ELECTROSTATIC CHARGING AND IGNITION OF DUSTS

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Electrostatic charging of powders and the ways in which charge can accumulate to give a hazardous situation are discussed. Examples are given of laboratory and industrial tests evaluating electrostatic hazards.

INTRODUCTION

Electrostatic sparks may not be the most common cause of explosions in industrial powder systems but they are one of the least well understood. In approximately 50% of all explosions no obvious ignition source is found. Electrostatic effects may well play a part in some of these as there is seldom any positive evidence left behind by static spark. One of the biggest problems in evaluating the electrostatic hazard is the difficulty in predicting how any material will charge. However, general rules can be defined and these will be outlined in this paper.

CHARGING OF POWDERS

Charge is produced when any two materials are moved while in contact. The amount of charge transferred depends on the work done in rubbing and on the nature of the two surfaces but the charge remaining on the surfaces after separation will depend primarily on the leakage rate and hence on the resistivities. In practical terms this means that the charge measured on a powder in any process is a function of the process itself and the resistivity of the powder.

Table I shows the charge levels produced on I.C.I. organic powders in various processes and it can be seen that the same material may produce very large variations in charge according to the amount of work done on it (Gibson (1)). It is therefore extremely difficult to measure electrostatic charging tendency in the laboratory and to relate it to the charge expected in practice in industry.

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TABLE 1

Operation	Charge per kilogramme ($C.kg^{-1}$)
Sieving	$2 \times 10^{-9} - 2 \times 10^{-11}$
Pouring	$2 \times 10^{-7} - 2 \times 10^{-9}$
Scroll Feed Transfer	$2 \times 10^{-6} - 2 \times 10^{-8}$
Grinding	$2 \times 10^{-6} - 2 \times 10^{-7}$
Micronising	$2 \times 10^{-4} - 2 \times 10^{-7}$

Two approaches have been taken at Southampton to attempt this measurement. The first is to apply the highest charge possible in a fan device shown in figure 1 and the second is to pass powder through straight tubes of 1cm internal diameter. The results of these tests applied to the same powder is shown in figure 2. The work done by the fan is much higher than in the tubes. Therefore a much higher charge is produced. However, a further significant difference was found. In the tests with the fan both the magnitude and polarity of the charge acquired can be a function of particle size. Figure 3. Thus when a silo is filled and the heavier particles become separated from the fines, there is also charge separation. The same effect has not been observed in laboratory tests with straight tubes but has been found in actual filling operations. Figure 4 shows the electric field measured with a rotating vane field meter situated in the roof of a silo which was being pulse filled with polyethylene powder. The meter measures the field due to the combined effect of all charges seen by the meter. It is therefore not possible to quantify the amount of charge from a single meter reading but it does give a clear picture of polarity. During filling the field was negative which was the overall mean polarity of the powdered material. When filling stopped the coarse particles settled rapidly leaving the fine positive dust suspended. This then gradually settled giving a slow drop in electric field.

The charge acquired in an industrial situation is often lower than is produced in the laboratory and in small scale tests because the maximum charge is limited not by the charging mechanism but by discharges. There are a number of limiting mechanisms but all are basically dependent on Gauss' Law which gives the electric field at a closed surface in terms of the total charge, Σq enclosed by the surface

i.e. $$\int EdS = \frac{\Sigma q}{\varepsilon_o} \quad \text{.......................(1)}$$

S is unit surface area, Σq is the total charge enclosed by that area and ε_o is the permittivity of free space = $8.8\ 10^{-12}$f/m. E is the electric field.

For a cylindrical pipe of length, ℓ and radius, r this can be written

$$E\ 2\pi r\ell = \frac{Q}{\varepsilon_o}\ \pi r^2 \ell$$ where Q is the charge/unit volume in the pipe

i.e. $$E = \frac{Qr}{2\varepsilon_o} \qquad \text{.........................(2)}$$

The electric field cannot exceed 3 10^6V/m at which level the air breaks down and a discharge occurs. Therefore the maximum charge/unit volume is defined by the tube radius. This limiting mechanism is in operation in most processes where high charges are produced by friction. In a tube in a laboratory, the limiting charge/particle may be considerably higher than in industry because the radius of the pipe is much smaller. Laboratory tests therefore give only a comparison of the charging ability of different powders and pipe materials and cannot be used to predict the charge that will be acquired in an industrial situation.

