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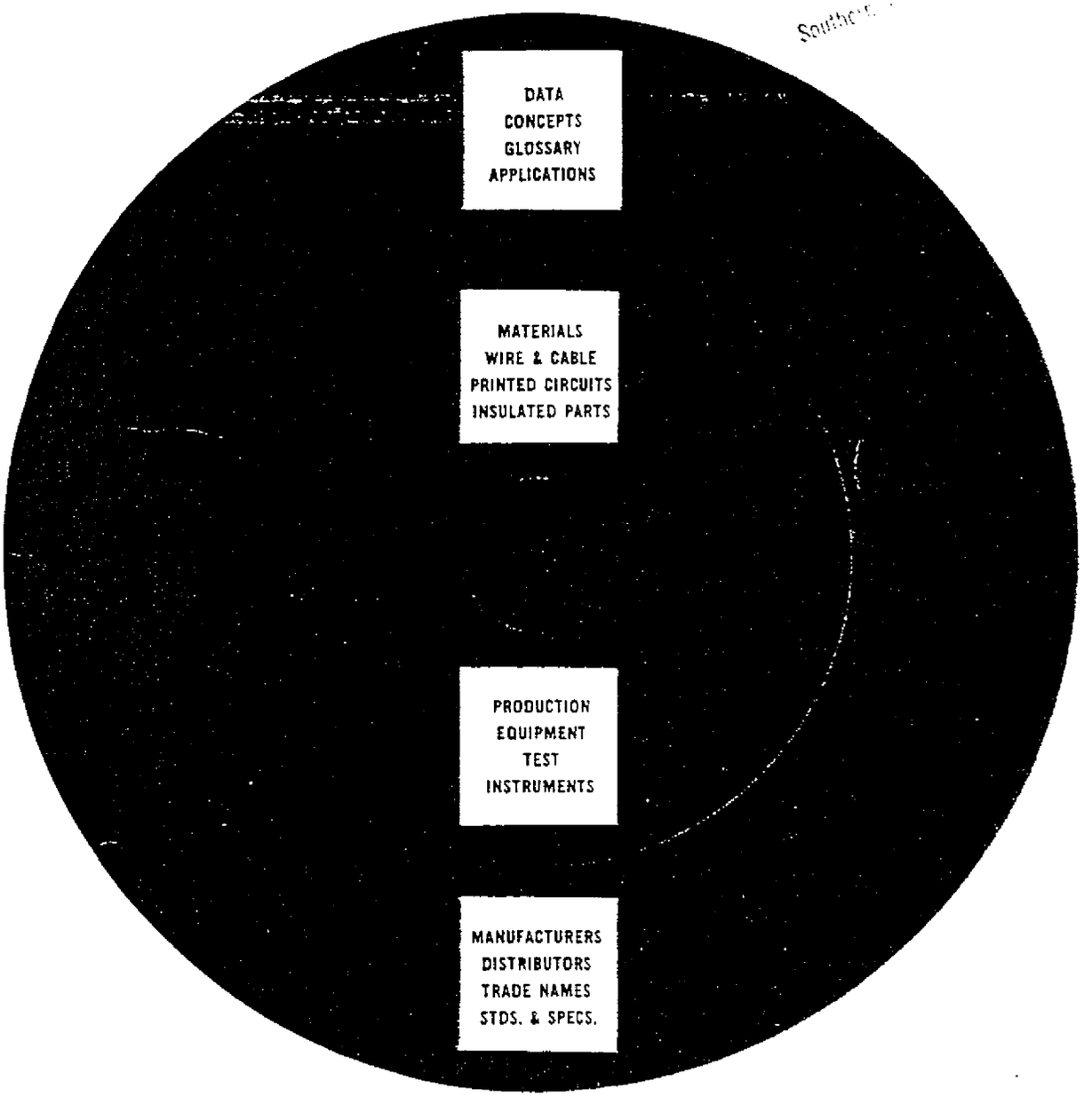

A complete, comprehensive source of information on insulation

SC-ELEC-03693

Section 3-3: Fibers, Yarns, Cords, Twines, and Lacing Tapes; and Untreated, Non-Adhesive Felts, Mats, Woven Tapes, and Fabrics

New Developments

HT-1 is the designation for a high temperature-resistant fiber (density 1.38) being produced on an experimental scale by Du Pont. Generically, HT-1 is a polyamide, but it differs from conventional nylon fibers by its ability to perform in high temperature applications above the melting point of existing polyfibers (482°F for type 66 nylon). After exposure at this temperature for 500 hours, it retains over 60 percent of its original room temperature strength of 5.8 grams per denier. In addition, it does not melt and is ignited only with difficulty at temperatures above 1,000°F, decomposing in the process to a friable char. It is self-extinguishing when flame is removed. The heat resistance of HT-1 reportedly suggests its use for class F and H insulation.

HT-1 can be produced as a filament yarn, staple fibers, paper (see next section), and in thick or board-like structures. Most HT-1 is currently being produced as a continuous filament yarn of 200 denier, 100 filaments (2 dpf filament size) with approximately one to 1.5 turns of "Z" twist. The color ranges from gray to silvery white with a high luster. Exposure to air at 475°F produces a yellowing effect within a few hours. It can be dyed only with great difficulty.

