

Marine Engineers' Handbook

Prepared by a Staff of Specialists

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With the general engineering fundamentals
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solvents; drying oil; varnishes based on cashew-nut-shell liquid, combined with resins (Harvel varnishes).

Varnishes have changed greatly in the last few years, since new oils have become available, and particularly since phenolic resins have been employed in their manufacture. The presence of plenty of linseed oil is no longer sufficient evidence of a good varnish, or the finding of rosin evidence of a poor one. Evaluation should be based on performance tests.

Impregnating Compounds. Bitumens and waxes are used to impregnate motor coils, the melted mix being forced into the coil in a vacuum tank, forming a solid insulation when cooled. Brittle compounds, which gradually pulverize due to vibration in service, and soft compounds, which melt and run out under service temperatures, should be avoided as far as possible. Impregnating materials for high-tension paper-insulated cables are usually a blend of petroleum products containing enough thickener to give the right degree of mechanical consistency. Chemical homogeneity of the materials is very important.

Oil. Refined grades of petroleum oils are extensively used for the insulation of transformers, switches, and lightning arresters. The following specification covers the essential points:

Specific gravity, 0.860; flash test, not less than 335 F.; cold test, not more than 14 F.; viscosity (Saybolt) at 100 F., not more than 120 sec.; loss on evaporation (8 hr at 200 F.), not more than 0.5 percent; dielectric strength, not less than 35,000 volts; freedom from water, acids, alkalies, saponifiable matter, mineral matter, or free sulphur. Moisture is particularly dangerous in oil. Skinner claims that 0.06 percent H_2O will reduce the dielectric strength approximately 50 percent.

Paraffin is used to impregnate paper and cloth. Specific inductive capacity, about 2; dielectric strength, 8,000 volts per mm; specific resistance, 240,000,000 to 3,900,000,000 megohms per cu cm.

Impregnated Fabrics. Fabrics serve as a framework to hold a film of insulating material, and must therefore be of proper thickness, texture, and mechanical strength, and free from nap or acidity. Cambric, muslin, lonsdale, and batiste are commonly used (see *Ind. Eng. Chem.*, July, 1928, p. 698).

Empire cloth is cambric treated with linseed oil by a special process. Similar products are oiled linen, oiled canvas, varnished cambric.

Insulating tape, also known as friction tape or binding tape, consists of stiff woven braid or tape impregnated with an adhesive and insulating compound adhering firmly to the braid. $\frac{3}{4}$ in. tape should have a breaking strength of not less than 33 and run not less than 150 lb. per lb.; other widths in proportion.

Cummar, or paracummar resin, is a synthetic resin made from low-boiling condensation products. It is made in different grades with melting points as low as 120 F. and as high as 320 F. As an insulator it has a dielectric constant somewhat lower than paraffin, but it possesses high surface resistivity particularly when exposed to moist air. It is used in molten condition in combination with the usual fillers such as asbestos, fiber, etc. Also used in paint and varnish, rubber compounds, printing inks, and as a substitute for other resins.

Thermosetting substances of the phenol-aldehyde type (Bakelite, Durez, Durite), and of the urea-formaldehyde type (Beetle) first sold and then undergo a chemical reaction which converts them quickly into an infusible product. The best all-around properties are available in the phenolics where numerous special types have been developed for high heat resistance (Durez 34), low power factor (Durez 1001, Bakelite XM2).

heat resistance (Bakelite XM1000), and other specialized properties. Materials are available for such specialized applications as the molding of telephone handles (Durez 1543), radio-tube bases (Durez 22607), and automotive ignition parts (Durez 2491). The urea plastics are lacking in heat resistance but are suitable for general-purpose molding and have fair arc resistance.

Paper. The present tendency is to use paper only as a backing or framework for an insulating film or compound, owing to hygroscopic qualities. Manila and kraft papers possess the best dielectric and mechanical strength, and when coated with good insulating varnish are excellent insulators. Japanese paper is extremely thin and strong, and is used in tubular insulation and also as a backing for mica paper. Various types of paper, paraffined, are used in condensers.

Vulcanized fiber, also known as hard fiber, is prepared by treating paper pulp or a textile material with a saturated solution of zinc chloride and afterward consolidating it under heavy pressure. The soluble materials are then carefully leached out by long soaking in water and the fiber dried out. It has a consistency like horn, but is generally found, in commerce, treated with glycerin or glucose, which makes it very pliable. In the hard form it can be planed, sawed, and worked like wood; and in the soft form it can be readily molded. It is claimed to be an efficient non-conductor of heat and an excellent insulator. The soft varieties are used in making artificial leather and rubber products. Its specific gravity is about 1.3; specific resistance, 53 megohms per cu cm. Furnished in 42 X 88 in. sheets 0.010 to 1 $\frac{1}{4}$ in. thick; and in tubes $\frac{1}{4}$ in. to 2 $\frac{1}{2}$ in. diam by 22 to 36 in. long. It must be thoroughly seasoned, tough and flexible, and, when unbaked, must stand bending around a circle having a radius of 10 times its thickness without cracking or splitting. After 12 hours' baking at 250 F. it must bend around a circle of radius 50 times its thickness. Tensile strength of sheets, lb per sq in., less than $\frac{1}{4}$ in. in thickness and over $\frac{1}{4}$ in., 5,000; $\frac{1}{2}$ in. to $\frac{3}{4}$ in., 3,000; $\frac{1}{4}$ in. to $\frac{3}{4}$ in., 7,000 lb per sq in. Electrical strength, about 1,200 volts per 0.01 in. of thickness.

