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DUSTING PROPERTIES OF INDUSTRIAL ALUMINAS

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Abstract

During later years much work has been done to reduce and to bring under control the external as well as the internal environmental problems in the aluminum reduction industry. To some extent attention also has been focused on dust problems and dusting of industrial aluminas. In the present study a correlation between the characteristics of four different industrial aluminas and their dusting properties has been sought. The study is based on laboratory examinations as well as on practical experience from a reduction plant. The purpose has been to find the determining parameters as regards dust generation, and to see how these are consistent with other quality criterias for alumina. In this way it may be possible both to specify the characteristics of an alumina with optimal properties under given conditions, and to see what will be the necessary adjustments on equipment and operating practises to minimise the dust problems.

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Introduction

For many years one of the severe problems in the aluminium reduction industry has been the emmissions of fluorine compounds and other pollutants to the external environment. In order to reduce these problems solutions have been worked out which often affects the internal working conditions in a negative way. These effects are often aggravated by demands of higher productivity, better utilization of process wastes, and other factors of economic significance.

During recent years, however, the internal working conditions have become a problem of growing concern. It can best be seen in the industrialized countries where employees due to a higher standard of living are paying far more interests in the comfort and the hazards of their working situations. The aluminium smelters have taken the consequence of this attitude and are therefore paying serious attention to all factors influencing the complex of both external and internal pollution problems.

A result of this development is increased demands on the quality of raw materials. Alumina as one of the major raw materials for the reduction industry plays an important role regarding environmental protection and internal working conditions. Because of the more common use of dry-scrubbing systems using alumina as the absorbing material for reclaiming of fluorine compounds attention has lately been focused on alumina dusting properties.

The dry-scrubbing process, especially for VS-Søderberg cells, turns the white, "clean" and nearly inert and non-hazardous alumina into a discoloured and unpleasant material containing fluorine compounds, sulphur dioxide and various carbon compounds. Alumina dust therefore has become not only a problem of level of comfort and "clean" dirt, but a question also involving health hazards.

Practical experience from a reduction plant with VS-Søderberg cells shows clearly that the alumina used varies widely with respect to dust formation tendency. The purpose of the present project is by a thorough study of these aluminas, supplied with laboratory examinations, to bring about which parameters are important for the dusting tendency. When more are known about the correlations between the alumina characteristics and their dust generating behaviour, and how these factors are consistent with other of the quality criterias for alumina, it should be possible to specify an alumina possessing optimal properties under chosen conditions. It should further be possib as well to see what will be the necessary adjustments on equipment and operating routines to minimize the dust problems.

Laboratory examinations

Four different aluminas with general characteristics as given in table 1, and for which the dusting behaviour in the reduction plant is well known, are included in the study.

A is a mineralized, high-calcined type (fluory) with a relatively high percentage of fines, but nevertheless no dust problems. This alumina, however, can not be used for dry-scrubbing and is also otherwise inconsistent with the quality criterias for the operating practice of this specific reduction plant.

B is a coarse-grained, low-calcined type (sandy) which generates but small amounts of dust and which otherwise is well suited for both dry-scrubbing and the reduction cells.

C is a fine-grained, very fluid, low-calcined type with a high percentage of small particles and which creates lots of dust problems, but is otherwise well suited.

D is a somewhat coarser and more calcined type from the same producer as C and with less dusting problems than C.

The cumulative size distribution curves, from 10 micron upwards are given in fig. 1.

Fig. 2 shows scanning electron micrographs of typical particles from these samples at 500 x magnification. The main difference to be seen is between A and the others. Alumina A consists of small, platy α-oxide crystallites arranged in a parallel way into domains of different orientation. This structure, giving a very rugged surface is characteristic for an alumina calcined with a mineralizer present. The three other aluminas are built up of highly coalesced pseudohexagonal crystallites showing the original gibbsite structure with a number of laminar cracks. The surface is still rugged, but nevertheless much more even than for A. This specially holds for alumina C.

In addition to the characteristics given in table 1 some other properties have also been examined. These are discharge flow velocity, electrostatic charging, dusting behaviour and impact strength. The results are summarized in table 2 and fig. 3 and 4.

The flow velocity was determined by discharging a chosen amount of alumina from the bottom of a small, circular, laboratory storage bin. Alumina A which was the least fluid gave well reproducible results. The other three, however, gave decreasing values by repeated testing of the same sample, until a steady flow was reached after four to five passages. This lack of reproducibility may be due to frictional electrostatic charging of the alumina particles.

