VAN DE GRAAFF GENERATOR DEMONSTRATION

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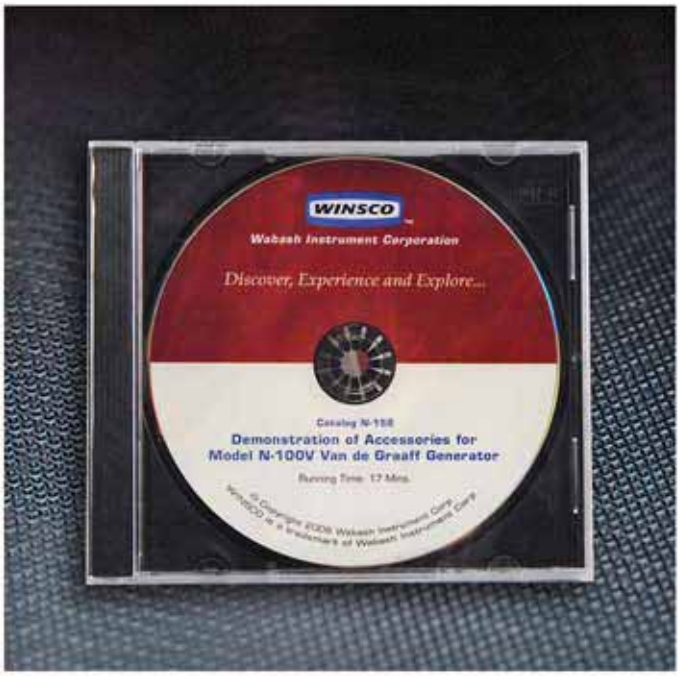
When two different materials in close contact are separated, there is usually a transfer of free electrons from one to the other. The result is that one becomes negatively charged and the other becomes positive. While these charges may be of fairly high voltage, say 5—10,000 volts, they will dissipate over time and both materials will return to a neutral charge condition. In the operation of the Van de Graaff, we have a motor-driven belt continuously separating from the lower, wool-covered pulley. We have two dissimilar materials being pulled apart and a negative charge does indeed appear on the belt. Because the belt is a good insulator, the charge is immobile and is carried to the upper pulley. Here again we have a change of materials, but in this case the charge is transferred to the pulley instead of remaining on the belt. As more charge continues to arrive, the voltage on the surface of the upper pulley rises until the electrons are able to escape across the air gap to the electrode brush. Once they have made that jump, they are free to flow out to the surface of the dome. Remember that like charges repel one another and the locale of greatest spacing will always be the outside surface of a conductor. In time, the charge on the dome will build up to the point where electrons will begin to escape by ionizing the surrounding air or arcing to a nearby ground point. In any case, a point of equilibrium will be reached, and the dome's voltage level will no longer increase.

N-122 DISCHARGE ELECTRODE

Let's look again at the basic arc discharge. If a grounded discharge electrode is brought near the dome, there is a sharp, cracking arc between the two. The length of this discharge will naturally be proportional to the voltage which we are developing on the dome under the conditions as they exist at this moment. With the small 4-inch discharge electrode, on a good day, we will typically get an arc of about 4-6 inches. A crude estimate of this voltage level is about 30,000 volts per inch.

N-122L DISCHARGE ELECTRODE

If we repeat this demonstration using the large ten inch discharge electrode, we will get somewhat similar results, except that the arc will be shorter, but more intense. The larger dome presents a less concentrated target for the arc and a higher voltage gradient is required across the air gap. Notice that there is obvious movement of the two domes,



indicating that there are some real mechanical forces at work. Before the discharge, the domes are attracted by induction, but this force is suddenly released by the arc. We will talk more about these forces a little bit later.

N-127 POINT TERMINAL

Let's go to the other extreme and approach the dome with a small object, say a single finger. Notice that it's possible to get very close before any arcing occurs. With a penknife pointed at the dome, the arc is only a fraction of an inch long. Yet if the small discharge electrode is again brought near, you can see that conditions really haven't changed. The explanation is simply that the sharp point provides a path of relatively low resistance for the charge to escape from the dome. In fact, the charge escapes so fast that the voltage level of the dome is drastically reduced and only very short arcs are possible. When this demonstration is done in the dark, you will see a faint glow around the point. This is called corona discharge. It is the continuous excitation and ionization of the air that causes the emission of light.

Placing a point terminal on the dome using its suction cup will create a very high voltage stress point in the atmosphere. This will result in ionization of the air in the vicinity. These negatively charged particles are immediately repulsed and there is a very noticeable wind. Holding your hand nearby

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clearly indicates the presence of a breeze. This can better be shown with a piece of ordinary facial tissue. Separate the usual two plies to get a very lightweight indicator. To be sure the there are no skeptics, remove the point terminal and again bring the tissue near the dome. It is obviously being attracted, not repulsed. The presence of the wind can also effectively be demonstrated with an ordinary child's pinwheel.

