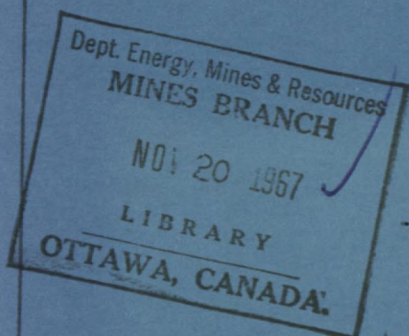




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OTTAWA

*AN INVESTIGATION OF THE SURFACE
OF CHRYSOTILE ASBESTOS FIBRE*



A.A. WINER AND L.L. SIROIS
MINERAL PROCESSING DIVISION

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AN INVESTIGATION OF THE SURFACE OF
CHRYBOTILE ASBESTOS FIBRE

Theoretical

The external surface layer of chrysotile is composed of hydroxyl ions adjacent to magnesium ions. It is expected to have basic properties and strong surface activity. A schematic structure of chrysotile is shown in Figure 1 (2).

A. A. Winer* & L. L. Sirois**

INTRODUCTION

In Canada the only commercial variety of asbestos mined is chrysotile, a hydrated magnesium silicate.

Chrysotile is one of Canada's most important industrial minerals and has many end uses, e. g., in asbestos-cement products and as reinforcing agents in resins. The overall desirable properties of chrysotile asbestos have not yet been duplicated by any one single material.

The remarkable nature of chrysotile is in large part due to its surface characteristics. Although some knowledge of the surface characteristics exists, much remains to be learned. It is unlikely that chrysotile asbestos can be fully exploited unless detailed studies of such characteristics as surface properties are undertaken.

This paper discusses the application of a commercial instrument, the Zeta Meter, for measuring the electrophoretic mobility of selected chrysotile asbestos fibres as well as another relevant fibrous mineral, brucite.

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PREVIOUS WORK

Theoretical

The external surface layer of chrysotile is composed of hydroxyl ions adjacent to magnesium ions and therefore, according to Pundsack (1), would be expected to have basic properties and strong surface activity.

A schematic structure of chrysotile is shown in Figure 1 (2).

Fiber Consists of $Mg(OH)_2$ Layers on Si-O Tetrahedra

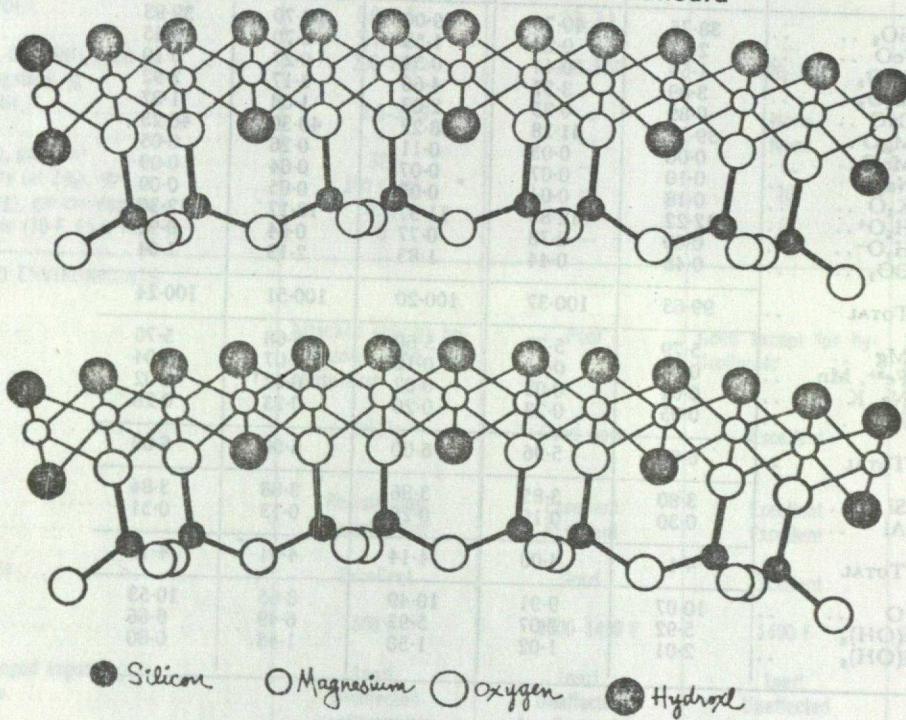


FIGURE 1. Schematic Representation of the Structure of Chrysotile Asbestos.

The chemical composition of some typical chrysotile asbestos samples is shown in Table 1.

TABLE 1

COMPOSITIONS AND CELL-CONTENTS FOR SOME TYPICAL CHRYSOTILES
(Analyst: D. G. Hiscock, Cape Asbestos Fibres Ltd)

	Thetford, King Beaver Mine	British Columbia, Cassiar	Russia, Asbest	Rhodesia, Shabani	Swaziland, Havelock Mine
SiO ₂	38.75	40.75	39.00	39.70	39.93
FeO	2.03	0.28	1.53	0.70	0.45
Fe ₂ O ₃	1.59	0.44	0.54	0.27	0.10
Al ₂ O ₃	3.09	3.37	4.66	3.17	3.92
CaO	0.89	0.35	2.03	1.08	1.02
MgO	39.78	41.28	38.22	40.30	40.25
MnO	0.08	0.03	0.11	0.26	0.05
Na ₂ O	0.10	0.07	0.07	0.04	0.09
K ₂ O	0.18	0.04	0.07	0.05	0.09
H ₂ O ⁺	12.22	12.86	11.37	12.17	12.36
H ₂ O ⁻	0.60	0.78	0.77	0.64	0.92
CO ₂	0.48	0.44	1.83	2.13	1.04
TOTAL	99.63	100.37	100.20	100.51	100.24
Mg	5.79	5.70	5.60	5.68	5.70
Fe ⁺⁺ , Mn	0.12	0.01	0.12	0.07	0.04
Na, K	0.04	0.02	0.02	0.02	0.02
Al	0.05	0.23	0.26	0.23	0.28
TOTAL	6.00	5.96	6.00	6.00	6.00
Si	3.80	3.85	3.86	3.88	3.84
Al	0.30	0.15	0.28	0.13	0.31
TOTAL	4.1	4.00	4.14	4.01	4.15
O	10.07	9.91	10.49	8.65	10.53
(OH) ₂	5.92	7.07	5.93	6.49	6.66
(OH) ₃	2.01	1.02	1.58	1.43	0.80

A comparison of important properties of selected inorganic fibres are shown in Table 2.

TABLE 2
A Comparison of Properties of Selected Fibres

Type →	Glass ^a	Asbestos		Alumina-Silica
		Chrysotile	Crocidolite	
NATURE OF FIBER				
Length, in.....	Filament, staple	Crude ¼-2 in.	¼-3	¼-10 in. staple
Width, μ.....	5-16	0.02	0.02	2-20 (mean)
Cross Section.....	Circular	Tulular	Cylindrical	—
PHYSICAL AND MECHANICAL PROPERTIES				
Specific Gravity.....	2.54	2.4-2.6	3.2-3.3	2.73
Breaking Tenacity, gm/den				
70 F, 65% RH.....	6.0-7.3	2.5-3.1	—	1.4-6.5
Wet.....	3.9-4.7	—	—	—
Ten Str (70 F, 65% RH), 1000 psi.....	200-220	300-570	100-300	50-230
Breaking Elongation, %				
70 F, 65% RH.....	2.0-3.75	—	None	1.4-2.7
Wet.....	—	—	None	—
Stiffness (avg), gm/den ^b	322	—	—	—
Strain Recovery (at 2%), % ^c	100 (3%)	—	100	—
Toughness (avg), gm-cm/den-cm.....	0.07	—	—	—
Moisture Regain (70 F, 65% RH), %.....	0	—	0	—
RESISTANCE TO ENVIRONMENTS				
Acids				
Strong.....	Attacked only by hydrofluoric and hot phosphoric	Poor	Good except for hydrofluoric	Seems to have chemical resistance similar to borosilicate glass fibers
Weak.....	Stable	Good-poor	Excellent	
Alkalis				
Strong.....	Resists most	Excellent	Excellent	
Weak.....	Resists most	Excellent	Excellent	
Other Chemicals.....	Excellent	Good	Excellent	
Heat.....	600 F	1000-1490 F	1400 F	2300 F max use temp; 3300 F melting point
Sunlight (prolonged exposure).....	Inert	Inert	Inert	Inert
Microorganisms.....	Unaffected	Unaffected	Unaffected	Unaffected
Flame ^d	Nonflammable	Nonflammable	Incombustible	Nonflammable

^aProperties may vary widely depending on glass composition; values here indicative of those of borosilicate. ^bRatio of breaking stress to breaking strain (i.e., gm/den to rupture divided by strain in cm/gage cm at breaking stress). ^cRecovery after 2% strain, except where specific percentage strain is given in parentheses. ^dBasic flammability of untreated fiber.

Badollet (3) summarized the reaction of chrysotile and other asbestiform minerals with a number of compounds, particularly acids and bases. The reaction with hydrochloric acid is said to proceed in three steps, according to Pundsack (1):

- (a) the reaction with free brucite, $Mg(OH)_2$,
- (b) the reaction with hydroxyl groups in the structure,
- (c) the reaction of the hydroxyl groups associated with the silica.

