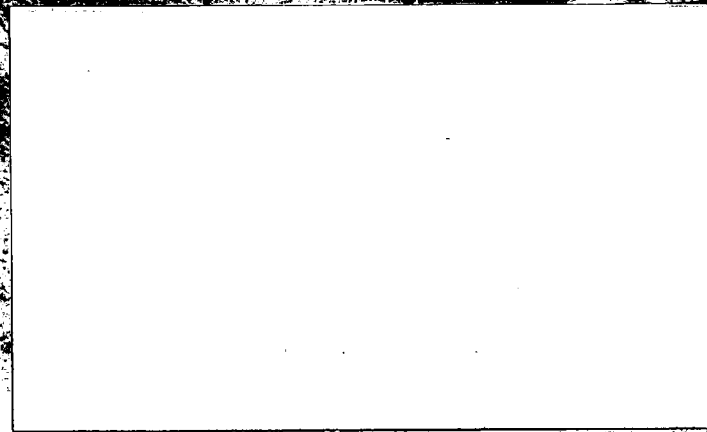
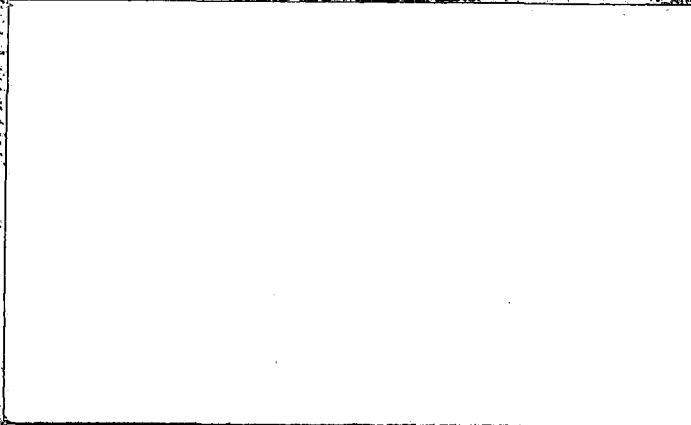


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PROGRESS REPORT

on

STUDIES OF THE PHYSICAL PROPERTIES
OF TALC, THEIR MEASUREMENT,
AND COMPARISON

to

JOHNSON AND JOHNSON

October 15, 1957

by

W. L. Smith

BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus 1, Ohio

K-3262-2

OK'd by O. F. Tangel and A. C. Richardson before typing.

cc: O. F. Tangel (3) A. C. Richardson R. D. Macdonald W. L. Smith (3) ✓

Battelle Memorial Institute

5 0 5 K I N G A V E N U E C O L U M B U S I, O H I O

October 25, 1957

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 "Studies of the Physical Properties of Talc, Their Measurement, and Comparison".

At the present stage of this investigation it can be seen that the lubricity of the Italian talc is closely related to its purity, crystalline habit, and particle-size distribution and is expressed in bulk density, surface area, porosity, and average diameter measurements. The acceptable Italian talc was found to fall within a small range of physical measurements. Lubricity was found to be controlled by the shape of the relatively small content of comparatively larger particles in the otherwise finer mixture.

It appears feasible that the slip of the Italian talc may be improved by the removal of the coarser mineral contaminants.

Your comments on the findings of this investigation will be appreciated.

Very truly yours,



W. L. Smith
Principal Geologist
Minerals Beneficiation Division

WLS:rr
Enc. (6)

R E S E A R C H F O R I N D U S T R Y

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STUDIES OF THE PHYSICAL PROPERTIES OF TALC, THEIR MEASUREMENT, AND COMPARISON

by

W. L. Smith

SUMMARY

In order to improve the physical properties of talc it is necessary to be able to measure the differences in talc and to establish a basis for the determination of improvement. To study the lubricous property of talc, an experimental lubricity measuring device was built, and the behavior of different talc samples was compared with their other physical properties. The comparative physical measurements were made upon sized fractions and whole samples of Italian talc with conventional laboratory devices. It was found that the acceptable Italian talc fell within a small range of the 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 comparatively larger particles in an otherwise finer mixture. At the present stage of the investigation, the improvement of the slip of the Italian talc appears feasible by the removal of the coarser mineral contaminants.

INTRODUCTION

The talc currently used by Johnson and Johnson, obtained from Pinerolo, Italy, is believed to be a blend of five or more different grades of ore which gives a high quality, lubricous powder. In a proposal for research on the improvement of the properties of talc, dated June 4, 1956, it was proposed to study the basic properties of the acceptable Italian talc and to determine if and how the quality might be improved. The development of objective tests which might serve in the evaluation of talc was recommended, with the initial work to be done upon the product now used by Johnson and Johnson.

In order to determine improvement in the quality of talc, however, it is necessary to measure the apparently small differences between acceptable talc and talc of lower quality. Previously, measurements have been made by subjective methods only, which were thought to be of insufficient precision to measure small differences. The development and correlation of physical measurements has been undertaken to permit the measurement of improvement. The measurements of the physical properties of acceptable talc, and their range, have been made upon a series of one kilogram samples of grade "EGT Extra 00000" taken at weekly intervals from the conveyor at the Cranford, New Jersey, plant just before the talc enters the ribbon blenders. An additional large sample of talc was obtained for tests requiring larger volumes of material.

As a test for the comparative lubricity of talc samples, a lubricity board was constructed. This device, though not providing absolute values, gives reproducible

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relative figures, with which the other physical properties, which can be more easily measured, may be correlated. This study, when coupled with proposed work on abrasiveness and other properties, should indicate the course to follow in beneficiation, the primary work on which Battelle reported in a letter dated June 12, 1957. The flotation work to date has been a laboratory expedient of producing talc of superior quality for physical tests.

DISCUSSION OF LUBRICITY

This report deals with lubricity and other physical properties including particle-size distribution and surface area, which are pertinent to lubricity. The desirable quality in talc, however, is only partly a matter of lubricity. That is, talc with the desired "feel" (as sensed subjectively) is not determined either by very high or very low lubricity (diminution of friction) but by a balance of physical properties which produces a particular sensory effect. This quality is referred to in this report as slip. The primary determining factor is the platiness of fine grained particles sliding over one another under slight pressure — not being lubricous in the sense of bearings which cut down friction by transmitting the moving forces to the rolling of an intermediate body, producing point friction; not being lubricous in the sense of a viscous fluid which buffers contact; but being lubricous in the sense of a series of leaves which impart the relative movement of two bodies along several planes parallel to the contact, producing the sensation of softness of surface contact.

The nature of the sliding of the platelets is a matter of kinetics, the changes in types of motion produced by applied forces. A certain intensity of force is required to maintain sliding between any two surfaces, and this varies with the nature of the surfaces. When the applied force is distributed along numerous planes rather than between two surfaces, the resistance to relative motion between the two bodies is distributed among a series of translation movements rather than in a rotational movement or in the overcoming of inertia in one plane. Inasmuch as the coefficient of sliding friction is apparently much less between talc platelets than between talc and flesh, the total friction resulting from the sum of translation movements is necessarily less than that of flesh in contact with flesh, and thus the lubricous property is sensed. The force producing the relative motion of two bodies is applied to the several planes of free moving talc platelets, which orient their greatest surfaces normal to the force applied; the contact of this series of parallel talc planes with flesh produces the silky or smooth sensation desirable in high quality talcum powder.

Grit (granular and acicular particles), where present, introduces point friction as in bearings, or plowing and thus is the primary objectionable contaminant in talcum powder.

The lubricousness or slip of talcum powder is determined by its mineralogical purity, the crystallographic habit of the talc, the size distribution of the powder, its moisture content, and the nature of the contaminants. Most of these factors must be determined petrographically, often on separated fractions of the powder. Other physical properties, such as surface area, average diameter, porosity, and bulk density, may be measured mechanically. Such physical measurements have been made, and the data have been correlated to determine which properties are significant in ground talc which has the desired slip. Measurements have been made to establish the

optimum limits of many of the properties relevant to lubricity. Data relevant to color, reflectance, moisture content, alkalinity, and abrasiveness will appear in a subsequent report.

