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Electrostatic Hazards in Liquids and Relevance to Process Chemistry

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Abstract:

Wherever there is flow of a liquid, there is the possibility of generating a static charge within it. The rate of flow, the conductivity of the liquid, and the diameter of the vessel/pipe have a dramatic effect on the electrostatic build up. Even though the system may be grounded, static charge can still accumulate and can often discharge in the form of a spark. This can lead to a number of problems in terms of process manufacture from the pitting of the vessel to the possibility of a fire where a flammable atmosphere is present. This report aims to highlight a number of issues with static buildup in liquids and the techniques, which can be used to minimise these hazards.

Introduction

The electrostatic hazards associated with dusts and powders have long been identified as a potential hazard in industrial processes, and a number of precautions can be used to control the buildup of static or to eliminate the risk of a fire or explosion.[1−3] A common technique is to bond any apparatus to earth, and hence any static charge may be safely dissipated to the ground.

The electrostatic hazards of liquids have been less well identified. An electrostatic charge can also build up wherever there is a flow of liquid or settling process occurring.[4] A charge can build up within the liquid, especially those with low conductivity such as hydrocarbons. Even with the pipe or vessel being earthed, a charge can remain within the liquid for a considerable period of time (in some cases minutes).[4−6] This can ultimately lead to a discharge or spark that could result in a fire if a flammable atmosphere is present.

The flow of a liquid in a pipe results in the separation of positive and negative ions in the liquid (see Figure 1). Hence, the electrical properties of the solvent play a major role in determining both charge generation and relaxation; the key parameters are dielectric properties and electrical resistance. The conductivity of a liquid is expressed in terms of siemens per metre (S/m) or more commonly picosiemens per metre (pS/m) (Table 1).

The Conductivity of Liquids. The conductivity of a liquid has a dramatic effect on its charging ability. In fact

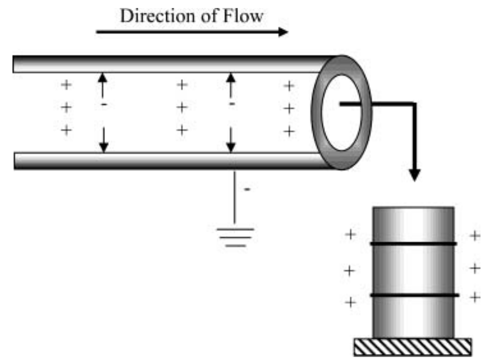

Figure 1. **The generation of static due to the flow of liquids.**

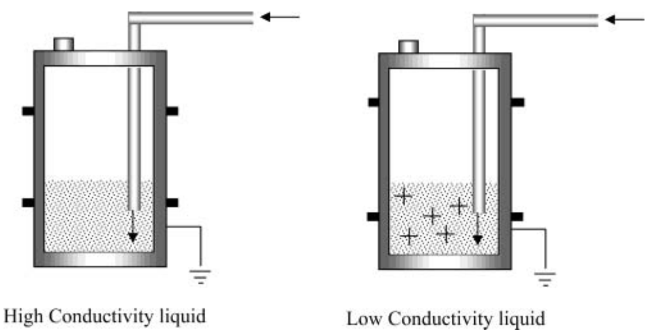

Figure 2. **Static buildup in low-conductivity solvents.**

liquids can be divided into three classes depending on their conductivity, high (>1000 pS/m), medium (50−1000 pS/m) and low (<50 pS/m). With a high conductivity liquid any static generated within the liquid can be conducted to the pipe/vessel and dissipated safely to earth. For intermediate liquids, the rate of charge generation can be critical, i.e. when charge generation is rapid, then there may not be time for the charge to be dissipated. Low conductivity liquids are unable to dissipate the static charge, and hence static buildup can occur even if the vessel is earthed as illustrated in Figure 2.[4,6] It is this class of liquids that gives the highest risk in the manufacturing process.

