

EXPERIMENTAL PRODUCTION OF FELDSPAR AND SILICA FROM SEVERAL RIVER SANDS IN KANSAS

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ABSTRACT

Six river and flood-plain sand samples from the vicinity of Kansas City, Wichita, Concordia, and Salina were treated by flotation methods to determine the feasibility of producing a feldspar concentrate and a silica concentrate for use in glass, glass fiber, and ceramic and allied industries. The following average values are from five of these tests: a feldspar concentrate yield of 27.1 percent with an average alkali content (K_2O+Na_2O) of 13.2 percent and a molecular ratio of K_2O to Na_2O of 3.6 to 1. The silica sand residue remaining after flotation of the feldspar is capable of being concentrated to an Fe_2O_3 content of less than 0.03 percent. These tests show that both a silica sand and feldspar product of commercial grade can be produced from the sand sampled at Concordia, Kansas City, and Wichita.

INTRODUCTION

The ceramic, glass fiber, glass, and allied industries have been expanding into Kansas and adjacent areas during the past decade. The raw materials used in these industries are acquiring a greater market potential yearly. At the present time feldspar and silica sand are shipped into the Kansas region at considerable expense for freight and handling. The Geological Survey has published the results of one investigation (Nixon, Runnels, and Kulstad, 1950) on a source of silica sand. The present study was undertaken to determine if common river sands which are available in very large tonnages could be utilized as a source for feldspar and silica sand. Preliminary examination has indicated that many river sands in Kansas contain almost 30 percent by weight of feldspar, orthoclase (potash) predominating. It was thought that suitable flotation methods could be worked out to produce a feldspar concentrate that would meet industrial specifications and that the silica sand fraction would meet, or could be further treated to meet, the glass and glass-fiber specifications.

The results of this study are presented in the following pages and show that feldspar concentrates and silica sand concentrates can be produced from common river sands. The analyses show that these products are comparable, with the possible exception of iron content, to the products now used and that they can be produced by standard commercial techniques. Due to the limited nature of this investigation, no attempt was made to prepare cost estimates although it is judged that the process described is economically feasible.

SAMPLES

Samples of sand for this investigation were obtained from six widely separated sand plants which are located where there is a possible market for feldspar and silica products. The method of sand production in each of these plants is the same. A mixture of sand and water is pumped from a dredge in the river or pond to the sand preparation plant where it passes through a coarse screen to remove trash, mud balls, and gravel. The sand is then graded by means of screens or classifiers to yield one or more usable sand products and fine sand that is discarded unless there is a market for it. Samples of the various sand grades, including the fine sand reject, were taken at each plant. The operator's estimate of the relative amounts of the various grades was used in making up composite samples of sand from each plant. Table 1 gives data on the sampling and compositing of the sand from various locations.

Table 2 presents data on complete chemical analyses of head samples of the composite and the fine sand from four of the plants. In preparing these samples the sand was crushed in a disk pulverizer, resulting in the addition of abraded iron to the sample. Part or all of this iron was removed with a hand magnet, and it is probable that some magnetite originally in the sand was also removed. Thus the iron analyses represent the less magnetic iron in the sand. The analyses of the fine sand were included because at most plants the fines are either a waste product or are produced in excess of market requirements, thus constituting a potential source of raw material.

Screen analyses of four of the composite samples are presented in Table 3.

PRELIMINARY TESTS

A number of preliminary tests were made to establish a procedure for separating the composite samples from the various plants into their constituent minerals. Several kilograms of the composite sand from each company was crushed to pass a 20-mesh screen by means of laboratory rolls in closed circuit with the screen. This was then weighed into 1 kilogram samples for use in the individual tests.

