Asbestos Bulletin [illegible] & Chem.

PLAINTIFF'S EXHIBIT

ASA-755

Physical Properties and Technical Applications of Asbestos Minerals

M. S. BADOLLET, Health Research Institute,
~~Fairleigh~~ Dickinson University,
Madison, New Jersey, U.S.A.

ABSTRACT

The study of the physical properties of asbestos minerals requires a careful isolation of the fiber from the wall rock and, at a later stage, a comparison of these physical properties with those of fibers that have passed through the milling and beneficiation processes.

The effects of mineral impurities, loss of fiber length and the formation of extreme fines (asbestic and/or associated minerals) often show up in the formation of special asbestos products as well as in the commercial production of asbestos papers, millboards, asbestos cement products, plastics and insulation materials, and in the filtration of blood plasma and wines.

Numerous test methods have been developed in Canada and in England for use in the asbestos industry. Special treatments of asbestos fibers have been used to improve their physical and chemical properties and to eliminate impurities.

Numerous problems connected with the use of asbestos fibers are discussed, such as the effects of asbestos on filtration, surface area, surface treatments using organic or inorganic materials, the surface charge on the fiber, the presence of magnetite and air pollution elimination.

Biological studies on finely ground asbestos, when dispersed in 0.9 per cent sodium chloride solution and then sterilized and injected into hamsters, show that by reducing the dose, the tissue damage can be largely avoided. In these experiments, Arizona asbestos fibers were carefully extracted from the wall rock, finely ground, and examined chemically and microscopically for any mineral impurities that might be present so that any effect on the hamsters would be directly due to the presence of the asbestos. The harsh Arizona fiber induced more extensive tissue response than the soft fiber when tested in hamsters.

Introduction

THIS PAPER is intended to offer comment on the physical properties of asbestos minerals in relation to the many diverse industrial uses of these minerals. As the author is a chemical engineer, the material is presented from an engineer's point of view. However, industrial hygiene work in the asbestos industry has entailed work by many physicians and biologists. These medical scientists tend to focus their interests on the response of tissues in man and in experimental animals, but often have limited familiarity with the chemistry, physics and technical aspects of the mineralogical material with which they work. Similarly, engineers familiar with the materials often have limited understanding of the language and techniques of the medical scientists. This gap may delay asking the right questions to arrive at solutions for industrial hygiene problems. Although the present paper is concerned with the properties and uses of the materials, the author would hope that it may be of some service in suggesting ideas to those investigating questions as to how these materials behave in biological systems, how they mediate biological responses and how such responses may be minimized. The author does not propose to present theories for biological mechanisms, and trusts that his colleagues in industry will not stop reading at this point, as the paper is intended primarily for them.

It might be noted at the outset that, in addition to the consideration of different properties of different varieties of asbestos, which influence their suitability and use for various industrial purposes, the reaction of asbestos fibers with inorganic or organic compounds can improve fiber properties for special uses, such as reducing the hydrolysis of chrysotile in water. Reacted fibers can affect texture and filtration properties and increase production rates of asbestos cement products, papers, millboards and other wet process products.

SUBMITTED TO THE C.I.M.: in September of 1968.

ORIGINALLY PRESENTED: in part at the Conference on Physics and Chemistry of Asbestos Minerals, Oxford, July 20, 1967. This work was supported in part by U.S. Public Health Service Research Grant UI-00351 from the Division of Urban and Industrial Health.

KEYWORDS: Asbestos minerals, Asbestos cement, Filtration, Fiber [illegible], Chrysotile, [illegible], Crocidolite, Amosite [illegible] hamsters.

Selection and Preparation of Samples

For fundamental studies on the physical or biological properties and technical use of asbestos minerals, selection and preparation of crude ores is the first step. This should be done by someone qualified to examine the ore deposit and its geological formation, and to note the presence of dykes, faulting, vein formation and associated minerals in the rocks bearing [illegible]

ASARCO ELP 0003525

asbestos fibers. This type of examination often furnishes valuable leads to the physical properties of the crude asbestos and the commercial fiber, and its use in industry.