Table 1 shows the base conductivity for a range of common solvents and some relaxation times. Many hydrocarbons have a low base conductivity, and these liquids often require special attention in handling. The conductivity of a solvent is also related to its viscosity; hence, the conductivity of liquid will be lower when it is cold.[5] It is therefore important in a manufacturing process to measure the conductivity of solvent at startup, or when the solvent is at its lowest temperature, viscosity, and conductivity.

The Generation of Static in Industrial Processes. The following section describes the various ways in which static can be generated in an industrial processes.

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(1) Smart, R. C. *The Technology of Industrial Fire and Explosion Hazards*; Chapman & Hall Ltd: London, 1947; p 164.
(2) Luttgens, G. *J. Electrost.* **1985**, *16*, 247.
(3) Cartwright, P. The Safety & Health Practitioner, March, 1996.
(4) Walmsey, H. L. *J. Electrost.* **1992**, *27*, Nos. 1 and 2.
(5) *National Fire Codes*; National Fire Protection Association: Massachusetts, 1997; 77-1.
(6) Ott, R. J. *Static Electricity, Ignition Hazards and Protection Measures*; The International Social Security Association (ISSA): Heidelberg, Germany, 1996.

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Table 1. **Conductivity and relaxation times for a range of common solvents/ liquid[4]**

solvent	conductivity(pS/m)	relaxation times (s)	solvent	conductivity(pS/m)	relaxation times (s)
octane (iso)	0		light fuels	1	
carbon disulfide	0.00008		toluene	1	2−200
decane	0.0001		cyclohexane	2	2−200
hexane	0.0001	2−200	SBP solvents	5	
carbon tetrachloride	0.003		anisole	10	
benzene	0.005		caprylic acid	10	
base luboils	0.01		electrical insulating oils	10	0.02−2000
heptane	0.03	2−200	styrene monomer	10	
dibutyl ether	0.1	0.2−200	shellsols	10	
dioxan	0.1		stearic acid butyl ester	10	
pet ether 40/65	0.1	0.2−200	white spirits	10	
xylene	0.1	2−200	diethyl ether	30	0.2−200
pentane	0.28	2−200	kerosene	50	2−200

Pipeline Flow. Since charging occurs all the way along the pipe, the charge reaches a maximum value where the charge generation is equal to the relaxation through the pipe wall (i.e. equilibrium is reached). The charge generated is dependent on pipe diameter, conductivity of the liquid, and rate of flow. The lower the conductivity of the fluid and higher flow rate, the greater the charge that can be generated.

Any blockages or restriction such as valves or filters can also increase charge generation due to turbulence generated in the pipe and the higher flow rate.

Mixing and Stirring. The presence of two phases in a reactor/vessel can lead to the generation of charge on stirring. The higher the agitation speed the greater the charge generation. In certain systems where a solid is being dissolved into a liquid, very high electrostatic charges can be generated. In this case special precautions may be required.

Free-Fall/Splashing of Liquids. The free-fall of liquids leads to turbulence and can be very important in the filling of reaction vessels in terms of static generation.

Other Industrial Processes. Water settling, immiscible mixtures, crystallisation, and aerosols cause very high charging in liquids.

The Consequences of Static Buildup. If a large-enough electrostatic charge is present in the solvent and there is an earthed object in close proximity, then a discharge or spark can occur. If there is a flammable atmosphere present and the spark has enough energy to ignite the solvent, then a fire can occur. There are many case histories where fires have been started due to static discharges from liquids involving a range of low-conductivity solvents.[2]

A nitrogen blanket can be used to prevent a flammable atmosphere, but this can still lead to problems with reactor pitting. An example of this is the damage caused to enamel-lined reaction vessels due to discharges of static electricity.[7] Enamel itself cannot become dangerously charged, unlike some plastics, and is therefore used extensively in the chemical and pharmaceutical industries. However, experience in the use of enamel vessels has shown that under certain conditions high electrostatic charging can occur and the sparks generated can cause pitting of the reactor wall. If this remains unchecked, it can lead to corrosion, extensive damage, reactor downtime, and even reactor replacement. Similar experiences have been seen for glass-lined reactors.[8]