HT-1 yarn is said to exhibit excellent dimensional stability. There is negligible dimensional change in cycling from 15 to 95 percent RH at room temperature. Physical properties remain unchanged after cyclic exposure to wet and dry conditions at room temperature. Shrinkage in dry air up to 260°C (500°F) is less than one percent. Boiling in water will produce an initial shrinkage of about 1.5 percent. HT-1 is also characterized by good resistance to oxidative degradation, acids, bases, and high energy beta or gamma radiation. Excellent resistance to hydrolysis and chemical inertness in solvents and gases commonly used in the electrical industry are claimed. It will degrade slowly in the presence of water vapor at elevated temperatures. In sealed tube hydrolytic stability tests, HT-1 exhibited a tenacity loss of about 70% after 1000 hours at 300°F compared to complete degradation for nylon and polyester fibers after 100 hours and acrylic fiber after 300 hours.

Other properties reported include a high modulus (resistance to stretch) of 156 grams per denier, excellent cut-through resistance, toughness, and outstanding abrasion and fatigue resistance.

Suggested insulation forms for HT-1 fiber products include tying cord, serving, braid, sleeving, tapes, and fabrics which are coated or which serve as reinforcement for laminates.

The electrical insulation properties of polypropylene have created some interest in these fibers in the form of mats and cloth. Use has been reported for a base cloth in plastic laminates. The product is a low dielectric constant (2.15) laminate for use in radomes, printed circuit boards, waveguide windows, antenna insulators, and other electronic applications. Dissipation factor is 0.0008.

A typical polypropylene fiber has a specific gravity of 0.90, tensile strength of 50-90,000 psi, melting point of 325-335°F, good resistance to acids, alkalies, and organic solvents. Polypropylene fiber is slow burning and loses strength under prolonged exposure to sunlight.

Author Credits

This entire section was staff prepared.

In the first portion of this section various terms are explained while in the middle portion the various fibers commonly used in electrical insulation materials are briefly described and evaluated. The last portion covers the forms which are available such as cords, tapes, fabrics, etc. Note that only untreated forms (except cords and lacing tapes) which are not described elsewhere are included in this section. For example, braided sleevings appear in section 3-6, treated fabrics in section 3-7, pressure sensitive cloth tapes in section 3-9, etc.

DEFINITIONS AND EXPLANATIONS OF TERMS

There are two forms of fibers—*staple fibers* which are the short fibers such as those of cotton, and *filament fibers* which are long strands such as those of many man-made fibers and silk.

Yarn construction can be varied according to actual fiber or fibers used, whether the fiber is staple or filament, staple length, size, weight, amount of twist, number of plies, etc. *Spun yarns* are produced by cleaning, paralleling, attenuating, and twisting staple fibers into yarn by spinning. Tensile properties of a spun yarn are determined both by the fiber used and by the degree of frictional adherence provided by the nature of the fiber and the twisting effect. Spun yarns wear well and offer good flexibility because individual fibers can move within the yarn construction. They also generally are characterized by a good bulking factor and absorption. The *cotton system* is used for spun yarn sizes—it is the number of 840-

yard hanks per pound. From a weight and bulk standpoint, *filament yarns* normally have better tensile properties than spun yarns but they do not compare in absorption and adherence, although these latter properties can be improved by construction. The *denier system* is used for many filament yarns—it is the number of grams per 9000 meters of length (in practice, the number of half-decigrams per 450-meter skeins). A filament yarn denier is the equivalent of 5315 divided by the cotton yarn number. To achieve the advantages of each, spun yarns and filament yarns may be twisted together into *plied yarns* and plied yarns may be twisted into *cabled yarns*.

In *woven tapes and fabrics*, the yarns which run lengthwise of the fabric are known individually as *ends* and collectively as the *warp*. The yarns running widthwise of the fabric are identified individually as *picks* and collectively as the *filling*.

In woven materials the most common type of weave is the *plain weave* or *taffeta weave* in which each warp yarn alternately goes over or under each filling yarn. This type of weave can be very tightly woven and generally permits sufficient stretch to conform well to irregular surfaces, the degree of conformability depending, of course, on the actual weave construction. In *twill weaves*, each warp yarn goes over two or more filling yarns, with the interlacing advancing one pick on successive warps. *Satin weaves* have fewer interlacings than plain weaves. The interlacings are regularly spaced in satin weaves. *Leno* is a variation of a plain weave—it is an open, net-like weave with the warps interlocked to prevent slippage. Of course, many weave variations are possible.

Mat or matting is a non-woven material in which there is an oriented or random distribution of the fibers (generally, the production process used involves some parallelizing of the fibers but theoretically, if perfect random distribution were possible, the strength would be equal in all directions). Bonding agents or resins are frequently used by the mat producers to achieve bonding together of the fibers and facilitate further processing into other forms by converters.

Lap is a felted form designed for recarding into a more refined felted material. It is a parallel collection of ribbon-like felted slivers. *Slivers* are the stranded fibers as they come from the carding or combing machines.

Felt is made of matted fibers which have been worked into a compact material by rolling and pressure. Bonding agents or resins are generally used.

Roving is a collection of carded fibers rubbed into a single soft and bulky strand without twist or a sliver which has been drawn out and slightly twisted. In the case of glass, roving is a collection of continuous filament untwisted yarns into a single bulky strand.

FIBERS

Acetate

Acetate fibers are cellulose based fibers in filament form characterized by high dielectric strength and a dielectric constant of about 5.0 at 60 cps and 50% RH. Cellulose acetate is a non-corrosive material which permits its use in contact with delicate conductors. It is resistant to transformer oils, weak acids, weak alkalies, salt water, and most ordinary varnish solvents such as naphtha, toluol, and alcohol.

There has been some mention of the use of acetate fibers in varnished fabrics but the primary electrical application appears to be in the form of woven cloth for pressure sensitive electrical tapes because of non-corrosiveness. Some use as woven tapes for coil wraps is also reported, as well as a yarn serving on wires.