Asbestos fibers in the form of crudes or in drill core should be opened by hand for laboratory tests to avoid fractures. If further processing is necessary, they can be opened by a very mild *willowing* action. The method of mechanical opening of the crudes will vary, depending upon the variety of asbestos. For example, soft chrysotile may require more vigorous treatment than crocidolite or amosite, and anthophyllite and tremolite require even milder treatment to yield comparable fiber lengths. More research should be applied to the process of opening asbestos ores so that the maximum fiber length can be preserved and less fines produced.

Although samples prepared directly from ores are valuable for fundamental studies, most tests in industry are necessarily made with commercially milled samples. These milled samples can, of course, contain a variety of associated minerals that can affect properties and uses.

Milling and Beneficiation

In milling plants, large quantities of ore, consisting of fiber, wall rock and many associated minerals, are crushed together. Some kind of mechanical separation is therefore necessary later in the milling process. Preliminary sorting of crudes from the rock is helpful in reducing contamination. Water washing processes have been installed in some cases to reduce nonfibrous materials and to direct the cleaner fibers to one milling line and the dirtier fiber and shorts to another milling line. In any case, a complete elimination of the associated minerals is extremely difficult. They can be objectionable in the manufacturing of some products.

The bulkiness or degree of opening of a fiber will govern the ability to pressure-pack the fiber product for shipment. For purposes of industrial hygiene, pressure packing is of value in reducing dust in the atmosphere and on the packing floor.

The hooding of equipment wherever possible will also reduce atmospheric dusts and improve working conditions.

The amount of extraneous material in a bag of commercial asbestos fiber is rather surprising. From the viewpoint of the quantity of *pure* asbestos, it can vary from a few per cent to 70 or 90 per cent, depending upon the grade. This extraneous material consists of broken pieces of wall rock, magnetite, brucite, small sizes of asbestos fibers, dusts and closely associated minerals in various forms.

Asbestos mill surveys have been made by checking the flow rates throughout the mill and collecting samples at each station for a period of several days. The samples are composited, weighted and tested by the various test methods available to obtain some idea as to which milling unit is damaging the fiber and producing fines and dust. The McNett wet classification[illegible] method provided the best evidence of this. At the completion of the survey, the mill foreman is told which equipment is damaging the fiber. He can then regulate the equipment to improve, change or eliminate the trouble spots.

Fiber Testing

Neutron activation analysis[illegible] has been used on several occasions to identify trace elements in samples of chrysotile, amosite and crocidolite. For example, one series of examinations showed that chrysotile, amosite and crocidolite all contained manganese 56 and sodium 24; antimony 122 was present in amosite; chromium 51 was present in chrysotile and amosite, but not in crocidolite; iron 59 was present in all three samples; antimony 124 was present in all three fibers; scandium 46 was present in all three; and cobalt 60 was present only in chrysotile. Apparently the radioactive sodium 24 was produced from the magnesium which is a normal constituent of asbestos, and the radioactive cobalt 60 came from the nickel which is an impurity in the chrysotile. These trace elements become important if the sample of asbestos is to be used in the filtration of wines, beers, blood plasma and pharmaceuticals and in biological studies. Therefore, a preliminary acid treatment to remove trace elements would be desirable before utilizing asbestos for such filtration purposes. Attention to trace elements in samples of asbestos may be of particular importance in biological studies for effects of asbestos on tissue, particularly in tests for carcinogenicity.

A set of samples taken by the writer in an Arizona underground mine brings out an interesting point. The area containing soft fiber (chrysotile) was free of faults and the fibers were well formed, with a *strong flexing* and tensile strength. About 20 feet away, where a series of faults occurred, harsh chrysotile was noted. These fibers were not well formed, showed a weak flexing and tensile strength and, after processing, lost length and produced a considerable amount of fines and dust. The soft fiber contained 13* per cent molecular water and the harsh fiber 12* per cent. Filtration tests showed the soft fiber to be slimy and difficult to filter; the harsh fiber was not slimy and filtered rapidly. This type of harsh fiber was recommended for the filtration of wines, either as straight fiber or in a blend with soft chrysotile or cellulose fiber for filter pads. When the filter pads contain 100 per cent soft chrysotile asbestos, the filtrates are relatively free from colloidal particles. As the quantities of cellulose or harsh chrysotile are increased in the asbestos blend, the filtration rates increase and the filtrates are not as free of colloidal impurities.