The degree of grinding to be used was selected by placing 1 kg charges of sand and 500 cc water in a 12 by 5 inch Denver labora-

TABLE 1.—*Location, company name, and proportions of sand samples used in this study*

Name of sand company	Location of plant	Type of operation	Grades of sand produced	Proportions used in making up composite	Date Sampled
Stewart Sand and Materials Co.	Turner, Kansas (near Kansas City)	Sand pumped from Kansas River	Concrete sand Mason's sand Fine sand	47.22 47.22 5.56	June 1, 1951
Dolese Brothers	21st Street and Big River, Wichita, Kansas	Sand pumped from Arkansas River	Concrete sand Plaster sand Fine sand	60.00 25.00 15.00	June 6, 1951
Walt Keeler Co., Inc.	Southwest of Wichita on highway K-42	Sand pumped from pond	Concrete sand Fine sand	80.00 20.00	June 7, 1951
Black Cat Sand Co.	47th Street and Little River, Wichita, Kansas	Sand pumped from Little Arkansas River	Coarse and medium mixed Fine sand	70.00 30.00	June 7, 1951
Ross Sand Co.	East of Concordia	Sand pumped from pond beside Re-publican River	Road gravel Concrete aggregate Plaster sand Fine sand	26.70 33.30 26.70 13.30	August 23, 1951
Salina Sand Co.	South of Salina	Sand pumped from pond beside Smoky Hill River	Concrete sand Fine sand	70.00 30.00	August 24, 1951

TABLE 2.—Chemical analyses of head samples of the composite sand and the fine sand from four locations

Company	Product	SiO ₂ *	Al ₂ O ₃ **	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition
Stewart Sand and Materials Co.	Composite	87.37	7.08	0.65	0.72	0.10	2.46	1.23	0.39
	Fine sand	85.24	7.55	0.71	1.31	0.15	2.81	1.46	0.77
Walt Keeler Co., Inc.	Composite	87.54	6.87	0.72	0.35	0.07	3.06	1.11	0.28
	Fine sand	85.75	7.58	1.11	0.61	0.15	3.16	1.33	0.32
Dolese Brothers	Composite	87.38	7.09	0.88	0.49	0.10	2.62	1.21	0.23
	Fine sand	86.48	7.70	1.37	0.63	0.16	2.09	1.29	0.28
Black Cat Sand Co.	Composite	88.39	6.38	0.72	0.36	0.08	2.90	0.93	0.24
	Fine sand	87.18	6.95	0.84	0.53	0.13	2.76	1.34	0.27

* By difference from 100.

** Contains also MnO, TiO₂, and P₂O₅ if present.

TABLE 3.—Screen analyses of four composite samples

Size, mm or mesh	Weight distribution, percent, of samples from			
	Stewart Sand and Materials Co.	Walt Keeler Co., Inc.	Dolese Brothers	Black Cat Sand Co.
Plus 9.4 mm		Trace	1.0	1.7
9.4 mm-3 mesh		1.1	1.7	2.8
3-4 mesh	Trace	1.6	1.6	3.0
4-6	1.2	3.2	3.2	5.5
6-8	2.5	5.3	4.6	7.7
8-10	4.1	8.0	6.3	11.8
10-14	5.4	9.3	6.9	12.2
14-20	6.5	10.7	7.4	11.8
20-28	11.5	15.8	12.6	9.5
28-35	13.6	15.2	15.9	10.8
35-48	23.7	15.4	21.4	11.2
48-65	16.7	8.5	11.6	7.4
65-100	10.9	4.2	4.6	3.4
100-150	2.7	1.0	0.8	0.6
150-200	0.9	0.4	0.2	0.2
200-270	0.2	0.1	0.1	0.1
Minus 270	0.1	0.2	0.1	0.3

tory steel ball mill with about 9 kilograms of steel balls, grinding for various lengths of time, and sizing the resulting pulp. A 15-minute grind was selected. Table 4 gives sizing data on sand ground for 15 and 20 minute periods.

Considerable iron-bearing magnetic mineral is present in the sands and also there was some iron abraded from the mill and balls. Because iron is most undesirable in feldspar and quartz products, most of it was removed magnetically. The ground sand for all tests was passed through a Frantz Ferrofilter. This device is a short cylinder filled with a network of soft iron grids that are magnetized

TABLE 4.—Sizing data on ground composite sand from Stewart Sand and Materials Company

Size	Sand ground 20 minutes	Sand ground 15 minutes
+ 48 mesh	0.1	0.1
48-65	0.1	0.7
65-100	2.6	13.7
100-150	10.1	17.4
150-200	20.4	18.9
-200	66.7	49.2
Total	100.0	100.0

by a direct current coil surrounding the cylinder. This forms a trap for magnetic particles, but lets nonmagnetic particles pass through with the water. After the current has been stopped the magnetic material may be washed out into a separate pan. In some of the tests the magnetic material was further separated by means of a hand magnet into products of different iron contents.

