Properties of Asbestos Fibres Imported into the United States

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ABSTRACT

A study of the physical properties of long grades of asbestos fibres imported into the United States during the past eight years has disclosed information that will contribute materially to effective selection and use of fibres for electrical products. The study embraced fibre lengths, volume resistivity under three different conditions, total iron by chemical analysis, magnetic rating, conductivity of an aqueous extract and its sodium chloride equivalent.

The fibres examined included chrysotiles from Rhodesia, British Columbia, and Barberton area; marlime from Bechuanaland and Province of Quebec; amosite and crocidolites from Africa and Australia; and anthophyllites from Mozambique and from Georgia in the United States.

Volume resistivity values provide a relative basis for estimating the electrical performance of end products; magnetic rating — an estimate of the quantity of iron compounds present in excess of those in the asbestos structure; conductivity of an aqueous extract; and an estimate of the ionizable impurities in fibres.

Tests of these factors yield information, not heretofore generally known, which may serve as a guide in the evaluation of asbestos fibres for electrical products.

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INTRODUCTION

ASBESTOS FIBRES imported into the United States include chrysotiles from Canada and Rhodesia; crocidolites from Africa and Australia; amosite from Africa; and miscellaneous small quantities of anthophyllite, tremolite, and chrysotile from other countries.

For the year of 1958, the United States imports of long fibres amounted to approximately 20,000 tons of chrysotile from Canada, 7,800 tons of chrysotile from Rhodesia, 18,000 tons of crocidolite from Africa, 5,700 tons of crocidolite from Australia, and 13,000 tons of amosite from Africa.

Since all asbestos fibres are graded and sold according to length for use in a wide variety of industrial products, this discussion has been limited to the longer fibres and to some of the physical and chemical properties that make them attractive in textiles, plastics, and other products that require long fibres.

TESTS APPLIED TO FIBRES

Fibre lengths are normally determined by the standard Quebec Screen test. Such large percentages of the fibres are retained on the top screen, however, that this test does not necessarily indicate the true length distribution. For this comparison, a 20-gram sample of the fibre was spread out upon a sheet of paper and lines representing the different lengths were placed at various intervals so that fibres of these lengths could be placed in piles above the mark of the approximate length. The fibres were then weighed and the results expressed in percentages per given length range. To define a limit for the fibre bundles that were picked out by tweezers, it was arbitrarily decided that any fibre with a cross-section less than 0.01 in. would be set aside and classed as "open fibre of miscellaneous lengths". All crudy fibres were graded between 0 to ¼ in., ¼ to ½ in., ½ to ¾ in., ¾ to 1 in., 1 to 1¼ in., over 1¼ in., open fibre, and rock not selected for size.

Crocidolite fibres are in most cases shorter than the chrysotile spinning fibres. They were classed in lengths of 0 to ⅜ in., ⅜ to 1 in., 1 in. and longer, open fibre, and rock.

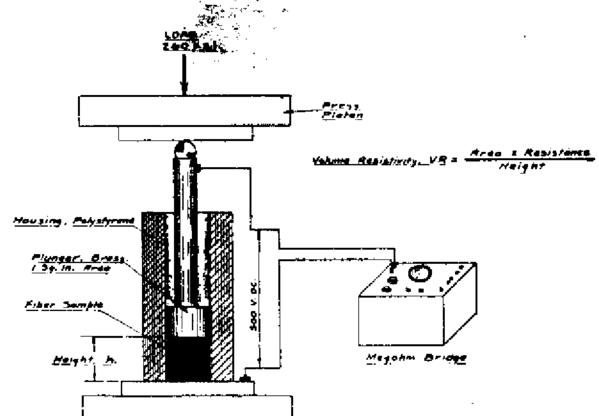

Figure 1.—Volume resistivity apparatus.

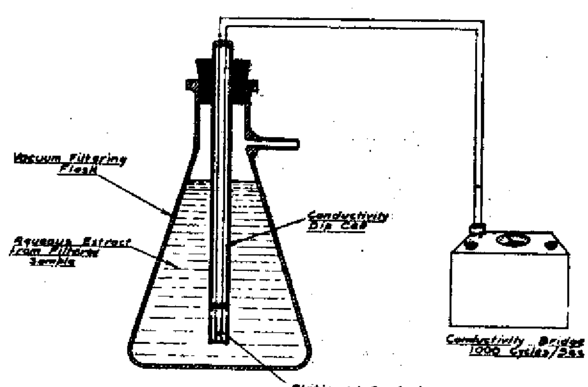

Figure 3.—Aqueous extract conductivity apparatus.

