

MINERALS SEPARATION TESTS ON THE
SYNTRON DIELECTRIC SEPARATOR

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BACKGROUND

In March 1972 the Minerals Research Laboratory was visited by several representatives of the Syntron Division of FMC Corporation, Homer City, Pennsylvania. It was proposed by them that the MRL consider accepting, on a free loan basis for a specified time, a laboratory size apparatus designed primarily to separate mixtures of metals and/or minerals by means of their respective differential responses when passing through a field of alternating high voltage. This apparatus was called a Dielectric Separator. The MRL engineers present at the initial conference were told that FMC was desirous of obtaining additional information regarding the capabilities of the apparatus, and would be favorable to leaving it at the MRL for a period of time, allowing the MRL staff to freely decide what sort of experiments to try with it, within the capabilities of the device as it was constructed.

The MRL decided to accept the loan of the separator on this basis. It was felt that open-ended experimentation of this sort with a novel apparatus, having a record of some successful separations, was suitable for the MRL. Further, in light of some needs and problems faced by certain sectors of the North Carolina minerals industry, it would be of great value if the performance of the separator should happen to point toward a possible new direction to go in these areas.

The separator was in the hands of the MRL, on the loan basis cited, from July 1973 through March 1974.

DESCRIPTION OF THE DIELECTRIC SEPARATOR

The physical structure of the separator is easily understood by reading the manufacturer's descriptive material. This includes two publications, "The Theory and Operation of the Syntron MK-1 Dielectric Separator" and Instruction

Manual No. S-1000. Complete copies of both are appended to this report.

A quick description of the separator is nevertheless offered here.

The device has an overall length of about 30 inches, an overall height of about 12 inches, and a width of about 10 inches. Pages 2 and 5 of the instruction manual furnish line drawing illustrations. There are five main components:

1. Vibratory feeder to meter the material to be separated,
2. Enclosed inclined deck wherein the particles encounter the separatory electric field,
3. Vibratory drive beneath the deck to impel the particles,
4. Plastic canopy covering the deck (2) to protect the operator during operation,
5. Control box.

The two vibrators can be adjusted to vary rate of particle movement, and the voltage of the electric field is also variable.

The deck (2, above) has a floor and ceiling, both of acrylic plastic, with a clearance of less than 1 inch. Both floor and ceiling have imbedded in them flat strips of copper in a sort of herringbone pattern, as illustrated. The strip patterns of deck and ceiling are identical, and coincide in an over-under relationship. When the electrical field is activated, the particles must move through concentrated vertical electrical field barriers existing between the upper and lower pattern of copper strips. Particles which are relatively unresponsive to the field are vibrated downhill along the center of the inclined deck, coming out as "center effluent" (page 2, instruction manual). Other particles, according to varying response, report to the side discharges as "middling effluent" or "outer effluent." Delineating a "rougher section" and two "cleaner sections" of the deck are two rows of vertical triangular plastic pillars extending the full height of the chamber ("mechanical flow directors" and "effluent splitters").

These create longitudinally, a center zone and two side zones. Otherwise, the deck surface is flat and uninterrupted between the feed intake and discharge apertures.

Variable test conditions which can be effected are as follows:

1. Voltage output (field intensity), central deck area,
2. Voltage output (field intensity), side deck area,
3. Rate of vibrated feed flow along the deck,
4. Rate of vibrated feed flow into the deck.

The inclination of the deck is not variable unless the entire unit, canopy and all, is tilted.

SELECTION OF TEST SAMPLES

Several MRL engineers ran casual, impromptu tests on the separator, and one engineer ran a more formal series as a project (J. Philip Neal Project No. 22) which is the principal topic of this report. Within the framework of this project, certain considerations influenced the selection of minerals to be tested and the manner and procedures of the tests.

To reduce the number of mineral combinations to be tried, it was decided that any minerals separation now being commercially performed by magnetic separation had little chance of being improved on by the Dielectric Separator. This eliminated ores containing ferromagnetics, garnet, biotite, hornblende, ilmenite and the like.

Any combination of minerals or materials not found in nature, or at least in the flowsheet of a minerals processing plant, was also eliminated.

In instances where mineral ores must be fine-ground (100 mesh or finer) to achieve liberation, the separator was judged to have poor prospects of success.

