PLAINTIFF'S EXHIBIT

E-18

ELECTRICAL INSULATION

Its Application to Shipboard Electrical Equipment

NOTICE

This Book Is the Property of the United States Government

In its search for new and improved electrical insulation the Bureau of Ships has promoted the use of high-temperature silicone insulation. These promotional efforts have been realized in material and equipment contracts with industrial concerns for complete test analysis of the insulation. These test data have been used to integrate design and application requirements for high-temperature insulation in new-ship construction programs as well as maintenance and repair of presently installed equipment.

As there is no previously published information that contains all the whys and wherefores of electrical insulation under one cover, it is believed that this book will cover a long-felt need in this important field.

This book should be put into the hands of personnel directly concerned with electrical insulation for ready reference and study. Any comments or suggestions that may improve this book will be welcome.

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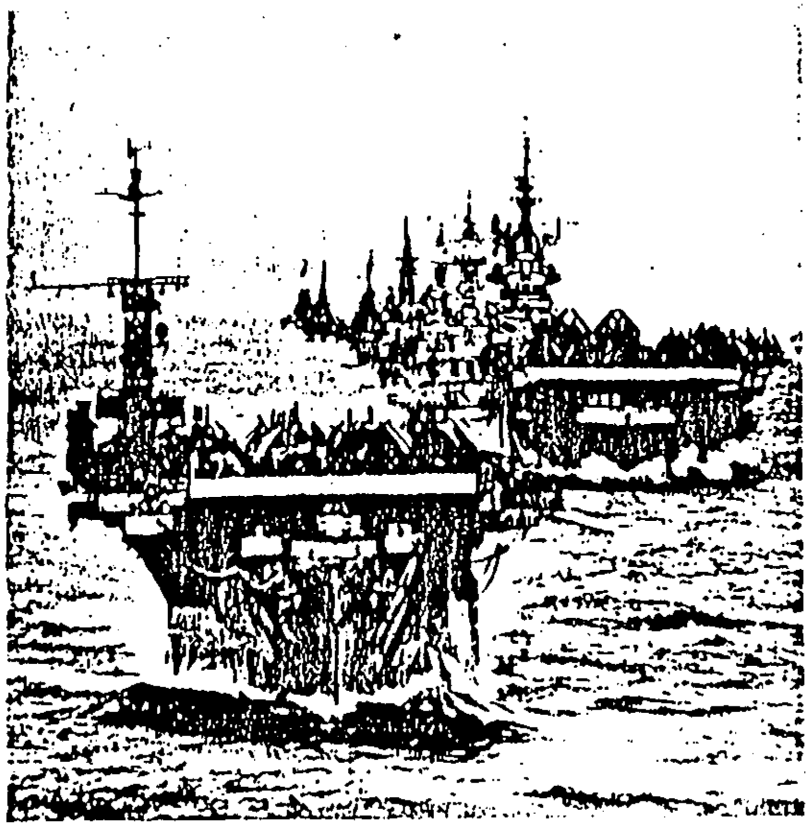

ELECTRICAL INSULATION

Its Application to Shipboard Electrical Equipment

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FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK TORONTO LONDON 1951

ELECTRICAL INSULATION

Preface

This manual has been prepared with two objectives in mind: (1) to make available under one cover the latest information on electrical insulating methods and materials, (2) to acquaint Navy personnel with the high-temperature silicone (class H) insulation which is now finding its place in the fleet in electrical equipment where moisture and temperature conditions have previously caused high maintenance costs when conventional materials were used.

The trends in design of electrical equipment today for shipboard use are toward higher temperatures; increased reliability; smaller, lighter weight equipment; and elimination of cellulose-base materials to reduce fire and toxic hazards.

As the insulation is the heart of the electrical plant, it cannot be overstressed that the best obtainable materials and the most reliable methods of application should be utilized to ensure continued operation with a minimum of maintenance.

Although this manual has been prepared on the basis of primarily covering rotating electrical equipment, the materials and methods of application are applicable in most cases to all types of electrical equipment.

