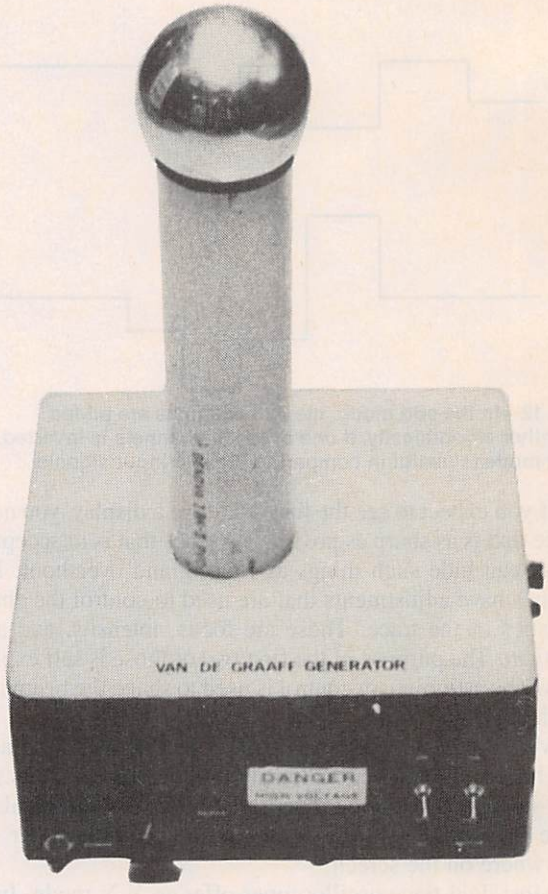
BUILD THIS

VAN DE GRAAFF GENERATOR

This amazingly simple device produces electrostatic effects beyond your wildest imagination, as static charges seem to fill the air

By D. E. Patrick



ANYONE WHO'S INTO ELECTRONICS FROM A HANDS-ON point of view (no pun intended) enjoys almost any unusual gadget that's apt to cross his path, whether it has some practical application or it is strictly a conversation piece. And if you're familiar with, or are curious about, the Telsa Coil (or have built one), then you'll probably find pleasure in building your own, working Van de Graaff Generator. Pound for pound, it develops even higher voltages than the Telsa Coil and is considerably safer to operate.

What It Does

A Van de Graaff Generator (see Fig. 1) is a high-voltage electrostatic generator in which electrical charges are carried to a metal sphere or collector by a rubber charging belt. The rubber belt is positively charged at the base of the generator by a high-voltage power supply that is connected to a wiper that rubs against the belt. The belt, which is wrapped around a motor-driven pulley in the base of the generator and an idler pulley at the top, carries the positive charges to the metal sphere where a second wiper removes the charges, causing the sphere to become highly charged.

The charges collected by the sphere are prevented from returning to ground by the insulating qualities of the charging belt, which passes through an insulating column or cylinder supporting the sphere. The voltage rise at the sphere is directly proportional to its diameter, but will be limited by leakage or sparkover through the air and down insulators to ground under no-load conditions. The power supply used can be anything capable of providing around 10,000-volts DC or more.

Other units similar in basic design to Fig. 1 can generate over 1,000,000 volts at standard atmospheric pressure. Also, generators, not too different from that unit, operating in pressurized gas mixtures with special insulating cylinders and other refinements, can produce voltages in excess of 10,000,000 volts. Even a mini, desk-top unit (see Photo) is capable of producing voltages in the 100,000-volt range. The upper limit is dictated by the diameter of the metal sphere collector, more than anything else. However, by simply scaling the basic parts shown in Fig. 3, you can build the monster of your choice.

Electromechanical Operation

Figure 2 shows a schematic of the power supply for the Generator. In the author's first working prototype, the high voltage required was provided by a 10,000-volt, 30mA sign transformer (the type used for neon lighting fixtures). Other high-voltage transformers suitable for our purpose include converted flybacks, auto spark coils, cannibalized supplies from copy machines, TV's, etc.

If desired, the sign transformer's primary voltage may be optionally adjusted using a variable transformer as Fig. 2 shows, or it may be connected directly to line voltage through a suitable fuse and/or switch. The author opted for the former. The variable transformer allows adjustment of the sign transformer's secondary voltage from around 0 to 10,000 volts. The sign transformer's output can be rectified and used directly, or passed through a voltage doubler or tripler from an old color-TV set. As shown in Fig. 2, that arrangement provides an adjustable output from around 0 to 30,000 volts.