The morphology of asbestos has been controversial but supporting evidence for the tubular shape has been increasing. Maser et al (4) in 1960 obtained electron micrographs that appear to show concentric and spiral form of end-view sections of chrysotile fibres. Attempts to reconcile the discrepancy due to density of chrysotile have been made by suggesting that the voids are filled with amorphous material. The tubular portion of the fibre is shown by electron micrographs to be either partially filled or of differential density.

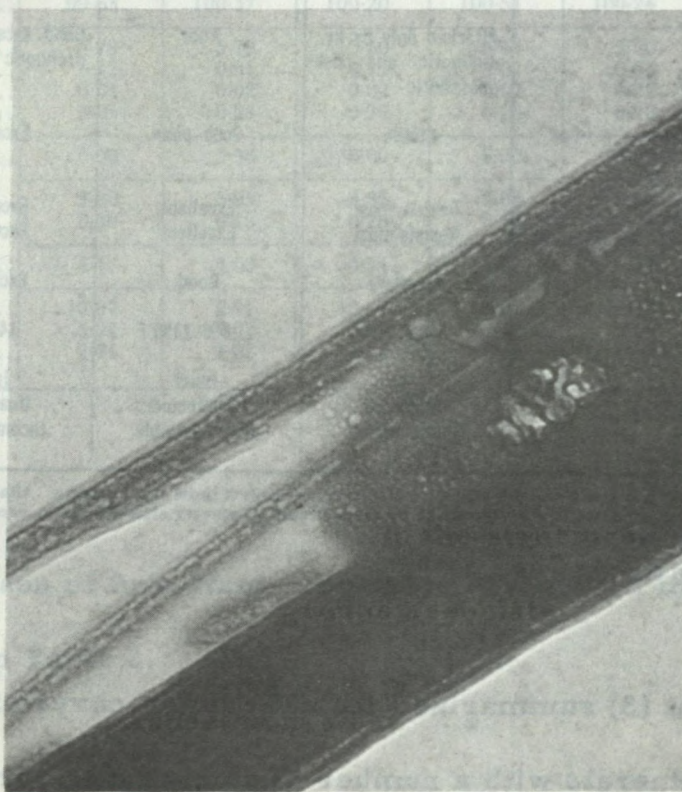


FIGURE 2. Electron Photomicrograph of an Iodine Stained Chrysotile Asbestos Sample from the Eastern Townships, Que. Plate Magnification X91,500.

Scanning Electron Microscopy, a relatively new scientific tool, was used to obtain micrographs of the fibre surface (5). Scanning electron photomicrographs showing the surface of two chrysotile samples are reproduced in Figures 3 and 4.

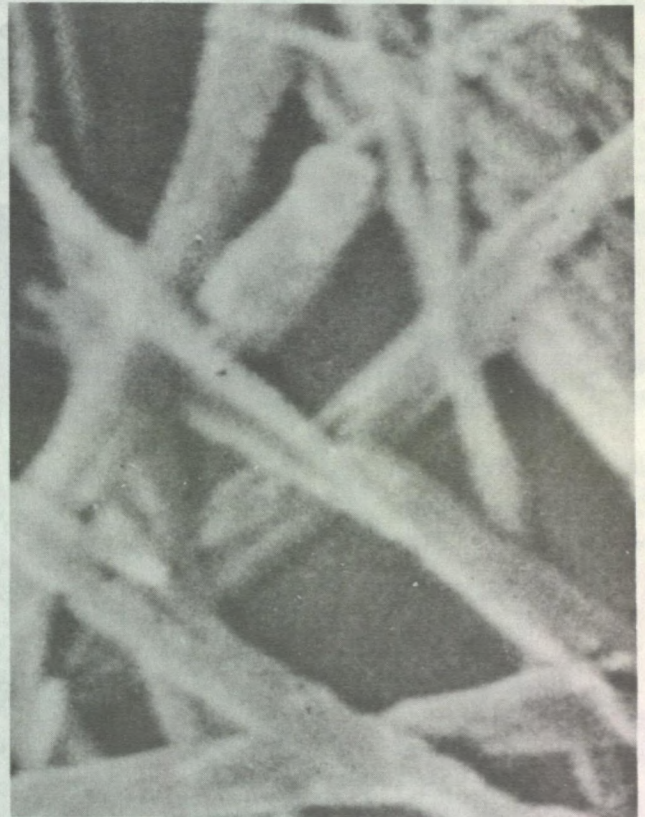
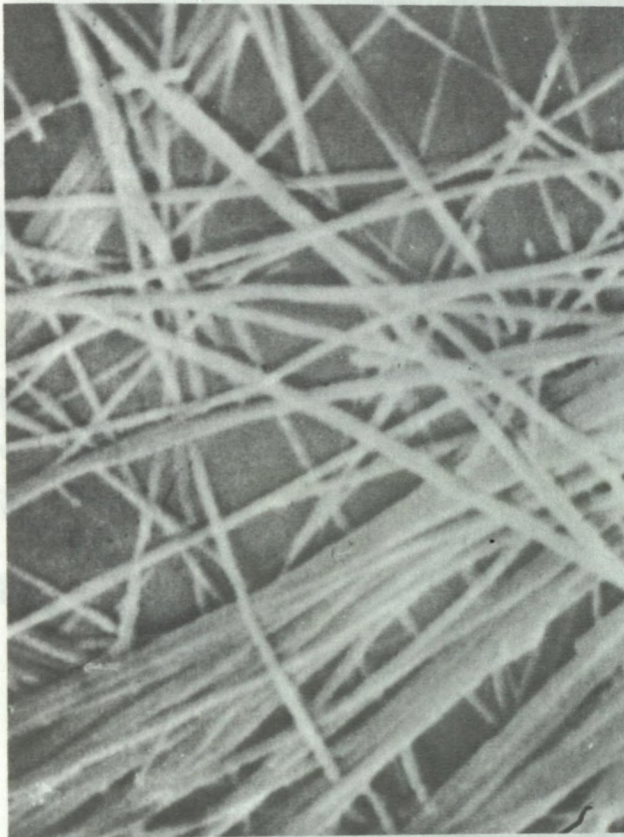


FIGURE 3. Chrysotile Fibre.
Sample from Eastern
Townships, Quebec
X15,000.

FIGURE 4. Chrysotile Fibre .
Sample from Coalinga,
California
X15,000.

(Courtesy of the Canadian Pulp and Paper
Research Institute)

FIGURE 6. Dispersed Chrysotile Asbestos Fibres from
Coalinga, California. Total Magnification

An electron photomicrograph by Faille et al. (6), Figure 5, shows fibrils of chrysotile from Coalinga, and they are present mainly as aggregates. This appears to substantiate the configuration of the fibres, in Figure 4, as obtained by the scanning microscope. It appears that drastic dispersive means must be taken to separate the aggregates. Discrete fibrils of Coalinga asbestos are shown in Figure 6.

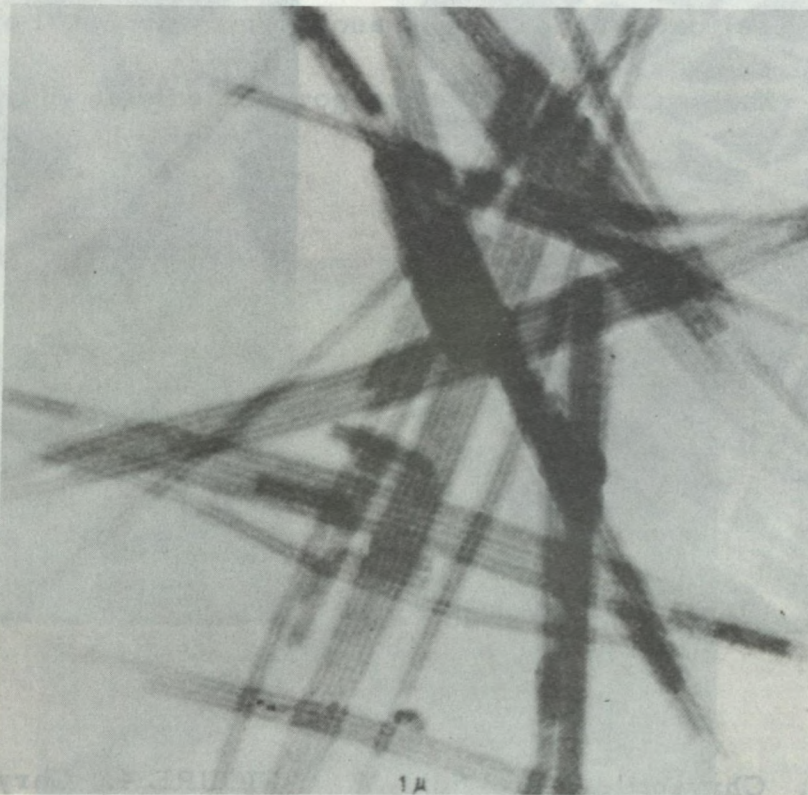


FIGURE 5. Electron Micrograph of Chrysotile Fibre from Coalinga, conditioned at 25°C.

FIGURE 2. Electron Photomicrograph of an Iodine Stained Chrysotile Asbestos Sample from the Eastern Townships, Que. Plate Magnification X91,500.

