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Estimation of the charge density of a liquid from the surface potential of an insulating container

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Abstract:

The use of insulating containers is often required for liquid products despite the electrostatic hazards this may cause, especially when the container is large. However, the insulating wall of the container allows us to measure the electrostatic information of the liquid inside, i.e., the surface potential of the container relates the potential and charge of the liquid inside. In general, the resistivity of the container wall materials is much higher than that of liquids even if the liquid is insulating. The liquid can therefore be electrically treated as conductive and equipotential. In addition, as the container sits on an earthed plane, such as the top of a scale during a filling process, almost all charges will move towards the lower inner surface of the container in at least 3 times of the charge relaxation time of the liquid. This charge distribution creates a charged parallel plate capacitor between the inner and lower surfaces at the bottom of the container with the wall insulating material. Using this model, we can determine the charge density of the liquid entering the container by measuring the outer surface potential of the container as follows:

$\rho = \varepsilon\pi D^2 V/(4dv)$,

where ρ is the charge density of the incoming liquid, ε is the permittivity of the container wall material, D is the container diameter, V is the measured potential of the outer surface of the container, d is the thickness of the container wall and v is the volume of liquid in the container. The potential of the liquid is assumed to be close to the potential at the side surface of the insulating container. For example, we estimated a reasonable charge density of 1.1-5.5 μC/m^3 with a measured surface potential of 0.2-1.0 kV in a 200 litre PE drum filling. As this estimation may allow us to avoid direct measurement of the charge density, it may be useful for hazard identification and risk assessment in filling operations.

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