ASBESTOS TEXTILE
ELECTRICAL INSULATIONS — PROPERTIES
PRESENT AND FUTURE IMPORTANCE

by Paul O. Nicodemus

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Introduction

There are many asbestiform (fiberous) minerals, but only one, chrysotile, is used for electrical insulation. This is a hydrated magnesium silicate which is most correctly expressed by the formula $Mg_3 [(OH)_4 Si_2 O_5]$. The hydroxyl (OH) ions are loosely bound to the remainder of the molecule and are easily liberated by heat as water, which amounts to approximately 14% of the total weight of the asbestos.

The asbestos fibers, which are actually elongated crystals, when properly opened, range in length from three-quarters of an inch downward. They are soft, silky and very flexible, which allows them to be processed into a variety of textiles and papers.

Impurities in the crystal (fiber) structure and between the fibers are the rule, and not the exception. Of importance as electrical insulation are two types of impurities which occur between the fibers - magnetite and inorganic salts.

Magnetite is a conductive iron oxide which occurs between and at the ends of the fibers in the form of spicules up to one twentieth of an inch in length. Although some of the magnetite is removed from the asbestos during the fiber opening operation, when present in the finished product, it affects the dielectric properties of the fibers. The amount present in the final product is an important basis for classifying asbestos products used for electrical insulations.

Inorganic salts which may be present, are metallic chlorides and carbonates. While not generally present in more than trace amounts, the fiber from certain mines do contain measureable quantities. As these salts are usually hydroscopic in high humidities, they take up enough water to lower the volume resistivity of asbestos products containing them.

Specification for Asbestos Textiles Used for Electrical Insulating Purposes

The basic specification for all asbestos textiles used for electrical insulating purposes is ASTM D 2100. This specification has been accepted as the asbestos textile standard by all electrical industry standardizing agencies such as, U.L., NEMA, IPCEA, AIEE and USASI, as well as all U.S. Government agencies.

This specification classifies asbestos textiles on the basis of the amount of magnetite present (Types) and amount of asbestos fiber (Grades) in the finished product.

Types

The amount of magnetite present is measured by a magnetic analyzer and is expressed empirically as the magnetic rating (MR). The method is based on the principle of comparing the electromagnetic effect of an unknown sample of asbestos with the electromagnetic effect of a standard magnetite sample.

The Types are based on the following magnetic ratings:

Type	Maximum Magnetic Rating (MR)
II	.75
IV	2.00
VI	4.00

The method for determining the magnetic rating (MR) is given in ASTM Method D 1118, Magnetic Rating of Asbestos Used for Electrical Purposes.

Significance of Asbestos Textile Types

The type of asbestos roughly defines the electrical characteristics of the textile. Generally, the higher the magnetic rating, the poorer the electrical properties of the material. The three types have the following intended application:

Type II is intended for thin-wall primary wire insulation, as on magnet wire and pyrometer wire.

Type IV is intended for heavy-wall primary insulation, as on asbestos fixture and appliance wire (UL Types AF and AI) and smokeless lead wire (Type A).

Type VI is intended for use where the electrical properties of the asbestos textile is of minor importance, i.e., overall wire and cable wraps and braids or cable fillers.

Grades

The word "grade" as used in the asbestos textile industry, indicates a system of classification based on the percentage of asbestos by weight, in the finished product. The standard grades with the percentage of asbestos content for each grade are listed in Table I.

Table I

Grade	Percentage of Asbestos by Weight
Underwriters	80 to 85 exclusive
A	85 to 90 "
AA	90 to 95 "
AAA	95 to 99 "
AAAA	99 to 100 inclusive

ignificance of Grades

As the percentage of long fiber asbestos available is relatively low as compared with the short fiber, they are used in the higher grades of asbestos textiles to improve processability and to impart strength for the desired serviceability to the end product.

As the grades decrease in asbestos content, the shorter the average length of asbestos fiber used. In order to process these short asbestos fibers into textiles, and give them strength, long organic fibers, usually cotton or rayon, known as carrier fibers, are blended with the asbestos fibers prior to processing.

The grade of asbestos textile used is largely dependent on the service temperature required of the insulation.

lectrical Properties of Asbestos Insulations

The effect of magnetite and mineral salts on the electrical properties of asbestos has been noted. Independent of these impurities, asbestos insulations have certain characteristics.

