# Risk assessment Salad Bowl Particle Accelerator- make and test!

## Company name: IOP Coaches Assessment carried out by: 06/02/24

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| What are the hazards? | Who might be harmed and how? | What are you already doing to control the risks? | What further action do you need to take to control the risks? |
| --- | --- | --- | --- |
| **scissor** | Sharp objects can cause cuts, could poke someone’s eye out | Warn of the participants of the dangers of scissor | Ensure scissors are only as sharp as required and in a good state of repair |
| **Electrical Appliances** | Users of the VdG | All electrical equipment must be PAT tested and testing must be kept up to date as indicated by a council sticker on the appliance, unless under 1 year old.  Adequate reporting procedures must be set in place with regard to electrical hazards.  Staff should visually inspect all pieces of electrical equipment for any sign of defects including:  Wear on cables, exposed cables, scorch marks on the plug and damaged plugs and sockets.  Arrangements should be made to ensure that equipment is repaired or disposed of as necessary.  Members of staff without the relevant competences must not interfere with or attempt to make repairs to electrical equipment.  Where practical, electrical equipment should be low voltage (110V or battery operated).  All mains supplies must be protected with residual current devices (RCD).  RCDs must be tested on a regular basis.  Leave equipment on for the minimum amount of time  Keep electrical equipment away from water and water sources. | Check Bridge has RCDs in the room being used |
| **Van de Graaff** | See info below. | No person with the following conditions or should use the VdG: epilepsy, coronary heart disease (e.g. angina, history of heart attack)  cardiac rhythm disorders. intra-cardiac conduction pathway anomalies  presence of an implanted cardiac pacemaker, hypertension (high blood pressure)  VdG diameter well below the max recommended | Ask if delegates have any of these conditions. If yes then they should remain a safe distance from the VdG (>2m) |
| **Aluminium Sticky tape** | allergies | Checked that there are no warnings on the tape from the site where it was purchased. | Ask if delegates have an allergy to adhesives |
| **Polystyrene balls** | Participants if they slip on the balls | Prevent these going on the floor and becoming a trip hazard by warning participants and store the balls in a container, not loose | Pick up any balls immediately if they fall on the floor |
| **Particle Accelerator** |  | Toss the balls into the salad bowl, rather than touching the sides. Ground the VdG after each run |  |

#### Risk assessment : Electric shock from a van de Graaff generator

Let me discuss firstly the risk of harm to pupils with unusual medical conditions[[1]](#footnote-1). Listed below are cardiac conditions which may place someone at increased risk of ventricular fibrillation (an uncoordinated rapid electrical activity of the heart; there is no effective pulse and death ensues rapidly). Subjects with any of these conditions should not receive electrical discharges from this equipment:

coronary heart disease (e.g. angina, history of heart attack)

cardiac rhythm disorders

intra-cardiac conduction pathway anomalies

presence of an implanted cardiac pacemaker

hypertension (high blood pressure)

Regarding epileptic subjects, the risk of seizure is unlikely, but epileptic subjects should not be encouraged to take the chance!

There is no evidence to suggest that persons not having any of these medical conditions are at risk of ventricular fibrillation on getting electric shocks from a school Van de Graaff generator. This is underpinned by a theoretical understanding, which indicates no risk of this occurring.

#### Physiological effects

The physiological effects of electrostatic discharges [1] depend on the spark energy (Table 1). This itself is dependent on the capacitance of the system and the stored charge, or potential with respect to earth.

|  |  |
| --- | --- |
| Spark energy(mJ) | Physiological effects of electrostatic discharges |
| 1 | Smallest spark energy felt |
| 10 | Some find 10 mJ uncomfortable due to muscular contraction.Others can accept several hundred millijoules before experiencing sharp muscular contraction |
| 1000 | Affects everybody severelyThere is an accident history of people being knocked unconscious by discharges of several joules |

The capacitance of the human body lies between 100 and 300 pF.

If the charging voltage is greater than 1 kV, which it is with a Van de Graaff, then the thresholds of perception and pain can be related to the capacitor discharge. Respective values would seem to be around 0.5 μC and 8 μC [2, 3] by extrapolating from a British Standard graph.

#### Van de Graaff shocks

If the field strength between two flat or large radius conducting surfaces exceeds 3 x 103 kV m-1 then a spark occurs [1]. Related to this [4], the theoretical maximum potential that the dome of a Van de Graaff can reach is 3*a* x 106 volts, where *a* is the radius of the dome in metres. Some values are shown in Table 2. The capacitance of the dome and stored electrical energy are derived using *C*  =  4*πε0a* and *E*  =  1/2*CV*2.

|  |  |  |  |
| --- | --- | --- | --- |
| Dome diameter (cm) | Capacitance (pF) | Maximum potential (kV) | Maximum stored energy (mJ) |
| 20 | 11 | 300 | 501 |
| 25 | 14 | 375 | 978 |
| 28 | 16 | 420 | 1373 |

It should be appreciated that the values for stored energy and potential will seldom be attained. They may hold when the air’s relative humidity is abnormally low, such as sometimes occurs after the passage of a cold front, or in a fohn wind. In other words, these tabulated values are the highest a machine can reach. On a typical day, it will be much safer.

