Electrostatic Problems

Contents: Reading, practical work and questions concerning industrial problems caused by electrostatics.

Time: Part 1 needs 2 periods if all the demonstrations are done. Part 2 needs 1 to 2 periods, and could be set for homework.

Intended use: GCSE Physics and Science courses. Links with work on electrostatics.

Aims:

- To complement and revise prior work on electrostatics
- To develop awareness of the importance of an understanding of physics in industry
- To provide an opportunity to apply physics concepts to explain given information
- To provide an opportunity to plan investigations involving the control of variables.

Requirements: Students' worksheets No.804. The apparatus for the teacher demonstrations is given below.

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It is assumed that the students will already have done some work on electrostatics. The unit is in two parts which can be used independently.

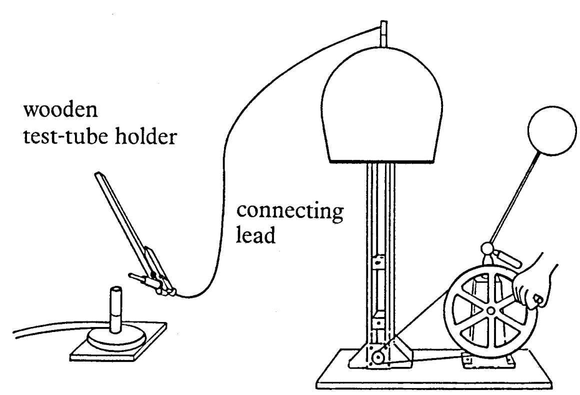
Part 1 Fire hazards

Demonstration — Sparks can start a fire

The teacher will need:

Van de Graaff generator
long connecting lead with crocodile clips
bunsen burner and mat. The bunsen burner needs to have the air-hole closed.

Assuming that the air is dry enough this is a quick and simple demonstration. Students may be surprised by the risk of fires and explosions in the food industry. They may appreciate the following extra demonstration.



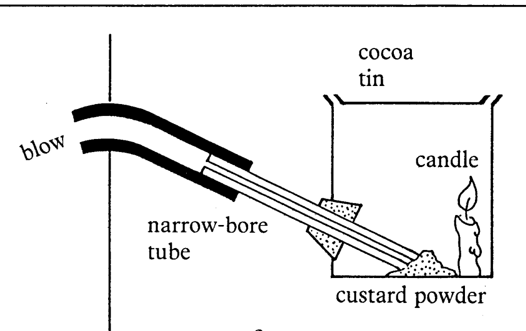
Demonstration — The custard powder bomb

(Details are not given on the students' sheets.)

The teacher will need:

the apparatus shown in the diagram
safety screen
eye protection for the teacher and students

See safety notes on next page



The explosion of a finely divided dust/air mixture can be shown by the standard 'powder bomb' experiment. Place a small piece of candle on the base of a suitable tin with a press-on lid, such as a syrup or cocoa tin. Insert a narrow-bore tube at least 30cm long through the side of the tin. Place a small amount of custard powder in front of the tube's opening. Light the candle and put the lid on the tin. Puff gently blowing down a long piece of rubber tubing from behind a safety screen. This causes the powder to spread throughout the tin as finely divided dust. The sudden expansion due to ignition of the air/dust mixture causes the lid to be blown off.

CAUTION - This demonstration must be done behind a safety screen and care must be taken not to overtighten the lid. A tin with a screw-on lid must NEVER be used.

Demonstration - Powders in pipes

The teacher will need the apparatus shown in the diagram. (The electroscope can be replaced by an electrometer)

Expandable polystyrene beads are used to represent a fluid filling a metal collecting tank (e.g. a copper or aluminium calorimeter). The beads can be discharged by warming them in a container above a bunsen flame.