Test methods[illegible] have been developed for determining the filterability, surface area, colour, grit, dust, length, degree of opening, wet classification, tensile strength, magnetic rating, volume resistivity and conductivity of asbestos. They do not give the identification methods for determining the associated minerals present. These methods are printed in the form of a booklet and are available for distribution by the Quebec Asbestos Mining Association and by Cape Asbestos Fibers Ltd., London.

Some of the other tests involve the use of the electron microscope, X-ray diffraction, differential thermal and infrared spectral data to show differences in the fibers that are not shown by other test methods.

The effect of opening asbestos fibers[illegible] and measuring their properties as the fibers are opened more and more shows what can happen in a factory where processing is necessary before the fiber can be made into a commercial product. For example, an African blue crocidolite, Rhodesian chrysotile, Canadian semi-harsh chryso-

*Determined by thermo-gravimetric analysis using the Thermoanalyzer. (Mettler Instrument Corp., Princeton, N.J.)

tile, Canadian soft chrysotile and a Canadian harsh chrysotile show, as the processing continues, that (1) the length has a tendency to decrease, (2) the dust or fines content increases, (3) the buoyancy increases, (4) the density decreases and (5) the surface areas increase. Therefore, the plant foreman must know just what degree of opening is necessary to obtain the best workable slurry for his machine to produce a satisfactory product.

The presence of magnetite[5] can be a serious problem, depending upon the use of the fiber, especially in the electrical insulation field. Magnetic rolls and a sudden flash of high-intensity heat have not been too successful in removing or converting the magnetite to ferric oxide, which is non-magnetic.

Methods of testing for magnetite have been proposed[6,7,8], but there is still room for more investigation.

Fiber Treatment and Effects

The field of sonics offers some interesting possibilities for opening asbestos fibers. Laboratory tests show that it can be accomplished.

The treatment of asbestos fibers, such as amosite or crocidolite, by inorganic or organic liquids may alter the physical and chemical properties sufficiently so that new applications may be found. By softening the stiff wiry properties of these two fibers, their importance in textiles will be greatly increased.

Adsorption of organics by chrysotile asbestos was reported by T. J. Weeks and J. P. Leinweber at the Oxford conference on asbestos in July of 1967. They used a Brice-Phoenix differential refractometer to measure the changes in the solute concentration.

Opening in water using a Waring blender[9] is a convenient method to prepare fibers for some types of tests in the laboratory. The samples should be washed with alcohol and ether to remove any polycyclic hydrocarbons and the benzo (a) pyrene sometimes found associated with asbestos.

The reaction with soaps such as stearates or oleates[10] can produce a water-repellant effect on the surface of the chrysotile — in the form of a thin layer of magnesium stearate or oleate. Textile chrysotile fibers at one time were treated by soap, with the roving later used covering as electrical in-

Surface treatment of a slimy soft chrysotile can be accomplished by the heat-treatment process, by an acid treatment or by the addition of sodium silicate[11] and flash drying[12]. Wetting agents such as polyacrylamid (Separan NP10) and aromatic sulfonate (Tamol N) have been used to floc the asbestos fines, improve filtration and reduce fiber losses.

In some cases, dispersing agents such as Soda Lig or Blancol are added to the tanks containing the asbestos slurries so as to keep the asbestos from settling and present a well-dispersed suspension that can be picked up by the wet machine process. The amounts of these reagents are kept small — just enough to accomplish the desired effect. Excessive amounts can cause frothing at the pumping station and defeat the purpose of flocculating or dispersing. There are times when it is necessary to open the fiber by additional grinding. In that case, such agents as Decerasol OT or Alkanol, when added in the proper amounts, can speed up the opening.