The electrical properties of untreated asbestos insulations remain fairly constant regardless of temperature. The electrical properties of treated asbestos insulations are somewhat dependent on the electrical and/or thermal characteristics of the treating compound. Treated or untreated asbestos textile insulations in general, provide no better electrical insulations than an air space of equivalent thickness, and vary with the relative humidity of the air.

The volume resistivity of chrysotile fiber varies from about 500 megohm inches for good chrysotile, under dry conditions, to less than .01 megohm inch for poor chrysotile at 90% relative humidity. *

The dielectric strength of asbestos textile insulations will vary from about 75 volts per mil for Type II asbestos insulations thoroughly impregnated with wax-like materials, at low humidities, to less than 30 volts per mil for untreated and paint- or varnish-impregnated Type IV insulations at 90% relative humidity. This is not true, however, of asbestos papers which, when saturated and surface coated with resins, give dielectric strength in excess of 300 volts per mil.

Asbestos Insulation at Elevated Temperatures

There are three inherent factors which have an important bearing upon the serviceability of asbestos insulations at elevated temperature.

1. The percentage of asbestos in the insulation.
2. The type of compound used to saturate and/or finish the insulation.
3. The design and construction of both the asbestos textile being used and the insulating system.

At temperatures above 250°F, in the presence of air, any organic-carrier fiber or reinforcing strands present, rapidly oxidizes to water and carbon

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* Testing of Asbestos Fibers
Dr. J.W. Axelson, Johns-Manville Corp.
Asbestos Textile Institute Meeting
October 8, 1965

...While this reduces the physical properties of the lower grades of asbestos textile, it does not affect the electrical properties except during the ... time the organic fibers are oxidizing or burning off. The higher the temperature, the shorter is the time the electrical properties are affected. This is not true, however, if the asbestos is enclosed in a manner which will prevent the complete oxidation of the organic fibers. In this case, the organic fibers deteriorate to carbonaceous matter which decreases the electrical properties of the insulation proportional to the amount of organic fibers present, lowering both the dielectric strength and volume resistivity.

At temperatures above 400°F, asbestos begins to loose water of hydration. This gradually lowers the physical properties, i.e., tensile strength and/or abrasion resistance, until a temperature of 900°F is reached, then the physical properties decrease rapidly. This loss of water of hydration will vary somewhat with the origin and grade of fiber. The loss of water of hydration at various times and temperature for a Canadian chrysotile fiber, Grade 4M12, is given in Table II, compiled by JM Research, 1941. After one hour at 1800°F, all the water of crystallization is lost (approximately 14%) and although the asbestos retains its fiberous form, the tensile strength and/or abrasion resistance approaches zero.

In general, the higher the asbestos content, the higher the temperature the asbestos will withstand. The effect of long term heat aging on the physical properties at various temperatures is given in Table III.

TABLE II

PERCENTAGE WATER OF CRYSTALLIZATION LOST BY HEATING CANADIAN CHRYSOTILE ASBESTOS FIBER, GRADE 4M12, AT VARIOUS TEMPERATURES AND PERIODS

Temperature °F	TIME OF HEATING -HOURS												
	1	2	3	4	5	6	8	16	24	48	72	168	336
400	0.69	0.68	0.70	0.79		0.68					0.94	0.90	0.87
500	0.47	0.63	0.70	0.60	0.55	0.60	0.69	0.62	0.63	0.84	0.85	0.98	0.97
600	0.86	0.89	0.92	0.92	0.98	1.00	1.23	1.29	1.32	1.35	1.55	1.72	1.73
700	1.70	1.87	1.74	1.54	1.61	1.57	1.90	2.00	1.95	1.90	1.93	2.03	2.10
800	1.93	1.91	2.08	2.27	2.26	2.39	2.46	2.42	2.40	2.69	2.80	3.05	3.02
900	2.57	2.65	2.80	2.95	3.11	3.23	3.37	3.55	3.77	4.06	4.27	5.05	6.31
1000	3.67	4.11	4.19	4.49	4.64	4.82	5.09	8.08	6.32	8.28	10.39*	11.79	12.40
1100	10.09	11.79	12.51	12.63	12.69	12.75	12.84	13.00	13.16	13.08	13.31	13.34	13.38
1200	13.12	13.30	13.31	13.45	13.49	13.59	13.62	13.63	13.68	13.74			
1300	13.43	13.52	13.55	13.55		13.57			13.77	13.77			
1400	13.72	13.77	13.82	13.87									
1500	13.80	13.89	13.95										
1600	14.01												
1700	14.03												
1800	14.22												