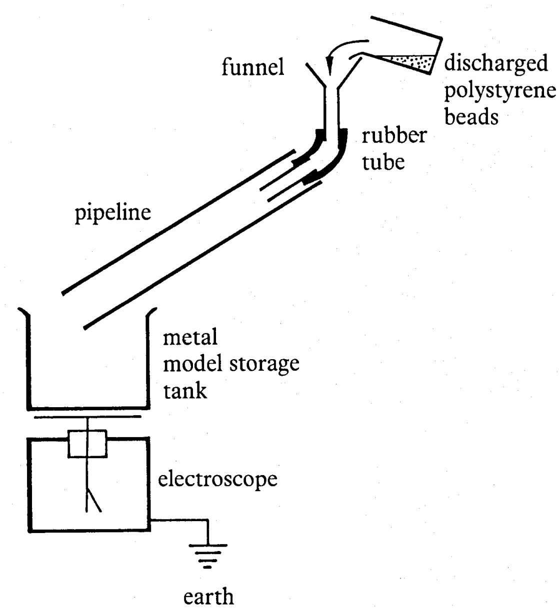
CAUTION - Great care must be taken not to ignite the beads as this produces a highly toxic gas.

All experiments involving polystyrene beads must be carried out on a tray in order to avoid spillage which would make the floor dangerously slippery.

The beads are poured into a glass funnel which can be extended using a length of glass tubing held in place by rubber tubing. The rate of filling can be altered by changing the angle of the pipeline. The height through which the beads fall freely can easily be altered. An earthed electroscope measures the static electricity generated through filling or agitating the fluid in a tank.

Pour 50 cm^3 of polystyrene beads down the pipeline. Make sure this is done over a tray. Note the deflection in the electroscope.

After seeing the initial demonstration the students can be asked to answer question 4. Each group might tackle a different variable. It is *not* intended that groups carry out the practical investigations themselves.



Discussion of results and background information for question 5.

1 Faster speed — more static electricity.
In practice in the oil industry a safe pumping rate is less than 1 metre per second.

2 The longer the pipeline, the higher the potential.

3 Agitation in a storage tank can cause the generation of dangerous static electricity. Storage tanks should be filled carefully to avoid turbulence.

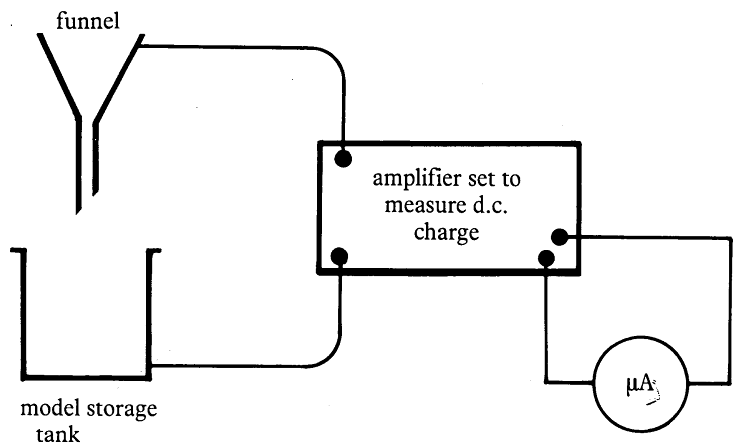
4 Additives in a liquid or powder to make it more conductive can be an effective way of reducing the build-up of charge.

Sometimes by mixing liquids a much larger potential can be produced. This can be demonstrated as follows. (Details are not given on the students' sheets.)

Demonstration - Charge due to flow

The teacher will need:

- apparatus shown in the diagram
- paraffin
- water
- beaker for pouring the liquid



When paraffin is poured into the funnel as shown in the diagram no potential difference is observed between the funnel and can. If this is repeated with a paraffin/water mixture (containing at least 50 per cent water) a large deflection on the meter is obtained.

This experiment illustrates the effect of water on the build-up of static charge in a flowing liquid. In practice, only very small quantities of water need be present as the liquid is pumped at high rates.

CAUTION - Special care is needed when handling paraffin mixtures, with regard to both their flammability and their disposal.

Part 2 Quality control

A knowledge of basic electrostatics can be used to interpret each of the rules on the warning notice. Students may like to discuss the extent to which they think that the operators in the factory need to understand the underlying physics if they are to follow the instructions.

