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PROGRESS REPORT

on

THE PHYSICAL CONCENTRATION OF TALC ORES – FLOTATION

to

JOHNSON AND JOHNSON

May 23, 1958

by

W. E. Brown, W. L. Smith, and R. D. Macdonald

BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus 1, Ohio

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505 KING AVENUE COLUMBUS 1, OHIO

May 28, 1958

Dr. W. H. Lycan
Director of Research
Johnson and Johnson
New Brunswick, New Jersey

Dear Dr. Lycan:

We are transmitting herewith six copies of our Progress Report on "The Physical Concentration of Talc Ores -- Flotation", by W. E. Brown, W. L. Smith, and R. D. Macdonald.

The data in this report show that it is possible to make from Italian No. 2 grade, by flotation, a talc product that is superior to the Italian No. 1 grade. We now have enough laboratory data to design either a pilot plant to produce larger quantities of this material for critical evaluation, or a commercial plant to produce a nominal 50 tons of beneficiated talc per day.

The data in this report indicate that it may be possible to produce a superior talc by flotation from any raw talc which contains an appreciable percentage of platy talc. We do not, however, have enough data as yet to prove this point. Additional experimental work is required to show whether by flotation one can make an acceptable product from other raw materials, such as Indian talc.

After you have reviewed this report, we would be pleased to discuss it with you or to answer any questions which may arise.

Sincerely yours,

O. F. Tangel

O. F. Tangel, Chief
Minerals Beneficiation Division

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PHYSICAL CONCENTRATION OF TALC ORES – FLOTATION

by

W. E. Brown, W. L. Smith, and R. D. Macdonald

SUMMARY

This report contains data for the physical concentration of talc ores by flotation methods.

Flotation experiments were made on two talc samples from the United States and one from Italy. Most of the tests were made on the Italian talc because it was considered to be of the most immediate importance.

The principal objective of the program was to obtain a product containing a high percentage of platy talc. The results of the tests show that each of the three different samples can be treated to yield a float product that is significantly improved in its content of platy talc. Table 1 summarizes the best results obtained and compares the raw flotation feed with the beneficiated product.

Table 1 shows that both the Oasis and Stone Creek samples were improved in grade. The original Oasis sample contained 48 per cent platy talc and the Float 1 product contained 83 per cent platy talc. The Stone Creek sample contained 30 per cent platy talc and the Float 1 product contained 85 per cent platy talc. Although these flotation products show a substantial improvement in platy-talc content, they lack about 5 per cent of being equivalent to the 88 to 90 per cent platy-talc content of Italian No. 1 grade which is currently being used by Johnson and Johnson as the raw material for baby powder.

Although the desired grade of at least 88 to 90 per cent platy talc was not attained on either the Oasis or Stone Creek samples, a substantial improvement was obtained as the result of relatively few tests. It is expected that a suitable method can be developed, through additional work, to yield a satisfactory product from the Oasis and Stone Creek talcs.

Italian No. 2 talc likewise responded favorably to flotation. Two methods were developed which yielded products that contained 96 to 97 per cent platy talc and 2 to 3 per cent of fibrous talc. Mineralogically, these products are superior to the Italian No. 1 talc which is being used by Johnson and Johnson for baby powder.

The flotation experiments established that the nonplaty talc can be depressed by using the proper amounts of either Dextrin* or hydrochloric acid. When Dextrin was used the froth of the float products was very voluminous and persistent which probably would create handling and filtering problems in full scale operations. When hydrochloric acid was used the character of the froth appeared normal and rapid filtration was obtained.

* Dextrin is made by the hydrolysis of starch and is manufactured by Clinton Foods Incorporated, under the name of Dextrin 603.

TABLE 1. SUMMARY OF FLOTATION RESULTS

Sample	Product	Weight Per Cent of Flotation Feed	Mineral Count, per cent: Platy Talc	Nonplaty Talc	Carbonates	Tremolite	Effective Reagent
Oasis	Feed	100.0	48	43	5	4	---
Oasis	Float 1	34.6	83	16	<1	1	Dextrin
Stone Creek	Feed	100.0	30	67	1	2	---
Stone Creek	Float 1	29.9	85	12	1	2	None
Italian No. 2	Feed	100.0	90	6	3	1	---
Italian No. 2	Float 1	83.9	96	3	<1	<1	Dextrin
Italian No. 2	Float 1, 2 and scavenger	82.7	97	2	<1	1	Hydrochloric acid
Italian No. 1	Not treated	100.0	88-90	8-10	<2	Trace	---

Note: Italian No. 1 is included for comparison.

One objection to the use of Dextrin, other than the unsatisfactory frothing properties, would be the possibility of fungus growth on the talc particles if it were not washed out completely or destroyed by heat during the drying operations.

INTRODUCTION

Johnson and Johnson is interested in a broad program which includes investigating the important talc deposits in the world, the measurement of the physical properties of talc, and the physical beneficiation of talc. The purpose of these investigations is to insure Johnson and Johnson of the least expensive and most reliable raw-material source and also to develop methods for further improving the properties of the talc used in baby powder.

At present, Johnson and Johnson is obtaining raw material for baby-powder talcum from Italian deposits. This talc is regarded as very good quality. Some additional improvement in quality is desirable, however, and may be possible by physical beneficiation methods. None of the known domestic talc deposits can compare in quality with the Italian talc, and part of this program is devoted to processing talcs from the more suitable domestic sources in order to obtain a product that is comparable in quality with the Italian talcs.

This Progress Report discusses information obtained on methods of improving the properties of talc. This work is identified on the over-all program being conducted at Battelle as Phase 3 — Physical Concentration of Talc Ores.

The specific objectives of Phase 3 are:

(1) To obtain a product which consists essentially of talc platelets

(2) To reject talc particles which are of a size and shape that create unpleasant dusting while dispensing talc from a container

(3) To obtain a talc product with an obvious sheen in order to convey to the consumer the immediate impression that the talc is of the highest quality.

In addition to achieving the foregoing objectives, it is desirable that the finished product will meet the following specifications.