THE ROLE OF MINERALOGICAL PURITY IN LUBRICITY

The Italian talc contains from about 97 to more than 99 per cent pure mineral talc. The predominant contaminant is carbonate, which is present in all size fractions, being slightly more abundant in the fines. Among other contaminants, present in trace amounts, are amphiboles, rutile, zircon, apatite, and titanite. The Italian talc is essentially free of opaques. The contaminants are generally prismatic or angular particles which act as grit and introduce point friction. A few such equidimensional or acicular particles present in an otherwise platy talcum, particularly if the grit is present in the coarser sizes, may be easily noticed subjectively. They diminish the lubricous feeling by the introduction of plowing, bearing-like particles, and the disruption of the lamellar movement of the talc particles. Inasmuch as the contaminants generally have diameters considerably greater than the thickness of talc platelets, their removal would improve the slip of any platy talc in which they occur in an effective amount. The small percentage of contamination in the Italian talc is an effective amount, as demonstrated by lubricity tests on a sample upgraded by froth flotation.

Further discussion of the nature of the impurities of talc was reported in earlier Battelle reports to Johnson and Johnson dated May 11, 1955^{(1)*}, February 29, 1956⁽²⁾, May 28, 1957⁽³⁾, and July 25, 1957⁽⁴⁾.

THE ROLE OF THE CRYSTALLOGRAPHIC HABIT OF TALC IN LUBRICITY

Platy talc is the most desirable for the purposes of the Sponsor. Whereas acicular and granular talc particles plow or roll, producing point friction, platy particles slide over one another producing the soft lubricous sensation desirable in talcum powder. The Italian talc averages about 10 per cent fibrous or acicular particles and about 90 per cent platelets. The amount of granular talc particles is negligible. Fibrous and granular particles of talc, though physically softer than the foreign mineral contaminants of talc ore, are none the less undesirable - if to a lesser degree. Such particles are most undesirable when present in the larger grain sizes where these crystals or aggregates may act as bearings or irritants.

Whereas different minerals may be separated from one another by physical processes, such as the removal of carbonates from talc by flotation, more difficulty is involved in separating particles of monomineralic, impalpable powder on the basis of their crystallographic habit, except where the crystal types concentrate in specific size fractions. Until beneficiation procedures for concentrating talc with the desired crystallographic habit are developed, talc which has the crystallographic habit preferred must be obtained by selective mining.

A detailed discussion of the various crystallographic habits of talc appears in a Battelle report to Johnson and Johnson dated February 29, 1956⁽²⁾.

* References are given on page 23.

THE MEASUREMENT OF LUBRICITY

Discussion

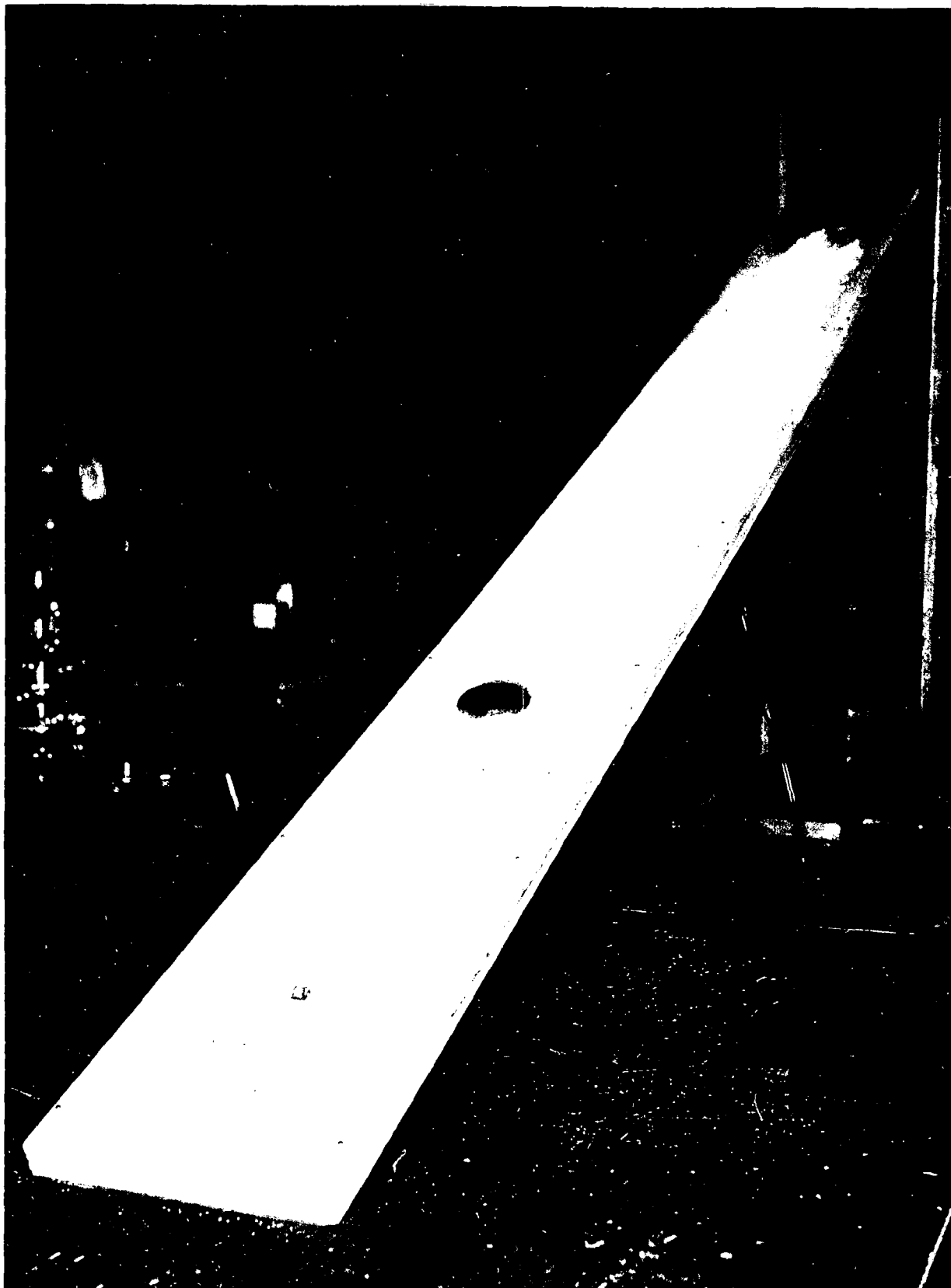
Although the desired property of talc, the slip or optimum balance of size distribution and friction is only partly a matter of lubricity, it is correlative within certain limits of lubricity. A standard method of objectively measuring the lubricousness of talc has not been devised previously. The lubricity has been determined comparatively by feeling a pinch of powder between the fingers. People experienced in so testing talc subjectively are able to distinguish fine differences in quality. Since the desirable and undesirable qualities of talc are a subjective matter, it is likely that subjective testing is preferable. However, since the subjective tests are a matter of sensation, involving human reaction to several physical properties, such tests are of little help in devising methods of improving the physical properties of talc or of measuring small differences in particular properties. Because of this it was necessary to build a device to objectively test and measure lubricity, apart from the other properties which contribute to the desirability of talc.

It is not to be inferred that an objective test can replace the subjective test or that pleasantness of sensation is mechanically measurable; however, the physical properties which contribute to the unctuousness of talc can be measured and their optimum limits can be determined. Thus the means of improvement of talcs can be visualized. The figures obtained on the lubricity-board experiments are compared with the more easily made measurements of other physical properties in order to determine if there is a correlation and to establish the desirable limits of particular properties in acceptable Italian talc.

The Lubricity Board

In order to obtain quantitative measurements of talc samples, against which the measurements of other physical properties could be compared, a simple machine was constructed with a minimum of interacting physical factors. This device consists of a wooden plane inclined at 25 degrees, which is covered with talc (Figure 1). The lubricity is determined by measuring the time it takes a 226-gram steel puck to slide over two microswitches spaced 5 feet apart (Figure 2). The microswitches actuate an electric timer.