A related material developed from acetate and tradenamed "Fortisan," (Celanese Corp. of America), is a high strength fiber with the following properties (Fortisan 36): specific gravity, 1.52; tensile strength, 155,000 psi; elongation, 6.2%; loses strength at 300°F; attacked by high and low acid concentrations; resistant to cold weak alkalies; generally unaffected by organic solvents; and flammable.

Asbestos

Asbestos occurs in nature as a mineral in various forms. One is a crystalline form which can be separated into fibers when properly processed. The most common type of asbestos for electrical purposes is chrysotile and all of the information presented here deals with this type.

Asbestos fibers by themselves are strong and flexible and resemble cotton fibers in appearance. Some are even finer than silk and it is possible to subdivide the asbestos into fibers so fine that they can be seen only with an electron microscope.

Asbestos has very good heat resistance and can be heated to high temperatures without burning. At about 900°F, a part of the water of crystallization is removed from the crystal structure of chrysotile and at about 1100°F, the hydroxyl radicals are removed from the crystal lattice with a greater deterioration of the fiber quality.

Because of the shiny smoothness of asbestos fibers, they slip apart easily when processed into yarns. This is why the tensile strength of asbestos yarns and textiles does not compare with other common fiber products. To raise the breaking strength of asbestos fiber products, other fibers or yarns are frequently combined with the asbestos for reinforcement.

Chemically, asbestos is attacked by hydrochloric acid, sulfuric acid, and other strong acids of the inorganic type. Asbestos is not affected by transformer oil or strong alkaline-earth type alkalies.

Asbestos yarn sizes are designated by the term "cut" which is the yards per pound of single plain yarn when multiplied by 100. Yarns as small as 50-cut are made.

Asbestos is available in nearly all forms—roving, yarn, cords, rope, lap, felt, mat, woven tapes, and woven cloths.

Standard grades for asbestos textile finished products based on the asbestos content have been established by the American Society for Testing Materials as follows:

*ASTM Standard Grade**	*ASTM Requirement, Limiting Asbestos Content by Weight*
Commercial	75% up to but not incl. 80%

Underwriters'	80% up to but not incl. 85%
Grade A	85% up to but not incl. 90%
Grade AA	90% up to but not incl. 95%
Grade AAA	95% up to but not incl. 99%
Grade AAAA	99% to 100% incl.

**See ASTM D-299 for test methods to determine grade.*

The temperature limits of the preceding grades would be determined primarily by the effect heat has on the non-asbestos content, the quantity of non-asbestos content, and the application. However, the following general temperature limits may serve as a guide:

Commercial	up to 400°F
Underwriters'	up to 450°F
Grade A	up to 550°F
Grade AA	up to 600°F
Grade AAA	up to 750°F
Grade AAAA	up to 900°F

For electrical insulation purposes the underwriters' grade meets most requirements but grades A and AA would be indicated for superior electrical insulation under heat conditions. In grades below AAAA, strength decreases rapidly above 800° F. When caustic or acid conditions exist, grade AAAA is required.

Ceramic

Staple alumina-silica fibers are available which possess extreme heat resistance and excellent thermal shock resistance. Electrical properties are reported to be excellent but, of course, will be determined by the form. The fiber is resistant to most chemicals including many strong acids. One brand which can be supplied ("Fiberfrax" bulk ceramic fiber, The Carborundum Co.) is said to have a specific gravity of 2.73, a continuous use temperature of 2300°F, and a melting point above 3200°F.

Forms available include roving, yarn, cord, rope, cloth, and felt.

Cotton

Despite the inroads made by man-made fibers, cotton is still used in large quantities for electrical insulation purposes. Cotton is a staple fiber with a natural twist which results in strong yarns. Cotton is a relatively strong and flexible material with good abrasion resistance, resilience, and high absorptivity. Tensile strength of the fiber is 61,000 to 127,000 psi and specific gravity is 1.58. It is attacked by high and low concentrations of acids and strong alkalies. It is generally unaffected by organic solvents and loses its tensile strength at elevated temperatures. It also has poor resistance to mildew unless treated and is flammable.

For electrical insulation purposes, cotton must be chemically pure. Cotton has a natural wax content of about one percent which adds pliability and strength but when untreated cotton products such as tape are used in hermetically sealed motors, the wax should be removed.

Cotton is available in practically all forms.

Glass

Glass fibers are available in both staple fiber and continuous filament forms. Glass has many desirable features. Its tensile strength is higher than that of any natural fibrous material of equal thickness. Values range from 204,000 to 220,000 psi. Specific gravity is 2.54.

For electrical purposes an "E" grade is used which is a borosilicate. Room temperature dielectric constant at 1 mc is 6.3 and power factor at 1 mc is 0.0037.

Glass fibers have excellent dimensional stability and are incombustible. Physical properties are maintained to 400°F and at 650 to 700°F approximately 50% of the strength is retained. The melting point is 1400 to 1500°F. Thermal conductivity is good which helps to dissipate heat in "hot-spots."

Glass fibers do not absorb moisture although moisture may form on the surface. Chemical resistance is excellent—glass is attacked by hydrofluoric, strong hydrochloric or sulfuric, and hot phosphoric acids; and by hot solutions of weak alkalies and cold solutions of strong alkalies. Solvents do not affect glass and it is not attacked by mildew.

The high physical properties generally permit space savings in equipment. Untreated glass fiber materials have limited abrasion resistance which means excessive flexing or rubbing should be avoided. A number of treatments are possible to minimize this problem.