The extremely fine particles in a ground pulp, or slime as the finest material is called, often cause difficulty in nonsulfide flotation. For this reason the pulp in all the tests was deslimed before flotation. The analyses presented in Tables 5 to 10 show that in all cases the slime contained more iron than any of the flotation products so that its removal was helpful in lowering the iron content of the finished products. Only about 8 percent of the weight of the sand was removed as slime. The method of desliming the sand was to agitate the nonmagnetic pulp from the Ferrofilter in the 3-liter glass cell of a laboratory Fagergren flotation machine. A reagent was added to disperse the slime and then the sand was permitted to settle for 8 minutes before the slime-laden water was removed by a siphon. The sand was repulped with water and again permitted to settle for 8 minutes before the unsettled slime was removed. This was repeated (total of three deslimings which should remove practically all the slime if it were completely dispersed). A sufficient quantity of any of the three dispersing agents tried gave satisfactory results. When a 5 percent solution of Daxad 23 was used, 2 cc of solution did not give complete dispersion, but 10 cc of solution did. In one test a total of 50 cc of 5 percent sodium metasilicate was used to effect complete dispersion of the slime. With a 5 percent Calgon solution the addition of 10 cc did not seem to disperse the slime completely, while the addition of 20 cc gave excellent dispersion. The pulps that had been deslimed with Calgon as dispersing agent seemed to float better than those that had had Daxad treatment. Hence 20 cc of 5 percent Calgon per kilogram of sand (2 pounds per ton) was selected as the dispersing agent for subsequent tests.

The usual method of separating quartz and feldspar by flotation is to depress the quartz by means of hydrofluoric acid and float the feldspar with amine. Previous experience with the flotation of feldspar from quartz had indicated that good results could be obtained if 4 cc of 48 percent hydrofluoric acid was used in tests of the size being made. During the preliminary work the quantity of acid used in two tests was reduced to 0.8 cc and 2.0 cc respectively. The

flotation results in each of these tests were definitely inferior to the results of similar tests in which 4 cc of acid was used. Therefore the larger quantity amounting to 4.4 pounds of HF per ton of sand was used in subsequent tests.

The primary amine acetates used as collectors in the flotation of the feldspar form a homologous series with a variable length hydrocarbon chain. Samples of distilled amine acetates with hydrocarbon chains ranging in length from 10 carbon atoms to 18 carbon atoms were supplied by Armour Chemical Division of Armour and Company. Different amines were used in a number of tests, the best results being obtained with the one having 12 carbon atoms. Thus in subsequent tests the collector was Armac 12-D, distilled dodecylamine acetate. Tests in which the quantity and method of addition of amine were varied showed that satisfactory results were obtained when it was added by stages of 0.1 pound per ton followed by conditioning for 1 minute and removal of the floatable material after each amine addition. The use of a little frother B-23 improved the flotation.

Previous experience with the flotation of Kansas River sand had shown that after the removal of the feldspar it was possible to float the quartz by raising the pH of the pulp to about 7 either by adding a caustic or by washing the acid out with fresh water. Very little additional amine is required to float a quartz product that is substantially more pure than the final nonfloated tailing.

LARGE-SCALE TESTS

After a satisfactory procedure had been established for separating the composited sand from the Kansas River at Kansas City into mineral concentrates, the same procedure was applied with minor variations to each of the composited sand samples. The best possible quality was desired in the feldspar and quartz concentrates that were to be analyzed. To achieve this, the final tests were made using 3 kilograms of sand instead of 1 kilogram and the products were cleaned or recleaned by floating them a second or third time to give what seemed to be optimum results. The procedures used in these tests are shown as flowsheets (Figs. 1, 2, 3). The operations enclosed within the dotted rectangle were carried out with three separate 1-kilogram samples, the three charges being treated in parallel for that part of the test. Those operations shown outside the rec-

tangle were carried out on the corresponding combined products from the parallel parts of the test.

