Reducing Electrostatic Discharge of Chemicals in Fluid Handling Systems

In the biopharmaceutical and pharmaceutical industries, the chemical integrity of fluids used during the process needs to remain as pure as possible. Contamination internal to the fluid path can generate process issues, and in the worst scenario, batch rejection. Rouging, biofilm buildup and cleanability are all potential risks in stainless steel pipe and systems.[1] As a consequence, the industry has been adopting polymeric piping systems which represent an alternative solution.

THE CHALLENGE

Organic solvents are commonly used in the pharmaceutical industry for synthesis upstream and downstream (culture media, separation, purification), and aggressive aqueous solutions are used for cleaning processes (CIP). Most of those solvents have low conductivity, which enables them to generate and hold electrical charge. When these solvents are transported in polymeric systems, there is a greater risk of static charge generation and discharge due to the nonconductive nature of the polymeric materials and the low conductivity properties of the solvents. Electrostatic Discharge (ESD) events generated in polymers can create leak paths through the tubing and possible ignition of the surrounding, potentially flammable, solvent-rich environment as shown in Figure 1.

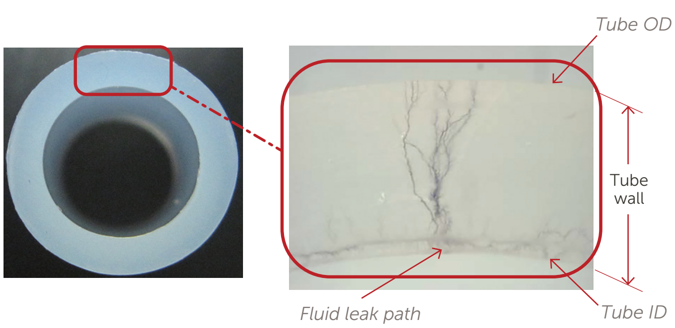

Figure 1. Example of electrical discharge through the polymeric tubing wall (0.062" diameter wall thickness).

FACTORS INFLUENCING STATIC CHARGE ACCUMULATION

Low conductivity fluid flowing in nonconductive tubing can cause charge separation at the fluid-tube wall boundary as shown in Figure 2a. This separation of charge is similar to what happens when two materials move with respect to each other and transfer charge as shown in Figure 2b. A charge is created as a result of the transfer of electrons and is similar to the charge that develops by walking across a carpet in dry conditions.

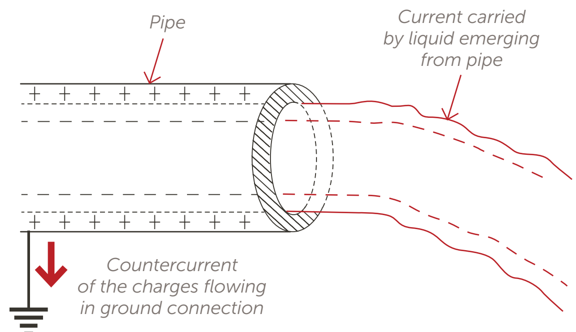

Figure 2a. Charge separation at the fluid-tube.[2]

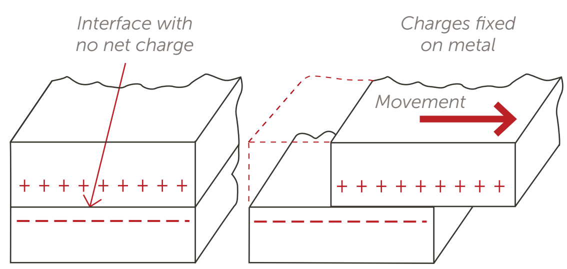

Figure 2b. Charge transfer caused by movement wall boundary.

POTENTIAL EFFECTS OF ESD ON POLYMERIC FLUID HANDLING SYSTEMS

Dielectric strength is the measure of a material's insulating strength. NFPA 77 defines the dielectric strength as "the maximum electrical field the material can withstand without electrical breakdown."[3] Dielectric strength is usually specified in volts/mm of thickness. As wall thickness and dielectric strength increase, the tubing becomes more resistant to electrical breakdown and discharge through the tubing wall.

ESD TUBING: PROPOSED SOLUTION FOR MITIGATING ELECTROSTATIC DISCHARGE

NFPA 77 lists several strategies for mitigating the amount of charge accumulation in electrically nonconductive pipes as a result of electrically nonconductive fluid flow.[4] Based on one of these strategies, Entegris has developed FluoroLine® tubing with static dissipative PFA stripes on the outside of the tubing that can be connected to ground (Figure 3). Charge accumulation that develops on the outside of the tube as a result of fluid flow is redirected to external ground paths. The purpose of having coextruded, PFA carbon stripes only on the outer diameter is to preserve the cleanliness of the tubing's pure PFA inner layer. Stripes were also used so the fluid can be seen inside the tubing.

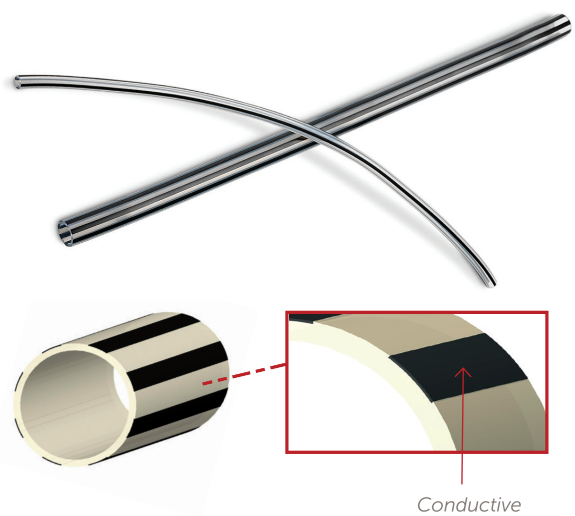

Figure 3. Entegris FluoroLine ESD tubing minimizes potential issues related to electrostatic discharge of solvent transportation.