NEMA standards publication No. GF2-1957 for staple filament glass yarns and No. GF1-1957 for continuous filament glass yarns have established a fiber and yarn designation system for glass as follows: The first letter indicates the glass composition by type (E is used for electrical). The second letter indicates staple (S) or continuous (C). The third letter indicates the filament diameter (D-0.00021-0.00025; E-0.00026-0.00030; F-0.00031-0.00035; and G-0.00036-0.00040). The next three figures indicate the strand or sliver number which represents 1/100 of the yardage of the raw glass fiber per pound. For continuous filament yarns two digits follow the strand number and the first digit shows the number of original strands which are twisted and the second digit shows the number of these yarns which are plied. For staple fiber yarns there is only one digit following the sliver number and this indicates the plies. When the yarn is reinforced with one end of a continuous filament glass yarn the letter R is added.

Thus a typical code for a continuous filament glass yarn would be ECE-225-4/3 and for a staple fiber yarn ESE-40/1-R.

Glass fiber products are available in practically all forms.

Nylon

Nylon can be supplied in both filament and staple forms. It is characterized by high strength, toughness, elasticity, good resistance to chemicals, excellent electrical properties, and resistance to abrasion, moisture, flexing, and heat.

Specific gravity is 1.14 and tensile strength for staple fibers ranges from about 60,000 to 100,000 psi and for filaments from about 70,000 to 130,000 psi depending on manufacturer and type.

Nylon melts before burning and is self-extinguishing. It softens at about 445°F and melts at about 485°F but these temperatures are lower for some

types. On prolonged exposure to elevated temperatures there is some yellowing and loss of physical properties.

Nylon will lose strength after long exposure to sunlight. It has fair resistance to acids in weak concentrations but poor resistance to strong acids. Resistance to alkalies is good and nylon is generally unaffected by organic solvents. It is not attacked by mildew.

At 1000 cps, 18% RH, and room temperature nylon has a power factor of 5.0% and a dielectric constant of 4.0.

Nylon is widely used in the form of lacing tapes for electrical/electronic purposes. There has been a slight use in the form of treated fabrics and as a yarn serving on wires, and significant use as a base cloth in rigid phenolic laminated plastics. It also is being used as a filler material for cable and wires.

Paper

Paper, of course, is made from fibers and is not a fiber itself. However, it is mentioned here because narrow strips or filaments of paper are twisted together into cords which have some tying applications in electrical units and which can also be used for filling and spacing purposes in cables. Fairly stiff paper cording can also be used for wedging purposes in such applications as small motor slots. See section 3-4 for properties of papers.

Polyester

Polyester is available in both staple fibers and filaments. Like nylon, it is water repellent. It also is characterized by good strength, dimensional stability, and resistance to abrasion, heat, and many chemicals. Specific gravity is 1.38 and tensile strength ranges from about 55,000 to 75,000 psi for the staple and 77,000 to 138,000 psi for the filament.

The grade produced by Du Pont ("Dacron") reportedly has excellent strength retention on prolonged exposure to heat. Polyester becomes sticky at slightly above 450°F and melts at about 480°F. It burns slowly.

There is some loss of tensile strength on prolonged exposure to sunlight but no discoloration. It has good resistance to most mineral acids, good resistance to weak alkalies, moderate resistance to strong alkalies at room temperature, and excellent resistance to common solvents. It is not attacked by mildew.

Electrical properties of polyester are good. Dielectric constant is 3.8 dry at 60 cps.

Polyester is available in most forms but the important forms for electrical applications are lacing tapes and treated mats and to a more limited extent, yarn servings on wire and woven coil tapes and cloths. There is considerable interest in the use of combination polyester/glass yarn cloths—such straight-cut treated cloths are suggested as possible replacements for treated bias-cut cloths since they both offer good conformance to irregular surfaces.

In addition to the fibers, polyester film can be slit into narrow ribbons and processed into yarns. A primary application for this material is in ropes used as guy lines for antennas where the polyester film does not affect the antenna pattern in any way.

Polytetrafluoroethylene

Polytetrafluoroethylene fiber materials have features similar to the desirable properties of other "Teflon" products. Specific gravity is 2.3 and tensile strength is 47,000 psi. The coefficient of friction is the lowest of all known fibers. It is a non-flammable material with excellent heat resistance —softening point is 621°F but it begins to give off some toxic vapors at somewhat lower temperatures. Resistance to nearly all acids, alkalies, and solvents is excellent. It is not affected by sunlight or mildew. Electrical properties are excellent. See section 3-10 for more information.

For electrical purposes, the major form used is treated and untreated lacing tapes. It also is used in the fabrication of ribbon conductors (conductive material is used in the warp and PTFE fiber is used as the filling).

Rayon

Rayon, one of the original man-made fibers, is a regenerated cellulose material available in both staple and filament types. Since the introduction of other synthetics, electrical uses of rayon have decreased. Specific gravity is 1.50 to 1.52. Tensile strength ranges from 29,000 to 88,500 psi depending on type.

Rayon loses strength above 300°F and decomposes at 350 to 400°F. It is flammable and does not melt. It will lose strength after prolonged exposure to sunlight. Like other cellulosics, rayon is generally resistant to organic solvents but is attacked by acids and strong alkalies. It is not resistant to mildew unless treated. Electrical properties are moderate.

Rayon is available in most forms but electrical usage is limited. A treated cloth is available.

Silica

Silica fibers are produced by several companies. Melted quartz which is a form of silica may be drawn into continuous filaments. Staple fibers can be produced from glass fibers which are acid leached to eliminate non-silica oxides, and then washed and fired (it is also possible to accomplish the firing after the product is in its finished form such as cloth).