The separation of each sand composite was started in the same way and the parallel parts of the tests were all alike except for variations in the quantity of amine required. Each 1-kilogram charge of sand was ground in the steel mill for 15 minutes and then passed through the Ferrofilter to remove magnetic material. The magnetics removed from the three charges in each test were combined and again passed through the Ferrofilter to remove the non-magnetic sand that had been caught mechanically. This was saved separately (called "magnetic tailing"). A hand magnet was used to produce a "magnetic middling" and "magnetic concentrate" from the material caught a second time in the Ferrofilter. The nonmagnetic sand from the Ferrofilter was deslimed by dispersing it with 2 pounds of Calgon per ton and then decanting it three times after 8-minute settling periods. The slimes from all three charges were combined.

The deslimed sand from each charge was prepared for feldspar flotation by agitating it with about 4.4 pounds of hydrofluoric acid per ton (4 cc of 48 percent HF per kilogram of sand) for 5 minutes. This gave a pH of about 3 with all the sands except that from the Salina Sand Company. With this sand the pH rose somewhat due to carbonate in the pulp so that 5 cc of acid instead of 4 cc was used. The feldspar was floated in stages using 0.1 pound of Armac 12-D per ton and about 0.05 pound of frother B-23. The sands from near Wichita and Concordia required only three stages to remove most of the feldspar. On these sands the first stage froth was considered the first float; the other two stages were combined as the second float. The sands from near Kansas City and Salina required four stages to float the feldspar. In these tests the first two stages constituted the first float and the last two the second float.

The acid was removed from the tailings after feldspar flotation by letting the sand settle, pouring off the solution, and repulping with water until the sand had been decanted three times. Then the sand was repulped, a drop of frother B-23 added, and much of the silica floated without any additional amine. After this flotation no further separations were made on the 1-kilogram charges, but only upon combined products from the three parallel parts of the test.

The first feldspar floats were combined and cleaned by refloatation using only a little frother B-23. This first float became "feldspar