There are two ways whereby the user can get a shock – from coming too near to a charged dome, or from an unintended discharge while being charged deliberately.

A person will get an unintended shock by carelessly coming too close to the charged dome. Most of the stored energy on the dome may then discharge to earth through the person’s body giving the unintended shock. If we set a limit on the stored energy that should reside on the dome to be 1 J, then the maximum dome diameter is 25 cm. There is, so far as we are aware, just one product on the educational market that breaks this limit. It is the newly designed STE model with a dome diameter of 28 cm. (We have raised this with STE.)

Another means of shock occurs when a person - usually a pupil – is deliberately charged up and gets unintentionally discharged. In such a system, the electrical properties of the human body play a significant part. The highest potential reached is governed by the minimum radius of external body parts. The value might be 5 mm with a pinkie. The system voltage comprising dome and body might then reach *V* = 3*a* x 106 V = 15 kV. With the body’s capacitance of 300 pF, the energy to be discharged = 1/2*CV*2 = 34 mJ and the charge stored on the person = *CV* = 4.5 μC. A sudden discharge of this amount of energy and charge would certainly be noticed. It would probably be disagreeable. It might even verge on being painful, but is unlikely to have any other direct effect.

But do bear in mind that any person getting a shock is at risk of harm from jerking or falling over in fright. There is then an indirect risk of a blow to the head, or damage to muscles, bones, or other parts.

**Operational rules**

In consideration of the above, the following rules should be applied:

1. Before using the equipment, the teacher should warn the class that it should not be used by anyone with a heart condition.
2. Because a human body has capacitance, do not let someone touch a charged dome, then walk away. In these circumstances such a person may carry quite a lot of charge and experience a disagreeable electric shock on touching earth. Any other person touching such a charged person is also at risk of getting a shock.
3. The dome may be safely discharged by touching it with an earthed, metal conductor mounted on an insulated stand or handle. If operated properly, the experimenter should not receive a shock.
4. The dome should be discharged immediately after every operation ensuring that it never stands idle in a charged condition.
5. The dome may be safely discharged through the human body by arranging that the person getting the discharge is in poor contact with an earthed conductor. Instruct him to place one hand, palm down, firmly in contact with the benchtop, which is presumed to be wooden, or of similar, low conductivity. The dome may then be discharged by bringing the other hand up to it, either by direct skin contact with the dome, or through a hand held metal wand or sphere. Break contact with the dome before breaking contact with the bench. These directions assume that the benchtop insulation resistance is at least one megohm to earth, which is usually the case. By following these instructions the dome should be safely and completely discharged with the person experiencing only a slight physiological effect.
6. If the capacitance of the system were to be greatly increased, for instance by connecting the dome to a Leyden jar, the stored electric energy can increase to a dangerous extent.

All science staff should be trained in how to work with the van de Graaff generator, being made aware to avoid a direct path through the human body to a good earth (an earthed conductor of low resistance).

#### References

1. BS 5958: Part 1 : 1991 *Code of practice for control of undesirable static electricity* Part 1 *General considerations* BSI
2. PD 6519 : Part 2 : 1995 *Guide to effects of current on human beings and livestock* Part 2 *Special aspects relating to human beings* BSI
3. *Preventing electric shock* Bulletin 173 SSERC 1992.
4. Berg R.E. *The Physics Teacher* 28 5 (May 1990) pp 281-5.

## Van de Graaff generator safety

Van de Graaff generator demonstrations can provide useful insights into electrical phenomena, which are at the same time memorable.

* It is essential the Van de Graaff generators for school science are obtained through reputable school science equipment suppliers. The electrostatic energy stored by the sphere should not exceed 0.5 J.
* Van de Graaff generators with mains powered pulleys must be electrically inspected and tested in the same way as other mains powered equipment.
* The electrical discharge from a Van de Graaff generator can wreck electronic circuits, so equipment such as computers and instrumentation with electronic circuits should be kept well away.

The Van de Graaff generators designed for schools are usually the triboelectric type – these are the most suitable. The transfer of charge is achieved by a rubber belt driven by a plastic pulley, with an arrangement of metal combs at either end of the belt. Charge is transferred to a metal sphere – a capacitor – and very high voltages are achieved between the sphere and ground, typically in the range 200 kV to 300 kV.   
   
Using a Van de Graaff generator, one is quite likely to receive a short shock by accidental or intentional contact with the charged dome. An enquiry to CLEAPSS has revealed no recorded incident of direct injury caused by shocks from the correct use of school Van de Graaff generators. However, some people are more sensitive than others and can find the shocks very unpleasant and painful. For this reason, only volunteers should take direct part in the practical work.   
   
The shock is a single unidirectional pulse of short duration - The current flowing and energy transferred should be well below that which could cause any risk of ventricular fibrillation.   
    
Generally speaking, sphere diameters of Van de Graaff generators should be about 20 cm or less.

Since the diameter of the collecting sphere determines the maximum p.d. (voltage) achievable, large spheres are mounted on taller columns to be more remote from the earth motor and control box.   
   
Machines are usually supplied with a “discharger", often another, smaller, sphere mounted on a metal rod that has to be earthed to draw sparks from the collecting sphere. 

1. **B**ased on correspondence with a medical inspector of the Health and Safety Executive. [↑](#footnote-ref-1)