Ignition risks associated with migratory antistatic liners at the point of use

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Abstract. Dissipative plastics are often used to reduce risks of static ignition sources in explosive atmospheres. Migratory agents which diffuse to the surface can aid dissipation. The agent attracts ambient moisture to the surface thus decreasing the electrical resistance. In tests it has been found that surface resistance of migratory liners can take around 24 hours to become dissipative. This brings into question whether conditioning periods recommended for surface resistance tests could be masking the ignition risk of materials. Surface resistance, transferred charge and gas probe ignition tests have been carried out to investigate the ignition likelihood further. Rubbing tests indicated that a protective lubricating film formed at around 1 hour that could prevent charge transfer events but subsequent rubbing removed the film leading to charge transfer events. Liner filling tests were set up similar to IEC 61340-4-4. This testing recorded charge transfer events of over 60 nC for all liners even after 24 hours exposure. Liner filling tests with the gas ignition probe produced ignitions with standard insulating liners (no migratory agent) but produced no ignitions or measurable charge transfers for migratory liners. A question remains over the use of charge transfer values to evaluate ignition risks for migratory static dissipative materials and more guidance is sought to help industry manage these risks.

1. Introduction
Dissipative plastics are often relied upon to reduce risks of static ignition sources in explosive atmospheres. Migratory molecules which diffuse to the surface can aid dissipation. The molecule involved in this paper is an ethoxylated amine organic compound. It has both hydrophilic and hydrophobic character. The molecule migrates to the surface due to concentration driving force and the repulsion caused between the polymer and the hydrophilic functional groups on the fatty acid chain (similar to how some surfactant molecules are structured). At the surface the hydrophilic groups attract ambient moisture into an invisible film, thus decreasing the electrical resistance of the surface and dissipating charge to earth. Many industries including food, pharmaceuticals and fine chemicals rely on liners for handling and storing products or intermediates and many of these processes also involve potential explosive atmospheres. In tests it has been found that surface resistance of migratory liners can take around 24 hours to fully transition from insulating to dissipative. This brings into question whether the conditioning period recommended for surface resistance tests such as given in PD CLC/TR 60079-32-1 2015 [1] could be masking the ignition risk of materials based on a migratory agent.

2. Rubbing charge transfer tests with associated surface resistance measurement
2.1. Method & Results
The transferred charge measurements were conducted according to the method in [1]. It was found that rubbing the liners with a cotton rather than a nylon cloth produced greater charge transfer events.
Samples were withdrawn from heat sealed packages containing 450 mm by 450 mm, 125 micron thick low density polyethylene migratory or standard liners. The surface resistance was determined before and after charge transfer testing and measured at several locations. The environment in the test laboratory was controlled to 50% relative humidity (RH) and 24 °C.

2.2. Discussions
The delay in achieving a lower surface resistance for the migratory liners is thought to be due to not having a concentration driving force for diffusion when the liners are in intimate contact with each other. Figure 1 (a) shows an initially high surface resistivity reading (10^{14} \text{ Ohm/sq}) for static dissipative liners soon after removal from packaging. Post charge transfer testing the surface resistance reduces to around 10^{10} \text{ Ohm}. This is more than what might be expected if the liner was exposed to the environment. The charge transfer may be accelerating the diffusion of the migratory agent or creating surface agents that are more conductive. It was noticed that charge transfers made the transparent film turn cloudy. This may be consistent with additive bloom where migratory agents come to the surface and cloud the optical properties of the film.

Figure 1(b) suggests that freshly withdrawn static dissipative liners are susceptible to rubbing and subsequent discharge and can produce discharges theoretically incendive to gas Group IIA atmospheres (>60 nC). However, when the liner had been conditioned for around 1 hour the initial attempt(s) at rubbing failed to produce a measurable charge transfer event. Repeated rubbing of the same location however brings back the charge transfer events. This is thought to be due to small amounts of surface agent being present but at too low a concentration to reduce the surface resistance. This small amount of agent could be protecting against tribo-charging through a lubrication mechanism. Continued rubbing is thought to remove the lubricant effect.

(a) 
(b) 

Figure 1. (a) Surface resistivity measurements on samples at different times post removal from packaging. Charge transfer tests were conducted between surface resistivity tests indicated by arrow. (b) Charge transfer test results from samples used in surface resistivity testing. Samples were all exposed to a controlled environment of 24 °C and 50% RH.

2.3. Conclusions
Migratory liners can be insulating when removed from packaging. All liners were capable of discharges above the 60 nC threshold for gas group IIA materials.