Volume Resistivity

(*Figure* 1)

Volume resistivity provides a relative basis for estimating the electrical performance of products to be made from fibre. Expressed in megohm-inches (or megohm-centimetres), it is the resistance between opposite faces of a unit cube of material.

Sufficient fibre is packed into a plastic cylinder on a brass base to reach a height of about 1 in. when compressed under a load of 260 p.s.i. The load is applied by a brass piston 1 sq. in. in area. A megohm bridge is used to measure the resistance between the piston and the base of the cylinder with 500 volts d.c. applied for one minute. The volume resistivity is calculated from the resistance and the measured height of the fibre by th formula:

$$\text{V. R.} = \frac{\text{Area} \times \text{Resistance}}{\text{Height}}$$

$$\frac{\text{Resistance}}{\text{Height}} \text{ for these electrodes}$$

The volume resistivity is measured after exposure to three conditions. The fibre is first dried for 16 hr. at 105°C.; exposed to laboratory standard conditions of 75°F., 50% *RH* for three days; and finally to humid conditions, 75°F., 91% *RH* for 16 hours. The measurement is made as soon as practicable after removal of the fibre from the oven or humidity chamber.

Total Iron as a Percentage of *Fe*

The total quantity of iron expressed as a percentage of Fe is determined by the regular wet chemical analysis. This test reports all the iron regardless of its form, *e.g.*, magnetite, ferric oxide, or any complex iron silicate that may be a part of the molecule.

Magnetic Rating

(*Figure* 2)

The magnetic rating test provides an estimate of the quantity of iron compounds present in excess of those in the asbestos structure itself. These are important because they are conductors and as such are undesirable in fibre for electrical applications.

Ten grams of fibre are placed in a test tube and inserted in a coil which forms one arm of an indus-

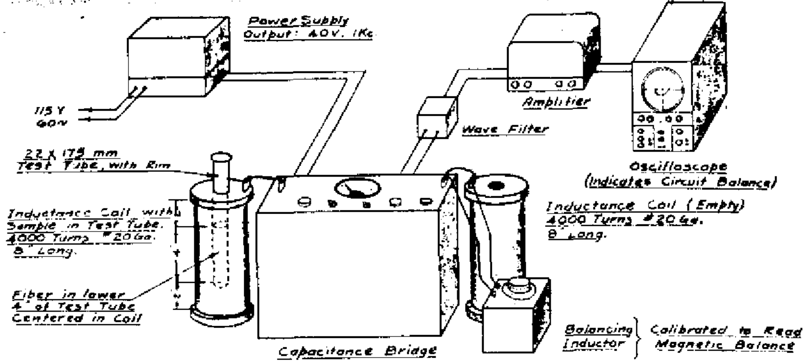

Figure 2.—Magnetic rating apparatus.

Table I.—Rhodesian Fibre

	Approximate Length, %							
	0-1/4", %	1/4-1/2", %	1/2-3/4", %	3/4-1", %	1-1¼", %	Over 1¼", %	Open Fiber, %	Rock, %
C&G1	3 - 9	14 - 28	13 - 17	5 - 9	2 - 5	0.2 - 3	39 - 53	Tr - 0.2
C&G2	2 -12	19 - 38	9 - 21	2 - 7	1 - 4	0.2 - 3	20 - 53	Tr - 1
C&G3	70 -74	6 - 15	2 - 8	0 - 0.6	0 - 0.4	0	10- 15	Tr
C&G4	90 - 98	0	0	0	0	0	4- 6	Tr - 1.5
C&G5	96 - 98	0	0	0	0	0	Tr- 2	1 - 3

	Volume Resistivity, megohm-in.		
	Dry 16 hr @105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
C&G1	6.2	0.26	0.063
C&G2	5.7	0.22	0.075
C&G3	16 - 530	0.27 - 0.96	0.05 - 0.13
C&G4	760 - 1500	0.75 - 1.2	0.12 - 0.39
C&G5	2100	0.48	0.07