Having narrowed the field with these considerations, attention was then directed to mineral combinations occurring in North Carolina, and to possible

needs and problems of North Carolina mineral processors. The following list of possibilities emerged:

1. Chromite - olivine
2. Serpentine - olivine
3. Calcite - quartz
4. Zircon - quartz
5. Zircon/calcite - talc
6. Phosphate - quartz
7. Potash/soda/calcium feldspar - quartz

At a meeting of the MRL Advisory Committee, and also by subsequent communications, approximately eight North Carolina mineral producing companies were notified that the MRL had the Dielectric Separator on hand and would be glad to run tests on any samples submitted or suggested. This did not result in the appearance or trial of any additional material beyond the foregoing list.

As a preliminary to running tests on the separator at the MRL, it was desired to obtain precise quantitative data on the operating conditions of prior tests. Page 19 of the attached technical paper lists a number of separations described as successful. Several direct requests were made of Syntron for such data, but none was received. Test conditions at the MRL were therefore set up empirically, employing the guidelines in the instruction manual.

TESTS ON A FELDSPAR-QUARTZ MIXTURE

Tests on a feldspar-quartz mixture were the first undertaken because of the great economic and environmental advantages which could result. The wet (flotation) process now used in feldspar beneficiation, while effective, is such that the industry would probably welcome a change to some process simpler, cheaper, safer (no HF), and invulnerable to challenge as a stream contaminant - provided it was of equal efficiency.

Ingredients of the test sample were as follows: perthitic potash feldspar ("K-spar"); oligoclase soda spar ("Na-spar"); and quartz. These were individually hand-picked in lump form, crushed, and wet-ground to U. S. 30 mesh, screened on 50 mesh, and the 30-50 mesh fractions then run individually through a high-intensity batch wet magnetic separator to remove, as best possible, iron-bearing contaminants. The three samples were then dried, re-screened on 50 mesh, and combined. Table I gives data on each of three minerals and on the combined sample.

TABLE I
PHYSICAL & CHEMICAL DATA, MRL FELDSPAR SAMPLE NO. 4173

	% Wgt.	ASSAY				Theoretical Pct of "Free Qtz"
		% K ₂ O	% Na ₂ O	% CaO	% Fe ₂ O ₃	
30-50 Mesh Perthite (K-spar)	42.9	12.8	2.2	0.06	0.05	5.4
30-50 Mesh Oligoclase (Na-spar)	35.7	0.9	8.6	2.59	0.05	8.9
30-50 Mesh Quartz	21.4	0.02	0.04	-	0.04	99.5
TOTAL (Calculated)	100.0	5.8	4.0	0.95	0.05	27.1
Combined Spars Minus Qtz. (Calc.)	78.6	7.4	5.1	1.21	0.05	7.0

Discussion of Table I

The "free quartz" data is derived from the known chemical assays of the three feldspars in pure form. Pure microcline will assay 16.9% K₂O, pure albite 11.8% Na₂O, and pure anorthite 20.1% CaO.

At the inception of tests on this mixture, the greatest degree of physical separation occurred with both rougher and cleaner fields advanced to maximum, and this was done in most cases. Each test used 50 grams of feed. Vibrator intensities were adjusted to keep test throughput time between 4 and 6 minutes.

The first three tests to be cited are those on pure quartz, pure K-spar and pure Na-spar. Table II gives data on these.

TABLE II

Test No.	Mineral	TESTS ON UN-MIXED FELDSPARS AND QUARTZ					Percent Outer Effluent	Assay, Outer Effluent Only		
		% Center Throughput	Assay, Center Throughput			%		%	%	
			% K ₂ O	% Na ₂ O	% CaO	Percent Middling	% K ₂ O	% Na ₂ O	% CaO	
13	Qtz.	95.5	-	-	-	4.5	-	-	-	
14	K-spar	68.3	12.7	2.2	0.04	17.2	14.5	12.8	2.2	0.05
15	Na-spar	50.6	0.8	8.6	2.39	5.3	44.1	0.9	8.7	2.37

Discussion of Table II

So far as the feldspars were concerned, there was no significant difference in assay between the test product which ran straight through and the one which showed maximum response; therefore, no assay was run on the so-called middlings. The quartz showed so little response that no assay was run on products.

In evaluating the above data, all that can be said is that differing percentages tend to report as the three products. The quartz might be said to exhibit a relatively uniform non-response.