IGNITION MECHANISMS

A spark, if it is to ignite powder must contain at least 10^{-7}C of charge which is dissipated in a single discharge lasting approximately 10µ seconds. Although powder may charge to 10^{-3}C/kg in some circumstances even at this level each individual particle can hold only approximately 10^{12} - 10^{15}C. The charge must therefore accumulate so that a large number of particles discharge simultaneously. Three means of charge accumulation can be envisaged:

Unearthed conductors

More than 90% of electrostatic ignitions are caused by sparks from unearthed conductors which can store charge. The voltage reached by a conductor with a capacitance C to earth is given by $V = \frac{Q}{C}$ and the energy of a spark by $\frac{1}{2}CV^2$. An unearthed conductor may be a man wearing insulating footwear, a trolley on nylon wheels, a sieve on rubber mountings or an unearthed road tanker. If the powder itself is conducting but is being loaded into plastic bins or containers then charge acquired as the powder leaves the pipe will be stored on the conducting mass of the settled powder. Sparks which are able to ignite dusts are easily produced in this way. The energy required to ignite a dust is generally above 5mJ. Table 2 shows the voltage to which an object must arise to give a spark of energy 1mJ. The quantity of charge required to give this voltage is also quoted for each capacitance.

Plastic surfaces

Plastic surfaces generally give sparks which are too low in energy to ignite a dust. The charge is distributed across the surface to a maximum surface charge density of 2 10^{-5}C/m^2 and only a small area can discharge in a single spark. The maximum charge on the surface is again fixed by the electric field above the surface reaching the breakdown limit of air and can be calculated.

It has been shown by Heidelberg (2) that if a plastic surface is backed by an earthed metal so that the electric field above the surface is reduced, a much higher charge can be stored. Effectively the capacitance of the surface is increased. If the charge density exceeds 2.5 10^{-4}C/m^2

a high energy spark can be produced with a large surface area discharging in one spark.

TABLE 2 - Relationship between Voltage, Capacitance and Spark Energy

Object	approx. capacitance pf	Voltage for 1mJ spark	equivalent charge (coulombs)
Beer can	2	30kV	$6\ 10^{-8}$
Bucket	20	10kV	$2\ 10^{-7}$C
Man	200	3kV	$6\ 10^{-7}$
Isolated equipment	up to 2000	1kV	$2\ 10^{-6}$

Sparks from PTFE, glass fibre and perspex surfaces have been studied at Southampton using an oscilloscope to monitor the current flowing to earth when a sphere was brought up to a charged surface. There was a considerable difference in the shape of the sparks from backed and unbacked plastic. Figure 5. The duration of sparks from different positions on the same sheet also varied by a factor of about 5 but there was no significant consistent difference between the materials.

Sparks from charged plastic were shown to have ignited a silo containing chocolate crumb when a PVC pipe wrapped with earthing wire was placed inside the silo for filling. Hughes (3). In the flour and grain industry conveyer belts are frequently used to transport products. As the belt passes over rollers they are able to acquire a high surface charge which becomes unstable as the belt leaves the roller.

SYMBOLS USED

E = electric field V/m

S = surface area (m^2)

Q = charge density (C/m^2)

ℓ = length (m)

q = charge (C)

r = radius (m)