Moisture:	Not more than 0.15 per cent.
Solubility in Hydrochloric Acid:	Not more than 6 per cent.
Fineness:	Not less than 99.7 per cent through a 100-mesh sieve. Not less than 98.5 per cent through a 200-mesh sieve.
Microscopic Structure:	Shall be platelets, and show no acicular or excessive granular crystals.

Bulk Density: Not less than 22 nor more than 27 pounds per cubic foot, when tested by the Scott Volumeter.

In further keeping with the standards of production, it is desirable that the finished talc product have essentially the same whiteness as that currently being marketed by Johnson and Johnson. Another objective is to reduce the alkalinity of the raw material so that the pH value of a moistened sample will approximate neutrality, or a pH of 7.

Products obtained from physical beneficiation experiments can be evaluated by microscopic examination and other physical measurements. These other physical measurements and their meaning are related to the properties of an accepted standard talcum product. A Progress Report on "Studies of the Physical Properties of Talc, Their Measurement and Comparison", October 15, 1957, by W. L. Smith, has been submitted to Johnson and Johnson on this subject and a second and summarizing one is in preparation.

The only method of physical beneficiation employed so far has been flotation. This is because one of the outstanding properties of talc, from the standpoint of physical beneficiation, is its natural floatability.

This report is composed principally of results from froth-flotation experiments. For this reason a short discussion of the froth-flotation process is included as Appendix B in the hope that it may be helpful in understanding the experiments.

EXPERIMENTAL WORK

Samples Tested

Three samples from separate sources were used for the beneficiation experiments. Two of these are from the United States and one from Italy. These samples have a wide variety of purity with respect to degree of platiness and the contained impurities, and probably are typical of what may be expected in talc deposits of potential interest.

Table 2 shows the composition of these samples as determined by microscopic count.

TABLE 2. MINERALOGICAL COMPOSITION OF SAMPLES INVESTIGATED

Sample	Mineral Count, per cent				Grind
	Platy Talc	Nonplaty Talc	Carbonates	Tremolite	
Oasis Mine (Nevada)	48	43	5	4	Minus 65 mesh (dry)
Stone Creek Mine (Montana)	30	67	1	2	Minus 65 mesh (dry)
Italian No. 2	90	6 (fibrous)	3	1	Minus 200 mesh (as received)
Italian No. 1	88-90	8-10 (fibrous)	<2	Trace	Minus 200 mesh (as received)

The mineral count given in Table 2 is made solely on the basis of incidence. No emphasis is given to the size of the particle encountered in the incidence, so the method of evaluation may at first seem questionable. However, repeated counts made on different fields of the same sample and different samples of the same material give suprisingly consistent percentages, and the percentages of carbonate present agree with chemical determinations of acid solubility. Because of this consistency, the method was accepted as sufficiently accurate for most of the investigations.

Particles in Table 2 which are identified as nonplaty talc may be composed of acicular, fibrous, granular, or cryptocrystalline aggregates of tiny platelets which resemble granules.

Nonplaty talc contained in the Italian samples is mostly fibrous or acicular in form. It is difficult to distinguish acicular talc from remnants of platelets and tremolite in sizes smaller than 10 microns.

Table 2 includes, for comparison, the composition of the Italian No. 1 grade which is the raw material currently used in Johnson and Johnson baby powder. The mineralogical difference between the No. 1 and No. 2 grades is almost insignificant. Italian No. 1 talc, however, costs several dollars more per ton. The Oasis and Stone Creek Mine samples were selected to determine whether talc of a low platy content could be improved sufficiently to compare favorably with the Italian talc and, if so, what recovery might reasonably be expected. Data on the beneficiation of various talcs would provide information that would permit an estimate of the tonnage of material necessary to supply the production requirements of Johnson and Johnson. Information could also be developed for the probable cost of beneficiation.

Ten exploratory experiments were made to observe the general response of the minerals during flotation and to learn the relative complexity of the problem. The summarized results of these experiments were contained in our letter report of January 24, 1958, to Dr. W. H. Lycan.

Sample From the Oasis Mine

The Oasis Mine sample came from Nevada and was supplied by the Sierra Talc and Clay Company. This material was available because it had been previously investigated by Battelle[1] for Johnson and Johnson as a potential raw talc source. The material on hand had been roll-crushed and then ground in a disc pulverizer through 65 mesh.

This sample, which contained about 48 per cent platy talc and 43 per cent granular talc, was selected for part of the investigation specifically because of its intermediate platy-talc content. It was believed that any significant improvement made on the ore would be more readily detected on low-grade materials than on high-grade materials.

Table 3 shows the flotation results obtained from five tests made on the Oasis sample and Table 4 gives the test operating conditions.

The results given in Tables 3 and 4 show that the Oasis talc in Test 1 was floated without any reagents and the platiness of the talc was increased from 48 per cent to 77 per cent. This definitely establishes that platy talc is more readily floated than granular

(1) Battelle Summary Report, February 29, 1956.

TABLE 3. SUMMARY OF FLOTATION RESULTS ON OASIS TALC SAMPLE (MINUS 65 MESH)

Test	Product	Weight Per Cent	Approximate Mineral Count, per cent: Platy	Nonplaty	Carbonates	Tremolite	Reagents Used
1	Float 1	32.2	77	20	1	3	None
	Float 2	27.0	45	50	2	3	Dowfroth 200
2	Float 1	32.4	75	24	<1	<1	None
	Float 2	36.4	45	45	10		Dowfroth 200
3	Cleaner float	31.6	80	18	1	1	Dowfroth 200
5a	Float 1	34.5	83	16	<1	1	Dextrin
8	Float 1	26.9	82	15	1	2	Dextrin
	Float 2	56.3	60	35	1	4	
	Flotation feed	100.0	48	48	5	4	

