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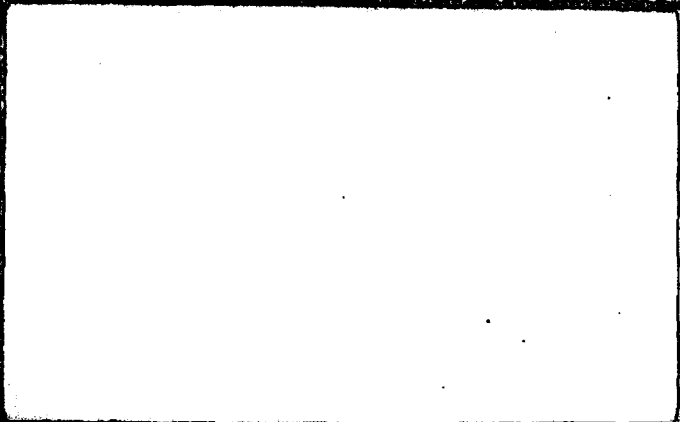
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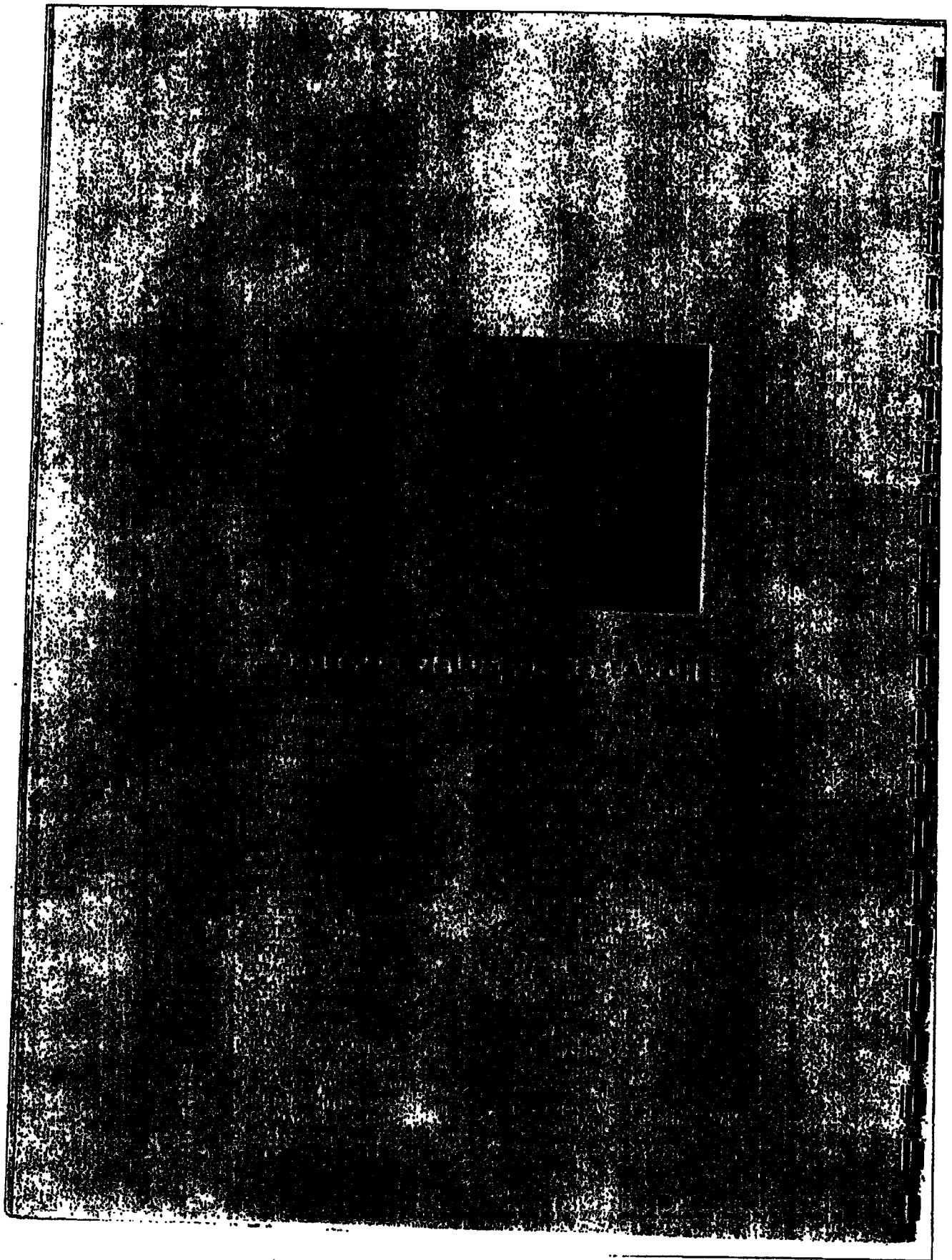
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PROGRESS REPORT

on

**FURTHER STUDIES ON THE MEASUREMENT
AND CORRELATION OF THE PHYSICAL
PROPERTIES OF TALC**

to

JOHNSON AND JOHNSON

Russell C. Croy
May 9, 1958

by

W. L. Smith

**BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus 1, Ohio**

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cc: W. L. Smith (3)

R. D. Macdonald

Files

O. F. Tangel (3)

A. C. Richardson

Battelle Memorial Institute

505 KING AVENUE COLUMBUS 1, OHIO

July 18, 1958

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

Dear Dr. Lycan:

This letter transmits six copies of our report "Further Studies on the Measurement and Correlation of the Physical Properties of Talc".

This report, plus that of October 25, 1957, demonstrates that lubricity may be improved and abrasiveness lessened by the removal of the mineral contaminants from talc. A minimum number of physical-property measurements are recommended as important in the comparison of high-grade talcs and in the evaluation of improvement of physical properties through beneficiation.

Because of urgency on other phases of Battelle's investigation of talc, further studies on the physical properties are postponed.

We would be pleased to have your comments on our findings.

Very truly yours,

Wm. L. Smith
Principal Geologist
Minerals Beneficiation Division

WLS/djo
Enc. (6)

DEDICATED TO THE ADVANCEMENT OF SCIENCE

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FURTHER STUDIES ON THE MEASUREMENT AND CORRELATION OF THE PHYSICAL PROPERTIES OF TALC

by

W. L. Smith

ABSTRACT

To establish the interrelationships of the physical properties of talc and to be able to visualize the means of their improvement, it has been necessary to devise means of measuring small differences in properties. To determine the nature and effects of grit, a chemical analysis for small concentrations of carbonate minerals and a machine for measuring the relative abrasiveness of talc samples were contrived, and the measurements were compared with those of other physical properties. The various other measurements were made on standard laboratory instruments, using both sized fractions and whole powder. Physical-property measurements of the talc demonstrated that the samples which produced the least abrasion were those with the greater platy talc component and those with the least amount of contaminants. It is concluded that the improvement of slip and the lessening of abrasiveness may be accomplished by the removal of the mineral contaminants, but not by the removal of size fractions.

Preliminary work on color and reflectance properties is presented, and demonstrates a relationship to particle size and, hence, secondarily to other physical properties.

The report includes an appraisal of the various physical-property measurements employed in the evaluation of improvement of talcs. A minimum number of measurements are recommended as important in the consideration of beneficiation for improvement and for comparison of natural high-grade ores.

INTRODUCTION AND SUMMARY

This report is a continuation of the studies of the physical properties of talc, their measurement, and comparison^{(1)*}, previously reported to Johnson and Johnson. The first Progress Report dealt with petrography, lubricity, and such physical measurements as average diameter, bulk density, porosity, and surface area. It was concluded from the previous study that the acceptable Italian talc fell within a small range of physical measurements and that the samples with the more desirable slip have the greater surface area, the smaller average particle diameter, the greater ratio of voids to total volume, and the lesser bulk density. Lubricity was found to be controlled by the shape of the relatively small content of larger particles in an otherwise finer mixture. Removal of the coarser contaminants, or preferably of all of the contaminants, was concluded to be a means of improving the slip of the talc.

* References appear at end of report.

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The conclusions of the previous progress report have been further substantiated by the following studies; however, since lubricity is but one of many of the properties of talc, the previous work represented but part of the picture. Whereas the previous report dealt primarily with the physical measurement of areas, diameters, weight, and directly related characteristics, this report deals with reflectance, color, moisture content, abrasiveness, alkalinity, and acid solubility - properties related to lubricity only through their common correlation through surface area, size, and component contamination.

As in the previous report, both particle size and shape and the amount and nature of the contaminants are investigated to determine the contributing factors to physical measurement variations. It is recommended as a result of these studies that the following measurements are sufficient to determine satisfactory talc within the range in composition of Italian talc. These are the determination of the mineralogy and particle size distribution, volumetric analysis of the carbonate component, and the measurements of the bulk density, moisture content, reflectance, and whiteness. This should also serve as a basis for the determination of acceptability in other talcs and beneficiated products, taking into consideration the differences in size distribution, crystallographic habit, and mineral contamination.

Because size distribution, as it is reported, is dependent upon the analytical procedure, the measurement of physical properties is made only on closely sized fractions in the coarser size ranges. Division into size fractions of the finer size portion of a powder which is composed of platelets is inaccurate by standard laboratory procedures and requires detailed petrographic examination of the products. A method proposed by R. W. Schatz⁽²⁾ which reports size distribution on the basis of theoretical spheres rather than on the basis of actual petrographic measurement serves as an excellent comparative measurement for powders with similar mineralogical and crystallographic composition. Of necessity, these figures show little resemblance to the measurements of the greater dimensions of the talc platelets. Consistent with the previous progress report, the particle-size-distribution data here presented are based on screened size fractions and the sizes given are those measured on a petrographic microscope.

As in the study of lubricity, in order to determine the improvement of specific physical properties, objective tests had to be devised to measure the small differences between acceptable talc and talc of lower quality. Until now, acid solubility was determined gravimetrically on the various talc samples. The small differences in per cent composition and per cent incidence of the carbonate component of Italian talc, and its close relationship to both abrasiveness and lubricity, required the development of an analysis for equivalent dolomite in low concentrations (Appendix B).