There is one point that must be remembered. Does the use of those agents in the presence of asbestos cement lower the strength of the finished asbestos cement products? If so, it may be necessary to avoid them entirely or use lesser quantities.

Asbestos fibers carry a surface charge — either electropositive or electronegative. During the nineteen thirties, chrysotile, amosite, anthophyllite, crocidolite, tremolite and actinolite were ground to a fine powder and tested in a cataphoresis cell using the ultramicroscope. Chrysotile was observed to have an electropositive charge in distilled water and all amphiboles were electronegative[13]. It has been suggested that the electropositive charge on commercial chrysotile is due to aluminum or iron ions and that the charge on pure chrysotile approaches the electronegative side.[*]

Chrysotile fines can be neutralized or brought to the iso-electric point by the addition of electronegative particles. This can be followed by the movement of particles, as observed in the cataphoresis cell under a given potential. For example, although diatomaceous earth, cement and other particles were all electronegative, the addition of chrysotile fines to any one of them brought about complete flocculation in a short time and filtration was improved.

In the early forties, a Swiss engineer developed a method for the clarification of raw sewage in aeration tanks. He added chrysotile asbestos to cause flocculation and, at the same time, increase the surface area so that bacteria could grow rapidly and aid in the digestion of the sewage prior to filtration. Actually, with the chrysotile being electropositive and the sewage electronegative, it was a case of using an appropriate amount of fiber to neutralize the negative charge and obtain a quick flocculation product that settled rapidly and was later removed by filtration.

Oil-well drilling produces chips of rock particles and mud. In some cases, clays and/or asbestos fibers are added to form a viscous mud to collect these particles so that they can be brought to the surface where they are removed by screening or filtering; the cleaned mud is returned to the well. In this case, the positive charged asbestos may have helped in forming large flocs that hold the drillings.

The colloidal properties of asbestos[14] and zeta potential measurements[15] have shown that the charges do exist and can be reversed by adding some inorganic reagents or by changing in the pH. Hodgson[16] measured the charges on crocidolite and amosite. The crocidolite had a weak charge of −10mV and amosite a weak charge of —20mV, whereas Martinez and Zucler (15) showed that chrysotile had a strong positive charge of +100mV, which may be a rather high value. In the production of certain types of cellulosic paper [17,18,19], the addition of chrysotile asbestos, with its electropositive charge, was helpful in retaining the negative-charged TiO_2 and at the same time furnished a high surface area. In the case of another type of paper, the asbestos must have the rubber latex deposited on it while in suspension. Here again, the negative-charged latex is held by the electropositive chrysotile during the sheet forming process.

Physical Properties and Applications of Asbestos

Chrysotile asbestos is the principal fiber used in many products, because of its physical properties and availability. For some purposes, it is surpassed by several amphiboles that have physical pro-

[*] Riddick, T. M., "Control of Colloid Stability Through Zeta Potential."

perties that give them particular advantages over chrysotile. The advantages of chrysotile asbestos, however, are generally greater than its disadvantages and, consequently, chrysotile is used in most products requiring asbestos. Chrysotile asbestos can have a large surface area, high strength, resistance to elements of the air, and flexibility, and it mixes well with resins and cements and does not support combustion.

The texture of asbestos fibers varies from very soft and silky to semi-harsh, or even to a harsh, splintery, brittle type. Quite often, the fiber source of the ore will reveal what has happened during the original crystallization period. The presence of dykes, faults, mineral impurities and crystal formation also furnish clues. Most harsh asbestos fibers have less water of crystallization, and this is particularly true of harsh chrysotiles. The soft chrysotiles are slimy in water, hydrolyze slowly and are extremely difficult to dewater; the harsh fibers can be dewatered rapidly. Advantage of this knowledge can be utilized in blending a harsh or semi-harsh fiber with the strong soft chrysotile, as in the production of asbestos papers and asbestos cement products. Blends of amphiboles such as amosite or crocidolite with slimy soft chrysotile can be very effective in increasing production rates, provided that the strengths of the end products containing these blends are not seriously affected.