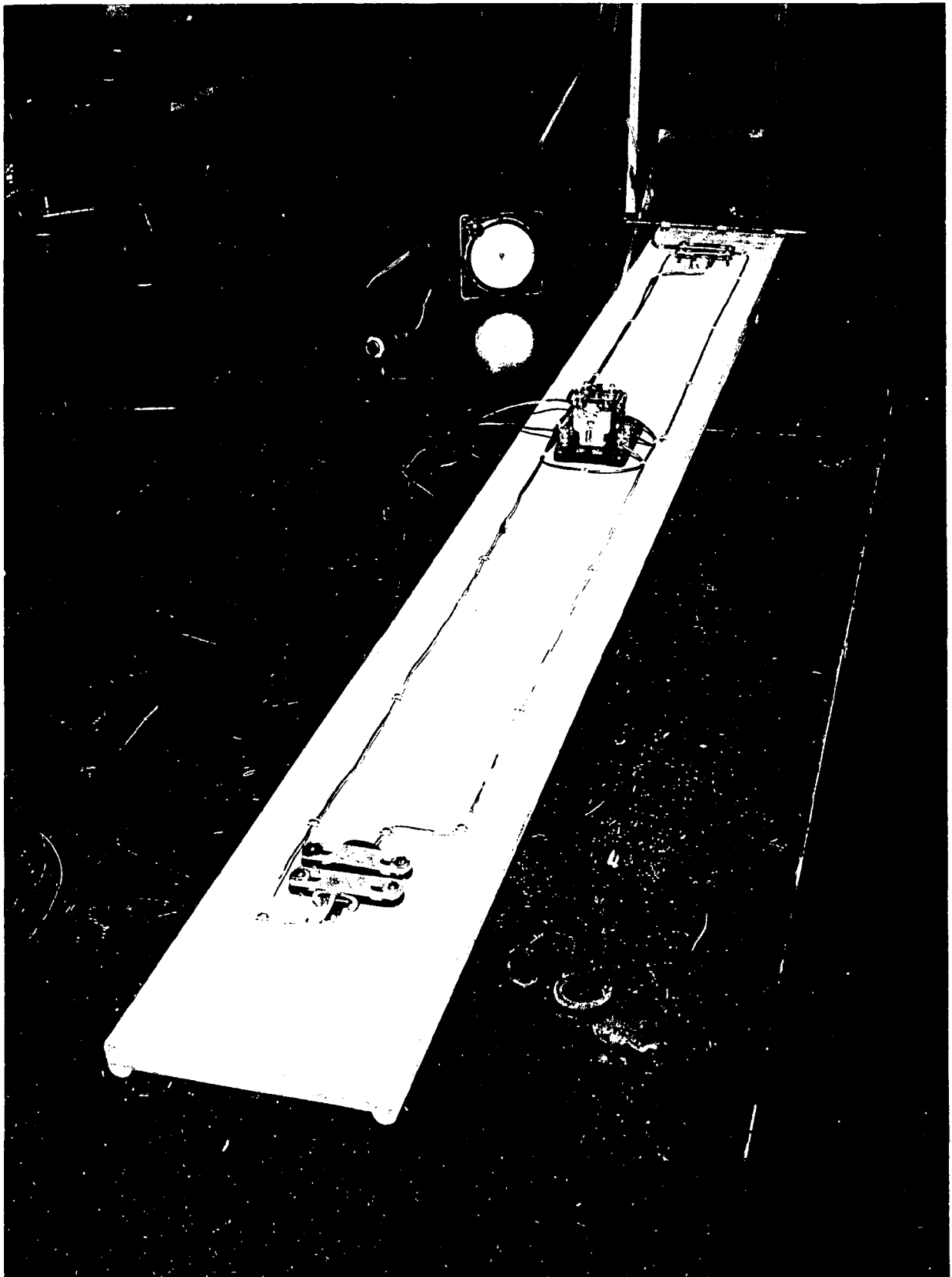
The lubricity board was designed as a preliminary device in making lubricity experiments; however, a routine method of measurement has been established and the device has demonstrated a reproducibility with an accuracy of more or less 1 per cent. Although more precise machines might be built, the lubricity board has proven to be an adequate means of measuring the comparative lubricity of talc samples and to be adequately precise for the comparison of data from other physical measurements. The measurements made on the lubricity board are presented in terms of .xxx second, the figures representing the average of fifty readings. A typical set of figures is shown in Table 1. A description of the lubricity board and the technique of its operation comprises Appendix A.



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FIGURE 1. THE LUBRICITY BOARD, SHOWING DESCENT OF STEEL PUCK

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FIGURE 2. UNDERSIDE OF LUBRICITY BOARD, SHOWING MICROSWITCHES AND ELECTRIC TIMER CONNECTED TO LOCK-IN RELAY

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TABLE 1. TYPICAL DATA FROM LUBRICITY-BOARD MEASUREMENT
OF ITALIAN TALC SAMPLE (CRANFORD, 12/22/56)

Measurement in Seconds				
Series 1	Series 2	Series 3	Series 4	Series 5
0.96 ^(a)	0.97	0.98	0.97	0.97
0.98	0.96	0.97	0.96	0.97
0.95	0.96	0.97	0.96	0.96
0.95	0.95	0.97	0.98	0.95
0.97	0.96	0.96	0.98	0.96
0.97	0.95	0.96	0.97	0.94
0.96	0.96	0.97	0.96	0.97
0.95	0.97	0.98	0.98	0.98
0.97	0.96	0.97	0.97	0.95
0.94	0.97	0.97	0.99	0.97
Average 0.965 second				

(a) Lubricity board newly covered for each series of ten slides.

Contrary to preconceived ideas about the behavior of solid lubricants, the puck was found to slide faster on poorer grades of talc than on cleaner samples with better slip. The controlling factor is the presence of contaminants or equidimensional particles which act as bearings while purer talc, within the limits of the particular size distribution, presents a surface composed of flat platelets, producing more friction and slowing the descent of the puck.

It is not suggested at this time that Johnson and Johnson conduct similar experiments on a lubricity board. Until the lubricity studies are completed, it is intended that the lubricity board serve only as a basis for comparison with other measurements by which the physical properties which control lubricity can be evaluated.

The Lubricity of Talc Samples

Lubricity-board measurements were made on 15 samples of talc obtained from the Cranford plant of Johnson and Johnson, collected at regular intervals from August 10 to December 22, 1956. Table 2 lists the figures obtained for each sample. The readings ranged from 0.936 second for the sample which permitted the fastest descent of the puck to 1.083 seconds for that sample which most slowed the descent.

To test the hypothesis that the faster descents were due to bearing-like contaminants, the lubricity figures were compared to those of the percentage of contamination. Table 2 lists the amount of contamination as compared to the lubricity of the samples. The contamination figures represent microscopically identifiable particles and do not include the impalpable fines. Although correlation was not perfect, the relationship of contamination to lubricity is clear in the extreme instances. The talc containing the greater amount of contaminants permitted the faster descents on the lubricity board. The slight differences in contamination were not discernible subjectively.

TABLE 2. LUBRICITY-BOARD MEASUREMENTS AND PER CENT CONTAMINATION OF TALC SAMPLED AT CRANFORD, NEW JERSEY, SHOWING RELATION OF LUBRICITY TO PURITY OF SAMPLE

Date Sampled	Contamination ^(a) , per cent	Lubricity-Board Measurements, seconds
9-6-56	<1	1.083 (slowest)
11-6-56	1	1.053
9-12-56	<1	1.030
9-19-56	<1	1.028
10-18-56	1	1.025
8-10-56	1	1.021
9-27-56	1	1.017
8-28-56	2	1.007
10-29-56	1-2	1.006
10-4-56	1-2	0.982
8-20-56	2	0.971
10-12-56	2-3	0.968
12-22-56	2	0.965
11-30-56	2-3	0.952
11-15-56	2	0.936 (fastest)

(a) Determined petrographically.

Inasmuch as the contamination figures were small, were close together, and could be prejudiced, the contaminants were removed from a sample of talc by froth flotation and the products were tested on the lubricity board. The test results, which are also noticeable subjectively, are given in Table 3.

TABLE 3. LUBRICITY-BOARD DATA ON FLOTATION PRODUCTS OF ITALIAN TALC, SHOWING DELETERIOUS EFFECT OF CONTAMINATION ON LUBRICITY

Product	Lubricity-Board Measurement, seconds
Starting sample	0.990
Float product ^(a)	1.046 (superior)
Nonfloat product ^(b)	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.