	Total Iron as Fe, %	Magnetic Rating	Aqueous Extract Conductivity, micromhos/cm	Aqueous Extract Equiv. NaCl, %
C&G1	1.0 - 2.6	0.3 - 0.7	182	0.087
C&G2	1.5 - 2.7	0.2 - 0.9	117	0.056
C&G3	0.27- 2.9	1.1 - 1.5	180 - 290	0.08 - 0.13
C&G4	2.5 - 3.2	1.2 - 1.9	190 - 280	0.09 - 0.13
C&G5	2.9 - 3.1	2.0 - 2.4	200 - 240	0.09 - 0.11

Table II.—Cassiar 3K Fibre

Approximate Length, %							
0-1/4", %	1/4-1/2", %	1/2-3/4", %	3/4-1", %	1-1¼", %	Over 1¼", %	Open Fiber %	Rock, %
18 - 19	10 - 28	3 - 10	1 - 4	0 - 1	0	45 - 57	0 - 1

Volume Resistivity, megohm-in.		
Dry 16 hr @105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
21 - 27	0.2 - 0.39	0.05 - 0.08

Total Iron as Fe, %	Magnetic Rating	Aqueous Extract Conductivity, micromhos/cm	Aqueous Extract Equiv. NaCl, %
1.6 - 2.3	0.7 - 1.3	322	0.154

tance bridge. The bridge is calibrated with U.S. Bureau of Standards standard magnetite, sample 29*a*, and hence yields a direct reading in magnetic rating.

Unit magnetic rating corresponds to 1.8 grams of standard magnetite. However, all magnetite is not of the same composition or permeability. Sample 29*a* was selected for uniformity and must be considered an arbitrary standard. Magnetic ratings based on it are, of course, also arbitrary.

Aqueous Extract Conductivity

(*Figure* 3)

The aqueous extract conductivity test provides an estimate of the ionizable impurities in the fibre. These impurities contribute to electrical conduction through fibre and may be important in other respects — for example, in corrosive tendency. The impurities content is expressed in micromhos per centimeter. It depends directly on the proportion of water and fibre used in making the extract, and values should be compared only when these are the same. As an aid in visualizing the quantity of impurity, the equivalent NaCl content of the fibre is calculated. This is the quantity of NaCl which would yield the observed conductivity, but it is not meant to imply that NaCl is actually present.

In making this test, 50 grams of fibre is added to 500 c.c. of distilled water. The mixture is shaken vigorously for one hour and allowed to stand overnight at 75°F., after which the liquid is separated by vacuum filtering. The resistance of the filtrate is measured by means of a conductivity dip cell with platinized electrodes and an impedence bridge operated at one kilocycle per second. The conductivity, k, is calculated from the resistance and cell constant and is corrected for the conductivity of the distilled water by the following formula:

$$k = 10^6 C \left(\frac{1}{R_s} - \frac{1}{R_o} \right) \text{micromhos/cm.}$$

where

C = Cell constant, reciprocal, cm.

R_s = Resistance of cell filled with sample, ohms

R_o = Resistance of cell filled with distilled water, ohms

TABLE III.—MISCELLANEOUS CHRYSOTILE FIBRES FROM AFRICA

	Approximate Length, %: 0-1/4", %	1/4-1/2", %	1/2-3/4", %	3/4-1", %	1-1¼", %	Over 1¼", %	Open Fiber, %	Rock, %
Barberton Area	40 - 45	2 - 5	0	0	0	0	50 - 58	Tr
Marlime	38.0	8.0	1.2	1.2	1.2	0	40 - 49	Tr

	Volume Resistivity, megohm-in.: Dry 16 hr @ 105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
Barberton	5.8	0.10	0.03
Marlime	0.87	0.13	0.05

	Total Iron as Fe, %	Magnetic Rating	Aqueous Extract: Conductivity, micromhos/cm	Equiv. NaCl, %
Barberton	0.15 - 1.29	0.1 - 0.3	184	0.09 - 0.11
Marlime	0.015- 0.77	0.3	222	0.11