TABLE 4. TEST CONDITIONS USED TO OBTAIN RESULTS ON OASIS TALC SAMPLE

Test	Product	Time, minutes: Wetting	Conditioning	Floating	Pulp pH	Per Cent Solids in Feed	Reagent, pound per ton of flotation feed
1	Float 1	10	0	5	8.6	13.0	None
	Float 2	0	0	5			Dowfroth 200, 0.17
2	Float 1	10	0	5	8.6	6.8	None
	Float 2	0	0	5			Dowfroth 200, 0.34
3	Cleaner float	2	10	5		9.0	None
5a	Float 1	5	5	5	8.6	13.0	Dextrin, 0.54
8	Float 1	5	5	5	8.6	13.0	Dextrin, 0.94

talc. The only requirement was agitation and aeration of the pulp. Additional recovery of talc was obtained by using Dowfroth 200 (a frothing and collecting reagent for talc) but the float product was essentially the same quality as the feed. Carbonates in the Float 1 product were reduced from 5 per cent to 1 per cent or less. Tremolite was more difficult to reject although less than 1 per cent was observed in the Float 1 product of Test 2. Tremolite rejection was accomplished by reducing the per cent solids in the flotation feed from 13 per cent to 6.8 per cent. Test 3 was made by refloating the combined Float 1 and Float 2 products of Test 1. This yielded a product which was 80 per cent platy talc and contained 31.6 per cent of the original feed weight.

Because platy talc is more readily floated than nonplaty talc, it was believed that the addition of a talc depressant such as Dextrin might have a selective depressing action on the nonplaty talc forms which had appeared in the Float 1 products. Dextrin was used in Tests 5a and 8, and the results show that Dextrin in the amount of 0.54 pound per ton of flotation-feed solids was effective and helped to produce a Float 1 product that was about 83 per cent platy talc. Dextrin in this amount appeared to be effective in causing a small increase in recovery. In Test 8, the Dextrin added was increased to 0.94 pound per ton of flotation-feed solids. The quality of the Float 1 product was essentially the same as in Test 5a, but the weight recovery decreased to 26.9 per cent compared with 34.6 per cent when the lesser amount of Dextrin was used.

The results of the five tests on the Oasis talc show that although none of the products obtained were mineralogically equivalent to the Italian talc, substantial improvement had been obtained. The best results were obtained from Test 5a which yielded a product containing 83 per cent platy talc. A comparison of the Oasis Float 1 product with the Italian samples is given in Table 5.

TABLE 5. COMPARISON OF OASIS FLOAT 1 WITH ITALIAN NO. 1 AND NO. 2 TALCS

	Weight Per Cent	Mineral Count, per cent				
		Platy Talc	Fibrous Talc	Granular Talc	Carbonates	Tremolite
Test 5a, Float 1	34.6	83	2	14	<1	1
Italian No. 1	100.0	88-90	8-10	0	<2	Trace
Italian No. 2	100.0	90	6	0	3	1

The quality of the Float 1 product approaches that of the Italian No. 1 talc, and it is not unreasonable to expect that an equivalent grade might be developed after further investigations.

The products of Test 8, which gave results of the same order as Test 5a were examined microscopically in considerable detail. Each flotation product was sized on a 200-mesh sieve and the oversize and undersize evaluated. These results are shown in Table 6.

The data given in Table 6 show that in the Float 1 product the plus 200-mesh talc is 61 per cent platy talc but the minus 200-mesh talc is 87 per cent platy talc. It is implied that better over-all results would have been obtained by grinding the Oasis sample all through 200 mesh before floating. This was not tried, and if necessary it can be done at a later stage in the program.

TABLE 6. RESULTS OF MICROSCOPIC EVALUATION OF FLOTATION PRODUCTS FROM OASIS TALC, TEST 8

	Weight Per Cent	Mineral Count, per cent Platy Talc	Nonplaty Talc	Carbonates	Tremolites
Flotation Feed					
-65+200 mesh	30	45	45	4-5	4
-200 mesh	70	49-50	40-43	4-5	3-4
All-200 mesh[(a)]	100	48	43	4-5	3-4
Float 1					
-65+200 mesh	29	61	37	<1	2
-200 mesh	71	87	10	<1	2
All-200 mesh[(a)]	(26.9)	82	15	<1	2
Float 2					
-65+200 mesh	50	24	71	1	4
-200 mesh	50	70	25	1	4
All-200 mesh[(a)]	(56.3)	60	35	1	4
Underflow					
-65+200 mesh	18	20	54	18	8
-200 mesh	82	22	54	15	9
All-200 mesh[(a)]	(16.8)	25	51	16	8

(a) Some of the plus 200-mesh particles that appear to be nonplaty are actually aggregates of minute platelets which become discrete platelets when ground finer than 200 mesh. A more accurate mineral count is obtained by grinding the entire product and then evaluating with the microscope. In addition to this, a minus 200-mesh product has a narrower range of sizes than a minus 65-mesh product which increases the accuracy of a microscopic count and finally, the minus 200-mesh product has a size range similar to the Italian talcs discussed in detail later in the report.

Sample From the Stone Creek Mine

The Stone Creek mine sample came from Montana and was supplied by the Southern California Minerals Company. This material was available because it also had been previously investigated by Battelle[1] for Johnson and Johnson as a potential raw talc source. The material on hand had been prepared to minus 65-mesh size in the same manner as the Oasis sample.

This sample contained 30 per cent platy talc and 67 per cent nonplaty talc.

Two flotation tests were made, and the results are given in Table 7. Table 8 lists the operating conditions during the tests.