Presspahn or fuller board is a specially prepared paper board which, when impregnated with oil, is an excellent insulator. Insulator presspahn is very hygroscopic. The material is mechanically strong but its dielectric strength is greatly injured by creasing. Presspahn is cellulose beaten into fine fibrillae and consolidated under pressure with gelatinization or chemical treatment. Its uses are similar to those of vulcanized fiber. Cellulith is produced by grinding wood pulp to a homogeneous mass and then pressing it. It is very hard, can be worked like wood, and is claimed to be a substitute for horn or ebony. Isolt is a form of paper maché impregnated and covered with a special insulating compound. Addit is a variety of isolt claimed to have great tensile strength and toughness and to ignite with difficulty. Litholite is a paper product used for insulation. It has high disruptive strength, good insulation resistance, and is claimed to be inflammable but tough. Pyralith is a chemically treated paper pulp obtainable in sheets from $\frac{1}{4}$ in. to 1 $\frac{1}{2}$ in. in thickness. It is very strong and rigid, and is claimed to have high disruptive strength and insulation resistance.

Porcelain is made from the purest white clay agglutinated by some substance such as powdered feldspar which softens and fuses at the temperature through which the ware is fired, rendering the mass semitransparent. The material possesses great stiffness, strength, and ability to resist sudden changes of temperature. It is used extensively for electrical purposes on account of its high durability and electrical resistance. A simple test for quality consists in chipping off the surface and noting whether the chip produces a flowing stain, which it will do on poor ware. Properties: The Locke Insulator Mfg. Co. gives the following average values: specific gravity, 2.427; specific inductive capacity, 4.4;

which has the most complete and most finely divided cellular structure. The obstruction to heat flow is offered by the surface resistances at the boundaries of the air spaces. Air itself is not a good insulator. The material should not absorb moisture and should be free from rot, mold, or offensive odors. The principal materials used for this purpose are cork, asbestos, and mixtures of asbestos and magnesia and mineral wool.

Cork is the outer bark of the cork oak. It is highly compressible, possesses great permanent elasticity, is an excellent nonconductor of heat, is waterproof, unaffected by moisture, and slow burning. The natural cork wood weighs 10 to 12 lb per cu ft. Cork is used for bottle stoppers, life preservers, cold storage insulation, carburetor floats, polishing wheels, washers and gaskets, cork paving brick, isolating pads for machinery, and in the manufacture of linoleum and cork tile flooring.

For cold-storage insulation, pure corkboard is made in sheets 12 in. X 36 in. X thicknesses up to 6 in. No artificial binder is used, the natural gums and resins in the cork sufficing to hold the material together after proper baking. The U. S. Navy Department specification requires that such pure corkboard shall withstand boiling in water for 3 hr without disintegration or more than 2 percent expansion in any direction. Granulated cork is likewise used for cold storage insulation as a filling material between confining walls. Granulated cork ordinarily refers to new corkwood finely divided, while the term regranulated cork applies to the granulated material which has been baked in making corkboard and which is a by-product of this material. Tests made at the Bureau of Standards give the following values of heat conductivity for cork products in Btu per sq ft per in. thickness per deg F per 24 hr: corkboard, no artificial binder, density 6.9 (9.9) [11.3] lb per cu ft, 6.5 (7.3) [7.4]; corkboard with bituminous binder, density 16.7 lb per cu ft, 8.4; ground cork, less than $\frac{1}{8}$ in., density 9.4 lb per cu ft, 7.1; regranulated cork, about $\frac{1}{8}$ in., density 8.1 lb per cu ft, 7.5. The pure corkboard used commercially weighs approximately 10 $\frac{1}{4}$ lb per cu ft. (See also Tables 4 and 6, pp. 389, 390).

Cork tile, made by essentially the same process as pure corkboard, is a quiet, non-slippery floor largely used for bank working spaces and in public libraries.

Linoleum is a mixture of cork dust with linseed and other drying oils reinforced on one side by burlap material. Machinery isolation is made from pure cork baked under pressure in thicknesses up to 6 in.