TABLE IV.—QUEBEC GROUP 3 FIBRES

	Approximate Length, %: 0-1/4", %	1/4-1/2", %	1/2-3/4", %	3/4-1" %	1-1¼", %	Over 1¼", %	Open Fiber, %	Rock, %
3D	13 - 20	7 - 20	12 - 30	2 - 9	0 - 4	4 - 6	30 - 53	Tr
3K	15 - 24	5 - 18	5 - 15	1 - 6	0 - 4	4 - 7	32 - 64	Tr
3R	20 - 25	5 - 8	10 - 15	1 - 3	4 - 12	0	47 - 50	Tr

	Volume Resistivity, megohms-in.: Dry 16 hr @105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
3D	3.5 - 46	0.31 - 0.76	0.05 - 0.17
3K	0.04- 15.4	0.009 - 0.36	<0.009 - 0.11
3R	0.24	0.04	0.023

	Total Iron as Fe, %	Magnetic Rating	Aqueous Extract: Conductivity, micromhos/cm	Equiv. NaCl, %
3D	2.2 - 3.6	0.8 - 1.9	186 - 337	0.089 - 0.160
3K	3.0 - 4.3	2.3 - 6.7	295 - 559	0.140 - 0.266
3R	4.0	5.6	304	0.144

All of these tests were applied to a series of fibres that have been imported into the United States during the past eight years.

Discussion of Properties

The electrical resistance of asbestos depends primarily on its very fine fibrous structure. It has such large surface area that the flow through the volume of the fibrils is negligible as compared with the flow over their surface. This would be true even if the surface resistance were as good as that of a good electrical insulator. It is further reduced by conducting impurities in the form of soluble salts which are frequently associated with asbestos. Chrysotile, in addition, has a type of surface which has little resistance when even a small quantity of moisture is present.

The volume resistivity test measures the resultant of all these factors. An increase in the moisture condensed on a good insulating surface would decrease its resistance considerably; the other factors multiply this effect. Thus a large drop in volume resistivity is observed in going from the dry to the standard condition, or from the standard to the humid.

Table V.—Amosite Fibre from Africa

	Approximate Length, %						
	0 - 1", %	1 - 1-3/4", %	1-3/4 - 2-3/4", %	2-3/4 - 3-1/2", %	Over 3½", %	Open Fiber, %	Rock %
B1	2 - 15	0.2 - 18	0.3 - 16	1 - 34	15 - 85	0.3 - 12	0.2 -1
D3	1 - 7	1 - 12	4 - 54	1 - 34	6 - 63	1 - 12	0 -4
M1	22 - 54	14 - 22	3 - 14	0.1 - 6	0 - 2	9 - 41	3 -10
D11	49 - 58	13 - 25	1.5 - 6	0 - 5	0 - 1	2 - 22	1 -24
MD	39 - 49	15 - 20	9 - 15	0 - 4	0	15 - 29	1 - 4

	0 - 3/8", %	3/8 - 1", %	1" and Over, %	Open Fiber, %	Rock %
W3	27 - 30	36 - 39	17 - 18	14 - 15	1 - 3
K3	21 - 30	41 - 50	7 - 11	15 - 22	1 - 2

	Volume Resistivity, megohms-in.		
	Dry 16 hr @105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
W3	30,000	14	0.78
MD	8,000	1400	1360
K3	20,000	34	1.32

	Total Iron as Fe, %	Magnetic Rating	Aqueous Extract Conductivity, micromhos/cm	Aqueous Extract Equiv. NaCl, %
W3	28.5	0.2	158	0.076
MD	30.8	0.2	73.9	0.035
K3	27.9	0.3	160	0.076

In this test the electric current flows along the surface of a fibre, through the junction where two fibres make contact, and along the next fibre as it pursues a somewhat tortuous path through the mass. The surface resistance to current along the fibre may be low as compared with the resistance of the junction between fibres. When this is so, the resistivity decreases with fibre length because, with long fibres, there are fewer junctions to be traversed and it is the junctions which provide most of the resistance. At high humidity, the moisture at the junctions enlarges their effective cross-section more than that of the film on the fibre. The junction resistance is then reduced more than the fibre surface resistance, and the correlation with length tends to disappear.

