

## THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, November 15<sup>th</sup>, 1892.

The 71st meeting of the Institute was held, this date, at 12 West 31st street. The meeting was called to order at 9 P. M. by Vice-President Hammer. In accordance with the notice issued, Dr. James Bowstead Williams made insulation tests of samples of various wires, using the apparatus described in his paper on "Oil versus Air as an Insulating Medium," beginning on page 601 of this volume.

The following associate members were elected at the meeting of Council:

Name.	Address.	Endorsed by
ARNOLD, CRAIG R.	Electrician and Treasurer Arnold Electric M'fg Co., Chester, Penn.	Carl Hering. H. C. Townsend. C. O. Mailloux.
BOHM, LUDWIG K. <i>Ph.D.</i> ,	Consulting Electrical & Chemical Expert, 81 Nassau St., New York City.	Carl Hering. Edwd. Caldwell. Wm. A. Rosenbaum.
DURANT, EDWARD	Electrician, with F. Pearce, 115 E. 26th St., New York City.	James Hamblet. Geo. F. Durant. R. W. Pope.
GALE, HORACE B.	Consulting Electrical and Mechanical Engineer, 40 California St., San Francisco, Cal.	E. J. Molera. W. F. C. Hasson. F. G. Cartwright.
HUNTING, FRED S.	Electrical Engineer, Fort Wayne Electric Co., Fort Wayne, Ind.	R. H. Read. A. S. Kimball. R. W. Pope.
McELROY, JAMES F.	Mechanical Sup't, The Consolidated Car Heating Co., 131 Lake Ave., Albany, N. Y.	W. C. Miller. F. L. Woodward. R. W. Pope.
STAHL, TH.	Creusot Works, Creusot, France.	C. P. Steinmetz. S. D. Field. R. W. Pope.
Total, 7.		

The following associate members were also transferred to full membership, their applications having been approved by the Board of Examiners.

BOURNE, FRANK	Electrical Engineer, Field Engineering Co., 143 Liberty St., New York City.
THOMAS, BENJ. F.	Professor of Physics, Ohio State University, Columbus, Ohio.
WURTS, ALEXANDER J.	Electrical Expert, Westinghouse Electric & M'fg. Co., Pittsburg, Pa.
METCALFE, GEORGE R.	Electrical Engineer, Editor, <i>Electricity</i> , New York City.
STILLWELL, LEWIS B.	Electrical Engineer, Westinghouse Electric & M'fg. Co., Pittsburg, Pa.

otal, 5.

## AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK CITY, December 21, 1892.

The Seventy-second meeting of the Institute was held this date, and in the absence of the President, was called to order by Vice-President Hammer, who acted as Chairman.

THE SECRETARY:—The next meeting of the Institute will be held on January 17th, when a paper will be read by Mr. Caryl D. Haskins of Lynn, Mass., on "Recording Electrical Meters."

At the meeting of Council, held this afternoon, the following Associate Members were elected:

Name.	Address.	Endorsed by
BLUME, JOHN C.	Assistant Electrician, American Telegraph and Telephone Co., 23 East 31st St., New York City.	F. A. Pickernell. Thos. D. Lockwood.
BOUGHAN, EDWARD L.	Supply Agent, American Telephone and Telegraph Co., 18 Cortlandt St., New York City.	F. A. Pickernell. T. D. Lockwood. Geo. A. Hamilton.
CARSON, DAVID I.	Sec'y and Gen. Supt., the Southern Bell Telephone and Telegraph Co., 18 Cortlandt St., N. Y. City.	F. A. Pickernell. G. A. Hamilton. Thos. D. Lockwood.
CREHORE, ALBERT CUSHING	Instructor in Physics, Cornell University, 117 East Buffalo St., Ithaca, N. Y.	Edw. L. Nichols. Ernest Merritt. Harris J. Ryan.
DUNBAR, F. W.	Assistant Electrician, American Telephone and Telegraph Co., 153 Cedar St., New York City.	G. A. Hamilton. F. A. Pickernell. Thos. D. Lockwood.
MAURO, PHILIP	Counsellor-at-Law in Patent Causes, (Pollock & Mauro), 620 F. St., Washington, D. C.	F. L. Freeman. E. Berliner. Thos. D. Lockwood.
MORROW, JOHN THOMAS	Electrical Engineer, General Electric Co., Lynn, Mass.	Elihu Thomson. E. W. Rice, Jr. H. F. Parshall.
PARKHURST, LIEUT. CHARLES D.	Inspector, Watervliet Arsenal, West Troy, N. Y.	Louis Duncan. E. G. Bernard. Geo. O. Squier
Total, 8.		

At the meeting of Council, held in Chicago, June 7th, the following Associate Members were elected.

BUBERT, J. F.	Electrical Engineer, The Mather Electric Co., 116 Bedford St., Boston, Mass.	W. A. Anthony. John Waring. W. H. Powell.
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## 796 ASSOCIATE MEMBERS ELECTED AND TRANSFERRED.

CLAFLIN, ADAMS D.	General Manager, The Mather Electric Co., 116 Bedford St., Boston, Mass.	W. A. Anthony. John Waring. W. H. Powell.
FORD, WM. S.	Assistant to Chief Engineer, The American Bell Telephone Co., Room 73, 125 Milk St., Boston, Mass.	T. D. Lockwood. I. H. Farnham. J. J. Carty.
SHAIN, CHARLES D.	District Manager, Edison General Electric Co., 44 Broad St., Box 3067, New York City.	Geo. M. Phelps. T. C. Martin. Jos. Wetzler.
THOMAS, BENJAMIN F.	Professor of Physics, Ohio State University, Columbus, O.	R. W. Pope. T. C. Martin. Jos. Wetzler.
WELLS, DOUGLAS	Sup't of Telegraphs, and Engineer to Government, Nassau, Bahamas.	Herbert L. Webb. G. A. Hamilton. R. W. Pope.
Total, 6.		

The following Associate Members were transferred to full membership, their applications having been approved by the Board of Examiners.

MOLERA, E. J.	Civil Engineer, 40 California St., San Francisco, Cal.
WILSON, HARRY C.	Sup't. of P. O. Telegraph with the Government, Kingston, Jamaica, W. I.
CHANDLER, CHARLES F.	Professor of Chemistry, Columbia College, New York City.

### REPORT OF MEETING OF BOARD OF EXAMINERS, DEC. 6TH, 1892.

Present—Messrs. W. B. Vansize, Chairman, E. T. Birdsall, G. A. Hamilton,  
C. O. Mailloux and E. P. Thompson. R. W. Pope, Secretary, present  
*ex officio*.

New applica- tions considered.	Applications reconsidered.	Approved and reported to Council.	Disapproved.	Laid over for further consideration.	Total considered.
	9	7	2		9
23		4	11	8	23
Totals, 23	9	11	13	8	32

THE CHAIRMAN :—[Vice President Hammer.] Probably you all have noticed little slips of paper on the seats and wondered what they referred to. The Council has, for several years, endeavored to secure something in the way of a badge which would meet the approval of the members of the Institute. Various committees have been appointed and the most recent committee, of which I happen to be a member, has presented quite a variety of wax models and sketches and drawings of different badges, and at the Council meeting this afternoon one of these badges was presented, and I asked the permission of the Council to put these papers in the seats with a view of spreading this matter more fully among the members and bringing out the suggestions that they may have to make. There is a feeling

that we should adopt something in the way of a badge, especially in view of the approaching World's Fair and the meetings connected therewith. All the engineering societies, with the exception of ours, have special badges. The Committee has under consideration also, a certificate of membership. I have here a small badge made up according to the paper that you find in the seats, and after the meeting is over I shall be very pleased to show it to any of the members who desire to see it. It is a thing which we cannot discuss now, but the Council through the Secretary will be very glad to receive any suggestions from any of the members as to improvements in this design, or criticisms upon it in any way. All that we wish to do is to secure the best thing and something that is endorsed by a majority of the members. I might say that the little sketch on the blackboard, which is, however, very crude, gives a slight idea of it. After the meeting is over, the badge, made up exactly as it is represented, can be seen.

