ELSEVIER

Journal of Electrostatics 47 (1999) 3-12

Journal of
ELECTROSTATICS

Electrical characteristics and mechanical behaviour of powders of the animal feeding industry

G. Artana [a], G. Touchard [b], F. Putier [c]

[a] Conicet-University of Buenos Aires, Fac. de Ingeniería, Depto. Ing. Mecánica, Paseo Colón 850, 1063, Buenos Aires, Argentina

[b] University of Poitiers, L.E.A., 40 Avenue du Recteur Pineau, 86022, Poitiers, France

[c] Tecaliman, rue de la Géraudière, BP 1627, 44316, Nantes Cedex 03, France

This article explains the laboratory and industrial tests we have undertaken with powders of the farm-produce industry. In the laboratory environment we have used three devices in order to measure different electrical properties of powders: the resistivity, the charge accumulation in a dielectric absorption test and the wall current appearing in a pneumatic conveyor because of the flow electrification phenomena. Thirty different products used in animal feeding have been tested and the results compared to other physical parameters. In an industrial environment experiments of charging process in industrial equipment used for mixing and pneumatic conveying have been made with five different products. We have correlated the results obtained in the industrial and laboratory environment. It is first clear that the prediction made with the laboratory measurement are in good agreement with those made in factory on a large scale device. More, interesting correlations have been pointed out between the mixing capability of products and the results obtained from the flow electrification tests. Thus, our results seems to indicate that from the electrical characteristics of the product it could be possible to make predictions about the mixing quality of products in industry prior to other analysis.

1. INTRODUCTION

Powder materials are involved in many industries (chemical, pharmaceutical, farm-produce, ...) requiring a large control of their mechanical behavior. However it seems not clear which is the set of measurement methods and which are the physical properties that best enable to predict the mechanical behavior of powders when they get in motion.

The powders are difficult to be classified as solids or liquids. When there is no movement of particles they have solids characteristics but when they move they behave much more as fluids. In this article we are interested to better understand the behavior of the powder in the last condition.

For a certain volume, the surface to mass ratio of powders is enormous when compared with the same volume of a solid material. As many electrical phenomena are surface phenomena

PII: S0304-3886(99)00026-1

the transfer of charges should be magnified in powders. So one would expect when particles are not too heavy and with a large charge relaxation time constant that the electric forces could have a significant influence in their motion. In this aspect, though a lot of work has already been carried out to characterize the electrical properties of such materials [v.g.: 1-7] still the influence of electrical characteristics on mechanical properties remain difficult to predict.

In farm-produce industry small quantities of additives are added to a support. Both products are granular materials and should be mixed homogeneously. However once product is mixed it passes through different operations and a demixing of the products may occur. As a result, the bags obtained at the end of the process may show inhomogeneities in composition in the bag itself or between bags of a same mixing process. This phenomenon is worrying, as animals must receive the same quantity of additives. More it has been noticed that this effect vary with the different additives and the different supports.

The objective of this work was to analyze if some electrical parameters can be correlated with some mechanical properties of the powders like segregation and to analyze the suitability of electrical measurements to select the support that is more convenient to be used with the different additives in order to obtain an homogeneous product.

The article is organized as follows: First we describe the experimental methods we have used to electrically characterize a set of powders in the laboratory. These experiments use devices based on a ventilated bed and on a pneumatic loop. Then a group of experiments have been undertaken in an industrial environment. They concern measurements on a section of a pipe of an industrial pneumatic conveyor and results obtained from a probe inserted in an industrial mixer. These results are finally correlated with the characteristics of homogeneity of the product obtained from the industrial process.

2. EXPERIMENTAL STUDY

The set of powders we have tested are used in the farm-produce. It was composed of 30 different powders for the tests undertaken in a laboratory environment and from this group 5 different powders have been selected to undertake the measurements in an industrial environment.

For these powders the mean particle diameter belonged to the interval 7μm to 900μm and the mass density was between $0.2 g/cm^3$ and $1.4 g/cm^3$.

We describe in next paragraphs the two groups of experiments that have been undertaken, those made in a laboratory environment and those in an industrial one.

2.1. Experiments in a laboratory environment

Three kinds of measurements have been made in a laboratory environment: resistivity, charge storage capability in a dielectric absorption test and the wall current appearing in a pneumatic conveyor because of the flow electrification phenomena. These measurements have been undertaken in the laboratory with the same devices and measurement protocol as described in a previous work [7].