TABLE 7. SUMMARY OF FLOTATION RESULTS ON STONE CREEK TALC SAMPLES (MINUS 65 MESH)

Test	Product	Weight Per Cent	Approximate Mineral Count, per cent: Platy	Nonplaty	Carbonates	Tremolite
4	Float 1	29.9	85	12	1	2
	Float 2	13.1	30	60	10	
6	Float 1	25.5	86	10	2	2
	Flotation feed	100.0	30	67	1	2

TABLE 8. TEST CONDITIONS USED TO OBTAIN RESULTS ON STONE CREEK SAMPLE

Test	Product	Time, minutes: Wetting	Conditioning	Floating	Pulp pH	Per Cent Solids in Feed	Reagent, pounds per ton of flotation feed
4	Float 1	10	0	3	9.0	13	None
	Float 2	0	0	3			None
6	Float 1	5	5	5	8.8		Dextrin, 0.54 Na_2SiO_3, 1.08

Test 4 shows that about 30 per cent of the talc is recovered in a float product containing 85 per cent platy talc. No reagents were used, which illustrates again that platy talc is more readily floated than nonplaty talc. Test 6 yielded a float product that contained 86 per cent platy talc and 10 per cent nonplaty talc. Dextrin and sodium silicate were used to reject the nonplaty talc but the effect, from the amounts used, was not pronounced.

The quality of the Float 1 products approaches that of the Italian No. 1 talc which is 85-90 per cent platy talc. Through additional experimentation a method probably can be developed, to treat the Stone Creek talc, which will yield a product of quality equivalent to Italian No. 1 talc.

(1) Battelle Summary Report, February 29, 1956.

Italian No. 2 Talc

Three tests were made on Italian No. 2 talc as part of the exploratory program, and the results are given in Table 9. Tests 10 and 11 were made at 6.8 and 13.0 per cent solids, respectively, using the same reagent combination in each, to determine the weight recovery obtained at low and intermediate per cent of feed solids. The results show that at 6.8 per cent feed solids the weight recovery was 75.3 per cent while at 13.0 per cent solids the weight recovery was 85.9 per cent. Test 12 was made at 13.0 per cent solids, without any reagents, to compare with Test 11. The results show that the Float 1 product was no better than the flotation feed and also only 59.9 per cent of the weight was floated. In Test 10 the froth of the Float 1 product was broken down easily, but in Test 11 the froth was very difficult to break down and filter. Undoubtedly this would present handling difficulties in a plant.

A summary of these results indicates that:

(1) Better recoveries are possible when using 13.0 per cent feed solids compared with 6.8 per cent feed solids.

(2) Dextrin is effective in reducing the amount of nonplaty (fibrous) talc in the Float I product.

(3) Dowfroth 200 is needed to obtain good weight recovery.

(4) The froth of the float products is easy to break down when the per cent feed solids is low. However, the lower per cent feed solids results in a lower yield of Float 1.

Following these exploratory experiments, a program was started to improve the froth characteristics without sacrificing the platiness of the Float 1 product and to maintain or raise the per cent of weight recovery. Forty-four flotation tests were made, all on Italian No. 2 talc.

TABLE 9. SUMMARY OF PRELIMINARY FLOTATION RESULTS ON ITALIAN NO. 2 TALC

Test	Product	Weight Per Cent	Approximate Mineral Count, per cent: Platy	Nonplaty	Carbonates	Tremolite
10	Float 1	75.3	96	3	<1	<1
11	Float 1	85.9	96	3	<1	<1
12	Float 1	59.9	89	8	2	1
	Flotation feed	100.0	90	6	3	1

TABLE 10. TEST CONDITIONS USED TO OBTAIN RESULTS OF TESTS 10, 11, and 12

Test	Product	Time, minutes Wetting	Conditioning	Floating	Pulp pH	Per Cent Solids in Feed	Reagent, pounds per ton of flotation feed
10	Float 1	5	5	10	8.7	6.8	Dextrin, 0.94 Dowfroth 200, 0.34
11	Float 1	5	5	10	9.0	13.0	Dextrin, 0.94 Dowfroth 200, 0.34
12	Float 1	10	0	10	8.9	13.0	None

Detailed Flotation Experiments on Italian No. 2 Talc

The methods considered in these tests called for trying various quantities of Dextrin and Dowfroth 200, replacing or supplementing Dextrin with Guartec (a guar gum), using an intermediate per cent of feed solids, stage addition of reagents, regulation of pulp pH during the flotation period, and dewatering and refloating the flotation underflow.

The complete tabulation of these results and the operational data of these tests are given in Appendix A. The more significant information contained in these tests has been abstracted and is given in the following tables.

Table 11 contains the results obtained from experiments relating to the effect that the quantity of frother used has on the amount of talc recovered.

TABLE 11. ITALIAN NO. 2 TALC INFLUENCE OF QUANTITY OF FROTHER ON WEIGHT RECOVERY OF TALC BY FLOTATION

Test	Float Product Weight Recovery, per cent	Dowfroth[a], pounds per ton of feed solids	Character of Froth Good	Fair	Poor	Platy Talc, per cent
36	51.0	None	x			Mostly fines
37	70.4	0.17		x		96
35	83.3	0.34			x	96
35	91.0	0.68			x	94

(a) Chemical composition is discussed in Appendix A.

Each of the tests reported in Table 11 was made at 10 per cent feed solids and included Dextrin[1] in the equivalent amount of 0.47 pound per ton of flotation feed solids. The pH of the pulp was 8.6.

The results of these tests illustrate the natural floatability of the talc and the additional collecting properties of the frother. Test 36 shows that 51.0 per cent of the talc

(1) Chemical composition is discussed in Appendix A.

floats without any frother. The amount of talc floated increases according to the amount of frother added. However, an increase in the amount of frother added resulted in froths more difficult to handle. When 0.34 pound of frother was added, the froth was composed of a large quantity of very fine bubbles that resisted defrothing. Addition of frother in increments of less than 0.17 pound per ton of feed might lead to better froth control, and this can be tried at a later date if suitable results are not obtained by other methods.

Tests 35 and 37 both yielded a float product that was 96 per cent platy talc. However, the recovery of talc was increased from 70.4 in Test 37 up to 83.3 per cent in Test 35 by the addition of twice as much Dowfroth, although the higher recovery was characterized by a less suitable froth.

A series of experiments was made to determine the effect of per cent of solids in the flotation feed on the amount of talc recovered in the float product. The results of these experiments are shown in Table 12.