Abrasiveness has previously been measured subjectively, similar to lubricity. However, because subjective measurements are not correlative, and because small, often significant differences cannot be so measured, an abrasion machine was built. This device, does not give an absolute value to abrasion, however, it provides reproducible figures which are of relative value and which are correlative with measurements of other physical properties.

Except where otherwise noted, the measurements presented in this report were made on the same samples of "ECT Extra 00000" talc, obtained from the Cranford, New Jersey, plant, which were used in the work reported in the previous Progress Report on physical properties.

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DISCUSSION OF ABRASIVENESS

A highly undesirable property of a talcum powder is abrasiveness or grittiness. Grit is undesirable in that it may scratch or otherwise irritate the skin, and even very small amounts of grit may quickly be noticed subjectively.

Grit consists of that portion of ground talc which is angular, or oversize, particularly in thickness. Grit includes both oversize and nonplaty talc particles as well as mineral contaminants. It occurs as aggregates of talc and contaminants, as acicular and fibrous particles of talc and amphibole, as shards and granules of amphibole or carbonate, and as prismatic grains of titanite, rutile, zircon, apatite, and other accessory minerals.

Where the grit is other than oversize talc, it has hardness and angularity sufficient to scratch. Talc which is oversize in its greater dimensions is rare in the samples studied. It is the product of incomplete grinding and may easily be removed on a 150-mesh screen. Talc which is oversize in thickness is of the nonplaty variety, the result of the incomplete alteration of pre-existing minerals or the formation of pseudomorphs after more equidimensional species. Such particles serve less as abrasives than as deterrents to proper slip. The 8 to 10 per cent of nonplaty talc in the Italian material is presumed to be derived from tremolite or enstatite. This mechanism is discussed in the reports on the Brazilian⁽³⁾ and Canadian⁽⁴⁾ talc deposits.

Whereas friction, as expressed in the sense of the translation movements of talc platelets over one another, produces the desirable property of slip, such friction is not a disruption of the free lamellar movement of the component particles of the powder nor a disruption of the free movement of the surfaces in contact. When, however, a lubricant fails to mask irregularities in the contacting surfaces or introduces asperities of its own, then point friction or plowing is initiated. Point friction and plowing are the sources of irritation or grittiness. Grit permits wear between the contacting surfaces by abrasion, either in the plowing or scratching mechanism of oversize and angular particles, or by the disruption of lamellar movement of the platelets which leaves areas unlubricated or introduces a damming-up and rolling of particles.

Although lubricity and abrasiveness may seem to be relative, or the presence of one may seem to preclude the presence of the other, no direct correlation should be expected between the two properties inasmuch as both are the functions of several variable factors. A decrease in grit, however, is certain to improve the lubricity of whole powders where particle size is not a controlling factor.

Idealized talc particles are rounded platelets which may be thought of as essentially two dimensional, the thickness being about 1/8 to 1/15 of the greater dimension, depending upon the crystalline nature of the mineral and the degree of subdivision attained. In the better grades of talc the greater dimensions of a platelet are nearly equal.

The Italian No. 1 talc contains from less than 1 per cent to about 3 per cent of contaminants. The contamination is natural and consists mostly of carbonate with minor amphibole and rare accessory minerals. The carbonate component has been identified petrographically as primarily dolomite ($\text{CaO} \cdot \text{MgO} \cdot 2\text{CO}_2$) plus a minor amount of probable magnesite ($\text{MgO} \cdot \text{CO}_2$). No calcite ($\text{CaO} \cdot \text{CO}_2$) was identified. The amphibole component has been established to be the variety tremolite ($2\text{CaO} \cdot 5\text{MgO} \cdot 8\text{SiO}_2 \cdot \text{H}_2\text{O}$).

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Table 1 based on Table 2 of the previous Progress Report⁽¹⁾ lists the incidence of contaminants in the Cranford samples. Table 2 shows the distribution of the major contaminants in the different size fractions of Italian talc.

TABLE 1. PREVIOUSLY REPORTED⁽¹⁾ PER CENT CONTAMINATION IN TALC SAMPLED AT CRANFORD, NEW JERSEY

Incidence of Contaminants(a), per cent	Date Sampled
< 1	9-6-56, 9-12-56, 9-19-56.
1	8-10-56, 9-27-56, 10-18-56, 11-6-56
1-2	10-4-56, 10-29-56
2	8-20-56, 8-28-56, 11-15-56, 12-22-56
2-3	10-12-56, 11-30-56

(a) Determined petrographically.

TABLE 2. THE DISTRIBUTION OF THE MINERAL CONTAMINANTS IN THE DIFFERENT PARTICLE-SIZE FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Incidence of Contaminants(a), per cent		
	Total	Dolomite	Tremolite
Unseparated	± 2	< 2	Trace
+200	< 1	< 1	0-trace
-200+250	1	1	0-trace
-250+270	1-2	1-2	Trace
-270+325	2	2	Trace
-325+400	2	2	Trace 1
-400	> 2	> 2	< 1

(a) Incidence determined petrographically.

Grit is present in all size fractions, being somewhat more abundant in the fines. In the coarser fractions the mineral contaminants and the talc particles which are over-size in thickness are most readily sensed subjectively. The presence of grit in the fines is largely masked to the senses by the presence of larger platelets. In this regard no solution to abrasiveness lies in the removal of entire coarse size fractions, inasmuch as the grit in the then remaining coarser fractions would be as readily noticeable subjectively and more abundant percentagewise. To remove the abrasive particles, it is necessary to remove both nonplaty talc and the mineral contaminants from the whole powder by such beneficiation methods as flotation⁽⁵⁾ and classification by cycloning⁽⁶⁾, the initial studies on which have been reported or are in preparation (Table 3).

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TABLE 3. THE EFFECT ON LUBRICITY OF THE REMOVAL OF MINERAL CONTAMINANTS AND NONPLATY TALC FROM ITALIAN TALC SAMPLES

Talc Sample	Incidence of Indicated Particle Type ^(a) , per cent				Lubricity-Board Measurement, sec
	Platy Talc	Nonplaty Talc	Dolomite	Tremolite	
Italian No. 1					
Feed	88-90	8-9	<2	<1	0.990
Float	95	4	Trace	Trace	1.046
Italian No. 2					
Feed	90	5	3	2	0.926
Float	98	<1	Trace	Trace	1.051

(a) Mineralogical incidence determined petrographically.

It is important to emphasize the difference between the incidence or frequency of contaminants and their per cent of total composition. The per cent incidence is determined petrographically by grain count. It is a two-dimensional measurement approximating area and does not consider the thickness of the particles observed. The incidence of a mineral or crystal type is of primary importance inasmuch as a powder consists of a mixture of discrete grains, each with its particular size, shape, and other physical properties. In considering the behavior of a powder as a lubricant, we are dealing with the mechanical interactions of individual grains in lamellar movement and thus are concerned with the frequency of types of grains, not with their per cent of total composition. That is, for example, in considering lubricity or abrasiveness we must deal with the incidence of individual particles of dolomite rather than with the total volume or weight per cent of the sample which is dolomite, except when dealing with closely sized samples. Conversely, when considering acid solubility, moisture content, and the analysis and evaluation of beneficiation products, we, of necessity, deal with total components; not the incidence of particles. While small differences in per cent incidence of contaminants in a powder may influence the physical properties of mechanical movement, in no case described here is the per cent incidence different from the weight per cent or the chemically analyzed component by more than 1 per cent of the whole sample.

THE MEASUREMENT OF ABRASIVENESS

Discussion

A standard method of measuring the abrasiveness of high-quality talc has not been devised previously. Abrasiveness or grit has been measured subjectively by testing samples between the fingers or teeth. As in the case of lubricity, the final analysis of acceptability in regard to abrasiveness is subjective: consumer reaction. Objective tests are not designed to replace the subjective tests; however, to be able to determine

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improvement in beneficiation procedures and to determine the correlative relationships of the physical properties of talc, it is necessary to be able to measure small differences in the physical properties and to be able to compare them to other quantitative measurements. Knowledge of these interrelationships serves as the basis for interpretation of improvement in quality and thus serves to make it possible to visualize methods of beneficiation.

