Gas explosions caused by static electricity

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There are two types of explosion which can result from the ignition of a gas-air mixture by a spark discharge. These are known as 'confined' and 'unconfined' gas-air explosions. With the former type there is a massive rise in pressure with temperature, which can result in the chamber blowing apart explosively (Figure 1). With the latter, there is a large sheet of flame (Figure 2) caused by the expansion of the gaseous mixture with temperature, and a consequential risk of fire. If gas leaks into a building, one way or another, there is a risk of harm to the property, and life or limb.

Figures 1 & 2 - Confined (left & unconfined (right). Note that as these explosions are transient events the still images above may not fully portray what happens in these explosions.

Equipment

Explosion chamber with electrodes
Van de Graaff generator (VdG)
Discharge sphere
Tubing from gas tap

Description

A mixture of methane and air is explosive when the concentration of methane lies in the range from 5% to 15%. The explosion is set off by an electrostatic spark. When the mixture ignites, the rapid increase in temperature brings about a huge increase in gas pressure. If the burning vapour were to be confined the resulting rise in pressure could destroy the chamber with a loud explosion. In this demonstration there is no risk of harm because of the flimsy nature of the chamber's lid. It is nothing more than a paper cap held down (for making a confined-vapour explosion) with an elastic band, or just the weight of paper (for making an unconfined-vapour explosion).

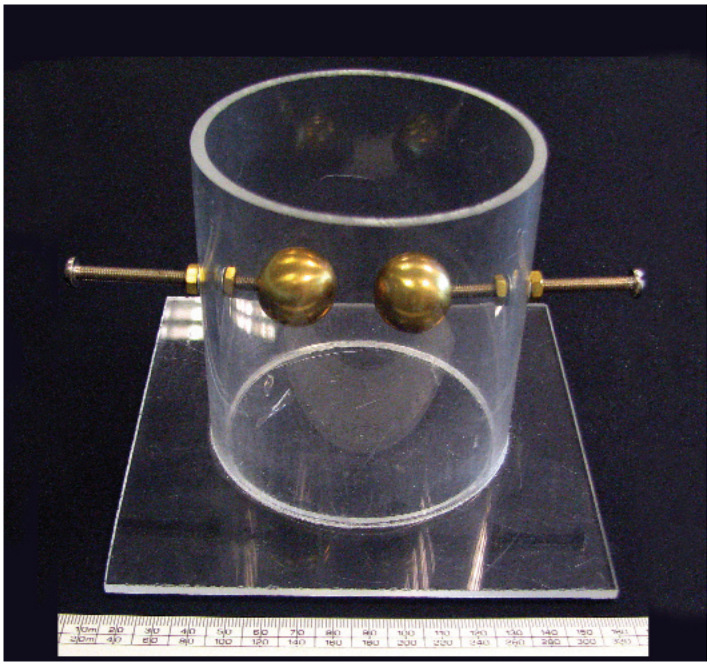

Figure 3 - Explosion chamber.

Explosion chamber

The explosion chamber (Fig. 3) was to our design and made for us by Wilson Fraser of Schools' Laboratory Equipment. The chamber is made of transparent Perspex comprising a short tube, 80 mm long, 84 mm outer diameter and 78 mm internal diameter, cemented to a plane base. The lid, being the one flimsy part, is a paper cap, which can either rest unsecured (Figure 4), or be clamped down by an elastic band (Figure 5). The two electrodes each consist of a 20 mm diameter brass sphere mounted on screwed rod, fastened with a pair of nuts at the chamber wall. The gap between the spheres is adjusted such that a large spark can jump from one to the other when the VdG is operating. In our setup the length of the spark gap is 15 mm.

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Method

The external contact on one of the electrodes on the explosion chamber is connected to the earth socket on the VdG. The external contact on the other electrode is connected to the VdG dome. Gas from the lab supply is allowed to flow into the chamber for about one second. The hose is removed and the paper cap is placed on the chamber. The VdG is switched on and set to run slowly, causing large sparks between the electrodes in the chamber. When the air-gas concentration becomes critical, the mixture explodes. For the confined-vapour explosion, the cap blows off and it and the elastic band can be thrown up to 2 m distant. There is a low pop and a small flame (Figure 1). For the unconfined-vapour explosion, the cap lifts off and is overturned, and a large flame emerges from the chamber with a whoosh (Figure 2).