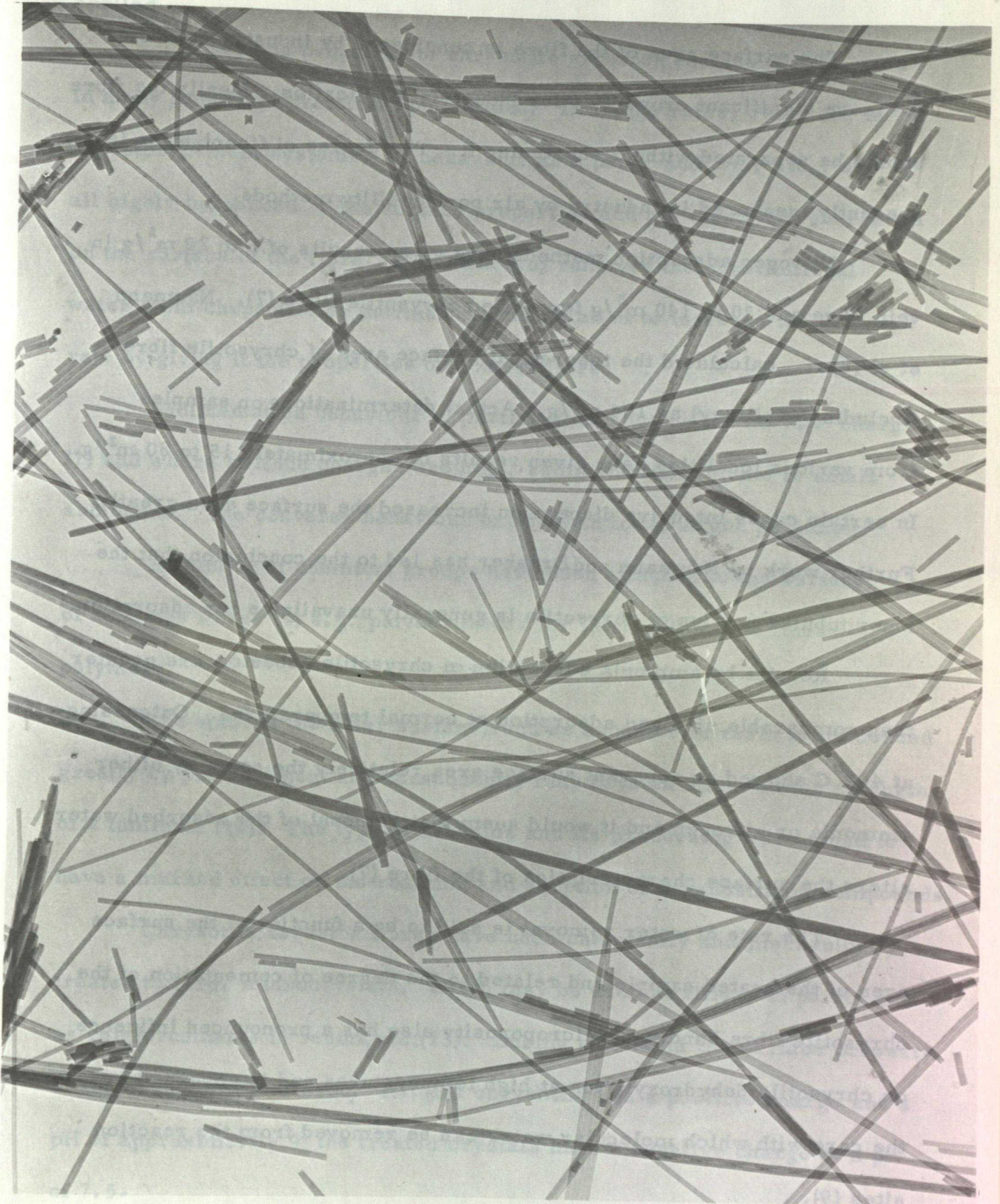


FIGURE 6. Dispersed Chrysotile Asbestos Fibres from Coalinga, California. Total Magnification 100,000x (40x Microscope, 2500x Camera)

The surface area of the fibre is considered by industry as one of the more significant properties for industrial application. Ideally the fibre should be separated without shortening it. The degree of fiberization is presently measured in industry by air permeability methods.

Nitrogen adsorption methods have given results of 6 to 20 m²/g in vein fibre and 30 to 140 m²/g for milled chrysotile fibre (7). Naumann et al (8) calculated the theoretical surface area of chrysotile fibre (including capillary) as 104 m²/g. Actual determinations on samples from various localities have given results of approximately 15 to 80 m²/g. In certain cases intensive dispersion increased the surface area greatly. Further work by Naumann and Drescher has led to the conclusion that the inner tubular portion of chrysotile is generally unavailable for adsorption.

Results by ammonia adsorption on chrysotile asbestos are greater than comparable nitrogen adsorption at normal temperatures. Outgassing at 400° C showed an apparent surface area relatively the same by either ammonia or nitrogen and it would seem that removal of the adsorbed water alters the surface characteristics of the fibre (7).

The rate of water removal is said to be a function of the surface area of the heated sample and related to the degree of cementation of the chrysotile fibre bundles. Microporosity also has a pronounced influence on chrysotile dehydroxylation at high temperatures and is governed by the care with which molecular water can be removed from the reaction sites (9).

Applied.

The surface behaviour of chrysotile asbestos enables it to be used in many important practical applications. Drainage rates, reactions in asbestos-cement systems, its behaviour as a paper additive, etc., are all highly influenced by the surface properties and the electrical charge on the surface of the fibre. Pundsack (10) removed the constitutional water from chrysotile by thermal dehydroxylation to increase the drainage rate by giving it the properties of a harsh fibre.

Sedimentation behaviour of particles depends on the surface charge (7) and where surface charges are high, sedimentation volume is small and dense. The converse behaviour exists with low-charged particles.

A number of chemical groups have been attached to the surface of asbestos fibres (4) e. g., polyacrimides for flocculation and linear polymers.

The state of the filler surface, such as asbestos in resin, is influenced greatly by pretreatment and consequently may have an effect on the strength of a laminate (12). The type of asbestos and its processing were found to have a marked effect on the reaction and sorption of organosilicon compounds.

Chrysotile asbestos fibres have been chemically and mechanically treated to form microcrystals, which may be used as fillers in paints and as reinforcements in resins, etc.(13). During treatment the surface property of the crystals is altered. Natural chrysotile has a positive charge and a pH of approximately 9; the treated crystals have a negative charge at a pH of 7.5.

Zeta-potential measurements have been effective in evaluating bentonites for use with taconite, specifically for predicting dry strengths (14). A patent has recently been issued for the use of asbestos fibres as a pelletizing additive (15) and possibly zeta-potential measurements can evaluate this additive for pelletizing use.

Martinez (16) reversed the charge polarity of chrysotile with sodium silicate, which occurred at a pH of 10.9, which is below the zero-point of charge of 11.8 found by Martinez and Zucker (17). They increased the rate of filtration by the deposition of sodium silicate on chrysotile. Sodium phosphate and sodium carbonate solutions were also used to decrease the positive charge on chrysotile but they did not reverse the polarity.

Measurement of Zeta Potential.

Various methods have been used for measuring the surface charge or zeta potential of chrysotile. Its zero-point of charge was determined by Pundsack (10) by titrating until a floc formed at a pH of about 10.1. Martinez and Zucker (17), using a streaming-potential method, found that its zero-point of charge occurred at pH 11.8. The maximum positive zeta potential occurred at a pH of 3.0. Robinson (18) using a streaming-potential method, obtained for MgO a zero-point of charge at pH 12.5 ± 0.5 . A potentiometric-titration method by Nemeth et al (19) indicated a zero-point of charge at pH of 10.7.

OUTLINE OF ZETA POTENTIAL THEORY

The interaction between a charged solid surface and an aqueous solution leads to the development of an electrical double layer. A simple illustration of this phenomenon occurs, for example, with silica in water, where negative charges are fixed on the mineral surface and the solution phase has an increased positive-charge density in the immediate vicinity of that surface. This excess charge will degrade with distance from the surface, and at the same time it will give rise to diffusion currents in the solution that will attempt to minimize this ionic concentration near the solid surface.

When a surface acquires its charge by obtaining ions from the solution, the process is mainly controlled by the activity, in the solution, of the species in question. Consequently, there must be a concentration at which all forces are in equilibrium and the total net transfer of ions becomes zero. When this situation occurs, there will be no excess charge on the surface and consequently no cause for the existence of an electrical double layer.

The zero-point of charge will occur when this electrical double layer is absent and the surface of the solid shows no excess positive or negative charge due to the presence of excess anions or cations. It is thus determined by the critical concentration or the activity of the potential-determining ions in the solution.

The zeta potential is the potential at the surface separating the immobile part of the double layer from the diffuse part. It is a simultaneous measure of the charge of the diffuse double layer, and of its distance from

this surface. When a liquid containing, for example, negatively charged particles is placed in an electric field, the negative particles are attracted to the anode and counter ions to the cathode. This attraction increases with the charge on the particle. The velocity of the particle in a given field increases with the charge density of the double layer.

There are two methods for evaluating the electrophoretic mobility of particles in liquids: they involve the measurement of particle velocity either individually, by observing the particles directly with a microscope, or collectively, by measuring the velocity of a mass of particles by following the movement of a sharp concentration gradient.

The measurement of the velocity of individual particles in a potential gradient is carried out in an apparatus shown in Figures 7 to 9. This apparatus consists essentially of a microscope with a calibrated reticule for the observation of the individual particles, and a transparent cell, equipped with platinum measuring-electrodes, that contains the colloidal suspension under study connected to a constant-voltage supply.

The cell itself is transparent, long, and cylindrical. The electrical double layer at the cell wall, itself, imparts a motion to the whole suspension in the cell. The suspension moves rapidly in one direction near the wall, more slowly farther from the wall, and in the opposite direction at the center of the cell. At some region in the cell there is no net motion applied to the suspension as the result of the zeta potential of the cell wall-liquid interface. It is in this region that the observed velocity of the particles in the system is equal to their electrophoretic velocity. Calculations have shown that this region is located at a distance equal to 14.8% of

the diameter from the wall of a cylindrical cell.