TABLE 12. ITALIAN NO. 2 TALC INFLUENCE OF FEED PER CENT SOLIDS ON WEIGHT RECOVERY OF TALC BY FLOTATION

Test	Float Product Weight Recovery, per cent	Feed Solids, per cent	Character of Froth			Play Talc, per cent
			Good	Fair	Poor	
10	75.3	6.8		x		96
21-24	83.9	13			x	96

In each of these tests the reagents added were Dextrin 0.94 and Dowfroth 0.34 pound per ton of solids. The pH of the pulp was 8.6.

The data of Table 9 show that a higher weight recovery is obtained when a higher per cent of feed solids is employed. At 6.8 per cent solids, 75.3 per cent of the weight is recovered, and of 13 per cent solids, 83.9 per cent of the weight is recovered. This is a substantial difference considering that the same degree of platiness in the float product is obtained by either approach. However, the froth produced from a feed of 13 per cent solids was difficult to handle.

The amount of Dextrin used has a marked influence on the platiness of the talc floated and a slight influence on the weight of talc recovered. Tests that illustrate the magnitude of these factors are given in Table 13.

TABLE 13. ITALIAN NO. 2 TALC INFLUENCE OF QUANTITY OF DEXTRIN ON WEIGHT RECOVERY OF TALC BY FLOTATION

Test	Float Product Weight Recovery, per cent	Dextrin, pounds per ton of feed solids	Mineral Count		Froth
			Platy Talc, per cent	Fibrous Talc, per cent	
12	81.7	0	89	8	Good
26	82.5	0.18	90	8	Poor
21-24	83.9	0.94	96	3	Poor
Flotation feed	100.0	--	90	6	--

Each test was made at 13 per cent solids, and 0.34 pound of Dowfroth was added per ton. The pH of the pulp was 8.6.

Data given in Table 13 show that Dextrin has a tendency, although slight, to increase the weight of talc recovered. More significantly, the data show that when no Dextrin was used, the talc floated was only 89 per cent in the platy form, which is essentially the same purity as the flotation feed. When the equivalent of 0.94 pound of Dextrin was added, the float product was 96 per cent platy talc.

It is indicated that Dextrin is not a talc depressant in every sense. More specifically, Dextrin acts as a depressant for nonplaty talc and a mild activator for platy talc. The distinction is not sharp, but it is evident. The separation of platy talc from nonplaty talc may be patentable, and the Battelle Patent Sectión is conducting a novelty and art search on the subject.

Guartec (trade name of guar gum distributed by General Mills) is also known as a talc depressant and froth modifier. Tests were made with various quantities of Guartec to determine whether it would selectively depress nonplaty talc and also whether any improvement in the quality of the froth might be expected. The summarized results of these tests are given in Table 14.

TABLE 14. ITALIAN NO. 2 TALC INFLUENCE OF QUANTITY OF GUARTEC ON TALC WEIGHT RECOVERY, PLATINESS AND FROTHING PROPERTIES

Test	Guartec, pounds per ton of feed solids	Feed Solids Per Unit	Float Product Weight Recovery, per cent	Platy Talc, per cent	Froth
17	0.47	13	87.6	94	Fair
16	0.94	13	71.0	94	Good
34	0.94	20	77.3	91	Good

In each of the tests reported in Table 14, 0.34 pound of Dowfroth was added, and the initial pH of the pulp was 8.6. No Dextrin was used.

Guartec, in the amounts used, did not aid in producing a float product that was as good as that obtained with Dextrin. When Dextrin was used, a product containing 96 per cent platy talc was obtained, but the best product obtained using Guartec was only 94 per cent platy talc. The type of froth produced with Guartec was much easier to handle, although this is not significant if satisfactory improvement in quality cannot be obtained.

The foregoing discussion describes the most significant data obtained regarding the floatability of talc when Dextrin and Guartec were used. The best results were obtained from Tests 21-24 when 83.9 per cent of the talc was recovered in a float product that was 96 per cent platy talc, 3 per cent fibrous talc, and less than 1 per cent each of dolomite and tremolite. The froth obtained by this method would be difficult to manage.

A comparison of the physical properties of raw Italian No. 1 and No. 2 talcs, and the froth flotation product from No. 2 talc, is made in Table 15.

TABLE 15. COMPARISON OF PHYSICAL PROPERTIES OF RAW AND FLOATED TALC (ITALIAN NO. 1 AND NO. 2)

	Italian No. 1	Italian No. 2	
	Raw	Raw	Floated
Bulk Density, lb per cu ft	23.7	21.5	23.6
Acid Solubility, per cent[(a)]	1.9	2.2	1.2
pH Alkalinity	9.2	8.8	8.7
Relative Lubricity[(b)]	0.935-0.990	0.926	1.017-1.051
Relative Abrasion[(c)]	0.00214	0.00259	0.00132
Weight Per Cent of Raw Talc	100.0	100.0	80-86
Mineral Count, per cent			
Platy Talc	88-90	90	96
Fibrous Talc	9	5	3
Dolomite	<2	3	<1
Tremolite	<1	2	<1

(a) The figures for acid solubility are at variance with information submitted unofficially in a similar table to Johnson and Johnson by R. D. Macdonald. The acid solubility as shown above is considered accurate, and a description of the method of analysis and the reason for using it will be discussed in a forthcoming report.

(b) The larger the number, the more lubricious the talc. See Battelle Progress Report to Johnson and Johnson "Studies of the Physical Properties of Talc, Their Measurement and Comparison", by W. L. Smith, October 15, 1957.

(c) The implication of these numbers will be discussed in a forthcoming report. The more abrasive material produces the highest number.

Table 15 shows that the floated Italian No. 2 talc has a more desirable mineral composition than the raw talc, less acid-soluble constituents (dolomite equivalent), better lubricity, and is about one-half as abrasive.