Thin asbestos papers for electrical insulation should be free from grit, unopened fiber bundles, magnetite and brucite. If these impurities are present, they will appear on the surface of the paper and produce weak spots when the paper is wound or wrapped around a wire carrying electrical current.

Air pollution is an important problem today. Its study involves the collection of large volumes of air in and around plants, mines, mills, subways, tunnels and points of heavy traffic congestion. If asbestos is thought to be involved, then sufficient solids must be obtained for tests by all available procedures, including electron microscope, spectrographic, infrared and neutron activation analyses. New micro test methods must be developed to complete this type of investigation successfully.

Asbestos, glass, cotton or wool, in the form of textile filter bags, are sometimes used in plants to recover fly ash, radioactive particles, and metallic particles from metallurgical and smelting plants. Extremely fine asbestos fibers may be added as a precoat to the bags to increase the efficiency of removal of particles polluting the air. These fine particles of asbestos may be precoated onto glass filter bags or cloth filter bags in the baghouse installation prior to placing them in use.

Miscellaneous Technical Applications

The presence of grit, whiskers, fiber bundles (unopened), magnetite, brucite and micaceous materials in commercial fibers may be objectionable when incorporated in a binder to be used in a spray gun, such as for sprayed undercoatings, and coatings for heat and sound insulation and fire protection. The asbestos must have bulk and fluidity with the binder.

Caulking compounds are sensitive to texture, foreign materials and changes in grades of asbestos, especially when applied by a gun.

Wall-joint fillers using asbestos must have good bulking value, good coverage, a smooth texture and be free of whiskers, grit, magnetite and micaceous materials.

Asbestos in paints must be free of grit and whiskers, and must be uniform in texture for the best application.

Plastics and molding powders are very sensitive to the physical properties of asbestos, even to the presence of moisture, brucite, associated minerals, iron and off-colour fibers. For example, the fibrous structure will increase the impact strength, allow a wide range for adjusting the quantity of fiber, furnish good binder retention and good workability, impart hardness and toughness to the moldings, increase heat and fire resistance, reduce deformation, make cold molding possible by controlling the flow under pressure in the molds, permit the blending of mineral and organic fillers, impart a good finish, improve electrical properties and reduce the cost of molding. The presence of iron in asbestos will produce off-colour plastic products, and a chelating agent may be necessary. A stabilizer for asbestos in plastics should function as a heat stabilizer, as an antioxidant and as an ultra-violet-light absorber to be ideal.

The thermal insulation[[illegible]] properties of asbestos have proved to be important in missiles and sat[illegible] and as special packings in atomic energy equipment.

In asphalt paving[[illegible]], the strength, reinforcing and absorptive properties of asbestos have resulted in an improvement in the plastic strength, tensile strength and static compression and a decrease in the cracking properties of thin films of asphalt filler mixes.

Other Applications of Asbestos

In many asbestos products, it is the reinforcing effect of asbestos that is needed and not the non-fibrous materials, which would be considered as expensive fillers. If fillers are needed in a product along with asbestos, they can be purchased at a lower price and under a manufacturing specification. The foreman in a plant that is using asbestos to produce a commercial product must have some idea of the quantity of pure asbestos that is available in a given grade of fiber. Then, he will know whether to use more or less fiber in his formula. Although it is true that the extraneous material may aid filtration, it will contribute little toward the strength of the product, and is thus an expensive method of obtaining this effect. In the case of manufacturing floor tile and plastics, it is important to know how much true fiber is present to obtain the maximum reinforcing effect. Too much true fiber will dry up the mix and require more expensive resins; on the other hand, the foreman can reduce the quantity of fiber and use less resin to obtain the consistency desired.

Commercial grades of asbestos fibers have been improved during the past ten years, so that there is less extraneous material present in a bag of fiber today.