In use, the cell is filled with the suspension under study, and a known potential is applied. With an objective lens that gives a small depth of focus, the microscope is focused at the stationary level and the time for a particle to move a known distance is measured with a stop-watch. The results are reported as mobility, in cm/sec (v/cm) or converted to zeta potential by Equation 1.

$$V_E = DE^2/4\pi\eta \quad (\text{Eq 1})$$

where

V_E = electrophoretic mobility

D = dielectric constant of the medium

E = externally applied potential

ζ = zeta potential

η = viscosity of the medium

EQUIPMENT

Photographs of the Zeta-Meter and details are shown in Figures 7, 8 and 9.



FIGURE 7. The Zeta-Meter Stereoscopic Microscope With Illuminator, Cell and Cell Holder, and Mechanical Stage.

the diameter from the wall of a cylindrical cell.

In use, the cell is filled with the suspension under study and a

known potential is applied. With an objective lens that gives a small

depth of focus, the microscope

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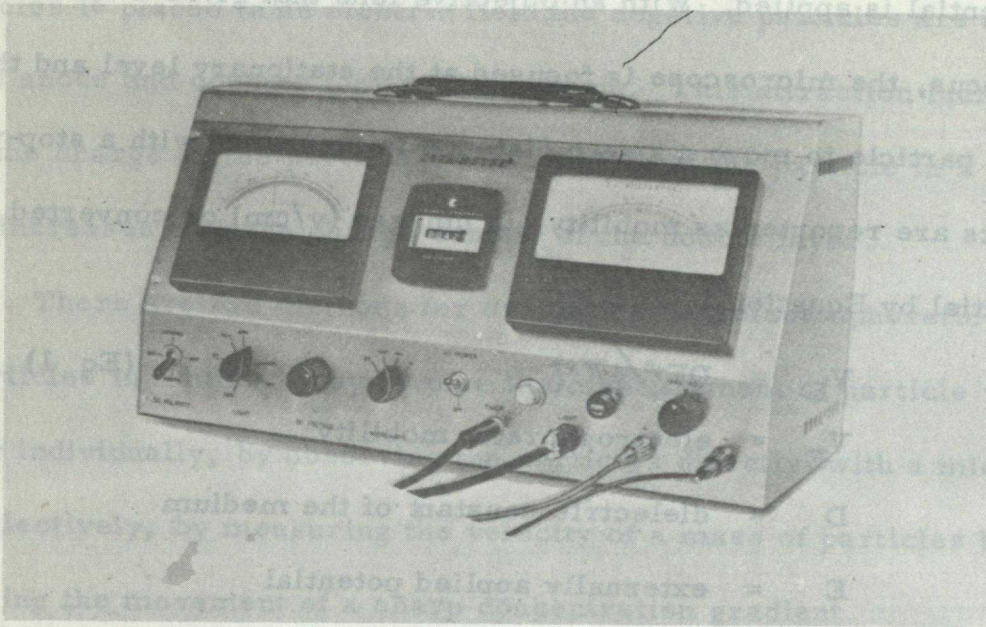


FIGURE 8. The Zeta-Meter Power Unit.

The measurement of the velocity of individual particles in a

viscosity of the medium

potential gradient is carried as in the diagram in Figures 7 to 9

This apparatus consists essentially of a microscope with a calibrated

EQUIPMENT

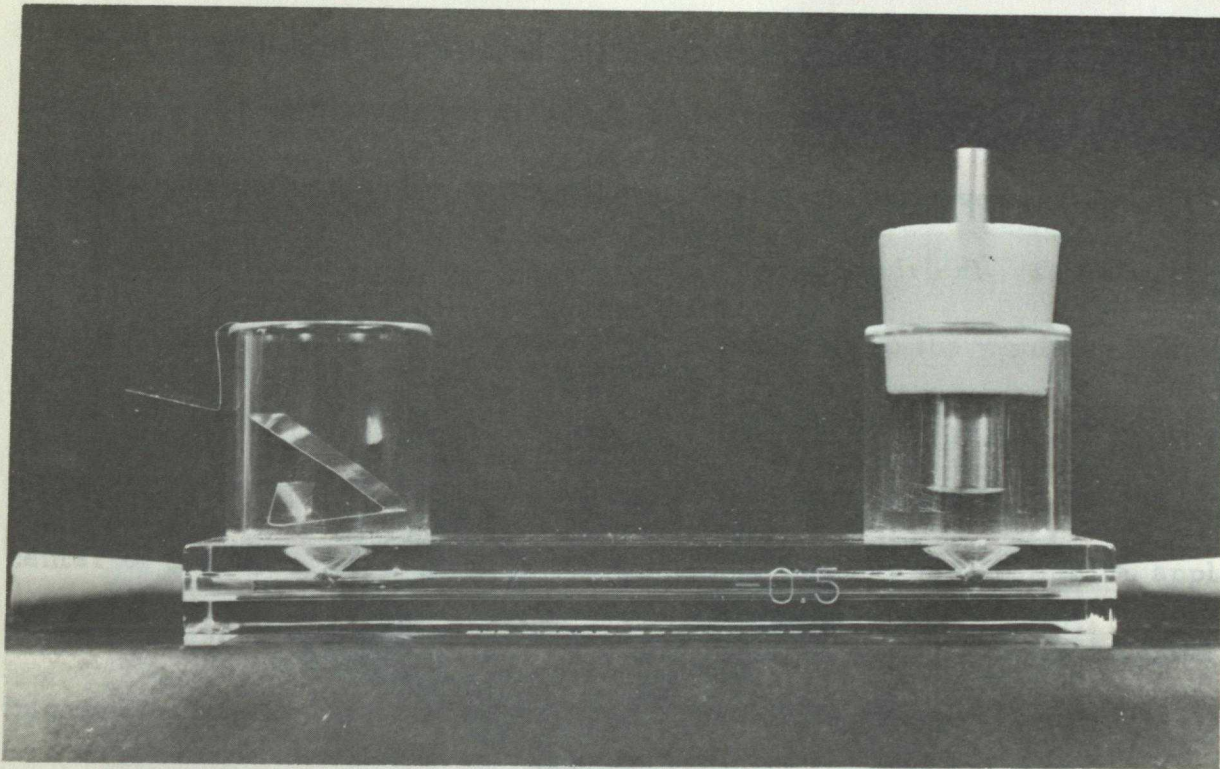


FIGURE 9. Details of Cell.

FIGURE 10. The Zeta-Meter Microscopic Microscope With

Holder, Cell and Cell Holder, and Mechanical Stage.

EXPERIMENTAL TECHNIQUE

The electrophoretic mobility was measured using the apparatus shown in Figures 7, 8 and 9. Solutions containing approximately 50 ppm of asbestos were placed in the cell (Figure 9) and the mobility was determined using an applied d-c voltage of 67V. In each determination a supporting electrolyte of 10^{-3} N potassium chloride was used. All readings were taken at a temperature of $25 \pm 1^{\circ}\text{C}$.

Curves of electrophoretic mobility were obtained by varying the pH of a 10^{-3} N solution of potassium chloride with hydrochloric acid and potassium hydroxide. The latter two compounds were used since they did not add different ions to the system. The above solution containing 50 ppm of asbestos was agitated in a Waring Blendor for 3 to 4 minutes. The large asbestos particles were removed by passing the asbestos suspension through a 325-mesh screen. Dissolved gases were removed by placing the suspension under high vacuum for about one minute. Following this, the temperature was decreased to $25 \pm 1^{\circ}\text{C}$ in a constant-temperature bath, and the electrophoretic mobility of the asbestos particles was measured.

Precautions, and Limitation of Measurement

The pH of distilled water will decrease to 5.8 because of CO_2 absorption from the atmosphere. In the neutral range very accurate pH measurements are required, therefore these were done in a nitrogen atmosphere. The electrophoretic mobility cannot be measured accurately with the Zeta Meter outside the limits of pH 2 and 11.5, since the

The electrical current in the electrophoretic cell (measured in micro-amperes) also changes markedly beyond these limits. For example, at pH 2, the current may be increased by nearly 15 percent within a few minutes.

Heat generated by the illuminator produces convection currents causing the particle to move in an erratic path. This causes difficulty in measuring the time and distance the particle has travelled.

All fibre samples were carefully examined under the microscope to insure that no adulterants, such as magnetite or brucite, adhered to the fibres. These adulterants would modify the velocity of the asbestos fibre, leading to erroneous results.

RESULTS AND DISCUSSION

The data obtained by electrophoretic measurements are presented in Table 3. Also included are the specific surface areas of the processed samples, previously determined by nitrogen gas adsorption.