To test this view, the electrostatic charging ability was determined. Again alumina A gave the lowest value and with good reproducibility, whereas for the others the charge increased and reached a steady value after three to four repeated tests with the same sample.

During this testing where samples did fall from some height into a Faraday box with wiremesh lid it was observed that when parts of alumina A, due to the fall were forced through the wiremesh lid it generated the far biggest dust cloud of the four aluminas. This is in clear contrast to the pot-room behaviour, and is due to the desagglomeration caused by forcing the alumina through the screen lid.

Fig. 3 shows pictures of the dust cloud raised when samples of alumina were suddenly released from a spring-loaded disk at the lower part of a wide, vertical, glass-tube through which there was passing an air stream at a velocity of about 0.4 m/sec. Calculation of terminal velocity due to gravity of particles with density 3.6 g/cm^3 shows that the mentioned velocity is sufficient to carry away particles with diameters less than approximately 65 microns- equivalent to minus 230 mesh.

The dusting behaviour index given in table 2 was measured by passing a given amount of air through a train of three washing bottles for a certain time, the first bottle containing a weighed sample. The first number is the amount of alumina found in the second bottle and the last number the amount carried over to the third. For alumina A the carry-over was neglectable due to an extended tunneling effect, caused by a marked tendency to agglomeration resulting in a high hanging angle.

This tendency to agglomeration for alumina A was clearly demonstrated in the impact strength test, as can be seen from fig. 4. In this test,samples placed in closed glass jar, are subjected to impacts from the blades of a fast rotating propeller.

Screen analysis gives a measure of break down and agglomeration. The curves in fig. 4 gives the ratio of fractional weight percent (after and before) versus grain size. For alumina A the agglomeration effect is demonstrated by a more than halving of the amount of small particles with a corresponding increase in particles greater than about 70 micron. Also alumina D shows a certain tendency to agglomeration. The break down of large particles is almost the same for aluminas B, C and D.

From fig. 1 it is seen that alumina A and C have a relatively wide size distribution and high percentages of fines, whereas B and D have a more narrow distribution with smaller percentages of fines. Calculations of terminal gravitational velocity shows that particles smaller than about 70 microns can be carried away at air velocities greater than about 0.5 m/sec. once they are whirled up.

This velocity is of the same order of magnitude as the ventilation and convection air streams met near the cells. Fig. 5 gives an impression of the whirl-up pattern during charging of alumina.

Based on grain size alone one should, thus expect the dust generation to be most pronounced for alumina C and to decrease in the order C-A-D-B. This sequence is not followed, however, because of the marked tendency to agglomeration found for alumina A and to some extent for D. This leads to a behaviour as if the particles in these aluminas are larger than the screen analysis really indicates. If the formed agglomerates disintegrates in one way or another, however, the dust generating behaviour will again be mainly determined by the amount of fines present, as was observed for alumina A in the electrostatic charging measurements.

The agglomerates are held together partly by van der Waals forces, partly by electrostatic forces and for alumina A probably to some extent by pure mechanical interlocking.

The flow properties of the alumina also plays a role in regard to dust generation. A low-fluid particle system will usually generate but little dust, as can be seen for alumina A, because of its tendency to form agglomerates and settle. As can be seen for alumina B, on the other hand, a high-fluid system will not necessarily generate large amounts of dust if only the particles are coarse enough. If, however, the system has both a high fluidity and high percentage of fines, as is the case with alumina C and also some less extent with D, it will also be highly dusting.

Practical observations

In a study considering the alumina alone, laboratory examinations may give sufficient knowledge of the dusting properties of the material as such, but will not always give the right picture of what happens in the reduction plant.

On its way from the calcining furnace to the reduction cells the alumina will pass through series of handling, storage and transport operations, all of which will cause the alumina to separate into fractions according to the particle size distribution. Alumina filled into bins will, if no special precautions are taken, separate with the coarse fractions toward the outer parts and the fine fractions towards the middle of the bin. This separating tendency increases,both with the spread in size distribution and the degree of free flow. The degree of free flow, further, is higher the lower the degree of calcining is.

When the alumina later is charged to the cells, more or less separated into coarse and fine fractions, it will generate more dust than if it was charged as a homogeneous mixture. In addition the operators of the plant will normally judge the dusting to be even more worse because in their minds the "bad" periods will count more than the "good" ones.

Measurements taken in the actual plant shows the effect of such separation. Average dust concentrations in the working area while using alumina C (containing much fines and considered to separate easily) varied from 18 to 32 mg/m^3, whereas corresponding figures for alumina B (a coarser material with less tendency to separation) were more equal, verying only from 13 to 15 mg/m^3.

