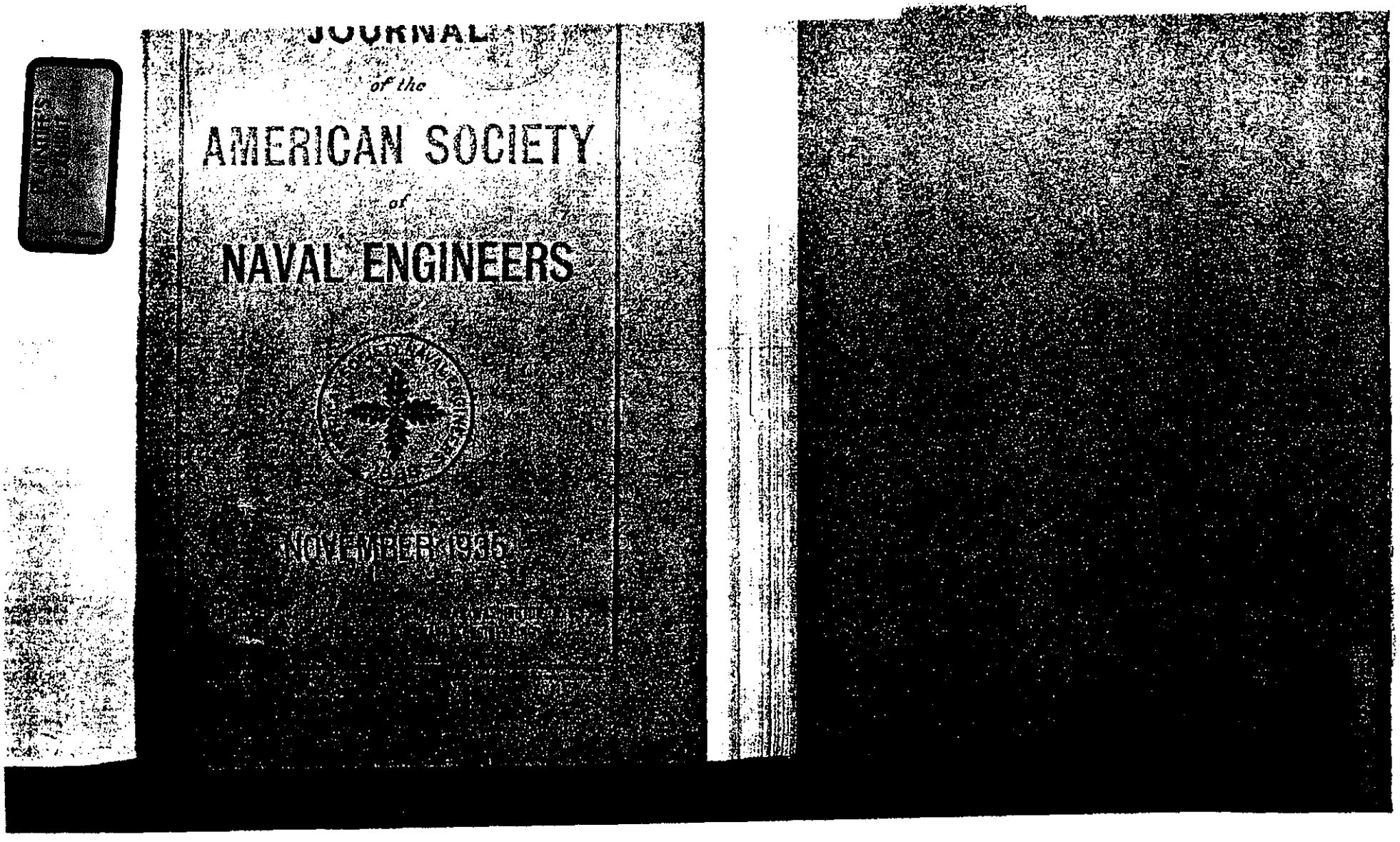
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NAVAL ENGINEERS
NOVEMBER 1985

from each basically different pattern and delivered to the Government. Such pilot castings could be examined, preferably by machining, to appropriate sections for dimensions or by cutting up so as to expose the internal condition of the castings and thus determine general soundness.

