



## **Summary of risks with conductive and non-conductive plastic pipes at retail petrol stations**

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### ***Introduction***

This note summarises my views on the use of conductive (i.e. dissipative lined) and non-conductive (i.e. insulating) plastic pipes for underground piping at retail petrol stations. The main text gives a simple bullet-point presentation of the arguments whilst Appendix A provides more technical details.

### ***Outline discussion***

#### **All pipes**

- In connection boxes and sumps, flammable atmospheres can occur both outside the pipe and, on disconnection, inside the pipe. Therefore sources of ignition (including electrostatic sparks and brush discharges) need to be prevented in these regions.

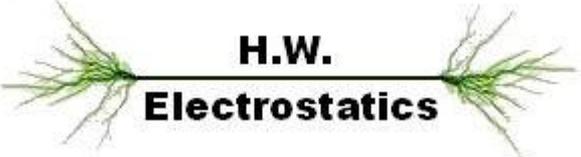
#### **Insulating (non-conductive) pipes**

##### ***General***

- Long sections of insulating pipe can be raised to extremely high voltages by the action of liquid flow and hence can produce incendiary brush discharges. Consequently, in general, insulating plastic pipes should not be used for above-ground service either in hazardous areas or for carrying flammable, low-conductivity liquids such as gasoline. This is clearly spelled out in static electricity standards (e.g. CENELEC TR 50404 sections 5.5.4.1 and 5.5.4.2).
- Insulating pipes are, nevertheless, tolerated in a few specific above-ground applications where the insulating section is relatively short or where the pipe is mostly buried leaving only short exposed sections. However, in these cases the risk of high voltage on the pipe surface needs to be considered and controlled. This requires detailed analysis of the proposed application.

##### ***For retail petrol station applications***

- The use of insulating plastic pipes is tolerable only because the majority of the pipe is buried leaving only short exposed sections at the ends.
- There is no earth contact for the insulating end sections that are exposed in sumps and connection boxes so it is essential to analyse the behaviour in detail to demonstrate that hazardous voltages will not occur.



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- A small number of scientific studies relating to insulating pipe voltages in petrol station applications have been reported. From an assessment of these results it can be concluded that:
  - Because of the relatively short exposed pipe lengths it is likely that only moderate voltages are developed in connection boxes and sumps. However these voltages are not far below the hazard threshold range for incendive brush discharges so safety margins are relatively low.
  - The uncertainties associated with the studies are comparable to or greater than the safety margins. This makes it hard to define safe design limits (e.g. maximum acceptable exposed pipe length) or operating limits (e.g. maximum acceptable flow speed) in standards.
  - The dissipation properties of old pipes have not been assessed. Voltages may be higher in aging systems.
  - Safety margins have only been assessed with hydrocarbon fuels. The introduction of oxygenated bio-components in increasing concentrations, will have an impact on the rate of electrostatic charging generation and may cause it to increase.
- There is a considerable installed base of insulating pipes at retail petrol stations. Incidents have been reported but, despite the uncertainties in the scientific studies, the frequency of occurrence is low and seems to be considered tolerable.
- Although the average risk seems to be tolerable, this may not be the case at sites with extremes of design (long sections of exposed pipe), or operation (fast flow, cold, dry ambient conditions) or where there are mistakes in construction (e.g. failure to backfill pipe trenches).
- Because safety margins are small, if the introduction of biocomponents causes any increase in charge generation it could have a significant impact on incident frequencies.
- It is critical that metal components mounted on the pipes are earthed. These earth connections must be individually provided for each such component and require regular verification during maintenance. This is straightforward with standard insulation and continuity testing equipment.

### **Conductive pipes**

- There is earth contact along the entire pipe in a properly installed system. Calculations show that pipe voltages would be very low even in exposed end regions.
- Because of the low voltages, the safety margins are large and there are no concerns about extreme operating conditions or future fuels.
- There have been no reported incidents, although the installed base is smaller.



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- It is critical that linings are earthed. This can be ensured with a well-designed system. The earthing requires regular verification during maintenance. This is straightforward with standard insulation and continuity testing equipment.

### ***Conclusions***

- The risks are uncertain with non-conductive pipes and may be unacceptable under extreme conditions or with future fuel compositions. Therefore the use of conductive systems is to be preferred.
- It is essential that conductive systems are engineered to provide reliable earthing of the conductive lining.
- Installation and maintenance procedures must supply verification that the lining is earthed.



## ***Appendix A: More detailed reasoning***

### **Relevant background information**

- Plastic pipes are normally buried with only short (~ 1 m long) exposed end sections where connections are made to truck delivery hoses, tanks or dispensers.
- Under unusual circumstances, longer lengths of exposed pipe may occasionally occur.
- Thresholds for incendiary sparks and discharges:
  - The capacitances of the conductive objects associated with these pipes, are such that the threshold voltage difference for creating incendiary sparks between conductive objects is more than 1 kV.
  - Measurements made with flat liquid surfaces suggest that the voltage threshold for generating incendiary brush discharges from insulating materials lies in the range 25 kV to 60 kV.
  - Measurements specifically on polyethylene pipes have indicated that more than 30 kV is needed for incendiary discharges. We therefore expect that the threshold lies between 30 kV and 60 kV.
- There is little or no specific streaming current data available for this application but based on comparisons with other activities, streaming currents of the order of 100 nA may typically be anticipated. However, tests on finished gasolines and gasoline components in dispenser equipment, have shown that streaming currents can vary by about a factor of x50 (largest/smallest).
- Occasional, albeit rare, reports have been received of ignition incidents and audible discharges with insulating pipes.