Typical properties of a continuous filament material (produced by General Electric Co.) include: specific gravity, 2.2; room temperature tensile strength, over 100,000 psi; annealing point, 2084°F; softening point, 3003°F; resistant to all acids except hydrofluoric and hot phosphoric; generally resistant to cold weak alkalies but dissolves in strong alkalies; resistant to organic solvents, sunlight, and mildew; and at 1 mc and room temperature dielectric constant is 3.78, power factor is 0.0006, and loss factor is 0.0009.

Naturally, the extreme heat resistance of silica fibers recommend them for critical applications. They are available in practically all forms.

Silk

When only natural fibers were commonly available, silk was used extensively for electrical insulation because of its continuous filament strength and space-saving thinness. Wire insulation wraps and thin varnished silk cloths are typical examples. With the

availability of other fibers, the use of silk today in electrical work is very limited.

Vinyl

Fibers made from various types of vinyl materials can be supplied both as staple fibers and as continuous filaments. Electrical uses are very limited although there are some applications for lacing cords. Generally, vinyl fibers are characterized by toughness, flexibility, and resistance to chemicals and water. Properties reported for a polyvinylidene chloride fiber ("Saran") include a specific gravity of about 1.7; tensile strength of 25,000 to 60,000 psi; softening point of 240-280°F; melting point of 340-350°F; resistant to all acids except hot concentrated sulfuric and to all alkalies except strong ammonium hydroxide; self-extinguishing; generally resistant to organic solvents; and good electrical properties.

FIBROUS FORMS AND APPLICATIONS

When referring to this portion it should be noted that only brief mention, if any, is given to fibrous forms which are covered in other sections. For additional data readers should consult section 3-6 on flexible sleevings and tubings; section 3-7 on treated fabrics and tapes; section 3-8 on composite insulations; section 3-9 on pressure sentitive tapes; section 3-10 on reinforced and laminated plastics; section 3-15 on mica products (flexible composites); and sections 3-18 and 3-19 on wire.

Yarns

Yarns are used primarily for producing other forms of fibrous materials such as braids, cords, woven tapes, cloths, etc. They can be treated to improve processing and handling characteristics (notably glass) or end product properties. Servings of fibrous yarns are used in a number of wire and cable constructions as well as braided coverings—common materials for this purpose include cotton, asbestos, glass, and a glass/polyester combination with nylon, silk, acetate, quartz, and rayon being used to a more limited extent. Fibrous wire coverings provide mechanical protection, provide the dielectric protection of an equivalent thickness of air, serve as a base or anchor for impregnating and coating compounds, and protect other wire insulations. Yarns and yarn combinations are also used as fillers in wires and cables.

Roving

As previously mentioned, roving is a collection of carded fibers rubbed into a single soft and bulky strand without twist or a sliver which has been drawn out and slightly twisted, except that in the case of glass, roving is a collection of continuous filament untwisted yarns into a single bulky strand.

For electrical applications, the primary roving materials are asbestos and glass. Ceramic fiber roving is also suggested for applications similar to asbestos roving but where even greater heat resistance is required.

Asbestos roving is used extensively in wires where heat is involved because of its thermal properties. The roving is wrapped over the conductor without compacting the fibers too densely in order to retain the thermal insulation qualities. It is useful in

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heater cords, heat resisting fixture wires, appliance cords where heat is a problem such as toasters and irons, heating elements, shipboard cable, etc.

Plain asbestos roving is a mixture of asbestos and cotton or other organic fibers. Reinforced asbestos roving has a core of cotton, nylon and cotton, glass, or other yarns to provide additional strength. Asbestos roving is covered by ASTM D-375-59, Specifications for Asbestos Roving for Electrical Purposes, with Methods of Test for; and military specification MIL-I-3053A.

Glass roving is widely used in reinforced plastics. Both standard rovings and chopped strand can be supplied. Some of the plastics applications include use of glass roving at the edges of large plastic products to provide extra edge strength; in molding compounds; and in plastic rod stock.

Lap

Lap is a fire resistant, untwisted, ribbon-like form of asbestos felt made from slivers of asbestos fiber blended with cotton or other organic fibers. It is used as a wrapping on wire and cable in the same manner as asbestos roving.

Felts and Mats

Felts and mat-like materials are non-woven products with either oriented or randomly distributed fibers permitting strength, conformability, and stretchability to be fairly well equalized in all directions or accentuated in a desired direction. Strength of an otherwise weak web is increased by inclusion of binder (which may be a homogenous fiber or resinous in nature) or by combination with a carrier. Practically any fibrous material can be supplied in mat or felt form but for electrical uses, the common types are asbestos mat and felt, glass mat, and polyester mat. A percentage of binding agents such as fibers, starch, phenolic resins, epoxy resins, polyester resins, or silicone resins is generally used.

Asbestos felts have been used to some extent for wire and cable insulation. They are also used in prepregs and as a base for laminated plastics. Asbestos felts and glass cloth reinforced asbestos mats are generally available treated with asphalt, polyvinyl acetate, silicone, and polytetrafluoroethylene resins in sheeting and tape forms for electrical insulation.

The primary electrical use for glass mat is as base reinforcing material for rigid polyester laminates (see section 3-14).

