

Insulation

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Section 3-18: Magnet Wire

New Developments

◀ DuPont has taken the wraps off its high temperature wire enamel previously known only as "ML" polymer and has revealed that the enamel is based on a polyimide polymer. The enamel was the only ML product described in last year's issue but this issue also includes information on polyimide coated glass fabrics (section 3-7) and polyimide varnish (section 3-12). Thus, insulation systems using all three materials can be developed. A composite film combining the advantages of a polyimide film next to the conductor and an outer polyvinyl formal film is also available.

◀ Apparently, a great deal of progress has been made in the long search for a practical ceramic or glass insulated wire for temperatures approaching or above the 500°C level. At least two such radiation resistant products have been announced. By combining an inorganic material with a heat volatile organic polymer used as a binder, a wire coating is achieved which has the flexibility and strength needed for handling and winding. After volatilizing the organic binder with heat, the fused inorganic film layer is left on the winding. The conductor is an oxidation-resistant clad-ding over copper.

Author Credit

This section was prepared by Harry L. Saums, Consulting Engineer, Anacosta Wire & Cable Co., Muskegon, Mich., under the auspices of the Wire and Cable Division, National Electrical Manufacturers Association.

The listings of enameled wires and of fiber and paper-covered wires give the following information:

A brief description of the composition of the insulating covering. This has been kept as simple as possible. In some cases the chemical composi-

tion has been defined in order to insure identification of the insulator. Trade names such as "Formvar," "ML," etc., are used if these materials are available to all magnet wire makers.

Usually the conductor is copper but in some cases nickel or silver-plated or clad copper is used and mentioned. No attempt has been made to indicate where aluminum can be used. Most of the insulations can be applied to aluminum conductors. Prospective users of aluminum magnet wires should discuss their problem with a magnet wire maker.

Standards and Specifications

Round copper wires are made to comply (where applicable) with the latest issue of American Standards Specifications for soft or annealed copper wire number C7.1.

Square and rectangular wires are made to comply (where applicable) with the latest issue of American Standards specifications for soft copper wire number C7.9.

The thermal classification is given using the nomenclature of the issue of AIEE No. 1 June 1957 entitled "General Principles upon which Temperature Limits are Based in the Rating of Electric Equipment." For example, 105°C (class A).

The assigned class is that believed to be accepted in the industry. In most cases the class assigned in the NEMA standard is used. If there is no NEMA standard, the class stated is from the published work of competent authorities who have evaluated the wire in accordance with "Test Procedure for Evaluation of the Thermal Stability of Enameled Wire" which is AIEE Publication No. 57. Or as provided in AIEE #1, the assignment is on the basis of experience in actual use.

There is no central authority for the assigning of a temperature class to any magnet wire. Therefore, the information given for each wire is

only the best data that can be obtained.

In some cases such as cotton, for example, the rating is specifically stated in AIEE #1.

The ratings given are for use of the wire in free air. Higher temperatures may be used in suitable gases, liquids, and solids. For example, wires used in hermetic motors may be operated at higher temperatures than the assigned class. Sealed systems employing air are subject to aging factors that depend upon the specific apparatus and the insulation system. Discussion of this is beyond the scope of this article.

The publication number of the applicable NEMA standard is given. If the specification has been accepted by the American Standards Association, the number and year of issue are stated.

NEMA magnet wire standard numbers may apply to those which have been accepted by ASA and those which have met all NEMA requirements relating to these standards but have not been accepted by ASA due to the time required for action but which are in a sufficiently advanced state of preparation by NEMA that they can be used.

The Military Specification data are taken from the 15 December 1959 issue Amendment 1. This specification (MIL-W-583B) requires that all enameled wires intended for classes 130, 155, 180, and 200 be approved before production and delivery to the military agencies. This is done by letter. The preproduction tests need not be repeated for individual lots. Wire makers can supply copies of their approval letters. The fact that this approval is necessary is stated for each wire to which it applies.

Comments

Availability of the wires is given based on information taken from many sources. Magnet wire makers' catalogs, NEMA specifications, pub-

lished papers, and advertisements were consulted. Makers differ greatly in the kind and size of wires which they will furnish. The data given in the listing are generally those considered to be available from more than one maker. Wires which do not come within the listing may be available from some makers.

Comments are given as to the intended or established use of the wire. An effort has been made to keep the comments as short and concise as possible. Outstanding advantages and disadvantages are given. The entire idea is to make the comments as short and useful as possible. It is impossible to answer every question that a user might desire to ask. The present complexity and size of the electrical industry are recognized by most magnet wire makers who offer technical information and service to engineers and manufacturers or users. Consult the maker of your choice.

