Electrical safety

Van de Graaff Generators

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Van de Graaff generators become electrically charged through a rubbing process similar to charging a balloon by rubbing it on a jumper. The Van de Graaff generator seems to break the rules: They can charge up to more than a hundred thousand volts and yet we allow pupils to hold on to them and inevitably some receive shocks.

Figure 1 – Hair standing on end after being charged

As a rule of thumb – every centimetre you can make a spark jump from the dome of a Van De Graaff generator represents a voltage of about 30 000 V. 8 centimetre sparks are not uncommon, suggesting that the voltage between the dome and earth could be 240 000V.This is thousands of times greater than our 'hazardous live' level.

The reason that we can expose (certain) pupils to the risk of a shock from a Van de Graaff lies in the fact that any discharge will be very short-lived. In these circumstances, we look not at current or voltage but at the energy of a shock. We can estimate an upper limit for the shock energy by carrying out a calculation based on the distance jumped by a spark and the diameter of the Van de Graaff dome.

If you want to know more about these calculations and the energy limits, please contact your course tutor at SSERC or read the optional Bulletin articles mentioned in the scheme of work.

The bottom line is this:

- A Van de Graaff generator with a dome diameter of 20 cm or less will not exceed safety limits.
- If you want to buy a Van de Graaff generator with a larger diameter, please contact SSERC first. We are likely to have tested it to determine whether it is below safety limits.
- If you have an old Van de Graaff generator with a dome of between 20 and 26 cm, keep using it unless people complain of violent shocks. Old Van de Graaffs rarely charge up to the levels they could achieve when new. Charge leaks away through contaminated belts and dome supports. Any dents or bashes in the dome also cause leakage.

There was a rumour for a time that charging **all** pupils is now banned. We don't know of any local authority that has such a rule, and neither should they. Follow the safety rules shown below and all should be fine but note that if your school or local authority does ban something that SSERC says is OK, you still have to comply with your employer's guidance.

Safety rules – general

- The most important rule – never charge a person with a heart condition or put them in a situation where they might get a shock. Teachers should check records beforehand and should also tell classes that those with heart conditions should not use the Van de Graaff. This advice applies to **all** Van de Graaff generator activities, including those described as 'low risk' below.
- Only volunteers should be charged. Pupils may know that they have a medical condition that means they should not be charged but may not wish to say so.
- Do not leave the Van de Graaff generator in a charged state. Discharge the dome after use. See below for ways to discharge the dome.
- A person who has been charged should be discharged before stepping away from the Van de Graaff. See below for a method of discharging a person.
- When pupils are charged, they tend to stand on plastic basins or bespoke steps to insulate them from the earth. If a pupil gets a fright or if a shock causes their body to jerk, they may fall off. This is unlikely to cause harm, but if the pupil has compromised mobility or coordination it may be best not to charge them.

Safety rules – specific demonstrations

- When charging a pupil, make sure that there is a gap of 10 cm or more between the pupil's legs and the bench the Van de Graaff generator is sitting on. This is to avoid sparks jumping between the pupil and the bench. Whilst this is not dangerous, it might be undesirable.
- If charging a chain of pupils, restrict the numbers of pupils standing on insulating basins to three, otherwise an excess charge could build up.
- Other demonstrations, such as lighting a Bunsen, are low risk, but see the discussion about Leyden Jars.

Safety – electrical equipment

There will be an electric field close to the Van de Graaff generator. More significantly, during spark discharges, electromagnetic energy is radiated from the spark gap. This radiated energy will be picked up by any nearby electrical leads across which high voltages can be induced. These voltages can destroy electronic apparatus. Vulnerable equipment includes anything supplied from a plugtop power supply such as a laptop computer, digital balance or digital camera because the long supply lead can act as an effective pick-up aerial. No such equipment should be within 2 m of a spark gap.

