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NUMBER 6

ection 3-8: Flexible Cloth, Film, Fiber, Mat, Metal, and Paper Composite Insulations

ew Developments

High temperature polyamide paper Nomex" nylon) has been combined th many other flexible insulation aterials to form composites with a ariety of properties. The paper is escribed in section 3-4. It does not elt or support combustion—above 500°C, it will char and can be consumed by fire, but it won't burn ndependently. The paper is said to offer a unique combination of good electrical properties, long useful life at temperatures well above class 180, and outstanding mechanical strength, toughness, and resistance to abuse. The paper reportedly resembles the best rag paper in tensile and tear strengths, flexibility, and toughness. It is recognized for use up to 220°C. Composite applications include turn, layer, or barrier insulation in transformers; slot, phase, and wedge insulation in motors and generators; and many other uses where high temperature resistance is required. Some of the typical composites follow:

Polyamide Paper/Polyester Film

The combination of polyamide paper with polyester film represents an improvement in cut-through resistance under severe overload conditions and superior thermal aging characteristics compared with many other polyester film composites. Two- and three-ply composites are common. The film provides reinforcement and/or dielectric strength as needed.

Polyamide Paper/Polyimide Film

Composites of polyamide paper with polyimide film offer advantages similar to the polyester film composites but the polyimide provides heat resistance more in keeping with that of the paper (well above 200°C continuous). The film is flame resistant, does not melt, and is infusible. Constructions are both duplex and triplex.

Other Polyamide Paper Composites

High temperature polyamide has also been combined with many other materials in order to obtain specific properties. For example, FEP and PTFE film composites for heat resistance and low coefficient of friction. Asbestos or asbestos-glass mat for high temperature stability, good compressive creep characteristics, and flame resistance. Unidirectional glass or glass fabrics for increased mechanical strength and thermal conductivity as well as thermal stability and flame resistance. Varnished glass fabrics add dielectric strength to these features. Polyester mat can be used to facilitate absorption of varnishes and resins.

◀ Development work is reported on composites made with different types of purified asbestos papers in combination with polyimide film and FEP film. They would appear to qualify for class 155 or 180.

Author Credits:

This section was prepared by the editorial staff with the assistance of others acknowledged at the end of this section.

Introduction

Some insulating materials are outstanding electrically, but may lack certain physical properties for a particular application. Others may be suitable in physical properties, but lack the electrical characteristics required. Likewise, thermal, chemical, and moisture resistance properties may be factors.

When this problem is encountered, it can often be solved by laminating one or more materials together to form a composite insulation. Since practically any material can be com-

bined with another, many different constructions have been made, and many new ones will be made in the future.

However, one thing must always be kept in mind when considering composite insulations: *Many physical and electrical properties of a composite insulation are not better than those of the material having the superior properties.* This often means there is no addition of property values as a result of a combination of materials. The same holds true for adhesives when used to bond the materials together. The composite is no better than the adhesive used. An adhesive must be chosen to withstand the operating conditions for which the composite was developed, except in cases where the adhesive only facilitates assembly and deterioration of the adhesive will not cause contamination.

The purpose of this Encyclopedia section is to list the major composites available together with their applications and general property features. Because materials can be combined in practically any thickness to obtain various property values, it is not practical in most cases to attempt to provide details here on specific property values or thicknesses. The reader is advised to refer to the other sections for a more thorough discussion of the various individual materials used to make composite insulations. Also, mica paper composites are not covered here but are discussed in Section 3-15 (Mica Products).

Throughout this section, the terms "duplex" and "triplex" are used in the various descriptions. *Duplex* means a laminate of two layers, e.g., silicone varnished glass/asbestos paper. *Triplex* means a triple layer laminate, e.g., silicone glass/asbestos paper/silicone glass.

It should be remembered that nearly all flexible materials can be combined—if a particular combination is not mentioned here, reference to other sections on the individual materials should provide pertinent information.

ASBESTOS PAPER COMPOSITES

Asbestos is an inorganic compound whose melting point is well in excess of 1000°F. Although several companies manufacture asbestos products, papers for electrical use must be of a highly purified grade. The principal ones used in composites are of either the short fiber types or long fiber asbestos-glass types. All are covered by Military Specification MIL-I-3503C as to purity of asbestos.