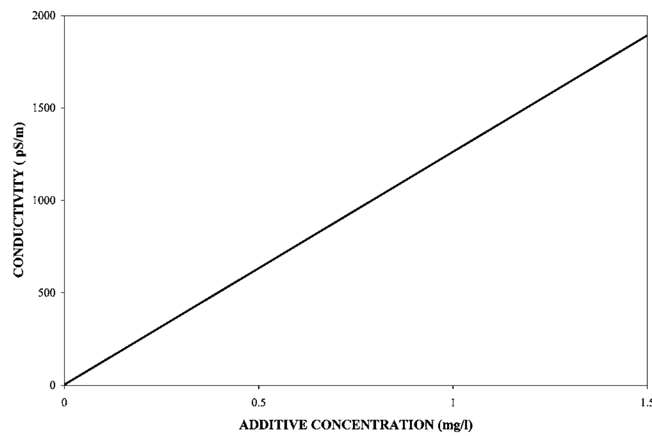

Figure 3. **Conductivity of toluene on dosing with Octastat 3000.**

Table 2. **Recommended minimum conductivity levels for a range of industrial processes[4]**

industrial process	conductivity (pS/m)
jet mixing	50
blending of liquids	50
settling	1000
crystallisation	1000
dissolving of solids	1000

Prevention of Static Buildup in Liquids. There are a number of ways in which static buildup in a low-conductivity solvent can be reduced or eliminated. The first way is to simply increase the conductivity of the liquid to a safe level by the addition of an additive; different dosage levels will be required for a particular industrial process.

As stated, static can be generated in a number of different processes, and the conductivity improvement required will vary. As Table 2 shows, crystallisation or dissolving of solids requires a higher conductivity due to the rapid rate of static generation compared to simple mixing of solvents. A number of antistatic additives are commercially available for the use in liquids.[4−6]

One example is Octastat, which can improve the conductivity of solvents at ppm levels. A typical graph is shown

(7) Maurer, B. *J. Electrost.* **1997**, *40−41*, 517−522.

(8) Lizawa, Y.; Kawashima, T.; Kodama, T. *J. Electrost.* **1999**, *46*, 103.

in Figure 3 for the dosing of toluene with Octastat 3000. A dose level of 1−2 ppm is required to raise the conductivity above 1000 pS/m. The exact dosage for many of these additives dependd on the particular solvent and the manufacturing process in which it is being used. It is therefore advised to measure the conductivity of the solvent directly using a conductivity meter for each application.

In pipes another way of limiting the buildup of static is to reduce the flow velocity. The recommended maximum flow for a low conductivity solvent is 1 m/s where a solid or second liquid could be present. Otherwise a maximum limit of 7 m/s is suggested. With conducting liquids in metal pipes, flow control is rarely required.

A careful selection of inlet and outlet points can help minimise the problems of static generation due to splashing, as does the use of wide bore valves.

Conclusions

The process implication for static generated in flowing liquids or two-phase processes are often overlooked. With flammable low-conductivity liquids there is always the issue of a spark which can lead to a fire, but it can also result in reactor damage.

The conductivity of a liquid determines the rate at which generated static can be dissipated to earth. The higher the conductivity of the liquid, the more rapidly the dissipation can occur. Some of the options open to a process chemist/engineer to control static in liquids are to reduce the flow rate in pipe work or to increase the conductivity of the solvent by using an antistatic additive.

ATEX 137 has increased the awareness of static electricity in manufacturing processes, and the issue of electrostatic buildup in liquids will therefore have to be addressed in current and future processes.[9]

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(9) Dangerous Substances and Explosive Atmospheres Regulations (DSEAR), Directive 1999/92/EC.