We will now have the pleasure of listening to a paper entitled "Micanite, and Its Application to Armature Insulation," by Mr. Edward P. Thompson, Member, for Messrs. C. W. Jefferson and A. H. S. Dyer.

The following paper was then read by Mr. Jefferson :

## MICANITE, AND ITS APPLICATION TO ARMATURE INSULATION.

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BY EDWARD P. THOMPSON, M. E., FOR CHARLES W. JEFFERSON AND  
ARTHUR H. S. DYER.

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An armature and its commutator consist of the combination of two elements; namely, electric and magnetic conductors and insulators. In the earlier days of armatures, the electrical and mechanical dimensions and proportions of the conductors were considered of prime importance. The first armatures were small and the electromotive force low, and consequently little attention, comparatively, was given to the element, insulation. Lately, simply paper, cloth, convolutions of ligatures, or these materials impregnated with shellac or similar insulating varnish or paint, were employed for the purpose of preventing leakage or short-circuit. To remove the solvent of the shellac, the armatures were baked for twenty-four hours. Judging from the variety of materials used at present, and the changes from one material to another, it would seem that the insulators are now receiving their share of consideration, while the core, wires, commutator-sections and other conducting portions are secondary details. Why so much difficulty with armature insulators and so little with other insulators, such as line insulators? Because, in the former, not only must the material be of extremely high resistance, but also unaltered under the effects of heat, and must be crowded into very small quarters. Space must be economized. If the electric current or heat alone were present, and if space were not so much limited, the problem would be easily solved. It yet remains to be proved that any known substance is abso-

lutely a non-conductor—nor is the resistance of a given conductor constant. Unfortunately for the armature constructor, the worse the conductor, the less the resistance with increase of temperature. An extra current is produced in metals upon variations of current. A diminishing of current occurs when first entering a substance of high resistance. Finally, and gradually the current becomes constant. This action for convenience is often called polarization. As this property is noticeable only in long lengths of the insulating material, it has little bearing upon any of the armature elements other than in connection with the covering of the wires. The substance possessing the property of polarization in a marked degree is gutta-percha.

Paper or fabrics by themselves, should never be used as an insulator, because when moist they conduct a current so well that they may properly be termed semi-conductors. A coating of shellac or oil upon almost any substance enormously increases its resistance, and protects porous and deliquescent substances from water. Paper thus covered, serves with machines of low electromotive force, the purpose of preventing leakage, but, by no means perfectly in practice, with large machines. Its advantages are more in the nature of convenience and cheapness than of efficiency.

Paper which has been thoroughly dried is of very much higher resistance—so high that it falls under the head of non-conductors, and therefore, the shellacs should not be applied until after the paper has been subjected to a thorough drying process.

It is a peculiar property that a given substance in a compact condition is of very marked higher resistance than when powdered or comminuted; for example, pulverized glass is a semi-conductor, while sheet glass is as high in resistance as silk. This property has been noticeable in armature practice. If the insulating material is cracked here and there, it is unfit for armature use. The cracks are in the nature of interstices between the particles of a powder, and at the cracks the material is in part ground. The explanation may lie in the distinction that the pulverized material has more surface, or that damp air exists in the spaces between the particles, or that a spark can traverse a gas better than a solid, or that each particle becomes coated with a film of moisture. The last seems the most probable, because the best surface concentrators of water usually exhibit the property most strongly.

The locations of insulation in an armature are between the armature disks to prevent eddy and Foucault currents; between the core and the windings to prevent the current from short-circuiting the coils through the core and burning out the armature; between the commutator-sections to prevent leakage from one coil to another; over projections or in grooves in the core; and around the wire to guide the current in convolutions. All these parts, even in the best made armatures become more or less abnormally hot. Means have been planned and sometimes put into practice for cooling the parts, and thereby saving the insulation. One method consists in constructing the armature after the style of a fan or with large radiating surface; another, in equipping a device to blow out the sparks at the commutator, and again, in using cooling insulating liquids. With whatever precautionary means the machine is equipped, the parts, either accidentally or through inefficiency of means, will become abnormally hot. The machine will be injured if combustible materials form the bulk of the insulator. The materials of an ideal armature consist of copper, iron, and a heat-proof and water-proof non-conductor. If the material is combustible, or altered in its chemical nature, by heat, its resistance is changed and generally lowered. Manufacturers of incandescent lamp filaments know that complete carbonization cannot take place except at a very high temperature, like 3000 degrees Fahrenheit. An armature may rise to 500 degrees. At this temperature, easily carbonizable materials, such as linen, cotton and other forms of cellulose are weakened, blackened and the resistance reduced. Shellac, although blackened at this temperature, is converted into those compounds whose resistance is not lowered. Shellac forms an exception therefore, in being charred by such a temperature without reduction of resistance.

There is a greater detriment than chemical change by heat. The material cracks, becomes somewhat comminuted, and the resistances, both mechanical and electrical are therefore greatly reduced. If paper or cloth, or even shellac is depended upon as the insulating material rather than as the binding material, it is not electricity proof; because principally, it becomes, when charred fractured at numerous points, if not completely pulverized. As to why shellac is not appreciably lowered in resistance by partial carbonization may be because it is an animal substance.

One of the most important attributes of an armature should be its rigidity. It should be like a rock in this particular. If the

insulation should consist of a soluble material, for example, and the same dissolved out after the completion of the armature; or of some material that would be reduced in size by heat; then the wire and bolts would soon become loose from the rapid rotation and vibration, and finally the armature would be useless. Change in volume of the insulators has caused nine-tenths of the armature break-downs.

In the matter of insulation between the disks it was found that oxidized or rusted laminated armature disks would insulate without any addition of paper or similar insulating films. The only difficulty with such a construction is one of degree. Iron rust insulates, and it is heat-proof; but it does not insulate sufficiently to compensate in most instances for its simplicity and cheapness, and besides it is not applicable to any other part of the armature than between the laminae of the core. The great advantage lies in the extreme thinness of the oxide coating, whereby a large amount of iron is obtained in the core. A modification has been suggested, which consists in placing thin mica sheets between every half-dozen of the disks. Again, iron wire, or ribbon rusted has been employed for armature cores. The wire or ribbon is formed into a ring, around which is the electric conductor. Another modification consists in case-hardening the iron, and also in japping the surface. As to commutator insulation, natural mica sheets have been almost universally employed.

If it were not for the matter of mechanical construction and heat, glass would make a good armature insulator. It could be molded into any form and made of any degree of thinness. Its objections, however, are well known. Very gradually, and more so than would be conjectured, mica made its appearance in armatures. The introduction of mica into practice appears to have been brought about in the following manner:—An accident would happen to an armature, and before the next night it must needs be repaired. In order to make the temporary remedy, mica sheets or bars would be interposed. In the case of subsequent accidents, the portion repaired by mica was the last to yield. Therefore it was proposed to build the armature primarily with mica. But this change took place very, very gradually, but surely. Manufacturers of stoves, the leading houses being also importers of mica, soon experienced a growth in the mica department of their business, until at present some import more for the electrical industry, especially for armature use, than for



stoves. Why it was not employed from the first, no one could positively assert, otherwise than to guess that no one probably thought of it, or insulation was not considered of much comparative importance, or cheapness of material in construction was allowed to counterbalance efficiency of action and durability.

