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Section 3-4: Treated and Untreated Papers and Boards

New Developments

"Nomex" paper and board in coated forms offers a number of insulation possibilities. One type is a paper with a high temperature, heat-sealable polyimide coating. The coating is in a "B-staged" (partially cured) condition and can be heat-sealed or formed into parts by the application of mild heat and pressure. Fabricated parts should be cured in an oven to develop maximum properties. Uses include turn, layer, and tube or barrier insulation in high temperature, dry type transformers where self-bonding sheet insulation is desirable; slot, phase, and wedge insulation in rotating equipment requiring bonding or stiffening of parts after forming; tapes and coil wrappers which heat seal, thus eliminating a varnish application; bobbins and tubes which require bonding during fabrication; and other specialty insulation uses.

Also available is an acrylic resin coated product for layer insulation in edgewound coils as well as for other purposes. It offers improved moisture absorption and less shrinkage. The coating is dried but not cured so that it will become adhesive when wetted with acetone. The coating will adhere to other materials when subjected to 135°C and will react as a thermosetting resin when cured at 135 to 155°C for three to six hours.

Various other coatings and impregnants can be supplied including polyesters, epoxies, and polyamide-imides.

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This section was staff-written.

INTRODUCTION

Paper is a term applied to all kinds of matted or felted sheets of fiber formed on a fine wire screen from a water suspension. This definition serves to distinguish paper from nonwoven fabrics made from air-blown or carded fibers. Paperboard is basically the same as paper, but is generally thicker, more dense, and less flexible. The distinction between the two is not sharp.

At this point it should be explained that paper-like materials are also made from flakes as well as fibers—although these flake products do not meet the strict definition above, they generally are considered to be papers. For example, mica can be made into a material known as mica paper—this product is not covered in this section but is thoroughly discussed in the mica section (3-15).

Another type of product which does not meet the preceding definition is particle board which is not made by a water suspension process. Also, although some wood fiber hardboards are made by a water suspension process, there are other hardboards which are air formed and do not use water in their forming process. However, these latter hardboards and particle board are often considered in the same light as a heavy paperboard and they are cellulosic in nature—thus, they are discussed in this section. However, they could be defined as rigid plastic laminates.

Papers and boards are used very extensively as electrical insulation in comparison to most other solids. This is because they are relatively cheap, unusually efficient, and extraordinarily versatile. They are low in cost because paper making is a continuous, high speed, low manpower process. Their efficiency is the result of a fine matrix structure that yields high mechanical and electrical strengths simultaneously, as well as providing ease of forming qualities and a smooth finish. Their versatility arises from the enormous variety of substances from which they can be prepared, and the great selection of thicknesses and sizes which are available. They may be composed of flakes or fibers, natural or synthetic in origin, and inorganic or organic in character. Paper and/or board may be produced in specific gravities as low as 0.2 to as high as 1.4, and in porosities differing by a factor of 10,000. Paper, furthermore, is produced for insulation in thicknesses as low as 0.00017", while board may be as thick as the designer requires. By impregnating paper and board with resins, varnishes, etc., a host of materials ranging from tough, flexible, flame-retardant tapes to rigid, reinforced panel boards may be produced. By combining paper or board with plastic films or fabrics, tough composite insulations may be prepared. Finally, by further mechanical and chemical treatment of some papers, hard and strong vulcanized fibre and fishpaper (see section 3-5) may be formed.

The chief problem associated with dielectric papers is that of non-uniformity, involving not only such gross failings as holes, clots, or impurities, but also subtle variations in strains, crystallite regions, and sorption sites. These are followed in importance by variations in dielectric constant, dielectric loss factor, dielectric strength, and conductivity.

A second serious limitation affects

chips under action of high pressure steam which results in fine lignocellulose fibers. This treatment does not destroy the lignin, woods' natural binder, but drives off volatile matter. After a washing operation, the fibers are felted and compressed into dried sheets that are subsequently pressed under heat and pressure to reunite the fibers and lignin into a uniform, strong panel of planned density. Such board may be obtained as a standard or untreated type of hardboard, but a treated or tempered variety is produced by impregnation of standard board and a subsequent baking operation to completely polymerize and oxidize the tempering oils. The material possesses high structural strength, good dimensional stability, moisture resistance, durability, ease of fabrication, resistance to abrasion, and smooth surfaces. It is hard enough to be machined and can be fabricated in a variety of ways. Supplied in thicknesses from 3/16" to 2", it is useful for flat and structural insulating parts.