The essentially pure talc product produced a slower descent of the steel puck than did the unseparated sample, and the flotation tailings permitted a descent considerably faster than did the unseparated sample. It may be concluded, on the basis of several experiments on the lubricity board, that the purer talc with the better slip requires a longer time for the puck to slide, while the samples more contaminated with granular "bearings" permit faster descents. Although the details of practical beneficiation of this talc by froth flotation have yet to be worked out, the amenability of the talc to

flotation and the obvious improvement in the purity and slip of the product indicate that beneficiation is a feasible consideration for the improvement of the Italian talc.

C THE RELATIONSHIP OF LUBRICITY TO PARTICLE-SIZE DISTRIBUTION

Discussion

The desirable slip in talcum powder does not depend alone on the physical lubricity of the mineral but on numerous interdependent physical properties, one of the more important being particle-size distribution. The relative amount of grains in different size fractions, the extreme sizes, and the crystalline habit of grains of different sizes play a major role in lubricity. Comparatively larger grains in an otherwise fine powder may roll like bearings, plow, or act as barriers to the free movement of smaller platelets. Too large an amount of very fine grains may behave as "flour" despite their particle shape and may disrupt or may clog the movements of larger platelets.

Size distribution is reflected in bulk density, porosity, surface area, and average diameter measurements. The samples of Italian talc were found to have physical properties which fall within a small range of many of these measurements and which can be related to lubricity in some instances. Too many variable properties exist in talc to assess specific requirements for many physical measurements; however, in testing for acceptable talcs, those ores with properties similar to the Italian talc should also be expected to have measurements within or close to the range of those obtained on the Italian talc. The measurements should be a useful guide in the blending of talcs and for the rejection of inferior grades.

Battelle wishes to emphasize that immediate conclusions should not be drawn from the following physical measurements alone, inasmuch as they represent but half of the story. A forthcoming report which will deal further with lubricity and other physical properties such as whiteness, abrasiveness, and moisture content, will expand the list of the properties required for an acceptable talc. Although many talcs may be rejected because they fail to meet certain physical requirements presented here, acceptability involves additional factors.

Particle-Size Distribution in Italian Talc

In a previous report to Johnson and Johnson⁽²⁾, Battelle reported a dry screen analysis and a particle-size distribution of Italian talc based on both dry screening and sedimentation in water. These findings are repeated in Table 4. Further, extensive particle-size distribution studies were made showing that three replicate analyses of a large sample of Italian talc were closely reproducible and in close agreement with the earlier analyses, although obtained from a separate sample (Table 5). Appendix B contains a description of the procedure for particle-size analysis.

TABLE 4. PREVIOUSLY REPORTED PARTICLE-SIZE
DISTRIBUTION DATA⁽²⁾ ON ITALIAN TALC

a. Dry Screen Analysis

Tyler Mesh Size	Weight Per Cent
+150	0.1
-150+200	1.8
-200+270	2.1
-270+325	13.5
-325	82.5
	<u>100.0</u>

b. Approximate Particle-Size Distribution Based on Dry
Screening and Sedimentation in Water

Size	Approximate Weight Per Cent
-100+200 Mesh	2
-200+325 Mesh	16
-325 Mesh + 15 Microns	62
-15 Microns + 10 Microns	9
-10 Microns	11
	<u>100</u>

TABLE 5. PARTICLE-SIZE DISTRIBUTION OF THREE SAMPLES
OF ITALIAN TALC

Size	Average Weight Per Cent	Per Cent Deviation From Mean
+200 mesh ^(a)	1	0.12
-200 mesh + 325 mesh	10	0.97
-325 mesh + 400 mesh	7	1.3
(38 microns)		
-38 microns + 30 microns	57	5.18
-30 microns + 15 microns	12	0.8
-15 microns	13	3.1
	<u>100</u>	

(a) Tyler.

To check the variation in particle-size distribution of the talc samples from Cranford, a series of measurements by dry screening and sedimentation were made on 12 samples. Table 6 lists the weight per cent of each size fraction. One of the samples, Cranford 10/4/56, might be eliminated statistically from the sample population; however, the variation is real and its data are included in the weight per cent deviation from the mean (Table 7). The effect of the variant sample shows clearly in the measurements of average particle size, specific surface, bulk density, and porosity (Tables 12, 15). The cause of the variation is not obvious petrographically, the sample being similar to the others except in size distribution. This variant sample demonstrates that the Pinerolo product is not uniform. Also, since the larger coarse fraction does not cause the expected effect on the lubricity measurement as do variations within the normal size distribution population, it shows that the matter of lubricity is more complex than is indicated by variations within a small range in particle-size distribution.

The Cranford samples have minor variations in particle-size distribution. In all of the samples, however, the -400 mesh (38 micron) + 30 micron fraction constitutes about one-half of the sample, with minor amounts in the smaller and larger fractions. This distribution should be kept in mind should platy talcs of other distributions be considered. Inasmuch as the size distribution may be as much a matter of the grinding and blending of ores as of the physical nature of the ore, fabrication of acceptable talcum powder from lower grade ore might be accomplished by a proper blend of sized fractions of platy talc.

Correlation of Lubricity With Particle-Size Distribution Data

In order to correlate the particle-size distribution and lubricity data, a large sample of Italian talc was sized and the size fractions were tested on the lubricity board. Experiments clearly showed that the coarser fractions permitted a faster descent of the puck while the finer fractions produced a slower descent. This is apparently due to the more equidimensional bearing-like particles in the coarser fractions. Table 8 demonstrates the relationship of particle size to lubricity, showing the larger, more desirable, lubricity figures for the fines, the lower for the coarser, gritty fraction.

Inasmuch as the lubricity of talc involves the physical properties of material of various grain sizes, lubricity measurements were made on various proportional mixtures of specific particle-size fractions and on powders from which specific particle-size fractions were removed. In order to determine if the over-all lubricity was controlled by the coarse or by the fine sizes, a series of lubricity measurements was made on proportional mixtures of the fine (-400 mesh) and coarse (+250 mesh) sizes. Table 9 clearly shows that the control is in the relative amount of coarser to finer grains. That is, a small amount of coarse particles added to an otherwise fine powder has a pronounced adverse effect on lubricity, whereas a similar percentage addition of fine particles to an otherwise coarse grained powder has comparatively little effect on lubricity. It may be concluded from this study that the removal of the coarser particles, which tend to be more equidimensional, will improve the slip. On the other hand, the addition of fines to gritty or granular powders makes comparatively little improvement.

TABLE 6. PARTICLE-SIZE DISTRIBUTION OF TALC SAMPLED AT CRANFORD PLANT

Date Collected	Weight Per Cent of Size Fractions					
	+200 Mesh	-200 Mesh +325 Mesh	-325 Mesh +400 Mesh	-400 Mesh +30 Microns	-30 Microns +15 Microns	-15 Microns
9-6-56	0.47	5.44	6.83	65.72	10.76	10.78
11-6-56	0.51	5.13	7.75	56.66	16.49	13.46
9-12-56	0.92	8.30	7.85	60.76	10.23	11.94
9-19-56	0.84	5.54	7.65	55.79	16.42	13.88
10-18-56	0.96	7.86	7.27	58.07	13.32	12.52
9-27-56	0.59	4.48	6.77	56.52	15.93	15.71
8-28-56	0.50	4.34	6.89	56.39	16.18	15.71
10-4-56(a)	1.22	6.38	9.36	40.02	31.74	11.28
8-20-56	0.65	6.08	7.98	57.53	16.64	11.12
12-22-56	0.88	3.42	12.30	52.27	20.01	11.12
11-30-56	0.72	6.38	10.33	57.86	11.21	13.50
11-15-56	0.88	6.93	9.91	48.72	22.08	11.48

(a) See comment under "Particle-Size Distribution in Italian Talc".

TABLE 7. DEVIATION IN PARTICLE-SIZE DISTRIBUTION IN WEIGHT PER CENT OF TALC SAMPLED AT THE CRANFORD PLANT

Size	Deviation, weight per cent (Excluding Sample 10/4/56)	Deviation, weight per cent (Including Sample 10/4/56)
+200 mesh(a)	0.26	0.39
-200 mesh + 325 mesh	2.44	2.44
-325 mesh + 400 mesh (38 microns)	1.78	1.78
-38 microns + 30 microns	8.50	12.85
-30 microns + 15 microns	5.42	10.75
-15 microns	3.72	3.72

(a) Tyler.