TEST PROCEDURE

Test assemblies were made to hold 4-foot and 28-foot long samples of tubing that simulate how customers would use this tubing (Figure 4). The tube ends were attached to PFA fittings (the same fittings customers use) so that charge would not be discharged through the end connections. To simulate a common flow condition used by customers during the commissioning of their systems, an alternating flow of nonconducting 18 Mohm deionized water (DI) and Extreme Clean Dry Air (XCDA®) purge gas was used. The tube was cut to length and installed in the fixtures with nonconductive PFA polymer fittings at each end. Tube samples, fittings and probe tips were wiped down with IPA after installation. DI water resistance was measured and monitored throughout the test. The electrostatic voltage field meter was placed with the probe at 1 cm distance from the tube.

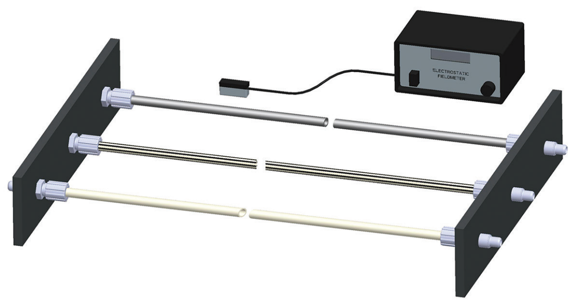

Figure 4. Test setup of 4-foot and 28-foot tube lengths.

Alternating flows of DI water and XCDA were introduced to the tube, and the field strength was measured at three different locations along the length of the tube. Each tube was subjected to this flow condition with and without a conductive ground strap connecting the tube to ground. In addition, the flow rate was reduced to 75%, 50% and 25% of the maximum flow rate to determine how the level of charge was affected.

TEST CONCLUSIONS

1. Grounding standard PFA tubing does not reduce the field voltage on the outside of the tube that is produced by flowing XCDA and DI water on the inside. Up to 20 K_V field voltage was measured with the XCDA/DI water delivery system (Figure 5).
2. Grounding ESD PFA tubing and stainless steel does significantly reduce the field voltage on the outside of the tube that is produced by flowing XCDA and DI water flowing on the inside (Figure 5).
3. The field voltage developed along 4- and 28-foot tube lengths does not vary significantly for PFA, ESD PFA and stainless steel.
4. With reduced flow rates, the maximum absolute field voltage was reduced for both grounded ESD PFA and PFA tubing.
5. No fluid leak paths were generated throughout this testing in either the PFA or ESD PFA tube.
6. The capacitance of a four-inch long PFA tube was measured to be 56 pF. Using this capacitance value and 20 K_V levels of voltage measured by the field meter in this test, the energy of discharge is calculated as 11.2 mJ. This energy level exceeds the MIE of common industry fluids and would be expected to cause fumes from these fluids to ignite.

Applying this same equation to grounded ESD tubing where a maximum of 1.5 K_V field was measured along with 52 pF capacitance, the discharge energy was calculated at 0.059 mJ and was below the threshold of ignition energy of the target fluids.

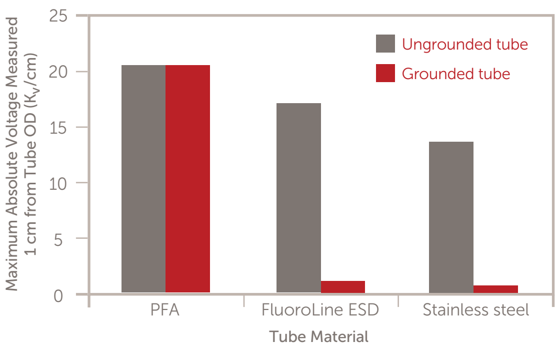

Figure 5. Field voltage on the outside of the tube.

CONCLUSION

As the biopharmaceutical and pharmaceutical industries continue to move toward polymeric fluid handling systems, it is important to understand the polymeric materials and their interaction with the process media. The manufacturing process utilizes many solvents and several of these can generate electrostatic buildup in polymeric piping systems. In order to mitigate process risk, Entegris has developed an effective polymeric piping solution that is proven to dissipate static charge accumulation on the exterior of the tubing. Entegris' FluoroLine ESD tubing has external static dissipative PFA carbon stripes that re-direct charge accumulation from the outside of the tube to external ground paths. This tubing maintains chemical purity, and when properly grounded, minimizes electrostatic discharge events, helping to increase process yields while ensuring safety.

REFERENCES

1. *Rouge in Pharmaceutical Water and Steam Systems*, ISPE Critical Utilities, Pharmaceutical Engineering ISPE, 2009.
2. Walmsley, H. L., *"The Avoidance of Electrostatic Hazards in the Petroleum Industry,"* p. 19 and p. 33.
3. NFPA 77: 3.3:16, 6:9:1, 7.4.3.4, 779.3.3.1 National Fire Protection Association.
4. NFPA 77 (A.10.2) National Fire Protection Association.

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