Short fiber asbestos papers are classified as to the amount and composition of the binder they contain. Those containing organic binders are recommended for class 130 use by the paper manufacturer. Equipment manufacturers, however, often use these products in composite form above class 130 temperatures. The more expensive papers contain from 15% to 25% polyvinyl acetate as a binder. Less expensive class 130 papers contain from 10% to 20% starch, wood pulp, or nitrile rubber. Class 155 papers contain from 40 to 50% epoxy resin. Class 180 papers contain from 15% to 50% silicone resin as the binder. Tensile and tear strengths are very low and depend upon amount of binder used.

Short fiber papers are also available without a binder which allows them to be used from class 130 through class 180 temperatures depending upon the equipment manufacturer's impregnating resin. These materials are low in abrasion resistance but have comparatively high tensile strength and are relatively inexpensive in composite form. These papers are made of a highly purified asbestos base. The fibers are thoroughly cleaned and matted in a wet felting process.

Long fiber papers have lower organic content (2% to 6%) than the short fiber papers and are manufactured with various amounts of glass fiber content. Glass fibers improve the physical properties and result in a lower-density, open structure paper which can be easily saturated. As with short fiber papers, the dielectric properties will greatly depend upon the saturating or impregnating resins used.

Asbestos Paper/Polyethylene Film

Both duplex and triplex laminations of asbestos paper and polyethylene film are produced. The polyethylene is used for its electrical and its moistu and chemical resistance properti: However, the composite is limited far as high temperature applicatio are concerned, due to the temperatu limitations of the polyethylene fil:

Asbestos Paper/Polyester Resin Treated Glass Cloth

Combination asbestos paper a: modified polyester resin treated gla cloth meets the requirements of cla 155 insulating materials. The i: sulation can be formed and creas: with minimum loss of dielectr strength. Bond retention is good. T: material is used as layer insulation dry type transformers and slot i sulation in rotating equipment.

Asbestos Paper/Oleoresinous Varnished Glass Cloth

Both duplex and triplex combin tions of this composite insulation a: available as sheet and rolls. It is class 130 insulating material havi very good physical and electric properties plus good heat resistan: It is easy to handle and permits for: ing and creasing with minimum lo of dielectric strength. Bond retenti: is good. The plain asbestos paper a: sorbs the electrical insulation varni: used in impregnating transforme: The varnished glass cloth gives add: protection to the impregnated insul tion.

Triple and duplex combinatio: find application as layer insulation dry type transformers and slot insul tion in rotating equipment.

Asbestos Paper/Resin Treated Polyester Mat

This composite material is co: structed of polyester fiber non-wov: mat which has been securely bond: to asbestos paper by application suitable resins which have been cur: under heat and pressure rolls. Th polyester mat has very good elong tion properties which are imparted the over-all insulation. It is main used to give additional strength to a bestos paper for ease of handling a: moisture resistance purposes. Havi good high-temperature characteristi: it should be applicable to seve: classes of operating temperatures d pending on the type of resin used f bonding.

Asbestos Paper/Silicone Varnished Glass Cloth

Duplex structures of silicone varnished glass and asbestos paper are sold in transformers requiring impregnation with silicone varnishes. The silicone varnished glass cloth has excellent electrical properties that are imparted to the composite insulation.

Silicone Treated Asbestos Paper/ Silicone Treated Glass Cloth

High heat resistance to class 180 ambient temperatures and overloads is possible with a construction consisting of both silicone treated glass cloth and asbestos paper. It is available as both duplex and triplex constructions. The triplex material is not as flexible as the duplex, but it is possible to form and crease it with a minimum loss of dielectric strength.

Purified Asbestos Paper/ Glass Cloth

When purified asbestos is bonded to plain glass cloth, a porous structure results having poor electrical properties. However, this construction is very good for use in transformers that are impregnated with suitable electrical insulating varnishes. The combination very easily soaks up the varnish and, after baking, the composition has good electrical properties.

Purified Asbestos Paper/Polyester Film

Asbestos paper laminated to polyester film is available in a variety of duplex and triplex constructions. The dielectric strength properties are good, but the power factor and dielectric constant tend to be high, especially in the three-ply combination. Here again, the composites are meant for insulating transformers when the transformer is subsequently impregnated with class 130 insulating varnishes. The asbestos readily accepts the varnish impregnation, and after baking the insulation is a heterogeneous composition with excellent electrical and physical properties. The composite in duplex form is also used as a cable binder.