In any case, a high positive potential (voltage) is applied to a charging belt (which can be an oversized rubber band) by a metal wiper in the the base of the Van de Graaff generator (see Fig. 1). Those positive charges are carried up to the metal sphere and removed by a second wiper, which is also the idler pulley.

If the idler pulley is metal and has metal-sleeve type bearings, the top side wiper can be eliminated as long as there is good electrical contact between the idler pulley and the sphere. There's nothing critical about the sphere; in fact, two copper bowls soldered together, or stainless steel bowls welded together, etc., will all suffice. We'll elaborate on that a little later, but for now let's take a closer look at the mechanical part of the unit.

The Mechanical Operation

Figure 3 is a sketch showing the insulating column and

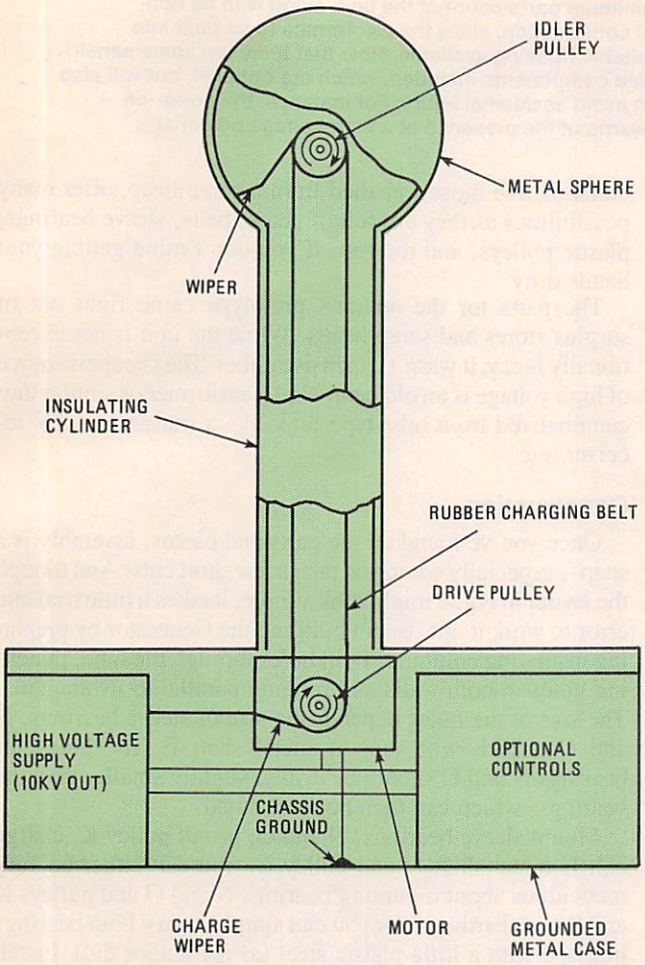


Fig. 1—Sketch showing the basic makeup of the Van de Graaff Generator. All the parts used to make the unit can be salvaged from old equipment that you may have laying around your shop.

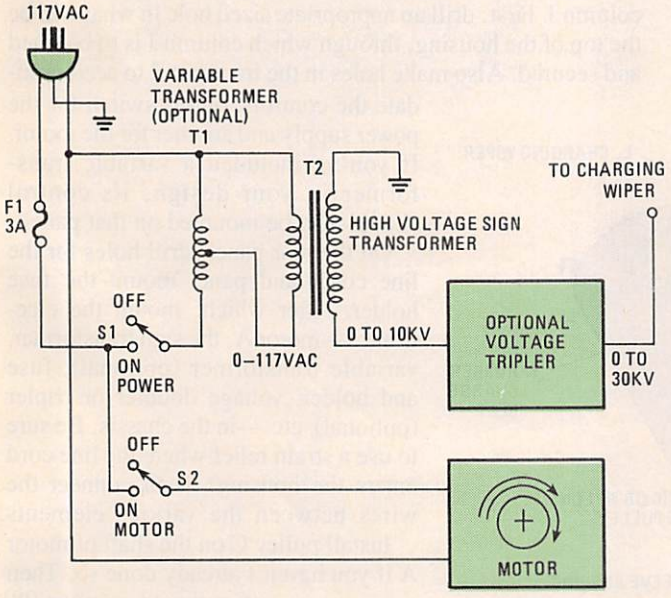


Fig. 2—Schematic of the power supply used in the Van de Graaff Generator. As can be seen, there is very little needed in the way of parts. The variable transformer, T1, is optional. T2, the sign transformer, is the type used in neon signs such as you might see in store windows; however, other high-voltage types may be used (see text).

spherical portions of the Van de Graaff Generator. Note that each element in the sketch is designated by a letter, which we'll use to call your attention to the topic area. As shown, power is applied to motor A, which drives a rubber charging belt (I) via pulley C, drive belt D, pulley E, a metal shaft (F), and pulley K. The motor is isolated from the high voltage supplied to wiper L at point M by a series of plastic or nylon pulleys—C, E, and K—along with drive belt D.