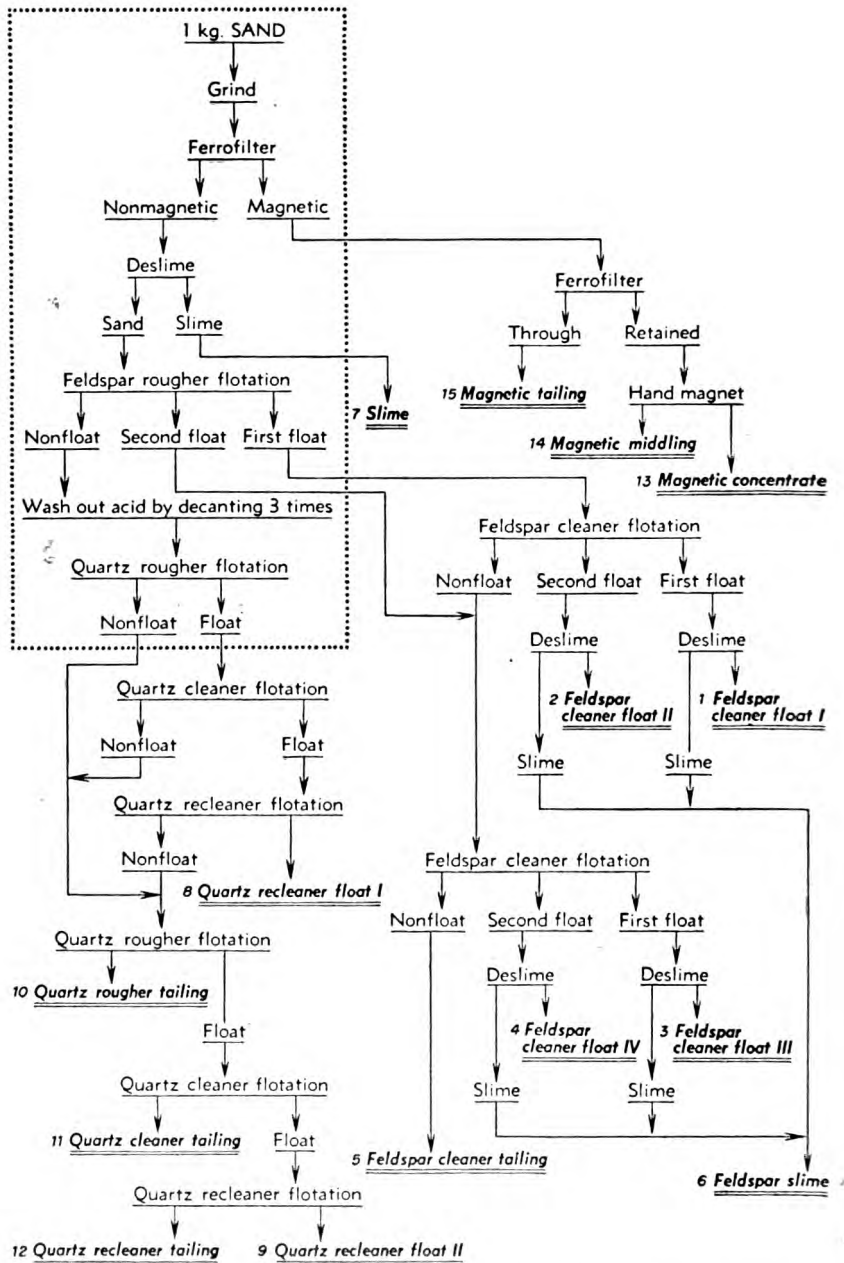


FIG. 2.—Flow sheet for separation procedure for sand from the areas of Concordia and Wichita, Kansas. Operations inside the rectangle were performed on three charges in parallel while those outside were performed on the combined products.

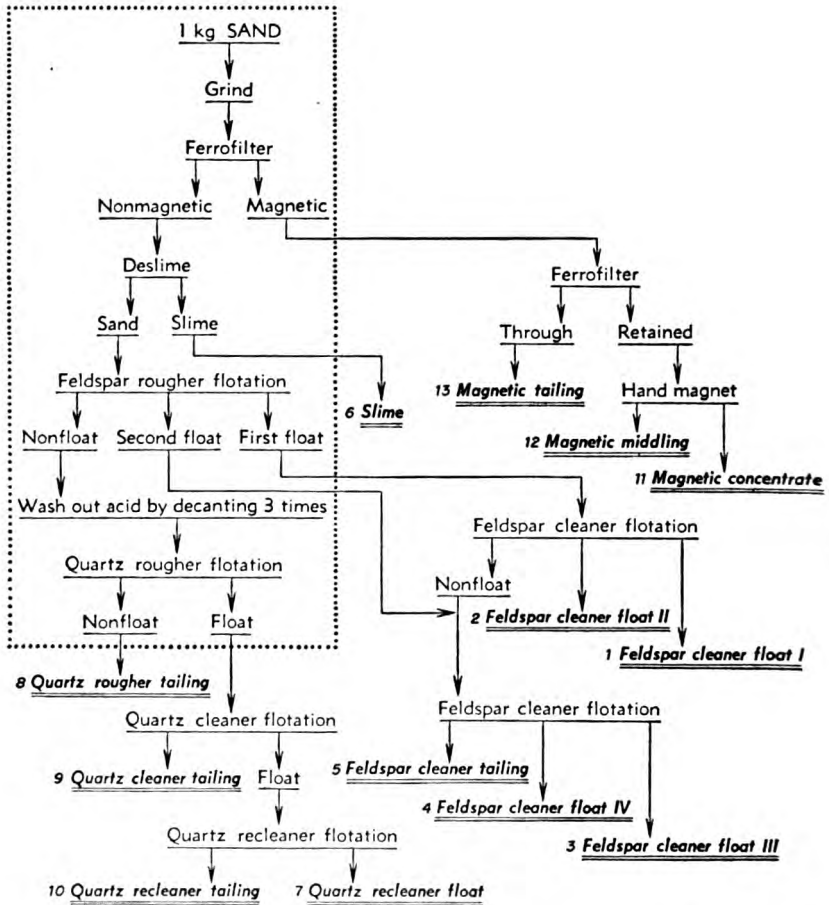


FIG. 3.—Flow sheet for separation procedure for sand from Salina, Kansas. Operations inside the rectangle were performed on three charges in parallel while those outside were performed on the combined products.