In such a case, provision could be made for cancellation of contract where it was quite evident from examination of pilot castings that the product could not meet requirements. In many cases the inspection of a pilot casting will suggest minor changes in foundry practice or possibly in design, which will overcome the trouble and prevent a repetition of similar difficulties in subsequent regular production.

In the production of intricate castings, such as turbine casing castings, details of design may vary greatly. With the best planned production methods, it is not always possible to obtain sound castings on the first attempt. In the correction of such conditions the value of pilot castings cannot be overestimated.

In carrying out a constructive method such as this, allowable time for completion is a very important factor. In many cases contractors are forced by urgent need of castings, to proceed with regular deliveries on a very close schedule as soon as patterns are received. In the case of a manufacturer having previous experience on exactly similar castings, this may present no great hardship but for other entirely reliable and competent concerns who have not been able to familiarize themselves with detail requirements and difficulties, the allowable time for completion of the usual Naval contract is inadequate for proper planning and execution of the project.

It is believed that with a greater appreciation of the foundryman's problems and the setting up of a procedure for deliberate examination of an initial casting made to new and unusual designs, many more reliable sources of supply could be developed and the Government could be assured of a more generally satisfactory product, and avoid long and costly delays in shipbuilding programs.

ASBESTOS FOR ELECTRICAL PURPOSES.

By C. Huba, Civil Member.*

HISTORICAL.

The term *Asbestos* is derived from a Greek word of the same form, with the inappropriate meaning of *Unquenchable* or *Unextinguishable*. In the light of the present use of the term, the derivation of the word should have been based on the more appropriate meaning of *unconsumable*.

Asbestos is a dense fibrous *mineral* composed of fine, flexible and easily separable filaments of a silky luster (see Plate 1). In common with many other minerals and inorganic substances, it resists high temperatures. But among all the minerals discovered which nature has evolved, even out of elements analogous to asbestos, not one has the fibrous, flax-like structure which, when mechanically macerated, strongly resembles raw cotton, jute, kapok and other *organic* materials used in the textile industries.

The heat resistance and the fire-proofness of asbestos, as we feature it today, have long been known to the civilized nations. It dates back to the ancient Chinese who are said to have woven it into mats for the probable use as heat insulators, and to the Egyptians who are said to have used it as wicks for the oil lamps on altars. It is likely that the mysteriousness of the continually burning lamps when continually fed with oil, has resulted in the application of the word *"Asbestos"* to its literal meaning of *"Unquenchable."*

In medieval times, the Romans are said to have used the fire-proofness properties of asbestos in the form of cremation shrouds where the actual remains of their dead could be sharply distinguished from the ashes of the fuel and which then could be set aside in urns. It is also said that *asbestos* was woven into table clothes which were cleaned after the feasts by throwing them in

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the fire. Because of the difficulty due to the shortness of the fibers, vegetable fibers were sometimes added, as we do today, to make the material more workable. In the fire, the vegetable fibers were then consumed and the pure asbestos fabric remained.

In the many centuries that followed the earlier applications of asbestos, the art was practically lost. About 1700, an Italian professor had his writings printed on paper made of asbestos with the idea of creating imperishable fire-proof documents. This application failed for the reason that although the "paper" did resist the fire, not so the printing. Later, about the middle of the last century, an Italian prepared strong asbestos boards as book covers with the idea of shielding the inflammable pages of books. Shortly thereafter another Italian proposed the use of asbestos for bank notes. This proposal was not taken seriously as it was realized that the lack of tensile strength of such notes would more than offset the advantage of incombustibility.

In the foregoing abbreviated historical review of the ancient, medieval and pre-modern use or application of asbestos, we find that in the present day applications to the *electrical* art, to which scope of this article is chiefly confined, the same properties are used, *viz.*, heat resistance, flame resistance and by the addition of organic fiber, such as cotton to obtain workability, dependence is placed on the asbestos fiber to maintain a serviceable *envelope* after fire has removed the organic materials. The specific application of asbestos to the electrical arts will be discussed in subsequent paragraphs.

THE MINERALOGY OF ASBESTOS.

Chemically, asbestos must always be regarded as hydrous silicate of magnesia, but one in which considerable variations occur, mainly in the percentage of lime, which may be entirely absent. Asbestos also may or may not contain alkalies or aluminum in *appreciable* amounts as well as iron in the form of ferris oxide or of actual metallic iron. All asbestos has a variable amount of water contained in its structure in the form of latent water (water of crystallization).