This manual necessarily includes much information supplied by the U.S. Navy as well as by many industrial organizations and individuals. It has been the objective of the author to blend this diversified information with other technical information so as to present a clear, concise yet comprehensive picture of the art of applying insulation to electric machinery. Contributions, help, and comments of the following companies are gratefully acknowledged:

Allis-Chalmers Manufacturing Company
Anaconda Wire and Cable Company
Bentley, Harris Manufacturing Company
Continental-Diamond Fibre Company
Cutler-Hammer, Incorporated
Crocker-Wheeler Electric Manufacturing Company
Dow Corning Corporation

Electric Machinery Manufacturing Company
Electro Dynamic Works of the Electric Boat Co.
Elliott Company
Fairbanks, Morse & Company
General Electric Company
Irvington Varnish & Insulator Company
Leese-Neville Company
Mica Insulator Company
Mitchell-Rand Companies
National Electric Coil Company
National Vulcanized Fibre Company
Owens-Corning Fiberglas Corporation
The Acme Wire Company
The Formica Insulation Company
The National Varnished Products Corporation
The Okonite Company
The Reliance Electric & Engineering Company
Trumbull Electric Manufacturing Company
U.S. Navy Department, Bureau of Ships
Varflex Corporation
Wagner Electric Corporation
Westinghouse Electric Corporation

In addition to the technical information and help furnished by representatives of these contributing companies, individual engineers have spent a great deal of time in review of the manuscript and guidance of the author in its preparation.

The assistance and helpful suggestions of H. P. Walker of the U.S. Navy Department, Bureau of Ships, Electrical Branch, have been of inestimable value. The splendid cooperation of A. J. Sherburne of the General Electric Company, T. A. Kauppi of the Dow Corning Corporation, and G. P. Gibson and many other associates of the Westinghouse Electric Corporation is acknowledged with deep appreciation.

Illustrations were offered by many of the contributing organizations. Those used are credited individually.

GRAHAM LEE MOSES

PITTSBURGH, PA.
February, 1951

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ELECTRICAL INSULATION

Its Application to Shipboard Electrical Equipment treatment on electrical insulation to improve the appearance.

2-134. *Insulation, Electrical, Plastic Sealer,* MIL-I-3064, *Insulation Class A or B*

Plastic sealer compound is for use in sealing openings and filling voids in electrical insulation. It has a consistency that can be readily worked with the fingers or a knife and is capable of being drawn or kneaded into long, thin rods. It is suitable for application at room temperature, 30 C or less. The material is oilproof, has good water resistance, and is relatively nonflammable. The material has high insulation resistance and must not break down on application of a 1,500-volt a-c test for 1 minute in ½ inch thickness.

2-140. MAGNET WIRE AND INSULATION

The purpose of this manual is to cover insulation and windings, but copper is almost inseparable, as the major objective of insulation is to confine the electric current to copper conductors. A brief summary of copper characteristics and wire standards is therefore in order.

There are many wire gauges, but the American Wire Gauge (AWG) is now the American standard. This was devised by J. R. Brown in 1857 and is also called the Brown & Sharpe (B & S) gauge. This gauge system is based on a constant ratio of areas between consecutive wire sizes. The ratio between the diameter of any size wire and the next smaller size is 1.122932. The ratio of areas of the consecutive wire sizes is approximately 1.26. Therefore, the resistance per unit length of successive wire sizes is the inverse ratio of the area (1/1.26, or 0.794) for the resistivity of the next larger size. The AWG system is based on the diameter of No. 0000 wire being 0.4600 inch and the diameter of No. 36 wire being 0.005 inch. Hence there are 38 sizes between the two and 39 steps from No. 0000 to No. 36.

Standard wire sizes always refer to copper sizes. The insulated size of the wire depends upon the type of insulation used. As some insulations are much thicker than others, there is a wide variation in the space occupied by copper when different types of wire covering are used. The percentage of the total winding space occupied by copper is called the "space factor."