Of all substances, mica probably is the best material for use in armatures, if it is desired to obtain not only efficient electric insulation, but also durability under the influence of heat. The highest temperature to which an armature is subjected, even by short-circuit or bad construction, will have no injurious effect upon mica. Mica, thick or thin, may be held in a gas flame without cracking, burning or melting. It remains unaffected. The reason of this is better understood when it is remembered that it consists of aluminic silicate, containing also potassic, sodic and lithic silicates, and some ferrous and ferric and manganic oxides. Its chemical constitution varies.

One quality of mica is that which is commercially termed *amber mica*, and is usually mined in Canada. It is so named from its appearance and not because it is amber or in any other way similar to it than in its color. *India mica* is a commercial form noted for its uniform cleavage, extreme thinness of its laminae, flexibility without fracture and its resistance, which is much higher than that of amber. *Carolina mica* is another variety. It is obtained in sheets in the western part of North Carolina. It is the best mica for stoves, but it is too hard for some electrical purposes. Mica occurs in so many specific forms that particular names have been given to it.

*Muscovite* is one of the most common varieties. It occurs in different colors, namely, a dark green, yellow, brown, white and gray. This is the form usually found in small scales in granite, gneiss, and mica schist, and at the same time it occurs in larger, tougher sheets than any other form. A complete scale is irregularly hexagonal in shape. *Lepidolite*, or *lithia mica*, has a pearly lustre, as distinguished from the vitreous luster of *muscovite*. Its scales are usually very small, and it is found in limited varieties of granite and gneiss. *Cryopholite* is a subvariety of *lepidolite*. A characteristic feature of the form *meionite* consists in its occurring much cracked within. It has been found in geodes. *Biotite* is a form found in volcanic rocks in small scales. It contains much iron and magnesia compounds. *Phlogopite* occurs usually in limestone. Its subvarieties are *aspidolite* and *mangan-*

ophyllite. A very brittle variety is lepidomelane. It is also practically opaque. Its subvariety is astrophyllite.

The insulating power of mica is superior to that of any other substance applicable to armatures. An advantage, peculiar to itself, is its even, laminated structure. How wonderful is the thinness of its individual layers! A piece of ordinary writing paper is about .005 inch. Mica layers have been obtained of a thinness of .00003 inch. Mechanical difficulties prevent its being split thinner. By pasting it upon a hard surface and splitting it off as much as possible, the remaining fragments are so thin as to become beautifully iridescent. The builder of armatures can therefore split the sheets into any desired and uniform thickness with great ease and accuracy. An interesting property of mica and one not generally recognized, is its homogeneity of structure and clear transparency, although so black when thick. The writer used a piece one-quarter of an inch thick for observing the late solar eclipse. The effect was better than with smoked glass and as efficient as black glass much thicker.

A valuable property of mica in connection with commutator insulation is its proper degree of hardness, whereby it does not wear away too rapidly under the action of the brushes. If rubber were used, for example, even if it did not burn, yet it would wear off and sparking result, because the commutator surface would not be truly cylindrical. The brushes would be set into vibration. Again, mica is capable of the finest pulverization, so that any wearing which does take place does not result in the liberation of gritty particles, which would also cause sparking. Such mishaps occur with hardened artificial plastic insulators. The insulation should be just so thick that the current cannot jump across from one section to the other.

Although so superior for armature insulation, mica is, in its natural structure, accompanied by certain objections, which, in trying to overcome, were more serious than had been anticipated, as it was not until after a long series of trials that a successful article was produced, and not until a novel apparatus for cheapening the process of manufacture was devised. The apparatus is now in operation on a large scale. The description at present is confined, however, to the article, and to full information of its structure, manner of using and properties.

The objections alluded to are:—Mica, as found in nature, occurs in flat sheets only. It has a high degree of elasticity, so that

when once bent and released, it assumes its original form. If folded, its brittleness causes fracture. If the natural sheets are compressed in a mold, to try to form armature insulator heads for instance, it is completely broken up.

Secondly. Natural mica sheets correspond financially to plate glass. The larger the sheet, the higher the cost per square inch. Mica in small pieces, from four to six square inches, is exceed-

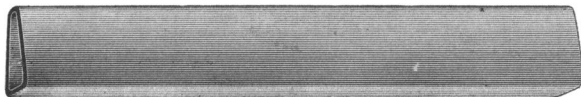


FIG. 1.—Micanite tube for insulating core projections.

ingly abundant and very cheap. It is often called waste mica, because very limited in its uses, and consisting often of trimmings from larger and more useful sheets. In medium and large sizes of armatures, the naturally built up mica is so expensive as to be objectionable, although not so much so as to entirely prevent its employment.

Thirdly. Between the hundreds, nay, thousands, of thin layers, damp air can enter, and also water, accidentally, which cannot easily or effectually be removed.

Fourthly. Mica splits so easily that handling causes injury.

Fifthly. Mica cannot be cut transversely to advantage. The edges are unworkmanlike, being ragged and jagged. Neatness in drilling, sawing and turning is difficult.

Among the attempts which have been made to overcome these

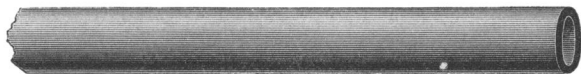


FIG. 2.—Micanite tube.

objections are those involving the use of pulverized or comminuted mica, which is mixed with a liquid cement and stirred into a paste. While still soft the mixture is rolled or compressed into any desired form, as if consisting of so much plaster-of-paris. In order to give it sufficient strength, one-third of the product is cement. The mica sparkles here and there on the surface, as it glitters on granite. This article should be called a cement insulator, and not a mica insulator, because the current can flow in a

straight circuit through the plate without encountering any mica. The cement forms numerous rectilinear paths for the current, independently of the mica; and therefore the product is in no sense an equivalent of mica.

A modification of this type of insulator consists of a coarse and thick textile fabric, whose pores and meshes are filled with a mixture composed of comminuted mica and a suitable adhesive substance. Another consists of finely divided asbestos mixed with pulverized mica, silicate of soda, and sulphur compounds. It is molded by pressure into any desired form.

The comminuted mica-cement type is useful in trolley wire supports and similar insulators, but for dynamos it is useless not only for the reason stated, but because of its softening and running under slight heat, being so necessarily rich in cement. If the cement is that kind that chars, the mica crumbles apart. Mineral powders have been mixed with it, to render it more fire-proof.

An example of the manner of using non-comminuted mica between the core and the windings consists in covering the core



FIG. 3.—Micanite armature slot insulator.

with paper, laying sheets of mica over the paper, then laying on another sheet of paper, fastening the whole together by convolutions of cord or similar ligatures, and finally applying the coils. During operation, the paper and mica may shift from their positions, and thereby affect the rigidity of the armature as a whole. Again, the process of applying the pieces, and keeping them temporarily in position, requires repeated efforts and results in a display of crude workmanship.

The exhibits before you show practical results of work carried on for the purpose of overcoming the objections named.

*Large Plates.*—One of these plates is a yard square and .035 inch thick. Another is of the same size and 1 in. thick, and another about 4 in. by 12 in. and 1 in. thick. They have nothing to do directly with the armature; but could serve as foundation plates for a dynamo or motor. They are practically all mica. A *natural* plate of mica of the larger size would be a curiosity—a rarity. Any of the sheets may be cut

up into any desired size and shape. The layers cling together much more tenaciously than in the natural plate. The path of least resistance from one side of the plate to the other is in a straight line, and a straight line intersects numerous mica sheets, and, therefore, the article is a mica insulator and not a cement insulator. These plates are made by such steps and apparatus

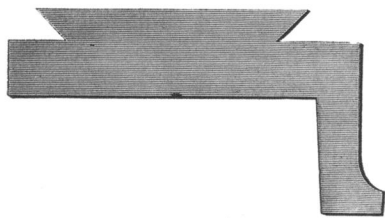


FIG. 4.—Micanite commutator-segment insulator.

that when subjected to heat in the armature, no injury whatever is produced.

