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by

R. Sack



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ELECTROSTATIC EXCITABILITY OF FLOWING DUST/AIR MIXTURES

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[FOOTNOTE: * Eng. Rudolf Sack is a group leader technician in the safety engineering department of the VEB Chemical Combine Bitterfeld.
END FOOTNOTE]

The VEB Chemical Combine Bitterfeld, among other things, is working on safety engineering problems of the electrostatic excitability of flowing dust/air mixtures. The first results have been published in the paper, "Electrostatic Excitability of Dusts," [1].

For whirled-up dusts and dusts which slide along the walls the

laboratory results were transferable to practical conditions; this was not possible, however, for flowing dust/air mixtures. First of all the following questions had to be clarified:

- What is the dependence between the charging current, respectively, the excess charge and the tube length?

- What are the causes for the unexpected shape of the charging curves?

- What is the relationship between the excess charge and the tube diameter?

For answering the first two questions a section of tubing was constructed with a length of 4 meters and which consisted of individual pieces of tubing. Tests were conducted in the tube with loose materials.

The third question could be clarified without supplementary experimental tests.

The new flow equipment which differs from that described in [1] consisted of the air storage, dosing apparatus, the 4-m long exciter tube and the dust catcher. The air storage and accessories remained

unchanged. The dosing apparatus, however, was changed so that the loose material to be studied was distributed through the intake pipe into the air nozzle. Thus more precise dosing was possible.

The 4-m long exciter tube was composed of 12 pieces of tube with the following lengths: 5, 5, 10, 10, 20 cm and 7 sections of tube, each 50 cm long. All tubing pieces were copper and had an inner diameter of 34 mm. They were put together with PVC sleeves. The charges arising in the dust could be measured on each piece of tubing. The dust catcher remained unchanged.

The design of the test setup is shown schematically in Fig. 1. All pieces of tubing were electrostatically insulated from each other and from the ground, $R \geq 10^{12} \Omega$.

The tests were conducted with powdered quartz and granulated PVC. The granulated PVC was sieved and divided into the following fractions:

Grain size > 1.0 mm, $1.0-0.63$ mm, $0.63-0.5$ mm and < 0.5 mm.

In all test runs the air speeds were either 40.5, 33, 22.5 or 11 m/s. The added quantities of material had a volume of 1.5, 3, 6 or 9 cm³.

In every test the flow time of the air was 1.6 s. The determined measured values have been converted into the charging current I_A in A or into the specific excess charge q in As/g.

TEST RESULTS

Fig. 2 shows the charging curves for powdered quartz (specific excess charge q in As/g) with $v = 22.5$ m/s and for various dust concentrations. From the charging curves the origination of the charge with respect to the charge size and polarity can be followed exactly. Charging curves with approximately the same shape resulted during all other investigated air speeds.

If one plots the charging current as a function of the dust concentration one obtains charging curves in accordance with Fig. 3.

Fig. 4 shows the dependence of the charging current on the flow speed of the air. Figs. 5-8 show the charging curves (specific excess charge q in As/g) for the various grain fractions of the granulated PVC. They show the values of the specific excess charges on the individual pieces of tubing and how the irregular shape of the charging curves arises. In order to limit test expenditure only a

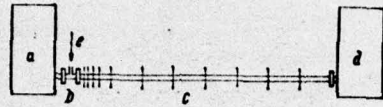


Fig. 1. Diagram of the test setup for flowing dust/air mixtures; a) air storage, b) air nozzle; c) exciter tube; d) dust catcher; e) dust input.