Several other tests using the mixed feldspars and quartz, which were untreated in any way after the wet processing and sizing described, resulted in a degree of non-differentiation comparable to that seen in the data of Table II. It was then decided to pre-treat the particle surfaces of each 50-gram sample in varied ways prior to running it through the separator. Table III gives data on certain tests showing maximum apparent differentiation.

TABLE III

SEVEN TESTS WITH VARIABLES, FELDSPAR - QUARTZ SEPARATION

Test No.	Variable, Pretreatment	Center Throughput			Middlings			Outer Effluent					
		% Wgt.	% K ₂ O	% Na ₂ O	% CaO	% Wgt.	% K ₂ O	% Na ₂ O	% CaO	% Wgt.	% K ₂ O	% Na ₂ O	% CaO
17	Mixed with 25 cc 10% HF plus 1 g. CaCO ₃ , evap. in Pt dish	74.7	6.0	4.8	1.02	21.5	3.8	2.0	0.23				
18	As #17, subst. 1 g. LiCl for CaCO ₃	12.1	5.2	3.9	0.79	2.7	85.2	4.2	0.87				
23	As #17, subst. 2 cc 10% H ₃ PO ₄ for CaCO ₃	61.9	5.7	4.3	1.00	26.7	11.4	3.4	0.67				
23 A	Additives as #17, but stirred 2 min. in glass beaker with 100 cc H ₂ O, rinsed & dried.	30.9	6.1	4.1	0.88	14.1	55.0	4.6	1.03				
27	Stirred in glass beaker 2 min. with 200 cc of 10% HCl plus 0.2 g. of Al powder. Rinsed & dried. Separator input voltage reduced from 110 V. to 94 V.	33.4	5.3	3.5	-	15.8	50.8	4.6	-				
28	As #27, 0.2 g. CaCO ₃ subst. for Al. Separator fields cut from 110 V. input to 90 V.	16.7	5.6	3.9	0.88	18.6	64.7	4.5	1.03				
33	As #27 but sample heated, run thru heated separator in 2 min. (Feed & sep. = 40°C vs. about 19°C for Test 27) Separator input voltage 95 V	33.5	4.7	2.8	0.52	14.9	51.6	5.0	1.15				

Discussion, Table III

Among other variables tried with less differentiation (if any) than in Table III were the following:

1. Heating sample to 500^o C, then cooling to ambient temperature.
2. Drying with tetrasodium pyrophosphate.
3. Drying with HCl alone.
4. Drying with amine acetate.
5. Drying with KCl.

Drying a sample with NaOH rendered it sticky and impossible to run properly. In terms of differentiation, one of the best tests shown on Table III was the last one, No. 33. Table IV shows additional information on this test, derived from assays and other data in previous tables.

TABLE IV

CALCULATED MINERAL PERCENTAGES, PRODUCTS OF TEST NO. 33

<u>Product</u>	<u>Pct. of 50-Gram Sample</u>	<u>K-spar</u>		<u>Na-spar</u>		<u>Total Spar</u>		<u>Quartz</u>	
		<u>% Wgt.</u>	<u>% Recov.</u>	<u>% Wgt.</u>	<u>% Recov.</u>	<u>% Wgt.</u>	<u>% Recov.</u>	<u>% Wgt.</u>	<u>% Recov.</u>
Ctr. throughput	33	35	28	21	20	56	24	44	68
* Middling	15	56	19	31	13	87	17	13	9
Outer effluent	52	44	53	46	67	90	59	10	23
Mid. plus outer eff.	67	47	72	43	80	90	71	10	32
TOTAL SAMPLE	100	43	100	36	100	79	100	21	100

* Calculated by difference.

Discussion of Table IV

Figures given on percentages of the feldspars and the quartz in each product represent materials balances derived from the assays of the initial hand-picked minerals and the assays of the products.

Certain trends are observable. The K-spar reported in highest percentage to the middlings, while the Na-spar moved to the outer effluent. Maximum total feldspar recovery was in the outer effluent, which contained about 10% quartz and was over half the sample.

Electrostatic Separation on Feldspar

For comparison of the dielectric separator tests with a commercial dry electrostatic separation process of past record, figures are quoted, following, from a paper presented in April 1957 at the Annual General Meeting of the Canadian Institute of Mining and Metallurgy, Industrial Minerals Division. Author was G. S. Diamond, and the title was "Electrostatic Separation of Feldspar and Other Non-Metallic Minerals." This paper cites the commercial separation of feldspar and quartz by electrostatics in Keene, New Hampshire by Golding-Keene Company. Table V gives pertinent data (abridged) from this paper.