TABLE 8. RELATIONSHIP OF LUBRICITY TO PARTICLE SIZE

Tyler Mesh Size	Lubricity-Board Measurement, seconds
Unseparated	0.990
+200	0.889
-200+250	0.951
-250+270	0.980
-270+325	1.030
-325+400	1.043
-400	1.099

TABLE 9. THE LUBRICITY OF MIXTURES OF COARSE AND FINE SIZES OF TALC, DEMONSTRATING THE CONTROL TO BE IN THE COARSE FRACTIONS

Per Cent Fines (-400 Mesh)	Per Cent Coarse (+250 Mesh)	Lubricity-Board Measurement, seconds	Difference in Lubricity
0	100	0.951	
10	90	0.951	.000
25	75	0.960	.009
50	50	0.970	.010
75	25	0.986	.016
90	10	1.038	.052
100	0	1.099	.061

Further measurements of the effect of particle-size distribution on lubricity were made by testing whole powder from which different size fractions had been removed. The measurements, Table 10, demonstrate that removal of the fines decreases the quality of the powder, whereas removal of the coarse fractions improves it. It would have to be determined by further tests of beneficiation products whether it is most advisable to remove entire size fractions or merely the small percentage of coarse contaminants.

TABLE 10. 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	Lubricity-Board Measurement of ^(a) Size Fractions	Test 1	Test 2	Whole Powder	Test 3	Test 4
+200	0.889	U	U	U	X	X
-200+250	0.951	U	U	U	X	X
-250+270	0.980	U	U	U	U	X
-270+325	1.030	X	U	U	U	U
-325+400	1.043	X	U	U	U	U
-400	1.099	X	X	U	U	U
Lubricity-Board Measurement		0.945	0.963	0.990	1.038	1.068
Approximate Weight Per Cent of Fractions Removed		97.	82.	0.	2.	3.

(a) Repeated from Table 8 for comparative purposes.

MOISTURE CONTENT

Of considerable importance to the lubricity of talc is its moisture content. This topic is more thoroughly treated in a forthcoming report. It is important, however, to note here that an increase in moisture content slows the descent of the puck on the lubricity board and falsely indicates superior lubricity. All of the Italian talc was found to contain a moisture content in the hundredths of one per cent. Analyses of various size fractions show that the moisture content is higher in the fine sizes, possibly due to adsorption on the greater surface area.

MEASUREMENT AND CORRELATION OF OTHER PHYSICAL PROPERTIES RELATED TO LUBRICITY

Surface Area Determinations by Nitrogen Adsorption

The relationship of lubricity to particle-size distribution has been shown to be a matter of friction and surface area, the finer platelets having the greater surface area per unit of weight.

Four samples of Italian talc from Cranford were measured for their surface area using the Brunauer, Emmett, Teller technique of nitrogen adsorption at liquid nitrogen temperatures (Table 11).

TABLE 11. SURFACE AREA MEASUREMENTS OF ITALIAN TALC, COMPARED WITH LUBRICITY-BOARD MEASUREMENTS

Cranford Sample Date	Lubricity-Board Measurement, seconds	BET Surface Area Measurement, m ² /g
9-6-56	1.083	3.57
9-12-56	1.030	3.18
9-19-56	1.028	2.93
10-4-56	0.982	2.26

The tests show a relationship between surface area and lubricity, the samples with the greater surface area also having the larger lubricity measurements. The values are believed to be accurate to within 5 per cent.

Average Diameter of Particles

An easily operated instrument for rapid particle-size determinations is the Fisher Subsieve Sizer. The instrument measures average particle size by determining the resistance to the flow of air by a weighed sample of powder under standard packing conditions. On the basis of the principle that a fluid meets less resistance to flow while

TABLE 12. COMPARISON OF THEORETICAL AVERAGE-DIAMETER MEASUREMENTS AND SPECIFIC SURFACE TO LUBRICITY-BOARD MEASUREMENTS OF CRANFORD SAMPLES

Cranford Collection Date	Lubricity-Board Measurement, seconds	Theoretical Average ^(b) Particle Diameter	Specific Surface, cm ² /g
9-6-56	1.083	2.60	8392
11-6-56	1.053	2.65	8233
9-12-56	1.030	2.60	8392
9-19-56	1.028	2.45	8905
10-18-56	1.025	2.60	8392
8-10-56	1.021	2.80	7792
9-27-56	1.017	2.80	7792
8-28-56	1.007	2.75	7934
10-29-56	1.006	2.80	7792
10-4-56 ^(a)	0.982	3.30	6612
8-20-56	0.971	2.90	7524
10-12-56	0.968	2.90	7524
12-22-56	0.965	3.10	7038
11-30-56	0.952	3.30	6612
11-15-56	0.936	3.20	6818

(a) See comment under "Particle Size Distribution in Italian Talc".

(b) Determined on Fisher Subsieve Sizer.

penetrating a bed of coarse particles than while penetrating a bed of fine particles, a figure is derived which disregards the shape of the individual grains, porosity, size distribution and other variables. Inasmuch as the average diameter figure represents a theoretical sphere, the data are of relative rather than actual value. Average diameter measurements made on the Fisher Subsize Sizer are shown in comparison with lubricity measurements (Table 12), demonstrating the correlation of small average diameters to talc with the larger lubricity measurement and larger average diameters to talc with the lower, less desirable, lubricity measurements. A clear-cut correlation of the theoretical average-particle-diameter measurements with the lubricity-board measurements is shown in Table 13.

TABLE 13. RELATIONSHIP OF LUBRICITY-BOARD MEASUREMENTS TO THEORETICAL AVERAGE DIAMETERS ON SIZED FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Lubricity-Board Measurements, seconds	Theoretical Average Particle Diameter, microns ^(a)
Unseparated	0.990	2.60
+200	0.889	7.40
-200+250	0.951	3.60
-250+270	0.980	2.50
-270+325	1.030	2.35
-325+400	1.043	2.25
-400	1.099	2.10

(a) Determined on Fisher Subsize Sizer.

Specific Surface Calculated From Average Diameter

The average particle diameter as determined on the Fisher Subsize Sizer may, by use of a simple equation, * be expressed in terms of specific surface in square centimeters per gram of dry powder. This is a simpler, less expensive method than nitrogen adsorption. Specific surfaces, as calculated from the average-particle-diameter measurements, are presented in Table 12 in comparison with lubricity. The calculated specific-surface figures, because of their derivation from average-particle-diameter measurements, are inversely correlative with particle size. The samples with the greater specific surfaces are those which impede the slide of the puck on the lubricity board, and which have better slip, while the samples with the smaller specific surfaces, those containing the larger particles, are the samples permitting faster descents of the puck on the lubricity board.

As in the case of the average particle-diameter measurement, the specific-surface calculations represent theoretical spheres which, since the powder is composed of platelets, are of relative rather than exact value. Whereas the surface area as determined by gas adsorption is relatively exact, the value of the surface-area figures derived from the theoretical average-particle-diameter measurements is purely comparative.

$$*\text{Specific surface (cm}^2\text{/g)} = \frac{6 \times 10^4}{\text{average diameter } (\mu) \times \text{specific gravity of talc}}$$

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The relationship of specific surface to the lubricity of sized fractions of Italian talc is presented in Table 14, which shows that the fractions with the better lubricity also have the greater surface areas.

TABLE 14. CORRELATION OF SPECIFIC SURFACE AND LUBRICITY-BOARD MEASUREMENTS OF SIZED FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Lubricity-Board Measurements, seconds	Specific Surface, cm^2/g
Unseparated	0.990	8392
+200	0.889	2948
-200+250	0.951	6061
-250+270	0.980	8727
-270+325	1.030	9284
-325+400	1.043	9697
-400	1.099	10390

Porosity

A measurement of porosity, independent of the other measurements, may be made on the Fisher Subsieve Sizer. The porosity figure represents the ratio of voids to the total volume of the packed sample, in a range of 0.40 to 0.80. Inasmuch as part of the test involves a manual operation, the results are subject to a human error. The porosity figures, however, are reproducible through the second decimal place. The range in porosity, 0.448 to 0.490, determined on the Cranford samples, is a relatively small range and should, by its close limits alone, be of assistance in evaluating Italian talc (Table 15). The more porous powders, those with the greatest amount of asymmetrical, platy grains, are also those with the larger lubricity-board measurements, hence the better slip. Correspondingly, the samples with the lower porosity, those containing the greater amount of equidimensional grains, are the powders which have the lower lubricity-board measurements.