In general, chrysotile asbestos has the widest use in commercial products such as asbestos cement, flooring materials (asphalt and vinyl tile), papers, millboards, roofing felts, textiles, automotive products (brake linings, clutch facings and packing) and many miscellaneous items. Fortunately, the physical properties of chrysotile make this fiber ideal; however, some amphiboles (crocidolite and amosite) are becoming important and are replacing chrysotile in some products.

In the spinning and weaving of asbestos fibers the softer varieties [illegible] best suited as they do not break up in the processing equipment. Soft chrysotile causes the least trouble; harsh chrysotile will show considerable loss due to its brittleness. Crocidolite can be spun into yarns and cloths by modifying the textile equipment so that the stiff and wiry properties of crocidolite can be handled. Amosite is of low flexing strength and is usually formed into mats and later treated with resins, depending upon its use in industry. The tensile strength and flexibility of asbestos are also important in spinning and weaving applications.

Where acid-resistant packings are required for acid pumps, crocidolite, the most resistant of the fibers, can be made into all-blue yarn and impregnated with a resin to form gaskets or, if required, it can be formed into millboards. Crocidolite and amosite fibers, when in the form of cloth, packings, yarns and baggings, and when treated with inorganic binders, can withstand temperatures higher than 480°F.

Reinforced plastics using crocidolite show good chemical and water resistance. For heat insulation, amosite is very useful due to its open volume and the fact that it contains air pockets. It is also used in reinforcing magnesium or calcium silicate insulation, where the filtration problem is greatly improved by the presence of this fiber.

Anthophyllite asbestos has good heat resistance and acid resistance. It has been treated with resins and used in plastics. Although this fiber does not have the strength of chrysotile, crocidolite or amosite, it has good bulking properties. Some anthophyllites are mostly iron-free and almost white in colour and are desirable in some types of plastics.

Tremolite, after an acid and caustic wash, is considered as a good fiber for use in the chemical laboratory for filtering chemicals and is sold for that purpose.

The physical properties of actinolite are not too attractive. It is a weak fiber, usually associated with other minerals, and would be considered as a cheap filler in industrial use.

Some Carry-over of Industrial Experience to Biological Experimentation

People in the asbestos industry have long been familiar with the slimy suspensions formed by soft chrysotile in water in contrast to the rapid settling of harsh fibers. As indicated in the preceding discussion, it is this difference in physical properties that favours the use of harsh fibers in certain products, such as asbestos cement, where it is desired to have water filter away rapidly for faster setting.

As also mentioned above, the author had taken a set of samples of harsh and soft chrysotile ores from a mine in Arizona. Fibers were hand-picked from these samples. The wall rock was cut away and the fibers were washed and processed to mean lengths of 30 microns in a Waring blender[illegible]. An aliquot of the processed soft fibers was heated until it lost the property of forming slimy suspensions in water. The samples were then turned over to Dr. Wm. E. Smith at Health Research Institute, Fairleigh Dickinson University, Madison, New Jersey. Dr. Smith's group has found that the injection of sterilized saline suspensions of some preparations of asbestos into the pleural space, the space surrounding the lungs of hamsters, elicited scar formation (*fibrosis*) and, occasionally, tumors (*mesotheliomas*)[illegible].

Working with the specially selected and cleaned fibers of Arizona chrysotiles, this group observed that the slimy character of suspensions of soft chrysotile in water carries over and persists in depots of this material in the pleural space of hamsters, whereas depots of harsh chrysotile become dry. There was much more extensive scar formation and more rapid development of tumors around the depots of harsh chrysotile than around the soft ones. The heated aliquot of soft chrysotile induced no more rapid development of tumors than the unheated aliquot, but tended to cause thicker scars than the unheated soft chrysotile[illegible].

In hamsters injected with a large (25 mg) dose of harsh chrysotile, tumors developed in 21 per cent of the animals. With a smaller (10 mg) dose, tumors arose in only 9 per cent of animals. Further reduction in dosage to 1 mg elicited no tumors at all[illegible].

