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Electrostatic ignition hazards in insulating or dissipative tubes and hoses for pneumatic transfer of powders—Measurements and model calculations

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ABSTRACT

When transferring powder through pipes or hoses made from insulating material, propagating brush discharges cannot be excluded. To calculate the limit value of the resistivity of the insulating material, below which no propagating brush discharges will occur, the charging current due to the powder transfer must be known. This charging current has been determined experimentally. Based on analytical calculations and computer models limit values for the resistivity of the hose material are derived from these experiments.

Keywords: Electrostatics; Dust explosion; Pneumatic transfer; Tubes and hoses; Propagating brush discharges

1. Introduction

Pneumatic transfer of powders or granules through pipes, tubes or hoses is well known to be one of the processes giving rise to the highest build-up of static electricity in industry. As soon as at least one part – the product or the equipment – is insulating, charge build-up occurs. In fixed installations usually metal pipes are used, which are reliably connected to earth. If highly insulating products are transferred through such pipes, the charge build-up on the pipes is immediately released to earth and no electrostatic ignition hazard related to pipes exists. The charged product is transferred into a receiving silo or container, where it may generate very high electrical fields and provoke discharges, but that is not the topic of the present investigation.

If however, e.g. for reasons of handling and manipulating the transfer line, the transfer line must be flexible, often tubes or hoses mainly made from plastics are used. Many different constructions are presently on the market, where the insulating material may also be combined with dissipative or conductive materials and structures (e.g. a plastics hose with a metal spiral within the wall). Such tubes or hoses may give rise to different types of discharges (see Glor et al., 2013). Brush discharges may occur mainly on the outer side of the tubes and hoses. Also spark discharges may occur at the outer or inner side of the tubes and hoses, if the tubes and hoses contain conductive material that is not properly grounded such as e.g. a metal spiral. In addition propagating brush discharges may occur if the tubes and hoses are made of insulating or a combination of insulating and dissipative or conductive materials.

The occurrence of propagating brush discharges during the pneumatic transfer of powders through hoses made from insulating material with an earthed metal spiral embedded in the wall has been observed in industry. Furthermore, Pavey (2009) demonstrated in experiments the formation of propagating brush discharges in such hoses and in similar

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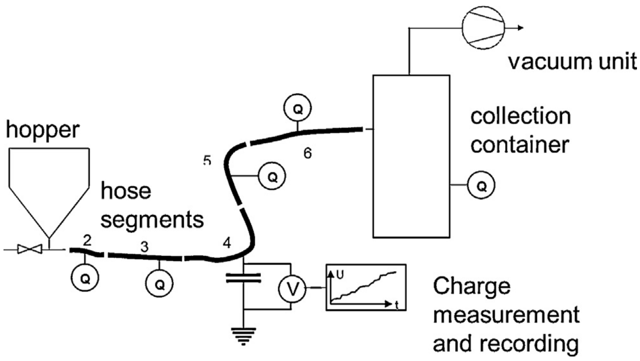

Fig. 1 – Experimental set up for the measurement of the charging current flowing through the surface of the wall inside pipes and hoses during pneumatic transport of powder.

Fig. 2 – Example of a transfer hose with a metal spiral embedded in plastic wall.

geometrical arrangements. According to the German guidelines on the avoidance of ignition hazards due to static electricity TRBS 2153 (2009), it is therefore required to use dissipative material for the inner part of the hose, in which the earthed metal spiral is embedded. Since – according to these guidelines – a dissipative property can be achieved by limits for the surface resistance as well as for the volume resistivity and the corresponding upper limits are $10^{11}\,\Omega$ (at 23 °C and 30% rh) or $10^{9}\,\Omega\,\mathrm{m}$ respectively, there existed qualified doubts, whether these limits are low enough to exclude propagating brush discharges under realistic conditions.