The equipment and operating practises in the plant also highly affects the amount of dust generated from a given alumina. Most important is the alumina charging and the crust breaking equipment and how these are adjusted and operated. In the actual plant the crust breaking is done by a wheelbreaker and the alumina is charged from a truck with an air-slide device. Used at high capacity these equipments will generally increase the amount of dusting. Further, when an air-slide is used for charging low-fluid alumina more air will be needed to keep constant the amount of material charged to the cells per time unit, thus affecting the dust generation.

Lastly the general condition of the cells will also be of great importance. Open bath for instance creates a tremendous rise in dust generation. This is mainly caused by the higher air velocities created by the high temperatures on the surface.

The importance of both cell conditions and proper operational handling can be illustrated by some measurements taken while using alumina C. In a period with relatively poor cell conditions and improper operational practises, the average dust load in the working area varied from 18 to 32 mg/m^3 while corresponding figures from a better period were 9 to 20 mg/m^3.

In order to get an idea of the variations in dust generation with regard to different cells and different operators doing sweeping of alumina on the cells, "instantaneous" dust samples were taken at different points at the cells, see fig. 6. The dust was collected on double stick tape during a cycle of crust breaking, alumina charging and sweeping, whereafter the particles were classified and counted from scanning electron micrographs. From the results given in fig. 7, considerable variations can be seen from "good" cells to "bad" cells, and the variations found between the operators show the importance of how the job is carried out. The results also showed a surprisingly small segregation in size between position 1, 2 and 3. The fact that quite large particles were found in all three positions shows the air velocity due to ventilation and convection is high enough to carry away even relatively coarse particles.

Practical experience from reduction plants shows that the quality and properties of the alumina used is of great importance with regard to dust generation. At the plant referring to, however, improvements of the same order could also be obtained by improving the cell performance and operational practice.

In order to minimize the dust generation one will have to both choose an alumina with good characteristics in regard to dust generation tendency and to improve the operations. If the available alumina necessitates it the operational practices must be adjusted according to needs.

It seems today to be impractible to produce alumina without any fines and the transport and handling equipment therefore should be thoroughly checked and modified in order to prevent the separation into fine and coarse fractions. This is highly important for low-calcined aluminas.

At the actual plant the dust problems have been further accentuated after a dry-scrubbing system for reclaiming fluorine compounds has been taken into operation. Examination of the aluminas after passing through the dry-scrubber shows no mechanical breakdown of particles for the three aluminas B, C and D, which is suitable for dry-scrubbing. Regarding the alumina as such the attempts to reduce the dust problems therefore will in principle be the same whether a dry-scrubbing system is in operation or not.

Conclusions

The dust problems in the alumina reduction industry caused by alumina may be reduced partly by choosing the correct alumina, partly by adjusting equipment and operating routine to the alumina available.

As regards the alumina the following characteristics are essential:

Particle size. Coarse alumina with a minimum of fines, i.e. particles less than about 40 microns shows low dust generation tendency.

Particle size distribution. A narrow particle size distribution will reduce the tendency to fractionating during handling, transport, storage etc. and thus also reduce the tendency of dust generation.

Degree of calcining. Normally, the dust generation tendency will decrease with increasing degree of calcining. The degree of calcining should therefore be chosen in the upper range of what otherwise is in accordance with the demands of the specific reduction plant. Alumina calcined with mineralizer present seems to have somewhat smaller dust generation tendency.

The tendency towards use of low-calcined aluminas, caused by a more extended use of dry scrubbing and other operational factors, as well as a general attention to work comfort, will demand aluminas with better and more specific characteristics with regard to both particle size and also to degree of calcining. These demands will especially be emphasized by the operators of VS-Søderberg plants.

Table 1.

	A	B	C	D
True density g/cm^3	3.88	3.59	3.60	3.62
Spec. surface, m^2/g (N_2-adsorp.)	2.4	55	45	42
α-alumina, % (calculated)	80-85	25-35	27-37	32-42
L.O.I. 300-1000°C, %	0.06	0.37	0.75	0.25
Na_2O %	0.72	0.52	0.72	0.42
CaO %	0.061	0.010	0.037	0.015
Bulk density, stamped, kg/l	1.24	1.09	1.22	1.19
" " , unstamped, kg/l	0.93	0.89	0.94	0.95
Angle of Repose	38.0	35.0	32.5	32.5
Mean grain size, micron	60	74	47	64
+200 mesh (74μ) %	31	50	11	27
-325 " (44μ) %	29	10	47	20

Table 2.