Further, they are superior to a sheet of mica as it comes from the quarry, in that they do not absorb water or damp air; in that they are stronger to resist either pressure or tension; in that they may be neatly and easily sawed and drilled; in that they are enormously less costly; and in that they are of about the same resistance. By picking the exhibit apart, you can easily learn the structure. The mica of which it is composed is non-comminuted, but the pieces are exceedingly thin. The thickness is, by measurement, about .001 in., *i. e.*, about as thin as tissue

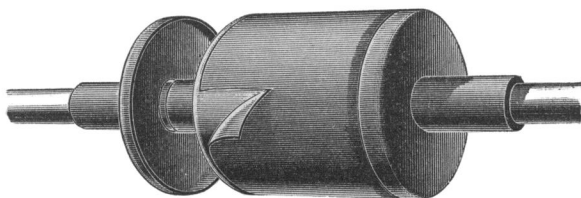


FIG. 5.—Complete drum-armature core protected with micanite.

paper. The sizes vary from 2, to 6 or 8 square inches. In each layer of mica, you may notice that the sheets overlap at their edges, and the cement between the layers is hardly noticeable. The former mentioned plate weighs about 4 lbs., and the latter over 100 lbs. It is a convenient quality in connection with mica that it can be split into pieces of the thickness re-

quired for the particular device under the process of construction. This property is also possessed by the plates exhibited. A thin and long knife may be caused to force its way in any of the many planes parallel to the surface, for the purpose of reducing the thickness or obtaining several thinner sheets from one thick plate.

Some tests were carried on to determine the relative values of these plates, and plates of comminuted mica and cement. Using the words of the electrician who originated and performed the tests, he says:—"For the purpose of insulating armatures, any solid insulating material should possess considerable strength and should maintain its strength when submitted to a moderate degree of heat. One piece tested consists of ground mica and shellac, mixed together and rolled or pressed between plates to a uniform thickness. In order to test it, I placed it upon a steam-table and left it for a minute, at the end of which period I tested its strength



FIG. 6.—Micanite ring for commutator.



FIG. 7.—Micanite washer.

by pressing the end of a piece of wire against its surface with very light pressure. The end of the wire, which was blunt and made of copper, easily pushed its way through the sheet and left a hole when removed. In removing the sheet from the steam-table it warped. The second plate consists of layers of sheets of mica, cemented together with overlapping joints. This sheet I placed on the same steam-table used for the other sheet, and after one minute had elapsed, tried to thrust the same piece of copper wire through the plate, but without success, though exerting all the strength that could be brought to bear upon it by my hand. After the sheet had been on the steam-table for five minutes, I placed it on a thick iron plate, laid a piece of the same copper wire upon its upper surface, put a second sheet of wrought-iron on top of it, and put the whole into a hydraulic press. It was then submitted to a pressure of 2,000 lbs. per square inch for one minute, and the result was the flattening of the wire and

a very slight crumpling of the mica sheet on the opposite side. The plate was then placed between two copper plates, and a weight of about four lbs. placed on the upper plate. The insulation resistance of the plate was then tested and found to be 25,500 megohms. I have used similar plates, similarly prepared, in motors, upon which a load of 50 H. P. has been placed, the entire thrust of the motor being received by the plates, which in this case were less than one-sixteenth of an inch thick. The temper-

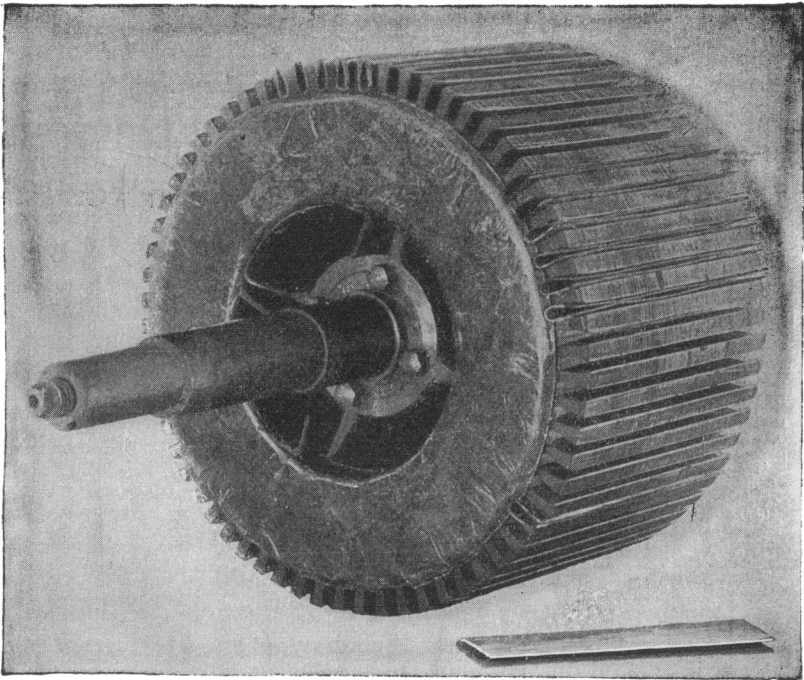


FIG. 8.—W. P. armature core showing application of micanite slot insulators, and annular flanged micanite head.

ature was brought up to 650 degrees Fahrenheit, sufficient to burn cotton and melt hard solder without injuring the insulation."

*Curved Specimens.*—Similar remarks substantially, may be made about these, as about the large plates. Natural mica plates could never be given a permanent set, or molded into curved forms. The armature head consists essentially of an annular disk, provided with flanges around one or both peripheries. It is

in one sense a continuous piece. The flanges, you may notice, are not made separably and then fastened to the disks. There are no joints. Some of the peculiarly curved forms are furnished in order to illustrate that the article may be manufactured in any imaginable form of uniform structure, and in single pieces of uniform properties throughout.

*Tubes.*—In order to show the unlimited forms into which the material may be molded, a tube several feet long is exhibited. It may be cut up for use in certain types of armature, or when long, for use on board ship, and in general interior conduit installations in certain limited cases.

*Stamped Forms.*—The flat pieces of peculiar form could be made from the beginning in individual pieces, but are much more economically stamped from larger plates. Before using the large plates for any purpose where an exact thickness is required, they are burnished or surfaced off by machinery. Some of the plates before you, are in the crude state, and little scales here and there can be peeled off. The others are so different as to resemble a metallic surface, and when struck, ring like metal. Some of the forms are for large commutators. Others are flat rings for field-magnet cores. The very irregular flat pieces are for certain types of commutators. On account of the almost metallic qualities the product can appropriately be termed an “insulating metal.” For convenience, it is called micanite.

*Commutators.*—In equipping a commutator with this material, it is necessary to know something which has been learned by early users, only through experience. The insulating and metal sections are put together in the usual manner, and the whole is heated to a temperature higher than that which it will reach in actual practice. While still hot, the elements are clamped tightly together.

Among the exhibits, is a mass of odd pieces of mica sometimes called waste mica; also, you will find similar pieces split as fine as possible. These are the result of the first operation. The next step consists in putting them together in the manner shown in the exhibits; that is, in layers with overlapping edges. Between them are layers of a cement having those qualities which fit the product for the purpose intended. Until only recently, these pieces were always laid on by hand. One girl could produce only one cubic foot per day. Now, one girl can do the work which formerly required twenty. The girl feeds the



machine, and it does the rest. The amount of cement employed is practically infinitesimal, because while in a plastic condition, the mass is subjected to such pressure that a mere trace remains, and yet sufficient to obtain proper adhesive qualities. From the beginning to the present, improved processes and new machinery have been required.