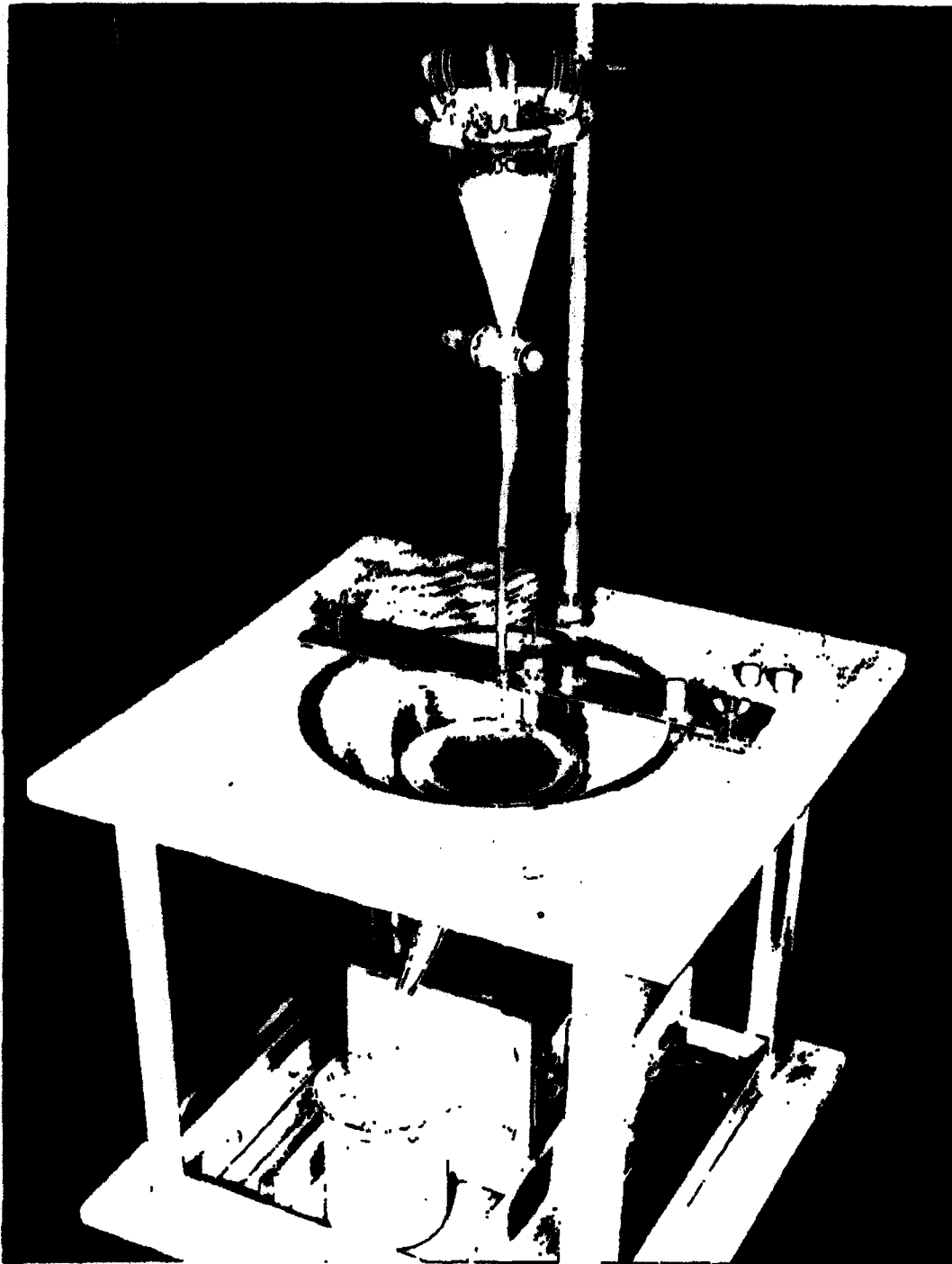
Since the subjective tests are of little help in measuring small differences in one of the many physical properties encountered, and since such tests have no basis for correlation, a machine was built to measure objectively, or test for, abrasiveness, apart from other physical properties.

The Abrasion Machine

Because it was necessary to measure small differences in the abrasiveness of talc, a machine was built to test the wear effect of small concentrations of grit on standard material. The machine was built of a 1/20-hp 1725-rpm electric motor mounted vertically and fitted with a 5-inch lap covered by a Buehler Microcloth held in place by a rubber belt. The lap portion of the machine is set into a steel bowl and covered with a plastic lid. Mounted on a ringstand over the lap a 500-ml open separatory funnel with stopcock is connected by a rubber tube with an adjustable pinch clamp to a feed spout. The separatory funnel contains the sample of talc to be tested in a slurry of 3 grams of talc to 350 ml of water. The feed spout and a cylindrical pellet holder are mounted in a removable crossbar over the lap. Accessibility to these parts is afforded through a hole in the plastic cover. Standard 1/2-inch-diameter pellets are held in the sample holder by a 16.1-gram weight to prevent their skipping or floating on the lap. A 1000-ml beaker mounted under a drain in the steel bowl catches the tested slurry. Figure 1 shows the over-all apparatus. Figure 2 shows the detail of the feed and abrasion mechanism. A detailed description of the abrasion machine and the technique of its operation are found in Appendix A.

In order to measure the abrasiveness of the talc in the slurry a test had to be designed where the object abraded would have a great enough loss to be measured physically. Since the abrasiveness to be measured was that of a powder containing generally from only 1 to 3 per cent of abrasive gangue particles, the material to be abraded had to have a hardness greater than that of the talc, less than that of the grit, and also had to be coherent and homogeneous. After testing a large number of materials it was decided to perform the bulk of the tests on pellets made of minus 400-mesh Italian talc pressed under 50,000-psi pressure. The pellets average 5.20 grams and have dimensions of 1/2 by 7/10 inch. The pellets have a hardness greater than that of the raw talc and less than that of the contaminants (Table 4). Carbonate pellets were made to test specifically for the rarer, harder components, in a similar manner, but using alcohol instead of water in the slurry.

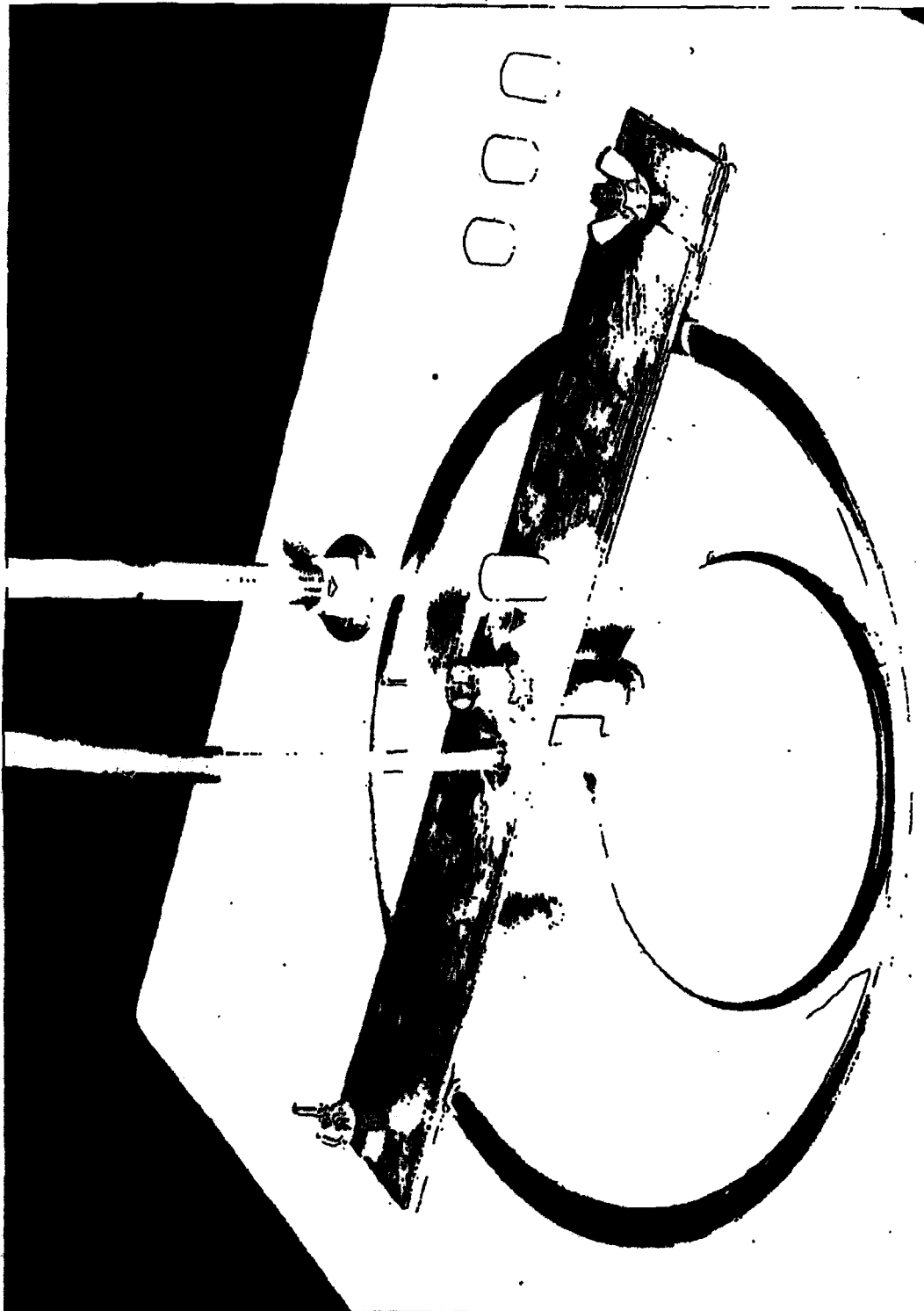
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FIGURE 1. THE ABRASION MACHINE SHOWING RESERVOIR CONTAINING
SAMPLE IN SLURRY TO BE TESTED FOR ITS ABRASIVENESS

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FIGURE 2. DETAIL VIEW OF ABRASION-MACHINE LAP SHOWING FEED SPOUT, CYLINDER IN WHICH PELLETS ARE HELD ON THE LAP, AND STANDARD PELLETS OF PRESSED TALC

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TABLE 4. RELATIVE HARDNESS OF THE TEST PELLETS AND THE GRIT PRESENT IN ITALIAN TALC

Mineral	Moh Hardness
Talc	1
Pressed-talc test pellet	± 2 (scratches talc)
Magnesite	3.5 (scratches talc pellet)
Dolomite	4
Pressed-carbonate test pellet	>4 (scratches dolomite)
Apatite	5 (scratches carbonate pellet)
Titanite	5
Tremolite	6
Rutile	6
Zircon	7.5

The abrasion-machine operation is timed electrically. The pellets are measured on a micrometer caliper before the test and afterward, after drying. The abrasion measurement is reported in decimal fractions of an inch per second. Although there are limitations to the use of a micrometer, the samples which were compared demonstrated differences in measurement large enough to be significant. Measurements based on weight were found to be entirely unsatisfactory inasmuch as some weight loss was due to spalling and abrasion of the pellet by the walls of the sample tube on portions other than that exposed to the lap and abrasive. This indicated losses which were no indication of the degree of loss due to action on the tested surface alone.

The abrasion machine subjects the standard pellet to abrasion by the sample of talc being studied, at a high rate of speed. It has been calculated that the pellet receives wear equivalent to being rubbed over more than 1800 ft/min of surface of the talc being tested. As expected, the abrasion machine demonstrates that the slurry samples with the greater incidence of mineral contaminants produce the greater amount of abrasion on the pressed pellets. It is also shown that those samples with primarily platy habit are less abrasive than those containing effective amounts of nonplaty talc.