Acknowledgements The demonstrations in Part 1 are taken from *The Science of Oil* (BP Education Service) and are reproduced in this form by courtesy of the British Petroleum Company p.l.c.. The student's writing in Part 2 is an edited version of a report by Mary Drake of Assumption Grammar School, Ballynahinch, Northern Ireland. The visit was to a Plessey factory. Figure 1 is from a photograph by Philip. C. Mitchell; Figure 4 supplied by The Plessey Company.

ELECTROSTATIC PROBLEMS

What's the problem?

Have you ever had a shock when getting out of a car? Have you ever seen sparks as you comb your hair or take off a pullover? Have you ever tried to get rid of dust on a record? If so, you have noticed some of the effects caused by static electric charges.

Figure 1

Things can become charged by friction. If you rub a plastic pen on your sleeve it becomes charged. It can be used to pick up small pieces of paper.

You only see the effect if the charge cannot leak away — if it is static (not moving). So you only notice the charge on non-conductors such as plastic and glass.

Electrostatics can be useful. Photocopiers use electrostatics to produce the black print on the paper copy. Electrostatic dust precipitators can remove almost all the dirt particles from the gases leaving a factory chimney.

This unit is about two of the **problems** caused by electrostatic charges in industry:

Part 1 investigates the way in which electrostatic charges can cause fires. Liquids and powders pumped through pipes may become charged. Sparks can then cause explosions if the material is flammable.

Part 2 explains why electronics manufacturers have to worry about electrostatics. Static charges can build up on workers and their clothing. Sensitive electronic equipment is likely to be damaged if touched by someone who has become electrically charged.

Part 1 Fire Hazards

Fires and explosions can be caused by sparks. They are a particular risk in the petroleum industry and in the food industry.

Demonstration — Sparks can start a fire

You already know that a spark can start a fire if you have ever lit a gas burner on a modern cooker. You turn on the tap and then press a button to produce a spark which ignites the gas.

This demonstration will show you that a bunsen burner can be lit with the spark from a Van de Graaff generator. Watch the demonstration. Copy the diagram in Figure 2 and label it. Describe what you see during the demonstration.

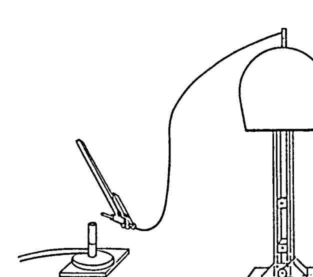


Figure 2

Now try questions 1 to 3 on the next page.

Problems in pipes

In the chemical industry and the food industry liquids and powders are moved from one place to another in pipes.

Static electricity can be generated when liquids or powders flow through pipes. This is because of the rubbing of the powder or liquid against the pipe wall. The voltages can be as high as 60 000 V. The charge on the powder or liquid has the opposite sign to that on the pipes.

Many liquids and powders are bad conductors so they stay highly charged for a long time. They slowly discharge eventually but there is always a danger of sparks if sudden discharge occurs.

Questions

1. *Workers in oil refineries and chemical works often have to wear special shoes. The shoes have soles which conduct electricity. Why do you think this is ?*
2. *In a car engine, a mixture of petrol and air burns inside the cylinders. How is the mixture ignited ?*
3. *A pile of flour is difficult to set on fire but flour dust in the air can explode if ignited by a spark. Why ?*

Demonstration — Powders in pipes

This demonstration shows the build up of charge on a powder flowing through a pipe. Watch the demonstration. Copy the diagram in Figure 3 and label it. Describe what you see during the demonstration.

The experiment can be extended to investigate some of the variables which affect the size of the charge. Possible variables:

- The speed of the beads
- The length of pipeline
- Stirring the beads in the storage tank
- Mixing an additive with the polystyrene beads. Choose an additive which conducts electricity
- Earthing (a) the pipe or (b) the container

Now answer questions 4 and 5.