In order to correctly specify the requirements to exclude the occurrence of these discharges from such tubes and hoses, it is important to know the charging current running to and through the inner surface of the hose during the powder transfer. If this charging current is known, either the potential or the surface charge density build up at the inner surface of the hose wall can be calculated or estimated by computer simulations. If either the potential stays below 4 kV or the surface charge density stays below $2.5 \times 10^{-4}\,\mathrm{C/m^2}$ no propagating brush discharges will occur, as specified in the relevant guidelines CLC TR 50404 (2003), TRBS 2153 (2009) and IEC 60079-32-1 (2013). Therefore, for the purpose of setting up reliable specifications of the volume resistivity limits of the material of the hose wall, experiments have been performed with a vacuum suction system. In these experiments the charging current running to and through the inner surface of the hose during the powder transfer has been measured under different conditions.

2. Experimental set-up and results

The test setup is shown in Fig. 1 and a typical hose with a metal spiral embedded in a plastic wall is shown in Fig. 2. The bulk material is sucked from a hopper through the hoses under test to the suction unit of a PTS (powder transfer system). The

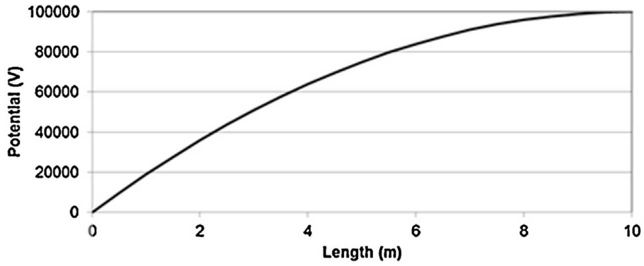

Fig. 3 – Potential as a function of hose length for a homogeneous hose with resistivity of the wall material $10^4\,\Omega\,\mathrm{m}$, thus just at the border from conductive to dissipative and wall thickness 5 mm. One end is grounded and the other end free. With current density of $1\,\mathrm{mA/m^2}$ the potential at free end will be 100 kV.

hoses were divided into several sections by cutting the wire spiral. Each section and the suction unit were connected to charge meters consisting of a capacitor and a high impedance voltmeter. The charge from each charge meter was recorded. For each segment the resulting current densities have been calculated, compared and analyzed.

Four different types of spiral wire hoses with different diameters and one conventional hose with an inner layer of white PTFE. At the latter the inner layer is not continuous but interrupted by a narrow conductive band in form of a helix.

The bulk materials used were polystyrene (resistivity of the bulk: $2 \times 10^{13}\,\Omega\,\mathrm{m}$, particle diameter: 3 mm), melamine ($5 \times 10^{12}\,\Omega\,\mathrm{m}$, 10 μm) and Lewapol, a modification of polystyrene ($3 \times 10^{12}\,\Omega\,\mathrm{m}$, 1 mm). Often at the beginning of a test run the polarity of the charge changed the polarity. After steep start a more moderate linear increase of the charge with time could be found.

The maximum current density measured in these experiments was $164\,\mu\mathrm{A/m^2}$. More details about the experimental set up and data collection can be taken from a paper by Fath et al. (2013). For reasons of safety a current density of $1\,\mathrm{mA/m^2}$ has been chosen for all further considerations and calculations representing a safety factor of about 6.

3. Calculations of the potential distribution along the inner surface of the hose wall

3.1. *Hose with homogeneous wall*

If the wall of the hose is made of a homogeneous material with a volume resistivity ρ, length L, wall thickness D, a constant current density i flowing to the inner surface and the hose is earthed at $x = 0$, the potential along the hose $U(x)$ can be described analytically in an easy way by the formula

$$U(x) = \frac{i\rho}{D(Lx - 0.5x^2)} \quad (1)$$

The potential is proportional to the current density i and to the resistivity ρ of the wall material. In the example of Fig. 3 the resistivity of the wall material is $10^4\,\Omega\,\mathrm{m}$, thus just at the border from conductive to dissipative, the wall thickness is 5 mm and the length of the hose is 10 m, one end is grounded and the other end free. With a current density of $1\,\mathrm{mA/m^2}$ the potential at the free end will be 100 kV. The resistance to ground at the end is $1.27 \times 10^{8}\,\Omega$. Brush discharges as well as spark discharges will occur.