2.1.1. Measurements in a ventilated bed

We have measured in a ventilated bed the resistivity and the relaxation of charges in a dielectric absorption test of the powders.

The cell used in our measurement is shown in Figure 1. It is composed of a body made of Teflon ① inside which there are two porous planar parallel circular electrodes ③, the lower one being the top of a pressurization chamber. Powder is placed between these electrodes (electrode diameter is 50 mm) and dry air flows from the chamber through the lower electrode, the powder, the upper electrode and exits to the atmosphere in the upper region. For the resistivity measurement the upper electrode is connected to a voltage source and the lower one is grounded through an electrometer.

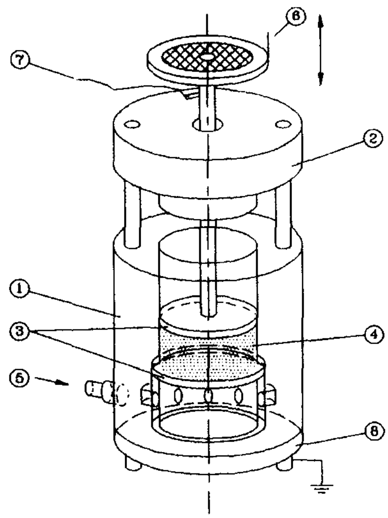

Figure 1. Cell of Measurement: ① Body in Teflon, ② Guide with ball bearing, ③ Porous electrode, ④ Powder, ⑤ Inlet of air flow, ⑥ Support for weight application, ⑦ Voltage supply connection, ⑧ grounded metallic support connected to the chamber and the lower electrode.

For the dielectric absorption test the upper is connected to a HV source and the lower one is grounded. When a high electric field is applied between the electrodes, the powder will get polarization charges and free charges. When disconnecting the source from the electrode a decreasing current may flow through a discharging circuit in parallel with the cell. If the powder has a resistivity high enough, the curves representing this current as a function of time (recorded with a data acquisition system) show initially a very clear exponential decay and after some time a residual current. We can associate the first part as corresponding to the relaxation of polarization charges and the rest to the relaxation of free charges. The integral of the residual current in time give as a good idea of the magnitude of these free charges.

2.1.2. Measurement of the powder charging in pneumatic transport

A schema of the experimental device is shown in Figure 2. The equipment is composed of three different vessels, upper (1), feeder (2) and lower (3). A set of valves (4) and (5) enable to link vertically the feeder vessel with the upper vessel (when introducing the powder in (2)) or with lower vessel (when making the measurements). The powder is pneumatically conveyed with nitrogen from the lower vessel to the upper one through the pipes. The top of the upper vessel is made of porous brass so that the air exits but not the powder. The particle flow rate is determined by operating the lower valve and if necessary we introduce vibration to help the powder to fall to the lower vessel. The development of the process of flow electrification is analysed by measuring the current on a part of pipe (6) made of stainless steel and electrically insulated with PTFE insulators (7) from the rest of the equipment. The current obtained with a picoammeter Keithley 642 (8) connected to a Keithley data acquisition board inserted in a PC computer (9) is integrated in time to obtain the total charge. The experiments were undertaken in the disperse regime of the diphasic flows. This was achieved by adjusting these valves to obtain a very large ratio of gas flow rate to powder flow rate.

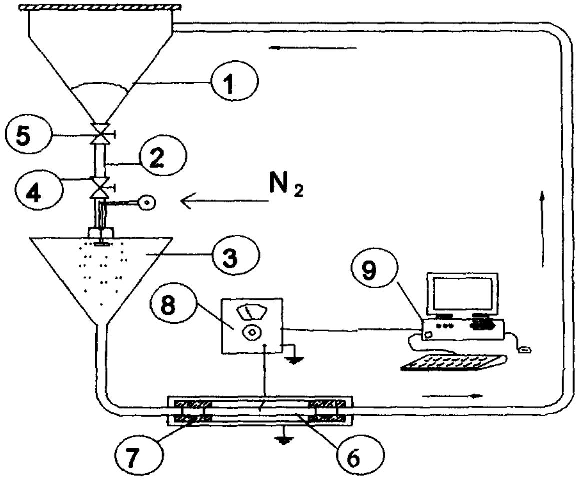

Figure 2. **Pneumatic conveyor experimental equipment.**

2.2. Experiments in an industrial environment

From the 30 products tested in a laboratory environment, 5 were selected as representative to undertake industrial tests. These products are in fact additives that are generally added to supports for animal feeding. Two concentrations of products were studied 0.2% and 20%. We made two kind of kind of experiments with these products: experiments in an industrial mixer and experiments in an industrial pneumatic conveyor. Clearly, for the 0.2% concentration no effect of additive was noticed on the electrical measurements, but for the 20% concentration variations were significant.