Chemically Reconstituted Ligno-Cellulose Board

This is another product which is not made by a water suspension process. It reportedly differs from both conventional hardboard and particle board. It is made of kiln-dried wood particles (ligno-cellulose) which are chemically reconstituted, dimensionally stabilized, and plasticized by heat and pressure. Low moisture absorption, uniformity, and the dimensional stability are important features cited. It may be machined and fabricated. It is a high pressure thermosetting laminate product available with phenolic or melamine impregnated faces of kraft paper, canvas, woven or mat glass, or other fabric, as well as thin metal. Thicknesses range from 3/16" to 2".

Particle Board

Produced from wood particles bonded together with a synthetic resin or other added binder.

INORGANIC PAPERS AND SYNTHETIC FIBER PAPERS

Asbestos

Most asbestos papers are composed of chrysotile asbestos fibers. The sheets have sufficient porosity to absorb saturants and are also quite flexible, incombustible, and may maintain their dielectric strength up to 300°C (572°F). Above this temperature, asbestos begins losing its water of crystallization and decomposes. In addition, the paper possesses a relatively high thermal conductivity and will not corrode, rust, or support fungus growth. Unfortunately, some types are low in mechanical strength, absorb moisture rapidly, and have rather high dielectric losses since both power factor and dielectric constant are relatively high. Although asbestos paper may be used just as it comes off the paper machine, it is generally impregnated with resins or fabricated as part of composite insulations.

Asbestos Papers and Boards

A commercial grade of asbestos paper is made from asbestos fibers which are mixed with starch to permit felting the material into continuous roll form. The mixture is processed on papermaking machinery and calendered to a smooth finish. Resistance to heat, fire, and chemicals is excellent but physical strength is poor. Thicknesses are 0.015" to 0.0625". A board of a similar grade is made in thicknesses to 0.125". It will resist temperatures to 177°C (350°F). Another rigid board, which uses a bonding agent, is available in heavier thicknesses.

Purified Asbestos Papers and Boards

These products are specially purified materials made in such a way as to remove conducting particles, foreign matter, and other impurities . . . and achieve a high degree of uniformity in the finished sheet. A number of forms are available including a sheet consisting only of the purified completely inorganic asbestos fiber—this form would normally be treated in some manner to meet handling and property requirements. Other forms contain specified amounts of glass fibers and are treated with different resins and impregnants including silicone, epoxy, asphalt, polyvinyl acetate, and others. Obviously, the heat resistance of the various purified asbestos paper and board products is influenced by the organic materials which may be used with them. Thicknesses range from 0.0025" to 0.025" for the paper and 0.031" to 0.25" for the board.

Asbestos-Cement Board

Asbestos fibers which are bonded with cement or other inorganic bonding agents into boards are available in thicknesses from ¼" to 2". To achieve special properties, the board may also be impregnated with other materials. Asbestos-cement board is used for arc barriers, deflectors, ducts, partitions, cable trays, etc.

Mica

See section 3-15 for information on mica papers.

Acrylic

Acrylic fiber papers have been produced both with and without resinous binders. They are characterized by negligible moisture pick-up; and better dimensional stability, ultraviolet resistance, thermal aging properties, and solvent resistance than the natural cellulose papers. They are also compatible with many resins, have good resistance to hydrolytic degradation, and reportedly can be used in class 130 and hermetic applications. As with many synthetics, their mechanical properties are lacking to a certain degree and their cost is considerably greater.