	A	B	C	D
Discharge flow velocity, kg/min.	0.8	2.1	1.1	1.3
Relative electrostatic charging (see text)	1.6	4.0	2.5	3.3
Dust behaviour index (see text)	very low	25/0.2	58/4.6	47/0.9
Impact strength index (see fig. 6)	1.3/0.4	0.6/1.5	0.6/1.2	0.6/0.9

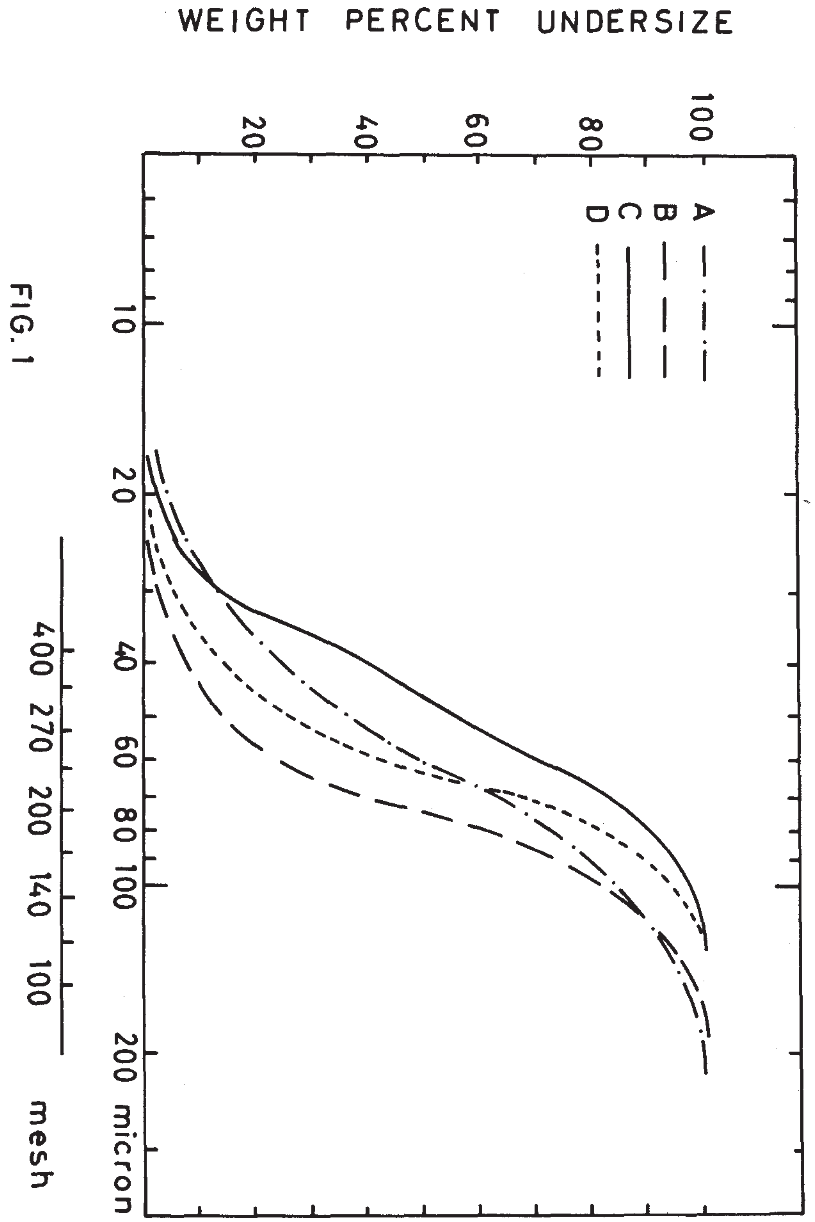
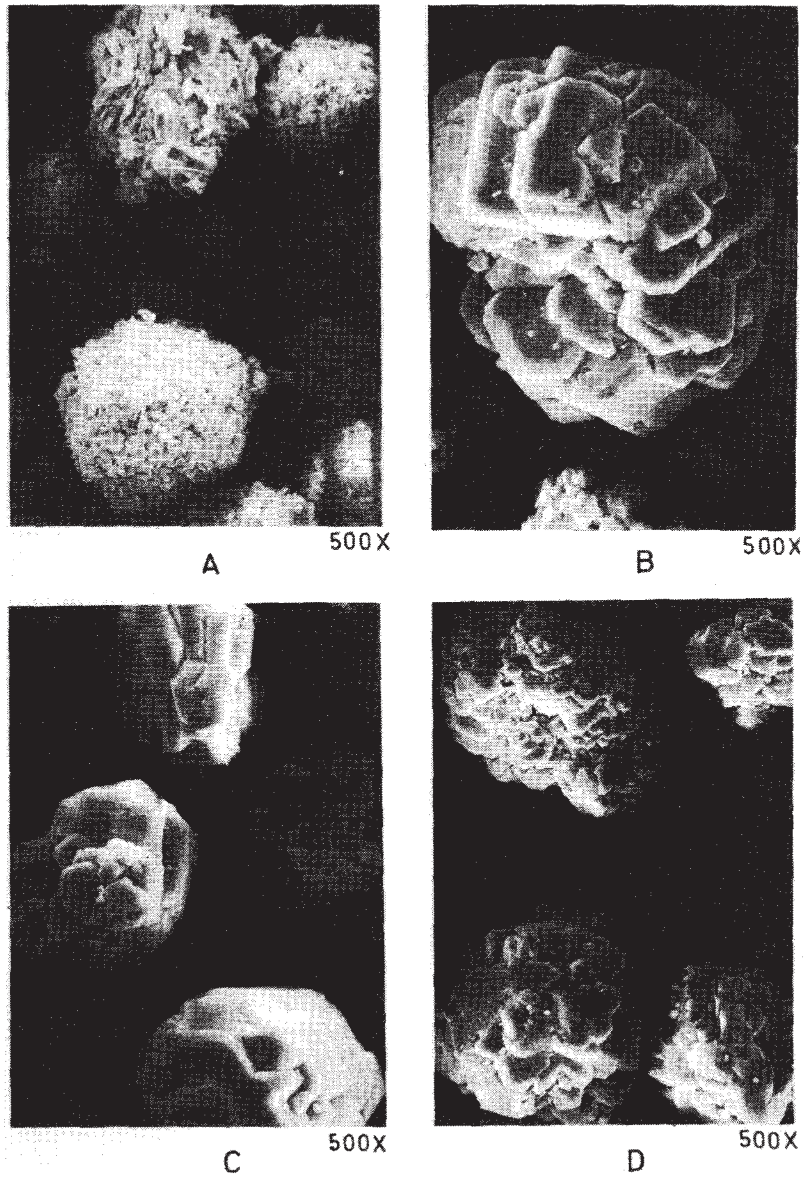