With the above method, it is assumed that the gas-air mixture is too rich in methane for an explosion to take place at the onset of sparking. It is only after some of the methane leaks out that the mixture goes critical. A suggestion for starting off with the mixture critical would be to fill a gas syringe with 40 cm^3 of methane and inject this into the chamber, then immediately seal with a cap. Knowing that the volume of the chamber is 380 cm^3 this should give a concentration of 10% methane and produce an energetic explosion.

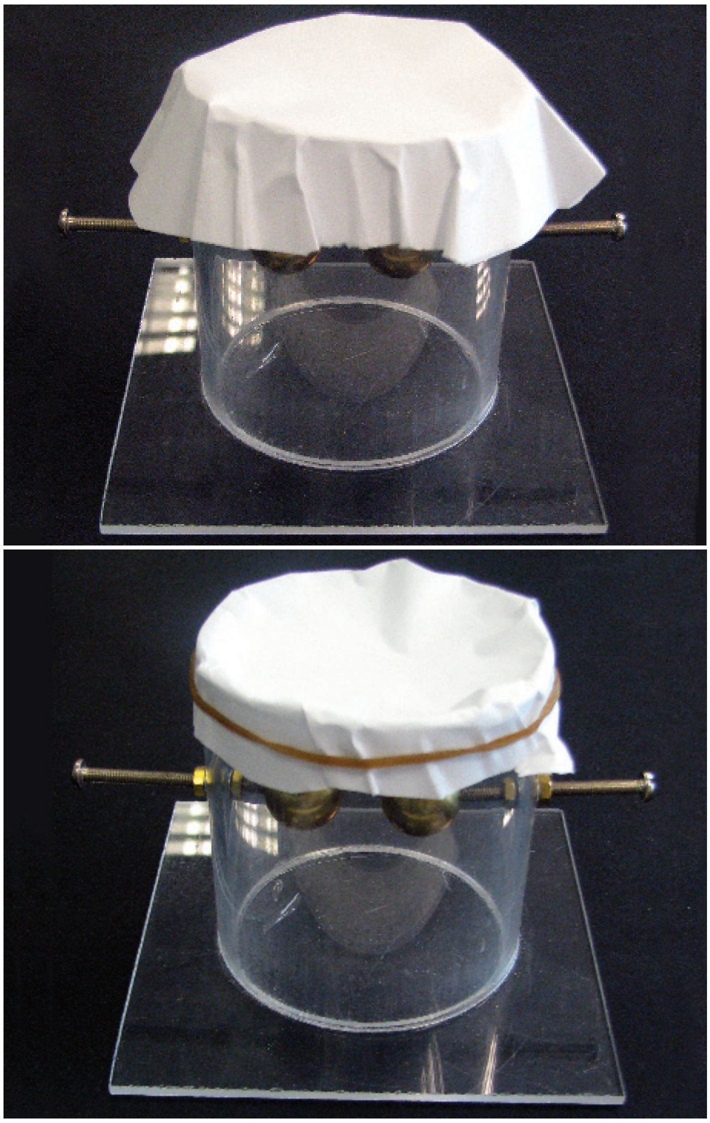

Figure 4 & 5 - Explosion chamber with loose-fitting cap (top) and tight-fitting cap (bottom).

Outcomes

The explosions dramatically show different aspects of the gas laws, either rapid expansion, or rise in pressure with temperature. They show the danger of static electricity and its propensity to start fires or explosions. They make the point that the main risk of injury from an unconfined-vapour explosion is burn or fire, whereas from a confined-vapour explosion it is blast.

Curricular links

Static electricity features several times in the physics courses. The hazards are often mentioned but rarely demonstrated. The activity could also be used in chemistry when fuels are covered, for example in Unit 5, Standard Grade.

Risk assessment

Provided that the demonstrator and onlookers are no closer than one metre from the chamber, there is no risk of harm from following the above method. Apart from wearing eye protection, no other control measures need to be taken. However if the method were to be changed, there could be a risk of a dangerous explosion. Please look at the Risk Assessment on the SSERC website (http://tinyurl.com/3uj5gas)