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P
c

TABLE 3

Electrophoretic and Surface Area Measurements
of Asbestos Samples

Fibre Sample	Origin	Specific Surface m ² /g	Zero Point of Charge (ZPC) pH
1. Vein fibre, chrysotile;	Eastern Townships, P.Q.	—	11.2
2. Processed chrysotile;	Eastern Townships, P.Q.	19.9	Estimated >11.5
3. Processed chrysotile;	Eastern Townships, P.Q.	23.2	"
4. Vein fibre, chrysotile;	Coalinga, Calif.	—	11.5
5. Processed chrysotile;	Coalinga, Calif.	53.7	Estimated >11.5
6. Fibrous brucite;	Eastern Townships, P.Q.	—	7.2
7. Vein fibre, chrysotile;	Eastern Townships, P.Q.	—	Results unrelia
8. Highly-processed fibre, chrysotile;	Eastern Townships, P.Q.	25.1	8.0
9. Vein fibre, chrysotile;	Western Canada	—	11.4
10. Specially treated vein fibre, chrysotile;	Western Canada	59.4	6 4
11. Vein fibre, chrysotile;	Eastern Townships, P.Q.	—	
by Zeta Meter			10.6
by Potentiometric titration			10.7

Curves showing the variation of electrophoretic mobilities and/or zeta potentials at different pH values are included in Figures 10 to 16.

Figure 10 shows the variation of mobilities and zeta potentials with pH, of chrysotile samples 1, 2 and 3 both in its raw and processed form. The zero-point-of-charge of the raw fibre occurs at pH 11.2; at this point the surface charge of the mineral changes from positive to negative. This reversal in

surface charge does not occur for the two processed samples, within the range of values studied. The surface characteristics of the two processed samples appear to be similar. This could be because of the similarity of treatment or because the treatment removed constituents leaving the fibre surfaces electrically similar.

A marked difference exists between the raw and processed samples as shown in Figure 10; the surface is less positively charged on the raw sample. The treatment on the two processed samples has had a marked influence on the character of the fibres, but no definite explanation can be given since the type of treatment is not known. It is possible that certain constituents associated with the fibre were removed during processing, which would be detectable by means of the Zeta Meter. Also, severe grinding may alter the electrical charges on a particle due to increased hydration (20).

Figure 11 shows the variation of mobilities and zeta potentials with pH of the Coalinga fibre in raw and processed form. There is also a marked difference between the raw and processed samples from Coalinga. In general the raw sample again appears less positively charged than the processed fibres. The zero-point of charge for the raw sample occurs at pH 11.5, whereas there is no charge reversal for the processed material within the range of pH values studied.

Raw samples shown in both Figures 10 and 11 have characteristic curves, indicating that electrophoresis is a useful technique for characterizing certain surface properties of asbestos. A raw sample of fibrous brucite from Eastern Townships, P.Q. was also examined and a graph of its

Zeta Potential
Electrophoretic Mobility - microns/sec per volt/cm

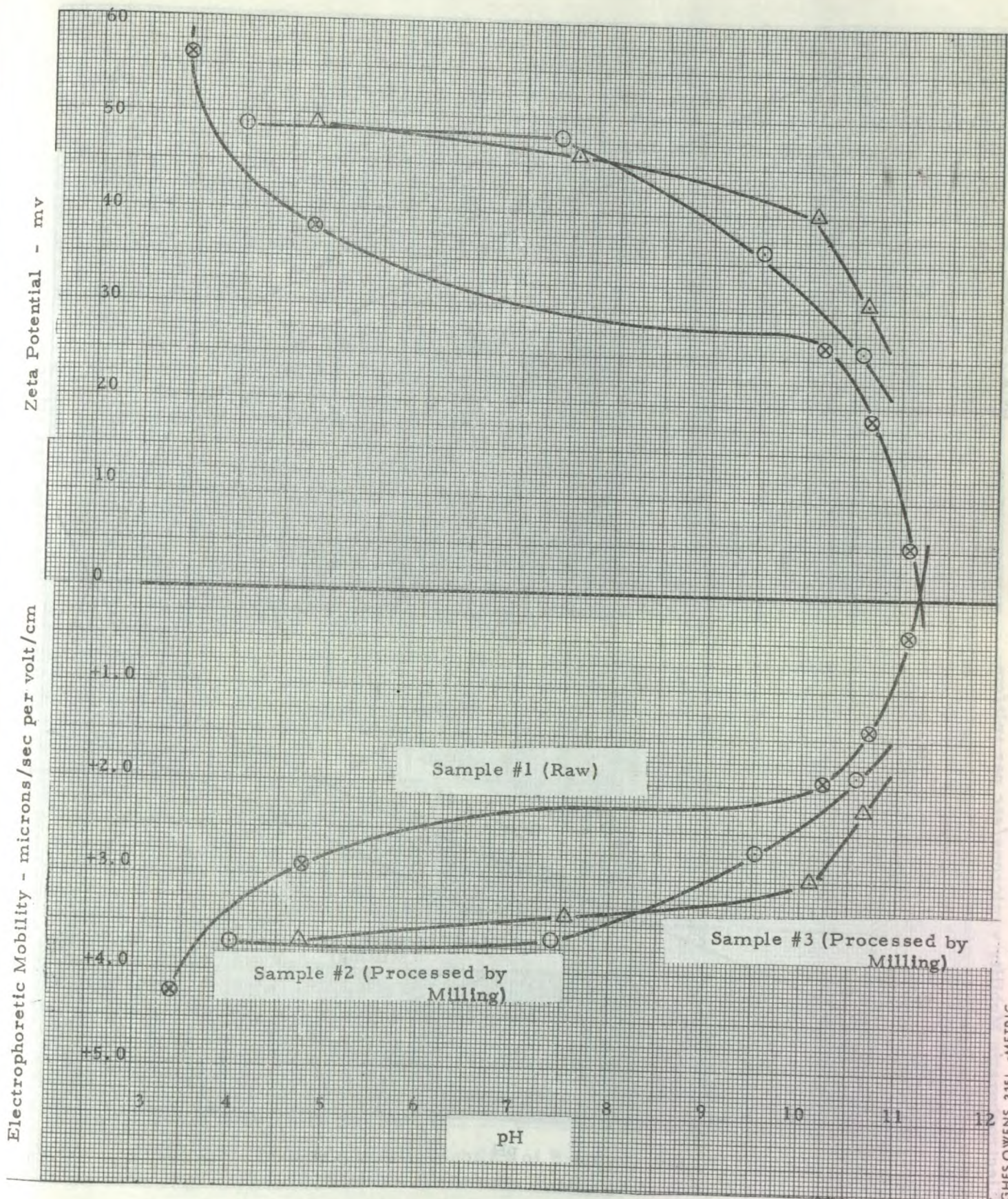


FIGURE 10. Electrophoretic Mobility and Zeta Potential of Chrysotile Fibre from the Eastern Townships, P.Q.

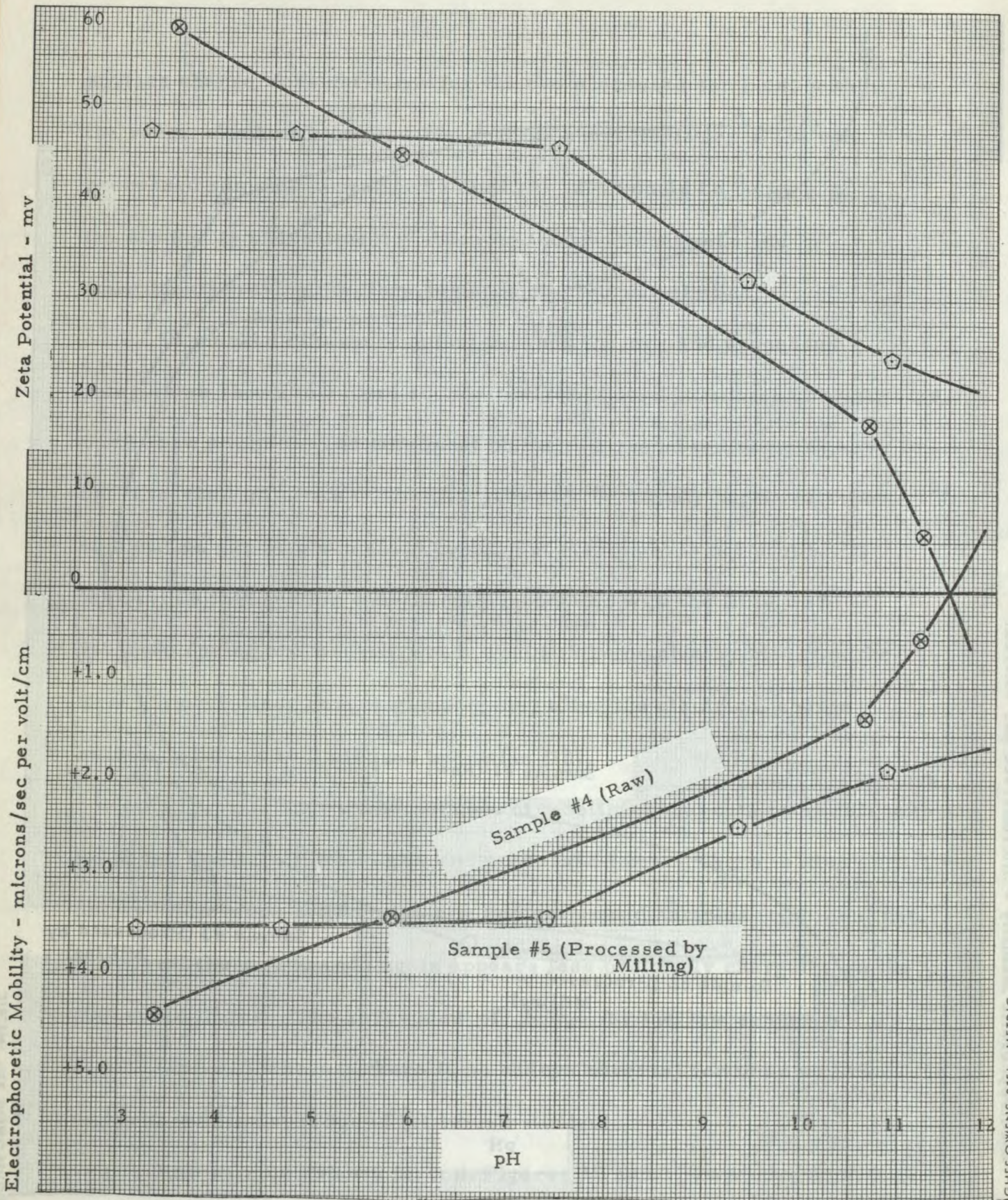


FIGURE 11. Electrophoretic Mobility and Zeta Potential of Chrysotile Fibre from Coalinga, Calif.

