<u>Investigation into the role of electrostatics in a vapour ignition incident during refuelling at a Snax service station.</u>

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During the delivery of unleaded petrol to a Snax service station on the Southend Arterial Road a small fire occurred in the manhole chamber containing the underground offset fill pipes. The manhole involved has four fill pipes and is constructed from GRP with a metal frame at the top. The pipes are plastic but have a metal transition fitting for connection to the tanker hose. When not in use the fittings have an aluminium cap with an o-ring seal in place. It is understood that the delivery driver had two hoses connected to the offset fill points and was delivering the product. One delivery had finished and he opened up the cap of the next fill point to commence delivery to that tank. He then went to place the cap on the pipe of the tank to which he had completed the first delivery when the ignition occurred. The fire was quickly extinguished and no one was hurt.

Initially it was suspected that the probable cause of the ignition was static electricity igniting an uncommonly high concentration of petrol vapour. This is not an unreasonable assumption since the metal termination on the plastic pipe was ungrounded. In order for an ignition to occur at this point however there must be an electrostatic discharge between the cap and the termination fitting of sufficient energy to exceed the minimum ignition energy of the vapour mixture.

Normally the caps made from aluminium are connected to the termination fitting by means of a short length of chain but in this case the chain was broken and consequently there was no electrical continuity between the fitting and the cap. It follows that electrostatic ignition would be reliant on either the fitting to be raised to high potential or the cap/delivery driver being raised to high potential.

Investigation

I visited the scene of the incident on Friday 3 August 2001 in order to make observations and measurements. A road tanker delivery was arranged for that day so that measurements could be undertaken during a fuel delivery. Plates 1 and 2 give an indication of the layout. The incident occurred with fill pipe/tank 2. This can be seen clearly in Plate 2 with the aluminium cap in place.

The initial test performed on the termination fittings was to establish the degree of electrical isolation by measuring the resistance (R) between each of the termination fittings and ground. In order to do this it was necessary to remove earthing cables that had been applied after the incident. In addition the electrical capacitance (C) of the fittings were also measured. From these two measurements it is possible to calculate the relaxation time for electrostatic charge on the fitting to decay. Table 1 gives the results for the fittings 2, 4, 5 and the vapour recovery point. It is interesting to note that with the exception of the diesel filling point 5 the charge relaxation times are extremely low. This includes fitting 2 where the incident occurred.

Tank/Fitting	**Insulation Resistance To Ground**	Capacitance	**Charge Relaxation Time (seconds)**
2	3.7 – 5.0 MΩ	44 pF	.0002
4	3.3 – 3. 8 MΩ	28 pF	.0001
5	> 100,000 MΩ	68 pF	> 7 sec
vapour recovery	5.0 – 6.8 MΩ	72 pF	.0005

Table 1 Electrostatic properties of metal termination fittings

Three tank filling operations were monitored. Delivery of unleaded to no.2, delivery of unleaded to no.4 and delivery of diesel to no.5. Again the earthing straps which were applied after the incident were removed for the purposes of these tests and procedures applied during the incident were copied as closely as possible. All monitored deliveries were undertaken at a flow rate of approximately 1000 litres per minute through a 4 inch hose. The electrical continuity of the hoses (from end to end) were checked and found to be sound. During filling which lasted several minutes, electrostatic potentials on both the fittings and the short length of accessible plastic pipe within the manhole were monitored. Potentials on the fittings and pipe were also monitored on completion of fill and disconnection of the hose.

Fittings 2 and 4 did not rise above zero potential at any time during fill or removal of the hose. During the delivery of diesel to tank 5 a small but insignificant level of static potential (less than +200 V) was observed on the pipe. On completion of fill and disconnection of the hose a small reading rising to a maximum of +100 Volts was observed on the fitting. These results were not surprising in light of the rapid charge relaxation times previously calculated. Measurement of electrostatic potential on the fittings is shown in Plate 3.

The final measurements undertaken were the electrical resistivity of the ground surface around the tanker filling point and the electrical resistance between the chassis/body of the tanker and ground (through the wheels and tyres). The ground resistance was measured between two 2.5 kg electrodes placed 0.5 m apart on the ground. This yielded a resistance value of 23 MΩ ($2.3 \times 10^7 \Omega$). The resistance between the body of the tanker and ground gave a value of 8 MΩ ($8.0 \times 10^6 \Omega$). Both of these values can be considered significantly conductive from the point of view of electrostatic ignition hazards.