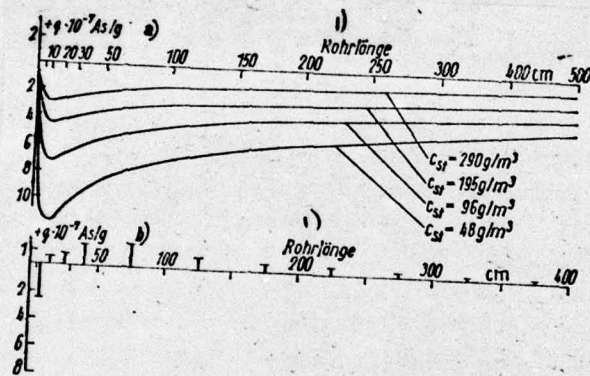


Fig. 2. Specific excess charges of flowing powdered quartz/air mixtures depending on the tube length; $q = f(\text{tube length})$; constant: $v = 22.5 \text{ m/s}$; tube: Cu, 34-mm diameter; a) parameter: dust concentration c_{st} ; b) q discrete on individual tube sections for $c_{st} = 48 \text{ g/m}^3$. ((KEY: 1) Tube length.)

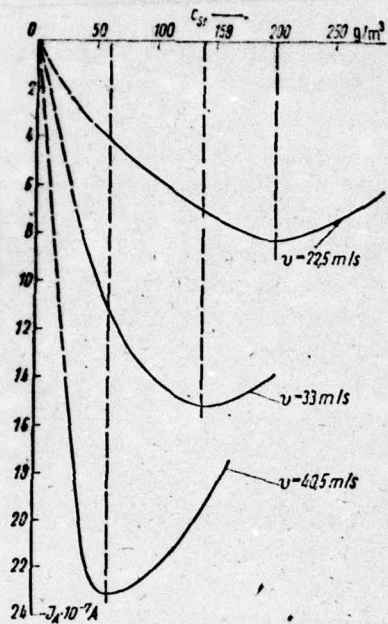


Fig. 3. Charging current of flowing powdered quartz/air mixtures with various dust concentrations; $I_A = f(C_{st})$; parameter: v ; constant; tube length = 4 m; tube: Cu, 34-mm diameter.

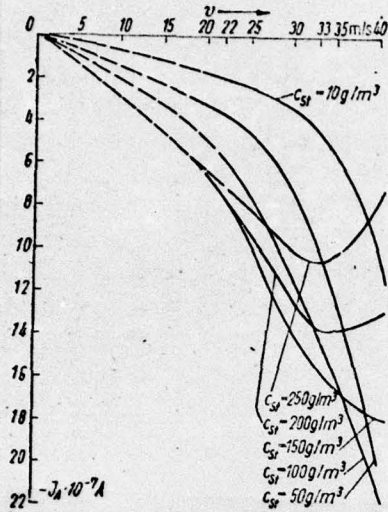


Fig. 4. Loading current of flowing powdered quartz/air mixtures with various flow velocities; $I_A = f(v)$; parameter: c_{St} ; constant: tube length = 4 m; tube: Cu, 34-mm diameter.

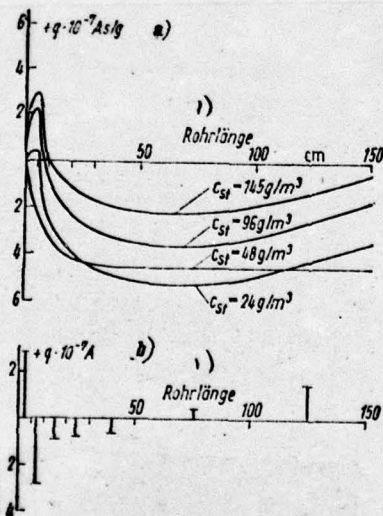


Fig. 5. Specific excess charges of flowing granulated PVC, grain size < 0.5 mm; $q = f(\text{tube length})$; constant: $v = 22.5$ m/s; tube: Cu, 34-mm diameter; a) parameter: dust concentration c_{St} ; b) q discrete on the individual tube sections for $c_{St} = 145 g/m^3$. ((KEY: 1) Tube length.)

tube length of 150 cm was measured.

EVALUATION OF THE TEST RESULTS

The size of the specific excess charges of the loose material during pneumatic transport is determined mainly by the intensity and the number of contacts of the dust particles with the tube wall. The loose material which is strongly whirled up in the nozzle is transported through the tube and initially makes frequent contact with the tube wall. After a certain distance the particles contact the tube wall increasingly less frequently and the excess charge becomes less per unit of tube length.