When the motor is energized, pulley C rotates, driving belt D, which then causes pulley E to rotate. Pulleys E and K are mounted on a common shaft (F), so that as E rotates so does pulley K, which sets charging belt I into motion. Shaft I, supporting pulleys E and K, goes through the insulating column (J) and is allowed to turn freely via sleeve bushings N and O on either side of the column. Charging belt I moves up through the insulating column to the metal idler pulley (P), which also acts as the second wiper. The idler pulley, attached to shaft Q, turns freely via another set of sleeve bushings, R and S.

Those bushings are part of a metal subassembly (T), which makes good electrical contact to the sphere (U). That subassembly (i.e., P, Q, R, and S) can be replaced by a fixed pulley and sleeve-bearing set. However, if the unit holding the pulley and sleeve bearings is made just large enough to slide sidewise into the sphere so that it catches the lips when turned around; the downward pressure of the charging belt will hold sphere and pulley assembly in place on the column. That method provides for easy belt replacement, while leaving the sphere seamless.

On the other hand, a much simpler approach would be to simply run the shaft through the sphere, albeit such an approach might not be esthetically appealing. In any case, the net effect of using several plastic pulleys allows the motor to be at ground potential, while keeping the high-voltage supply isolated. Of course, there are other ways of accomplishing that. A series of plastic gears, for example, might be

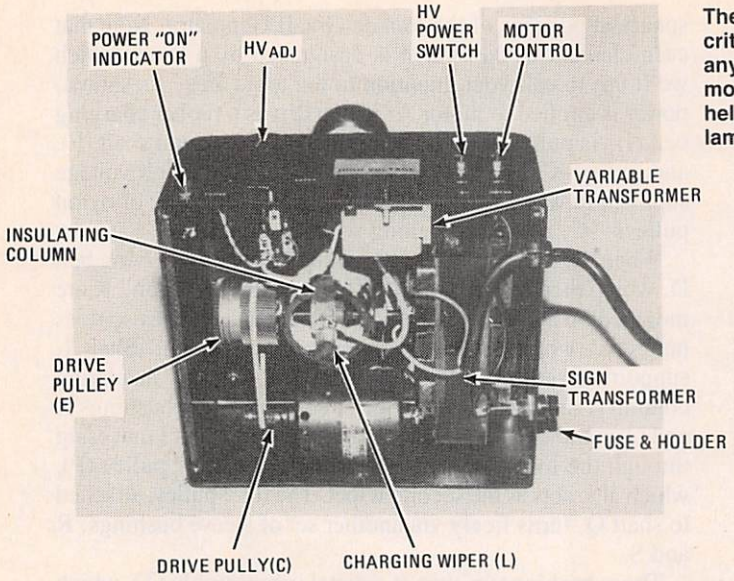
PARTS LIST FOR THE VAN DE GRAAFF GENERATOR

Metal sphere—float, bowls welded or soldered together, world globe (see text)
Insulating cylinder—OK to use PVC, ABS tubing,or Plexi-pipe
Pulleys—3 required, plastic or nylon, idler pulley located in the sphere metal
Wipers—2 required, spring steel, copper, beryllium, or brass.
Rubber belt—2 required, tape-machine belts or oversized rubber bands.
Charging belt should be as wide as feasible
Sign transformer—10,000-VAC secondary winding, Gateway Electronics (see text for substitutes)
Case—should be metal and grounded; size is not critical.
Fuse and holder, knobs, pilot light, line cord, hookup wire, hardware, etc.

OPTIONAL

3-ampere variable transformer
Voltage doubler—30,000 to 35,000-VAC, TV-type, doubler or tripler (see text)

A kit of parts is available from Electronic Technical Consultants: All parts needed to build a desk-top Van de Graaff Generator $75.00, postpaid.



The minimum parts count of the unit, along with its non-critical construction, allow the electronics to be built into any suitable housing available. Note that there are some panel-mounted components included, which are optional, but will also help to avoid accidental injury. For instance, the power-on lamp warns of the presence of a high-voltage potential.

used instead of pulleys and belts. Either system allows for motor-speed reduction if the pulley or gear on the motor drive shaft (C) is made small in comparison to pulley E. There's nothing critical about construction; any one of a number of possibilities can be used to achieve the same thing.