More precise abrasion machines could be built; however, the device used is satisfactory for the purpose of comparing samples within the range of those tested and is an adequate means of obtaining comparable measurements of the effect of grit. Typical figures obtained by the abrasion experiments are shown in Table 5.

TABLE 5. TYPICAL FIGURES OBTAINED BY ABRASION TESTS ON
FOUR SAMPLES OF ITALIAN TALC

Test	Incidence of Contaminants(a), per cent	Pellet Measurements, in.		Difference in Measurements, in.	Time, sec	Abrasion(b), 10 ⁻³ in./sec
		Before	After			
1	2	0.6453	0.5566	0.0887	38	2.33
2	2	0.6435	0.5483	0.0952	41	2.32
3	2	0.6184	0.5374	0.0810	36	2.25
4	2	0.6442	0.5699	0.0743	32	2.32

(a) Determined petrographically.

(b) Significant figure: 2.3×10^{-3} in./sec.

The Abrasiveness of Talc Samples

Fifteen samples of talc collected at the Cranford plant of Johnson and Johnson, the same samples used in the previously reported lubricity experiments⁽¹⁾, were tested on the abrasion machine. The results of the measurements are shown in Table 6. The measurements show a range of from 1.62 to 2.69×10^{-3} in./sec wear on the standard pellets. These figures are generally correlative with the incidence of contaminants, as determined petrographically, as reported in the Progress Report dealing with lubricity⁽¹⁾. As it will be shown further in the report, this relationship only holds in whole unseparated powder where particle size is not a fundamental controlling factor. The correlation of lubricity-board measurements with contamination reported in Table 2 of the previous Progress Report⁽¹⁾ shows a similar general relationship between contamination and lubricity. Where the lubricity experiments concluded that the samples containing the greater amount of contaminants demonstrated the poorer lubricity, the abrasion-machine experiments show that the samples with the greater contamination produce the greater amount of abrasion. Thus, when dealing with whole, unscreened powders, the removal of grit should also serve to improve lubricity.

Although the removal of grit improves the lubricity of whole powders, the relationship of lubricity to abrasiveness cannot be considered to be mathematically inverse. The properties which control abrasiveness are the size and shape of the contaminants and their incidence in the coarser fractions; whereas, the properties which control lubricity are the over-all size distribution, those previously described properties directly related to surface area, plus the incidence of the coarser components. When measuring screened fractions of powders both abrasiveness and lubricity are influenced by the specific particle size, and abrasiveness will be directly related to the grit component, whereas in whole powders the finer abrasive particles will be in part masked by the coarser platelets.

To test further the effect of contaminants upon abrasiveness, the contaminants were removed from a sample of talc by froth flotation and the products were tested on the abrasion machine. The same samples had previously been tested for lubricity⁽¹⁾. The test results, which are noticeable subjectively, are reported in Table 7.

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TABLE 6. RELATION OF PURITY OF SAMPLE TO ABRASIVENESS
AND LUBRICITY IN WHOLE POWDER

Date Sampled	Abrasiveness, 10 ⁻³ in. / sec	Incidence of Contaminants(a), per cent	Lubricity-Board Measurement, sec
9-12-56	1.62	<1	1.030
8-10-56	1.70	1	1.021
9-19-56	1.84	<1	1.028
9-6-56	1.87	<1	1.083
10-18-56	1.88	1	1.025
9-27-56	1.90	1	1.017
10-4-56	1.90	1-2	0.982
8-20-56	1.91	2	0.971
8-28-56	1.97	2	1.007
11-6-56	2.15	1	1.053
11-15-56	2.30	2	0.936
10-29-56	2.32	1-2	1.006
11-30-56	2.32	2-3	0.952
10-12-56	2.59	2-3	0.968
12-22-56	2.69	2	0.965

(a) Previously reported⁽¹⁾, determined petrographically.

TABLE 7. ABRASION AND LUBRICITY MEASUREMENTS ON FLOTATION
PRODUCTS OF ITALIAN NO. 1 TALC

Product	Abrasiveness, 10 ⁻³ in. / sec	Lubricity-Board Measurement, sec
Starting sample	2.14	0.990
Float product(a)	1.50 (superior)(c)	1.046 (superior)
Nonfloat product(b)	3.03 (inferior)	0.873 (inferior)

(a) Essentially pure talc, representing 90 per cent of starting sample.

(b) 85 per cent talc, 15 per cent contaminants, representing 10 per cent of starting sample.

(c) Less abrasive float products have been made from Italian No. 2 talc.

The float products clearly demonstrate superiority over the starting sample in regard to both abrasiveness and lubricity. The deleterious effect of contaminants is shown by the inferior measurements derived from testing the reject product of the flotation process.

THE RELATIONSHIP OF ABRASIVENESS TO PARTICLE-SIZE DISTRIBUTION AND CONTAMINATION

Discussion

The abrasiveness of the talc studied is determined by its component grit. When dealing with the mechanics of a powder in lamellar motion, we are dealing with the interrelationship of individual particles, and thus are concerned with the per cent incidence and particular sizes and shapes of individuals. The distribution of the contaminants and nonplaty talc in the different size fractions is thus a primary consideration. The coarse contaminants are those which scratch and are quickly noticed subjectively. The finer contaminants clog the lamellar movement of the talc platelets and initiate rolling of the powder, introducing aggregate asperities.

In the previous reports to Johnson and Johnson^(1, 2, 7) the problem of particle-size distribution has been thoroughly discussed. It does not seem requisite here but to re-emphasize the importance of establishing the particle-size distribution of a powder when studying its physical properties or the means of their improvement. Since the size of the abrasive particles, as well as their incidental abundance, contributes to abrasiveness, it was necessary to determine the size distribution of the contaminants.

Correlation of Abrasiveness With Particle-Size Distribution and Contamination

Portions of the same samples which were used to test for lubricity and other physical properties were used in the following experiments on abrasiveness. Size fractions were made of Italian talc and were measured for their abrasiveness on the abrasion machine. Results of the experiments show that the finer particle-size fractions are more abrasive than the coarse. This is in agreement with the incidence of grit determined petrographically. Chemical analyses for equivalent dolomite on these samples are also in agreement. These analyses appear in the section of this report dealing with acid solubility.

Table 8 shows the results of abrasion tests of size fractions on standard talc pellets. When comparing size fractions a parallel relationship exists between lubricity and abrasiveness, as a function of particle size. Thus, were only the fines, the most lubricous fraction, used for baby powder, this fraction would also be the most abrasive. In order to retain the more lubricous particles yet remove the more abrasive, it is necessary to remove the contaminants only. Both lubricity and grittiness cannot be improved by the removal of particle-size fractions.

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TABLE 8. RELATIONSHIP OF ABRASIVENESS AND LUBRICITY TO PARTICLE SIZE AND CONTAMINATION IN SIZE FRACTIONS OF ITALIAN NO. 1 TALC

Tyler Mesh Size	Abrasiveness, 10 ⁻³ in. / sec	Lubricity-Board Measurement, sec	Incidence of Contaminants ^(a) , per cent		
			Total	Dolomite	Tremolite
Unseparated	2.14	0.990	±2	<2	Trace
+200	1.30	0.889	<1	<1	0-trace
-200+250	1.59	0.951	1	1	0-trace
-250+270	1.72	0.980	1-2	1-2	Trace
-270+325	2.00	1.030	2	2	Trace
-325+400	2.33	1.043	2	2	Trace-1
-400	2.48	1.099	>2	>2	<1

(a) Determined petrographically.

In order to show which effects are primary, and which are secondarily related because sized materials are analyzed, tests were made on the plus 200-mesh fraction of the talc as received from Italy, on the minus 400-mesh fraction, and on the plus 200-mesh material after it was crushed to pass a 400-mesh screen. The natural plus 200-mesh material had but a trace of contaminants compared with the more than 2 per cent present in the natural minus 400-mesh fraction. Abrasiveness and lubricity tests (Table 9) show clearly that the abrasiveness is controlled primarily by the contamination and only secondarily by the size fraction analyzed. It also shows that the lubricity is controlled primarily by the particle-size fraction tested, and only secondarily by the contamination present in the specific size range. This experiment serves as the basis of interpretation for relating the physical properties of sized material, and also establishes the controlling factors behind lubricity and abrasiveness in whole powders.

TABLE 9. COMPARISON OF LUBRICITY AND ABRASIVENESS TO GRAIN SIZE AND CONTAMINATION

Sample	Abrasiveness, 10 ⁻³ in. / sec	Lubricity-Board Measurement, sec	Incidence of Contaminants ^(a) , per cent
Natural +200-mesh fraction	1.30	0.889	Trace
Natural -400-mesh fraction	2.48	1.099	>2
+200-mesh fraction ground to -400 mesh	1.12 ^(b)	1.108 ^(c)	Trace

(a) Determined petrographically.

(b) The abrasiveness of this sample is only slightly less than that produced by the same sample prior to grinding, much less than the natural minus 400-mesh fraction which contains more grit.

(c) The lubricity of this sample is greatly improved by regrinding, but it is essentially like the natural minus 400-mesh sample despite the difference in the grit present.

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TABLE 10. ABRASIVENESS AND LUBRICITY MEASUREMENTS OF ITALIAN TALC SAMPLES FROM WHICH SPECIFIC PARTICLE-SIZE FRACTIONS HAVE BEEN REMOVED

X Represents Fractions Removed From Whole Powder
U Represents Fractions Tested

Tyler Mesh Size	Incidence of Contaminants ^(a) , per cent	Lubricity-Board ^(b) Measurement of Size Fractions, sec	Abrasiveness, 10^{-3} in./sec	Test 1	Test 2	Whole Powder	Test 3	Test 4
+200	<1	0.889	1.30	U	U	U	X	X
-200+250	1	0.951	1.59	U	U	U	X	X
-250+270	1-2	0.980	1.72	U	U	U	U	X
-270+325	2	1.030	2.00	X	U	U	U	U
-325+400	2	1.043	2.33	X	U	U	U	U
-400	>2	1.099	2.48	X	X	U	U	U
Lubricity-Board Measurement, sec				0.945	0.963	0.990	1.038	1.068
				—Increase in slip and abrasiveness—→				
Abrasiveness, 10^{-3} in./sec				1.88	1.88	2.14	2.27	2.34
Approximate Weight Per Cent of Fractions Removed				97.0	82.0	0.0	2.0	3.0

(a) Determined petrographically;

(b) Based on Table 10 of previous report⁽¹⁾.