A wide variety of magnet-wire coverings is available commercially, and all have some desirable characteristics to recommend them. The various standard materials and the ASA designations are listed in Fig. 2-5. The most important consideration in the selection of magnet-wire insulation is to recognize the dielectric strength limitations of all magnet-wire coverings. *The insulation dielectric of magnet-wire coverings should be considered to be that of the equivalent spacing.* Dielectric tests on wire samples should be recognized as comparative only. Magnet-

Properties of Annealed Copper

Specific gravity	8.89
Weight	0.321 lb per cu in.
Resistivity (25 C = 77 F)	10.5 ohms per circular mil foot
Coefficient of resistivity (25 C = 77 F)	0.00386 per deg C 0.00214 per deg F
Specific heat	3.25 watt-min per lb per deg C 1.8 watt-min per lb per deg F
Thermal conductivity (100 C = 212 F)	9.7 watts per sq in. per deg C per in. thickness 5.4 watts per sq in. per deg F per in. thickness
Tensile strength	30,000 lb per sq in.
Coefficient of expansion	0.000017 per deg C 0.0000094 per deg F

Fig. 2-4. Industry Standard Abbreviations—Magnet-wire Symbols

(Army-Navy nomenclature differs in some respects. See Sec. 2-141)

Basic Magnet-wire Letter Symbols

Asbestos	A
Bonded	B
Cotton	C
Double	D
Enamel	E
Glass	G
Heavy	H
Cellophane	K
Cellulose acetate	L
Paper	P
Silk	S
Thermoplastic (synthetic)	T
Varnish-treated (including silicone)	V

Combination insulations are specified by using the approved letter symbols in the order of application to the conductor. A list of popular combinations of the above and their proper symbol indications follows:

Asbestos Covered

Single asbestos	A
Single asbestos varnish	AV

Enameled

Enamel	E
Heavy enamel	HE

Cotton Covered

Single cotton	C
Bonded single cotton	BC
Single cotton varnish	CV
Double cotton	DC
Bonded double cotton	BDC
Double cotton varnish	DCV
Heavy double cotton	HDC

Paper and Cotton Covered

Single paper single cotton	PC
Single paper double cotton	PDC
Double paper single cotton	DPC
Double paper double cotton	DPDC

Silk and Cotton Covered

Single cotton single silk	CS
Single cotton double silk	CDS
Double cotton single silk	DCS
Double cotton double silk	DCDS

Thermoplastic Insulated

Single	T
Heavy	HT
Triple	TT
Quadruple	QT

Glass Insulated

Single glass	G
Double glass	DG
Single enamel single glass	EG
Heavy enamel single glass	HEG

Cellulose Acetate Covered

Single acetate	L
Single enamel single acetate	EL
Single acetate single cotton	LC
Double acetate	DL

Cellophane Covered

Single cellophane	K
Single enamel single cellophane	EK
Heavy enamel single cellophane	HEK

Enamel and Cotton Covered

Enamel single cotton	EC
Enamel bonded single cotton	EBC
Enamel single cotton varnish	ECV
Enamel double cotton	EDC
Enamel bonded double cotton	EBDC
Enamel double cotton varnish	EDCV
Heavy enamel single cotton	HEC
Heavy enamel bonded single cotton	HEBC
Heavy enamel single cotton varnish	HECV
Heavy enamel double cotton	HEDC
Heavy enamel bonded double cotton	HEBDC
Heavy enamel double cotton varnish	HEDCV

Silk Covered

Single silk	S
Bonded single silk	BS
Single silk varnish	SV
Double silk	DS
Bonded double silk	BDS
Double silk varnish	DSV
Enamel single silk	ES
Enamel bonded single silk	EBS
Enamel single silk varnish	ESV
Enamel double silk	EDS
Enamel bonded double silk	EBDS
Enamel double silk varnish	EDSV
Heavy enamel single silk	HES
Heavy enamel bonded single silk	HEBS
Heavy enamel single silk varnish	HESV
Heavy enamel double silk	HEDS
Heavy enamel bonded double silk	HEBDS
Heavy enamel double silk varnish	HEDSV

Paper Covered

Single paper	P
Single paper bonded	BP
Double paper	DP
Double paper bonded	DPB

Enamel and Paper Covered

Enamel single paper bonded	EBP
Enamel double paper bonded	EDBP
Heavy enamel single paper bonded	HEBP
Heavy enamel double paper bonded	HEDBP

wire covering should be selected on the basis of physical strength, temperature classification, space factor, and ability to withstand winding abuse rather than dielectric strength as evaluated by laboratory tests.