FIG. 1


A
500X
B
500X
C
500X
D
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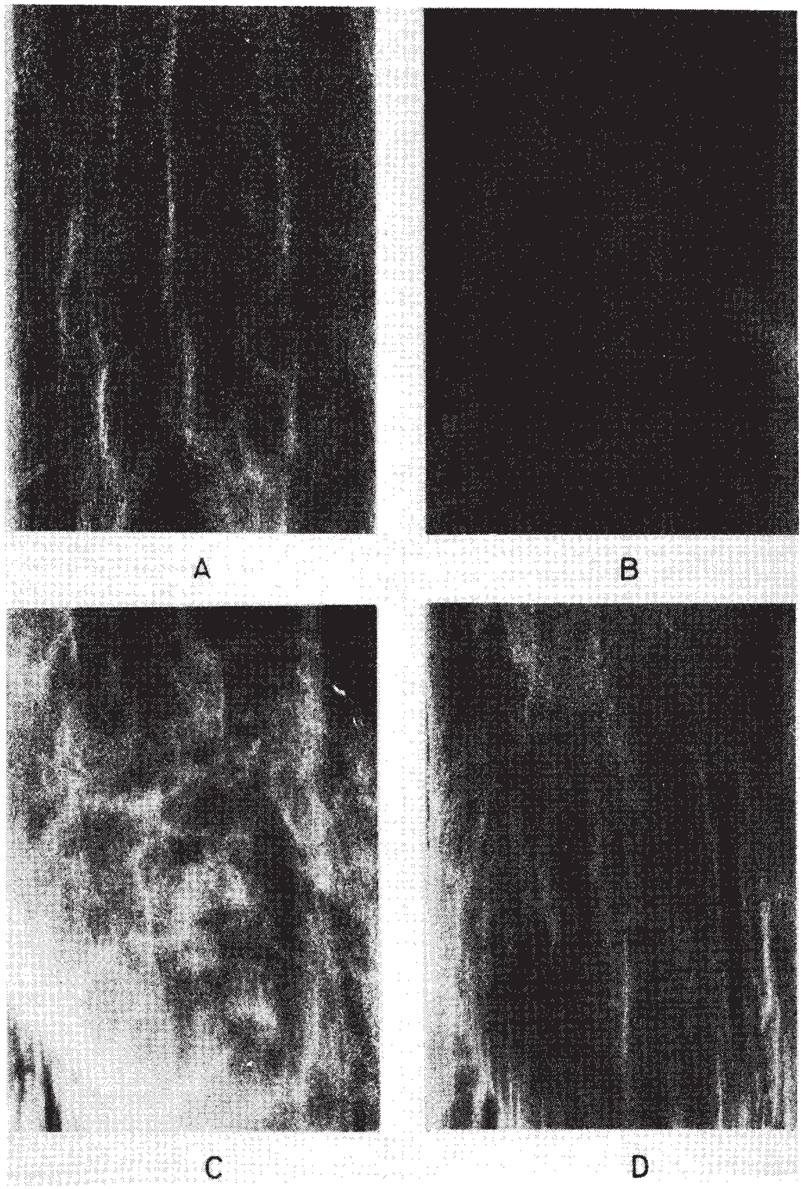
A
B
C
D