In the previous study of lubricity⁽¹⁾, measurements were made on powders from which different size fractions had been removed, and on mixtures of specific size fractions. The experiment demonstrated that the over-all lubricity was influenced primarily by the coarser particles. Similar experiments on abrasiveness have been made and show that it is not possible to increase the lubricity by removing total size fractions without increasing the abrasiveness (Table 10).

Because talc contains tremolite and rare accessory minerals as well as carbonate as abrasive components, a test was devised to measure the abrasiveness of the harder contaminants. Carbonate pellets were made by fusing a three-to-one mixture of sodium carbonate and sodium borate into a melt. The fusion product was crushed and pressed into pellets under 15,000 psi. The resulting pellets were harder than the talc or the carbonate contaminants but softer than the tremolite and accessory minerals. The pellets were slowly soluble in water; therefore, alcohol was used as the fluid in the test slurries. The test results are not necessarily correlative with measurements made on talc pellets, but demonstrate the distribution of the harder contaminants (Table 11). All other abrasive data contained in this report have been determined on pressed talc pellets.

TABLE 11. THE DISTRIBUTION OF THE CONTAMINANTS HARDER THAN CARBONATE IN ITALIAN TALC AS SHOWN BY ABRASION TESTS MADE ON CARBONATE PELLETS

Tyler Mesh Size	Abrasiveness (on Talc Pellets), 10 ⁻³ in./sec	Abrasiveness (on Carbonate Pellets), 10 ⁻³ in./sec	Incidence of Contaminants ^(a) , per cent		
			Total	Dolomite	Tremolite
Unseparated	2.14	0.9	±2	<2	Trace
+200	1.30	0.5	<1	<1	0-trace
-200+250	1.59	0.7	1	1	0-trace
-250+270	1.72	0.6	1-2	1-2	Trace
-270+325	2.00	0.6	2	2	Trace
-325+400	2.33	0.8	2	2	Trace-1
-400	2.48	0.9	>2	>2	<1

(a) Determined petrographically.

To demonstrate the effect of the rarer contaminants on the abrasion of pressed talc pellets, a series of sized fractions of Italian talc were leached free of the carbonate components and measured on pressed talc pellets. Table 12 shows the degree of abrasiveness produced by the leached samples.

TABLE 12. ABRASION TESTS USING LEACHED AND UNLEACHED SIZED FRACTIONS, DEMONSTRATING THE EFFECT OF DOLOMITE ON ABRASIVENESS

Tyler Mesh Size	Abrasion, 10^{-3} in./sec	
	Unleached Powder	Leached Powder
Unseparated	2.14	1.50
+200	1.30	1.34
-200+250	1.59	1.60
-250+270	1.72	1.72
-270+325	2.00	1.71
-325+400	2.33	1.90
-400	2.48	1.75

An additional test, not relative to the beneficiation of Italian talc, but designed as an experiment to serve as a basis for study of lower grade talc, was made on a series of mixtures of Italian talc and minus 400-mesh calcium carbonate (Table 13). Although the data are not to be considered correlative with those of Italian talc, they demonstrate clearly the increasing effect of contamination on abrasion.

TABLE 13. ABRASIVENESS OF MIXTURES OF ITALIAN TALC AND CALCIUM CARBONATE

Per Cent Italian Talc(a)	Per Cent CaO·CO ₂ (-400 Mesh)	Abrasion, 10^{-3} in./sec	Difference in Abrasion, 10^{-3} in./sec
100	0	2.14	0.75
90	10	2.89	2.20
50	50	5.09	3.08
10	90	8.17	5.48
0	100	13.65	

(a) Contains about 2 per cent native carbonate.

MEASUREMENT AND CORRELATION OF OTHER PHYSICAL PROPERTIES

Moisture Content

The previous Progress Report⁽¹⁾ introduced the problem of moisture content in talc, suggesting that the fine-grain-size fractions should adsorb more moisture on its greater surface area per unit of weight. Table 14 shows the moisture content of size fractions of Italian talc, demonstrating an increase in moisture content with decreasing particle size. Because of the relationship of particle size to other physical properties,

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the moisture content of the sized fractions was found to be apparently correlative with a number of other measurements, indicating coincidental relationships which would not hold true in unsized samples.

TABLE 14. RELATIONSHIP OF MOISTURE
CONTENT TO PARTICLE SIZE
IN ITALIAN TALC

Tyler Mesh Size	Per Cent Moisture ^(a)
Unseparated	0.05
+200	0.01
-200+250	0.03
-250+270	0.03
-270+325	0.04
-325+400	0.05
-400	0.06

(a) Moisture content determined by method outlined in Johnson and Johnson's Raw Materials Specifications sheet.

The lubricity of talc is related to its moisture content insofar as the moisture content of the finer fractions is higher. In lower grade talc the moisture content was found to be much higher. Six domestic talcs, fabricated to a particle-size distribution similar to that of the Italian talc, showed from 0.08 to 0.20 per cent moisture on analysis. The higher moisture content of some inferior talcs requires that moisture be determined on samples prior to testing for lubricity. Moisture tends to make talc pasty, producing a false indication of superior lubricity on the lubricity board. To demonstrate that the 0.05 per cent moisture content of Italian talc did not affect the lubricity, tests were run on talc from which the moisture had been driven off. A nonreproducible difference of only 0.006 second was recorded, and is not considered to be a significant figure.

To further test the correlation of moisture content and particle size, the talc samples collected at Cranford were analyzed and the data compared with the percentage of fines in the sample. Table 15 compares the moisture content and the percentage of the powder finer than 400 mesh, as compiled from Table 6 of the previous Progress Report⁽¹⁾. The samples with the greater component of fines were found to contain the greater moisture content. No absolute interpretation should be given this relationship. The figures are all very close and their similarity is of greater importance than the correlation. However, there is a theoretical basis for the variance, and the data are presented for whatever they may be worth in the light of future studies. The correlation seems more than coincidental. Moisture content shows no other correlation in whole powders.

Inasmuch as the lubricity-board studies⁽¹⁾ showed that the lubricity variations depended upon the coarser fractions, the small difference in the fine component as related to moisture content should have no expression in lubricity.

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TABLE 15. THE RELATIONSHIP OF MOISTURE CONTENT TO PER CENT OF MINUS 400-MESH PARTICLES IN WHOLE SAMPLES OF TALC COLLECTED AT CRANFORD

Per Cent Fines ^(a) (-400 Mesh, Tyler)	Per Cent Moisture	Date Sampled
88.28	0.06	8-28-56
88.16	0.07	9-27-56
87.26	0.06	9-6-56
86.61	0.06	11-6-56
86.09	0.05	9-19-56
85.29	0.05	8-20-56
83.91	0.05	10-18-56
83.40	0.05	12-22-56
83.04	0.05	10-4-56
82.93	0.03	9-12-56
82.57	0.03	11-30-56
82.28	0.04	11-15-56

(a) Repeated from previous report⁽¹⁾.

Johnson and Johnson's Raw Materials Specifications sheet states 0.15 per cent moisture content to be the tolerable upper limit. The Cranford samples, as well as the size fractions, contain considerably less moisture. This indicates that any beneficiation which would change the size distribution, hence the moisture content, would not produce a product of unsatisfactory moisture content.

Inasmuch as a pasty consistency in talcum powder would be undesirable, samples which by exposure or otherwise have taken on excess moisture must be restored by proper drying. One problem arising from flotation experiments was the tendency for the products to agglomerate after drying. It is possible that this moisture can be removed by spray drying. The problem of proper drying is to be considered further in the beneficiation phase of the program.

Absorptive Power

A physical property closely related to moisture content and particle size is the absorptive power of talc. The hygroscopic property is highly important, inasmuch as it is a factor in deodorizing, coloring, in the carrying of perfume or other agents, and in the retention of moisture. Because this subject is only partly understood at this time, it will not be reported on here. The property is not immediately pertinent to the other mechanical and physical relationships in this report except through moisture content.

Alkalinity

The 15 samples of Italian talc collected at Cranford were measured for pH on a Beckman pH meter standardized at neutrality and checked with Beckman buffer solutions of pH 7 and pH 10. The figures are accurate to about 0.1. The samples were prepared by mixing 5 grams of talc with 10 cc of distilled water (pH 6.9). The solutions were agitated and permitted to stand for 2 hours prior to their measurement. The pH of the Cranford samples ranges from 9.0 to 9.3 (Table 16).

TABLE 16. pH OF CRANFORD SAMPLES

Date of Sample	pH
8-10-56	9.1
8-20-56	9.0
8-28-56	9.3
9-6-56	9.1
9-12-56	9.1
9-19-56	9.2
9-27-56	9.2
10-4-56	9.2
10-12-56	9.2
10-18-56	9.0
10-29-56	9.1
11-6-56	9.3
11-15-56	9.0
11-30-56	9.1
12-22-56	9.2

To see if there was any relationship of pH to other physical properties, a Cranford sample with a pH of 9.2 was sized and the fractions were measured (Table 17). The size fractions each measured 9.2, which showed that within the precision of the instrument there was no difference due to particle size or variation in the concentration of carbonates. Studies in progress will determine the practicality of removing the dolomite to the degree that the pH will be lowered. Effective lowering of the pH would lessen Johnson and Johnson's expense of the acid additive.

TABLE 17. pH OF SIZE FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	pH
Unseparated	9.2
+200	9.2
-200+250	9.2
-250+270	9.2
-270+325	9.2
-325+400	9.2
-400	9.2

Acid Solubility

Acid-solubility measurements were made as a part of the study of the carbonate component of Italian talc. It has been demonstrated that carbonate comprises the major amount of the contamination and that its removal decreases abrasiveness and improves lubricity.