2.2.1. Experiments in an industrial mixer

First we measured in an industrial mixer, the current generated during the mixing process on a probe placed inside the mixer. The sensing part of the probe was placed in such a position that it was in contact with the mixing powder but not damaged by the rotating blades. The movement of the powder during mixing produced a wall current in the sensor that flowed through an electrometer to earth. This current was recorded with a data acquisition system. Figure 3-4 shows the experimental device.

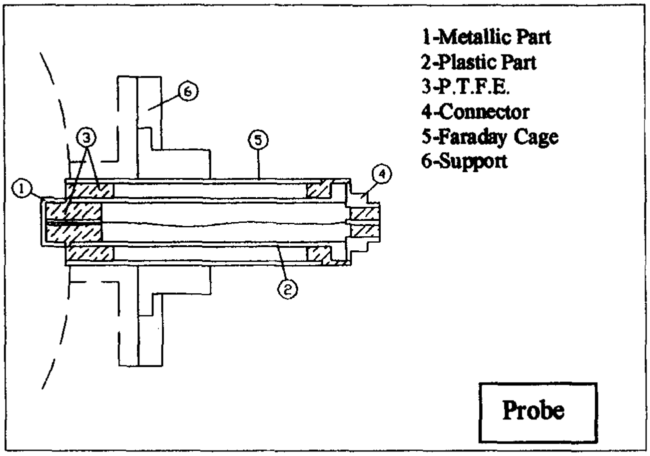

Figure 3. Schema of the probe

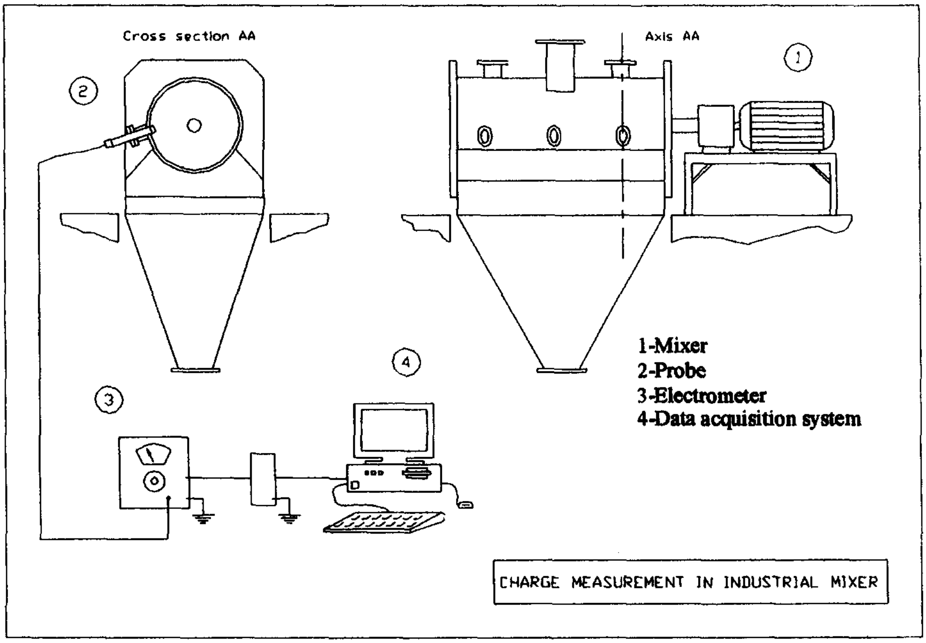

Figure 4. Experimental set up for measurements in the mixer

2.2.2. Experiments in an industrial pneumatic conveyor

The second kind of experiment was made on an industrial pneumatic conveyer where powder flowed in a disperse regime with dry air. Figure 5 shows the factory installation. Powder coming out from the pneumatic conveyor (about 45 m long) was weighed prior to be introduced in the mixer, then discharged to a storage vessel to finally pass through a packaging device. We replaced a part of the pipe of the pneumatic conveyor by another of the same material (stainless steel), diameter (10 cm) and length (1 m). This part was well insulated from the rest of the conveyor by dielectric materials (Teflon) and surface conduction was prevented by flowing dry air around the pipe (Figure 6). An external metallic cylinder of the same length acted as Faraday pale. We measured the wall current during the flow of product with an electrometer and recorded our results with a data acquisition system.