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was dissolved in HCl and water and then dehydrated to precipitate the silica. The dehydrated mass was then treated with HCl and filtered to remove crude silica. The resulting solution was again dehydrated and the procedure repeated to recover the remaining crude silica. The combined precipitates of crude SiO_2 were ignited to 1200°C ., weighed, treated with HF and H_2SO_4 to evolve the silica, reignited, and weighed. The loss of weight was recorded as SiO_2 . It was found, however, that retention of calcium in the crude silica and the subsequent formation of calcium sulfate caused the final weighing to be high, thus giving a low value for the silica. This condition was corrected by determining the amount of retained sulfate with BaCl_2 and adding this percentage to the observed percentage of silica. The necessity of this step was demonstrated to our satisfaction by repeated determinations of silica on the Bureau of Standard's standard feldspar No. 99.

When analyses had already been completed before the necessity of this silica correction was discovered, adjustment of the silica percentage, by difference from 100 percent (100.00 minus analyzed constituents equals SiO_2) was considered safe and adequate.

R_2O_3 GROUP ANALYSIS

The determination of R_2O_3 (Al_2O_3 , Fe_2O_3 , TiO_2 , ZrO_2 , V_2O_5 , P_2O_5 , and MnO) was done by accepted methods except for a gravimetric determination of TiO_2 with cupferon reagent (Runnels, Utter, and Reed, 1950). Thus the reported results were Al_2O_3 (including P_2O_5 and MnO if present), Fe_2O_3 , and TiO_2 (including ZrO_2 and V_2O_5 if present).

SODIUM AND POTASSIUM ANALYSIS

The alkalis were determined with a model 52-C Perkin-Elmer flame photometer after taking the sample into solution with HF and H_2SO_4 . This procedure eliminates the tedious J. Lawrence Smith method of sintering the sample. Where the potassium content is higher than the sodium content, as in this study, the flame photometer gives reliable results for both elements (Broderick and Zack, 1951).

TRACE ELEMENTS ANALYZED

Qualitative spectrographic analyses of the feldspar products were made with an Applied Research Laboratory 1.5-meter grating spectrograph. The following elements were observed: manganese, silver, strontium, chromium, zirconium, nickel, copper, vanadium, and lead. All occurred in amounts estimated to be from 0.1 per cent (strontium and manganese) to spectrographic traces. Lithium, rubidium, cesium, and barium were not detected.

SUMMARY OF ANALYSES

Tables 5, 6, 7, 8, 9, and 10 present data on the weight distribution and the chemical analyses of the products from the large-scale tests discussed earlier.

Table 11 summarizes the composition and proportion of feldspar in the various composite sand samples as calculated from the analyses of the feldspar concentrates presented in Tables 5 through 10.

SUMMARY

Sands from the two major rivers in Kansas contain about 30 per cent feldspar, about 65 per cent quartz, and small amounts of many other minerals including magnetite and ilmenite. It was shown that the sands may be separated into a number of products having different mineralogical compositions. The object of such separations was to obtain a product containing the relatively valuable and abundant feldspar with a minimum of iron-bearing minerals. To accomplish this as much iron as possible was removed by magnetic separation and by desliming before flotation of the feldspar to separate it from the quartz. As a result of this treatment the quartz residues were easily treated by further flotation to make high-grade silica products.

Chemical analyses of the products showed that the feldspar concentrates contained nearly pure feldspar with an iron content somewhat higher than the best commercial grades. The silica products were of high quality and would meet the chemical requirements of most users.