The per cent solubility was first determined gravimetrically by the method outlined in Johnson and Johnson's Raw Materials Specifications sheet. The figures obtained were considerably lower than the 6 per cent solubility limit permitted by the specifications; however, they were greater than the figures anticipated from the small amount of carbonate minerals observed petrographically. Solubility analyses determined gravimetrically ranged from 2.10 to 2.81 per cent, showed no relation to any of the physical property measurements. It was assumed that there was either a greater amount of soluble matter in the impalpable fine fraction, or that there was a constant large sample loss during handling.

To resolve the problem the carbonate component was determined petrographically to be primarily dolomite, and a volumetric method of analysis was devised to analyze closely for small concentrations of dolomite in talc (Appendix B). The figures derived from these methods and computations are presented in this report as "equivalent dolomite". It is the measure of the total per cent of dolomite in the sample, not its incidence, which is a function of grain size. The equivalent dolomite analysis is recommended as a substitute for the previously used gravimetric analysis. The method is adjustable for larger concentrations, and other computations may be substituted when carbonates other than dolomite are present.

Equivalent dolomite is correlative with petrographically observed contamination and with related physical properties both in size fractions and in whole powder. A grab sample of Italian talc from the large bulk sample obtained from Cranford, containing slightly higher than average contamination, was analyzed for equivalent dolomite. The analysis showed 1.87 per cent. To check the analyzed percentage against the incidence, a series of grain counts was made on separate immersions, running 1.8, 1.8, 2.0, 1.8, 1.9, and 1.9 per cent. The average 1.84 is essentially the same as the 1.87 per cent

determined volumetrically. In other cases a concentration of dolomite in the coarse sizes cuts down incidence, as a concentration of dolomite in the fines increases incidence. In the consideration of contaminants in regard to flotation, or of the measurement of lubricity or abrasiveness, the actual incidence of the contaminants is the important consideration. Within the range of Italian No. 1 talc, however, the difference is usually small.

Table 18 shows a comparison of the gravimetric and equivalent dolomite analyses, the incidence of contaminants, and lubricity, as listed against increasing abrasiveness. Table 19 shows contamination and equivalent dolomite compared with decreasing lubricity. These show the primary relationship between abrasion and contamination, and the secondary relationship of abrasiveness to lubricity in whole powders. This was also demonstrated by Table 9 of this report. Table 20 compares the equivalent dolomite, contamination, abrasiveness, and lubricity of sized fractions of Italian talc, demonstrating that the fines contain the more abrasive particles.

Inasmuch as the carbonate in the Italian talc constitutes a rare component in all size fractions, its removal by sizing is not practical. Any practical beneficiation process would be concerned with effectively removing the carbonate from the whole powder, thus improving the slip while eliminating the major abrasive. The effects of flotation on lubricity, abrasiveness, and contamination are presented in a report⁽⁸⁾ on the beneficiation of Italian No. 2 talc.

REFLECTANCE AND WHITENESS

Discussion

The terminology of properties involving the behavior of light is very complex and for the purposes of this report the discussion will be limited to reflectance, whiteness, and gloss. Reflectance is the measurement of the return of light off of a surface in ratio to the intensity of the incident light. This may be measured in terms of brightness, apart from color. Whiteness may be measured in either terms of reflectance over the whole spectrum as "lightness", or in the sense of the absence of specific colors. Gloss is the measure of shininess of surface or specular reflection, as distinct from total reflection.

Gloss, closely related to reflectance and whiteness, will be discussed in a future report when ample samples are prepared to enable assessment of the factors which control the property. Gloss is a separate measurement from those here reported.

Although one may visualize the differences between whiteness, lightness, brightness, and gloss, one cannot subjectively differentiate one from another with any precision or determine the contribution of a specific property to over-all effect. The important consideration is the total subjective effect, which is quickly noticeable. However, in figuring means of improving the over-all effect we must relate the contribution of particle size, shape, and specific contamination to both the over-all effect and to specific properties. For example, fibrous talc is white, but less reflective than platy talc. Rutile is highly reflective, but not white. The beneficiation studies designed to

TABLE 18. COMPARISON OF THE GRAVIMETRIC AND VOLUMETRIC ANALYSES FOR DOLOMITE AND THE RELATIONSHIP OF EQUIVALENT DOLOMITE TO THE INCIDENCE OF CONTAMINANTS AND LUBRICITY, AS LISTED AGAINST INCREASING ABRASIVENESS

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Date of Cranford Sample	Abrasiveness, 10^{-3} in. / sec	Incidence of Contaminants(a), per cent	Equivalent Dolomite (Volumetric), per cent	Acid Solubility(b) (Gravimetric), per cent	Lubricity-Board Measurement(b), sec
9-12-56	1.62	<1	1.5	2.14	1.030
8-10-56	1.70	1	1.5	2.47	1.021
9-19-56(c)	1.84	<1	1.7	2.61	1.028
9-6-56	1.87	<1	1.6	2.64	1.083
10-18-56	1.88	1	1.6	2.44	1.025
9-27-56	1.90	1	1.6	2.39	1.017
10-4-56	1.90	1-2	1.6	2.10	0.982
8-20-56	1.91	2	1.7	2.71	0.971
8-28-56	1.97	2	1.6	2.51	1.007
11-6-56	2.15	1	1.6	2.57	1.053
11-15-56	2.30	2	1.6	2.27	0.936
10-29-56	2.32	1-2	1.6	2.78	1.006
11-30-56	2.32	2-3	1.7	2.81	0.952
10-12-56	2.59	2-3	1.7	2.58	0.968
10-22-56	2.69	2	1.7	2.30	0.965

(a) Determined petrographically.

(b) No relationship demonstrated.

(c) Petrographically found to contain rare but coarse dolomite.

TABLE 19. EQUIVALENT DOLOMITE, ABRASIVENESS, AND PER CENT CONTAMINATION LISTED AGAINST DECREASING LUBRICITY

B A T T L E M E M O R I A L I N S T I T U T E	Date of Cranford Sample	Lubricity-Board Measurement, sec	Incidence of Contaminants ^(a) , per cent	Equivalent Dolomite (Volumetric), per cent	Abrasiveness ^(b) , 10 ⁻³ in. /sec
	9-6-56	1.083	<1	1.6	1.87
	11-6-56	1.053	1	1.6	2.15
	9-12-56	1.030	<1	1.5	1.62
	9-19-56(c)	1.028	<1	1.7	1.84
	10-18-56	1.025	1	1.6	1.88
	8-10-56	1.021	1	1.5	1.70
	9-27-56	1.017	1	1.6	1.90
	8-28-56	1.007	2	1.6	1.97
	10-29-56	1.006	1-2	1.6	2.32
	10-4-56	0.982	1-2	1.6	1.90
	8-20-56	0.971	2	1.7	1.91
	10-12-56	0.968	2-3	1.7	2.59
	12-22-56	0.965	2	1.7	2.69
	11-30-56	0.952	2-3	1.7	2.32
	11-15-56	0.936	2	1.6	2.30

(a) Determined petrographically.

(b) None, or poor correlative relationship.

(c) Petrographically found to contain rare but coarse dolomite.

TABLE 20. COMPARISON OF CONTAMINATION, EQUIVALENT DOLOMITE, ABRASIVENESS,
AND LUBRICITY IN SIZE FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Incidence of Contaminants ^(a) , per cent			Equivalent Dolomite (Volumetric), per cent	Abrasiveness, 10 ⁻³ in. /sec	Lubricity-Board Measurement, sec
	Total	Dolomite	Tremolite			
Unseparated	±2	<2	Trace	1.9	2.14	0.990
+200	<1	<1	0-trace	0.6	1.30	0.889
-200+250	1	1	0-trace	1.1	1.59	0.951
-250+270	1-2	1-2	Trace	2.0	1.72	0.980
-270+325	2	2	Trace	2.0	2.00	1.030
-325+400	2	2	Trace-1	2.1	2.33	1.043
-400	>2	>2	<1	2.1	2.48	1.099

^(a) Determined petrographically.

remove specific particle sizes, shapes, or contaminants, in order to improve the appearance of the talc, will be best controlled when the reflectance and color properties can be assigned to particular components of the powder. As in the lubricity and abrasiveness studies, when the causes of variations are determined, it becomes possible to visualize the means of improving the subjective property.

The reflectance properties of talc begin a new category of measurements. The reflectance properties are distinct from other physical measurements insofar as direct relationships are concerned, except when particle size, surface area, and purity are concerned, as the following experiments demonstrate.

It is apparent at this stage of the investigation that some degree of over-all appearance can be controlled by the selective removal of particular particles.

The Measurement of Reflectance and Whiteness

The Italian talc is nearly pure white and highly reflective. The work under way on reflectance and whiteness is designed to devise a means of improving these properties, particularly in lower grade talc, as the result of interpreting their variations in response to the variations of other physical properties. The program includes determining the effect on whiteness and reflectance of the removal of specific sizes, shapes, and contaminants by beneficiation.

To date the measurements include only those made on a Photovolt Photoelectric Reflection Meter* and on a Gardner Color Meter**. The Photovolt instrument measures diffuse reflectance in terms of "whiteness" or luminous apparent reflectance (LAR). Whiteness in this sense is a matter of lightness without regard to color. A green tristimulus filter is used in the measurement, a standard procedure which permits interlaboratory comparisons. The instrument is calibrated against standard enamel and porcelain plates. The LAR of the Cranford samples is presented in Table 21, showing a range in measurement of 95.0 to 97.5, with no discernible relationship to other properties of the whole powder.

To determine the relationship between LAR and particle size, measurements were made on size fractions, which demonstrated greater reflectance in the fines (Table 22). This indicates that particle size and surface area are important factors. To test if particle shape is also a factor, measurements were made on the products of cyclone classification. These measurements showed that the underflow (platy talc) has a greater reflectance than the overflow (fine acicular talc). A third test made on flotation products demonstrated that purity of sample is also a factor, the float product producing a higher reading than the starting sample. The data related to shape and purity will be included in a report on the beneficiation of talc.