3. Liner filling trials – Charge transfer and surface resistance measurements
3.1. Method / apparatus and results
IEC 61340-4-4 [2] describes a test setup that is used to test Flexible Intermediate Bulk Containers (FIBCs) (See figure 2 (a) for schematic). The container is filled with corona charged 2 mm polypropylene beads at a controlled rate. This test was adapted so that a 450 mm wide by 450 mm
long (125 micron thick) liner was filled with charged beads as opposed to the >250 litre FIBCs covered by the standard. The beads were charged using a corona rod and fed at 1.1 ± 0.1 kg s⁻¹ with an average streaming current of 3.0 ± 0.2 µA. Figure 2 shows a schematic of the experimental setup. The migratory liners were unpackaged and separated into two sets. One set of liners were exposed to laboratory air and then had surface resistivity measured while the other set were also exposed to the same laboratory air but were subjected to being filled with charged beads and had measurements of charge transfer.

3.2. Discussion

Figure 2 (c) would suggest that as the surface resistivity drops with exposure time so does the amount of charge transferred. It is interesting that charge transfer events greater than 60 nC are still occurring even after 24 hour conditioning when the surface resistivity would be considered dissipative for enclosures under the criteria in PD CLC/TR 60079 32-1 2015 [1].

It can be shown that the surface resistivity streaming current and the leakage current leaving are approximately consistent with Ohm’s law and the expected surface potential measured by field meter (where the reading was not saturated). The implications of this may suggest that to reduce the surface potential of the liner it may be necessary to achieve an even lower surface resistance for these types of electrostatically charged transfer processes (filling liners from pneumatic conveying / milling / micronising etc…).

The question remains as to whether the charge transfer events are truly capable of igniting real explosive atmospheres.
3.3. Conclusions
Migratory static dissipative liners filled with charged polypropylene beads produced charge transfer events greater than 60 nC even after 24 hours conditioning where the surface resistivity was in the typically dissipative range (less than 1E+12 Ohms/Sq).

4. Liner filling trials – Gas ignition probe and surface resistance measurements
4.1. Method / Apparatus
The equipment was identical to the previous liner filling trials reported in section 3 apart from the use of a gas probe as the test electrode for provoking charge transfer events from the liner surface. The gas probe used ethylene gas (gas group IIB). These sets of tests were applied to a standard liner with no migratory additive, to migratory liners conditioned at different times and a corona treated migratory antistatic liner.

4.2. Results
A standard liner gave high surface resistivity (6.1×10^{14} Ohm/sq) and produced an ignition 13s into the filling trial. A fresh un-conditioned migratory static dissipative liner with a surface resistivity of (8.5×10^{12} Ohm/sq) gave no ignitions or measurable charge transfer events. A conditioned (6 hours) migratory static dissipative liner with a surface resistivity of (2.7×10^{12} Ohm/sq) gave no ignitions or measurable charge transfer events. A conditioned (72 hours) migratory static dissipative liner with a surface resistivity of (2.01×10^{11} Ohm/sq) gave no ignitions or measurable charge transfer events. A corona treated liner with a surface resistivity of (8.9×10^{10} Ohm/sq) gave no ignitions or measurable charge transfer events.

4.3. Discussion
The lack of ignitions (and charge transfer events) for migratory liners may be due to an inherent property of the system (probe plus liner type). The following differences are noted; the gas probe electrode is of a different geometry (charge transfer probe was 15 mm diameter, gas probe 20 mm diameter). The migratory liners used in the gas probe trials were from a different production run. The migratory antistatic liners in the gas probe trials also behaved differently in terms of transient surface resistivity. They started a little bit lower but did not reduce with exposure to air at the same rate. The most likely difference to cause this lack of ignitions is probably due to the liners being different. This further indicates that the simple measurement of surface resistivity is not enough to predict if ignitions or charge transfer events will happen. More research will be needed to increase our understanding in this area.

4.4. Conclusions
Standard insulating liners used in the gas probe filling trials produced ignition events.

Migratory static dissipative liners in fresh, conditioned and corona treated forms did not produce any measurable charge transfer events or ignitions with the gas probe.

There is a need for better guidance on how to measure liners to ensure static ignition risks are characterised and understood better by vendors and end users.

5. Reference
[1] PD CLC/TR 60079-32-1:2015: “Explosive atmospheres. Electrostatic hazards, guidance”, IEC.
[2] IEC 61340-4-4:2018: “Electrostatics. Standard test methods for specific applications. Electrostatic classification of flexible intermediate containers (FIBC)”, IEC.