ε_o = permittivity of free space F/m

REFERENCES

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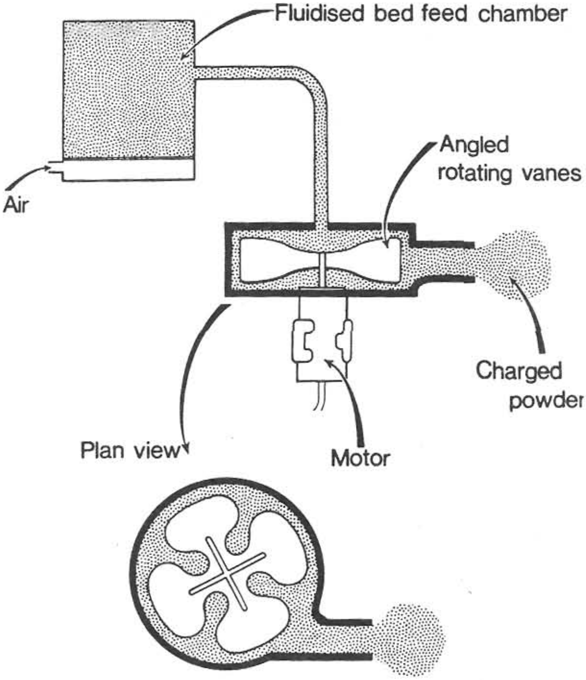
2. Heidelberg, E., Report of Physikalisch-Technische Bundesanstalt, Braunschweig, Germany. English translation Industrial Course in Electrostatic Hazards, Southampton University 1976.

3. Hughes, J.F., Bright, A.W., I.E.E.E., Transactions on Industry Applications, Vol. 1A - 15 No. 1 January/February 1979.



Schematic Presentation of Assembly
used for Charging Powder

Figure 1

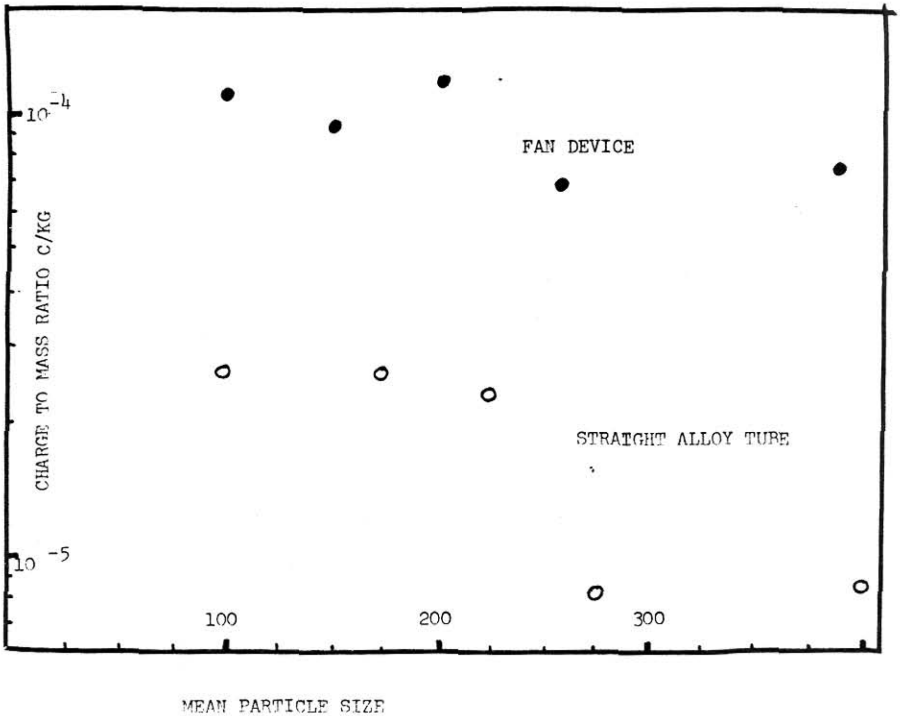


Figure 2 CHARGING AS A FUNCTION OF PARTICLE SIZE.