The absence or presence of aluminum, alkalies and iron in variable percentages, in combination with the basic silicate of magnesia, together with characteristic percentages of latent water, serves to

determine both the source of the geographical origin of asbestos, its mineral classification and its application to the industrial arts. The many varieties of asbestos which are found in small or large deposits all over the world, are distinguished and classified along broad lines into two mineral groups known as (*a*) Serpentine (*Oliven*) and, (*b*) Amphibole (*Hornblende*). The Serpentine group includes a *variety* known as Chrysotile (*crys-o-til*) in which variety we are principally interested for *electrical* purposes on account of its great flexibility, heat resistance, spinning qualities and characteristic very small percentages of iron. The group known as Amphibole (*am-fi-bol*) comprises many varieties, not usable for electrical purposes on account of either their brittleness, high iron content or both.

Mineralogy distinguishes many varieties of asbestos, which it designates by different names according to the system in which their crystallization occurs in nature. In the following table, the kinds which are of the greatest practical importance to the electrical and mechanical industries are classified according to their qualities and their principal places of deposit:

Mineral Group	*Variety*	*Chemical Composition*	*Qualities*	*Important Deposits*
Serpentine (*Oliven*)	Chrysotile	Hydrated Silicate of Magnesia	Long fiber greatest flexibility and heat resistance; less acid-proof	Arizona Canada Rhodesia Australia Siberia
	Picrolith	Hydrated Silicate of Magnesia	Long fiber very brittle	Canada
Amphibole (*Hornblende*)	Anthophyllite	Magnesia Silicate of Calcium	Brittle acid-proof	Georgia Montana
	Tremolite	Magnesia Silicate of Calcium	Brittle and less heat resistance but acid proof	Italy Africa Balkan States
	Actinolite	Ferril Magnesia Silicate of Calcium	Brittle and less heat resistance but acid proof	North America
	Crocidolite	Ferric Silicate of Sodium	Flexible, little heat resistance acid proof	Cape Colony
	Amosite	Highly ferric	Long fiber fit spinning	Transvaal

The foregoing table clearly shows the necessity on the part of the manufacturers who fabricate raw asbestos into finished products, of having considerable experience and knowledge of the varieties of asbestos, their qualities and their origin. By the same token, it is highly desirable for the purchasers or users of the finished asbestos products, to be informed of the basic qualities and limitations of the many varieties available.

Knowledge of the origin or source such as Canada, Italy, Siberia, etc., which may be listed as the principal source of supply for certain varieties, alone does not furnish conclusive information as to the particular qualities desired for select applications such as required for electrical purposes.

In general, it is to be expected that desirable varieties of asbestos as for example *chrysotile*, if obtained say from Arizona or Rhodesia, would be of a definite quality and be immediately applicable for the purpose intended. However, due to the fact that the geographical locations to which the many varieties are assigned on the basis of important deposits (see Plate 2), are areas of enormous extent, several or many of the varieties of asbestos have been discovered in each of the areas while new discoveries are being reported every year. This together with the opening up of roads to many previously inaccessible deposits and the introduction of modern mining methods, has made available for the market demand, an increasing supply of every important variety. The geographical location of the deposits, therefore, although an important guide as to the variety likely to be obtained, is no longer conclusive.

By examination of the chemical analyses of the various classes and varieties recorded by many authorities, it will be observed that there is a striking similarity in chemical composition of *chrysotile* asbestos from widely separated deposits, but on the contrary, there is a distinct difference in chemical composition between *chrysotile* and the *amphibole group*. Representative analyses showing the similarities and differences are compiled as follows:

CHRYSOTILE.