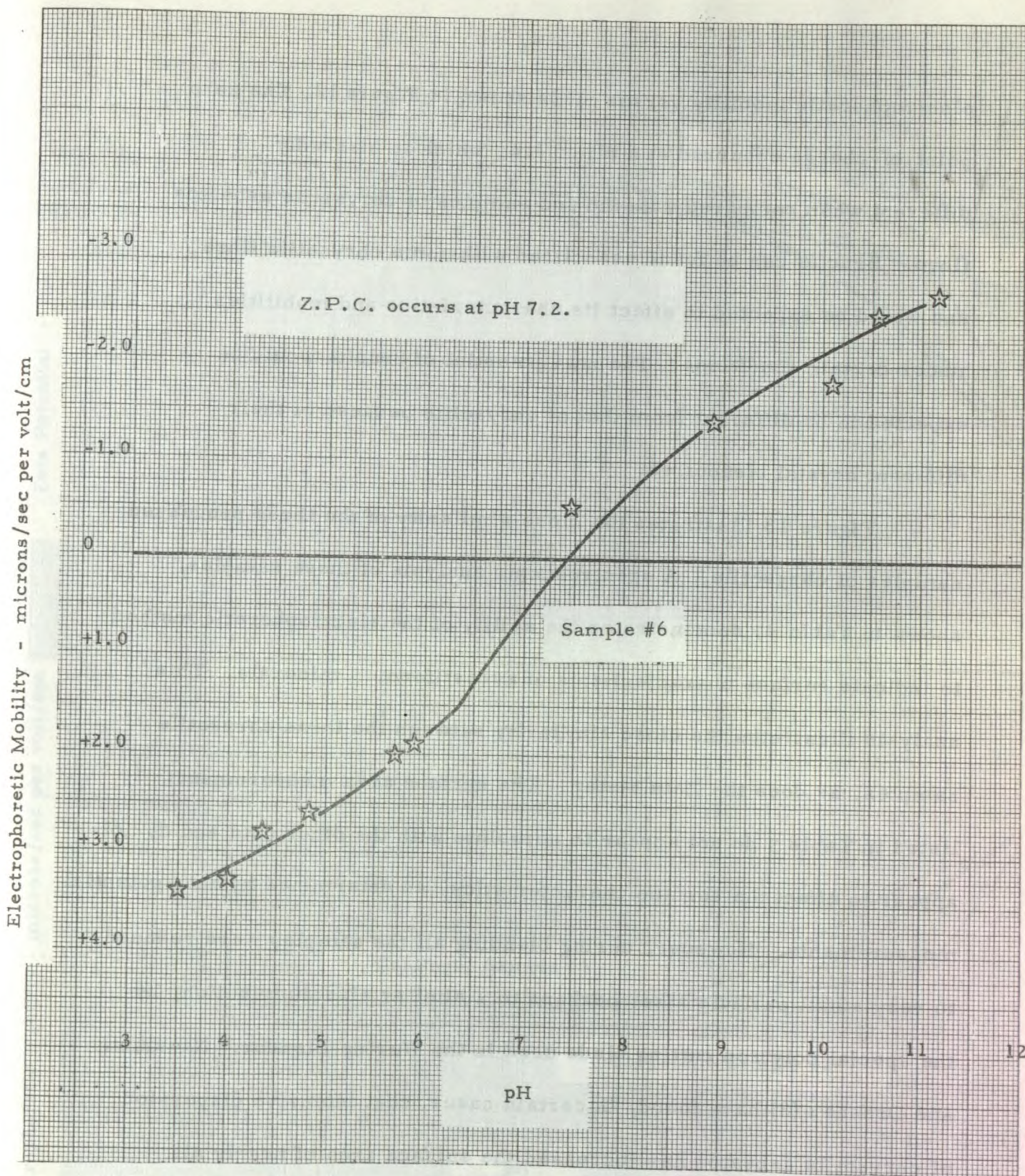


FIGURE 12. Electrophoretic Mobility of Brucite Fibre from Eastern Townships, P.Q.

electrophoretic mobility versus pH is shown in Figure 12. The zero-point of charge occurred at a pH of 7.2, which is markedly different when compared with the two samples of chrysotile asbestos fibre. Brucite can be found associated with some chrysotile fibre and would be expected to affect its characteristics and mobilities under certain conditions. The zeta potential of brucite would be expected to be different from that of chrysotile because of their different crystal structures.

Figure 13 illustrates the close similarity of the three processed samples of chrysotile. A spectroscopic analysis of these samples, shown in Table 4, demonstrates the ability of the electrophoretic method to indicate surface characteristics of asbestiform minerals. This analysis illustrates the close similarity between the three chrysotile samples, as does the Zeta Meter. The surface area measurements listed in Table 3 do not appear to correlate with the other data and do not appear to affect the surface characteristics, as determined by zeta-potential measurements. However, during blending all the samples were reduced to very small particle size, perhaps to a similar size distribution, by the special polytron cutting blade used in the Waring Blendor. Naumann and Dresher (8) have found, in certain cases, that intensive dispersion of chrysotile asbestos has increased the surface area of nearly all chrysotile asbestos.

FIGURE 13. Electrophoretic Mobility and Zeta Potential of Chrysotile Fibre from Coalinga, Calif.

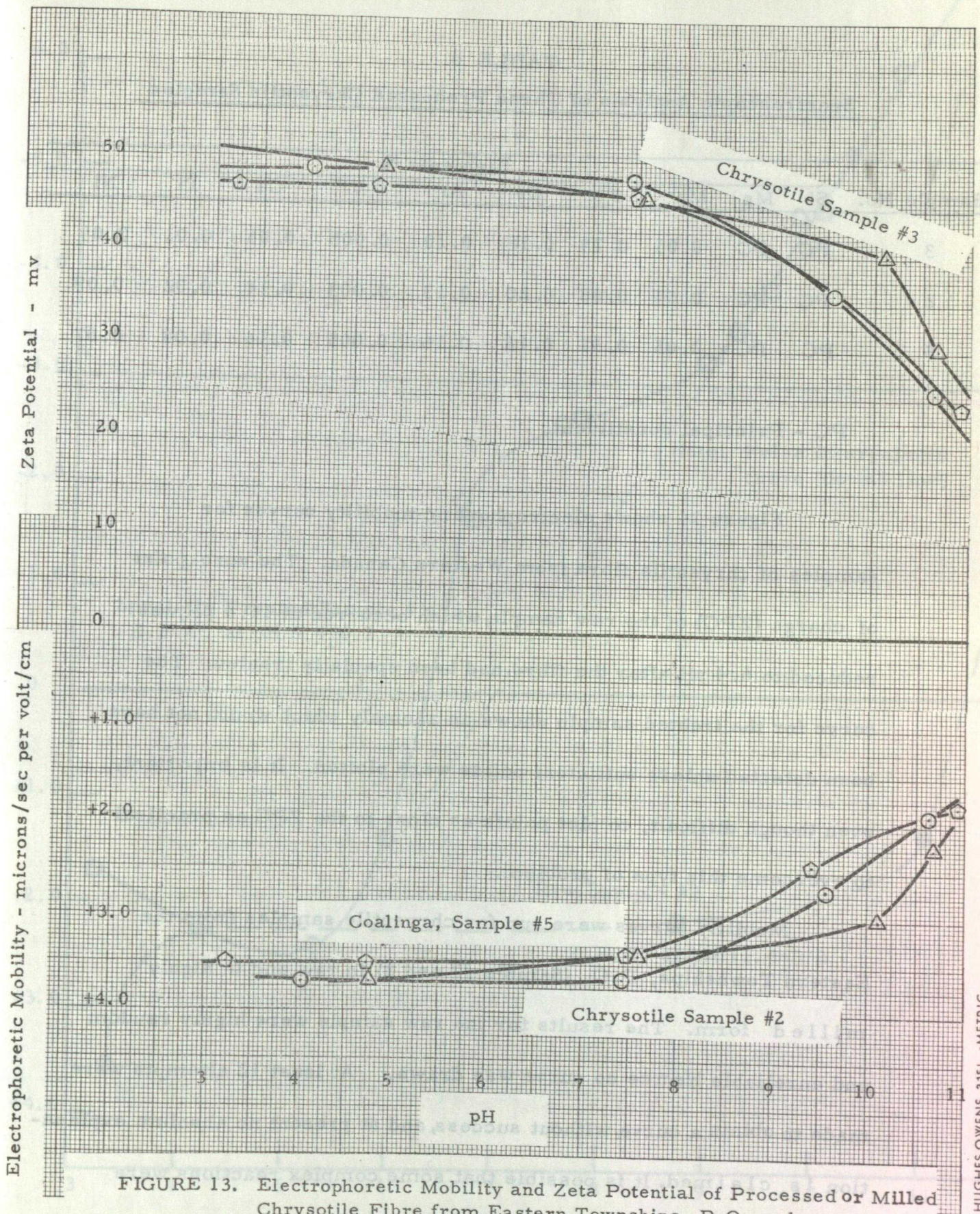


FIGURE 13. Electrophoretic Mobility and Zeta Potential of Processed or Milled Chrysotile Fibre from Eastern Townships, P. Q. and Coalinga, Calif.

