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Van de Graaff Generator Safety

Introduction

Van de Graaff generators build up and maintain a high voltage static electric charge—some of them up to 500,000 volts. Safely operating a Van de Graaff generator is essential if students are to have the opportunity to see the many exciting and memorable static electricity demonstrations performed with a Van de Graaff generator.

Concepts

- Van de Graaff generator safety
- Static electricity

Materials

Van de Graaff generator

Meter stick, wood (no metal), or 1-m wooden dowel (optional)

Discharge electrode

How a Van de Graaff Generator Works

Most Van de Graaff generators build up a positive electric charge on their domes by separating negative electric charge from positive electric charge. This is accomplished by a rotating insulated belt. When two different materials are rubbed together, one object takes away electrons from the other object. The electron-removing object becomes negatively charged, leaving the second object with a positive charge. The tendency of an object to become positively or negatively charged is a property of the materials being rubbed together.

In a Van de Graaff generator, the lower pulley connected to an electric motor rotates a rubber belt that is also looped over the upper metal pulley. The lower pulley and belt rub together causing electric charge transfer and separation. The lower pulley becomes negatively charged and the inside of the rubber belt becomes positively charged. Because the rubber belt is an insulator and not a very good conductor of electricity, the positive charge does not evenly distribute over the belt. Instead, the inside of the belt remains positively charged, while the outside of the belt becomes negatively charged as a result of electric *induction*. Electric induction occurs because the negatively charged particles (electrons) on the belt experience a repulsive force from the negatively charged pulley (like charges repel). The electrons on the belt tend to move as far from the pulley as possible—to the outside of the belt. At the base of the Van de Graaff generator, a grounded metallic comb is located near the rotating belt and pulley. The grounded metallic comb allows the built-up negative charge on the outside of the belt to “bleed” off, thereby making the entire belt (inside and outside) more positively charged.

At the top of the Van de Graaff generator, another metallic comb assembly is connected to the metal dome and is located near the rotating belt and upper metal pulley. The upper metal pulley retains the positive charge as the positively charged belt moves over the pulley. The outside of the belt passes the metal comb connected to the dome and negative charges on the dome drain onto the more positively charged belt (opposite charges attract). The negative charge remains on the belt until it is allowed to drain off at the grounded base comb assembly.

The positive charge that accumulates on the upper metal pulley quickly distributes itself evenly over the metal dome because like electric charges repel each other, and because the metal dome is an excellent conductor of electricity. The Van de Graaff generator dome can continue to gain positive charge because the positive charge that accumulates on the pulley on the inside the dome does not “feel” the positive charge on the outside of the dome. This is due to the fact an electrically charged shell does not produce a net electric field (and therefore a net electric force) inside the shell. So, the positive charges that are deposited on the metal pulley continually move to the outside of the dome due to their own repulsive forces until a large electric potential is created on the dome. The amount that can be collected is based on the diameter of the dome and the dielectric breakdown of the air surrounding the Van de Graaff Generator. The larger the dome (more surface area), the more charge that can be collected. However, when the

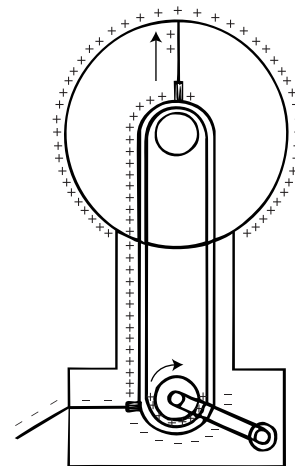


Figure 1.

dielectric breakdown of air is reached (30,000 volts/cm in dry air), electric discharge occurs into the air which removes some of the static charge on the dome. Dielectric breakdown prevents the dome from collecting an “infinite” amount of charge.

Static Electricity Hazards

Van de Graaff generators typically produce a very small amount of current (microamperes). Therefore, an accidental shock from a Van de Graaff generator may be startling and it may be painful, but it will not cause serious harm to most individuals, even at a high voltage. The discharge may stimulate the nerves and cause muscles to contract briefly, but it will not produce thermal burns or damage to cells. The strength of the current is difficult to determine since it is based on the total resistance of the shocked individual and the voltage discharge by the Van de Graaff generator (potentially up to 500,000 volts). Table 1 gives the approximate physiological effects on a “normal” male for different levels of direct current (DC) applied for one second. The static discharge from a Van de Graaff generator lasts only a fraction of a second. However, electric currents running through the body, even a small amount, can still lead to possible problems and injuries.

Current (milliamperes)	Physiological Effects
1–5	Threshold of sensation
>5	Mild Shock
>30	Painful shock
>50	Muscle paralysis
>75	Severe shock
>250	Possibly fatal

Although the shock from a Van de Graaff generator is not permanently damaging, methods to prevent electric shock should always be taken. Purposely discharging an individual quickly so that they can “feel” a shock should *never* be done. Everyone’s body responds differently to electric shocks. What might be slightly painful to one person might be seriously dangerous to another.

When operating a Van de Graaff generator, always have a grounded discharge electrode that can be used to discharge the Van de Graaff generator before the generator is touched. Most Van de Graaff generators have a ground terminal on the base where a discharge electrode can be connected. The discharge electrode protects the operator from being shocked before getting near the generator or turning it off. However, discharging an individual requires a special technique. When an individual is charged by a Van de Graaff generator for a hair-raising demonstration it is very important to discharge the individual in a slow, controlled manner before he removes his hand from the Van de Graaff generator dome. Do NOT use a grounded discharge electrode to ground the individual. Instead, discharge the charged individual by first turning off the Van de Graaff generator by flipping the ON/OFF switch with a wooden meter stick (no metal ends) or a 1-m long dowel rod. Don’t touch the Van de Graaff generator with your bare hand because this will cause a quick discharge. When the Van de Graaff Generator is turned off, touch the charged individual with the wooden meter stick until his hair falls. Continue to touch the individual for another 15–30 seconds so that he is completely discharged before allowing him to step off the insulated platform. **Caution:** Only perform hair-raising type demonstrations with a Van de Graaff generator that has an ON/OFF switch so the Van de Graaff generator can be turned off with an insulated rod, and does not have to be touched with a bare (grounded) hand.

Additional Safety Precautions

Before operating a Van de Graaff generator for experiments or demonstrations, it is important to become knowledgeable and familiar with the principles of the experiment and the expected results. Ask an experienced Van de Graaff generator operator if you have questions.

Do not use a Van de Graaff generator near water, grounded water faucets, or other grounded objects such as doors or walls. Also, do not operate near electrical equipment such as computers, televisions, or magnetic recordable devices (VCR tapes or floppy disks). Make sure no flammable gases are present.

Materials for Van de Graaff Generator Safety are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6476	Van de Graaff Generator, 400-kV
AP4699	Van de Graaff Generator
AP5634	Discharge Electrode

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.