The recognized basic wire coverings are summarized in the following, which comments briefly concerning the characteristics of each and the temperature classification:

Asbestos (A). Covering may be "felted on" or applied as a tape. It partakes of the characteristics of the basic asbestos and varnish (when treated). This wire may be either class B or class H insulation depending upon the type of varnish treatment.

Cotton (C). Insulation is always applied as a yarn in one or more thicknesses. It is seldom if ever varnish-treated and is class O or class A insulation depending upon varnish treatment employed on the finished coil.

Enamel (E). This is the thinnest type of insulation which has the best space factor. It is a class A insulation.

Glass (G). Glass is applied in the same manner as cotton and is nearly always varnish-treated. It is either class B or class H depending upon the type of varnish used.

Cellophane (K). This is a specialized class A wire covering.

Cellulose Acetate (L). This is another special form of class A wire covering.

Paper (P). Paper covering is widely employed both alone and in combination with enamel. It is a class O or class A insulation depending upon whether or not varnish treatment is employed.

Silk (S). Silk is the thinnest variety of fiber wire covering. It is class O or class A depending upon whether varnish-treated.

Thermoplastic (Synthetic) (T). This is a special form of enamel and includes those varieties commonly termed Formex or Formvar. It is class A insulation.

2-141. *Wire, Magnet*, JAN-W-583

Insulated magnet wire is available for all temperature classes of insulation. This specification covers a variety of types as tabulated below. Where no numeral is included in the type designation, single covering is indicated. The inclusion of numerals 2 or 4 designates double or quadruple covering. The nomenclature follows general industry practices as shown in Fig. 2-4 with several important changes.

The copper conductors under this specification are solid individual wires, either round or rectangular in shape.

Complex combinations of these basic types of wire covering are also made for special applications. These are described at length in JAN-W-583.

Type designation	Insulation class	Insulation
C	O or A	Cotton
E	A	Enamel
F	O and A	Fiber, synthetic
R	A	Resin
P	O or A	Paper
A	B	Asbestos, impregnated with a moisture-resisting compound
AV	B	Asbestos, impregnated with varnish
GV	B	Glass yarn, impregnated with varnish or other insulation having adequate moisture-resisting properties
GH	H	Glass yarn, impregnated with a high-temperature silicone varnish

3. Selection of Insulating Materials and Construction of Coils, Commutators, Slip Rings, and Brush Holders

The primary function of electrical insulation on coils is to guide the current through useful channels without leakage into undesired paths. Insulation on coils must possess many important electrical properties such as great dielectric strength, high electrical resistivity, low dielectric loss, and resistance to moisture absorption. These primary properties will determine the electrical effectiveness of the insulation, but the physical properties are at least as important as the electrical ones. Insulation must be capable of withstanding severe mechanical abuse during the manufacturing operations as well as reasonable physical stress during its operating life. Properties such as tensile strength, compressive strength, resistance to abrasion, flexural strength, tear strength, and bond strength plus ability to withstand bending without loss of electrical properties are all of importance. The chemical properties of insulating materials are also of equal importance. Insulations must be resistant to oils and common solvents and must not be damaged seriously by weak acids and alkalies. Low inflammability is desirable especially for shipboard applications. It is also desirable that materials be resistant to ozone degradation when exposed to corona. Thermal stability is probably the most important chemical property, as the thermal aging of insulation is known to be one of the most significant properties in determining the life of a winding. Coils of machines are supported on insulation, and often the individual conductors are completely surrounded by insulation. Since the heat generated within the winding must