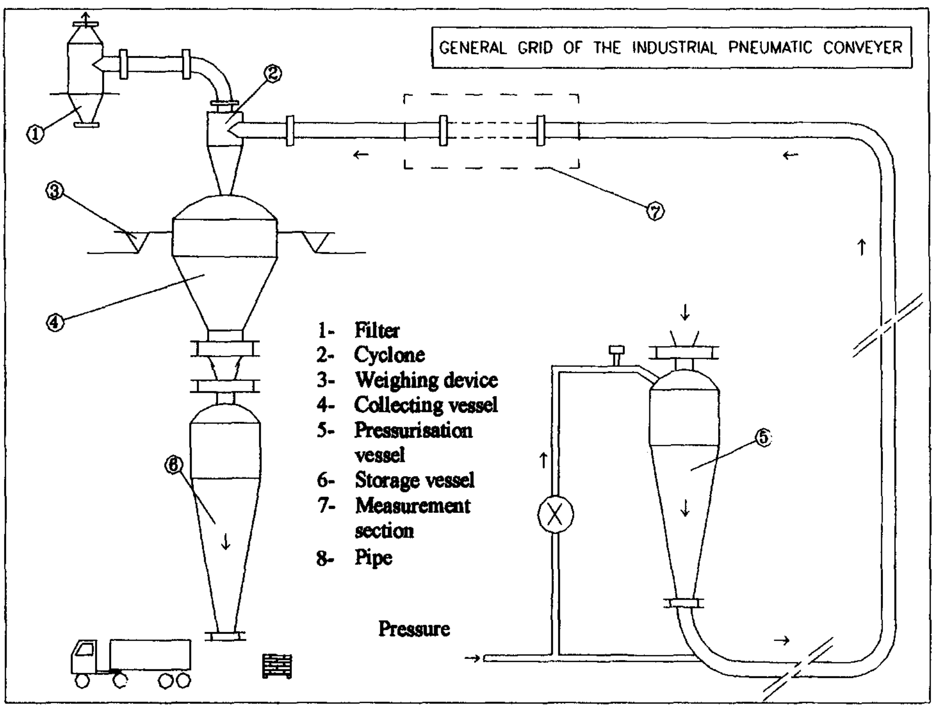

Figure 5. Industrial Set up

After all experiments powders coming directly from the mixer, from different bags and from different parts of a same bag were sampled. Then in laboratory the variation in mixing homogeneity has been measured.

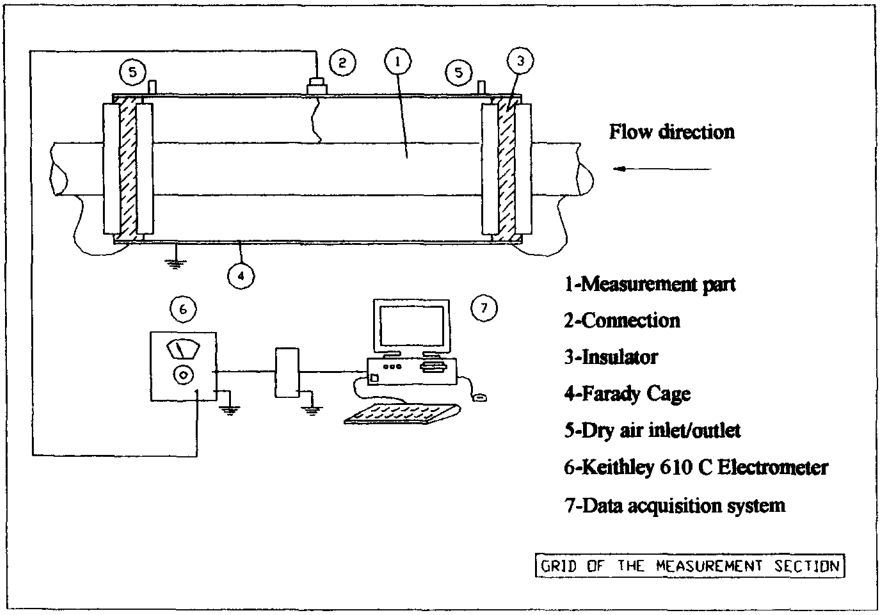

Figure 6. Device for flow electrification measurements

3. ANALYSIS OF RESULTS

3.1. Correlations between laboratory tests

With the data obtained from the 30 samples, we analyze the correlations of the electrical resistivity, the charge storage capability obtained from the dielectric absorption test and the charge per unit mass separated by flow electrification obtained from the pneumatic conveyor test.