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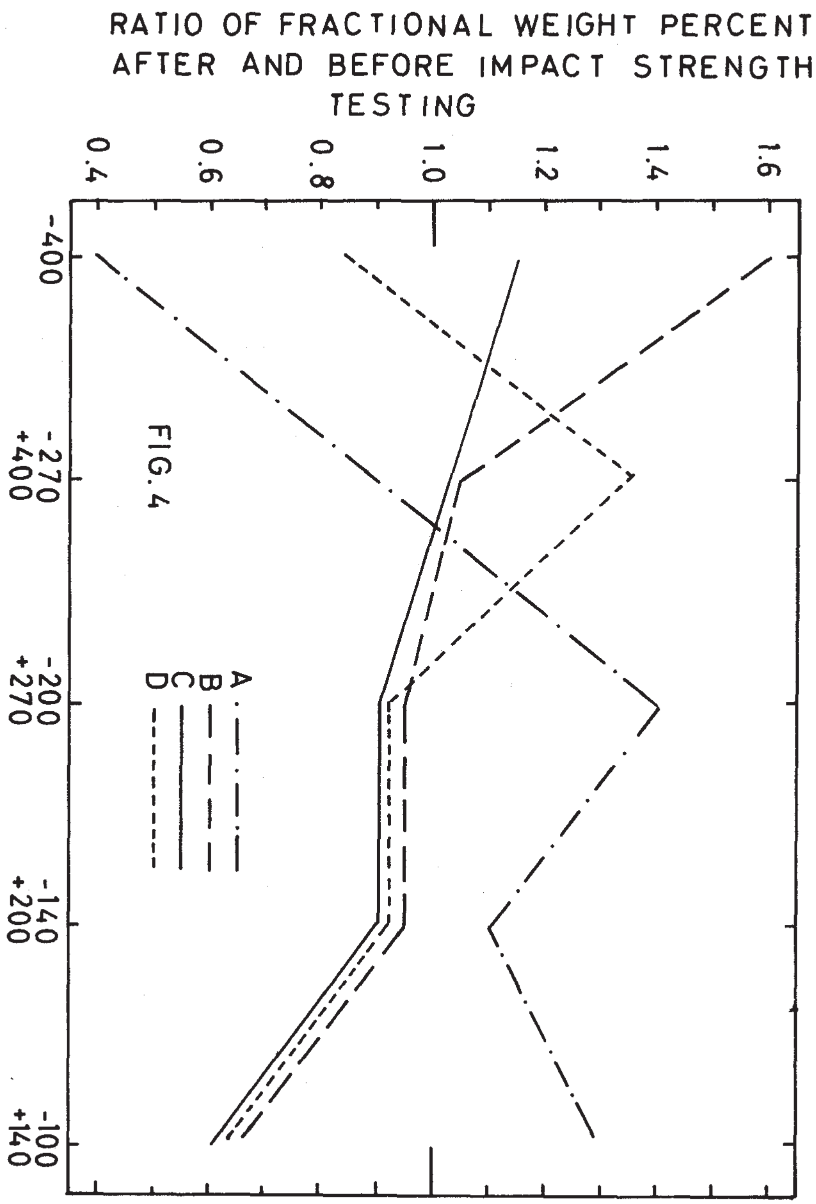