Where to get the parts

The simplest approach to getting the parts to build the Van de Graaff Generator is to order them. But you can usually save a few shekels by a little judicious shopping. Most of the mechanical parts can be found at your local hobby shop, with the exception of the sphere and insulating column. However, you can generally find a world globe at most stationery stores and the PVC (polyvinyl chloride) or ABS tubing at any hardware store.

On the other hand, the local *bone yard* is an even cheaper and sometimes better way to go, especially if you can find an old cash register, adding machine, copier, etc. Mechanical clunkers like those, recalled from a scrap heap, offer many possibilities as they are full of gears, belts, sleeve bearings, plastic pulleys, and the rest, if you don't mind getting your hands dirty.

The parts for the author's prototype came right out of surplus stores and scrap heaps. While the unit is not exceptionally fancy, it wasn't expensive either. The cheapest source of high voltage is an old neon-sign transformer or similar unit cannibalized from tube-type junk like a transmitter, TV receiver, etc.

Construction

Once you've found all the parts and pieces, assembly is a snap—especially when you take a few short cuts. And though the layout in Fig. 3 might look simple, it takes a little trial and error to work it out. Begin building the Generator by preparing insulating column J. Drill holes through the tube, punching holes in both walls and running parallel to its diameter. The size of the holes depends the size of sleeve bearings, N and O, which will support metal shaft F. The holes for bearings N and O should be drilled slightly smaller than the bearings, which can then be force-fitted.

Mount sleeve bearings, N and O; install pulley K, charge belt I, metal shaft F, and pulley E. You can either be very meticulous about mounting bearings N and O and pulleys K and E with hardware, or you can simply epoxy both bearings in place with a little plastic steel (as the author did). Install wiper L with screws, or you can slap on a little plastic steel to stick it in place.

With that done, set the column to the side and prepare the housing in which the motor and the electronics will be located. (Refer to photos). The housing will also support column J. First, drill an appropriate sized hole in what will be the top of the housing, through which column J is to be fitted and secured. Also make holes in the front panel to accommodate the controls: on/off switch for the power supply and another for the motor. If you've included a variable transformer in your design, its control should also be mounted on that panel.

On the rear panel, drill holes for the line cord, and panel mount the fuse holder. After which, mount the electronics—motor A, the sign transformer, variable transformer (optional), fuse and holder, voltage doubler or tripler (optional), etc.—in the chassis. Be sure to use a strain relief where the line cord enters the housing. Then connect the wires between the various elements.

Install pulley C on the shaft of motor A if you haven't already done so. Then

(Continued on page 98)