Table 16 shows the porosity of sized fractions of Italian talc as compared with its lubricity-board measurements. The porosity is clearly shown to be less in the coarser fractions with the poorer slip and greater in the finer fractions.

TABLE 15. POROSITY, BULK DENSITY, AND LUBRICITY OF CRANFORD SAMPLES

Cranford Collection Date	Porosity Ratio	Bulk Density, lb/cu ft	Lubricity-Board Measurements, seconds
9-6-56	0.490	22.942	1.083
11-6-56	0.480	22.958	1.053
9-12-56	0.475	23.259	1.030
9-19-56	0.456	23.437	1.028
10-18-56	0.452	22.860	1.025
8-10-56	0.460	23.528	1.021
9-27-56	0.464	23.096	1.017
8-28-56	0.470	22.642	1.007
10-29-56	0.461	22.491	1.006
10-4-56(a)	0.475	24.061	0.982
8-20-56	0.460	23.756	0.971
10-12-56	0.455	23.429	0.968
12-22-56	0.452	22.616	0.965
11-30-56	0.448	22.725	0.952
11-15-56	0.450	22.583	0.936

(a) See comment under "Particle-Size Distribution in Italian Talc".

TABLE 16. CORRELATION OF POROSITY AND LUBRICITY-BOARD MEASUREMENTS OF SIZED FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Lubricity-Board Measurements, seconds	Porosity Ratio
Unseparated	0.990	0.448
+200	0.889	0.401
-200+250	0.951	0.426
-250+270	0.980	0.439
-270+325	1.030	0.446
-325+400	1.043	0.442
-400	1.099	0.455

Bulk Density

The bulk density of ground talc may be measured on a Scott Volumeter. The Cranford talc samples were found to have bulk densities ranging between 22 and 25 pounds per cubic foot. Table 15 lists the bulk densities of the Cranford talc samples. The bulk-density measurement is not precise enough to accurately compare small differences but is valuable in establishing a range of acceptability. When sized fractions are tested, the bulk density is seen to have inverse relationships with porosity and specific surface and to have a direct relationship with average particle size. Thus, as shown in Table 17, bulk density is inversely correlative with lubricity as a function of particle size. The coarser fractions, with poorer slip have the higher bulk density; the finer fractions having the lower bulk density. The relationship of bulk density, moisture content, and lubricity is presented in a forthcoming report.

TABLE 17. THE RELATIONSHIP OF BULK DENSITY TO LUBRICITY-BOARD MEASUREMENTS OF SIZED FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Lubricity-Board Measurements, seconds	Bulk Density, lb/cu ft
Unseparated	0.990	23.030
+200	0.889	34.261
-200+250	0.951	26.645
-250+270	0.980	20.721
-270+325	1.030	19.335
-325+400	1.043	19.139
-400	1.099	16.894

CONCLUSIONS

Because this study represents but part of the picture of evaluating acceptable talc by means of its physical properties, it is not possible to state final conclusions without qualifications. Several relationships between physical properties, however, have been established for acceptable Italian talc and the range of their variations have been measured. A forthcoming report including studies of other physical properties will add to the picture and will indicate the course to follow for beneficiation of the Italian talc in order to improve its physical properties.

The physical properties of the Italian talc samples have been measured and the following ranges in values were obtained:

- (1) Contamination: from less than 1 to more than 3 per cent.
- (2) Crystallographic habit: more or less constantly 90 per cent platy, 10 per cent fibrous.
- (3) Lubricity-board measurement: from 0.936 to 1.083 seconds.
- (4) The ratio of voids to total volume: from 0.45 to 0.49.
- (5) Theoretical average particle diameter: from 2.45 to 3.30 microns.
- (6) Bulk density: from 22.49 to 24.06 lbs/cu. ft.
- (7) Specific surface: from 6612 to 8905 cm²/g.
- (8) Moisture content: hundredths of one per cent.
- (9) Particle-size distribution:

+200 mesh	0.47 to 1.22 per cent
-200+325 mesh	3.42 to 8.30
-325+400 mesh (38 microns)	6.77 to 10.33
-38 microns + 30 microns	40.02 to 65.72
-30 microns + 15 microns	10.23 to 22.08
-15 microns	10.78 to 18.23.

Physical measurements on sized fractions of Italian talc showed the coarser particle fractions to have lower, less desirable, measurements on the lubricity board and the finer fractions to have the larger, more desirable, measurements. The sized fractions with the preferable lubricity were found to have the higher porosity and specific surface and the smaller particle size and bulk density (Table 18).

Lubricity-board studies on Italian talc fabricated to particular size distributions show that the lubricity is controlled by the relatively small amount of comparatively larger grains in an otherwise finer mixture. Lubricity-board studies also show that the lubricity of the Italian talc may be improved by the removal of the coarser size fractions. This is not a simple matter, however, as it involves the variation in size of the abrasive particles.

TABLE 18. SUMMARY OF PHYSICAL PROPERTIES OF SIZED FRACTIONS OF ITALIAN TALC

Tyler Mesh Size	Lubricity-Board Measurements, seconds	Average Diameter, microns	Specific Surface, cm ² /g	Porosity Ratio	Bulk Density, lb/cu ft
Unseparated	0.990	2.60	8392	0.448	23.030
+200	0.889	7.40	2948	0.401	34.261
-200+250	0.951	3.60	6061	0.426	26.645
-250+270	0.980	2.50	8727	0.439	20.721
-270+325	1.030	2.35	9284	0.446	19.335
-325+400	1.043	2.25	9697	0.442	19.139
-400	1.099	2.10	10390	0.455	16.894

Measurements on flotation products show that the removal of the small per cent of contaminants improves the lubricity of the talc .

The physical properties of the Italian talc can be improved, with the least possible loss of sample, by removing the mineral contaminants from either the coarse fractions or from the sample as a whole. This appears to be one clear cut course to follow in improving the Italian talc.

(The original notes on the laboratory work described in this report are in Battelle Laboratory Record Books No. 12667, pages 1 through 71, and No. 13034, pages 1 through 77. The work was done in the period from November 7, 1956, to September 30, 1957.)

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APPENDIX A

DESCRIPTION OF LUBRICITY BOARD
AND TECHNIQUE OF OPERATION

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APPENDIX A

DESCRIPTION OF LUBRICITY BOARD
AND TECHNIQUE OF OPERATION

The experimental device described as the lubricity board in this report consists of a wooden plane inclined at 25 degrees, which is lightly, but completely, covered with talc. The lubricity is determined by measuring the time it takes a steel puck to slide over two microswitches which actuate an electric timer.

The inclined plane is made of 6-ply birch plywood, 3/4 inch thick, 6 inches wide, and 6 feet long. The even-grained wood was sanded smooth to prevent the grain from influencing the descent of the puck. Twenty-five degrees was selected as the inclination from horizontal after much experimentation which showed it to be the minimum angle at which a sustained slide could be made on all of the Italian talc samples.

The microswitches are located 6 inches from each end of the slide, in the middle of the board, making the measured path a length of 5 feet. The microswitches are connected to a double-pole, 115-volt, Struthers-Berm lock-in relay which actuates a Standard Electric Time Company electric timer. The steel puck weighs 226 grams, is 3/4 inch by 2-1/2 inches, has rounded edges, and presents a circular sliding surface of 1-3/4 inches diameter. Such are obtainable from amusement equipment distributors as a piece used in the game of American Shuffleboard. One flat surface of the puck was ground smooth and polished for the lubricity experiments.

The talc is applied to the lubricity board from a 9-ounce Johnsons' Baby Powder can until a thin even layer is present over the measured path. The puck is manually released from a dead start from the top of the slide, 6 inches above the first microswitch. For purposes of eliminating errors of freak descents, lubricity is measured as the average of 50 runs. The board is newly covered with talc after each 10 runs, although no difference in lubricity measurements could be accounted for between those early and late in a series. The puck was washed in warm water and thoroughly dried between runs.