N-124 ELECTRIC WHIRL

A near cousin to the point terminal would be the Electric Whirl. This is a device with three or more arms balanced on a central pivot which allows it to rotate with ease. When brought near the dome of an operating machine, the arms will immediately begin to rotate. The electrons first escape from the dome to the arms. The high voltage concentration at the points ionizes air particles, which are then repelled. The reaction to this repelling force causes the arms to rotate. Even if you spin the arms in the "wrong" direction, they will come to a stop, and start back up with the correct rotation.

N-125 ELECTRIC PLUME

The Electric Plume is simply a collection of ribbons attached to a suction cup. When it is mounted on top of the dome, the ribbons will each become charged. Here again, the forces of repulsion between like charges comes into play. Each ribbon becomes negatively charged and tries to get as far as possible from the dome and from each of the other ribbons.

N-141 RACING BALL

The Racing Ball is another way to show the force of repulsion between like charges. With this device we have a plastic ball sitting in a level dish which is connected to ground. Above the ball is a flat plate which is brought close to the dome or may even be connected to the dome with a wire. The upper plate becomes negatively charged, and some of this charge will migrate to the top of the ball. A repulsion force is then created between the ball and the upper plate which can only result in the ball rotating. When the ball is first influenced by the charge, it may move in almost any direction. After a few moments it will usually be helped by the rising sidewall of the dish to find a continuing path around the dish. When setting up this demonstration it is important to have the dish quite level. The forces involved are not all that great, the ball is fairly large and it isn't going to roll uphill. (Note: This demonstration was omitted from the DVD because of its similarity to some of the other included demonstrations in terms of the principles involved. Also, it did not really introduce any new material.)

N-142 HOLLOW CYLINDER

This is called a Hollow Cylinder because that's just what it is. On the topside we have two pithballs tied by light thread, and on the inside we have two more pithballs suspended in the center of the cylinder. The best way to demonstrate this device is to charge it indirectly from the dome of the generator. The small discharge electrode or the proof plane will work very nicely. Touch the Van de Graaff dome with the smaller ball and then transfer the charge by touching the ball on top of the hollow cylinder. What we can observe here is that the pithballs on top become charged and are repulsed from the cylinder, just as you would expect. But note that the balls inside the cylinder are completely unaffected. This is because the charge on the cylinder resides on the outside surface only. It will not go onto the inside of this conductive surface because of the forces of repulsion. Let's go back for a moment and comment on why it's best to charge the hollow cylinder in an indirect manner. When the Van de Graaff is working well, there is usually enough electric wind to upset proper charging. Both the pithballs and the cylinder will become charged by the ionic wind before you have a chance to use the charge transfer device. If you want to charge directly from the generator, first turn the machine off. The voltage level will naturally subside but there will still be enough charge for this demonstration.

N-139 LIGHTNING PLATE

The Lightning Plate makes for a fun demonstration, but at the same time, clearly shows some interesting aspects of charge behavior. The top of the plate is connected to the high voltage of the dome and the other end is connected to ground. The plate is simply a pattern of flat metal conductors on an insulating surface. When the Van de Graaff is operating, the discharge path is quite visible at the ends of each of the conducting sections. First, note that the discharge path is not a random jumping from one section to another, but clearly follows the shortest path to ground. Second, note that the discharges are quite uniform in intensity even though some are longer than others. The explanation for this type of discharge pattern is that the dome will charge the first metal section until it has enough potential to jump to the next one. The process continues down through the pattern until the charge reaches ground.

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N-132 VOLTA'S HAIL STORM

Volta's Hail Storm is another fun device that also shows some important aspects of electrostatic charges. The unit is a hollow tube of clear plastic with metal top and bottom plates. For the first demonstration we will remove the lid and load the unit with about a tablespoonful of vermiculite. Now bring the small ball on the top near the generator and the action starts. The small particles jump up and fall back in a wild and vigorous manner. What is happening is that the particles are first attracted by induction to the upper plate. As soon as they touch, however, they acquire a negative charge and are then violently repelled toward the bottom plate. If the lower plate is at ground potential, the negative charge will be lost and the cycle will repeat.

Another demonstration with Volta's Hail Storm is to show the precipitation of smoke. For this, we must remove the vermiculite and in its place put a small piece of ordinary wire screening. Now the tube is filled with smoke and the top replaced. Quickly bring the unit close to the dome and the smoke disappears. It has been attracted to one of the electrodes where its charged is neutralized and the particles stick. This, of course, is the principle on which industrial smokestack precipitators operate.