Polyamide (High Temperature)

Paper of "Nomex" nylon (see section 3-3) and boardlike forms made from the paper perform acceptably for continuous service at temperatures up to 220°C (428°F). The paper is a combination of two forms of a long chain synthetic polymer—fibrous binder particles (fibrids) and short length fibers. Sheets are formed on conventional paper-making equipment; the fibrids and short length fibers are then permanently bonded to each other by hot calendering. Sheet structures are available in thicknesses from 2-mil to 30-mil and rigid boardlike structures of any desired thickness can be produced by flat pressing multiple layers of the paper together at high temperature and pressure (540°F and 2,000 psi). The material is self bonding, permitting the construction of rigid struc-

PAPER HANDLING AND STORAGE

The following suggestions outline good handling and storage techniques which are especially applicable to cellulose papers:

Do's

1. Keep the moisture resistant wrapping on rolls of paper until they are ready to use. Avoid damage to wrapping.
2. Use paper in the order in which it is received to minimize the possibility of changes in moisture content over extended periods of time.
3. Store paper in $55 \pm 5\%$ relative humidity both in the warehouse and on the production line.
4. If it is not practical to store under these conditions, normal warehousing can be employed if special care is taken to avoid extreme conditions.

Don'ts

1. Store paper in hot areas around steam pipes and unit heaters, or in exposed areas such as loading docks.
2. Unwrap paper until it is needed.
3. Allow cut coils or fabricated parts to remain for prolonged periods of time in non-humidified areas.
4. Turn off the humidification system in the assembly area over the weekend or overnight if insulated work is still on the floor or on conveyors.
5. Wind rolls of paper in the opposite direction to that marked on the wrapper, as this will tend to loosen the roll and may damage the paper.

APPLICATIONS OF INSULATING PAPERS

Paper and board are used extensively as insulation in equipment capable of generating, transmitting, or utilizing low frequency electric power. One of the reasons that it has not been used successfully as insulation at high frequencies is because its dielectric constant and dielectric loss factor are frequency dependent as shown in figure 1.

Generators, transformers, cables, reactors, capacitors, and motors are large users of paper and board for a variety of reasons: sometimes purely as mechanical spacers, sometimes as solid dielectrics, and sometimes for both reasons. For example, it is conventional to wrap the armature of a liquid or wax filled capacitor in a thick wrapper to give the structure mechanical rigidity. Again, paper is frequently used in combination with mica flakes to give the discrete inorganic crystals a continuous substrate in slot armour for generators and traction motors. Moreover, coil spacers in power transformers serve efficiently because of the mechanical properties of the board.

The tabulating card used extensively in automatic business machines is a spacer in a dynamic system. Such cards are used extensively as "punched cards" where the information is deposited as a series of holes. They in turn are read by wire brushes which make contact with a drum. A second method of character reading information on tabulating cards is called "mark sensing" and involves determining the presence of a carbon mark on a card by measuring continuously its electrical surface conductivity. In such applications, the design engineer is very conscious of the tensile, tear, and burst strengths and other mechanical properties of the paper and board. It is only after a prospective item passes these tests, that he inquires into its electrical characteristics.

The dielectric properties of paper become paramount when used in high-voltage capacitors. Because of the stringent requirements placed on the chemical and electrical properties of such paper, few mills produce it.

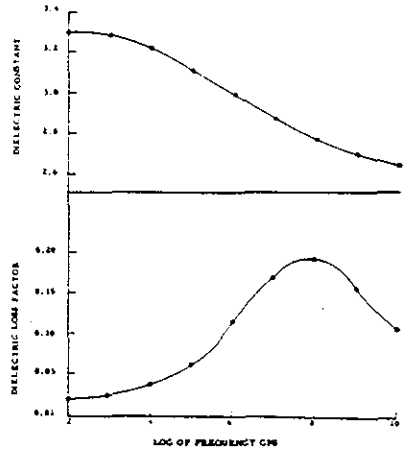

Figure 1, the variation of the dielectric constant and dielectric loss factor of a cellulose paper with frequency.

Mechanical tests are run as an index of uniformity, but they are not considered to play a qualifying role in the operation of the unit. This is why papers having physical properties quite different from those of kraft tissue have been suggested for use in capacitor units.

The paper used as turn insulation in transformers and as the dielectric in high voltage cables not only must have excellent mechanical properties but must possess good electrical properties as well. In transformers, paper and board have a twofold purpose: they confer mechanical rigidity on the structure and at the same time (when suitably impregnated) sustain high electric stresses. The papers and boards used in such an application must have low a–c losses or the transformer will become hot in use. The paper is wrapped onto the conductor at relatively high speeds; papers must possess high tensile strengths and very high tear strengths, otherwise the tape will snap on being served, causing costly delays. The paper must also have a customized coefficient of friction since it must be bent when formed into a coiled structure to encompass the leg of the transformer.