As can be seen from Figs. 2, 5 and 6 the polarity of the excess charge of strongly turbulent flowing loose material/air mixtures and of approximately laminar flows of the same mixtures can be opposite. Therefore the charging curves acquire an irregular shape.

In the case of powdered quartz (Fig. 2) the largest negative excess charges occur in the first 10 cm of the tube. Afterwards, positive excess charges are formed. The largest value of excess charge is measured at 10 cm.

After 100 cm the total excess charge changes only slightly and

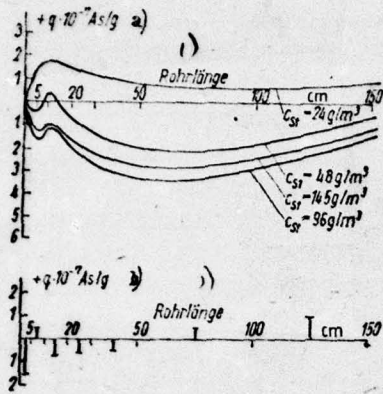


Fig. 6. Specific excess charges of flowing granulated PVC, grain size from 0.5-0.65 mm; $q = f(\text{tube length})$; constant: $v = 22.5 \text{ m/s}$; tube: Cu, 34-mm diameter; a) parameter: dust concentration c_{st} ; b) g discrete on the individual tube sections for $c_{st} = 145 \text{ g/m}^3$. ((KEY: 1) Tube length.))

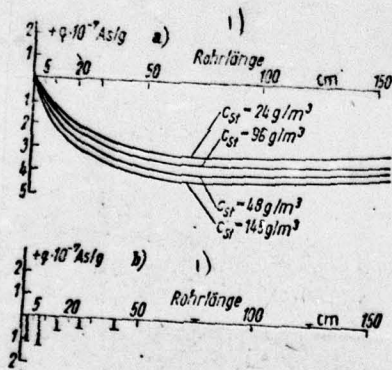


Fig. 7. Specific excess charges of flowing granulated PVC, grain size from 1.0-0.63 mm; $q = f(\text{tube length})$; constant: $v = 22.5 \text{ m/s}$; tube: Cu, 34-mm diameter; a) parameter: dust concentration c_{st} ; b) g discrete on the individual tube sections for $c_{st} = 145 \text{ g/m}^3$. ((KEY: 1) Tube length.))

remains negative.

In the case of granulated PVC the excess charge following the whirling up of the material at the beginning of the tube depends on its fineness. Fine-grained material is easily whirled up and because of its high surface area per unit of weight it shows high excess charges with greatly differing polarity (Figs. 5 and 6).

Large-grained material (Figs. 7 and 8) cannot be whirled up as easily and therefore shows smaller excess charges and no change in polarity. The largest values of excess charges were displayed in tube lengths from 10 to 50 cm.

In the case of fine-grained granulated PVC the excess charge changes noticeably even with tube lengths greater than 1 m. In contrast, with large-grained granulated PVC from 50 cm on change can no longer be determined.

If one observes the charging currents independently from the tube length then a dependence arises on dust concentration. In Fig. 3 the charging curves show that for every flow velocity there arises a maximum at a certain dust concentration. This fact was also shown during tests with 20-cm long exciter tubes which are described in [1]. The dust concentration which produces a maximum of the charging

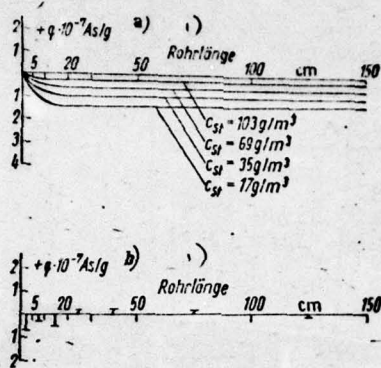


Fig. 8. Specific excess charges of flowing granulated PVC with a grain size $> 1.0 \text{ mm}$; $q = f(\text{tube length})$; constant: $v = 22.5 \text{ m/s}$; tube: Cu, 34-mm diameter; a) parameter: dust concentration c_{Se} ; b) q discrete on the individual tube sections for $c_{Se} = 17 \text{ g/m}^3$. ((KEY: 1) Tube length.))

current, in combination with the flow velocity seems to make possible optimum conditions for charging the particles.