Combined Water, by direct determination = 14.20%

*120 hours

(Reference: Information compiled by JM Research 1941)

While it is impossible to give definite temperatures that the various grades of asbestos textiles will safely stand, Table IV, gives the limiting temperatures at which the various grades are generally used, based on retention of physical properties.

Table IV

Grade	Temperature	Max. amount of organic reinforcing strand and/or carrier fiber allowed.
Underwriters	450°F	20%
A	550°F	15%
AA	600°F	10%
AAA	750°F	5%
AAAA	900°F	1%

The electrical properties of untreated asbestos insulations at these temperatures remain fairly constant and saturated asbestos insulations are dependent on the electrical and thermal properties of the saturating compound used.

Where physical properties are not important, as in low-voltage pyrometer wires insulated with untreated, felted, Grade AAAA asbestos and quartz fiber braid, or with felted Grade AAAA asbestos saturated with special compounded metallic oxides combined with silicates or phosphates have been used for temperatures in excess of 1500°F. At these temperatures, the electrical properties of the asbestos is roughly equivalent to silicate clays.

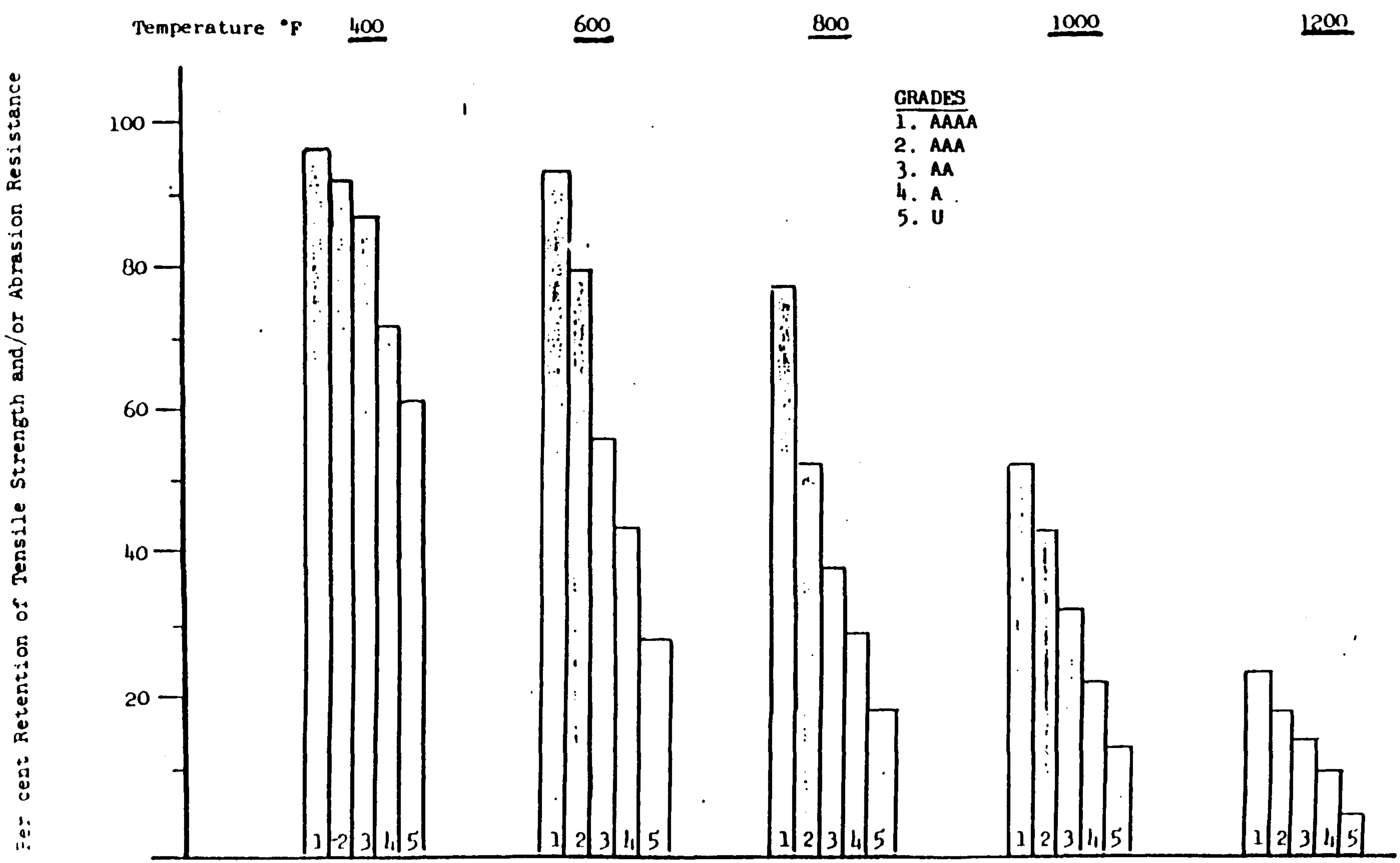
Other Properties of Asbestos Textiles

1. Radiation resistance

Asbestos has exceptionally good resistance to nuclear radiation and will withstand an integrated epithermal neutron flux of approximately 10^{20} NVT

TA III

EFFECT OF LONG-TIME HEAT AGING ON TENSILE STRENGTH AND ABRASION RESISTANCE OF ASBESTOS TEXTILES



efore significant structural changes occur.**

2. Saturating Characteristics of Asbestos

a) As the water of crystallization of asbestos exists as negative hydroxyl (OH^-) ions, the fibers are wet most readily by water and polar solvents. Saturating compounds should therefore be dissolved in water or in polar solvents.

b) Paradoxically, the asbestos fibers carry a positive electrical charge, so pigment particles in treating compounds should be negatively charged so they will cling to the asbestos fibers.