N-146 NEON WAND

Another demonstration that commands a lot of attention is the lighting of a Neon Wand or a fluorescent lamp by allowing the current (a few microamps) to flow through a person's body to ground. The neon wand works better because it gives off more light for the available power. It is a glass tube, filled with neon, which has metal electrodes at either end. These electrodes facilitate the passage of current. Hold the tube by the handle end and then bring the other end close to the generator. The voltage across the gas in the tube excites the neon and light is emitted. When using the wand, always point one of the electrodes directly at the dome. Do not bring the middle of the tube toward the dome as the tunneling action of the electrons will cause very tiny leaks through the glass wall, allowing air to enter. The unit will then no longer work. A small fluorescent tube will also work, but the light output is harder to see unless the room is darkened.

When using either the Neon Wand or the fluorescent tube, better performance is obtained if the person holds a grounded bare wire in their hand. This will reduce the resistance path and increase the light output. As a matter of fact, almost all of these demonstrations will come off better if the person is well grounded.

To increase the light output of the Neon Wand, place a small piece of foam on the bare electrode wires, something of the size of a typical packing peanut. This will insulate the wand from drawing a continuous current and allow the generator to build to a higher voltage before it arcs to the electrodes. Now, instead of a continuous low current, we get rapidly repeated discharges of much greater momentary current amplitude and hence, more light.

N-144 FLYING BALL AND SILVER SNAKE

Now that we have just made a pronouncement about the importance of grounding, let's talk about a demonstration in which it is quite unnecessary. We are going to look at two items which together can be used to show a great deal about electrostatics. The first of these is the Silver Snake. It is an insulating plastic rod from which hangs a length of metallized ribbon. When the ribbon is brought near the generator, it is attracted by induction, but then repulsed as soon as it touches the dome. After a few moments, the charge will leak off into the air, and the ribbon will again strike at the dome. There may be wide variations in this action, depending on the operating voltage level of the dome and the relative humidity. If the humidity is unusually low, the charge may not leak off very fast.

The Flying Ball is just about what the name indicates. It is a lightweight metallized ball on the end of a thread hanging from the end of an insulating rod. The first step in this demonstration is to carefully and slowly bring the ball near the dome. Hold the ball with your hand to keep it from being charged by the electric wind from the generator. This must be done slowly so as to clearly show the attraction by induction that will take place when the ball is released three or four inches away. As soon as the ball touches the dome, as you would expect, it is sharply repelled. The ball shape tends to hold the charge longer than any other geometric shape, and the ball will now "float" around the dome but always at a respectful distance. The forces of repulsion are clearly present all around the dome. And the higher the generator voltage, the better the demonstration. Naturally, the voltage charge on the ball will eventually dissipate and the cycle will repeat.

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STAND UP HAIR

The last demonstration that we will attempt is the most requested of all: that of making a person's hair stand up. This is fun for the class, but not necessarily an easy act to pull off. If the entire person can be raised to a high enough potential, then the hair will act in much the same way as the electric plume did earlier. Easy to say, not so easy to do.

The first step is to insulate the person from ground by having them stand on something sturdy, such as a plastic milk delivery crate. Be sure it is the real thing and not some cheap, lightweight imitation. Second, pick your volunteer carefully, making sure they have no medical condition (such as a pace maker), that would possibly pose a problem. Obviously, the smaller the person, the less surface area there will be for charge leakage back to the atmosphere. All metal items such as rings, watches and pens should be removed. These will act like the discharge points, as we have shown before. The forces of repulsion are modest, so pick a candidate with clean, dry, straight and relatively short hair of perhaps three or four inches in length. Long and curly hair will simply not disentangle and the demonstration will be a disappointment. On a good, dry day, don't be afraid to try a volunteer with somewhat longer straight hair. If it's a go, it makes for a very good show. Blond hair is usually finer than brunette and therefore is often a better choice.

Have the subject place their hand on the dome with clear instructions to keep it there at all times until the demonstration is over. After the machine has been started, it will begin to build up charge and will reach its maximum level in a minute or so. Throughout all these demonstrations you have seen that the generator by itself will come up to potential very quickly, typically in fifteen seconds or less. It is wishful thinking to believe that, if you let it run for five or ten minutes, something spectacular will happen. You should see some hair activity almost immediately.

When presenting this demonstration, have your volunteer stand on the side of the machine opposite from the controls. This allows you to reach the On-Off switch without getting physically close to the volunteer, as this might initiate an arc discharge from them to you. After turning the machine to the "off" position, you can easily drain the charge from the machine and the person by pointing your open penknife or other sharp object at the dome.

It is our hope that this DVD will help you in using the Van de Graaff generator and some of the accessories that are available. We are always pleased to hear from teachers who may have comments or suggestions. If you know of a new demonstration, or a way to improve upon those we've included here, and would like to share it with us or your colleagues, please write or call and ask for our manager of school product engineering. Or, you can visit our website at www.winsco.com and use the "Contact Us" page.

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