Dr. James Bowstead Williams has carried on a long series of tests upon the comparative specific resistance of mica and mica-nite. The data and results are as follows :

The conditions of the tests were absolutely the same in all cases. The potential was constant, being over 3,000 volts, A dynamometer served to maintain the same pressure for different materials. All the samples were kept at the same temperature and under the same hygroscopic conditions for several days. Samples were of uniform thickness. The best samples of mica-nite gave approximately the same reading as the best India mica, indicating that the resistance of mica-nite is equal to that of the best commercial mica.

I will close this paper by presenting certain topics which appear to be suitable for discussion, but which need not be adhered to. I hope you will discuss among yourselves as much as possible.

#### SUGGESTIVE TOPICS.

*Armature.*—Rigidity and its dependence upon insulating material employed. What has been learned by observation and special tests?

*Preservation of Insulation.*—Is it better to try to remove the cause of heating, or to neutralize the heat?

*Burning Out Armatures.*—What does insulation have to do with it, and what are the remedies? Also, what are the causes?

*Durability of Insulation.*—Differences in connection with armatures for inside use, such as installations and outside, *i. e.*, railway, mining and elevator use. Effects of atmosphere, motion and rough treatment.

*Financial.*—Does the expense of insulation, if the best, have an appreciable effect upon the cost of construction, and, on the other hand, will it pay in the end to put in a cheaper material?

*Comparative Merits of Insulating Materials for Different Conditions.*—Effects of high potential. Power to resist spark puncturing. What have tests shown as to properties of materials to withstand “break-downs,” independently of high ohmic resistance?

## DISCUSSION.

THE CHAIRMAN :—I am sure the members of the Institute have been much edified by the exceedingly interesting paper Mr. Thompson has presented to them this evening, and for my part I should like to see more papers of this practical character presented to the Institute together with exhibits such as Messrs. Jefferson and Dyer show here to-night.

Will Vice-President Hering please take the chair in order that I may open the discussion upon the paper?

[Vice-President Hering here took the chair.]

MR. HAMMER:—We see to-night what seems to be a most important advance in the art of armature insulation, which, while it may be new to many has, I understand, been thoroughly tested, endorsed and adopted by the largest electrical company in this country.

Some who are here can doubtless date their experience in armature insulation back a dozen years or longer, and tell tales of experiments with mica, paper, ebonite, plaster-of-paris, of fields bored out to receive armatures intended for other machines, and more often armatures swollen by heat, moisture, or mechanical expansion until the chafing against the pole-pieces necessitated such a step; of coils burnt out and rewound, burst bands replaced; of dynamos which would not energize their fields because of low resistance, crosses in the armature circuit, of experience with high bars, soft bars, disconnected bars, short-circuited and grounded bars in the commutator, and other troubles too numerous to mention, many of which, by reason of increased knowledge and improved methods the electrical engineer to-day knows little of.

Mr. Thompson very truthfully remarks "that change of volume has caused nine-tenths of the armature break-downs." This change of volume has been mainly due to mechanical strains and heat.

Moisture by lowering the insulation between adjacent coils, framework and coils, commutator and shaft, etc., causes grounds and short-circuits followed by overload, charring and burning of insulation and disastrous results; besides this, the swelling of substances used upon the armature which absorb moisture create serious mechanical difficulties, such as bursting of wire bands, chafing against field magnets, putting armature out of balance, etc.

Insulating materials which absorb oil and moisture should never be used. Paper and vulcanized fibres have been largely used in armature construction, and are pretty fair mechanically, and while suitable in constructing the core, are unsuitable for commutator insulation, as are plaster-of-paris, asbestos, and such substances. Air-gaps are sometimes employed but necessitate constant cleaning to prevent the copper or other metallic dust from the brushes and commutator collecting between and short-circuiting the commutator bars.

Heat affects insulating substances by contracting, expanding, charring and burning, according to the degree of heat and character of materials employed, and in armatures heat is produced by the resistance in the armature windings, overload on machine, heavy grounds, short-circuits, hysteresis, Foucault or eddy currents in iron cores, armature windings, conductors and magnet pole-pieces, and by the use of commutator bars or brushes of insufficient size or imperfect contact between the same; and in armatures of both dynamos and motors, heat will to some extent always be present, and as it cannot be entirely eliminated and is often excessive under conditions of overload and accident, the neutralization of the heating effects by the employment of high-class materials is of vital importance.

Increasing the speed, involves increase of mechanical difficulties due to centrifugal force, which strains connections at commutator bars, lugs and radial bars, endangers the insulation of overlapping coils at ends of the armature, and strains the bands of piano or other wire enclosing the coils. Furthermore, there is the "drag" produced upon the armature coils by the magnetic field which is constantly varying, causing a strain, and a racking strain is produced by armatures being out of balance, a fault which is still sometimes met with. Besides all these difficulties, high speed increases the friction of rubbing surfaces, and the difficulty and expense in lubrication of the same.

From the foregoing it is self-evident that it is of paramount importance in armature construction that materials be employed possessing strength, rigidity, excellent qualities to resist heat and moisture, and to the highest degree insulators of electricity. These qualities, experience has shown us mica possesses perhaps to a greater degree than any substance known, and apparently the inventors of the process which has resulted in the remarkable samples we see here to-night, have by using "scrap mica" silenced the objections to its extensive use on account of its price, and by the methods of manufacture, enabling them to form this refractory material into almost any shape, have very greatly enlarged mica's sphere of usefulness and conferred a great benefit upon the electrical profession and the world at large. It would be interesting to know the specific inductive capacity and specific resistance of the micanite or combination of mica and shellac.

Fleming Jenkins gives the specific inductive capacity of mica as compared with air as 5, while that of gum lac or shellac is as low as 1.95.

Gordon and Silow give shellac a value as compared with air of 2.74. Mica not given.

Culley gives shellac fourth place in the list of materials of highest resistance and lowest conductivity, rating dry air first, ebonite second and paraffin third.

Munroe and Jamieson give the same rating excepting in case of certain kinds of glass, which they rank as second.

Ayrton and Perry give as the approximate specific resistance of shellac after several minutes' electrification as over 100 times that of mica.

Extension of alternate current practice, and use of high potentials, especially in power transmission work, gives a far greater importance to insulating substances, such as are here shown and they should meet with an extensive application.

Besides its application to dynamo and motor work, there are other fields of great importance, such as in the construction of alternate current transformers, this method admitting of the forming of the insulating substance for separating the high and low potential coils, insulating the core and encasing the high potential leading-in wires, and in the construction of direct current motor transformers, which I look to as developing a large field in this country, this material should find an extensive application in insulating the high and low potential wires in the armature.

In physical apparatus, such as induction coils of large power, the problem of insulation is of vital importance. It is interesting to observe that the largest two coils ever made in the world, the Apps or Spottiswood coil in England, and the Wallace coil of this country, have both been pierced, due to insufficient insulation at the high potentials employed, notwithstanding the great care in manufacture. I have here a photograph of the great Wallace coil, made by William Wallace of Ansonia, Conn., in 1869-70, which gave a spark 27" in length.

In the construction of powerful condensers, lightning arresters, switch-boards, instrument and machine bases, a field is open to the employment of such materials.