In hamsters injected with 10 mg of amosite, the yield of tumors was again 9 per cent. When only 1 mg of amosite was injected, none of the animals developed tumors[illegible].

The finding that hamsters would [illegible] injected with asbestos provided a test species of demonstrated susceptibility. The follow-up experiments with graded doses afford evidence that tumor risks in operations where they may exist in the asbestos industry can be avoided by appropriate measures to reduce the amount of exposure.

Different varieties of asbestos fibers have been assembled and prepared as standard samples by Dr. R. E. G. Rendall, Pneumoconiosis Research Unit, Johannesburg, South Africa, in collaboration with Dr. V. Timbrell, Medical Research Council, Llandough Hospital, Penarth, Glamorgan, Wales. The Pneumoconiosis Research Unit is making these samples available to those interested in work on the biological effects of asbestos.

CONCLUSIONS

This review illustrates that any operator using asbestos minerals must keep in mind many factors that may influence his final product. The undesirable effects of mineral impurities may need control. Fundamental studies on the changing physical and chemical properties of asbestos have developed new uses, and undoubtedly will develop more.

Improved milling techniques can improve the quality of asbestos fibers by preserving the length and producing fewer fines. Treatments of asbestos with heat or with inorganic or organic compounds can also improve fibers for special uses.

By taking advantage of the different textures of different asbestos fibers, such as harsh, semi-harsh or soft, improvements can be made in wet processes.

Many methods for physical and chemical tests of asbestos minerals have been proposed by the Quebec Asbestos Mining Association and by Cape Asbestos Co., Ltd., London, and are available from those sources. Electron microscopy, X-ray diffraction, and differential thermal and infrared spectral analyses bring out differences not shown by the usual test methods.

Some biological differences in response to harsh and soft chrysotile were noted. Harsh fibres induced more extensive scar tissue formation in hamsters than soft fibres. Tissue damage was proportional to the amount of fibre injected.

ASARCO ELP 0003529

(1) *Manual of Testing Procedures for Chrysotile Asbestos Fibers,* Asbestos Textile Institute, Quebec Asbestos Mining Association, Thetford Asbestos-Cement Products Association.

(2) Private communication, Raybestos Manhattan Inc.

(3) *Test Methods for Blue and Amosite Asbestos Fibers,* Cape Asbestos Fibers Ltd., London.

(4) Badollet, M. S., "Processing Asbestos Fibers — Effect Upon Physical Properties," *C.I.M. Transactions,* Vol. LIII, April, 1950.

(5) Nicodemus, P. O., "The Significance of Iron in Asbestos Materials Used for Electrical Insulation Purposes," *A.S.T.M. Bull.,* Apr., 59, p. 62.

(6) *American Society for Testing Materials Test Method D 1118-57,* Magnetic Rating of Asbestos Used for Electrical Purposes.

(7) Badollet, M. S., and Edgerton, N. W., "The Magnetic Content of Asbestos by Magnetic Separation," C.I.M. Annual General Meeting, Quebec, March, 1961.

(8) Wromski, J., "Magnetic Rating of Asbestos Fibers by a Magnetic Force Method," *S.P.E. Journal,* Vol. 19, No. 11, Nov., 1963.

(9) [illegible] A., "Preparation of Asbestos Fibers for Experimental Use," *New York Academy of Sciences,* Vol. 132, (Art. 1), 451-455, December 31, 1965.

(10) Badollet, M. S., U. S. Patent 2,068,219, Jan. 19, 1937.

(11) Martinez, Edward, "The Effect of Sodium Silicate on Filtration Rate of Asbestos Fiber," *C.I.M. Bulletin,* Vol. 57, pp. 1042-1044, Oct., 1964..

(12) Pundsack, F. L., and Reimschussel, G. P., "Method of Improving the Filtration Characteristics of Asbestos," U.S. Patent 3,173,-831, March 18, 1965.