The magnetic rating test suffers from several defects and even more from frequent misinterpretation. In addition to the mass of conducting particles, the test result is influenced by their permeability, size, shape, and orientation. Because of these influences, attempts to use it as an adjunct to the total iron test to separate structural iron from that in the form of inclusions are not usually very successful. The real purpose of the test is to estimate the danger of electrical failure from conducting particles bridging, or partially bridging, the insulation. The fact that the test yields an unduly high result when the particles are large or elongated is actually an advantage, because these are the particles which are most likely to bridge a gap. The principal defect of the test is that it does not go far enough in the direction of picking out large particles. The fibres which are associated with magnetite will usually, after the milling process, contain so many small particles of magnetite that these completely determine the result of the test, and a few of the large dangerous ones may pass undetected.

The milling process tends to concentrate magnetite with the shorter fibre lengths, so that magnetic ratings are higher in lower-grade fibres.

There is a great tendency to attribute any poor electrical property of asbestos to its magnetic content. Although it is conceivable that the magnetite particles might bridge a gap and reduce its resistance to zero, this is relatively unlikely. If the particles are uniformly distributed and not too large as compared with the gap, they will affect such properties as volume resistivity and power factor only in proportion to the volume of magnetite present, *i.e.*, a few percentage points lower than in asbestos with no magnetite. They have their greatest effect on properties like dielectric strength and burnout rating, which are sensitive to local defects.

The aqueous extract test provides an estimate of the contribution that ionizable salts make to the reduction of volume resistivity. This is important because it is usually the only factor over which we have any control. The type of fibre to be used is apt to be determined by economic or workability considerations, and the volume resistivity enters only as a secondary consideration. The fibre may be improved by finding a new source with a low ionizable salt content; in a dry process not much more can be done. In a wet process the test indicates how much washing may be required to raise a particular fibre to a satisfactory level.

There are some indications that asbestos fibres tend to contain more ionizable salts than the parent rock with which they are associated. The conductivity is therefore greater with long fibres than with short.

Fibre length measurement is a problem that has always confronted the asbestos industry. The normal Quebec Screen test for classifying asbestos, for example, does not distinguish ⅛-in. fibre length from ¼-in. or any other length. A Ro-Tap analysis likewise does not make a distinction between fibres of different lengths. In these cases fibres intertwine and prevent a true length classification, and these 'balling up' effects are greatly increased as the fibres are shaken or rotated on a screen surface.

The Sutter-Webb combining apparatus has been suggested and tried by many; some believe that it is a good way of determining length of fibres. The most frequent objection is that the small sample used in the test is not a good representation of the fibre product.

In the fibre length measurements made in this presentation, a large sample was used and only the crudy fibre bundles larger than 0.01-in. in cross-section were measured. Fines which mechanically adhered to the bundles were not accounted for, so the total weight of different lengths represents crudy fibre bundles that will produce a large volume in willowing or carding equipment.

Rhodesian Fibres

A series of C. & G. fibres which had been gathered over a period of eight years were examined. Determination of the various properties discussed in the foregoing pages were made on these with the results shown in Table I. Whenever possible, the data show the variations with a minimum and maximum range.*

Hand-picked fibre lengths show that they have a fairly good distribution over the ranges for each length increment. The data show the usual trends of resistance and magnetic iron with fibre length. The soluble salt contents seemed to increase with shorter fibre, which is contrary to the previously mentioned indication.

Cassiar 3K Fibre

Cassiar 3K fibre has been of considerable interest in textiles and is used in plastics and other electrical products. This grade of fibre is considered equal to some grades of Rhodesian and better than many Canadian equivalent grades (see Table II).

Miscellaneous Chrysotile Fibres from Africa

An interesting sample of chrysotile from the Barberton District and one from the Marlime deposit in Bechuanaland, Africa, were examined for length and electrical properties (see Table III).

The resistivity, total iron, magnetic rating, conductivity, and NaCl equivalent values are similar to those of Arizona fibres and are better than Canadian chrysotile fibres. These fibres should be valuable for use in electrical products and plastics.

Quebec Group 3 Fibres

The tests on Quebec Group 3 fibres (Table IV) show that, even from neighbouring locations, the fibres may differ considerably in soluble salt content, and hence in volume resistivity.

The *3K* and *3R* fibres with the exceptionally high magnetic ratings were ground and re-measured, with no significant change. This eliminates the possibility of orientation and shape effects. Since there was not sufficient total iron to account for it, the high rating value is attributed to high permeability of the magnetite.

Amosite Fibre from Africa

The grading of African amosite fibres by a Canadian classification method is difficult owing to the long fibre lengths and high percentage of crudy fibre bundles that remain on the top screen by the Quebec Screen test.