Purified Asbestos Paper/Unidirectional Glass Yarns

Two layers of asbestos paper reinforced with unidirectional glass yarns make up a composite that is chiefly used as a binder for cables. A commonly available construction consists of 0.004" purified asbestos paper reinforced with sixteen No. 150-1/0 yarns per inch. These continuous filament yarns have a nominal diameter of 0.0069".

Purified Asbestos Paper/Glass Cloth, Polyvinyl Acetate Adhesive

Several duplex and triplex constructions are made from purified asbestos paper and leno (open weave) and tightly woven glass cloth bonded with polyvinyl acetate adhesive. The asbestos sheet may contain varying amounts of polyvinyl acetate ranging from small amounts to saturation.

Duplex leno glass cloth/asbestos paper constructions are made by bonding a continuous sheet of polyvinyl-acetate-saturated purified asbestos to 7-mil leno glass cloth (scrim) with a polyvinyl acetate adhesive. Besides affording an economical method of reinforcing and strengthening the asbestos sheet, the glass cloth provides one surface with the abrasion resistance of glass. This material is used for coil insulation, slot liners, phase separators, rotor bar wrapping, binding tapes for motor coils, and layer or wrapper insulation in transformer windings.

Triplex leno glass/asbestos paper constructions consist of a sheet of 7-mil leno glass sandwiched between two continuous sheets of polyvinyl-acetate-saturated purified asbestos paper, all securely laminated with polyvinyl acetate adhesive. Pressure rollers are employed, and a relatively dense sheet results. This greater density results in a considerably higher dielectric breakdown strength than the duplex material. Uses include coil insulation, slot liners, phase separators, rotor bar wrapping, binding tape for motor coils, and layer or wrapper insulation in transformer windings. Both the duplex and triplex constructions are reported to have thermal stability above class 130.

Duplex tightly woven glass cloth/ asbestos paper differs from the above constructions in that the asbestos sheet is more than 85% highly purified asbestos fiber and contains only a small amount of polyvinyl acetate resin to facilitate controlled satura-

tion. These composites adapt very well to coating or treating with various electrical insulating resins and varnishes and perform well through the temperature range of class 130 insulation. In the thinner grades, the material is very flexible, while the thicker grades are stiff. Specific uses are slot liners, phase separators, layer, wrapper, and barrier insulation, rotor bar wrapping, intercoil insulation, motor-coil binding tapes, and cable wrapping.

The *triplex construction* consists of tightly woven glass cloth inserted between two layers of asbestos sheet and bonded with polyvinyl acetate adhesive. The construction is denser than the duplex material and has a greater dielectric strength for a given nominal thickness. It, too, can be saturated with insulating varnishes and resins. It has considerable flexibility in the thinner gauges, while the thicker material is rather rigid. Specific applications include slot liners, phase separators, layer, wrapper and barrier insulation, rotor-bar wrapping, inter-coil insulation, motor-coil binding tapes, and cable wrapping.

Silicone Resin Treated Purified Asbestos Paper/Glass Cloth, Silicone Adhesive

A very good class 180 insulating material, this composite is reported to remain thermally stable at temperatures up to 250°C. Manufactured in duplex construction, it consists of a sheet of standard purified asbestos paper, saturated with silicone resin, backed with tightly woven glass cloth and bonded with silicone adhesive.

FLAKED GLASS PAPER COMPOSITES

Flaked glass paper is made on standard paper making machines using approximately 15% cellulose (kraft or glassine pulp) as the binder. This material is normally used in composite bonded to either polyester film or glass cloth. The flake tends to dust during handling, and this can be minimized in composites by proper selection of bonding resins and other processing conditions. Flaked glass laminates bonded with epoxy resins are currently being used at class 155 temperatures. The material has excellent electrical properties—dielectric strength of the individual flake is up to 2800 vpm. Because it is a non-hygroscopic material and only susceptible to moisture adsorption (which is negligible), it offers definite advantages over other high temperature materials such as asbestos which must be completely impregnated to reduce the problem of moisture absorption.

Flaked Glass/Polyester Film

The combination of flaked glass sheet and polyester film creates tough materials, possessing high mechanical strength, chemical inertness, thermal stability, and high dielectric strength. The composites are available in a multitude of duplex and triplex constructions. They are used as motor and generator magnet wire wrapping, slot and phase insulation; and transformer coil wrapping, layer and barrier insulation.