We can see Figure 7 that the charge by flow electrification in pneumatic conveyer generally increases when the electrical resistivity increases except for five products, more it seems that we have two families, one with a large increasing and the other smaller. Like in [7] the correlation considering the whole data is very poor but however it should be pointed out that all the results are behind a 45° line.

On Figure 8 capability to store charge is compared with resistivity, it seems that no clear relation exists between these two parameters. One would expect that if charge generation were constant for all the materials the worst materials to relax would be those with higher resistivity. As no strong corelation exist between the results of the dielectric absorption tests and the resistivity, it seems that the generation of free charges is different for the different materials considered in our work.

On Figure 9 we have plotted the flow electrification chargeability in terms of the charge stored, even if again no clear correlation exist (like in [7]), however nearly all the results remain under a 60° line. More surprising is the correlation that appears between the conductivity and the density of the product (Figure 10). As dry air is rather insulating, it would be normal that the conductivity of powders compared to apparent density has a correlation, but what is strange is that the density of the material used to make the powder itself seems to have also a correlation with the electrical conductivity of the powder.

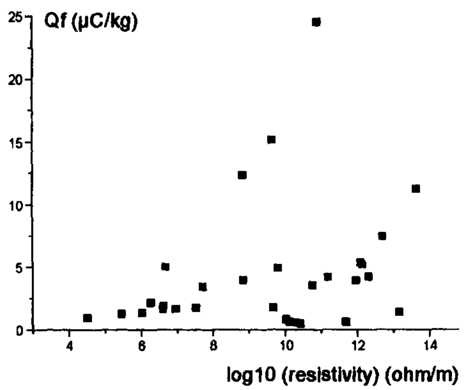

Figure 7. Flow Electrific. vs resistivity

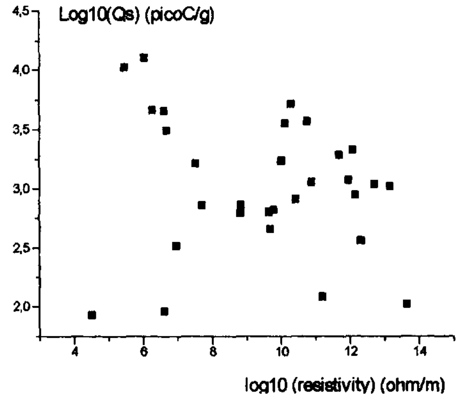

Figure 8. Stored charge vs resistivity

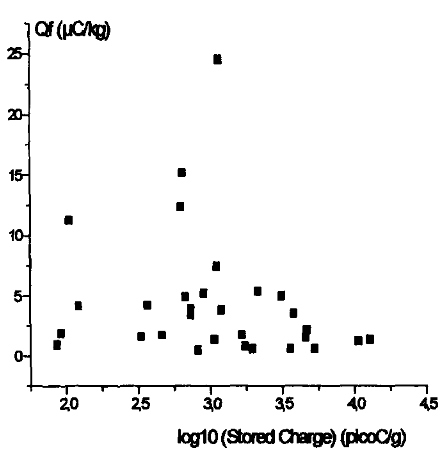

Figure 9. Flow elec. vs stored charge

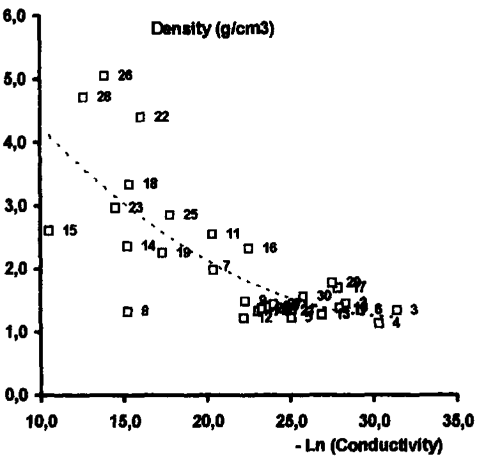

Figure 10. Density vs conductivity

3.2. Correlations between industrial experiments

Correlation between the flow electrification of the product in the conveyer and the current measured on the mixer probe is given Figure 11. The correlation is also rather good which is not so surprising as the charging phenomena are similar.