APPENDIX B

PROCEDURE FOR PARTICLE-SIZE ANALYSIS

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APPENDIX B

PROCEDURE FOR PARTICLE-SIZE ANALYSIS

In a previous report to Johnson and Johnson from Battelle⁽²⁾ a procedure for sizing Italian talc was outlined. For purposes of the present investigation, the following procedure was developed by D. A. Jacobs of the Battelle staff.

One hundred grams of talc is wet screened at 325 mesh with water. The +325 mesh product is dried and dry screened on a Ro-Tap for 30 minutes producing +200, 200 x 325, and -325 mesh fractions. The -325 mesh fraction of the dry screening is combined with the -325 mesh product of the wet screening. A suspension of -325 mesh material is allowed to settle through a 10-centimeter column in a 4-liter beaker to which sodium silicate has been added in the amount of 1 pound per ton, and agitated for a period of 10 minutes. The sodium silicate is added to the first 30-minute settling of each sample only. At the end of the first 30-minute cycle, the supernatant column of liquid is siphoned off. This liquid contains the -15 micron fraction. Four cycles are required to remove the -15 micron fraction entirely. Another series of 4 cycles with settling times of 5 minutes produces the 15 x 30-micron fraction, which is siphoned off, plus sands of 30 microns x 325 mesh. The sands are dried and dry screened at 400 mesh on a Ro-Tap for 30 minutes, producing 325 x 100 mesh and 400 mesh x 30 micron fractions. The sizing flowsheet is presented as Figure B-1.

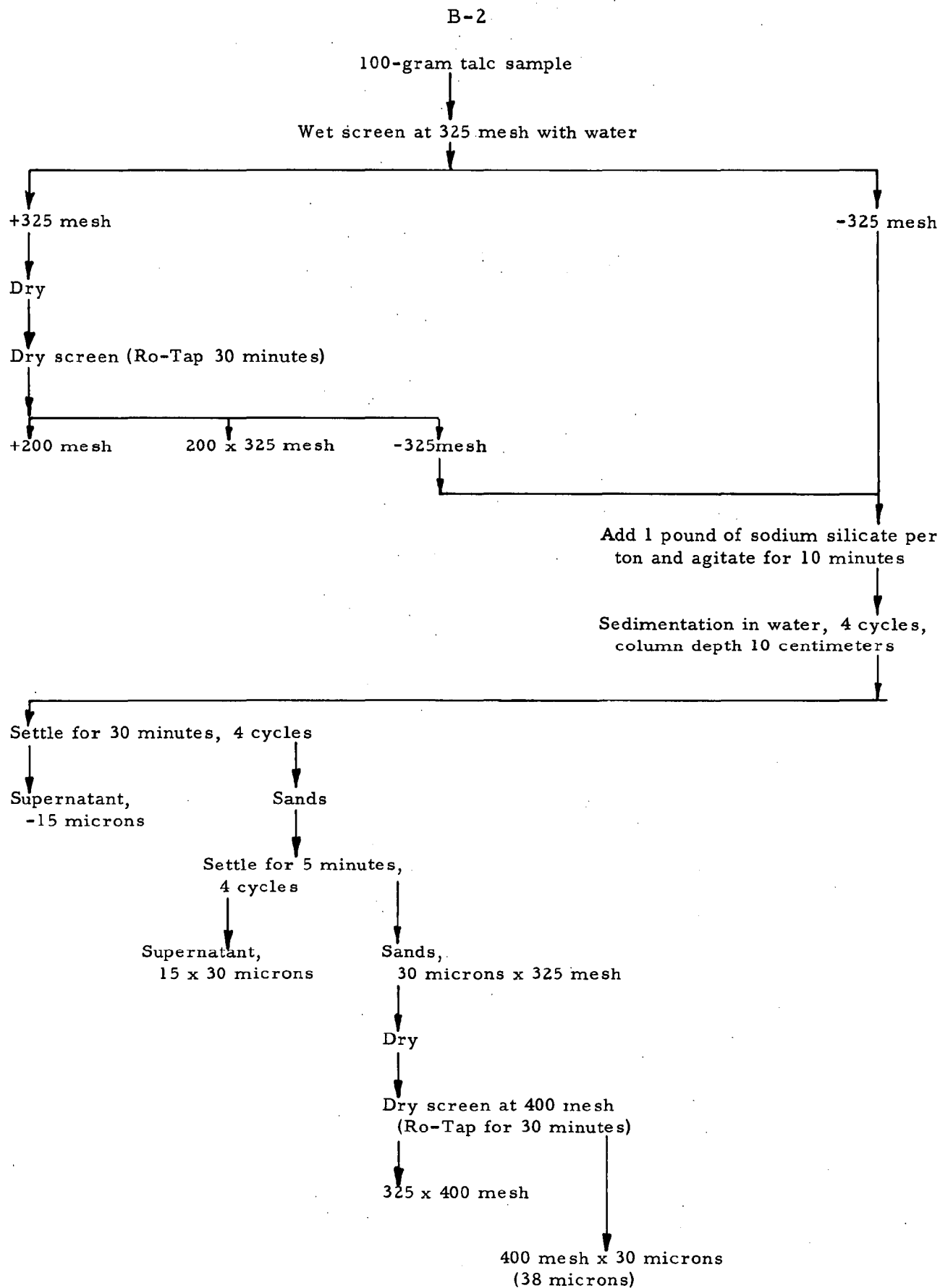
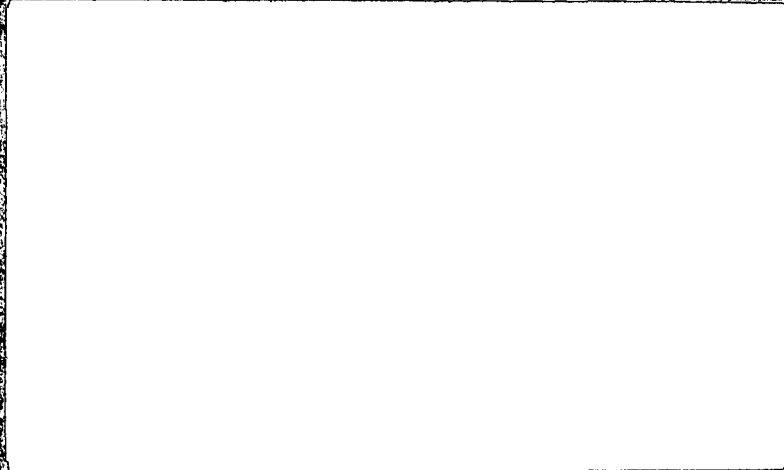


FIGURE B-1. STANDARD FLOWSHEET FOR SIZING OF TALC SAMPLES
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PROGRESS REPORT

on

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

to

JOHNSON AND JOHNSON

Russell C. Cope
May 9, 1958

by

W. L. Smith

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5 0 5 K I N G A V E N U E C O L U M B U S , O H I O

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.

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 ($2\text{CaO} \cdot 5\text{MgO} \cdot 8\text{SiO}_2 \cdot \text{H}_2\text{O}$).

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).