As an indication of the high tension which will ultimately be employed in power transmission and other work, and the necessity of high-class insulation, it is interesting to note that the Ferranti company in England is now supplying electricity for lighting purposes from the Deptford station at a potential delivered direct from the dynamos to the Ferranti mains at 10,000 volts.

These mains consist of concentric tubes of copper insulated by paper and run underground to sub-stations where step-down transformers are employed. The manager informed me that they had had considerable difficulty in keeping up the insulation in the armature. Each day the fields are slid apart and the armature carefully cleaned. The paper-insulated tubes apparently worked very well, but judging from the row of burned out transformers I saw being repaired, there is an excellent field for micanite in the high-tension transformer industry.

I understand that this material is produced very cheaply, and while in armature work we must consider mechanical and electrical perfection first, some comparative figures showing the cost of the material would be interesting and appropriate in this paper.

Mr. Thompson refers to the use of micanite in long tubes aboard ship and in general interior conduit installations. I should like to learn if it can be made cheaply enough in this form to fill such requirements.

The Chair will call upon Mr. Harold Binney to continue the discussion.

MR. THOMPSON :—Mr. Binney has sent a note saying that he is prevented from appearing this evening. He had some notes written out, but not in proper form to be read. He expected to come at the last minute, but the doctor would not let him on account of sickness.

As to interior insulation for shops and houses, a micanite tube, I suppose, would be used in the most important places, as through partitions, if too expensive to use generally. I simply mentioned that as a possible use of it. The principal object in bringing the tubes before the meeting was to show in what curious forms the substance could be produced, the tube being probably the most difficult one. natural mica being never known in a tubular form. In ships its cost would not prevent its use, because so superior to cheaper insulators. The *best* should be employed in ships, regardless of cost.

MR. CHAS. P. STEINMETZ :—We have listened to-night and at the last meeting to some very interesting statements regarding that quality which is called electrical resistance—not the resistance offered to the currents flowing in our electric circuits which we want as low as possible, but that resistance which hinders the escape of current from our circuits, which resistance we want as high as possible. That is, in other words, the insulation resistance. I have given the problem of electric insulation a good deal of attention also in the last year, and have made quite a number of tests which I hope to be able at a future meeting to report more fully.

My experience, however, has led me to an opinion somewhat different from that generally expressed. *I believe very little in insulation resistance.* It is a very nice thing indeed—on paper—to read that the insulation resistance of a machine is twenty or thirty megohms, or even higher. But, when you have determined the insulation resistance in the usual way, by the deflection of the galvanometer using a storage battery of say 100 volts, and then starting the machine, relying upon the “insulating resistance” of 30 megohms, it is not so nice upon breaking the circuit for the first time to see the inductive discharge from the series field break clear through your 30 megohms, reducing the insulating resistance to nil, and burning out the armature.

While, at the other hand, the insulation resistance of the machine may be suspiciously low, only a few hundred thousands of ohms, and still the machine may run continuously for years and years, under all conditions of load and overload, without breaking down, nay, getting better all the time, the more the insulating material dries by the heat developed in the machine.

What we want is, to insulate the electric circuits of the machine so that the machine will stand and work without breakdown under all conditions of usage ; and as long as air, which is the *poorest* insulation, that is which breaks down easiest, has an *infinite* electric resistance, while just the *best* insulating materials—best in “disruptive strength,” that is standing electric stresses without giving way—as mica, have a comparatively *low* electric resistance, the insulating resistance gives us no indication as to the reliability of the insulation of the machine. To see this more plainly, let us examine the behavior of different insulating materials.

Take, for instance, two plates, put them against each other at a distance of, say, one-tenth of a millimeter, that is .004 of an inch of air between them. Now, measure the resistance at say 100 volts difference of potential between the plates. It is infinitely high. For I do not think anybody ever measured the true resistance of air and found any other result than infinite. Now, raise the potential difference between the plates to 500 volts. A spark will pass across the gap and this insulating resistance which a moment before was infinite, is now reduced to nil ; it has broken down. Now, replace the air-gap by a piece of dry fibre of the same thickness, and measure again the insulating resistance in the usual way. You will find the resistance measurable, hence infinitely smaller than the resistance of your air-gap. Still you may raise the potential to 500 or to 1,000 volts, and the fibre will stand the pressure. It will break down under a stress of about 1,300 volts. Now, replace the fibre sheet with a sheet of mica. The resistance is very much smaller than the resistance of the fibre, to say nothing of the air. But you may raise the difference of potential at the terminals to 10,000 or 20,000 volts and the mica sheet will stand. The electricity will rush out from the terminal plates upon the mica sheet in long, glowing streamers, beating against the mica with a hissing noise, and forming a broad, electrostatic aurora of violet light, and still the mica will not break down. This is the property we want, but this disruptive strength has nothing to do with insulating resistance. On the contrary, those insulating materials which have the highest resistance, like air, just happen to have the lowest disruptive strength, while those materials which are relatively inferior in insulating resistance, like mica, stand electric stress best. I have never found another material which will stand such enormous electrostatic stress, for the same thickness, as mica will stand, and still its electric resistance is comparatively low. The consequence, therefore, is, if we insulate a machine or any other apparatus, the measured insulating resistance will say nothing to us about the disruptive strength of the machine. There may be, perhaps, two bare wires almost touching each other, with a thin film of air between ; a galvanometer test will show a resistance of heaven knows how many megohms, and still the machine will break

down instantly, while you may insulate this whole machine with, say, ordinary fibre or mica and you will find—if the fibre is a little damp—perhaps only a few hundred thousands of ohms resistance; still the longer the machine runs, the higher its resistance becomes, and the better the machine gets, and it will not break down. So a very high insulating resistance is not a measure of the reliability of the machine against breakdowns. If we consider it from this point of view, we may learn something even from the civil engineer, though we generally boast—properly—that we are much far the advanced in exactness of methods. When the civil engineer wants to build a bridge for instance he does not measure the elongation of a test piece of the iron to be used by a micrometer, but he loads it until it breaks, and then determines the breaking strain, and thereupon bases his calculations. That is what we want to do also—to expose our material to an electrostatic stress until it breaks down, and judge it thereby, but not by its specific electric resistance. For even if the specific resistance is very low—comparatively—the current which may leak through the insulation is by far too small to do any harm. Resistance tests of the machine insulation are of a relative value in so far only, as they may give us a clue as to whether there is a weak spot somewhere in the insulation, but not necessarily so.

They will not show how safe the machine is. But it will show if we connect the copper part to one terminal and the iron part to the other terminal of a circuit carrying a potential of 3,000 volts and then see the machine not broken down. The megohms might be all right—the fire underwriters occasionally require them. But otherwise it is safer to test by applying a higher potential than the machine has to carry. Because if an insulation stands a potential of 3,000 volts we are sure it will stand a potential of 500 volts. But then there are other points to consider in insulation—the mechanical behavior of insulating materials. While mica has enormous strength against breakdowns, the least kink in a mica sheet, the least bend, will reduce the strength enormously, and while a single sheet of mica will stand enormous potential, simply bend it over a couple of times—you hardly see any kink—still it breaks down at a much smaller potential. But still it is very much better than air or even dry fibre.

Furthermore, you have to consider how the insulating material behaves not only against heat but against electric arcing, because in many cases, for instance at the commutator or the breaking-switch you want insulating material which is fire-proof, and keeps up its insulating qualities against the electric arc. All organic compounds are not fire-proof and consequently not fit for places where the electric arc strikes. Take any one of these mixed compounds, even micanite, put it between the discharge plates and raise the potential difference until a spark, followed

by the arc, strikes across—it is set on fire. Micanite may stand the heat of the armature all right where the spark does not touch it. The temperature may rise several hundreds of degrees, so that the micanite gets black, the cement is charred, and it will continue to insulate, but still the arc will set it on fire. While if you take a sheet of genuine mica and let the arc strike across, along the edges of the mica sheet, the arc simply melts the mica down farther and farther, but it cannot set it on fire. Most of the other organic compounds are very much worse indeed, because they are set on fire by the least arc, some even with a kind of explosion. This is another point to be considered.