Although the possibilities of further improvement of quality, recovery, and froth properties were far from exhausted when using Dextrin or Guartec, a different approach seemed advisable for two reasons. First, Dextrin and Guartec, although not toxic, might be objectionable because they are organic compounds that may cause rancidity or fungus growth if not thoroughly removed or destroyed during the process. This, of course, would be undesirable for baby powder. The second reason for a different approach is that a more controllable froth is desirable. In nonmetallic flotation processes, excessive frothing is not uncommon when the operation takes place in pulps having a high pH value. Most of the foregoing tests were made at a pH of about 8.6, and while this is not considered extremely high, investigation of lower pH values appeared to be worth while. In order to lower the pH to approximately neutral, it was decided to use an inorganic acid, such as hydrochloric, and complete the flotation before the acid was neutralized by the dolomite in the pulp and before the pH began to rise noticeably.

A series of tests was made using hydrochloric acid as a pulp modifier with some encouraging results. Data obtained from these experiments are shown in Table 16.

TABLE 16. FLOTATION RESULTS OBTAINED USING HCl AS A PULP MODIFIER AND VARIOUS AMOUNTS OF DOWFROTH AS A TALC COLLECTOR (ITALIAN NO. 2 TALC)

Test	Dowfroth, pounds per ton of feed solids	Feed Solids, per cent	Float Product Weight Recovery, per cent	Platy Talc, per cent	Froth
43-46	None	10	60.2	98	Good
52-55	0.04	10	57.8	98	Good
39	0.11	10	71.1	97	Good
43-46	0.13	10	74.5	97	Good
52-55	0.17	10	75.6	97	Good
41	0.22	10	77.6	95	Fair
40	0.21	10	76.7	94	Poor
50	0.17	18	77.1	96	Good
51	None	3	53.0	97	Good

In each test the equivalent of 0.09 pound of HCl per ton of ore was added, and the pulp pH was about 7.6-7.8. The wetting time before reagent addition was 5 minutes, and the conditioning time with HCl before flotation was 2-3 minutes.

The results given in Table 16 show that a float product containing at least 97 per cent platy talc and having acceptable frothing properties is readily obtained.

Increasing the amount of frother increased the weight recovered, but it was noted during this series of tests that 0.11 pound of Dowfroth was about the maximum that could be added to obtain the Float 1 product without encountering frothing problems. The float products all filtered rapidly but the underflow products filtered slowly. This suggests that the solids in the underflow are much finer than the float products.

The size distributions of the products obtained from Tests 43-46 were determined. These were discussed in a letter report dated April 1, 1958, to Dr. W. H. Lycan. The data show that the flotation feed was 13.5 per cent finer than 4.7 microns but the flotation underflow was 26.7 per cent finer than 4.7 microns. Although the Float 1 product contained only 9.7 per cent of the weight finer than 4.7 microns, it is our belief, as judged from handling of the product, that flotation alone did not remove enough particles of dust-forming size to be acceptable. Elimination of those sizes which create air borne talc particles probably will require a cyclone type of treatment, and a number of experiments are planned to determine what factors are involved and whether hydraulic or pneumatic cyclone treatment is the more feasible.

CONCLUSIONS

Data and observations obtained from the flotation tests to date have established that:

(1) Platy talc floats more readily than nonplaty talc.

(2) A frothing agent, such as Dowfroth 200 is helpful in obtaining reasonable talc recovery.

(3) About 13 per cent solids is the optimum feed pulp density for treating Italian No. 2 talc.

(4) Either Dextrin or hydrochloric acid is an effective reagent for rejecting nonplaty talc.

(5) When Dextrin is used to depress nonplaty talc, the froths produced are voluminous and difficult to handle. When hydrochloric acid is used to regulate the pulp pH and depress nonplaty talc, the froths produced are normal and will filter rapidly.

(6) Italian No. 2 talc can be floated to yield a product which is mineralogically superior to Italian No. 1 talc.

(7) Oasis and Stone Creek types of ores can be floated to yield products that approximate the quality of Italian No. 1 talc. It is believed that methods can be developed for these types of talc which will yield satisfactory products.

(8) Flotation will reject some of the objectionable fine talc, but more complete removal of the fines probably will require classification by hydraulic or pneumatic cyclones.

FUTURE WORK

Future experiments would have as an objective a higher recovery of platy talc. Such experiments would be based on the use of hydrochloric acid to control the pulp pH and thereby the rejection of nonplaty talc while using different techniques of frother addition for improved recovery.

Flotation alone does not reject a sufficient amount of the particles which are potential dust; therefore, experiments would be made to remove these sizes by hydraulic cyclones.

After optimum beneficiation conditions have been obtained, it would be planned to produce enough product for various physical measurements and also enough product to send to Johnson and Johnson for their subjective appraisal.

We propose to investigate the feasibility of nearly complete removal of dolomite by leaching the float products with an inorganic acid. Nearly complete removal of dolomite would be necessary if it is important to obtain a talc product having a neutral pH.

Flotation tests would be made on samples of Italian No. 2 talc which represent different lots or shipments in order to establish that the beneficiation process is applicable to any potential differences in source material.

The original notes on the laboratory work described in this report are in Battelle Laboratory Record Book No. 14265, pages 1 to 100, inclusive; and also in Laboratory Record Book No. 14668, pages 1 to 33, inclusive. The work was done in the period from December 11, 1957, to May 12, 1958.