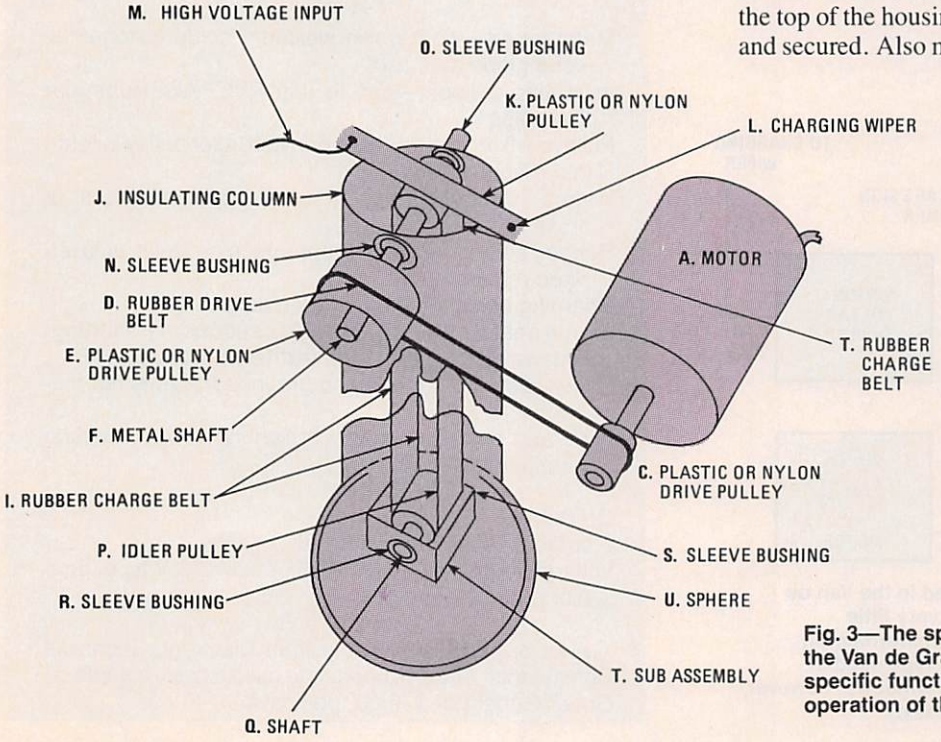


Fig. 3—The spherical and cylindrical sections of the Van de Graaff Generator; each element has a specific function that is vital to the safe operation of the generator.

VAN DE GRAAFF

(Continued from page 44)

stretch the rubber drive belt from pulley C to pulley E. (Refer to photos.) Once that is done, set the bottom half of your Van de Graaff Generator aside until the sphere is completed.

Assuming that you've picked up a world globe or similar painted sphere, remove the paint using Stripe-Ezz™ or a similar product. Then drill a hole in the globe (refer to photos) through which the charge belt will pass. Begin with a ⅓-inch bit, working your way around in a circle. Enlarge the holes using increasingly larger drill bits until the hole has reached the desired size. That's the same method that might be used when installing panel-mount meters. An easier way is to use the right size hole cutter or, if you have one, a nibbling tool. But no matter how you cut the hole, go back over the edge with a grinding stone to smooth and deburr the opening.

Once the globe has been prepared, install the wiper, charge belt, and metal pulley (which can act as both a wiper and belt support). If you want to be able to get at the pulley so you can change belts, make adjustments, etc, mount the idler pulley (P) on a subassembly, as shown in Fig. 3. That assembly will be mounted in the globe at a right angle.

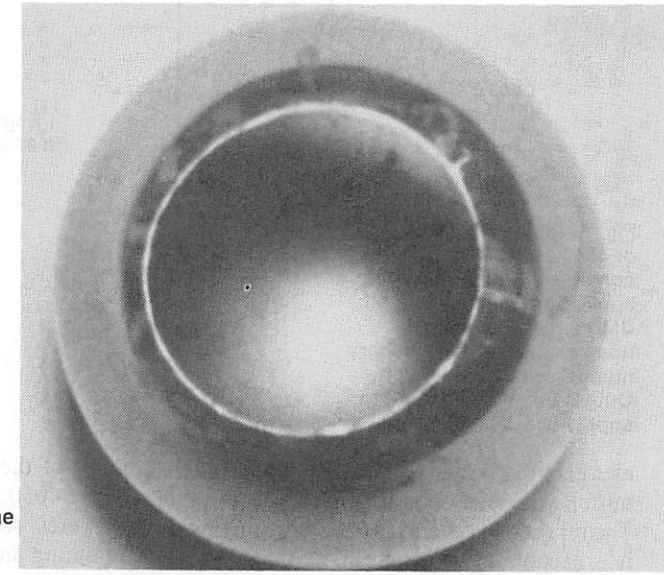
In doing so, make sure that it cannot fall out once it's turned out by 90 degrees, as described earlier. In other words, make the assembly supporting the pulley act like a lag bolt. If you handle the pulley in the sphere that way, the force of the drawn charging belt pulling down on the sphere will keep it in place. But be sure that the idler pulley can turn freely. Another solution is to simply fix the pulley assembly in place with hardware.

That completes the basic assembly.

Final notes

As mentioned previously, the potential difference or voltage rise between the sphere and ground is limited by the dielectric qualities of insulating column, insulators, air, etc. Also, maximum potential developed will be directly proportional to the area of the sphere. Thus, increasing the diameter of the collector sphere, cylinder height, and starting potential, will also effect an increase in output potential; but construction will still be basically the same.

Finally, after you've gotten all the hardware rounded up and whipped together, it's a good idea to cover all high-voltage points, which can arc over to ground, with some good quality silicon rubber or RTV sealer. That is especially necessary if you decide to boost a 10,000-volt sign transformer's output to 30,000 volts or more. Remember that, because of the unit's high-voltage output, its case should be grounded to prevent unplanned hair-raising experiences. ■



In preparing the sphere for use in the Generator, several small holes may be drilled in a circular pattern. Then using increasingly larger bit sizes, the circular pattern is removed. However, a hole-boring attachment (such as the type used in lock mounting) may be used with a drill to accomplish the same thing. But whatever method is used, be sure to deburr the opening before using the sphere in the Generator.