Hence we must make up our minds that there is no insulating material which is fit for every purpose; that each insulating material has its special application; what is very good for one case is not good for another. So for places, where arcing is to be expected, as on commutators or switches, I do not think that we can ever get anything better than genuine mica, or asbestos paper, or soap-stone, porcelain, or any other mineral compound. In all places, where not exposed to arcing, mixed organic compounds will be very good. The disruptive charge will not pass through micanite at even more than moderate potential. It is not as strong as genuine mica—perhaps not more than one-half or one-quarter as strong, but even then far superior to any other similar material. In other cases ordinary dry fibre is a very good insulating material. It has come into discredit more than it deserves, because it gets damp, and when it gets damp, it no longer insulates, but in places where it cannot get damp, especially where it is kept slightly warm, it is a very reliable material and has a much higher value than is very often supposed. Again, where very high insulating resistance is required, as in electrostatic apparatus, there is paraffin and hard rubber, which surpass, I believe, all materials except air. So we have to find out which insulating material is the best for a particular use; there is no insulating material which is good for every purpose.

MR. A. E. KENNELLY:—I would like to say, in reference to the subject last mentioned, that the value of a material like micanite does not seem to lie wholly in its insulating capabilities, but rather in the fact that enables us to employ in it a substance with say one-fourth of the resistance to electrostatic rupture that true mica has, at a far lesser cost; and it is surely better to have something which has a quarter of that capability and which is within your commercial means than to know that a substance exists having the full capability, but which is so precious that you cannot use it at all. I think the paper is an interesting one, because it gives us a number of details which can only be gained by experience.

In regard to mixtures, I should think that any material which contained silicate of soda would be a suspicious one, for silicate of soda is not an insulator. It is, of course, a high resistance material but it conducts quite appreciably.



PROF. W. A. ANTHONY :—I am very much interested indeed in this material, and the company for which I have been working for the last few years has been making some use of it in the construction of machines, and have found it a very excellent material in a great many places. I agree with Mr. Steinmetz that the measurement of the insulating power of the material is no test of its value in the machine. The effect of this high insulation, of course is good. But the important fact is, that it will stand a great deal of mechanical wear and tear, and a very high temperature without breaking down in insulation; and you may even have something of a short-circuit without burning through it, while almost any of the other insulating materials are at once burnt out and destroyed by any short-circuiting. It seems to me that this is one very great step in advance, in the structure of insulating materials, enabling us to use what is practically as perfect an insulator as mica, and obtaining it in just such forms as we want it. I confess that I was very much surprised when I first saw the great variety of forms in which it could be made.

MR. CARL HERING :—I would like to ask a question about the tubes made of this material. I notice that they have lap and butt joints, and they are apparently not made of a continuous sheet. Will such a joint stand well; is it not apt to open?

MR. CHAS. W. JEFFERSON :—This tube [indicating,] for instance, is made from a thin sheet rolled out. The sheet was about five feet long; so, really, it is not a butt joint. *These* [indicating] are not made from a large sheet, but they have an over-lapping joint of about an inch or an inch and a-half, and it is the same with all these. But the tubes we make from thin sheets or thin strips have quite a considerable length.

MR. HERING :—I had reference to this particular tube [indicating] which seems to have a regular butt joint.

MR. JEFFERSON :—That large tube is made like this small tube. It may appear as if it was a butt joint; but it is not.

MR. RALPH W. POPE :—It appears to me that the remarks of Mr. Steinmetz on this question are a very fine illustration of the difference between theory and practice. That is, we measure the insulation very carefully in the laboratory, and calculate that it is going to answer a certain purpose. It is then introduced in practice, and we learn by experience that not merely insulation resistance, but other qualifications are required, showing, as he says, that different insulations are adapted for different conditions.

My object in rising was to call attention to a reference in the paper which has been corrected once, but the error has been so widely circulated that it seems almost impossible to eradicate it. The paper says on page 800:—"All these parts, even in the best "made armatures become more or less abnormally hot. Means "have been planned and sometimes put into practice for cooling "the parts, and thereby saving the insulation. One method con-

"sists in constructing the armature after the style of a fan, or with large radiating surface; another in equipping a device to blow out the sparks at the commutator."

This blowing out of the sparks is the point to which I refer, for the reason that Prof. Thomson, at the meeting held in May, 1891, in his discussion of the paper by M. E. Thompson, on "An open coil are dynamo," spoke as follows:

"I called Mr. Thompson's attention to his statements in regard to the blowing out of the sparks as expressing an erroneous idea in relation to the machine. This erroneous idea he will find expressed in Prof. Silvanus P. Thomson's 'Dynamo-electric Machinery' that the air-blast in the Thomson-Houston three coil machine is for the purpose of blowing out the spark. That is not at all the case; it never was the case; and the air-blast was introduced for no other purpose than to make it possible to run the machine steadily at high differences of potential with a commutator that could be freely oiled."

This is on page 389 of vol. viii. of the TRANSACTIONS. As this error is creeping into dictionaries, and other works which are supposed to be standard, we should all take pains to correct it wherever possible.

PROFESSOR FRANCIS B. CROCKER:—I think that what Mr. Steinmetz said about tests of insulation at different voltages is the key-note of the problem. But I think he went a little too far in saying that the usual test of insulation showed nothing or showed next to nothing. It seems to me that although a test of insulation resistance is not conclusive, I would much prefer to run a dynamo or a system of conductors, or any other electrical apparatus or system, when it showed 100 megohms insulation than when it showed 100,000 ohms insulation. In fact if it showed 100,000 ohms insulation, I should be afraid to start up. If it showed 100 megohms I should have considerable confidence that it would run all right. It seems to me that the best way to do, is to test the insulation at the voltage at which you intend to work. That covers both points. You test the insulation, which has been the customary thing to do for some decades now, and you also subject it to a potential, or power to break down, which Mr. Steinmetz rightly considers very important. There is no objection to it except the practical difficulty of getting a potential of whatever is necessary—one or two thousand volts, or whatever it may be. But Mr. Williams showed us at the last meeting an electrostatic method of doing that, and for some months past I have been making tests of insulating materials, at several thousand volts with a direct current dynamo machine, without any difficulty whatever. We pass the current from the dynamo machine through the given insulation and a galvanometer according to the ordinary direct deflection method well known to all of us, and observe the insulation resistance—the old-fashioned insulation resistance which Mr. Steinmetz thinks

amounts to nothing—and at the same time we test the power to withstand disruptive discharge. It seems to me that that kills two birds with one stone. We get a quantitative result and also a test of the power to withstand the stress, and that stress of a potential which is applied to actually break down an insulator is very similar to a mechanical stress. It is a good deal the same kind of a stress as a point would exert resting on the centre of a pane of glass—at a certain pressure it will break through. That, of course, is simply an analogy, but it is quite close.

In testing the disruptive resistance or the breaking strain, Mr. Steinmetz said very truly that we ought to put it on the same basis as all other engineering problems, and that is to make an actual breaking strain test. In mechanical or civil engineering we simply take a test piece and subject it to a breaking test. Now, we can do the same in electrical engineering, and I think it should be the custom—I know it has in the practical work that I have been engaged in—to subject machines intended for 500 volts strain, to, 1,500 volts test pressure. That is no more than is proper. It is simply a factor of safety of 3. If you raise the factor of safety to 5, so much the better. Electrical engineers should have their factor of safety, and should consider it part of their work just as much as civil or mechanical engineers.