WEB:WLS:RDM/dpc

APPENDIX A

DETAILS OF FLOTATION WORK

TABLE A-1. DETAILED RESULTS OBTAINED FROM FLOTATION OF ITALIAN NO. 2 TALC

Test	Product	Weight Per Cent	Approximate Mineral Count, per cent: Platy	Nonplaty	Dolomite	Tremolite	Feed, solids per cent	Flotation Time, min	Reagents Used, pounds per ton of feed: Dextrin	Guartec	HCl	Dowfroth 200	Other	Froth Character: Good	Fair	Poor	Remarks
Flotation Feed	Italian No. 2	100.0	90	6	3	1											
11	Float 1	85.9	96	3	<1	<1	13	10	0.94	0	0	0.34	0			x	
12	Float 1	59.9	89	8	2	1	13	10	0	0	0	0	0	x			Same purity as feed
	Float 2	21.8						5	0	0	0	0.34	0	x			
	Float 3	7.3	Not determined					5	0	0	0	0.17	0	x			
13	Float 1	87.2	93	6	1	<1	13	10	0.94	0	0	0.34	0			x	Tap water used to pulp solids
14	Float 1	84.4	Not determined				13	10	0.94	0	0	0	0.34(a)			x	
15	Float 1	64.4	95	4	<1	<1	13	5	0.94	0	0	0.17	0		x		
	Float 2	16.6	92	6	1	1		5	0	0	0	0.17	0		x		
16	Float 1	71.0	94	ND	ND	ND	13	5	0	0.94	0	0.34	0	x			Filtered quickly
	Float 2	15.0	Not determined					5	0	0	0	0.34	0	x			
17	Float 1	87.6	94	5	<1	<1	13	5	0	0.47	0	0.34	0		x		
	Float 2	7.3	91	6	2	1		5	0	0	0	0.34	0	x			Same purity as feed
18	Re-cleaner	36.0	96	3	<1	<1	13	15	0	0.47	0	0.34	0		x		Float 1 refloated twice
19	Cleaner	56.5	Not determined				13	15	0.47	0.11	0	0.34	0			x	Float 1 refloated once
20	Float 1	66.6	Not determined				13	5	0.94	0.61	0	0.34	0		x		
	Float 2	10.7	Not determined				13	5	0.47	0	0	0.17	0	x			
21-24	Float 1	83.9	96	3	<1	<1	13	10	0.94	0	0	0.34	0			x	Duplication of Test 11; average of four tests
25		Discarded because of contamination															
26	Float 1	82.5	90	8	<2	<1	13	10	0.16	0	0	0.34	0			x	
27	Float 1	75.0	Not determined				13	10	0.16	0	0	0.17	0		x		
28-32		Discarded because reagents had deteriorated															
33	Float 1	68.1	92	5	1	2	13	5	0	0.94	0	0.34	0	x			
	Float 2	20.7	87	6	3	4		5	0	0	0	0.34	0	x			
34	Float 1	77.3	91	6	2	1	20	5	0	0.94	0	0.34	0	x			
	Float 2	12.9	Not determined														
35	Float 1	83.3	96	2	<1	1	10	10	0.47	0	0	0.34	0			x	
	Float 2	7.7	91	7	1	1		5	0	0	0	0.34	0	x			
36	Float 1	51.0	Not determined				10	10	0.47	0	0	0	0	x			Predominantly fine particles
	Float 2	27.6	Not determined					5	0.47	0	0	0.34	0	x			Contains coarse platelets and contaminants
37	Float 1	70.4	96	2	<1	1	10	10	0.47	0	0	0.17	0		x		
	Float 2	16.3	Not determined						0.94	0	0	0.85	0	x			
38	Float 1	83.1	Not determined				10	10				0	0.50(b)	x		x	
39	Float 1	52.5	99	<1	<1	<1	10	ND	0	0	0.9	0	0	x			Exceptionally good grade; at end of test pH of pulp was 7.4
	Float 2	18.6	96	3	<1	<1		ND	0	0	0	0.11	0	x			
40	Float 1	76.7	94	4	2	1	10		0	0	0.09	0.21	0			x	
41	Float 1	88.3	96	2	<1	1	10	7	0	0	0.09	0.11	0		x		
	Float 2	9.3	93	4	<1	<2		5	0	0	0	0.11	0	x			
42		Discarded because of contamination															
43-46	Float 1	60.2	98	1	<1	<1	10	10	0	0	0.09	0	0	x			Filtered rapidly
	Float 2	14.3	96	2	1	1	5	0	0	0	0	0.13	0	x			Filtered rapidly
	Underflow	25.5	67	21	6	6											pH of pulp was 7.6, filtered slowly
47		Discarded because of contamination															
48	Float 1	58.0	Not determined				10	10	0	0	0	0	0.30(c)	x			Reagent 620 produced buff-colored products
	Float 2	14.2	Not determined					3	0	0	0.09	0.11	0	x			
49	Float 1	To be repeated, results questionable						10	0	0	0.09	0	0	x			Flotation feed source was obtained from cyclone underflow
	Float 2							5	0	0	0	0.13	0	x			
50	Float 1	62.8	97	2	Trace	Trace	13	10	0	0	0.09	0	0	x			
	Float 2	14.3	94	5	<1	1		8	0	0	0	0.17	0	x			
51	Float 1	53.0	97	2	<1	<1	3	10	0	0	0.09	0	0	x			
52-55	Float 1	57.8	98	<2	<1	<1	10	5	0	0	0.09	0.04	0	x			
	Float 2	18.8	96	3	<1	<1		5	0	0	0	0.13	0	x			
56(d)	Scavenger	6.1	95	3	<1	1	7	10	0.89	0	0.13	0.11	0	x			Underflow from Tests Nos. 52-55 was cycloned and cyclone underflow used as flotation feed

Note: Some tests are not evaluated mineralogically because of unsatisfactory froth characteristics or because weight recovery was too low.

Reagents used: Dextrin is made by hydrolysis of starch and manufactured by Clinton Foods Incorporated, under the name of Dextrin 603.
Guartec is the General Mills trade name for guar gum.
HCl is reported as pounds per ton of reagent grade hydrochloric acid which is about 38 per cent of HCl.
Dowfroth 200 is a water-soluble frothing agent manufactured by the Dow Chemical Company. The chemical formula is $CH_3\text{-}\underset{OH}{CH}\text{-}CH_2\text{-}O\text{-}C_3H_6\text{-}O\text{-}C_3H_6\text{-}O\text{-}CH_3$.

(a) Dowfroth 250.
(b) Ultrawet "K".
(c) Reagent 620.
(d) Test 56 was made on the underflow product of Tests 52-55, and recovery of 6.1 per cent refers to the original feed for Tests 52-55.

APPENDIX B

FROTH FLOTATION

APPENDIX B

FROTH FLOTATION

Froth flotation is a process of material separation for solid particles, usually finer than about 200 microns in size. The separation takes place in an air-water mixture, and is a result of the adhesion of certain particles to air bubbles and the wetting of other particles by the water phase. Whether a particle will adhere to the air phase and be floated, or be wetted by the water phase and sink depends on the character of its surface.