TABLE 4.
Spectroscopic Analysis of Three Processed Chrysotile Samples

Sample No.	Elements %									
	Si	Mg	Mn	Fe	Cr	Al	V	Ca	Ti	Ni
3	PC	PC	0.05	0.79	0.18	0.10	0.005	0.06	0.01	0.09
2	PC	PC	0.04	0.88	0.20	0.13	0.003	0.14	0.02	0.09
5	PC	PC	0.05	0.57	0.16	0.16	0.005	0.14	0.04	0.07

PC - Principal constituent

Figure 14 shows electrophoretic-mobility curves for samples of chrysotile fibre from Western Canada. The zero-point of charge (ZPC) of the raw sample, which occurred at 11.4 pH, was reduced to 6.4 pH after the fibre had been specially treated. The curve for the treated sample shows an anomaly which would not have been detected unless sufficient points were plotted. It is important, even though difficult, to plot points as close to the ZPC as practical to overcome this type of problem.

Mobility curves were run for chrysotile samples from the Eastern Townships, P.Q. (Sample #7 and 8) in raw and in highly milled form. The results for the raw sample were highly random and unreliable hence no curve was drawn. At least 12 attempts were made to obtain a curve, without success, and at present no absolute explanation is claimed. It is possible that some complex reactions were proceeding and no equilibrium was reached during these experiments.

Mobility (microns/sec per volt/cm)

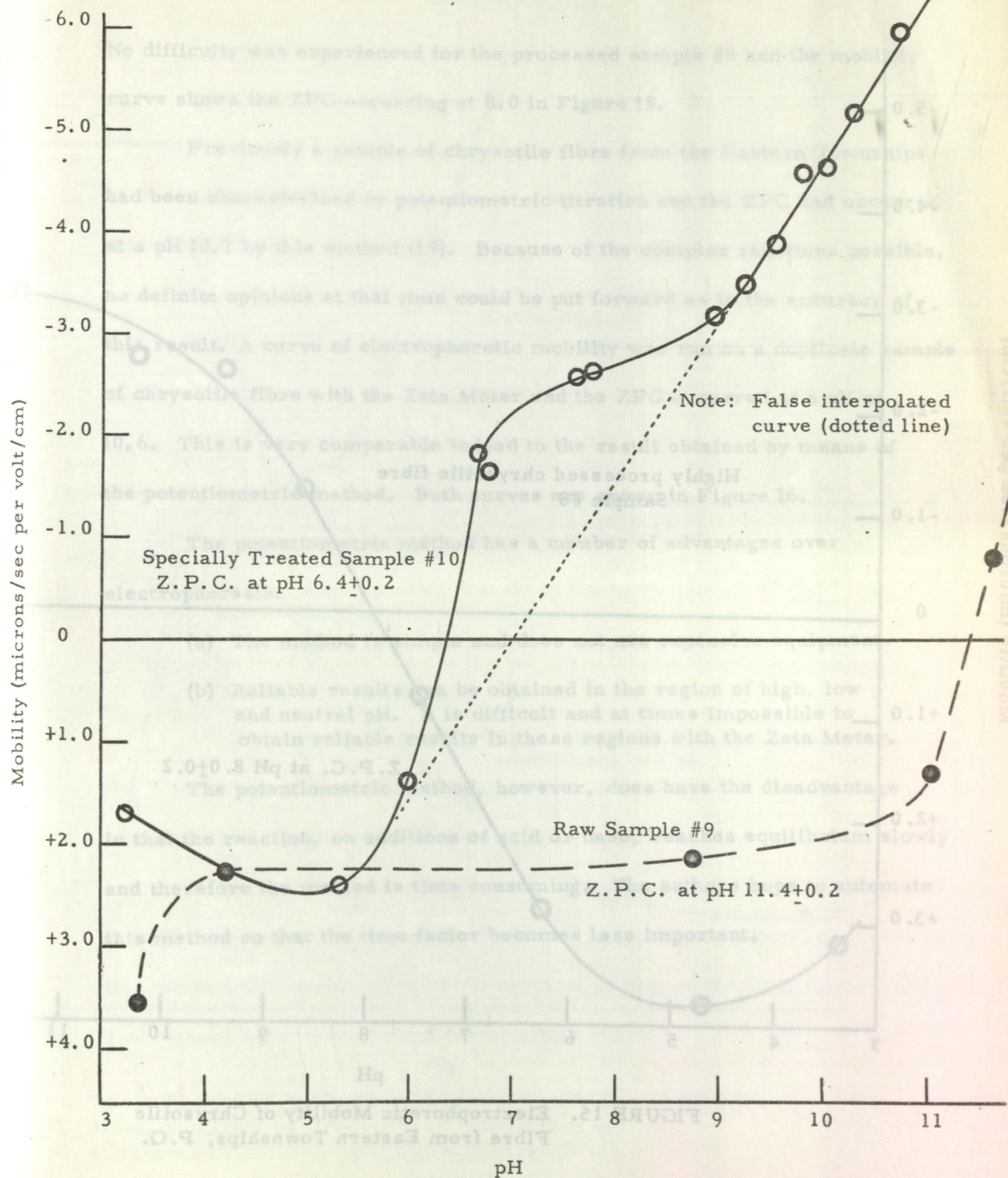


FIGURE 14. Electrophoretic Mobility of Chrysotile Fibre from Western Canada

TABLE 4

Spectroscopic Analysis of Three Processed Chrysotile Samples

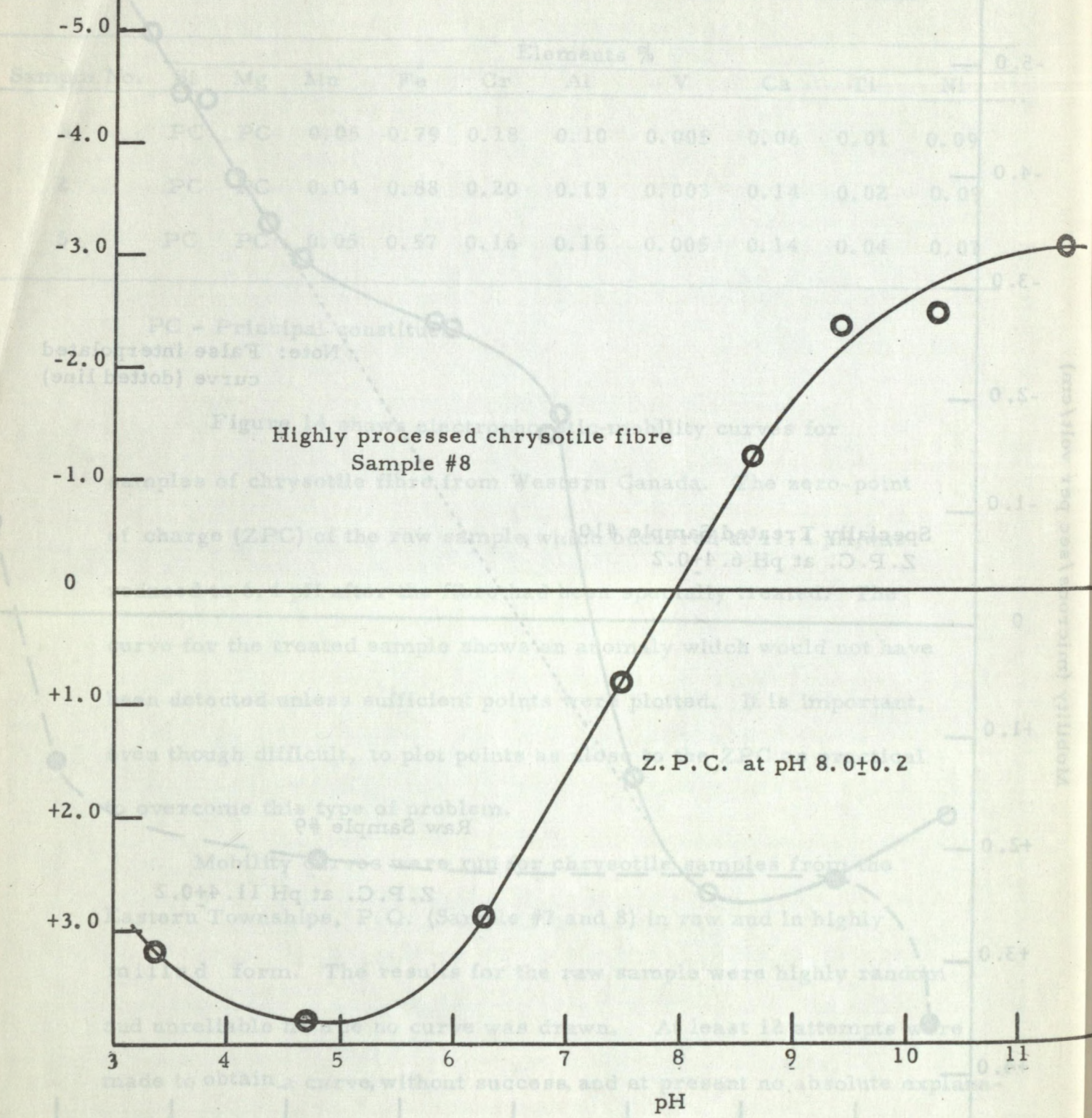


FIGURE 15. Electrophoretic Mobility of Chrysotile Fibre from Eastern Townships, P.Q.