A dynamo machine or electrostatic machine can easily be obtained which will give any reasonable voltage, from one to five thousand. I have a small machine that gives 5,500 and will run all day long at 5,000 volts. Such machines can easily be obtained. Why not subject any insulation to such a test, and at the same time pass the current through some galvanometer or other device to show quantitatively the insulation resistance at the same time that we test its power to withstand the potential? In regard to the galvanometer, I will point out one difficulty due to electrostatic disturbance, that is, the needle of a galvanometer connected to a dynamo or electrostatic machine, giving 5,000 volts, or anything approximating that, will be acted upon just the same as a pith ball in the vicinity of an electrostatic machine—it will fly around and you will get a false deflection. That is quite confusing sometimes and very difficult to eliminate. The proper way to overcome this seems to be either to ground the terminal of the source connected to the galvanometer so as to reduce the potential to zero, or else to make the potential of the coils equal to that of the needle by connecting the needle to the coils by a little wire passing down into a bath of sulphuric acid, or something of that sort. The electrostatic disturbance will be much greater than the current-effects, in a great many cases. Mr. Williams uses purely electrostatic means—an electrometer—and observes how long it takes to discharge at a given charge. But it seems to me that purely electrostatic strain is not so severe on a given insulator as the current from a dynamo machine. I think that 5,000 volts applied from a dynamo machine is a more severe test than 5,000 volts applied

from an electrostatic source. There is some power behind in one case, and nothing behind in the other. That sounds a little absurd. But I think there is something there that we are not quite familiar with. So far as my experience goes, a potential applied with the backing of a dynamo machine, so to speak, is a more severe test than a simple electrostatic potential without any dynamo.

THE CHAIRMAN :—It seems to me that the remarks of Professor Crocker upon backing up the insulation tests with the current from the dynamo and the remarks which Mr. Kennelly made relative to the using of this material and its advantage over mica and other expensive substances, *i. e.*, that it can be not only formed, but that it has the great advantage of being considerably less in cost are very pertinent and I think from the remarks of Professor Anthony and of others here and from statements made to me by the gentlemen who presented these samples to-night, that this material is not in an altogether experimental stage, that it has been worked commercially and on a considerable scale for a number of years. I would like to ask Mr. Thompson if he can give us a little information as to the relative cost of this material, taking any particular size or sizes, as compared with mica.

MR. THOMPSON :—Mr. Brooks or Mr. Kingsley, I think, would be better able to give figures on that. They are posted on the business points better than I am.

MR. LEWIS W. KINGSLEY :—I would state that on sizes, say 6 by 8, the cost would be one-half that of mica. In very small sizes it costs more than small mica, but with large sizes it costs one-half, and you can get, of course, any size much larger than you can obtain it from the mine.

MR. STEINMETZ :—I do not want to be misunderstood with regard to my opinion about insulating resistance. I do not mean to say that insulating resistance is of no value whatever. It has some value. It shows whether everything may be all right or whether something may be wrong. We are all familiar with the insulating resistance of materials, and know about what resistance we have to expect, and where we find exceedingly low insulating resistance we must suspect something is wrong. Very often we find that the insulating resistance becomes all right by a couple of hours sojourn in the steam box, especially where fibre or asbestos paper was used. Hence the low insulating resistance is a good hint to look things up and see whether everything is all right. But it is no reliable test of the safety of the machine.

Then with regard to exposing all the materials to a break-down test, that is what we have done for several years, and found it very reliable. But if we want to combine it with the resistance tests, then the only safe way would be to make the tests at a potential considerably higher than the normal, because as long as we have inductances in our circuit we cannot avoid occasionally a sudden rise of potential beyond the normal value, as in break-

ing circuits, etc., and we have to take this in account because this insulating resistance especially of air does not vary as a continuous function of the potential, but is infinite up to a certain point, and then suddenly drops to zero, practically. So we have to make the insulating tests considerably above the normal potential.

I am glad to see Professor Crocker propose the same factor of safety as we have used a long time, testing 500 volt machinery by 2,000 volts.

But with regard to the source of these testing potentials, I do not think we need to bother much about continuous current dynamos. For what purpose do we have the alternating current transformer? From ordinary 50 volt mains we can obtain any potential difference, of 2,000 volts just as well as of 3 000 volts, and I even think the alternating potential test is more reliable, because alternating stress is more severe than continuous electrostatic stress. Lately I looked up the literature for tests about disruptive discharges through the air and found quite a disagreement of that kind, so that I am almost inclined to believe that the disruptive strength of air is less with alternating potentials and decreases with increasing frequency. So if we use a frequency of 150 periods and 2,000 volts, we are sure the insulation will break down if it is liable to break down. *Power* indeed must be behind the *potential*.

With regard to micanite I can only say that I found it very reliable—superior to all the other insulating materials except genuine mica, but it is not absolutely fire-proof, so that I prefer to keep it away from the arc.

THE CHAIRMAN:—I think the gentlemen of the Institute will agree with me that we know a great deal more about mica to-night than we ever did before, owing to Mr. Thompson's admirable paper and the discussion which followed its reading. If there are no further remarks I will call upon Mr. Thompson, if he desires to say anything on the points discussed by the gentlemen present.

MR. THOMPSON:—I will not take time to say anything further. I think I have had my say in the paper. But Mr. Jefferson probably may have some further practical experiences to disclose.

MR. JEFFERSON:—I would like simply to state that a great number of armatures have been insulated with this material and have always been tested on 3,000 volts alternating, with what they call a transformer up to 10,000 volts. We had a great number of armatures that would stand that potential with this micanite with a resistance of 190 megohms which is as high as we have, all the way from 190 down to 50 megohms.

THE CHAIRMAN:—Have any mechanical tests been made further than those referred to in the paper? There is a mechanical test referred to here in which the mica is placed under a great strain.

MR. JEFFERSON :—Yes, sir ; the armature has been bound with a ribbon and the layers of the ribbon insulated with micanite and asbestos and then the current passed through the wire—sufficient to burn, almost melt the wire, and we found that the insulation has kept very well indeed.

THE CHAIRMAN—Did it set fire to it?

MR. JEFFERSON :—No ; there was nothing to set fire to. It did not blaze.

MR. THOMPSON :—I might add in regard to shellac or cement which was referred to, that those experienced with glue and its uses know that, in general, the less the cement and the greater the pressure, the better the adhesion. The amount of cement in these articles is almost infinitesimal. So it almost comes up to Mr. Steinmetz's standard about genuine mica being so superior. If the cement is so minute in quantity it is almost the same thing as mica.

THE CHAIRMAN :—If there are no further remarks, we will take pleasure in listening to Dr. Williams who is going to show us some interesting experiments in connection with these and other insulating materials.

DR. J. B. WILLIAMS :—There have been quite a number of specimens of different materials sent in that are claimed to be good for armature insulation, and I propose this evening to compare their resistance with that of pure mica by the electrostatic method. I will test them at a potential of nearly 4,000 volts. I will take the pure mica first. The thickness of this sheet which I am about to test is 45 mils. The disks between which it is placed—the equivalents of metallic disks—are about one-half inch in diameter. I will use just sufficient pressure to spread the buckskin-covered electrodes out firmly onto all portions of the surface of the tested material.

I would state that I believe there is a good deal in Professor Crocker's remark about having the power behind, and it is my intention in the near future to bring apparatus here before the Institute, and show the effects of alternating currents of one and two hundred thousand volts on different insulating material.

[Dr. Williams then went on with the tests, and when he had finished the meeting adjourned.]