Materials that either ionize or hydrate in water are nonfloaters, and most minerals are in this group. Sulphur, graphite, and talc are exceptions and are called natural floaters. Materials with a hydrocarbon surface, such as solid paraffin, are not wetted by water and will adhere to air bubbles. A material normally water wettable and nonfloatable can be made nonwettable and readily floatable by coating it with a monomolecular film of a paraffin-type chemical (collector), which presents a surface to the air-water mixture essentially the same as solid paraffin. The polar part of the chemical causes the hydrocarbon chain (nonpolar group) to stick to the surface of the mineral.

The reagents employed in flotation, grouped according to their function, are frothers, collectors, and modifiers. In the flotation of talc, however, collectors play no part and are not discussed here because talc has a naturally nonwettable surface.

Frothers

Frothers reduce the surface tension of the water and stabilize the air bubbles. The frother molecule is heteropolar: one part of the molecule has an affinity for water and the other has an affinity for air. The most widely used frothers are pine oils, cresylic acid, and various aliphatic alcohols. Substances with structures similar to alcohols, phenols, ketones, or aldehydes are most suitable, but many other organic compounds are potential frothers.

Frothers usually have only slight collecting properties, that is, they do not adsorb on minerals in such a way as to make the surface nonwettable. Some outstanding exceptions are that certain frothers aid in the collection of talc, graphite, molybdenite, sulphur, and coal, and this fact has been used in the work done on Italian talc.

Modifiers

Modifiers are chemicals which can be used to affect the wettability or nonwettability of a surface. They are used most commonly in connection with collecting reagents, to modify the degree of surface action, so that species of minerals may be separated with greater selectivity. Modifiers also affect the surface characteristics of naturally nonwettable minerals such as talc, and can be used to increase the quantity of talc which will float under a given set of conditions or the quantity of waste material which can be prevented from floating.

Modifiers usually are inorganic reagents, but some organic ones are used also. Some of the common ones are hydroxides, oxides, silicates, carbonates, and phosphates of sodium or calcium, mineral acids, short-chain organic acids, starch, dextrin, gums, and glues.

Flotation Variables

Every ore contains at least a small quantity of soluble salts, and the water used for milling, regardless of its purity, contains many kinds of ions. This means that every flotation system, before the addition of any reagents, contains literally dozens of ions which are capable of competing for a place on the surface of mineral particles. After the addition of collecting, frothing, and modifying reagents, this situation is further complicated, and when the air is introduced, the oxygen and carbon dioxide of the air take their turn at altering the pulp conditions.

In addition to the chemical variables, there are physical and mechanical variables in a flotation system, such as particle size, water to solid ratio, speed of agitation, flotation time, place of reagent addition, type of machine used, temperature, cell arrangement, and sequence of mineral flotation. The kind and quantity of slime present in a flotation pulp are also factors of importance.

The combination of these chemical, physical, and mechanical variables results in a heterogeneous system of such complexity that it defies the time-honored method of scientific investigation, which is, to change one variable while holding all others constant. The change of any one variable simultaneously changes many others. For example, a change in acidity (pH) by the addition of hydrochloric acid will not only change the concentration of hydrogen, hydroxyl, and chloride ions present in accordance with the laws of mass action, but it may change the concentration of nearly every ion present in the pulp, and any one of these concentrations may be critical to successful flotation. In addition the change in acidity will affect the ability of the frother to produce a stable froth.

Flotation as an Art

It is because of this inherent complexity that flotation is often referred to as an art rather than a science. Successful results on any ore are obtained only by an "artistic balance" of the many variables. Actually, the picture is not so bad as might be supposed, for the majority of the variables usually are of minor importance and only five or ten must be studied closely.

This brief discussion of flotation variables is included to stress the point that each ore presents its own intricate system, and that the set of conditions which gives optimum results for one ore may require modification for another.

Laboratory Flotation Procedure

The flotation equipment used for these experiments is the standard Fagergren Laboratory Flotation Cell of 500 gram solids nominal capacity. It is a batch machine, but it is known that the results obtained with this type of equipment can be translated reasonably well in terms of large-scale continuous commercial operation. The

Fagergren cell is made up of a cylindrical glass bowl which will hold about 1.75 liters of pulp. The pulp is agitated by a rotor which is placed concentrically inside a stator, both of which are made up of multiple stainless steel rods in a rotunda configuration. As the rotor spins in the pulp, a partial vacuum is created directly beneath it which draws air through a concentric shaft and discharges it at the bottom of the cell. As the air enters the pulp, it is expelled with great shearing force between the rotor and stator and becomes diffused in the form of minute bubbles in the pulp.

The general laboratory procedure used for the flotation of talc samples was as follows:

Pulverized talc and water were added to the flotation cell in the proportions that would give the desired per cent of solids. The rotor was started and the pulp agitated until the solids were wetted. Selected reagents were then added and the pulp conditioned for a few minutes. The air was turned on and the flotation period started. The mineralized froth which forms on the surface of the pulp was skimmed off with a paddle for a specified time or until no more froth formed. Additional reagents were added, if desired, for increased recovery of talc. During the test, records were kept to show the type of water used, per cent solids, pH, quantity and kind of reagents, time allowed for conditioning and flotation, and other significant observations.

If the froth, or float product, was not of the desired purity, some of the standard methods for improvement were:

(1) To decrease the rate of aeration, which decreases the rate of froth overflow

(2) To decrease the per cent solids in the flotation feed

(3) To use less powerful frothing reagents

(4) To use a more effective depressant

(5) To refloat the froth in a second-stage operation

(6) To make the separation at another pH level

(7) To decrease the time of froth collection.

Some of the methods used to increase the recovery of high-grade platy talc were:

(1) To increase the rate of aeration

(2) To increase the per cent solids in the pulp

(3) To dewater the underflow and repeat the test on the unfloated solids and at a relatively high per cent solids.