c) The refractive index of asbestos fibers is 1.50 to 1.55. This is also the refractive index of the solids of many asbestos saturating varnishes. On thin-walled insulations, as asbestos-insulated magnet wire, this results in transparent spots called "shiners" in the insulation where the conductor can be seen. Although these transparent spots are usually as thick as the remainder of the insulation and as good electrically, visually it appears as though there is no insulation at these spots. For this reason, treating compounds used for thin-walled asbestos wire insulation, usually contain finely ground pigments to minimize the incidence of these "shiners".

3. Fungus Resistance

While asbestos fibers are fungus resistant, cotton or rayon carrier fibers and reinforcing strands, if present, are subject to fungus attack. Such insulations may be made fungus resistant by incorporating a fungicide in treating

** Handbook of Asbestos Textiles
Third Edition, page 33

-mpounds or by the use of cellulose acetate, nylon or polyester carrier fibers and any of these plus glass as reinforcing strands.

Present Uses of Asbestos Textiles as Electrical Insulation

Wire and Cable Insulation

By far the largest users of asbestos textiles for electrical insulation are the wire and cable manufacturers. This industry uses almost, if not all, of the asbestos lap produced; a large percentage of the roving (either as roving or as fillers) and large quantities of yarn. In addition to these textiles, the industry uses a large portion of the non-woven asbestos tapes.

Lap is the asbestos textile used in the largest poundage. This product, either alone or in combination with other insulating materials, is used as the insulation for a wide variety of wires and cables.

The lap is carded onto wires up to approximately one inch in diameter from sample carding machines in the form of an asbestos felt. After wrapping around the wire, the felt may be treated with a wide variety of compounds, depending on the end use of the wire.

A list of the standard wires, which account for the large majority of lap being used, with the insulating materials and treating compounds used, the maximum temperature and voltage ratings, and principle uses are given in Table V. Two nonstandard wires are also included in this table.