The Gardner Color Meter, among other applications, measures properties designated as Rd and +b. The Rd measurement is one of reflectivity in the sense of brightness, apart from color. The higher the Rd value obtained, the greater the brightness. The +b measurement is one of color based on yellowness, but corresponding to whiteness in near white materials. The lower the +b value the greater is the whiteness.

*Model 810, Photovolt Corporation, New York, New York.

**Gardner Instrument Company, Bethesda, Maryland. This is similar to the instrument used by Johnson and Johnson's Research Laboratory.

Measurements made on the Cranford samples showed a range of 91.30 to 93.25 for Rd and 1.55 to 1.95 for +b, with no correlation as yet established with other physical properties (Table 21).

To test if particle size has any effect on Rd and +b, measurements were made on a series of size fractions, showing that brightness increased in the finer fractions and that whiteness increased with fineness except for the minus 400-mesh fraction (Table 22). In order to interpret the aberrant figure the minus 400-mesh fraction will have to be subdivided and further +b values obtained. It is expected that the concentration of extremely fine acicular particles in the minus 400-mesh fraction accounts for the decrease in the +b measurement. It appears, since 1.60 is the value obtained on the whole powder, that whiteness is lower in the extreme particle sizes, both coarse and fine.

To test the effect of purity of sample on Rd and +b, measurements were made on beneficiated products, showing that the removal of contamination measurably improves Rd and +b. Measurements to be made on cyclone products will demonstrate the effect of particle shape on these properties. These studies will be presented in a forthcoming report on the beneficiation of talc.

Further work is recommended in the matter of improving the sheen of talc. Further investigation is required in the tracing of the specific properties of reflectance to specific particles prior to visualizing beneficiation for the improvement of sheen. It is hoped to be able to adapt a Glossmeter for use on powdered talc in order to be able to correlate properties and plan beneficiation for the improvement of specular reflectance. When sheen can conclusively be traced to specific physical properties of the powder, then beneficiation for its improvement can be visualized.

THE DUST COMPONENT

For the purpose of this report dust may be defined as that fraction of the talcum which remains air borne when the powder is shaken from its container. The dust may be collected for examination by passing a moistened glass slide through the dust cloud which remains suspended in the air when talc is shaken from a container, or by similarly sampling the suspended material after an open container is struck on the bottom onto a table or similar surface. Such action produces two classes of matter, a cloud comprising the bulk of the talc which quickly settles, and a fine portion which does not. Material so collected has been analyzed petrographically and has been found to be composed primarily of platy talc, essentially free of contaminants or acicular particles. This talc represents the finer sizes of platelets - the maximum diameter being about 15 μ in the larger particles. This roughly corresponds to the theoretical $<5\text{-}\mu$ sphere fraction⁽²⁾ not including any amount of nonplaty grains or coarser platelets.

The nature of the dust component has been established and it appears likely that it is amenable to beneficiation. Work is at present under way devising a means of comparatively measuring the dust component of talc samples, and to devise a means for its removal should it be practically separable from the whole powder.

TABLE 21. Rd, +b, AND LAR MEASUREMENTS ON THE CRANFORD SAMPLES

Sample Date	Rd	+b	LAR
12-22-56	93.25	1.75	97.5
9-12-56	93.15	1.80	97.0
8-10-56	93.00	1.90	97.0
10-18-56	92.55	1.75	97.5
11-15-56	92.45	1.75	97.0
9-6-56	92.35	1.75	95.0
8-28-56	92.20	1.65	96.0
9-19-56	92.15	1.55	96.0
9-27-56	92.10	1.60	97.0
8-20-56	92.05	1.90	95.5
11-30-56	91.80	1.75	96.0
11-6-56	91.75	1.75	96.0
10-29-56	91.55	1.55	97.5
10-12-56	91.35	1.60	96.0
10-4-56	91.30	1.95	96.0

TABLE 22. Rd, +b, AND LAR AS RELATED TO THE PARTICLE SIZE OF ITALIAN TALC

Tyler Mesh Size	Rd	+b	LAR
Unseparated	91.40	1.60	96.0
+200	85.60	1.90	91.0
-200+250	89.15	1.45	92.0
-250+270	90.36	1.35	92.5
-270+325	90.50	1.30	93.0
-325+400	91.50	1.20	96.0
-400	92.55	1.50	96.0

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APPRAISAL OF PHYSICAL-PROPERTY MEASUREMENTS IN THE
EVALUATION OF ORES AND BENEFICIATION PRODUCTS

The foregoing studies, and those previously reported⁽¹⁾, have established the relationships between many of the physical properties of talc and subjective evaluation. Many of the devices employed were helpful in establishing the interrelationships of physical properties, have served their purpose, and their use is not requisite to evaluate the acceptability of talc, inasmuch as the interrelationship of properties permits such an evaluation to be made on the basis of a minimum of measurements.

The subjective tests do not measure specific properties and thus are only of comparative value in deciding what is the specific problem in a nonacceptable talc, or how it may be made acceptable by beneficiation. Such tests, however, must remain the final analysis of acceptability of beneficiation products or in the selection of natural high-grade talcs.

The subjective tests are both a matter of touch and visual comparison. Tested by touch, individual consideration may be given to slip and abrasiveness. Quickly noted in nonacceptable talcs or improper grinds of otherwise acceptable talcs are dry floury feelings, pastiness, the rolling of the powder, poor spread which leaves portions unlubricated, and coarse or sharp grit. Visually it may be quickly noted if the powder is colored or off-white, without sheen, spreads unevenly, contains coarse brilliant particles, or contains a high component of extremely fine dust.

To measure improvement in talc, to maintain quality control, or to visualize proper beneficiation for the improvement of a talc, it is necessary to measure specific physical properties of the powder as a whole, to know the size and shape of the talc particles, and the nature of the contaminants.

Following the subjective appraisal, of foremost importance is petrographic examination. Such a study establishes the platy or nonplaty nature of a talc, identifies the contaminants, and should establish the general size distribution, incidence, degree of subdivision, habit of aggregation, and crystallographic varieties, of the talc, carbonates, amphiboles, and accessory mineral components.

In order to beneficiate for the improvement of slip or the elimination of grit, it is necessary to know the size distribution not only of the crystallographic types of talc present, but also of the different impurities. Size-distribution procedures yield products which may be studied petrographically. These include screening, in the coarser fractions, and sedimentation in the fines. The measurements assigned sedimentation products in usual procedures should be checked petrographically inasmuch as talc platelets behave in the manner of theoretical spheres of much smaller dimensions. A practical method of comparing powders, so long as the theoretical measurements do not become mistaken for actual diameters, is the Andreason sedimentation technique, previously reported⁽²⁾. When this method is employed with supporting petrography it should be a satisfactory device for evaluating beneficiation products.

Without proper size and mineral knowledge of a sample of talc, beneficiation procedures cannot be developed. Control over the physical properties of a talc of known and fairly constant composition could be kept by the use of refinements of the experimental lubricity and abrasion-measuring devices. However, a knowledge of the mineralogy and size distribution is recommended for any talc.

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The measurement of surface area, specific surface, porosity, and average diameter will be considered further in regard to compactibility and ullage, and the absorptive power of talc; however, these are not necessary to consider as prerequisite to beneficiation studies for the improvement of the physical properties of talc. The lubricity board and abrasion machine were built to measure small differences in heretofore purely subjective properties and to relate them to established physical measurements. With proper mineralogical and size-distribution knowledge, these properties will be reflected in the other physical measurements.

The following presents the measurements which should be attained in beneficiation products in order to produce material equivalent in quality to Italian No. 1 talc. Improvement of these properties will, of course, produce superior powder, when not improved at the expense of other physical properties. Beneficiation studies on Italian No. 2 talc have produced powder considerably superior to grade No. 1 Italian talc in slip, purity, and the absence of grit.

The following are the recommended requirements for beneficiation products to be the equivalent of Italian No. 1 talc. The items considered important at this stage of the investigation are marked with an asterisk.

Mineralogy*

Platy talc, 90 per cent or more
Nonplaty talc, less than 10 per cent
Carbonates, less than 2 to 3 per cent
Amphiboles, less than 1 per cent
Accessory minerals, trace only
Opaques, none.

Size Distribution*

- (1) Whole powder: Greater than 150 mesh, none
Greater than 200 mesh, less than 1 per cent
Greater than 325 mesh, less than 10 per cent
Greater than 400 mesh, less than 20 per cent.

The powder should have a size-distribution curve over its general range similar to that shown by Andreason sedimentation measurement⁽²⁾ of theoretical particles. Many of the particles finer than the theoretical 5- μ spheres are undesirable, representing fine acicular grains and dust. Fines, however, should not be removed to the extent that the bulk density is raised beyond present specifications.

- (2) Contaminants: Greater than 250 mesh, less than 1 per cent
-250 to +400 mesh, not more than 2 per cent
Finer than 400 mesh, less than 3 per cent.

Note: There is reason to believe that the grind of Italian No. 1 talc is finer than optimum for the production of a superior beneficiated talc. Possibly talc 100 per cent minus 100 mesh would be fine enough. The principal reason for a minus 200-mesh grind for the currently used product may be to reduce the grit to a size where the platelets mask it. With beneficiated talc this would not be necessary and there would be less fines to discard.

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Lubricity Measurement

Greater than 0.93 second, preferably greater than 1 second.

Porosity

Approximately 0.45 to 0.50.

Average Particle Diameter

Approximately 2.4 to 3.3 μ . This measurement is made on the Fisher Subsieve Sizer, the figures are of theoretical particles but are not to be compared with those from the Andreason measurements.

Bulk Density*

22 to 24 lb/cu.ft.

Specific Surface, Theoretical

Greater than 6600 cm^2/g ; preferable measurements lie in the 8000- cm^2/g range.