TABLE 5.—*Chemical analyses and weight distribution on products from composite sand sample from Stewart Sand and Materials Co., Turner, Kansas*

No. on flow-sheet (Fig. 1)	Product	Weight distribution, percent	SiO ₂	Al ₂ O ₃ *	Fe ₂ O ₃	TiO ₂ **	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition†	Total
1	Feldspar cleaner float I	8.5	63.82	19.21	0.49	0.18	0.83	1.16	10.20	3.73	0.38	100.00
2	Feldspar cleaner float II	8.2	65.36	18.61	0.44	0.26	1.32	0.87	8.72	4.10	0.32	100.00
3	Feldspar cleaner float III	8.8	64.57	19.65	1.01	0.26	0.74	1.11	7.97	4.12	0.57	100.00
4	Feldspar cleaner float IV	1.6	65.48	17.30	1.21	0.38	3.15	0.40	6.61	4.01	1.46	100.00
5	Feldspar cleaner tailing	3.2	79.24	8.37	1.04	1.53	2.25	0.49	3.38	2.06	1.68	100.00
6	Slime	6.7	76.94	11.26	2.93	0.13	0.43	0.36	3.78	1.86	2.29	100.00
7	Quartz recleaner float I	22.6			0.030							
8	Quartz cleaner float II	18.8			0.056							
9	Quartz tailing	17.5			0.34							
10	Magnetic concentrate	0.5	33.09	8.39	51.29	4.31						
11	Magnetic middling	0.8			13.74							
12	Magnetic tailing	2.8			1.98							
		<u>100.0</u>										

* Contains MnO and P₂O₅ when present.

** Contains ZrO₂ and V₂O₅ when present.

† 105° to 1000° C.

TABLE 8.—Chemical analyses and weight distribution data on products from composite sand sample from Black Cat Sand Co., Wichita, Kansas

No. on flow-sheet (FIG. 2)	Product	Weight distribution, percent	SiO ₂	Al ₂ O ₃ *	Fe ₂ O ₃	TiO ₂ **	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition†	Total
1	Feldspar cleaner float I	11.6	64.47	19.39	0.43	0.14	0.72	0.18	10.47	3.81	0.31	99.92
2	Feldspar cleaner float II	5.6	65.90	19.33	0.40	0.22	0.74	0.15	10.20	3.39	0.30	100.66
3	Feldspar cleaner float III	8.6	66.27	18.45	0.76	0.48	1.03	0.22	7.77	3.91	0.54	99.43
4	Feldspar cleaner float IV	0.8	75.44	13.21	1.44	0.55	1.14	0.34	4.04	3.26	0.70	100.12
5	Feldspar cleaner tailing	1.9	95.05	2.19	0.61	0.30	0.37	0.11	0.71	0.42	0.41	99.80
6	Feldspar slimes	0.6	67.23	15.22	4.21	0.56	1.17	0.50	6.31	2.57	2.51	100.28
7	Slime	8.6	74.79	10.57	2.49	0.16	0.43	0.31	5.59	3.47	2.19	100.00
8	Quartz recleaner float I	17.2			0.028				0.06	0.04		
9	Quartz recleaner float II	17.3			0.024				0.29	0.17		
10	Quartz rougher tailing	6.8			0.37				0.22	0.11		
11	Quartz cleaner tailing	11.2			0.075				0.10	0.06		
12	Quartz recleaner tailing	5.7			0.045				0.08	0.04		
13	Magnetic concentrate	0.6			56.61							
14	Magnetic middling	0.6			10.86							
15	Magnetic tailing	2.9			1.60							
		100.00										

* Contains MnO and P₂O₅ when present.

** Contains ZrO₂ and V₂O₅ when present.

† 105° to 1000° C.

TABLE 9.—*Chemical analyses and weight distribution data on products from composite sand sample from Ross Sand Co., Concordia, Kansas*