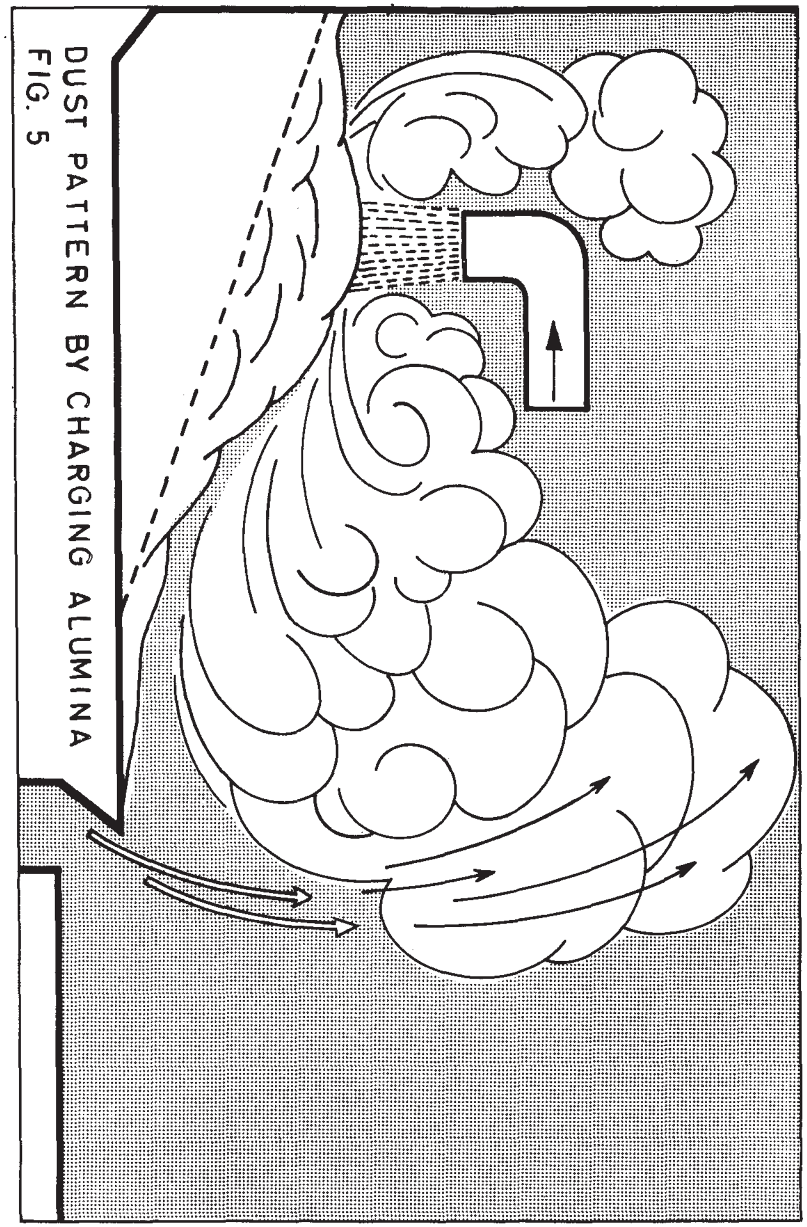
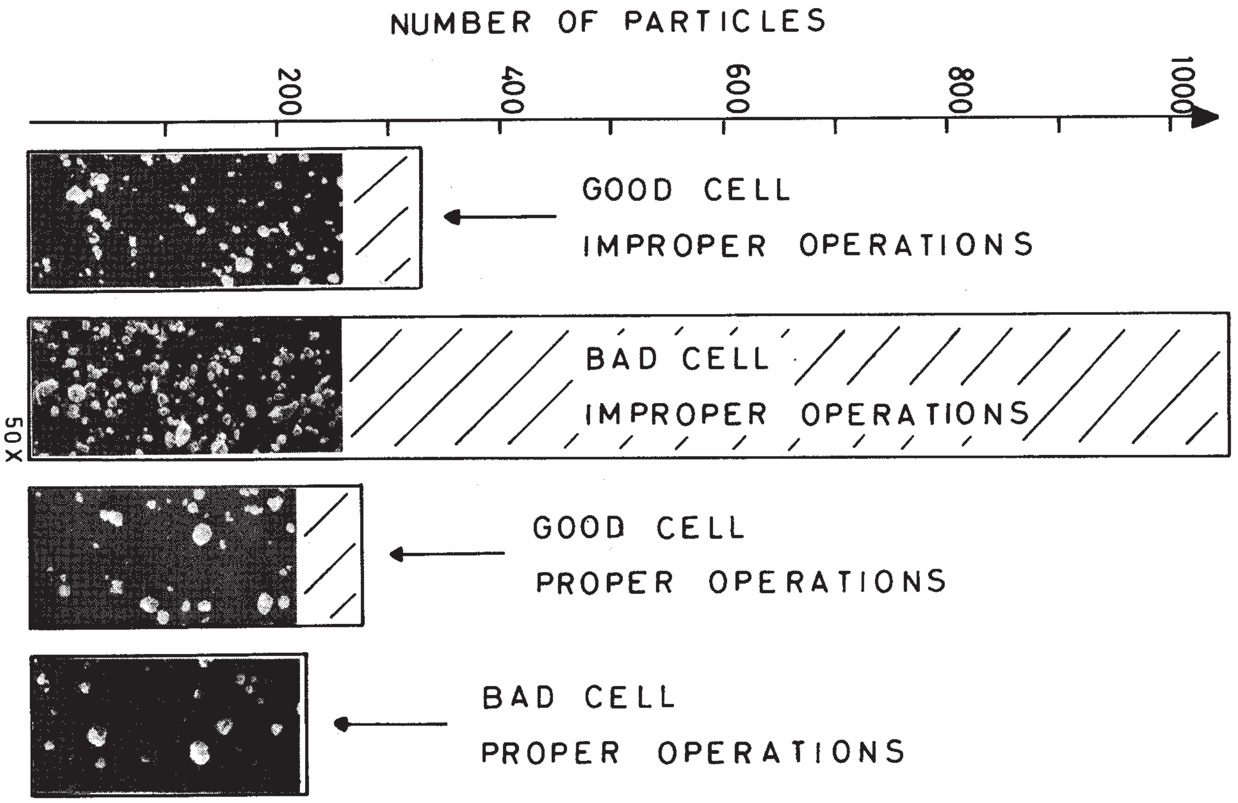