List of Typical Applications For Papers and Boards

Coil layer insulation
Electronic component can lining
Punched and fabricated insulators
Formed insulation parts
Motor slot insulators
Switch box liners
Coil forms
Tubing
Cupped washers
Motor end laminations
Spacers and fillers
Phase insulation
Armature collars
Barriers
Capacitor insulation
Coil wraps
Insulating brackets
Separators
Panel boards
Housings
Spreaders
Structural insulation parts
Cable and wire wraps
Transformer insulation
Field coil pole insulation
Tabulating cards
Pressure-sensitive tapes
Insulation composites

needs. Until the synthetic fiber industry recognizes this requirement, mechanically strong, totally synthetic fiber papers cannot be expected; until then, their strength will come from resins, impregnants, and sizings. A second misunderstanding has also tended to limit the quality of the synthetic fiber papers; the fibers which have been exploited so far are invariably chemically inert, and unswollen by water. When it is recalled that cellulose has neither of these two properties *per se*, it suggests that synthetic fiber papers made from less impregnable constituents might yield valuable products.

Papermaking physics is a facet of the science which is in its infancy. It is distinguished from papermaking chemistry (the popular academic study) and papermaking engineering (the popular practical study). As the term papermaking physics implies, it is concerned with the nature and source of the physical properties of paper. Instead of relating the observed properties to the lignin, cellulose, pentosan, and ash content of fibers, it looks for relationships in their morphology and mechanical behavior. Taking a leaf from the book of polymer physicists, it attempts to relate the macroscopic properties of paper to the behavior of individual fibers and to such variables as temperature and plasticizer content. This approach will be recognized as an adaptation of the present relaxation theory of high molecular polymers.

The analogy between the preparation of a plastic film from a casting solution of polymer and the production of paper suggests some of the opportunities for exploitation inherent in this approach. It is known that the temperature and the rate of solvent removable from a casting solution affect appreciably the mechanical properties of the dried film. It is explained that this is because the molecules on passing from the swollen dispersed state consonant with polymer solution to that of the dried plastic may very well become trapped in a strained or unrelaxed state. The properties of the dried film depend significantly on the "state of relaxation" of the molecules. Paper-making fibers undergo similar time dependent relaxations and the mechanical properties of the paper arise from their state. It is interesting to think that the reason why papers differ in elongation and hygroexpansivity arises from this cause. Based on this interpretation it has been suggested that the well-known "humidity cycling" data which have been interpreted as equilibration processes are actually the hygroexpansivity plots of new paper created by testing procedure. In its idealized form, it envisions the same paper as possessing an unlimited number of hygroexpansivities depending on the state of relaxation of the fibers; when the fibers are taut, the amount of expansion is of course least, when relaxed, most.

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SUPPLIER DIRECTORY LISTING

IMPORTANT: For fabricated or converted paper 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 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