No attempt has been made to include the voluminous data regarding performance characteristics, dimensions, and methods of tests. All of these data can be obtained by consulting the specifications or obtained from magnet wire makers.

Actually, the characteristics of the wires described fit them for proper use in their respective fields. No one wire is completely best in all characteristics. Each may have one or more outstanding features. And no one wire can be used in all electrical devices.

Packaging

The packaging of magnet wires is now an extensive subject. Wires are offered on spools or reels and in pails and drums. In general, the round wires are put on spools in keeping with their size and other characteristics. The smaller the wire, the smaller the spool. To conserve winder's time, some round wires are packaged in 100 pound pails or in drums containing as much as 800 pounds. Here too, the size of the wire is a governing factor in the selection of a usable pail or package. Square and rectangular wires are always put on reels. The most common reels are those with 12-inch and 24-inch flanges.

Round wires are random wound on spools or reels. The round wires are put into the pails and on reels following a carefully designed pattern. In all cases the wire is so packaged that it will reach the user in good condition and be capable of proper removal from the package by the winding process.

ENAMEL AND FILM COATED WIRE

Acrylic ("Lecton"—Du Pont)

Basic resin is a copolymer of acrylonitrile plus acrylate and phenolic resin. The enamel film is applied from an aqueous dispersion.

Thermal Classification—105°C (class A).

NEMA Standard MW 4.

Military Specification. Not specifically covered in MIL-W-583B. Available in round wires, grades single, heavy and triple.

The insulating film is resistant to refrigerants and many solvents. It resists refrigerant R-22 and is used in hermetic sealed motors where the refrigerant is in contact with the wire. The temperature rating given as 105°C (class A) applies to use of the wire in air. In hermetic motors containing refrigerants this rating may be exceeded.

Cellulose Lacquer

Coating resin is based on cellulose acetate.

Thermal Classification—105°C (class A)

NEMA Standard—None.

Military Specification—None. Not covered by MIL-W-583-B.

Available in round wires, sizes 36 Awg and smaller. Coating thickness in 3 grades. Thinnest for paper-filled coils, medium thickness for general random winding, and thickest grade for severe winding conditions.

Chief advantage is that film may be soldered through using alcohol rosin flux and tin-lead solders at moderate temperatures.

Ceramic

The inorganic insulating film is composed largely of metallic oxides. This is deposited on various conductors such as copper, nickel-clad copper, or other metals over copper to prevent oxidation of the copper.

Thermal Classification—Depends

upon the particular coating and conductor. Some constructions may be operated as high as 500°C.

NEMA Standard—None.

Military Specification—None, since not specifically covered in MIL-W-583B.

Available in a limited range of round wires. In general, sizes 20 Awg and finer. No standards on insulation thicknesses have been developed.

Used where high temperature or nuclear radiation may be present.

Since this is a new development in a field that is growing rapidly, the user should obtain specific information from the supplier.

Ceramic-Conversion Type

The insulating film is an organic enamel with ceramic or glass materials dispersed throughout. It is smooth and glossy and generally resembles the familiar enamels. The conductor is an oxidation-resistant cladding over copper.

Thermal Classification—500°C. No assigned class.

NEMA Standard—None

Military Specification—None

Available in round sizes #18 to #40 Awg inclusive. Grades single, heavy, and triple in as-received condition.

Windings are made with this wire in the usual manner. The bobbins or other parts of the insulation system must be inorganic. After the coil is finished it is heated sufficiently to drive off all the organic portion of the film and to sinter or fuse the ceramic particles into a continuous insulating film. The maximum temperature reached is above the 500°C rating.

The wire can be used in any electrical device where high temperature operation is needed.

Ceramic with Polytetrafluoroethylene Overcoat

The insulation is a ceramic film deposited on a conductor of copper, or copper protected by a coating of nickel or other metal. A coating of polytetrafluoroethylene ("Teflon"—Du Pont) is applied as an overcoat.

Thermal Classification—Class 220°C.

NEMA Standard—MW-8.

Military Specification—MIL-W-

first composite enamel insulations.

Thermal Classification—105°C (class A).

NEMA Standard—MW-17.

Military Specification—MIL-W-583B. Class 105—types T, T2, T3, and T4.

Available in round sizes, 8 Awg to 46 Awg, and in grades single, heavy, and triple.

This composite enameled wire combines the characteristics of the two resins. The nylon improves the windability and the choice of impregnating varnishes. The windings can be dipped while hot into varnishes having strong solvents. It is used principally in rotating equipment that requires the cured varnish to be hard and strong in order to withstand high rotational speeds.