TABLE

ASBESTOS INSULATED WIRE

Types	Insulating Materials	Maximum Temperature Rating °C	Maximum Voltage Rating	Principle Uses
[illegible]	Lap (Type IV Grade A or better) coated with a nonsmoking compound.	200°	300 V	Internal wiring of small electric heating appliances, as toasters, grills where excessive heat exists.
[illegible]	Type [illegible] wire and asbestos braid (Type IV Grade A or better) finished with a nonsmoking compound.	200°	300 V	Water heaters, ranges and electric heating appliances where excessive heat and abrasion exist.
I	Wrapped plastic film and lap (Type IV Grade U) saturated with heat-, flame-, and moisture-resistant compounds (hot melt waxes).	125°	300 V	General appliance wire for internal wiring of ranges, water heaters and other major heating appliances where heat and some moisture exist.
[illegible]I	Type [illegible] wire and asbestos braid (Type VI Grade U) saturated and finished with heat-, flame-, and moisture-resistant compounds (hot melt waxes).	125°	600 V	Same as Type AI, but where abrasion exists.
I	Same as Type AI except slightly heavier walls of asbestos.	150°	300 V	Internal wiring of lighting fixtures and other specialized uses where heat and moisture exist.
AV	Lap (Type IV Grade U) Varnished cloth, asbestos lap (same) braid (Type IV Grade U) All asbestos saturated with heat-, flame-, and moisture-resistant compounds (not melt waxes). Braid finished same.	110°	600 V to 5000 V depending on insulation thickness	High-temperature power cable for boiler rooms etc., in normal dry locations.
[illegible]VI	Same as VA except lead sheath replaces asbestos braid.	110°	600 V to 5000 V depending on insulation thickness	High-temperature power cable where submerged or excessive condensation is present.
[illegible]VB	Lap (Type IV Class U) Varnished cloth, asbestos lap (same) cotton braid. Asbestos saturated with heat-, flame-, and moisture-resistant compounds. Braid finished heat-, flame- and moisture-resistant paint.	90°	600 V	Switchboard Wire
[illegible]	Extruded Thermoplastic (PVC) Lap (Type IV Class U) cotton braid. Asbestos saturated with heat-, flame-, and moisture-resistant compounds. Braid finished with heat-, flame and moisture-resistant paint.	90°	600 V	Switchboard Wire
HID Heater Cord	Uncured rubber - Heavy untreated asbestos - Singles twisted - Cotton or Rayon braid.	90°	300 V	"Heater Cord" for small electrical heating appliances.

NON STANDARD WIRES

Thermocouple [illegible]	Lap (Type II Class U to Class AAAA) high temperature pigmented varnishes.	to above 800°	Very low	Thermocouple and Thermocouple lead wires.
Magnet wires	Lap (Type II Class U to Class AA) high temperature pigmented varnishes.	to 180°	Very low	Small round and rectangular motor and transformer coil wires.

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The wires produced in the largest amounts are the Type AF and Type AI wires. These account for almost as much lap usage as all of the other types of wire combined.

Two or more conductor cords and cables are made from many of the above wires, often employing asbestos fillers and braids.

A cord which uses a considerable amount of lap is the so called "heater cord" Type HPD.

In this cord, untreated lap or roving is used over either a cured or uncured rubber insulation to physically separate the twisted single conductors and as a thermal insulation where the cord is joined to an electrically heated appliance.

On single wires with diameters in excess of approximately one inch (usually referred to as cables) where lap cannot be used, asbestos roving and asbestos paper tapes are used, either alone or in combination with other insulating materials. The wires produced in the large sizes are usually Type AVA or Type AVL cables.

Notice that for the standard wires, the highest temperature rating is 200°C, although low voltage thermocouple wires are used in excess of 800°C.

Other Insulations Competing With Asbestos

Now let us look at the insulating materials which have or are replacing asbestos wire and cable insulations. Most of these wires have Underwriters' Laboratories, Inc., approval, or are made to military specifications. The most important single wires and cables in this class are listed in Table VI. With the exception of the high-temperature aircraft, wires are arranged roughly in chronological order with respect to the dates when commercially introduced, beginning in the early 1940's.