FIG. 4



DUST PATTERN BY CHARGING ALUMINA
FIG. 5



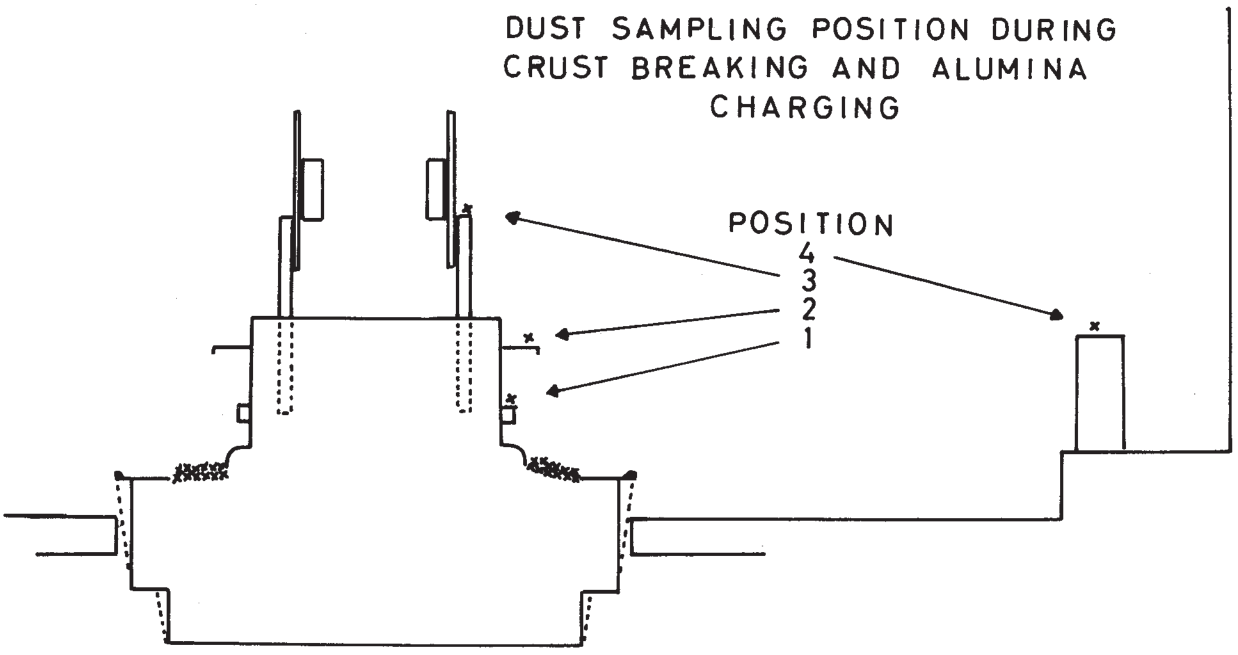

DUST SAMPLING POSITION DURING CRUST BREAKING AND ALUMINA CHARGING

FIG. 6