Polyvinyl Formal with Polyvinyl Butyral Overcoat (Self-Bonding)

Composite enamel magnet wires having a polyvinyl formal film next to the conductor and a polyvinyl butyral overcoat.

Thermal Classification—105°C (class A).

NEMA Standard—MW-19.

Military Specification—None.

Available in round sizes, 10 to 44 Awg. Made in three grades or types. Grades 1, 2, and 3. The single, heavy, and triple undercoats have a single overcoat making the total film thickness equal to heavy, triple, and quadruple.

The overcoat is a thermoplastic resin used to cement or bond the turns in a winding together. This can be done by heating the coil after it is wound by passing current through the coil. The wire can be wet with a solvent while being wound. This activates the overcoat. The solvent escape can be improved by heating the coil.

Used in complicated coils which must be self supporting. Also to eliminate bobbins in encapsulated coils.

Polyvinyl Formal with "ML" Undercoat

This composite film wire has a coating of "ML" next to the conductor. The outer coating is of polyvinyl formal. The film thickness proportions are about 25% "ML" and 75% polyvinyl formal. Here the polyvinyl formal coatings may be any of those

in previous listings.

Thermal Classification—180°C (class H)

NEMA Standard—None

Military Specification—None

Availability is generally the same as for the standard polyvinyl formal (Formvar) wires in all shapes—round, square, and rectangular—all grades and sizes. This is a very recent development, so specific statements of what can be secured cannot be made at this time.

This newly developed magnet wire combines the good properties of both of the kinds of coating to present a unique magnet wire of high thermal stability. It has excellent heat and solvent shock resistance. The thermoplastic flow point is high. It has outstanding resistance to burnout. It has high resistance to hydrolysis. The polyvinyl formal on the outside contributes the excellent windability for which it is well known. The "ML" undercoat contributes the thermal stability of this polymer. May be used in any electrical equipment.

FIBER AND COVERED WIRE

Asbestos Fiber

Insulation consists of a layer of resin impregnated asbestos fibers. The outer surface may be varnish treated or coated with an adhesive.

Saturants for 130°C (class B) are phenolic or asphaltic.

Saturants for 180°C (class H) are silicone.

The felted asbestos insulation is applied to the conductor by employing adhesives, a card, and sizing dies.

Thermal Classification—130°C (class B) with phenolic or asphaltic varnish; 180°C (class B) with silicone varnish.

NEMA Standard—None.

Military Specification—MIL-W-583B, class 130, type AV. Note—this specification may require special handling by the wire maker.

Available in round sizes #2 Awg to #25 Awg. Rectangular and square 2400 to 166,000 square mils.

Used primarily in a-c generator stator windings or apparatus subjected to overload. Coating is tough and withstands high pressures. Space factor similar to double cotton. Dielectric strength comparable to served or

wrapped insulation but generally somewhat lower.

Cotton Yarn

The insulating covering is made of one or more servings of cotton yarn.

Thermal Classification—If not impregnated, 90°C (class O); if impregnated, 105°C (class A).

NEMA Standard—Round Wires—MW-11; Rectangular Wires—MW-12.

Military Specification—MIL-W-583B—Class 90, types C, C2.

Available in round sizes—4/0 Awg to 36 Awg and in all sizes, square and rectangular. Single and double served.

This, the oldest magnet wire, is used where space separation of the conductors is required and where complete penetration of insulating varnishes, compounds, or oils is desired.

Glass Fiber, Organic Bond

The insulating coating consists of one or more servings of glass fibers bonded with an organic varnish. The composition of the varnish varies but usually is based on phenolic resins.

Thermal Classification—155°C (class F).

NEMA Standard—Round Wires—MW-41; Rectangular Wires—MW-42.

Military Specification—MIL-W-583B. Class 130, types GV, G2V.

Available in round sizes 2/0 Awg to 40 Awg and in all sizes, square and rectangular. Single and double served.

This wire is used in a wide variety of apparatus designed to operate at the class temperature, 155°C. The glass acts as a spacer between turns. Being varnished, it is readily treated by impregnating varnishes. Insulations made of glass fibers are available so that a suitable insulation system can be made.

The wire is particularly useful in dry type transformers and in rotating machines.

Glass Fiber, Organic Bond With Dispersed Ceramic Filler

The insulation consists of one or more servings bonded with a varnish in which ceramic or glass powder is thoroughly dispersed. The conductor is copper-core with an oxidation protective cladding. The varnish is completely fugitive when heated suffi-

or endure the winding hazards satisfactorily.