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WIRE AND CABLE REPLACING ASBESTOS-INSULATED TYPES

[illegible]	Insulating Materials	Maximum Temperature Rating °C	Maximum Voltage Rating	Principle Uses
[illegible]	[illegible] fiberglass, varnish impregnated.	200°C	None	High-temperature motor, generator and transformer coils.
[illegible]	Extruded neoprene or Hypalon®	90°C	300 V	Small electric heating appliances such as coffee makers, toasters, grills, etc.
[illegible] UL Type [illegible] and MIL-[illegible]	Silicone rubber, fiberglass braid, lacquer or varnish finish.	200°C	to 1000 V	Clothes dryers, ranges, TV hook-up wire, motor leads.
PTFE Teflon® 1. UL Appliance	PTFE tapes, fiberglass braid, silicone varnish finish.	250°C	600 V	Ovens and other high-temperature equipment.
2. MIL-W-[illegible] and UL Appliance	Extruded PTFE	200°C	to 1000 V	Hook-up, aircraft, appliances, etc.
[illegible] UL Appliance	Extruded PTFE, fiberglass braid, PTFE coated.	250°C	600 V	Ovens and other high-temperature appliances.
[illegible] Wires UL Type [illegible]	Extruded PVC, cotton braid. Heat-, flame-, and moisture-resistant finishes.	90°C	600 V	Replacement for TA wire.
UL Type [illegible]	Extruded flame-retardant cross-linked polyethylene.	90°C	600 V	Replacement for TA wire.
[illegible] Approved [illegible] 1	Extruded cross-linked polyethylene	90°C	1000 V	Ballast and motor lead wires, certain appliance applications
2	Extruded cross-linked polyethylene	105°C	600 V	Ballast motor and transformer leads.
	Extruded cross-linked polyethylene	125°C	600 V	Class 125 motor and transformer lead wires, certain other appliances to 125°C
[illegible]	Heavy-wall extruded high-temperature synthetic rubber such as EPR.	130°C	to 5000 V	Large sizes (similar to AVA uses). Class 130 motor and transformer leads, cable and power supply.
	Extruded cross-linked polyethylene, asbestos saturated with heat-, and flame-resistant compounds.	150°C	300 V	Ranges, ovens, certain other appliances. (Similar to type AI wire.)
[illegible] Wires [illegible]	Silicone rubber, glass or dacron braid, varnish finished.	200°C	600 V	High-temperature aircraft wire.
2. MIL-W-[illegible]	PTFE, PTFE glass tapes, PTFE coated fiberglass braid.	260°C	600 V	High-temperature aircraft wire.
MIL-W-[illegible]	Asbestos, glass braids or tapes, PTFE tapes, fiberglass braid PTFE coated.	400°C	600 V	High-temperature aircraft wire.
[illegible] MIL-[illegible]	FEP coated polyimide tapes, colored FEP finish.	200°C	600 V	Aircraft wire, Space vehicles.
[illegible] Manufacturers	PTFE tapes and FEP coated polyimide tapes.	200°C	600 V	Aircraft wire.

The first material to challange asbestos as a high-temperature insulating material was fiberglass. By the early 1940's, continuous filament fiberglass yarns were used for the manufacture of thin cloth and tapes which could be used in place of asbestos cloth and tapes. It was next used as exterior braids over high-temperature wire and cable insulations as asbestos or silicone rubber. In some cases, varnished glass braids replaced asbestos braids formerly used. Next came fiberglass-insulated magnet wire. This double wrapped fiberglass insulation has almost completely replaced asbestos-insulated magnet wire.

Although untreated fiberglass has almost no abrasion resistance, this deficiency has been overcome to a considerable extent by treating the fiberglass insulating materials with tough high-temperature varnishes.

While not normally considered a high-temperature insulation, the next material to make an inroad on asbestos wire insulation was neoprene. This material was approved by Underwriters' Laboratories, Inc., as the insulation for a new type of "heater cord" designated as Type HPN. This is a parallel cord, insulated with neoprene or Hypalon, which has and will continue to be used in place of the HPD cord containing asbestos. It has the same ratings as HPD cord, 90°C and 300 volts. It is now being used on most small electrically heated appliances where there is no excessive heat at the appliance terminals, such as: toasters, warming trays, coffee makers, etc. HPN cord has the added advantage of being less expensive than the HPD cord.

Two other high-temperature insulating materials introduced in the late 1940's were polytetrafluoroethylene (PTFE), also known by the trade name of Teflon, and silicone rubber.

... introduced in the early 1940's, as a skived tape, has good electrical pr... excellent moisture resistance and is good for continuous use up to 25... It was first used in combination with both asbestos and fiberglass. La... method of extruding it directly on conductors was developed. Extruded, unf... tapes, which could be wrapped on wire, and then fused, were also made ava...