### **Electrostatic requirements for pipes**

Pipes must provide for safe operation under normal conditions and, preferably, should also help to protect operations carried out under the “unusual” conditions that give rise to longer exposed lengths of pipe than normal. To do this the voltages on insulating plastic surfaces must be kept below the threshold for incendiary brush discharges (30 – 60 kV) and the voltages on metal objects associated with the pipes must be kept below the threshold for incendiary sparks (1 kV).

### **Assessment for insulating pipes**

#### ***Normal use (short exposed sections)***

- Calculated voltages for typical conditions are ~ 27 kV. This is just below the incendiary threshold range and about a factor of x2 below the top of the range.
- There are few published voltage measurements. The maximum measured voltage so far reported with relatively short exposed sections is ~8.5 kV, which is lower



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than the calculated voltage and approximately x4 to x8 below the threshold for incendiary brush discharges. However none of the measured voltages was obtained at the location where the calculations suggest it would be highest.

- Neither the calculations nor the measurements cover worst-case conditions in terms of temperature (lower = worse) or available streaming current (higher = worse).
- Based on a) the relatively small (x1 to x8) margins between the measured/calculated voltages and the voltage threshold for incendiary brush discharges, b) the variability of fuel charging tendency (x50) and c) the fact that worst-case conditions have not been used in the assessments (they are not easy to identify), we expect that the voltages occurring in normal use could occasionally exceed the incendiary brush discharge threshold. This interpretation is consistent with the occasional, but rare, reports of ignitions or audible discharges with insulating pipes.
- The introduction of bio-components into hydrocarbon fuels may increase the charging tendency of the fuel. It is not certain that this will happen but it is a real possibility. If such a trend occurred, the existing safety margins could be reduced or eliminated, resulting in more frequent instances of ignition with insulating pipes. It is thus possible that insulating pipes may not be suitable for handling some future biofuel mixtures.
- Both the measured and calculated voltages on insulating pipes are well above the threshold voltage for incendiary sparks from isolated conductors mounted on the pipe. Hence all conductive objects on the pipe (e.g. valves etc) must be individually earthed and the earth connections need to be periodically checked.
- Voltages have only been measured on relatively new pipes. It is not known how the pipe resistance or charging properties change with age.
- Because our present knowledge of the boundaries of fuel charging and dissipation behaviour in insulating pipes is only semi-quantitative, it is hard to specify suitable control measures (in terms of flow velocity limits, maximum allowable exposed pipe length etc.) in standards. Any recommended control measures would need to be relatively restrictive to allow a suitable margin for the uncertainties.
- Although existing polyethylene pipes do not appear to be capable of being charged to hazardous levels by wiping or rubbing, it is hard to guarantee this for all possible pipe and rubbing material combinations. Some controls (e.g. verifying no external flammable atmosphere) over surface cleaning operations are therefore needed.

### *Additional hazards in exceptional use (long exposed sections)*

- For an insulating pipe, the calculations suggest that the worst-case voltages increase approximately in proportion to the sum of the exposed (unburied) pipe length) and a short transition length of the buried section. If a significant portion of the pipe is exposed (not buried), this can lead to the occurrence of very high



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predicted voltages that easily exceed the threshold range for incendiary brush discharges quoted above.

- Voltages of over 90 kV have been observed in one set of measurement tests on a long unburied pipe. The test had to be terminated prematurely for safety reasons.
- Clearly non-conductive plastic pipes do not offer adequate protection against brush discharges from the pipe surface in conditions of exceptional use when there are long exposed sections.

### Assessment for conductive pipes

#### *Normal and exceptional use*

- With an earthed lining, calculations suggest that voltages will be of order 100 mV (millivolts) or less, even with exceptional (long) lengths of exposed pipe. With such low voltages there is no risk of incendiary sparks or brush discharges due to flow charging.
- With earthed dissipative linings, the safety margins between the voltages produced by flow charging and the thresholds for incendiarity are x 10 000 for sparks and x300 000 to x600 000 for brush discharges. It is very unlikely that future biofuels will charge more than existing fuels by this sort of margin so conductive pipes should provide for electrostatic safety for any currently foreseeable future fuel.
- The capacitive coupling between the surface charge and the earthed lining will reduce the voltages generated by rubbing the pipe surface. Hence the risk of incendiary sparks or brush discharges due to rubbing will be lower than with an insulating pipe. However, the insulating outer part of the pipe wall is generally too thick to be completely certain that the earthed lining will keep the surface voltage to a safe level. Therefore any conductors not in contact with the lining need to be independently earthed and controls over cleaning and wiping etc are still needed.
- If the pipe lining (or a section of it) is not earthed, the voltage on the lining could (depending on the insulation resistance to ground) be high enough to generate incendiary sparks. Hence it is important to ensure that all sections of lining are earthed<sup>1</sup>. The reliable provision of this earthing is a critical requirement of good system design. The performance of the earthing arrangements is readily checked by standard continuity testing.

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<sup>1</sup> It should be noted that for typical streaming currents of order 100 nA an insulation resistance of more than  $10^{10}$  ohm is needed to permit a voltage of more than 1 kV to develop.