The table gives the useful combinations stating the availability as round and rectangular wires including square as a rectangle. The data given under the individual listings apply to the combinations. In most cases where the individual wires are covered by the stated specifications the combinations are also mentioned.

LITZ WIRE

Originally, as designed by Litz, this was a conductor consisting of a plurality of enameled strands transposed continuously along its length. It was intended to be used in winding coils having the best time constant,

$$\left(\frac{L}{R}\right)$$

The term is used today in reference to wires of this type and also wires with limited transposition of the strands.

The enamel used is usually polyurethane because it is solderable.

Two or more wires may be laid parallel or twisted and covered with textile threads such as rayon, nylon, silk, etc. Or the wires, if parallel, are covered with an enamel.

No specifications, except those privately issued, are published.

The wire is usually available in fine sizes and a few strands.

It is used in winding coils intended for use at high frequencies.

Acknowledgment

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SUPPLIER DIRECTORY LISTING

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 the product 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 numbers of advertisements.

Products Covered in this Section

Enamel and Film Coated Wire

Acrylic (6, 10, 11, 12, 14, 22, 23)
Aluminum oxide (aluminum conductor only) (19, 22)
Cellulose lacquer (7)
Ceramic (12, 20, 21, 24, 25, 26)
Ceramic-conversion type (26)
Ceramic with polyimide (formerly tradenamed "ML" resin) overcoat (25, 26)
Ceramic with polytetrafluoroethylene overcoat (25, 26)
Ceramic with silicone overcoat (25, 26)
Chrome oxide filled enamel, inorganic bond (22)
Epoxy (1, 2, 6, 7, 8, 10, 11, 12, 18, 20, 22, 23, 30)
Epoxy with self-bonding epoxy overcoat (1, 6, 11, 12, 20, 22)
Epoxy modified with polyester (6, 22)
Nylon (1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 20, 22, 23, 29, 30)
Oleoresinous (1, 3, 6, 8, 10, 11, 12, 14, 17, 18, 20, 22, 23, 29, 30)
Polyimide (formerly tradenamed "ML" resin) (5, 7, 11, 12, 14, 15, 18, 22, 23, 25, 26, 29, 30)
Polyester (1, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 18, 20, 22, 23, 25, 29, 30)
Polyester modified with polyurethane (6, 7, 10, 11, 14, 18, 20, 22, 23, 29, 30)
Polyester modified with polyurethane and with a polyester overcoat (1, 6, 7, 10, 11, 12, 13, 18, 20, 22, 23, 29)
Polyester with polyvinyl butyral overcoat (self-bonding) (6, 12, 13, 18, 22, 29)
Polytetrafluoroethylene (3, 4, 5, 6, 25, 26, 28, 30, 32)
Polyurethane (1, 6, 7, 8, 10, 11, 12, 13, 14, 15, 17, 18, 20, 22, 23, 26, 29, 30)
Polyurethane with friction surface (7, 10, 11, 13, 20)
Polyurethane with nylon overcoat (1, 6, 7, 8, 10, 11, 12, 13, 14, 18, 20, 22, 23, 29, 30)
Polyurethane with nylon and polyvinyl butyral overcoats (7, 10, 11, 12, 13, 18, 20, 22, 29)
Polyurethane with polyvinyl butyral overcoat (self-bonding) (6, 7, 10, 11, 12, 13, 14, 18, 22, 29)
Polyvinyl formal modified with phenol formaldehyde (6, 10, 11, 12, 14, 17, 18, 20, 22, 23, 26, 29)
Polyvinyl formal modified for hermetic use (1, 8, 10, 11, 12, 13, 14, 18, 20, 22, 23)
Polyvinyl formal with nylon overcoat (1, 6, 8, 10, 11, 12, 13, 14, 18, 20, 22, 23, 29, 30)
Polyvinyl formal with polyvinyl butyral overcoat (self-bonding) (1, 6, 10, 11, 12, 14, 18, 20, 22, 29)
Silicone modified with polyester (5, 6, 15)
Silicone with polytetrafluoroethylene overcoat (5, 6)