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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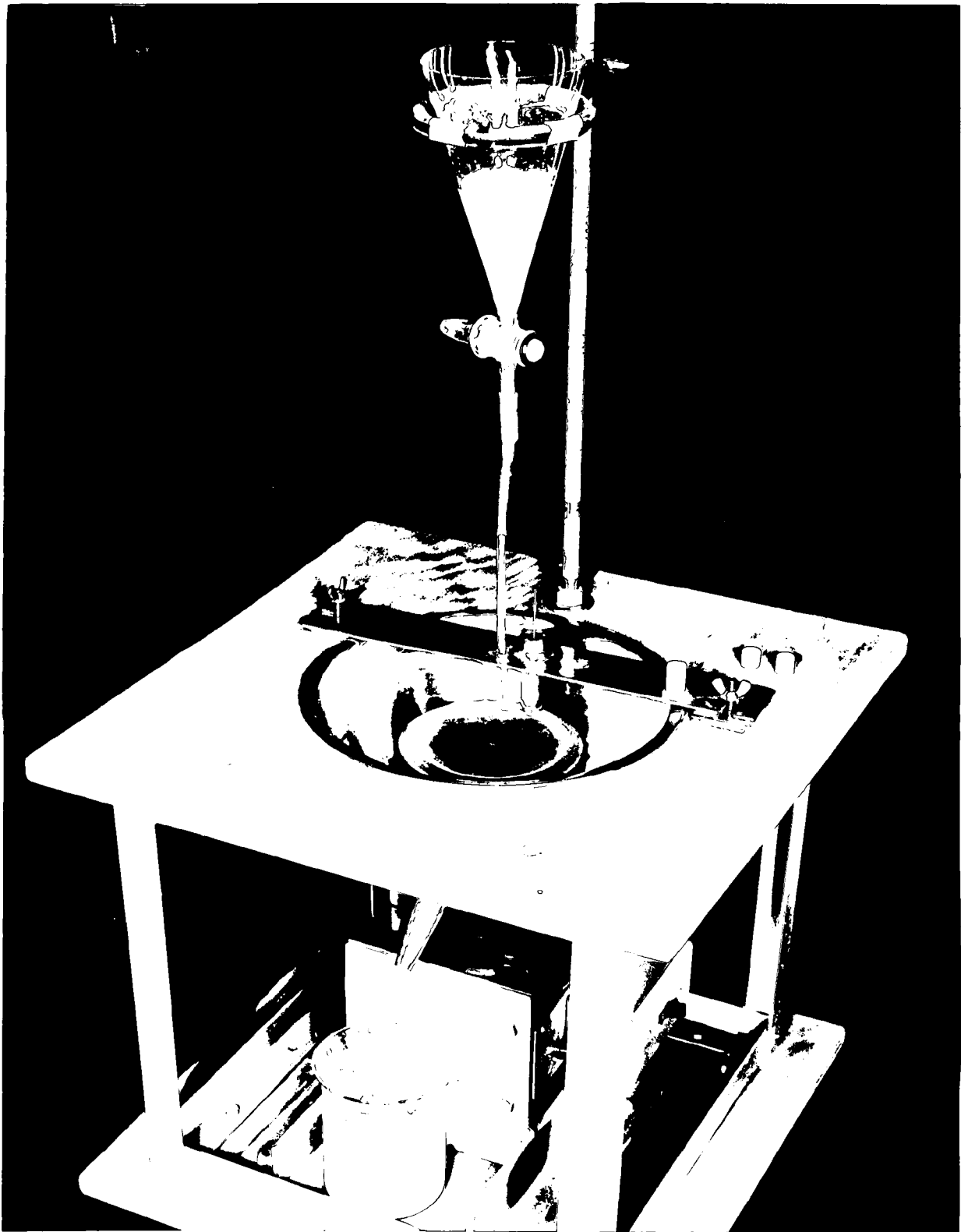
improvement in beneficiation procedures and to determine the correlative relationships of the physical properties of talc, it is necessary to be able to measure small differences in the physical properties and to be able to compare them to other quantitative measurements. Knowledge of these interrelationships 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.

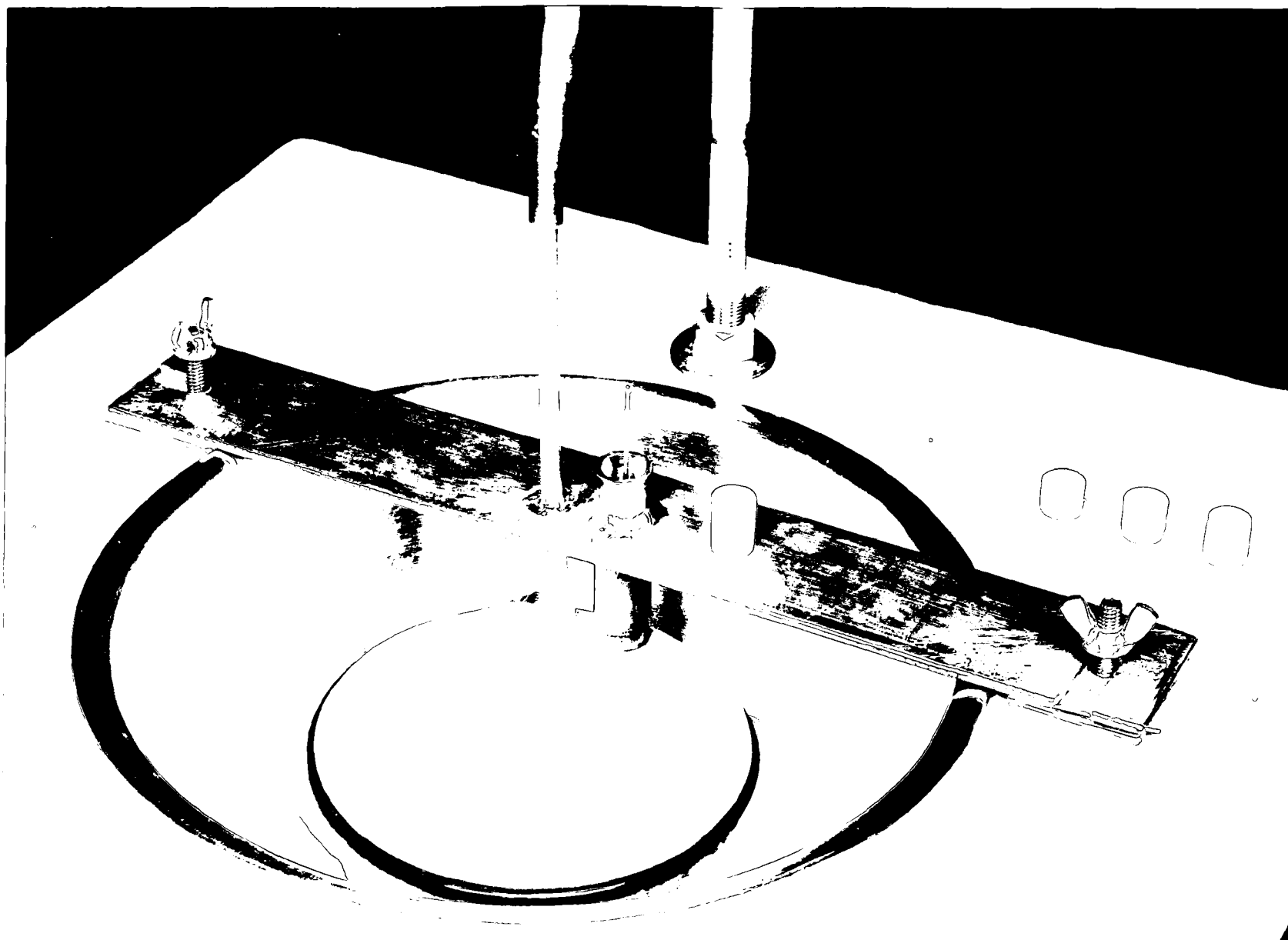
In order to measure the abrasiveness of the talc in the slurry a test had to be designed where the object abraded would have a great enough loss to be measured physically. Since the abrasiveness to be measured was that of a powder containing generally from only 1 to 3 per cent of abrasive gangue particles, 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

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.

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.

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.

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.

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 1.8+ 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

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

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 610, 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 $15\ \mu$ 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 GRANFORD 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

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.

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.

+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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- (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).
- (8) Brown, W. E. , Smith, W. L. , and Macdonald, R. D. , "The Physical Concentration of Talc Ores - Flotation", Battelle report to Johnson and Johnson (May 23, 1958).

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

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.

APPENDIX B

DETERMINATION OF EQUIVALENT DOLOMITE CONTENT
IN ITALIAN TALC BY VOLUMETRIC ANALYSIS

by

W. E. Brown

BATTELLE MEMORIAL INSTITUTE

Wage procedure:

5 gram sample in 500 cc 0.2 N HCl digest at 100°
for 45 min. heat to boiling - cool. add methyl
orange indicator.

titrate with 0.1 N NaOH

Calculation:

$(cc\ HCl \times N) - (cc\ NaOH \times N) = \text{millequivalents acid}$
millequivalents $\times .92$ = % dolomite
grams HCl $\times 1.54 \times 100$ = % carbonates in sample.

5 gram or	millequivalents $\times .92$	= % dolomite in sample
5 gram "	" $\times 1.54$	= % carbonates in sample
5 gram "	" $\times .84$	= % magnesite

as Magnesite

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

For
5 grams

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

as magnesite using 2 gram sample.

$Me + 21 = \% \text{ carbonates}$

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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 ⁵⁵25 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

$47.6 \times 0.97 = 46.17$ 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.