TABLE V

ELECTROSTATIC SEPARATION DATA, FELDSPAR-QUARTZ ORE

<u>Product</u>	<u>Wgt. Pct. of Feed</u>	<u>% K₂O</u>	<u>% NaO</u>	<u>% CaO</u>	<u>% Free Silica</u>
Feldspathic Product	54.1	9.3	3.6	0.3	13.0
Siliceous Tails	45.9	3.7	2.8	0.2	53.4
Total Separator Feed *	100.0	6.7	3.2	0.2	32.3

* Calculated from the preceding two lines, not in original paper.

It was reported that the separator feed was pre-heated to 350° F.

With respect to the feed to this electrostatic process, there was no information regarding assays on any mineralogically (relatively) pure feldspars in the ore, such as in Table I of this report. However, certain assumptions can

be based on known mineralogical relationships. Potassic and calcic feldspars blend only to a very limited extent in an isomorphic series; sodic spar does so with both K-spar and Ca-spar. Therefore, the CaO assays of Table V can be assumed to be part of a sodic spar in the anorthite-albite series (since pure anorthite and albite are rare). It can also be assumed that most (though not all) of the sodic content will be tied up in a soda-calcium spar. A crystalline K-spar in an economically-useable pegmatite will generally assay from 12.5% upwards to about 14.2% K₂O when liberated and concentrated to highest grade. The mathematics of such an assay will generally include an Na₂O percentage of perhaps 2% for this mineral, with most of the remainder free silica.

Making trial calculations with the foregoing in mind, a certain ratio of K-spar, Na-spar, and quartz of given assay appears likely. Table VI gives theoretical assays of the feldspar minerals and quartz comprising the feed to the electrostatic process.

TABLE VI

CALCULATED PROXIMATE MINERALOGICAL BREAKDOWN OF ELECTROSTATIC FEED
(Based on Table V Assay)

<u>Mineral</u>	<u>Assay</u>			<u>% Free Silica</u>	<u>Percent of Feed</u>
	<u>% K₂O</u>	<u>% Na₂O</u>	<u>% CaO</u>		
K-spar	13.8	1.8	0.02	3.0	47
Na-spar	0.9	9.7	0.80	8.0	24
* Quartz	0.0	0.0	0.00	100.0	29
Total Feed	6.7	3.2	0.20	32.5	100
Combined Spars Alone	9.4	4.5	0.28	4.9	71

* For easier calculation, assumed pure.

Discussion of Table VI

This data, while derived on a proximate basis, is considered accurate enough for the comparison intended. Given the assumption of a K-spar (as Table I) having

an assay of only 12.8% K₂O, a mineralogical and chemical balance could not be drawn based on the assay of Table V. Percent free silica assigned to the feldspars is empirical.

Continuing from Table VI, data equivalent to Table IV can be constructed regarding the electrostatic products. Table VII gives these figures.

TABLE VII
CALCULATED PROXIMATE MINERALOGICAL BREAKDOWN OF PRODUCTS,
ELECTROSTATIC SEPARATION

<u>Product</u>	<u>Wgt. Pct. of Feed (Table V)</u>	<u>Pct. K-spar</u>	<u>Pct. K-spar Recov.</u>	<u>Pct. Na-spar</u>	<u>Pct. Na-spar Recov.</u>	<u>Pct. Total Spar</u>	<u>Pct. Total S. Recov.</u>	<u>* Pct. Qtz.</u>	<u>Pct. Qtz. Recov.</u>
Feld. Prod.	54	66	76	24	54	90	68	10	19
Sil. Tails.	46	25	24	24	46	49	32	51	81
Total Feed	100.0	47	100	24	100	71	100	29	100

* Does not include inferred free silica in K-spar and Na-spar.

Discussion of Results, Electrostatic vs. Dielectric Processes on Feldspar Ores

The most meaningful comparison between these two processes, given only the foregoing data, appears to be in terms of efficiency of mineralogical separation of K-spar, Na-spar, and quartz - not chemical values. This can be done by comparing data of Table IV vs. Table VII. The electrostatic process effected a recovery of 76% of the K-spar and 54% of the Na-spar, with a total feldspar recovery of 68%. The dielectric process (considering the combined middlings plus outer effluent) recovered 72% of the K-spar and 80% of the Na-spar, with total spar recovery of 76%. Feldspathic concentrates from both processes contained close to 10% quartz in separable form, not including "free silica" locked in with the feldspars. The dielectric process, then, recovered slightly more feldspar but was not as selective in separating Na-spar from K-spar as was the electrostatic process.