*Variations in test data could also be due to fibre from different mine areas during this eight-year period.

Table VI.—Crocidolite from Africa and Australia

	Approximate Lengths, %				
	0 - 3/8", %	3/8 - 1", %	1" and Over, %	Open Fiber, %	Rock, %
Sample 1 Cape Province	39 - 46	12 - 17	2 - 8	30 - 40	2 - 4
Sample 2 Cape Province	48 - 59	14 - 22	1 - 5	17 - 30	Tr- 4
Sample 3 Transvaal	54 - 58	27 - 31	0 - 2	9 - 16	1 - 2
Sample 4 Australia #3	41 - 58	17 - 37	0 - 15	Tr - 20	2 - 10

	Volume Resistivity, megohms-in.		
	Dry 16 hr @105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
Sample 1 Cape Province	48,000	34	1.42
Sample 2 Cape Province	64,000	34	0.56
Sample 3 Transvaal Prov.	109,000	95	2.3
Sample 4 Australian #3	68,000	51	1.15

	Total Iron as Fe, %	Magnetic Rating	Aqueous Extract: Conductivity micromhos/cm	Aqueous Extract: Equiv. NaCl, %
Sample 1 Cape Province	28.2	2.0	124	0.059
Sample 2 Cape Province	26.8	0.4	114	0.053
Sample 3 Transvaal Prov.	25.3	2.1	74	0.0035
Sample 4 Australian #3	26.0	5.4	114	0.054

Table VII.—Anthophyllite Fibre

	Volume Resistivity, megohms-in.		
	Dry 16 hr @105C	Standard 3 days @75F, 50% RH After Drying	Humid 16 hr @75F, 91% RH After Standard
U. S. Georgia	900,000	1700	19.3
Mozambique	190,000	2100	6.4

	Total Iron as Fe, %	Magnetic Rating	Aqueous Extract: Conductivity micromhos/cm	Aqueous Extract: Equiv. NaCl, %
U. S. Georgia	6.4	0.1	115	0.055
Mozambique	5.5	0.6	23	0.022

Seven different grades of amosite were examined for length and three samples were studied for their electrical properties (Table V). The length measurements were made on a large number of samples received during the past ten years.

The total percentage of iron is normally high since iron is part of the structure. However, this is not detrimental because the magnetic iron is low. These fibres, when dry, show the high resistance that the non-chrysotile fibres may attain. The *W*3 and *K*3 fibres suffer from soluble salts which lower the resistance when moisture is present.

Crocidolite Asbestos

Several grades of crocidolite asbestos fibres were examined for length and electrical properties (see Table VI). The data are based upon miscellaneous samples examined over the past ten years.

Sample 3, which represents a Blue fibre from the Transvaal, has the highest volume resistivity, lowest conductivity, and lowest NaCl equivalent. Although the magnetic rating of this sample is equal to that of the Cape sample 1 and higher than that of the Cape sample 2, it is much lower than that of the Australian sample 4. The Cape sample 2 magnetic rating of 0.4 is unusually low, values normally being within the range of 3 to 5.

Anthophyllite

Deposits of anthophyllite appear in many parts of the world and in Table VII a comparison is made of fibres from two of these deposits. In most cases the fibre lengths, that may appear long before milling, are greatly reduced after processing — as a result of poor flexibility and brittleness; therefore, fibre length measurements are of little value. In these two particular cases, however, the sample from Mozambique varied in length from 1/8 to 1½ in.; the Georgia sample, from 1/16 to ½ in.

Both fibres have good electrical properties.

Conclusions

(1) A series of long chrysotile fibres representing deposits in Rhodesia, British Columbia, the Province of Quebec, and Africa have been tested, with measurement of length and determination of other physical properties such as volume resistivity, total iron content, magnetic rating, conductivity, and NaCl equivalent.

(2) The same types of tests were applied to a series of amosites, crocidolites, and two anthophyllites.

(3) Length measurements were indicative of the quantities of crudy fibre bundles larger in cross-section than 0.01 in. that would increase in bulk during any willowing or carding action.

(4) The physical properties as shown by volume resistivity, iron content, magnetic rating, and conductivity are new data that can be applied to fibres that are to be used in electrical products.