No difficulty was experienced for the processed sample #8 and the mobility curve shows the ZPC occurring at 8.0 in Figure 15.

Previously a sample of chrysotile fibre from the Eastern Townships had been characterized by potentiometric titration and the ZPC had occurred at a pH 10.7 by this method (19). Because of the complex reactions possible, no definite opinions at that time could be put forward as to the accuracy of this result. A curve of electrophoretic mobility was run on a duplicate sample of chrysotile fibre with the Zeta Meter and the ZPC occurred at a pH of 10.6. This is very comparable indeed to the result obtained by means of the potentiometric method. Both curves are shown in Figure 16.

The potentiometric method has a number of advantages over electrophoresis.

- (a) The method is simple and does not use expensive equipment.
- (b) Reliable results can be obtained in the region of high, low and neutral pH. It is difficult and at times impossible to obtain reliable results in these regions with the Zeta Meter.

The potentiometric method, however, does have the disadvantage in that the reaction, on additions of acid or base, reaches equilibrium slowly and therefore the method is time consuming. The authors hope to automate this method so that the time factor becomes less important.

FIGURE 16. Curves showing Zeta-Potential of Charge Obtained by Potentiometric Titration and Electrophoresis for Chrysotile Fibre from Eastern Townships, P. Q.

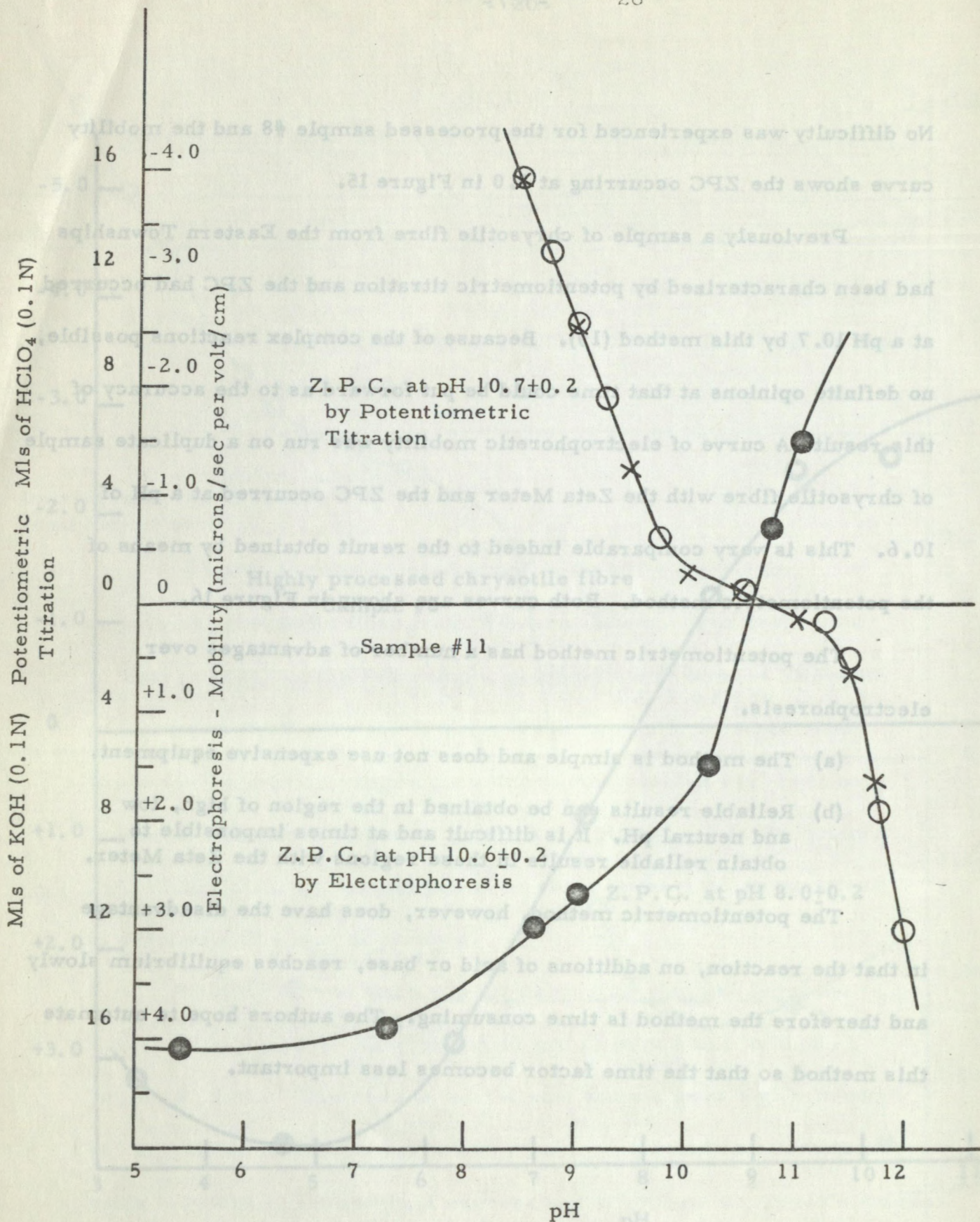


FIGURE 16. Curves Showing Zero-Point of Charge Obtained by Potentiometric Titration and Electrophoresis for Chrysotile Fibre from Eastern Townships, P.Q.

CONCLUSIONS

The results of this investigation indicate that brucite and other associated minerals can affect the fibre characteristics of chrysotile. Processing or milling of the fibre appears to alter its zeta potential, possibly because of removal of some of the associated minerals. The fibre from Coalinga and the Eastern Townships appears to have become more similar after processing, as evidenced by their zeta potential or electrophoretic mobility.

It is possible that zeta potential measurements can be used to predict fibre behaviour at any processing stage or in the final product.

It may also be possible to determine by means of zeta potential measurements:

- (a) location or origin of the fibre sample.
- (b) predict changes in the property of the fibre thus aiding in selective mining.
- (c) alteration of surface properties of the fibres by various chemical treatments.

All the conclusions above were based on the results obtained with the Zeta Meter. This instrument appears to be suitable for measurement of electrophoretic mobilities of asbestiform minerals.

It appears that potentiometric titration may also be a simple, accurate method for determining the zeta potential of asbestiform minerals. Automating this method will simplify and obviate to a large degree the time factor involved. The authors have been working towards this end.

REFERENCES

1. F.L. Pundsack & G.M. Reimchussel, "The Properties of Asbestos: Basicity of Chrysotile Suspension", J. Phys. Chem. 60 (1956).
2. Anon. "Chrysotile Fibres - Filled or Hollow Tubes", Chem. & Eng. News, Sept. 30 (1963).
3. M.S. Badollet, Encyc. Chem. Tech. 2, 734 (1953).
4. Maser et al, "Chrysotile Morphology", Am. Mineral., 45 (1960).
5. Anon. "The Scanning Electron Microscope", Wireless World, Jan. (1966).
6. M. della Faille et al, "The Influence of Dehydroxylation on the Morphology and Texture of Chrysotiles", Industrial Silicates, Nov. (1966) (French).
7. A.A. Hodgson, "Fibrous Silicates", The Royal Institute of Chemical Lecture Series No. 4 (1965).
8. A. W. Naumann and H W. Dresher, "The Morphology of Chrysotile Asbestos as Inferred from Nitrogen Adsorption Data", Am. Mineral., 51, May-June (1966).
9. A.W. Naumann and H.W. Dresher, "The Influence of Sample Texture on Chrysotile Dehydroxylation, Am. Mineral., 51 (1960).
10. F.L. Pundsack, "The Properties of Asbestos I. The Colloidal and Surface Chemistry of Chrysotile", J. Phys. Chem. 59
11. K.N. Nikolaev and T.I. Pogayzkaya, "Use of Polyacrimide in the Production of Asbestos Cement", Stroit Mat. 11 (1965).
12. A.B. Davydov and Z.G. Ivanova, "Preliminary Processing of Asbestos as a Plastics Filler and Its Sorption Properties", Soyiet

13. Anon. Chemical Week, Oct. 1, (1966).
14. R.L. Stone, "Relation Between the Zeta Potential of Bentonite and the Strength of Unfired Pellets", Presented at SME Meeting, Tampa, Florida, Oct. 3, (1966).
15. W.C. Streib, "Use of Inorganic Fibre as a Binder in a Pelletized Ore", U.S. Patent #3, 151, 972 (Oct. 6, 1964) Assignor Johns-Manville Corp., N.Y., N.Y.
16. E. Martinez, "The Effect of Sodium Silicate on the Filtration Rate of Asbestos Fibre", Can. Min. & Metall. Bul. Oct. (1964).
17. E. Martinez and G.L. Zucker, "Asbestos Orebody Minerals Studied by Zeta Potential Measurements", J. Phys. Chem. 64 (1960).
18. M. Robinson, "Surface Charge of Alumina and Magnesia in Aqueous Media", J. Am. Ceram. Soc. 47 (1964).
19. N. Nemeth et al, "Application of Potentiometric Titration to the Study of Surface Electric Phenomena" Mines Branch Investigation Report IR 65-19, (1965) Ottawa, Canada.
20. G.A. Parks, "The Iso-Electric Points of Solid Hydroxides and Aqueous Hydroxo Complex Systems", Chem. Rev., 65 (1965).