	Canada (Thetford).	*Canada (Danville).*
	Per cent	Per cent
Silica	39–43	41.8–42.8
Alumina	1.5–3.5	
Iron Oxide	0.2–2.5	2.2–3.7
Magnesia	40.0–41.5	39.5–42.0
Water	14.0–14.5	14.0–14.5
	Russia (Ural).	*Russia (Siberia).*
	Per cent	Per cent
Silica	42.5–43.5	41.5–42.0
Alumina	Traces to 0.5	Traces to 0.5
Iron Oxide	Traces to 0.15	6.0–7.0
Magnesia	41.8–42.6	35.1–36.0
Water	14.3–15.3	16.0–16.5
	Africa (Rhodesia).	*Italy (Cyprus).*
	Per cent	Per cent
Silica	40.0–43.0	40.6
Alumina	0.6–1.7	1.0
Iron Oxide	Traces to 4.5	4.9
Magnesia	38.2–39.6	39.0
Water	13.0–14.5	14.5
	Arizona (U. S. A.)— *Typical.*	*Africa (Rhodesia)*— *Typical.*
	Per cent	Per cent
Silica	40.5	40.99
Alumina	0.17	1.03
Iron Oxide	1.80	4.15
Magnesia	42.66	38.53
Water	15.40	13.24

AMPHIBOLE (HORNBLENDE).

	Cape Colony— *Crocidolite.*	*Transvaal—Amosite.*
	Per cent	Per cent
Silica	50.5–51.5	49.0–53.0
Alumina		5.7–9.4
Iron Oxide	35.5–36.0	34.0–44.0
Magnesia	0–3.0	0.7–6.2
Alkalines	7.5–9.0	0–2.5
Water	3.5–4.0	2.2–3.0

	Georgia (U. S. A.)— *Anthopyllite.*	*Natal—Tremolite.*
	Per cent	Per cent
Silica	56.4	58.8
Alumina	1.2	5.3
Iron Oxide	11.4	.....
Magnesia	28.7	22.7
Lime	1.7	10.6
Water	1.6	0.5

One of the striking things shown by the chemical analyses of the representative varieties, is in the water content. The chemical, latent water, water of crystallization or water of composition, all being synonymous terms, exists as part of the physical structure and plays an important part in the flexibility of the fibers. It has been determined by many investigators that the water content of the softer, and more flexible varieties contain, in general, from 14 to 17 per cent, while the less soft and less flexible varieties contain from approximately 10 to 12 per cent. Certain varieties of the *amphibole* group are extremely low in water content (2 to 4 per cent) and are listed as being very hard and brittle. All of the soft and flexible varieties, however, when heated to a high temperature sufficient to drive off the chemical water content, become transformed into a substance which can be readily pulverized by rubbing between fingers.

The connection between the water content and the flexibility of the various varieties of asbestos, has been firmly established in the trade practices and serves as one of the important identifications of the soft and flexible chrysotile variety which consistently contains 14 to 17 per cent water content.

Some asbestos fiber of good chemical composition for electrical use is found in localities where the surrounding rock contains large amounts of magnetic iron oxides or even free metallic iron and it is not practicable to eliminate this undersirable material from the crushed and fiberized asbestos. This factor of free magnetic iron known as magnetite therefore becomes very important in the analysis of asbestos to determine its suitability for electrical use. It does not form a chemical part of the asbestos but is associated with the fibers much like fleas on a dog.

MINING AND EXTRACTION.

Asbestos deposits in the various parts of the world are found in the form of veins in asbestos-bearing mineral rock (see Plate 3). It appears chiefly on the sides of low mountain ranges, or in surface cut-croppings of plateaus (see Plate 4). The mining methods depend largely on labor conditions and on the extent to which machinery is employed. On mountain slopes, it is extracted in terraces or caves hewn into the rock. The work in the open then progresses step by step along perpendicular sunken levels divided into terraces (see Plate 5). Where the deposits are on level ground, excavations are begun in round or angular form and are deepened in open cuttings, like amphitheaters. The pit thus formed is graded at one end, to allow the material to be hauled out (see Plate 6) or, the pit is surrounded by towers between which wire cables are stretched. Trolleys run back and forth along the cables carrying buckets or baskets of the mined mineral out of the pit (see Plate 7).

The mined rock (see Plate 8) is first subjected to a first rough sorting by hand before it leaves the place of its extraction. As far as practicable, adherent unusable rock is cobbed off, then the product is conveyed to a central point to be properly assorted according to the quality and length of the fibers. It is usual to separate the product into two general classes, the pure fibers and those adhering to rock. Each of these classes are subdivided into long, short or very fine grades.