Balsa is the wood of a large tropical tree found in Latin America. It is the lightest wood known, commercial grades weighing 8 to 15 lb per cu ft. When properly prepared, over 90 percent of the volume of the wood consists of air spaces. U. S. Bureau of Standards tests show conductivity of 7.5 to 8.3 Btu per sq ft per in. thickness per deg F in 24 hr. Tests at the Massachusetts Institute of Technology show about half the strength of spruce, weight, kiln dry 7 to 11 lb per cu ft; modulus of rupture 2,367 lb per sq in.; maximum crushing strength in compression parallel to grain 2,317 lb per sq in.; shearing strength parallel to grain 351 lb per sq in. Natural balsa is subject to decay. It can be made waterproof and non-absorbent to oil and gasoline. It can be sawed, planed, and worked like ordinary wood, and painted, stained, or varnished. Largest commercial size of balsa boards is 4-in. X 6 in. X 6 ft. Principal uses: refrigerator lining, life preservers, floats, and other purposes where lightness combined with strength is desired. Diatomaceous silica is a mineral of low density consisting of the fossilized cellular skeletons of microscopic organisms called diatoms. Other names for

this type of material are: Kieselguhr, diatomaceous earth, infusorial earth, Sil-O-Cel, and celite. Material from the better deposits is almost pure silica which fact accounts for its high heat resistance. Where the material has been contaminated with clay, lime, sand, and other foreign matter, the density is increased and the insulating value and heat resistance are decreased. Insulating bricks are sawed directly from the material in the better deposits, for use at temperatures up to 1600 F.

Diases. Calcined bricks are made for temperatures as high as 2500 F. The material is also used in powdered form as an insulating fill and is mixed with asbestos fiber and bonding material for the production of moulded blocks and pipes insulation for use at temperatures up to 1800 F. Calcined granular material is used as an insulating fill at higher temperatures and is mixed with Portland cement to provide semirigid refractory insulating concrete for furnace doors, furnace foundations, the fireproofing of steel members, etc.

Other uses of diatomaceous silicas are in the manufacture of a clarifying agent for use in filtering, as an admixture to improve the workability of concrete, stucco, and mortar, as a lightweight mineral filler for use in compounds such as polishes, paints, varnishes, enamels, lacquers, insecticides, matches, incense, catalysts, dynamite, etc.

Asbestos is a heat-resisting fibrous mineral, the most important deposits of which are in Canada. The chrysotile variety, because of its fineness of fiber, tensile strength, elasticity, and flexibility, is commercially the most important and references to asbestos without other designation presumably indicate this variety. Other useful varieties are Amosite or Rhodesian asbestos and blue or Cape asbestos, both from South Africa. The amphibole or hornblende variety is of little commercial value because of its brittleness and lack of fiber strength.

Uses. High-quality asbestos because of its incombustibility, its low heat and electrical conductivity, and its resistance to the action of most chemical agents has a wide variety of uses among which are heat and electrical insulations, packings and gaskets for high-temperature service, brake linings and friction materials, cloth for theater curtains, and heat-protective clothing, roofings, and building materials. It is spun and woven into yarn, rope, and cloth, is formed into asbestos felt, paper, roll board, and wall board for insulation; is mixed with Portland cement to make fireproof shingles and asbestos wood, and it constitutes either the principal ingredient or the essential reinforcing material for most insulations in the range of temperatures from 150 to 1600 F. Among the insulations consisting principally of asbestos are laminated-felt types made up of successive layers of this felt, the felted fiber types (asbestos fiber and bonding material) and the air cell types made up of successive layers of felt and corrugated asbestos paper.

It has an approximate dielectric strength of 4,000 volts per mm and a specific resistance of 16×10^4 . Good asbestos should not burn or show any flame under the blowpipe nor should it be affected by concentrated hydrochloric acid. Asbestos wood is obtainable in standard sheets 36×48 in., and in thicknesses from $\frac{1}{4}$ in. by $\frac{1}{8}$ in. to 1 in., and then by $\frac{1}{2}$ in. increases to 2 in.

The U. S. Navy specifications call for asbestos millboard in standard sheets 20×40 in., the various thicknesses to have the following weights: $\frac{1}{8}$ in., 25 to 29 lb; $\frac{1}{4}$ in., 21 to 24 lb; $\frac{1}{2}$ in., 14 to 16 lb; $\frac{3}{4}$ in., 11 to 12 lb; 1 in., 7 to 8 lb; $\frac{1}{2}$ in., 3 $\frac{1}{2}$ to 4 $\frac{1}{2}$ lb. Asbestos millboard is generally made hard, but, if desired, can be made medium or soft. The material should stand a dry heat of 400 F without injury and should not be affected by acids.

The U. S. Navy specifies for asbestos plaster for pipe covering a mixture of 5 per cent of long asbestos fiber, 65 percent of infusorial earth (see above) and 30 percent of fireproof binding material. The material must mix with water to proper consistency, and, after drying, should not burn or show any flame. It should not bake hard like a brick but be capable of compression. One bag, 140 lb net weight, should cover 40 sq ft of surface 1 in. thick.