Although measurements were not undertaken on the footwear and clothing worn at the time of the incident, the tanker driver present during these tests was wearing standard issue footwear from Texaco. This was measured and found to be sufficiently conductive and within the limits laid down in BS5958.

Weather conditions at the time of the above measurements were good. It was warm and sunny throughout the day with a temperature of 25C and relative humidity of 56%. There was heavy rainfall throughout the previous day however the conditions within the manhole were good with only a little water present in the base of the chamber.

Analysis

Based on the description of the incident a requirement for an electrostatic ignition source is that either the pipe termination fitting or the cap (or driver holding the cap) should be at high potential. This potential should be such that the resultant electrostatic discharge between the cap and the fitting exceeds the minimum ignition energy of the fuel vapour. The usual analytical approach can be applied.

Presence of flammable atmosphere

The flammable range of petroleum spirit vapour in air is 1% - 7% by volume. The minimum ignition energy varies greatly over this range and has a minimum value of 0.25 mJ near the stoichiometric concentration. A sensitive flammable atmosphere obviously existed at the time of the incident since ignition occurred.

Electrostatic charge generation

It is understood that the conductivity of the fuel at the time of the incident was around 400 pS/m. Based on previous work with plastic pipelines, a flow rate of around 2 m/s (equivalent to approximately 1000 L/min) would produce potentials of below 1000V. This would not be expected to be hazardous.

Charge accumulation

This is the second requirement for electrostatic ignition. Electrostatic charge can accumulate on plastic surfaces and on isolated metal components -the latter being more dangerous since sparks can result.

When the pipe system was installed it is likely that the termination fittings were electrically isolated from ground. However, the build-up of contamination on and around the fittings has now produced a dissipation path to ground -clearly indicated in Table 1. From the results in Table 1 it is apparent that electrostatic charge <u>could not</u> be stored on the fittings with the possible exception of diesel line 5 which exhibited far less contamination and as a consequence a higher resistance to ground.

Note: It is also conceivable that due to the earlier fire a carbon deposit was generated on the external pipe surfaces thus contributing to the charge dissipation. No evidence of such a deposit was observed during this investigation and it is considered that this effect would be small compared to that of the general contamination.

Can a sufficiently energetic electrostatic discharge occur?

Based on the above data the answer to this question must be no. Firstly there is insufficient charge generated in the first place due to the high conductivity of the fuel (fuel conductivity was not measured as part of this investigation but was reported by Texaco). Secondly it is difficult to see how charge could accumulate on the fitting which had a measured charge relaxation time of 0.2 milliseconds. Even if the fitting had been perfectly clean and therefore electrically isolated and based on a capacitance of 44pF an electrostatic potential of between 3.4 and 6.0kV would be required for ignition. This level of potential could not be envisaged with fuel of this conductivity at these flow rates.

The above reasoning can be applied to electrostatic charge generated on the tanker driver. Here assumptions must be made since measurements were not undertaken on the driver involved in the incident or his clothing and footwear. The driver present at the tests had Texaco issued antistatic footwear and appropriate clothing and would not normally be considered a risk.

Conclusions

Based on observations and measurements during this investigation and the analytical reasoning above, it is difficult to see how this ignition incident could be caused by an electrostatic discharge from the termination fitting.

Other possible electrostatic causes which should be considered are electrostatic discharge from another source e.g. the driver or the aluminium cap. Can it be guaranteed that the driver was wearing issued antistatic footwear at the time of the incident? If the driver had been standing or kneeling on the manhole cover which is constructed from moulded plastic he may have become charged despite wearing antistatic footwear. Alternatively, the cap alone could become charged if it was placed on a charged cover and then transferred to the manhole in a gloved hand.

Possible sources of ignition other than static electricity are impact sparks between the cap and the fitting and possibly thermite reaction. These sources could be investigated but at first glance seem unlikely.

Although there is no technical evidence to support ignition by electrostatic spark in this instance it was recommended that the practice of grounding the transition fittings by means of a bonding wire (as undertaken in immediate response to this incident) be continued.

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Plate 1. Tanker delivery

Plate 2. Manhole and offset fill pipes. Those not in use have caps in place.
Ignition incident ocurred with No. 2 (bottom left).

Plate 3. Measurement of electrostatic potential after filling.