Where modern machinery is available, the rock-borne asbestos is roughly broken up in stone crushers and stored for a period of time to dry out the free water so that the further processing may be effected. The product is then carried through a crushing mill where the rock becomes broken and separated from the fibers (see Plate 9). Modern machines are so designed and operated that the asbestos fibers of the first grade may not be destroyed and thus become suitable only for the manufacture of asbestos boards. The saving of the long fibers combined with the highest attainable *quantity*, is one of the most important problems as the commercial value of the first grade long fiber asbestos is many times that of the lower grade short fiber product.

After the crushing operation, the product is ready for a final forcible separation of the fibrous asbestos from the rock. This is accomplished in a revolving drum-shaped container in which revolves a shaft with a number of arms bearing long sharp-edged teeth or knives. In this process the fibrous mass is freed from the small remnants of rock which it still contains, and at the same time the bundles of fibers are separated or split open into characteristic filaments of asbestos. Plate 10 shows the relative volume occupied by equal weights of unopened and opened asbestos.

It is a curious fact that all asbestos fibers may be "opened up" or subdivided into an infinitesimal number of filaments. The only limiting factor is in the resistance of the fiber to being manipulated or "picked" into smaller divisions, or in the impracticability of human skill to further divide the fibers. One sample of asbestos fiber picked to fine filaments by the aid of needle points, when viewed at 500 magnifications was estimated to measure .000007 inch diameter. Examination of the ends of one of these isolated fine filaments, showed that it was made up of *innumerable* smaller filaments. The "softness" or the "fluffiness" of processed asbestos therefore becomes a matter of the latent water content and the extent to which the mechanical separation is accomplished. Certain varieties of asbestos open readily while others *resist* being opened to the same extent. These factors are associated with the basic varieties of asbestos and serve to further determine the commercial value or use to which they are finally applied.

When the process of final crushing of the stone is completed and the fibers "opened," the material is then passed through shaker-sieves where the rock about the size of grains of corn, drops through as waste, and the light, pure asbestos fibers are blown by compressed air into collecting bins. The rock remaining in the sieves, which still contains some fine fibered asbestos, is carried to additional crushing machines where the remaining fibers are extracted by suction blowers.

The dust arising from the separation processes is extremely troublesome and has led to many ingenious schemes to lessen the hazard and inconvenience to the workers. The use of air suction blowers in many parts of the processes has greatly reduced the annoyance, but even so, the fineness of some of the asbestos set

loose in the processing at the mines or in the factories using raw asbestos, surpasses all imagination. The fibers floating in the air may vary from the visible diameter of a spider's web to sizes a thousandth or a millionth, invisible to the human eye as single fibers, but seen collectively as a foggy haze which settles in every niche and corner of the factory. A wire mesh screen with 1-inch holes, has been observed in a factory where in the course of time the floating asbestos bridged the entire screen with fairylike invisible fibers, which remade the screen into a solid translucent window.

THE APPLICATION OF ASBESTOS.

After the separation, opening of the fibers and grading according to quality and length, the product is ready for fabrication into the many forms of materials as we use them today. Among the important applications for mechanical purposes are: brake linings, shingles, wall-boards, flooring, steam packings, pipe coverings, filters for corrosive liquids, furnace linings, fire-proof clothing, etc. For these uses, asbestos is mechanically combined with various materials to obtain the resultant properties desired. Such materials may be asphalt, rubber, cement, magnesia, saw-dust, cork, cotton and many other ingredients. Plate 11 shows a batch of selected chrysotile asbestos blended with 10 per cent cotton being fed into a carding machine as the first stage in making asbestos roving for electric cables. Plate 12 shows the exit from a carding machine of blended asbestos in the form of a mat being folded and carried on a conveyor to the next process. Plate 13 shows a "cheese" of asbestos roving in which the mat of asbestos has been worked loosely around a cotton thread core to obtain the necessary strength for further fabrication. This roving forms the basis of the dense compact felted walls of asbestos insulation as applied to flameproof cables. Plate 14 shows a number of "cheeses" of asbestos being worked into the form of strong asbestos yarn suitable for the outer braid of a flame resisting electric cable.