No. on flow-sheet (Fig. 2)	Product	Weight distribution, percent	SiO ₂	Al ₂ O ₃ *	Fe ₂ O ₃	TiO ₂ **	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition†	Total
1	Feldspar cleaner float I	7.4	64.60	19.49	0.25	0.16	0.43	0.32	10.54	3.77	0.44	100.00
2	Feldspar cleaner float II	4.2	64.90	19.48	0.28	0.09	0.98	0.13	9.93	3.80	0.41	100.00
3	Feldspar cleaner float III	10.0	65.59	19.19	0.46	0.34	0.66	0.12	9.22	4.00	0.42	100.00
4	Feldspar cleaner float IV	5.2	64.82	19.15	0.81	0.26	1.44	0.11	7.89	4.68	0.49	99.65
5	Feldspar cleaner tailing	5.6	79.99	13.78	0.54	0.17	1.18	0.07	3.94	1.84	0.49	100.00
6	Feldspar slimes	0.6	64.35	15.26	3.99	0.76	3.39	0.67	5.50	2.60	3.48	100.00
7	Slime	9.3	75.51	10.89	2.70	0.17	1.55	0.36	4.28	2.11	2.32	99.89
8	Quartz recleaner float I	16.8			0.069				0.07	0.07		
9	Quartz recleaner float II	18.4			0.025				0.02	0.04		
10	Quartz rougher tailing	2.8			1.12				0.90	0.80		
11	Quartz cleaner tailing	5.8			0.39				0.42	0.39		
12	Quartz recleaner tailing	9.7			0.16				0.23	0.18		
13	Magnetic concentrate	0.9			36.08							
14	Magnetic middling	0.6			10.80							
15	Magnetic tailing	2.7			1.56							
												100.0

* Contains MnO and P₂O₅ when present.
 ** Contains ZrO₂ and V₂O₅ when present.
 † 105° to 1000° C.

TABLE 10.—Chemical analyses and weight distribution data on products from composite sand sample from *Salina Sand Co., Salina, Kansas*

No. on sheet (FIG. 3)	Product	Weight distribution, percent	SiO ₂	Al ₂ O ₃ *	Fe ₂ O ₃	TiO ₂ **	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition†	Total
1	Feldspar cleaner float I	8.6	64.62	18.24	1.87	0.15	1.16	0.18	9.91	3.22	0.92	100.27
2	Feldspar cleaner float II	3.3	64.21	17.07	2.49	0.59	2.85	0.41	7.96	2.81	1.51	100.35
3	Feldspar cleaner float III	6.6	70.53	10.05	5.29	0.74	4.54	0.22	4.61	1.71	2.43	100.00
4	Feldspar cleaner float IV	1.2	71.34	4.12	5.45	‡	11.50	0.33	1.06	0.89	5.31	100.00
5	Feldspar cleaner tailing	1.3	77.22	1.09	1.55	0.01	11.69	0.10	0.19	0.16	7.99	100.00
6	Slime	9.8	75.39	6.72	5.84	0.50	3.84	0.57	2.16	0.97	4.01	100.00
7	Quartz recleaner float	33.2			0.073				0.03	0.04		
8	Quartz rougher tailing	13.0			3.56				0.46	0.21		
9	Quartz cleaner tailing	5.5			0.67				0.23	0.13		
10	Quartz recleaner tailing	12.3			0.20				0.11	0.07		
11	Magnetic concentrate	0.6			59.01							
12	Magnetic middling	1.4			7.98							
13	Magnetic tailing	3.2										
		100.0										

(298)

* Contains MnO and P₂O₅ when present.

** Contains ZrO₂ and V₂O₅ when present.

† 105° to 1000° C.

‡ Reported with Al₂O₃.

TABLE 11.—Calculated yield and chemical composition of combined feldspar products from composite sand samples
 (Data from Tables 5 through 10)

Sand company	Yield, weight percent	SiO ₂	Al ₂ O ₃ *	Fe ₂ O ₃	TiO ₂ **	CaO	MgO	K ₂ O	Na ₂ O	Loss on ignition†
Stewart Sand and Ma- terials Co.	27.11	64.63	19.06	0.69	0.24	1.08	1.01	8.82	3.99	0.49
Walt Keeler Co., Inc.	26.92	65.30	18.94	0.63	0.32	0.73	0.16	9.57	3.76	0.37
Dolose Brothers	27.87	65.55	18.91	0.74	0.25	1.11	0.16	9.25	4.06	0.53
Black Cat Sand Co.	26.58	65.67	18.89	0.56	0.28	0.84	0.19	9.35	3.74	0.39
Ross Sand Co.	26.79	65.06	19.31	0.44	0.24	0.80	0.18	9.44	4.04	0.44
Salina Sand Co.	19.66	66.94	14.45	3.41	0.44	3.20	0.24	7.27	2.50	1.79

* Contains MnO and P₂O₅ when present.

** Contains ZrO₂ and V₂O₅ when present.

† 105° to 1000° C.

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