With a high flow velocity this charging condition of the particles, i.e., the charging maximum, is achieved even with low dust concentrations. With decreasing flow velocity the charging maximum is shifted toward higher dust concentrations.

The shape of the charging curves as a function of the flow velocity depends on the dust concentration. Fig. 4 shows that with small dust concentrations the charging current rises sharply only with greater flow velocities; with increasing dust concentration the sharp charging rise begins with smaller flow velocities. Only if a certain dust concentration is reached is it recognizable that there is also a maximum of the specific excess charge. It occurs at a certain flow velocity which depends on the dust concentration. Here also the charging maximum is that state in which the optimum charging of the dust particles results.

The obtained test results show unambiguously that the size of the specific excess charge depends on the wall surface and the contact possibility of the particles. Under the assumption of equal dust concentration and flow conditions the following relationship is valid for the dependence of the specific excess charge on the

diameter of the tube:

$$Q_{a1} = \frac{Q_{a2} \cdot d_1}{d_2}$$

Q_{a1} excess charge with tube diameter 1

Q_{a2} excess charge with tube diameter 2

d_1 tube diameter 1

d_2 tube diameter 2.

This linear dependence, however, cannot be used for conversions for practical situations because the technical flow conditions are different with different tube diameters.

CONCLUSIONS

Considerable electrostatic charges arise in pipelines during the pneumatic transport of loose material only if there is frequent contact of the particles with the wall of the pipe.

This can occur when

- the loose materials are fed into the pneumatic system (input

point),

- bends, angles, branches, baffles or sensors are built into the pipeline which increase the frequency of contact of the particles with the pipe wall,

- the pipe has rough surfaces on the inside or if the pieces of pipe are not precisely fitted together.

In straight pipes only insignificant electrostatic charges occur.

Fine-grained materials become more highly charged than coarse-grained materials. This can be attributed to the greater surface per unit of weight for the fine-grained materials and their better ability to fly. Both factors, large surface area and good ability to fly, enhance contact intensity and frequency.

During pneumatic transport of loose material there arises a charging maximum at a certain dust concentration depending on the flow velocity. Through appropriate choice of dust concentration and flow velocity the electrostatic charges can be minimized. This, however, requires tests in the technical installations, at least on models, resp., laboratory apparatus with the parameters recommended

at the end of this paper.

The dependence of the charging of the loose materials on the pipe diameter is considered to be linear. This fact, however, cannot be used for converting the excess charges because the flow conditions have a much greater effect on the contact frequency of the particles with the wall than does the pipe diameter, resp., the size of the pipe wall surface.

The largest specific excess charges on loose materials arise after the whirling up of the materials in pipes with lengths of from 5-50 cm.

It is possible to make inferences about the electrostatic behavior of flowing loose materials in technical installations if, for example, the laboratory tests are conducted in an apparatus with the following parameters:

Exciter tube: copper tube, 34-mm inside diameter and tube piece lengths 5, 5, 10, 20, 50 and 50 cm;

Flow velocity: 11, 22, 33 and 40 m/s;

Amount of dust: 1.5, 3, 6 and 9 cm³;

Flow time: 1.6 s. The values obtained with the named parameters should be appropriately evaluated as follows:

$q = f(\text{pipe length})$

$q = f(v)$, resp., $I_A = f(v)$

$q = f(c_{st})$, resp., $I_A = f(c_{st})$

This evaluation makes possible a summary of the electrostatic conditions to be expected during the pneumatic transport of loose material through pipelines in technical installations.

LITERATURE

- [1] Sach. R.: Elektrostatische Erregbarkeit von Stäuben. Der Elektro-Praktiker 28 (1974) H. 8, S. 252-256.

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