For electrical purposes, asbestos for U. S. Navy requirements is used in four principal combinations as follows:

(*a*) Switchboard panels of the larger sizes for mounting electrical apparatus not exceeding 600 volts. In this form, the medium length fiber chrysotile asbestos is used as a matrix with hydraulic

cements, impregnated with water-proof asphaltic compounds. It has replaced the former slate and marble switchboard on account of *the greater resistance to mechanical shock.*

(*b*) Molded phenolic compounds used in many forms of small electrical devices and accessories requiring some resistance to flame or high heat. In this application, short fiber chrysotile asbestos is used as a matrix and serves to increase the mechanical strength and flame resistance of the phenolic compound. It has, in general, replaced porcelain and other vitreous materials formerly used in the U. S. Navy.

(*c*) Insulation for copper wire used in motor or generator field coils and armature windings, where the operating temperatures are beyond the range of organic insulations. In this application, long fiber chrysotile asbestos, in which a small percentage of cotton may be incorporated to produce a workable roving, is spun on the conductor and felted into an elastic covering with flame and water resisting compounds.

(*d*) Insulated cables for light and power, where high ambient temperature is encountered, such as boiler and engine room spaces on shipboard. In this application long-fibered chrysotile asbestos is felted with a matrix of about 15 per cent cotton and is applied as a protective covering over vulcanized rubber wall or varnished cambric tape which are used as the primary insulation. The asbestos covering is impregnated with flame and water resisting compounds and serves as a secondary insulation after fire has destroyed or carbonized the inflammable primary insulation.

THE PROPERTIES OF ASBESTOS.

In considering the use of asbestos from an engineering standpoint, the basic physical properties should be carefully weighed so that full advantage may be taken of its desirable characteristics with due regard for certain unsatisfactory properties which may result in misapplication.

There is not a great deal of literature available on the technical properties of asbestos and if recourse is made to the adaptations of asbestos as described and catalogued by the various manufacturers of asbestos products, the user may perhaps be misled to some extent unless informed of the desirable and undesirable properties from the user's standpoint.

Let us then catalogue the known properties of asbestos so that in the application, the results to be expected may be predetermined to a degree which will avoid misapplication.

(*a*) *Non-decaying.*—This property possessed by asbestos, is often forgotten in considering application. It is evident that since asbestos in its natural state has existed for periods estimated in millions of years under all conditions of exposure to the elements, the non-decaying property is established to a firm degree which in its application is strongly contrasted with decayable organic materials such as wood, cotton, cork, hemp, silk, etc. The non-decaying properties of asbestos in many applications, may be considered to be of first importance.

(*b*) *Non-inflammability.*—This property, of course, is the one which is the most usual to recognize and associate with asbestos. Being a true mineral, it has no tendency to ignite or burn when held in a flame. The effect, however, of applying high temperature, is to drive off the water of crystallization. Asbestos in this form entirely loses its flexible fibrous property and may readily be reduced to powder. It is stated that Canada *chrysotile* withstands temperatures of 2000 to 3000 degrees F. and that a temperature of 5000 degrees produces no visible effect on some varieties. *Anthophyllite, tremolite* and *amosite* containing low percentages of water, in general, withstand higher temperatures than other varieties. Where the resistance to high temperatures is of first importance, selection should be made of the variety of asbestos of the higher qualification in this respect.

(*c*) *Acid Resistance.*—Certain varieties of asbestos such as *anthophyllite, tremolite, actinolite* and *crocidolite* are highly resistant to acids, alkalies and other corrosive liquids. These varieties have important application in the chemical industries as filters and caulking of apparatus whose contents contain chlorine, sulphuric acid, ammonia, poisonous gases, etc. The *chrysotile* variety used in the electrical arts, however, is not as acid resisting as the amphibole group.