(13) Badollet, M. S., "Asbestos — A Mineral of Unparalleled Properties," *C.I.M. Transactions,* Vol. LIV, pp. 151-160, 1951.

(14) Pundsack, F. L., "The Properties of Asbestos, I. The Colloidal and Surface Chemistry of Chrysotile," *Jour. Phys. Chem.,* Vol. 59, pp. 892-895, 1955.

(15) Martinez, E., and Zucker, G. L., "Asbestos Orebody Minerals Studied by Zeta Potential Measurements," *Jour. Phys. Chem.,* Vol. 64, pp. 924-926, 1960.

(16) Hodgson, A. A., "The Surface Properties of Asbestos Fibers," *Asbestos Mag.,* pp. 2-14, Nov., 1965.
Hodgson, A. A., "Fibrous Sili-[illegible] Properties," The Royal Institute of Chemistry, Lecture Series, Number 4, pp. 23-30, 9-10, 29, 1965.

(17) Wollery, R. G., "Effects of Chrysotile Additions to Cellulosic Paper," *Tappi,* Vol. 18, pp. 92A-96, 1965.

(18) Naumann, A. W., "Properties of Asbestos Suitable for Use in Cellulosic Paper," *Tappi,* Vol. 43, Aug., 1965.

(19) Feigley, D. A., "Beater Saturation of Asbestos Fibers," U.S. Patent 2,759,813, Aug. 21, 1956.

(20) Badollet, M. S., "Asbestos," *Encyclopedia of Chemical Technology,* 2nd Edition, p. 746, Interscience Publishers, New York, 1963.

(21) Smith, W. E., Miller, L., Elsasser, R. E., and Hubert, D. D., "Tests for Carcinogenicity of Asbestos," *Ann. New York Acad. Sci.,* 132, (Art. 1), pp. 456-483, 1965.

(22) Smith, W. E., Badollet, M. S., Miller, L., Hubert, D. D., Langer, A. M., and Churg, J., "Comparison of Biological Responses to Harsh and Soft Chrysotile," (in press).

(23) Smith, W. E., Hubert, D. D., Miller, L., Badollet, M. S., and Churg, J., "Tests for Threshold Levels of Carcinogenicity of Asbestos," (in press).

Brazilian Society for Metals — XXIV Annual Congress

Sao Paulo, Brazil,
July 7-12, 1969

THE CONGRESS of the Brazilian Society for Metals is to take place during the week of July 7 to 12, 1969, and the program is to consist basically of the following:

I—*Open Sessions,* with subjects freely discussed.
II—*Technical Lectures,* comprising specific technical subjects, delivered by world-wide experts.
III—*Technical Papers* to be presented by the authors, followed by intensive discussion. These technical papers may cover any branch of metallurgy — extractive or transforming, ferrous or non-ferrous metals or physical metallurgy.

At present, the program is still at a tentative stage and the following topics were suggested:

For Open Sessions

1 — Training personnel for the metallurgical industry.
2 — Materials for cutting and forming tools.
3 — Development in the production of copper and nickel and its alloys.
4 — Problems and techniques relating to the operation of blast furnaces aiming at the lowest possible coke rates.
5 — Problems related to the supply of cast iron and malleable and nodular castings to the automotive industry.

For Technical Lectures:

1 — Six examples of rather startling research in physical metallurgy.
2 — New developments in the extractive metallurgy of non-ferrous metals.
3 — Investment and financing problems for the metallurgical industry.
4 — Strategy of research in the metallurgical industry.
5 — Present state of continuous processes in steel production.
6 — Precipitation in steels.
7 — New ceramics.
8 — Solidification of metals and alloys.
9 — New techniques in mechanical forming of metals.
10 — Present status of techniques of continuous casting.

So far Prof. Robert F. Mehl, Prof. Arthur G. Quarrell and Prof. Kai Grjotheim have already confirmed their presence and accepted the invitation to deliver lectures. Several technical papers from foreign authors are expected.

For additional information, contact the Organizing Committee: P.O. Box 3503, - São Paulo, Brazil, S.A.