Flaked Glass/Glass Cloth

This composite combines the physical properties of glass fabric with the very good dielectric properties of the flaked sheet. When subjected to high temperature, the material demonstrates good thermal conductivity and dimensional stability while maintaining dielectric properties. It has good impregnation characteristics, excellent cut-through resistance, and high moisture resistance. Suggested uses include motor and generator magnet wire wrapping and coil insulation (usually tape); and transformer layer, barrier and coil insulation.

FISHPAPER COMPOSITES

Fishpaper is made from high-grade rag paper by chemical treatment with zinc chloride. It has a harder surface and is stiffer with higher dielectric and physical strength properties than ordinary rag paper. Its forming qualities are very good. It has been usually combined with varnished cambric and cellulose acetate film.

Fishpaper/Cellulose Acetate Film

Cellulose acetate film is combined with fishpaper to produce an insulating material having a high dielectric strength without greatly increasing the thickness of the paper. In addition, the film imparts qualities of toughness, and moisture and chemical resistance.

Fishpaper/Varnished Cambric

Both bias cut and straight cut varnished cambric are combined with fishpaper to produce a rugged insulation having high dielectric strength. A tough, flexible and long-lived insulating adhesive is used to bond the two materials.

The two types of fabric have similar properties except that the straight cut does not have as much stretch or elongation as the bias cut. Both yellow and black varnished cambrics are used. There is not much difference between these two materials, except that the black tends to have slightly better dielectric strength while the yellow may be slightly better in respect to abrasion resistance. The major use for these materials is as motor slot insulation.

KRAFT PAPER COMPOSITES

Kraft paper made from selected wood pulp is an economy electrical paper. It has somewhat less dielectric and physical strength than other papers. However, in combination with cellulose acetate or polyester film, it is still a superior insulating material to most other papers alone.

Kraft Paper/Cellulose Acetate Film

This composite is available in various duplex and triplex combinations. Application is limited, but the material has been put to some use as phase separators in motors.

Kraft/Polyester Film

In general, these composites have much better physical and chemical properties than the kraft/cellulose acetate combinations. Although they are used mainly as transformer insulation, they can also be used as slot and phase insulation in rotating equipment where service requirements are less critical and economy is an important factor. The composites are rated class 105.

The material is available in both duplex and triplex constructions. Because kraft paper is manufactured in thin gauges, these constructions are particularly suitable for small units where space is critical.

RAG PAPER COMPOSITES

Rag paper, as the name denotes,

per foil are being used for shielding purposes and as conductors in transformers and coils. In some cases, the foil is centered on a wider width of kraft paper so that the extra paper edge or margin provides additional electrical and mechanical protection to the conductor.

Copper is also combined with water repellent paper and resin impregnated paper for use as flexible printed circuit materials.

Polyester Film/Aluminum or Copper Foil

One composite is commonly available as 0.00035" aluminum foil bonded to 0.002" polyester film with an oil-resistant adhesive containing no chlorine. Its over-all thickness is 0.0025". Used in oil-filled cables, it is designed to have a minimum oil resistance of 20 hours at 125°C.

A seam overlay material for cable application is a lamination of aluminum foil/paper/polyester film. It is used to shield the corrugated metal seam from penetrating the outer polyethylene jacket during sheathing operations and prevents a thin spot from occurring in the longitudinal forming of the corrugated aluminum seam. It also provides for a tighter cable and makes it possible to reduce the thickness of the outer jacket.

Other composites of polyester film with copper foil in a variety of finished thicknesses are used for printed circuits, conductors in coils, cable shielding, and for electrostatic shielding wraps on bobbin wound and toroidal coils and transformers. For winding applications such as in magnet coils, the polyester film strip might be wider than the copper foil so that the extra edge margin will protect against turn to turn flash-over. For printed circuits, cover sheets of polyester film are available with a heat sensitive backing for protecting circuit.

PTFE-Fluorocarbon/Aluminum Foil

This composite has aluminum foil, 0.0002" to 0.005" thick, coated on one or both sides with PTFE film without use of adhesives. The fluorocarbon coatings are from 0.00006" to 0.004" thick. Applications include use in capacitors and transformers.

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SUPPLIER DIRECTORY LISTING

IMPORTANT: For fabricated or converted composite insulation products, see other sections, especially section 3-22.