...res insulated with PTFE found immediate use as special high-temperature ho... aircraft, thermocouple wires, coaxial cables, and control cables. Its inherent high cost has limited its use for wires and cables. It is, however, still being used in combination with asbestos and fiberglass for high-temperature aircraft, thermocouple and appliance lead wires.

Introduced at about the same time as PTFE was another high-temperature wire and cable insulation - silicone rubber. Its growth in this field has also been slow because of its high cost. During the 1950's, Underwriters Laboratories, Inc., listed several types of silicone rubber fixture and appliance wires, i.e., Type SF fixture wire. As the price of silicone rubber decreases, its use will increase. It is now being used in many places where asbestos insulated wires were formerly used, because of its superior electrical properties, especially at high humidities.

The approval by Underwriters Laboratories, Inc., of Type TBS Switchboard wire in 1956 was the next important inroad on asbestos wire insulations. As can be seen from Table VI, the insulation of this wire is quite similar to Type TA Switchboard wire, with one important difference, there is no asbestos between the primary extruded insulation and the cotton braid. It has the same ratings as Type TA wire, 90°C and 600 volts. As would be expected, customers started using this wire at the expense of Type TA wire.

In 1958, the General Electric Co., introduced a new wire and cable insulation - Vulkene® - a chemically cross-linked polyethylene. The cross-linking changes the polyethylene from a thermoplastic material which becomes soft and finally melts with increasing temperatures, to a thermosetting material which does not melt at elevated temperatures. This material has the excellent insulating qualities of polyethylene combined with higher temperature serviceability. Its excellent insulating properties are maintained under conditions of high relative humidities at elevated temperatures.

Since its introduction, many types of Vulkene insulated wires have been approved by the Underwriters' Laboratories, Inc. Several of these wires will further curtail the use of asbestos insulations. They are:

1. Type SIS Switchboard. This wire consists of a flame resistant extruded cross-linked polyethylene insulation which requires no braid. This wire has the same ratings as Types TA and TBS Switchboard wires and is replacing both of these products.

2. A cross-linked polyethylene insulated motor lead wire having ratings of 125°C and 600 volts. This wire is replacing asbestos- and fiberglass-insulated wires.

3. The wire that will probably cause the greatest replacement of asbestos as an insulating material is the recently Underwriters' Laboratories, Inc., approved 150°C - 300 volt appliance wire. This wire consists of a primary insulation of cross-linked polyethylene over which is applied a thin wall of felted asbestos saturated with a heat-, and flame resistant compound. Note that this wire is similar to asbestos-insulated Type AI wire but has a temperature rating 25°C higher.

While this wire has limited approval for specific applications, it will probably replace a considerable amount of the present Type AI wire.

In addition to these Vulkene insulated wires and cables, GE recently introduced new Vulkaflex apparatus and motor lead cable. This cable has a rating of 130°C at voltages up to 5000 volts. This cable is insulated with EPR., one of the new heat resistant synthetic rubbers. It will probably replace some of the Type AVA wires.

Other wire and cable manufacturers are now producing or will produce these types of wires within the next few years.

Another class of recently introduced wire insulations are the new aromatic polyamides and polyimides. They are being used as wire enamels and for making yarns, cloth, woven-tape, and film-tapes.

In several respects the "hottest" high-temperature wire insulations at the present time are the polyimide-film tapes coated with the copolymer of "fluorinated ethylene and propylene" (FEP). These tapes can be wrapped on a conductor and fused. The wire may then be finished with a color coating of FEP, applied from a suspension.

This insulation is used for the newest type aircraft wire covered by MIL-W-81381. The wire is rated at 200°C and 600 volts. The insulation thickness is either 7 or 12 mils, depending on the type. Wire made with these tapes has excellent electrical properties.

While the above developments made serious dents in the asbestos used for wire and cable insulations, the use of these new wires tended to stabilize and the increased production of Type AF, AI and several other types of wire during the early 1960's, led to complacency on the part of the asbestos processors. Statements to the effect that asbestos would always maintain or expand its position in the wire and cable insulating field, were common.

This complacency was partially justified, for each year, the sale of asbestos laps, rovings, yarns and paper tapes to the wire and cable industry increased.