Fiber and Paper Covered Wire

Asbestos fiber, organic bond (13, 27, 31)
Asbestos fiber, silicone bond (13, 27, 31)
Asbestos fiber with glass fiber reinforcement, organic bond (13, 27, 31)
Asbestos fiber with glass fiber reinforcement, silicone bond (13, 27, 31)
Asbestos fiber with second serving of glass fiber, organic bond (27, 31)
Asbestos fiber with second serving of glass fiber, silicone bond (27, 31)
Cotton yarn (1, 2, 6, 7, 10, 11, 12, 13, 14, 16, 18, 20, 22, 23, 27)
Glass fiber, organic bond (2, 6, 7, 10, 11, 12, 13, 14, 16, 18, 23, 27)
Glass fiber, silicone bond (2, 6, 7, 10, 11, 12, 13, 18, 20, 27)
Glass and polyester fibers, organic bond (6, 7, 10, 11, 12, 13, 14, 18, 20, 23)
Glass and polyester fibers, silicone bond (6, 10, 11, 12, 13, 18, 20)
Nylon fiber (1, 6, 7, 11, 12, 14, 18, 22)
Paper tape (2, 6, 7, 10, 11, 12, 14, 18, 20, 22, 23)
Paper tape with second serving of cotton yarn (2, 6, 7, 10, 11, 12, 14, 18, 20, 22)
Silk yarn (6, 11, 18)

Combination (Enamel and Film/Fiber and Paper) Covered Wire

Glass fiber with purified asbestos paper cover (6)
Oleoresinous enamel with asbestos fiber cover, organic bond (6, 7)
Oleoresinous enamel with cotton yarn cover (1, 6, 7, 11, 12, 14, 18, 22)
Oleoresinous enamel with glass fiber (6, 7, 11, 14, 18)
Oleoresinous enamel with nylon fiber cover, organic bond (1, 6, 7, 11, 12, 14, 18, 22)
Oleoresinous enamel with paper tape cover (6, 7, 11, 12, 14, 18, 22)
Oleoresinous enamel with silk yarn cover (1, 6, 7, 11, 18)
Polyimide (formerly tradenamed "ML" resin) with glass fiber, silicone bond (11, 12, 18, 20)
Polyester film with purified asbestos paper cover (6, 7)

Polyester modified with polyurethane and with a polyester overcoat with glass fibers, silicone bond (7, 11, 18, 23)
Polyester modified with polyurethane and with a polyester overcoat with glass and polyester fibers, silicone bond (7, 11, 18, 23)
Polyvinyl formal enamel with asbestos fiber cover, organic bond (6, 7, 13)
Polyvinyl formal enamel with cotton yarn cover (1, 6, 11, 12, 13, 14, 18, 20, 22)
Polyvinyl formal enamel with glass fiber cover, organic bond (6, 11, 12, 13, 14, 18, 23)
Polyvinyl formal enamel with glass and polyester fibers (11, 12, 13, 14, 18, 20)
Polyvinyl formal enamel with paper tape cover (6, 11, 12, 14, 18, 20, 22)

Suppliers of Preceding Products

- 1—Acme Wire Co.
- 2—Alcoa, Rome Cable Div.
- 3—ALPHA WIRE CORP., SUBSIDIARY OF LORAL ELECTRONICS CORP.
- 4—American Standard Wire & Cable Co.
- 5—AMERICAN SUPER-TEMPERATURE WIRES, INC., A SUBSIDIARY OF HAYES INDUSTRIES, INC.
- 6—ANACONDA WIRE AND CABLE CO.
- 7—BELDEN MANUFACTURING CO.
- 8—Chicago Magnet Wire Corp.
- 9—Dielectric Materials Co.
- 10—THE ELECTRIC AUTOLITE CO., WIRE AND CABLE DIV.
- 11—ESSEX WIRE CORP., MAGNET WIRE DIV.
- 12—GENERAL CABLE CORP.
- 13—General Electric Co., Wire and Cable Dept.
- 14—General Motors Corp., Packard Electric Div.
- 15—HUDSON WIRE CO., MAGNET WIRE DIV.
- 16—Nehring Electrical Works
- 17—New Haven Wire & Cable, Inc.
- 18—THE OKONITE CO., KENNECOTT WIRE AND CABLE DIV.
- 19—Permaluster, Inc.
- 20—PHELPS DODGE COPPER PRODUCTS CORP., INCA MFG. DIV.
- 21—PHYSICAL SCIENCES CORP., AFFILIATE OF PACKARD BELL ELECTRONICS
- 22—REA MAGNET WIRE CO., INC., SUBSIDIARY OF ALCOA
- 23—Reynolds Metals Co.
- 24—Secon Metals Corp.
- 25—Simolex Wire & Cable Co., Hitemp Wires Co. Div.
- 26—Sprague Electric Co., Special Products Div., Wire Dept.
- 27—Standard Wire and Cable Co.
- 28—Thermal Wire of America
- 29—Viking Wire Co., Inc.
- 30—Warren Wire Co.
- 31—Westwood Cable Corp.
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