Abrasion-Machine Measurement

Talc pellets - less than 2.7×10^{-3} in./sec, preferably less than 2×10^{-3} in./sec.

Carbonate pellets - less than 1×10^{-3} in./sec.

Moisture Content*

Less than 0.08 per cent, preferably 0.05 per cent or less.

pH

Less than 9.4, preferably closer to 7 in order to lower the expense of the acid additive.

Acid Solubility*

Gravimetric, less than 3 per cent
Volumetric, less than 2 per cent.

LAR

95.0 or greater.

Rd*

91.0 or greater.

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+b* Less than 2.0. (An additional color measurement, -a, should be taken when talcs with a yellow-green tint are studied.)

The above measurements concern purity, slip, and grit, and the measurement of acceptability of beneficiation products. Yet to be reported on are preferred measurements on the Glossmeter, preferred limits of the dust component, absorptiveness, and compactibility. Although specific problems may arise when other than Italian talc is considered, the above measurements should generally suffice for most raw talcs in the measurement of improvement by beneficiation or of acceptability in regard to Johnson and Johnson's present requirements.

FUTURE WORK

Future work related to the physical properties of talc includes studies of the absorptive power to talc, measurements of gloss as distinct from whiteness and reflectance, measurements of compactibility, the dust component, studies on the effects of different methods of drying processed talc on its physical properties, and further evaluation of the physical properties and mineralogy of beneficiation products.

Because of immediate pressure on other phases of work for Johnson and Johnson most of the above studies will be held in abeyance.

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- (4) Smith, W. L., letter report to Johnson and Johnson on the talc deposits of Madoc, Canada (July 25, 1957).
- (5) Brown, W. E., letter report to Johnson and Johnson on the flotation amenability of Italian and other talcs (January 24, 1958).
- (6) Report in process describing results of classification of talc by cycloning.

- (7) Sclar, C. B., Snider, R. H., Macdonald, R. D., and Tangel, O. F., "An Investigation of Selected Talc Deposits of the United States", Battelle report to Johnson and Johnson (February 29, 1956).
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The original notes on the laboratory work described in this report are in Battelle Laboratory Record Books No. 13034, pages 78 through 96; No. 14187, pages 44 through 100; No. 14431, pages 7 through 100; and No. 14677, pages 1 through 8. The work was done in the period from October 21, 1957, to May 5, 1958.

WLS:djo/gpi/bah

APPENDIX A

DESCRIPTION OF ABRASION MACHINE AND TECHNIQUE OF OPERATION

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APPENDIX A

DESCRIPTION OF ABRASION MACHINE AND TECHNIQUE OF OPERATION

The experimental device described as the abrasion machine in this report (Figures 1 and 2) consists of a 1/20-hp 220-volt 60-cycle 1725-rpm three-phase Westinghouse electric motor, mounted vertically at operating height, fitted with a steel lap. The steel lap has a diameter of 5 inches and is designed so a lap cloth may be held in place by a rubber belt. A Buehler Microcloth was selected as a standard lapcloth. The lap is housed in a steel bowl 5 inches deep and 9-1/2 inches in diameter. A spout extends from the bottom of the bowl to carry the tested slurry into a beaker. A plastic shield is fitted over the top of the bowl to prevent spatter. A hole in the shield permits observation of the operation and access to the sample holder and slurry feed tube.

The slurry feed tube and a cylindrical 1/2-inch-diameter sample holder are fitted into a metal strip which is fastened in place over the lap. The sample holder is fixed 2 inches from the center of the lap. Directly behind the sample holder the slurry feed tube is fixed in a similar position so that the clockwise rotation of the lap brings the slurry which is to be measured under the standard talc pellet. The talc test pellet is held onto the lap by a 16.1-gram weight which prevents the pellet from skipping or floating on the rotating lap. The slurry feed tube is connected by a rubber tube with an adjustable clamp to a separatory funnel held in a ringstand. The funnel is a 500-ml open-top separatory funnel equipped with a stopcock, and serves as the reservoir for the slurry which is to be measured. The time of operation is kept on a Kodak electric timer.

The pellets are made of minus 400-mesh Italian talc pressed in a F. S. Carver Laboratory Press under 50,000 psi. The pellets are 1/2 inch in diameter, and the 5.2-gram samples used make a pellet about 7/10 inch long.

In addition to the standard talc pellets used in the measurement of total abrasive particles, carbonate pellets were used to measure abrasion by the harder contaminants alone. The carbonate pellets were made by fusing three parts by weight of sodium carbonate to one part of sodium borate into a melt. The fused melt was then crushed and pressed similarly as the talc pellets, under 15,000 psi. Because of swelling during drying the carbonate pellets must be measured wet, unlike the talc pellets. Also, because of slight solubility, the slurry to be tested must be a mixture with alcohol instead of water. The carbonate pellets are less satisfactory than the talc pellets, however, they served a specific experimental purpose.

In operation, the slurry, composed of 3 grams of the talc to be measured, in 350 ml of distilled water, passes onto the rotating lap at a rate controlled by a clamp on the feed tube. The slurry is carried under the standard pellet where the abrasive components wear the pellet at a rate approximating abrasion of the pellet by some 1800 ft/min of surface composed of the sample slurry. Pure samples of talc were found to effect little abrasion, while contaminated talc was found to quickly wear away the pellet. The amount of abrasion loss as measured on a Starrett micrometer caliper is divided by the number of seconds of abrasion to provide figures representing the degree of abrasion.

Should similar experiments be repeated, the following are important considerations. In any series of tests the operation time of the machine should be essentially the same. The talc slurry should be kept in suspension by agitation. A new lap cloth should be used

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as soon as any wear is noticed. All the talc pellets used in a series of tests should be pressed at the same time. Talc pellets should be dried overnight before measuring, to prevent any swelling effects of absorption of water. When any reruns are required on the abrasion machine, the slurry feed should be adjusted to reproduce former readings before comparative data are sought. To make proper comparative measurements the abrasion machine should be operating so as to make replicate tests showing a difference of not more than 0.1×10^{-3} in. /sec of abrasion.

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APPENDIX B

DETERMINATION OF EQUIVALENT DOLOMITE CONTENT
IN ITALIAN TALC BY VOLUMETRIC ANALYSIS

by

W. E. Brown

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3/1/5

Procedure:

5 gram sample + 200 cc HCl digest at 100°
for 45 min. heat to boiling - cool. add methyl
orange indicator.
titrate with NaOH.

Calculation:

$(cc\ HCl \times N) - (cc\ NaOH \times N) = \text{millequivalents acid}$
millequivalents $\times \text{wt. of } CaCO_3 \text{ or } MgCO_3 \text{ per HCl used}$
grams HCl $\times 1.26 \text{ or } 1.54 = \% \text{ carbonates in sample}$

5 min or 500 cc HCl $\times .92 = \% \text{ carbonates in sample}$
5 " " $\times 1.54 =$ " " "
5 gram or " $\times .84 = \% \text{ magnesite}$

as Magnesite

$$\frac{\text{grams HCl} \times 1.15 \times 100}{5} = \% \text{ carb.}$$

For
5 gms

millequivalents $\times .92 = \% \text{ dolomite}$
" $\times .84 = \% \text{ magnesite}$
" $\times 1.00 = \% \text{ calcite}$

as magnesite using 2 gram sample.

$$Me \times 2.1 = \% \text{ carbonates}$$

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APPENDIX B

DETERMINATION OF EQUIVALENT DOLOMITE CONTENT
IN ITALIAN TALC BY VOLUMETRIC ANALYSIS

by

W. E. Brown

- (1) Prepare a solution of approximately 0. 2N sodium hydroxide and determine exact normality.
- (2) Prepare a solution of approximately 0. 2N hydrochloric acid and determine exact normality.
- (3) Weigh out for analysis a 5. 000-gram sample of talc and put in a 250-cc beaker.
- (4) Add ⁵⁵ 25 ml of distilled water to the talc sample and stir with a glass rod to thoroughly wet the talc.
- (5) Add 50 cc of the HCl solution prepared in Step (2). 20 cc
- (6) Heat sample, containing water and HCl, for 45 minutes at 105 C.
- (7) Raise temperature to boiling for approximately 1/2 minute to expel H₂CO₃. Use care so that the sample does not boil over.
- (8) Cool to room temperature.
- (9) Add 4 drops of methyl orange indicator to the cooled sample and stir.
- (10) Titrate the sample with the NaOH [from Step (1)] to a yellow end point. This determines the amount of unused acid.
- (11) Calculate the per cent dolomite. An example of the calculations is as follows:

Given: Normality of NaOH = 0. 2055 [from Step (1)]
Normality of HCl = 0. 2120 [from Step (2)]

Each milliliter of HCl contains $\frac{36.5}{100} \times 0. 2120 = 0. 0077$ gram of pure HCl

1 ml of NaOH neutralizes 0. 97 ml of HCl

1 gram of HCl neutralizes 1. 26 grams of dolomite

47. 6 ml of NaOH was required to titrate a 5-gram sample which had been digested with 50 ml of HCl.

1.26 dolomite
1.15 magnesite
1.37 calcite

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$47.6 \times 0.97 = 46.17$ ml of unused HCl
 $50.00 - 46.17 = 3.83$ ml HCl consumed by dolomite
 $3.83 \times 0.0077 = 0.0295$ gram HCl consumed by dolomite
 $0.0295 \times 1.26 = 0.0372$ gram dolomite dissolved by HCl
 $\frac{0.0372}{5.000} \times 100 = 0.74$ per cent dolomite.

Note: In order to test the accuracy of this method of analysis, some relatively pure dolomite (taken from a mineral specimen) was analyzed. The weight of the sample analyzed was 0.0300 gram. The foregoing analytical method showed the sample to contain 0.0306 gram of dolomite. Another check test was made by analyzing a sample of Italian talc for per cent of CO_2 , and converting the CO_2 content to the theoretical amount in dolomite. The CO_2 analysis indicated that the dolomite content was 2.26 per cent. By volumetric analysis the dolomite content was calculated to be 2.18 per cent.

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