Medical implants

Here we are referring to 'active' medical implants, i.e. those with electronics inside them. The following advice does not apply to the likes of artificial hip joints, though it may not be wise to charge somebody with such an implant because, as mentioned above, their mobility may be poor.

Referring to the phenomenon in the **Safety – electrical equipment** section, two devices give us particular cause for concern - pacemakers and cochlear implants. None of the organisations that we consult for advice appear to have researched this field. In the absence of such guidance, we are

forced to be very cautious and recommend that people with such implants remain 6 metres or more from a VdG. The problem, as we see it, is radio frequency pulses as opposed to strong static electric fields. At a recent radiation protection conference, we did ask an expert on electromagnetic fields to comment on our advice. Her reply vindicated out approach.

We have also been asked about insulin pumps. If the pump has a supply connected to the main body of the device with a lead, then the same advice applies.

Discharging a dome (no person holding on)

Here we assume the Van de Graaff generator has been switched off. Most Van de Graaff generators have a 4 mm socket on their metal base. The simplest way to discharge a charged dome is to use a metal 'wand' connected to this earthing point using a long lead. The person holding the wand does not get a shock.

The dome can also be discharged through a human body. One hand should be placed on a bench and a pointed finger brought up to touch the dome. Alternatively, this can be done using a pointed metal object. This results in what is known as a corona discharge, which is much gentler than the discharge that would occur were you to bring a closed fist up to the dome.

Discharging a dome and person

Again, we are assuming that the Van de Graaff has been switched off. If a person is holding on to the dome, they can discharge themselves and the dome by following these steps:

Keep one hand on the dome.

Extend a pointed finger to the bench to cause the gentle corona discharge. Keep the hand on the dome and bench for a couple of seconds then remove the hand from the dome, then the hand from the bench.

People who have been charged should always be discharged before walking away from the Van de Graaff generator. If not, they could get a shock when they brush against furniture or another person. In the latter case, the other person would also receive a shock.

Open evenings

Van de Graaff generators can be a great attraction at open evenings when parents, carers, siblings and members of the public may visit a school. Schools doing this mustfollow the safety rules and should, in particular, consider:

Can you be sure that you are not charging somebody with a heart condition, or putting them at risk of receiving a shock?

Can you be sure that nobody with an active medical implant (pacemaker, cochlear implant etc) will be closer than 6 metres from a spark discharge?

Training

It should not be assumed that new staff know all the Van de Graaff generator safety rules.

Leyden Jars, Wimshurst Machines

A Leyden Jar is usually a glass jar with foil on the inside and outside. It can be used to store electrical charge. If it is connected to a Van de Graaff generator, the energy stored in the system can breach safety limits. Charge-storing devices such as this and buckets of water should not be connected to the Van de Graaff.

A Wimshurst machine consists of two rotating glass discs with metal segments. The discs rotate in opposite directions, and through a process known as electrostatic induction, a charge is built up. The charge is collected in Leyden Jars (see above). Due to the energy stored, Wimshurst Machines should not be used for charging people and must only be operated by someone who knows what they are doing. This includes knowing how to discharge the Leyden jars.

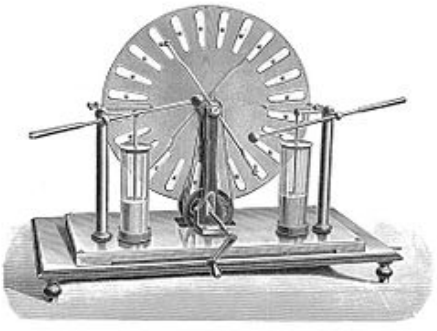

Figure 2 – A Wimshurst Machine

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All Wimshurst Machines can really be used for is to demonstrate charging by electrostatic induction (there are other ways) and for making big sparks. It is hard to justify their educational value. SSERC does not recommend that anyone buys a Wimshurst Machine. They are of very limited educational value and, when carrying out an activity where there is a significant risk, you have to be able to justify doing so on educational grounds.