In the past several years, polyester non-woven mats have reportedly been utilized in flexible laminates with polyester film, as a cover for mic tapes, and as slit tape to be varnis impregnated either before or aft application. The properties of the m can be varied over a wide range respect to weight, thickness, porosit strength, elongation, and smoothnes This is accomplished by manipulati of such variables as fiber diamete ratio of polyester to polyester bind fiber, and the heat and temperatu conditions under which the sheet

Typical Cords and Lacing Tapes*

Supplier	Designation	Description	Nom. Dimen., Inch	Breaking Strength, Lbs.	Approx. Yds./Lb.
[1]R-M	310-P	Plain asbestos, unsized	1/16		189
[1]R-M	310-S	Plain asbestos, sized	3/32		82
[2]IMC	6	Cotton cable laid	1/64	13	1100
[2]IMC	48	Cotton cable laid	1/8	108	133
[2]IMC	12	Flax cable laid	3/64	50	490
[3]OCF	EC9-5U	Glass, untreated	.077	307	105
[3]OCF	EC9-5N	Glass, neoprene treated	.085	250	93
[4]Suf	SR-4.0	Glass, vinyl coated	.065	176	
[4]Gud	20	Glass, flat braid, vinyl coated	.080x.010	50	
[5]Gud	20	Glass, flat braid, silicone treated	.080x.010	50	
[6]B-H	TG-30	Glass, flat braid, PTFE treated	3/32x.012	65	
[7]Dod	TB-314	Glass, braided cord, PTFE treated	.045	45	311
[6]B-H	N-30-W	Nylon, flat braid, waxed	3/32x.012	50	
[5]Gud	18	Nylon, flat braid, synthetic rubber	.090x.0125	50	
[6]B-H	D-30-P	Polyester, flat braid	3/32x.012	50	
[5]Gud	15	Polyester, flat braid, waxed	.035x.005	4	
[5]Gud	26	Polyester, flat braid, synthetic rubber	.220x.014	145	
[5]Gud	276	PTFE, flat braid	.025x.014	10	
[5]Gud	302	PTFE, round twist, synthetic rubber	.010	4	
[5]Gud	256	PTFE, flat braid, silicone finish	.110x.011	33	
[5]Gud	230	PTFE, flat braid, pre-shrunk	.031x.023	15	
[8]HIT	UC-100-6	Silica cord	.090	10	120
[8]RI	EP-132	Vinyl, round	1/32	2.5	
[8]RI	EP-132	Vinyl, square	1/8x1/8	19.6	
[8]RI	EP-132	Vinyl, rectangular	1/16x3/16	37.2	

**Note that a variety of sizes, treatments, and suppliers not listed in table a available. Designation shown is individual supplier's style or code numb Breaking strength values shown are minimum or average. Temperature limits a generally determined by the fiber, treatment, and application.*

[1]Raybestos-Manhattan, Inc. [2]Insulation Manufacturers Corp. [3]Owens-Corning Fiberglas Corp. [4]Suflex Corp. [5]Gudebrod Bros. Silk Co., Inc. [6]Bentley-Harris Manufacturing Co. [7]Dodge Fibers Corp. [8]Resinite Dept., Borden Chemical Co. [9]H. Thompson Fiber Glass Co.

unified. For applications where still higher strengths are required, these polyester mats can be combined during formation with light polyester woven fabrics. The resulting constructions are dimensionally stable, receptive to resins, and ravel-resistant when slit to tapes.

Cords, Twines, and Lacing Tapes

Cords and lacing tapes are discussed together because their applications are so similar—they both are used for tying down insulation and windings, lashing of motor coils and transformer windings, banding of armatures and commutators, holding leads in position, wire and cable harnessing, and general electronic lacing work. In addition, cords may be used for space filling and separation purposes. Cords are yarns which have been twisted or plied together—weaker fibrous cords may use another type of fibrous yarn for reinforcement. Lacing tapes are braided or woven. There are also some round braided cords.

Fibers commonly used in electrical cords and lacing tapes include cotton, glass, nylon, and polyester. Asbestos, polytetrafluoroethylene, silica, and vinyl cords are also available. Cords and tapes may be treated in various ways to improve properties such as abrasion resistance, knotting strength, flame resistance, fungus resistance, handling, fray resistance, holding ability at high temperatures, etc. Treatments include wax, oil, neoprene, vinyl, silicone, polyester, varnish, polytetrafluoroethylene, rubber, sizing, etc.

The 100% polyester mats described previously can also be slit into tape and subsequently twisted into twines suitable for coil tying applications. In this form, they have excellent knot strength and abrasion resistance and are compatible with resin impregnation systems.

Typical types of cords and lacing tapes are shown in the table.

Woven Tapes

Although this portion is primarily concerned with untreated woven tapes, the availability of a parallel strand cotton tape should be mentioned since it is used for similar coil winding purposes. The parallel strands are bonded together with a special adhesive but this treatment is strictly for bonding purposes and not for improvement of other properties as is the case with treated tapes covered in other sections.

The most common tapes for electrical insulation are woven from cotton, glass, and asbestos yarns but woven polyester, silica, acetate, and various combinations are also available.

Woven tapes are used for taping field and armature coils, banding wire insulation, cushioning insulation for the end turns of coils, tying and fastening purposes, coil wraps, transformer insulation, anchoring and insulation of leads, wire and cable insulation wraps, splice insulation, physical spacing, and filling of space.

When tapes are applied, they can be lapped (generally one-third to one-half), edge butted (which might take more time), or spaced (which provides only physical spacing). In order to reduce labor time, it is important to always use the widest tape width possible when applying tape wraps but it should be rememembered that narrow tape widths provide the smoothest wrap for tiny or sharply curved coils and components.

Selection of proper tape material, weave, width, thickness, construction, etc., should be determined by the requirements of the application—factors to be considered include tensile strength, machine or hand wrapping, heat resistance, cushioning, tear strength, elongation, conformability, ability to be impregnated, and compatibility with other materials in the insulation system.