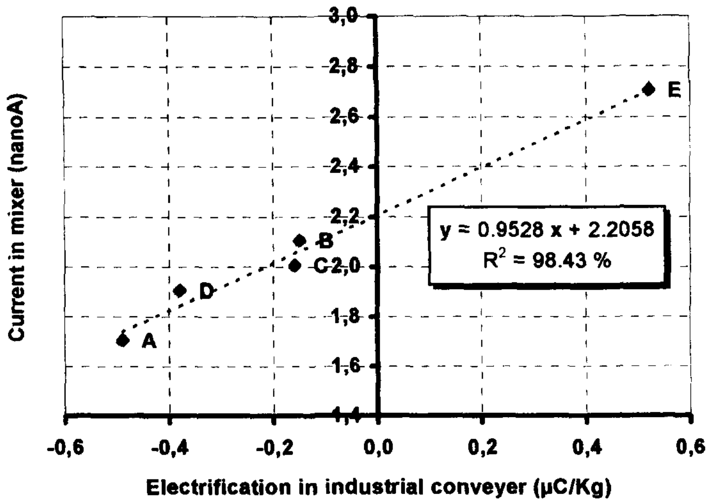

Figure 11. Correlation of pneumatic conveyor and mixer experiment

3.3. Correlations between laboratory tests and industrial experiments

The comparison between experiments made in the small conveyer of the laboratory and this industrial conveyer (not shown in the article) give a correlation of 99.57%, which is rather good. These results indicate that without introducing an important error the comparison of the charging of different powders in a pneumatic conveyor of an industry can be done directly with data obtained from the laboratory tests.

3.4. Correlation with homogeneity characteristics in the final product

The variation of mixing homogeneity was obtained with the sampling of powders from the bags and from the mixer immediately after a mixing process. A large value of this variation indicates less homogeneity and a tendency to the demixing phenomena or segregation.

We found that the mixing is well homogenous and stable for the products which generate charge electrification in opposition with the charge electrification of the support that holds the additives.

Indeed, if we consider laboratory measurements, the support used in the industrial environment tests generate in the pneumatic conveyer a charge of 2.7nanoC/g, thus the product the most in opposition is product A then D, C, B, and E. We can see Figure 12 that the coefficient of variation in homogeneity vary in the same way. This result is interesting as the capability of product to keep a good homogeneity with its support could be measured with a simple electrical measurement made in laboratory.

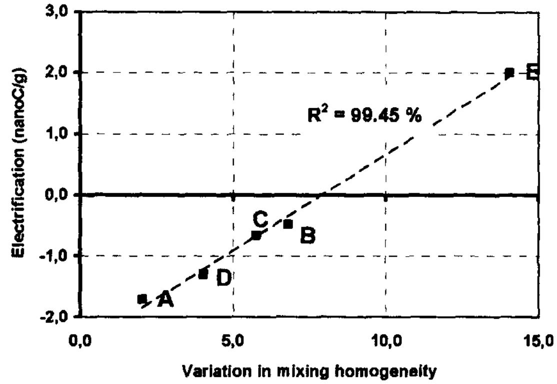

Figure 12. Correlation of flow electrification and variation in mixing homogeneity

4. CONCLUSIONS

This work indicates that there exists a strong correlation between the industrial and laboratory electrical experiments we have undertaken. So, if it is desired to compare the electrical behavior of powders processed in a same plant there should not be any reason to prefer to undertake measurements in factory than in laboratory.

From our measurements it seems that the demixing process is prevented when the support and the additives acquire charge of different sign when passing through a pneumatic conveyor or mixing process.

So, it seems possible to undertake electrical measurements in the laboratory to select the support more convenient to be used with the different additives to obtain a homogeneous product.

Because of the strong correlation of electrical measurements between industrial and environmental experiments, the simple laboratory tests could be undertaken prior to other complicated analysis.

Acknowledgements

This work has been done with the support of TECALIMAN under contract CNRS n°780286.

REFERENCES

1. Benmadda M. et al, Revue Phys. Appl., 22, (1987), 1071.
2. Boudalaa M. et al, Revue Gén. de l'Electricité, 8/91, (1991), 10.
3. Crowley J., Fundamentals of Applied Electrostatics, J. Wiley & Sons, NY, 1986.
4. Glor M., Electrostatics Hazards in Powder Handling, J. Wiley & Sons, NY, 1988.
5. Jones T., Ling J., Powder Handling and Electrostatics: Understanding and Preventing Hazards, Lewis Pub., Michigan, 1991.
6. Masuda H. et al, J. of Electrostatics, 2, (1977), 341.
7. Artana G., Sammartino S., Morin M.F., Touchard G., Proc. of the ESA 24th Annual Conf. on Electrostatics, Milwaukee, (1996), 96.