(*d*) *Heat Conductivity and Heat Resistance.*—Asbestos does not have the low heat *conductivity* which is sometimes credited to it. In other words, as a heat *insulator*, it is inferior to such materials as cork, wood, hairfelt, rubber, cotton, wool and many other similar

classes of materials. The value of asbestos for heat *insulation*, is due to its non-inflammability and also to its fibrous structure which permits manufacture into coverings of porous nature containing air with resultant increase in its value as a heat insulator. The degree of heat conductivity or heat insulation obtained from asbestos depends almost entirely on the form in which it is fabricated or the materials with which it is impregnated. *In its natural unseparated* state, asbestos is a rock-hard material and could not be considered as a heat *insulator but rather* it would be classed as a *fair conductor* of heat, equivalent to natural stone, marble or slate. However *when fiberized* and fabricated into one of the many commercial forms such as corrugated asbestos paper, asbestos millboard, magnesia-asbestos steam pipe covering, etc., such materials are classed as heat *insulators* by virtue of the air entrapped in the resulting structure. Air, as we know, has a very high insulating value. Therefore, the actual numerical value of asbestos as a heat insulator depends, within certain limiting values, on the amount of air entrapped in the structure, the commercial structural form, and the heat insulating value of the materials incorporated with the asbestos. In general, the heat insulating value of any asbestos products fabricated for this purpose, is lower than cork, hair-felt or wool-felt. It is for this reason that these latter materials are used for refrigerating insulations and asbestos materials are used only where high heat or flame resistance is required *in addition to heat insulation*, such as applications for steam pipe coverings or oven linings.

Paradoxically as it may seem, asbestos when used as a flame resistance material for the protection and insulation of electric wires and cables, is so fabricated by tight assembly and impregnating waxes, as to result in a material which has fair heat *conductivity*. The heat conductivity obtained is about equal or inferior to rubber insulation which it replaces when flame resistant cables are required. It is fortunate for the industry that asbestos in the form used for this purpose has heat *conductance* of approximately the same order as rubber; for, if otherwise, the current carrying capacity of the copper conductors would have to be de-rated due to the fact that copper has a large positive temperature coefficient. If asbestos in this application turned out to be a good heat *insulator*, the electrical losses, due to lack of heat radiation, would become

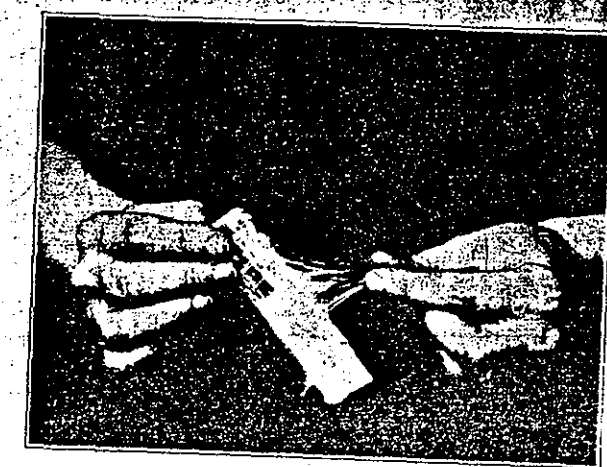

PLATE I.—THIS SHOWS THE SILKY NATURE OF ASBESTOS FIBERS. HARD AS ROCK IN THE VEIN, ASBESTOS IS SOFT AND FLUFFY WHEN FINALLY FIBERIZED.

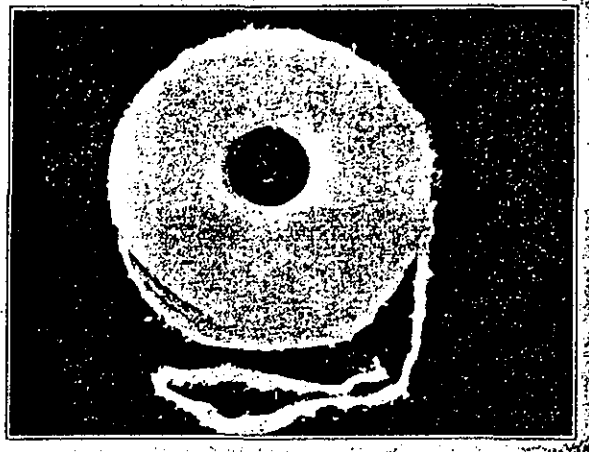

PLATE 13.—THIS IS THE PRODUCT OF THE CARDING PROCESS. SOFT, FLUFFY UNTWISTED ASBESTOS ROVING IS WOUND UP ON THESE FORMS OR PACKAGES CALLED CHEESES.