Acetylated paper (39)
Acrylic fiber paper (39, 40)
Asbestos board, inorganic binders and cements (19, 44)
Asbestos paper and board, organic binder (14, 19, 24, 34, 44)
Asbestos paper, organic varnish treated (9, 14, 19, 34)
Asbestos paper, silicone varnish treated (19, 34, 41, 44)
Purified asbestos paper and board, untreated (19, 34)
Purified asbestos paper and board, epoxy resin treated (19, 34, 44)
Purified asbestos paper and board, polyvinyl acetate resin treated (19, 34)
Purified asbestos paper and board, silicone resin treated (19, 34, 44)
Purified asbestos paper and board, partial organic content, organic bond (19, 34)
Bond paper, varnished (14, 41, 47)
Ceramic fiber paper (4, 24, 37, 39, 40)
Creped paper tape and sheeting (1, 9, 12, 17, 19, 22, 24, 26)
Fibre board, high density, sized and unsized (3, 5, 6, 18, 39, 40, 45)
Glass flake paper (29, 43)
Glass micro-fiber paper (17, 24, 30, 40)
Glass micro-fiber paper, polytetrafluoroethylene treated (15, 30, 39)
Glassine paper (chemical wood pulp) (25)
Hardboard (wood pulp), lignin resin bonded (5, 23)
Kraft cable paper (5, 9, 17, 22, 26, 37, 43, 46)
Kraft capacitor tissue (5, 20, 41, 46)
Kraft capacitor tissue, varnished (28, 41, 47)
Kraft, cyanoethylated, paper and board (5, 9, 22, 37, 39, 45)
Kraft paper and board (3, 5, 9, 13, 17, 22, 26, 37, 39, 43, 45, 46)
Kraft paper and board, resin impregnated, size coated, or varnished (2, 3, 14, 17, 28, 35, 36, 39, 41, 46, 47)
Kraft paper and board, thermally stabilized (3, 9, 17, 22, 26, 37, 39, 43, 45)
Kraft paper and board, wax coated (13, 17, 39)
Kraft paper, adhesive coated (9, 13, 45)
Parchment (31)
Particle board (3)
Polyamide fiber paper and laminated board (heat resistant type tradenamed "Nomex") (2, 9, 18, 27, 38)
Polyamide fiber paper ("Nomex"), coated (2, 7, 14, 27, 38, 42)
Polyester fiber paper (11, 32, 38, 39)
100% rag paper (8, 21, 24, 39, 40)
100% rag paper, varnished or resin impregnated (2, 7, 39, 41, 47)
75% rag paper and board (5, 21, 24, 39, 40)
50% rag paper and board (5, 21, 24, 39, 40)
65% rag paper, water gum adhesive one side
Rope paper (17, 21, 22, 37, 38, 43)
Rope paper, varnished (28, 38, 47)
Rope/wood pulp papers (17, 21, 22, 37, 43)
Silica paper (16, 24)
Soft fibre board (wood pulp, not vulcanized) (39, 40, 45)

Suppliers of the Preceding Products

1—THE BORDEN CHEMICAL CO., MYST TAPE DIV.
2—THE BUDD CO., POLYCHEM DIV.
3—Celotex, Inc., Durel Div.
4—The Carborundum Co., Refractories & Electronics Div.
5—CASE BROTHERS, INC.
6—Case & Risley Press Paper Inc.
7—Chase-Foster, Inc.
8—COTTRELL PAPER CO., INC.
9—DENNISON MFG. CO., INDUSTRIAL PRODUCTS DIV.
10—E. I. DU PONT DE NEMOURS & CO. (INC
11—The Eaton-Dikeman Co.
12—Eagewater Paper Co.
13—Ethyl Corp.
14—General Electric Co., Insulating Mater Dept.
15—General Plastics Corp.
16—Haveg Industries, Inc., Sil-Temp Materials D
17—Hollingsworth & Vose Co.
18—The Itan Fibre Co.
19—JOHNS-MANVILLE
20—Kimberly-Clark Corp., Peter J. Schweitzer D
21—Krafelt Co.
22—John A. Manning Paper Co.
23—MASONITE CORP.
24—The Mead Corp., Hurlbut Papers, Technical Papers Div.
25—3M CO.
26—Mosinee Paper Mills Co.
27—NVF CO.
28—NATVAR CORP.
29—Owens-Corning Fiberglas Corp., Fiberglas dustrial Materials Div.
30—Pallflex Products Corp.
31—Paterson Parchment Paper Co.
32—Pellon Corp., Industrial Div.
33—Port Huron Paper Co.
34—RAYBESTOS-MANHATTAN, INC., ASBESTO TEXTILE DIV.
35—Reichhold Chemicals, Inc.
36—Reiss Associates Inc.
37—RIEGEL PAPER CORP.
38—Riegel Paper Corp., Industrial Films Div.
39—ROGERS CORP.
40—SPAULDING FIBRE CO., INC
41—SUN CHEMICAL CORP., ELECTRO-TECHNICAL PRODUCTS DIV.
42—TRW ELECTRO INSULATION, TRW INC.
43—UNION MILLS PAPER MFG. CO.
44—U. S. Polymeric, Inc.
45—WEST VIRGINIA PULP & PAPER CO., BOARD PRODUCTS SALES DIV.
46—Weyerhaeuser Co. Paper Div.
47—ALLIED PRODUCTS CORP., ACME CHEMICALS & INSULATION CO., DIV.