CHARGE TO MASS RATIO VERSUS PARTICLE SIZE OF A FOOD PRODUCT, ILLUSTRATING THE BIPOLAR NATURE OF THE MATERIAL

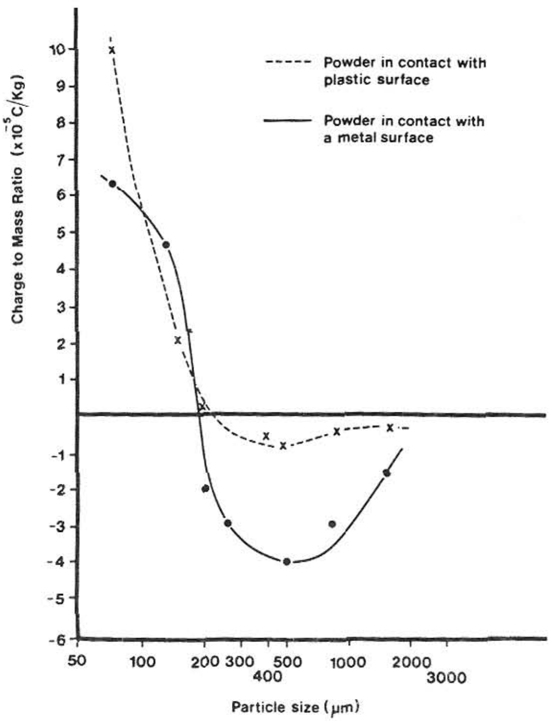


Figure 3

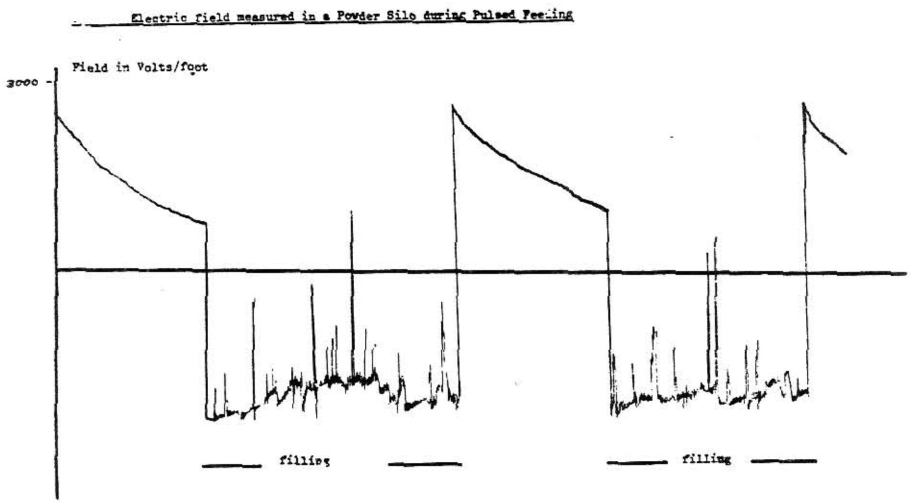

Electric field measured in a Powder Silo during Pulsed Feeding
Field in Volts/foot
3000
filling
filling

Figure 4

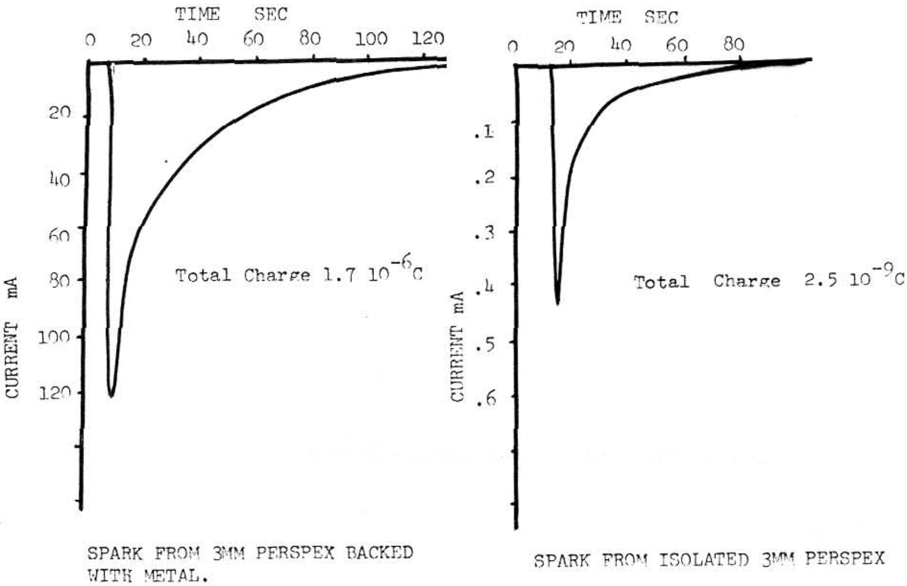


Figure 5 Current Flowing in a Spark from a plastic to an Earthed Sphere