It is possible to slit tape from woven

ASTM Physical Requirements for Cotton Tape

[1]ASTM Type	Thickness, Inches	Width, Inches	Total Ends (Warp)	Picks Per Inch (Filling)	Min. Yds. Per Lb.	Breaking Strength, Min. Lbs.	Recommended Yarn Numbers
A-1	.005	½	36	36	350	25	20/1 Warp
		¾	56	36	270	30	38/1 Filling
		1	72	36	200	40	
A-2	.007	½	36	36	290	25	
		¾	56	36	190	30	
		1	72	36	140	40	20/1 Warp
		1¼	92	36	110	50	30/1 Filling
		1½	108	36	90	60	
A-3	.007	½	36	28	300	25	
		¾	56	28	200	30	
		1	72	28	150	40	20/1 Warp
		1¼	92	28	120	50	30/1 Filling
		1½	108	28	100	60	
B-1	.013	½	52	40	220	40	
		¾	76	40	150	65	
		1	100	40	115	85	20/1 Warp
		1¼	135	40	85	115	30/1 Filling
		1½	148	40	75	130	
B-2	.020	½	40	40	110	50	
		¾	60	40	95	75	
		1	80	40	70	100	20/2 Warp
		1¼	100	40	55	125	20/1 Filling
		1½	120	40	45	150	
C-1	.030	½	60	40	110	60	
		¾	80	40	90	75	
		1	100	40	70	90	20/2 Warp
		1¼	132	40	55	115	20/1 Filling
		1½	150	40	45	140	

[1] *"A" indicates plain weave; "B" is herringbone weave (at least single point twill, two up and two down); and "C" is non-elastic weave.*

Polyester Fiber Tape*					
Thickness, Inch	Width, Inch	Total Ends	Picks Per Inch	Break Strength, Lbs.	Nom. Yds./Lb.
.0035	½	50	72	30	600
	⅝	62	"	37	480
	¾	75	"	45	400
	1	100	"	60	300
	1¼	125	"	75	240
	1½	150	"	90	200
.005	½	50	72	30	600
	⅝	62	"	37	480
	¾	75	"	45	400
	1	100	"	60	300
	1¼	125	"	75	240
	1½	150	"	90	200

*Wm. E. Wright & Sons Co.

cloth sheeting but very little of this type is used because of poor tear strength and raveling. Woven tapes generally are woven to the width desired with a selvage edge—this type of edge is obtained by weaving the warp yarns closer together at the edge in order to increase tear strength and prevent raveling.

Woven asbestos tape for electrical insulation is commonly called listing. Asbestos tape is generally available in both commercial and underwriters' grades in widths from ½ to 3 inches. Both ferrous and non-ferrous types are made—ferrous means that the magnetic iron in the tape does not exceed 2% and that the total iron content (magnetic and chemically combined) does not exceed 6%—non-ferrous means that the magnetic iron does not exceed 0.75% and the total iron content does not exceed 1.75%. Variations in construction are possible such as combining asbestos warp yarns and cotton filling yarns or reinforcing the asbestos with glass. For the asbestos fine tapes in thicknesses of .010", .015", .020", .025", and .030", underwriters' grade is standard. Commercial grade is used for thicknesses of 1/32", 1/16", ⅛", 3/16", and ¼". Other grades can be supplied on special order. Asbestos is used because of its thermal properties, flexibility, and resilience.

ASTM D 315-58T, Specifications and Methods of Test for Asbestos Tape for Electrical Purposes, covers underwriters' grade tape in thicknesses from .010" to .030" and widths from ½" to 2". Construction specifications tabulate the total ends, picks per inch, and pounds per 100 feet for each thickness and width.

Cotton tapes are supplied in a variety of weaves, thicknesses, widths, and constructions to provide different degrees of tensile strength, tear strength, elongation, resilience, and other properties. Plain weave tapes with their excellent stretchability are used most widely but there is also some use of herringbone weaves (twill) which are also called webbings or staybindings. Cotton tapes readily absorb varnishes and other impregnants.

Cotton tapes are covered by ASTM D 335-51, Specifications for Woven Cotton Tapes for Electrical Purposes. The table shows the ASTM physical requirements for cotton tape.

Most glass tape for electrical insulation is woven from continuous filaments, the staple fibers being used only where cushioning and resilience are desirable. As with cotton tapes, a wide variety of tape constructions are available. Some of those which have been supplied for a considerable length of time are shown in the table. ASTM D 580-49 covers Standard Methods of Testing and Tolerances for Woven Glass Tapes while military specification MIL-Y-1140C covers glass tape for electrical insulation.

Glass yarns are now woven in combination with polyester yarns for certain applications where some stretch is desirable.

Typical physical specifications for polyester fiber tape are also tabulated.

Cloths

For electrical insulation purposes, cloths and fabrics are nearly alwa treated or combined in some manne They serve primarily as treated clo insulation materials and prepregs (s section 3-7) and as base materials f laminated plastics (see section 3-14 They are also used in composite i sulations (see sections 3-8 and 3-13 Asbestos, cotton, glass, and glass polyester are generally used f treated fabrics but there has bee some usage of nylon, rayon, and sil Asbestos, cotton, glass, and nylon a commonly used for laminated plasti with limited usage of silica, polyeste and other man-made materials. Mu of the general information given f woven tapes would also apply to fa rics such as strength, flexibility, resi ence, stretchability, etc.

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SUPPLIER DIRECTORY LISTING

NOTE: Numbers in parentheses following e product covered in this section correspond the numbers shown in front of each supplier products listed here (thus indicating which f supply the product concerned). Only compa names are listed here—see Part 4, section 4-1, addresses of suppliers. Bold face type indicates vertisers—see advertisers' listing at back of b for page numbers of advertisements.