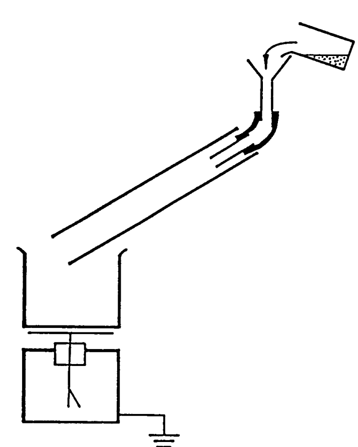


Figure 3

Earthing

When pipelines enter storage tanks there can be a large voltage between the metal pipe and the metal tank if they are not connected together. There may also be a voltage between the charged powder (or liquid) and the storage tank. These voltages mean there is a danger of sparks which may start a fire.

The problem can be overcome by connecting a metal strip from the pipe to the storage tank and then earthing the storage tank.

Questions

4. *Choose one of the listed variables. Draw up a plan of an investigation to find out how the build up of charge on the polystyrene beads is affected by changing your chosen variable.*
5. *From the results of the demonstration, suggest how you could reduce the risk of sparking from the build up of electricity in a pipe.*

Part 2 Quality control

The following paragraphs were written by a school student after visiting a factory making integrated circuits. The factory belonged to a company which makes equipment for telephone exchanges.

'Protecting electronic components from static electricity'

Electrostatic charges are often generated in everyday life, for example, when you take off a pullover. The potentials are high but the amount of charge is small. This means that only very small currents flow which are quite harmless to human beings.

In industry it is a different story. Electrical components such as integrated circuits are easily damaged even by a small current. Manufacturers cannot afford to have components damaged by such currents.

For this reason special precautions are taken by the operators when working with sensitive devices. The work surface is designed to conduct electricity. This is done using mats filled with carbon. Any electrostatic charges quickly flow to earth.

The operators are 'strapped to earth' by special wrist straps connected to the conducting work surface. Cotton overalls are recommended, and even cotton seat covers which can conduct charge to earth. Cotton conducts electricity better than artificial fibres such as nylon.

The components are protected from stray electrostatic charge. Integrated circuits, for example, are packed in special aluminium containers. Other components arrive in boxes with conducting bases. This prevents the build up of static charges.

In areas where sensitive devices are used, warning notices are placed in prominent view.

(An example of a warning notice is shown on the next page.)

In industry it is important to maintain the reliability of products. Understanding electrostatics can help to improve the quality of electronic components.

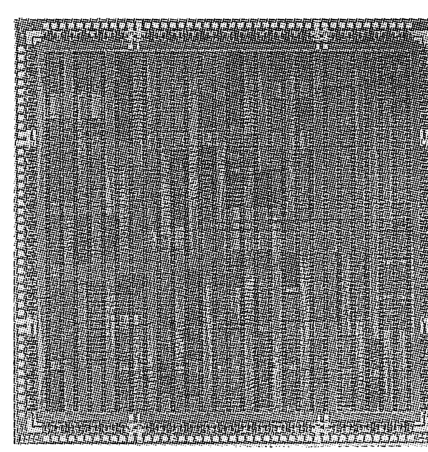


Figure 4 An integrated circuit on a silicon chip, highly magnified

STATIC SENSITIVE COMPONENTS REQUIRE PROTECTION FROM ELECTRICAL ENERGY GENERATED BY YOU

Please take the necessary precautions to minimise component failures and improve the reliability of products. Follow this code of practice before starting work in the special handling areas:

1

Make sure that the overalls provided are protecting components from your clothing.

2

Attach the wrist strap provided.

3

Handle boards and units by their edges only. Avoid touching leads and track.

4

Ensure tools, components and work are placed on the conducting work surface.

5

Avoid putting paperwork on the conducting work surfaces.

6

Do not wear gloves or fingerstalls

7

Touch the conducting surface before unpacking components.

8

Do not bring unauthorised electrical equipment into the special handling areas.

9

Keep components in their special packs as long as possible.

10

If you have to put components on the work surface make sure that the terminals are in contact with conducting surface.

11

Make sure that components and assemblies are correctly packed before they leave the special handling areas.

Question

6 *Use your knowledge of electrostatics and the writing on page 3 to explain why each of the eleven rules is necessary.*