NOTE: Numbers in parentheses following each product covered in this section correspond with the numbers shown in front of each supplier of products listed here (thus indicating which firms supply composites made from the product concerned). Rather than listing all the numerous composites possible, only single products used in composites have been listed. If a supplier's identifying number is listed after two different single products, this would generally indicate that the supplier would be able to supply a composite made from the two products concerned. Only company names are listed here—see Part 4, section 4-1, for addresses of suppliers. Bold face type indicates advertisers—see advertisers' listing at back of book for page number of advertisements.

Products Covered in this Section

Aluminum (1, 2, 4, 5, 7, 8, 9, 19, 21, 24, 25, 28)
Asbestos paper (1, 4, 5, 7, 13, 14, 18, 24)
Asbestos paper, silicone resin treated (1, 4, 5, 13, 14, 18, 24)
Asbestos paper, purified (4, 5, 12, 13, 14, 18, 24, 28)
Asbestos paper, purified, polyvinyl acetate treated (1, 4, 5, 7, 13, 14, 18, 24)
Asbestos paper, purified, silicone resin treated (4, 5, 13, 14, 15, 18, 23)
Cellulose acetate film (1, 4, 5, 21, 24, 28)
Copper (1, 4, 7, 9, 11, 14, 21, 22, 24, 25, 26, 27, 28)
Cotton cloth, oleoresinous varnished (1, 4, 15, 21, 23, 24, 26)
Fishpaper (1, 4, 5, 7, 21, 24, 26)
Flaxeo glass (4, 24)
Fluorinated ethylene propylene film (1, 5, 6, 9, 24)
Glass cloth (4, 5, 9, 12, 14, 19, 21, 24, 26)
Glass cloth, oleoresinous varnished (4, 12, 14, 16, 21, 23, 24, 26)
Glass cloth, polyester resin treated (4, 5, 9, 12, 16, 21, 23, 24, 26)
Glass cloth, silicone resin treated (2, 4, 5, 12, 16, 21, 23, 24, 26)
Glass yarns, unidirectional (2, 5, 12, 24)
Kraft paper (1, 4, 5, 7, 12, 19, 20, 21, 24, 25, 26, 28)
Nylon film (extruded—no adhesive) (9, 21, 24)
Polyamide fiber paper (heat resistant type trade named "Nomex") (2, 3, 4, 5, 7, 12, 19, 21, 24)
Polycarbonate film (1, 5, 9, 21, 25)
Polyester film (1, 2, 4, 5, 7, 9, 10, 12, 14, 19, 21, 25, 26, 27, 28)
Polyester mat (1, 4, 5, 9, 14, 21, 22, 24)
Polyethylene (1, 5, 7, 10, 14, 17, 19, 21)
Polyimide film (2, 3, 4, 5, 9, 21, 24, 27)
Polypropylene film (1, 4, 5, 7, 10, 17, 21)
Polytetrafluoroethylene film (1, 2, 3, 4, 5, 6, 8, 11, 14, 21, 24, 25)
Rag paper (1, 4, 14, 21, 24, 26, 28)
Rope paper (1, 4, 12, 20, 21, 24, 26, 28)
Sulphate paper, unbleached (1, 4, 5, 20, 21)

Suppliers of the Preceding Products

1—ARVEY CORP., LAMCOTE DIV.
2—THE BORDEN CHEMICAL CO., MYSTIK TAPE DIV.
3—THE BUDD CO., POLYCHEM DIV.
4—Chase-Foster, Inc.
5—Chase & Sons Inc.
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8—DODGE FIBERS CORP.
9—Dodge Fibers Corp., Circuit Materials Div.
10—EXTRUDO FILM CORP.
11—Garlock Inc., Garlock Electronic Products Div.
12—General Electric Co., Insulating Materials Dept.
13—JOHNS-MANVILLE
14—3M CO.
15—NATVAR CORP.

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16—NEW JERSEY WOOD FINISHING CO.
17—Plymouth Rubber Co., Inc.
18—RAYBESTOS-MANHATTAN, INC., ASBESTOS TEXTILE DIV.
19—R. J. Reynolds Tobacco Co., Archer Aluminum Div.
20—RIEGEL PAPER CORP.
21—Riegel Paper Corp., Industrial Films Div.
22—ROGERS CORP.
23—SUN CHEMICAL CORP., ELECTRO-TECHNICAL PRODUCTS DIV.
24—TRW ELECTRO INSULATION, TRW INC.
25—Tefilo Industries
26—Westinghouse Electric Corp., Insulating Materials Div.
27—G. T. Schjeldahl Co., Electrical Products Div.
28—LENNI PRODUCTS, INC.