

# ***Instructions & Applications for***

## ***Van De Graff Generator***

### **Introduction:**

The Van de Graaff generator deposits a very large amount of positive electrical charge on the metal dome (oblate, globe). This massive volume of positive 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. It has acquired positive electrical charges. The other insulator, having gained excess electrons (negative electrical charges) becomes electrically negative. These charges are static because 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 neighboring 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 plastic 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 negative charges while the inside surface of the rubber belt (in the vicinity of the plastic pulley) acquires an equal amount of positive charge. The outside surface of the rubber belt acquires an equal amount of negative charge by induction. An electrode, in the form of a comb or brush, is provided to drain away these negative charges from the outside surface of the rubber belt to the "ground."

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

Positive charges stay on the inside surface of the belt and travel upwards as the belt moves up. At the top, it runs over a metallic pulley (aluminum) which picks up these positive charges and retains them. Free electrons from the metallic 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 buildup of charges on each. Soon this buildup reaches ionization intensity in the vicinity of the two comb assemblies and a large number of positive and negative charges are generated. The positive charges are transferred to the collector dome by the upper comb and the negative charges are drained to the ground by the lower comb. The belt plays an important role in transporting negative charges from upper to lower comb and positive 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 buildup of positive 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, the air between dome and lower housing gets ionized and a discharge with 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 1- 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 vapor 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.

(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 would be 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 neighborhood. Negative ions will rush towards the collector dome and neutralize their charges. Positive 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 positive 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 aluminum foil 1" 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 collector dome at its equator (along the seam) on opposite sides and in opposite directions. Conductors can be attached with clay or tape. Observe how pressure differences in the vicinity of these conductors exert torques on the collector dome which begin to rotate slowly but steadily. The dome continues to rotate as long as the generator is running. The mass of the dome is in excess of 200 grams excluding masses of the conductors. 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.

## **Carry 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 buildup of positive electrical charges on the dome.

Bring a rounded object (metallic, for best results, such as a mixing bowl or juice can Discharge Wand) 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 1/2" away.) If you withdraw the rounded object, the discharges become feeble and less frequent and may be seen only in a darkened room.

You should hear intermittent crackling sounds and see feeble sparks in darkness.

### **(4) St. Elmo's Fire:**

Electrical discharges from clouds to the earth are of three different types.

## **Point Discharge**

There is no visible light or sound. Point discharges are responsible for 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 Fire in a dark room by installing a sewing needle perpendicular to the dome 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 not to obtain a shock as you approach the dome with your hand.) 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) Lighting:**

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 nonconducting holder for the light bulb to avoid receiving a shock as you approach the dome. The outside glass surface nearest the dome acquires negative charge by induction. The charge builds up on the glass surface to discharge intensity. As discharge occurs, negative 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 12' 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) Test Probe**

This can be made out of a spherical metal object, about 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.

#### **(2) Neon Bulb Probe**

Mount a small neon bulb (i.e. Ne<sub>2</sub>) 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) Movable Electrode**

Take a piece of well-insulated stranded copper connecting wire about 3' long. Bare a length 1" on each side. 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) Cylindrical Box**

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 mar or peanut butter jars) to the ends. Glue one cap to the tube but do not glue the other.

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

## **Safety, Operation and Maintenance:**

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

1. Plug the generator into a grounded (3-prong) 220 volt 50 Hz outlet only.
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.
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 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 200,000 volt generator should produce a spark length up to 8" (5" is typical).

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 vapor 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 you hundreds of hours of operating use under low-humidity conditions. 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 (or have first assembled it in kit form), you may loosen it by stretching TWICE to twice its normal length for a period of several seconds, then releasing. Do not stretch further than the width of your outstretched arms. Stretching too far may break the belt. By following this procedure, you should have relaxed the belt to its proper tension.

## **Common 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" (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 mitigate 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 buildup of dust or lint on the collector dome itself or on the glued joint of the two halves of the dome. Such buildup should be cleaned with a damp cloth. The housing that covers the motor and plastic pulley should be cleaned as well.

### **Storage:**

To store 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:** 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 pulley with rough cloth and wipe off any deposits caused by wear and tear. Clean the lower pulley with a soft cloth. Clean both pulleys occasionally with isopropyl alcohol, especially if you are having operating problems.

## **What To Do If Your Generator Does Not Work**

1. Check for loose, worn, frayed wires. Replace defective parts.
2. Check humidity. See if you can dry out the inside of your generator with a hair dryer or operate on low-humidity days.
3. Loosen the belt. Take it out and stretch it twice to about double its length. Do not overstretch. Belts may be brittle and break.
  - If the belt has been exposed to cold weather, you can thaw it out in hot water.
4. Remove lint from belt, housing and globe. Wash belt in soap and water. Rinse and dry thoroughly. Lint drains your output. (For globe and housing, you may use a dishwasher.)
5. Wipe upper pulley with alcohol. Remove upper pulley, wipe all surfaces and replace. Belts vary in composition and sometimes leave a film or residue on the pulley which drains charge. Lower pulley is Teflon and is not affected.
6. Adjust brushes: There may be too much clearance between belt and wire combs. Adjust combs by bending until they come within 1/8" (mm) of the belt but do not touch the belt. If you have cut your brush too much, order a replacement.
7. Allow warm-up period. Let your generator run a few minutes before experiment. This often offsets high humidity. You can dry the inside of the column with a hair dryer before experimenting.
8. Maintain regularly. Lubricate upper pulley bearings with a drop of oil, oil cannot touch belt or pulleys. Wash belt after 50 operating hours with soap, rinsing thoroughly. To clean upper pulleys, use rough cloth, to wipe off any deposits caused by wear. Clean the lower pulley with a clean cloth.