However, if the relative rate of production of the HPN, SF and TBS Types of wire to the increase in production of the asbestos insulated wires were examined, it would have been noted that the production of the former types were increasing at a much faster rate than were the old stand-bys as Types AF, AI, TA, and HPD, and this trend is continuing.

In 1961, asbestos insulated wires accounted for 2.6% of the total wire and cable sales dollar. In 1967, it accounted for only 1.9% of the total sales dollar. Between 1961 and 1967, the total wire and cable sales dollar olume increased 90%, while the sale of asbestos-insulated wires increased only 45%. only half as much growth as the wire and cable industry as a whole.

Now lets look at asbestos textiles used for electrical insulating purposes other than wire and cable. These are the tapes, cloth, and sleeving. The products used in the greatest quantities are the woven tapes, known in the asbestos industry as "decimal" tapes, as their thickness is measured in decimal portions of an inch as opposed to commercial tapes where thickness is measured in fractional portions of an inch. In the electrical industry they are known as listing.

These tapes have a wide variety of uses. Type II tapes are used as the primary insulation for certain types of magnet wire and bus bar insulation. Type IV tapes have the highest and most diversified usage. Their principle uses are for secondary insulation, for end turns of large size magnet wire, and for coil wrapping.

Asbestos cloths, Types II and IV, are usually impregnated with varnishes, phenolic, eopxy, and silicone, and are used as high-temperature slot insulations for motors and generators. They are also used as high-temperature, abrasion-resistant panel insulations for various uses.

Although not an asbestos textile, the importance of asbestos paper as electrical insulation should be mentioned. In tape form, impregnated with resinous materials, they are used as insulations for large-size cables and some magnet wire insulation for transformers.

Its greatest use, however, is for laminated composite molded insulations, high-temperature (200°C) panel and molded insulations for various uses.

What materials have or are replacing these asbestos products? Woven fiberglass tapes and cloth have been used to some extent, but due to the inferior abrasion resistance of the asbestos materials, this has been limited. In fact, in some instances where glass textiles were used, asbestos is again being specified.

Tapes and cloth, made with a combination of fiberglass and asbestos yarns, are finding increased usage. The advantage of this combination is the high strength of the glass and the abrasion resistance of the asbestos.

Teflon in tape or sheet form may not be considered a competitive material for asbestos papers, but is a high temperature plastic which is widely used as electrical insulation.

As with wire insulations, the new polyamide and polyimide tapes, cloth, and particularly paper, are beginning to be used for specialized applications.

While this paper is at present much more expensive than asbestos paper, it is finding specialized uses as turn, layer, and barrier insulation on dry-type transformers. It can be bonded in place by pretreatment with a partially cured ("B" stage) polyimide coating. A similar paper is used for wrapping coils, thus eliminating a varnish treatment. These materials are rated up to 220°C.

Dollar values are not available for asbestos textiles used for electrical insulations other than wire and cable. It is believed that there has not been the sharp downward trend which has occured in that industry.

Now we have seen the insulating materials which are gradually but surely replacing asbestos insulation. What is being done about it?

To survive, an industry must keep up with new developments. Table VI lists eighteen basic single-conductor wires and cables, developed roughly within the past 25 years. About half of these have been developed in the past ten years.

Now look at Table V. How many new asbestos-insulated wires have been developed within the last 25 years? The answer is none, as all of these wire designs are over 30 years old.

How many new products have been developed by the asbestos textile industry as new or improved electrical insulating materials during this time? How many products employing asbestos electrical insulation in place of other materials have been introduced during this period? The answer is very few.

During the 1940's, thin asbestos papers and tapes were introduced, which have found considerable use as electrical insulations, but this is not a textile.

The only really new development in this field is the very recently developed fine cut asbestos yarns. These will find many uses in the electrical insulating field. Can it replace fiberglass braids, cloth, and tape? Only if it is pursued in an aggressive manner. Not just by showing the yarns, tapes, and cloth, but by making, or having made end-use products. Show where and how it is better. Compare technical data. Show the end product to the processors, and also to the end-product users. Make him want it. Until you can sell the end-use product, you will not sell the yarn.

After examining the many materials which are making inroads on asbestos insulations, can the statement still be made that asbestos will at least maintain its present position as an electrical insulation?

It is entirely up to the asbestos processors. It will be true only if they do "as best as" they know how in two areas; development and marketing.