Conclusions Regarding Feldspar Beneficiation

Since the dielectric separator was apparently a "first generation" device, and the tests and data developed around it at the MRL were often empirically based, conclusions must be tentative.

It is believed that the dielectric separator could conceivably equal the performance of an electrostatic separator in the area of feldspar beneficiation. A prediction of superior performance would be rash. For thorough evaluation, a great deal more research would be called for, perhaps exploring the following:

1. Field configuration and closed circuit processing.
2. Feeding via variably-inclined deck vs. free fall.
3. Elevated feed temperatures (not possible with an acrylic deck), or other pre-charging techniques.
4. Additional particle surface treatment with reagents.
5. Effects of wider particle size range of feed.
6. Feed capacity in weight unit/second/area unit (on "second generation" device).

In later stages of development, a meaningful power input figure could also be derived.

The most successful test on the dielectric separator (No. 33) involved pre-treatment of the ore with reagent (HCl + AlCl₃). It was then put through the separator at a slightly elevated temperature (105° F). Economically, this comes out as additional trouble and expense. However, compared to that is the apparent necessity (as reported) of heating feldspar ore to about 350° F prior to carrying out electrostatic separation.

Up to the present, the process of electrostatic separation of feldspar has lost in economic competition against froth flotation, which usually gives concentrate recovery figures of 95% or better, with 5% or less free silica. Also, the flotation process now appears more reliable, with fewer technical problems. However, if feldspar flotation is threatened for reasons related to environment or available energy or materials, then there will be increased incentive for exploring

further any alternative processing, even at the cost of decreased recovery. At such a time, dielectric separation could merit further research for that purpose.

TESTS ON AN OLIVINE-SERPENTINE MIX

Several casual tests on a commercial olivine product sold for foundry sand gave indication that the dielectric separator could remove impurities from this. One controlled test was run on a 50 gram sample, 30-50 mesh. Voltage for both circuits was maximum; temperature was 105° F; and throughput took 4 minutes. Table VIII gives results.

TABLE VIII

SEPARATION OF OLIVINE FROM SERPENTINE AND CHROMITE
(Sample No. 4220)

<u>Cent. Throughput</u>		<u>Middling</u>		<u>Outer Effluent</u>	
<u>% Wgt.</u>	<u>% Ign. Loss</u>	<u>% Wgt.</u>	<u>% Ign. Loss</u>	<u>% Wgt.</u>	<u>% Ign. Loss</u>
84.1	0.51	7.2	0.92	8.7	1.79

Discussion of Table VIII

The serpentine and talc still present in the samples used were largely diverted into the middling and outer effluent, along with some of the olivine particles which probably had serpentine attached to them. It was observed that the black grains of chromite present in the material had some tendency to report with middlings or outer effluent, but the center throughput still contained about half the original amount of that mineral, indicating little or no success in chromite concentration.

Conclusions Regarding Olivine Beneficiation

The dielectric separator apparently can upgrade olivine foundry sand by removing impurities with high ignition loss. At present, olivine is upgraded, after mining and grinding, by hydrosizing (hindered settling), wet gravity

separation (shaking tables), or by calcining. It does not appear that another process is now sought to overcome any outstanding deficiencies of the methods cited, unless perhaps calcining becomes too expensive and a cheaper dry process is desired.

TESTS ON OTHER MINERALS

Other mineral combinations tried on the dielectric separator included the following:

Calcite - quartz, 30-50 mesh

Zircon - quartz, 60-100 mesh

Zircon-calcite-talc, 30-100 mesh

Phosphate-quartz, 30-50 mesh

No tests on these combinations gave discernible indication of mineral separation.

FINAL CONCLUSIONS

The dielectric separator tested at the MRL was a prototype device which had potential to demonstrate the applicability of a basic principle to assorted minerals separations. The research involving it, performed at the MRL, was directed at certain limited areas wherein there were specific needs or possibilities related to North Carolina minerals. In two cases (feldspar and olivine) test results indicated apparent avenues for future extended research.