Products Covered in this Section

Acetate cloth (41, 43, 53)
Acetate fibers and yarns (7)
Asbestos cloth (6, 22, 33, 34, 47, 53)
Asbestos cord (33, 34, 47)
Asbestos felts and mats (47)
Asbestos fibers and yarns (15, 22, 33, 34, 46, 47)
Asbestos roving and lap (33, 47)
Ceramic cloth (11, 53)
Ceramic cord (11)
Ceramic felt (11, 58)
Ceramic fibers and yarn (11, 58)
Ceramic roving (11)
Cotton cloth (19, 35, 53, 59)
Cotton fibers and yarns (12, 35, 52)
Cotton mat (25, 35, 43, 59)
Cotton twines (7, 12, 17, 52)
Cotton tying tape (9, 12, 24)
Flax twines (7, 8, 36)
Fused quartz yarns and rovings (18, 23)
Glass cloth (6, 12, 19, 20, 29, 30, 37, 41, 44, 49
Glass cords, treated and untreated (17, 20, 33 49, 55)
Glass fibers and yarns (13, 20, 33, 37, 42, 44, 4
Glass lacing tapes, treated and untreated (20,
Glass mats (20, 33, 37, 42 44)
Glass roving (6, 17, 20, 30, 33, 37, 42, 44, 55)

Nylon cloth (19, 25, 41, 43, 53, 59)
Nylon fibers and yarns (1, 5, 15, 39, 52, 53, 56)
Nylon lacing tapes and twines, treated and untreated (2, 7, 25, 26, 28, 31, 36, 40, 43, 45, 56)
Paper cord (51)
Polyamide fibers and yarns (heat resistant type tradenamed "HT-I") (15, 53, 56)
Polyamide cloth (heat resistant type tradenamed "HT-I") (15, 25, 43, 53)
Polyester cloths (19, 25, 38, 41, 43, 53, 59)
Polyester fibers and yarns (5, 7, 15, 52, 56)
Polyester/glass cloths (12, 19, 41, 53)
Polyester lacing tapes, treated and untreated (25, 26, 28, 35, 36, 43)
Polyester mats (16, 25, 35, 38, 43)
Polypropylene fibers (14, 48, 56)
Polypropylene cloth (25, 43, 48, 53, 59)
Polypropylene mats (35)
Polytetrafluoroethylene lacing tapes (3, 4, 10, 20, 32, 57)
Rayon fibers and yarn (5, 7, 15, 52, 56)
Rayon cloth (19, 25, 41, 43, 53, 59)
Silica cloth (27, 53, 58)
Silica cord (23, 27, 55, 58)
Silica fibers and yarns (23, 27, 58)
Silk fibers and yarns (7, 26)
Silk cloth (53)
Vinyl lacing cords (26, 31, 45, 52, 56)
Woven acetate tape (12, 53)
Woven asbestos tape (6, 33, 34, 47)
Woven ceramic tape
Woven cotton tape (9, 12, 21)
Woven glass tape (6, 12, 19, 21, 29, 33, 37, 44, 50, 53)
Woven glass/asbestos tape (6)
Woven glass/polyester tape (6)
Woven polyester tape (6, 12, 53)
Woven silica tape (27, 53, 58)

Commos Glass Tapes

Thickness, Inch	Width, Inch	Total Ends	Picks Per Inch	Approx. Yds./ Lb.	*Min. Breaking Strength Range, Lbs.
		Tight (B) Weave			
.003	3/16	21	42	620	45
	1/2	30	42	419	60-64
	3/4	45	42	282	95-97
	1	63	42	206	135
	1 1/2	108	42	122	190-232
.005	3/16	21	39	279	125-129
	1/2	27	39	216	148-166
	3/4	39	39	149	244-249
	1	51	39	113	313-335
	1 1/2	75	39	77	459-477
.007	3/16	21	39	231	125-129
	1/2	27	39	179	148-166
	3/4	39	39	123	239-244
	1	51	39	94	313-335
	1 1/2	75	39	63	459-477
		Medium (A) Weave			
.005	1/2	24	35	258	100-106
	3/4	32	35	185	135-142
	1	42	35	140	160-175
	1 1/2	62	35	95	250
.007	1/2	24	32	179	130-161
	3/4	32	32	128	175-215
	1	42	32	97	240-283
	1 1/2	62	32	67	370-418
.010	1/2	16	21	133	160-213
	3/4	24	21	89	250-321
	1	32	21	68	350-428
	1 1/2	48	21	45	550-662
.015	1/2	14	16	95	210-319
	3/4	20	16	66	320-426
	1	26	16	50	440-593
	1 1/2	40	16	33	660-835
		Medium (C) Weave			
0.005	1/2	24	29		90-114
	3/4	32	29		124-152
	1	42	29		158-200
	1 1/2	62	29		232-295
0.007	1/2	24	29		114-132
	3/4	32	29		152-177
	1	42	29		200-232
	1 1/2	62	29		295-342
0.010	1/2	16	21		165
	3/4	24	21		249
	1	32	21		332
	1 1/2	48	21		497
0.015	1/2	14	16		207-254
	3/4	20	16		296-376
	1	26	16		386-490
	1 1/2	40	16		593-752
0.020	1/2	11	14		253-334
	3/4	15	14		345-464
	1	21	14		485-632
	1 1/2	31	14		713-962
0.025	1/2	20*	14		450-608
	3/4	30*	14		690-912
	1	40*	14		920-1216
	1 1/2	62*	14		1426-1885

Intended as a guide and not for establishing specifications.

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