ 10-286** uses 220 v 50/60 Hz.)

2. Do not operate in a wet or damp location or outdoors (to avoid shock).
3. Check for loose, worn or frayed wires. Replace any defective parts. (See parts list).
4. Since discharge of electricity can damage electronic devices, keep away from appliances such as televisions, computers, stereos, microwave ovens, and cell phones.
5. The shock caused by touching the generator directly is not harmful and is similar to the shock received when walking across a carpet and touching a metallic object. It may feel uncomfortable however and should therefore be avoided.
6. Adult supervision is required.

Getting the Right Output:

Output is determined by the number of popping sounds you can hear in a timed interval or by estimating the length of spark.

The size of the globe determines voltage. The voltage determines the spark length. The shape of the globe needs to be smooth and round. Any burrs or sharp points will cause loss of charge. Dents will not materially affect performance as long as dents are smooth and shallow with no rough edges.

Operation:

Best results are obtained in low humidity. High humidity causes charges to dissipate, lowering the electrostatic field, as water vapour in the air drains your charge. High humidity also causes gradual deterioration of the belt.

We recommend that you operate your generator at humidity levels of 75% or less. Your machine will run, however, at humidity levels up to 90%. At humidities in excess of 90%, the life of the belt will be shortened drastically even though the machine may function normally. The belt may show signs of breakdown after 20 operating hours.

Your belt contains a special ozone retarding formula which should give hundreds of hours of operating use in low humidity. The tension of the belt, however, is crucial. Belt tension is high

when it leaves our factory but may loosen with use. If your belt is too tight when you first receive your machine, you may loosen it by stretching TWICE to twice its normal length for several seconds, then releasing. Do not stretch further than the width of your outstretched arms.

Operating Problems:

a. Unsatisfactory Performance:
Low Current Yield

If your generator produces weaker than normal current, it will result in weak lightning discharges at shorter than normal distances. This is caused primarily by a damp or dirty belt. Wash the belt with soap and then rinse thoroughly. Check, also, for too much clearance between belt and upper and lower combs. Combs can be adjusted manually by bending them toward the belt for better contact and should be within 1/8" (3 mm) of the belt, but not touching it. If your comb is too short, order replacements from us.

Another common cause of initial poor performance is high humidity. Dry the inside of the column and globe with a **hair dryer** before using. This removes humidity inside the machine. You may also run the generator for several minutes before raising hair. This creates enough heat to eliminate effects of humidity.

b. Unsatisfactory Performance:
Low Voltage Yield

If your generator produces a weaker than normal electrostatic field, it will result in less intense discharges. You may also see localized tiny flashes on the collector dome. This is due to a build-up of dust or lint on the collector dome itself. Such build-up should be cleaned with a damp cloth. The housing that covers the motor and plastic pulley should be cleaned as well.

Storage:

If storing for a long time, remove the belt to relax its tension so it will not lose its original strength. Store in a **dry** place.

Maintenance:

Bearings: No maintenance is required for upper pulleys with ball bearings. For pulleys with solid bearings, apply a drop of lubricating oil once a year to upper pulley bearings.
Belt: After every 50 operating hours, apply soap and scrub to remove any deposits of conducting material that may accumulate on the belt. Rinse thoroughly to remove soap.

Pulleys: Clean upper and lower pulleys with a soft cloth. Clean both pulleys occasionally with alcohol, especially if you are having operating problems.

Accessories Included:
-Neon indicator and a helicopter.
-Rubber drive belt
-Silicon main belt
-Discharge sphere -Head of hair

Dimensions:
Sphere Diameter 280mm
Overall height 760mm
Base length 380mm
Base depth 230mm
Weight 8kg