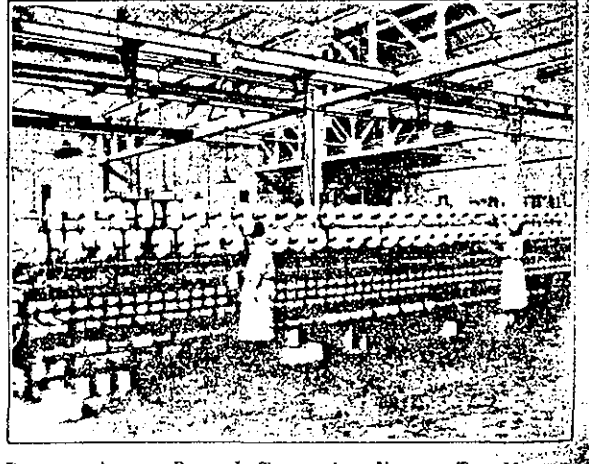

PLATE 14.—ASBESTOS ROVING IS TWISTED INTO YARN ON THIS MACHINE. LARGE PACKAGES OR "CHEESES" OF ROVING ARE MOUNTED AT THE TOP OF THE MACHINE. THE ROVING IS DRAWN OFF THE CHEESE AND [illegible]

progressively higher. The de-rating then would be necessary to a point where the electrical losses balanced the radiation factor of the insulation.

(*e*) *Electrical Resistance.*—Certain varieties of *chrysotile* asbestos lowest in iron content, such as is found almost exclusively in selected products of Arizona and South Africa, are the most suitable for electrical insulation. Iron may exist in asbestos as magnetic iron, iron oxide or as a silicate of iron. The presence of magnetic iron directly affects the electrical resistance of the product while in the other forms it is regarded as an impurity more or less inert from an electrical standpoint.

In the use of asbestos for electrical insulation, it is necessary to impregnate the fibers with water-resisting compounds. This is due to the fact that the fibers readily absorb atmospheric moisture. The fibers of asbestos, unlike cotton, silk, wool, etc., do not absorb water into their structure but carry the moisture by external capillary action. For the same reason, any impregnating material applied to asbestos is not absorbed into the fiber structure but dependence is placed entirely on the ability of the impregnating material to seal the entrances to the fiber assembly.

In view of the foregoing, it is difficult to assign definite values of electrical resistance to asbestos unless a definite fabricated product is specified. In the form of switch-board material, composed of asbestos and hydraulic cement, impregnated with asphaltic bitumen, the electrical resistance is rated in terms of breakdown volts per mil thickness (.001 inch). This varies from 50 to 75 volts per mil according to the total thickness of the material compared with varnished cambric 900 to 1400 volts or mica 4000 to 5000 volts per mil.

When impregnated asbestos is applied as a flame-resisting covering for electric cables, the assembly, including layers of varnished cambric tape, is rated at 2000 volts total. After a specified flame application which consumes part of the non-asbestos material, the break-down value per cable averages 900 to 1500 volts total or 45 to 75 volts per mil of composite insulation.

When asbestos is incorporated with phenolic material and is *molded into various shapes for lamp sockets, switch bases, etc., the* break-down volts average 400 to 500 per mil. This fairly high

value of course is due to the property of the phenolic compound rather than to the asbestos.

The electrical resistance values of asbestos, as indicated from the foregoing, has no definite value in itself, except to indicate that in general it is to be classed as a non-conductor. The properties of asbestos which are exploited in its assembly with other electrical materials are in the main purely mechanical, that is, used for its permanence, flame-resistance, as an inert matrix for impregnating insulating compounds, and as a structural re-inforcement for phenolic molded compounds or other similar composite assemblies.

SUMMARY.

An attempt has been made to indicate the diversified properties of asbestos and its application especially to the electrical industries as applied to materials used in the U. S. Navy. The principal advantages in the use of asbestos for the above purposes may be summarized as follows:

(a) Used as a matrix for other electrical materials to increase the mechanical strength and resistance to shock.

(b) Used to prevent or retard the total destruction by external or internal fire of basic electrical insulating materials such as: rubber, varnished cambric, cotton, silk, enamel, varnish and phenolic compounds.

(c) Used as a secondary insulation when heat has completely destroyed or carbonized the basic electrical insulating materials which, excluding mica and vitreous materials, are invariably inflammable or readily carbonized at fairly low temperatures.

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[1] D. W. Taylor,
(1935).

[2] This coefficient
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