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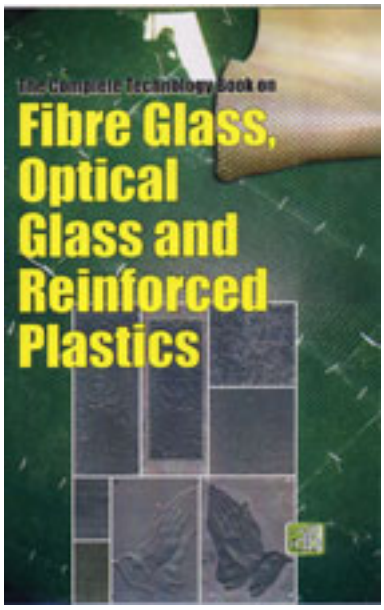
The Complete Technology Book on Fibre Glass, Optical Glass and Reinforced Plastics



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Although many natural materials were used in the past by man, answering his instinctive urges to prevent heat loss from or entry into his dwellings, no material in modern technology has satisfied the all around requirements as has fiber Glass. Fiber glass, optical glass and reinforced plastics have important applications and uses in the making of various products. Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. Fibre glass behaves as a thermal insulation because of its entrapment of small cells of air, and prevention of movement of the air in those cells. In acoustical applications, fibre glass presents to advancing sound waves a myriad of small anechoic chambers which reflect the sound inward from many diverse surfaces until it becomes blotted out. Optical glass is a high glass material that has been seen specifically formulated to posses certain desirable characteristics that effect the propagation of light. The two primary parameters that define the basic types of optical glass are its refractive index and its dispersion. Transportation on wheel is of special significance to the reinforced plastics industry on a number of counts. Suppliers of reinforced plastics parts are often called upon to furnish prototypes of products being considered for auto, truck and bus applications. Performance and quality demands on materials used in aerospace vehicles have given rise to many plastics developments and have kept profits in the plastics industry at a higher level than those in other major markets.
Some of the fundamentals of the book are fibres based on natural polymers:
fibres based on synthetic polymers, fibre glass blown wool or insulation products and their applications, fibre glass in wall construction for reduced sound transmission, ceramic fibre papers, ceramic fibre textiles, commercial polymerization processes, continuous filament fibre forming methods, marine applications, reinforced plastics for transportation on wheels, plastics in aircraft and aerospace, structural laminate bag molding process, reinforced molding compounds, filament winding, etc.

The present book contains processes and other valuable information for fiber glass, optical glass and reinforced plastics. This is very resourceful book for entrepreneurs, technocrats, institutions, researches etc.

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FIBRE GLASS BLOWN WOOL OR INSULATION PRODUCTS AND THEIR APPLICATIONS

INTRODUCTION-PARAMETERS AND TEST METHODS

Fibre glass behaves as a thermal insulation because of its entrapment of small "cells" of air, and prevention of movement of the air in those cells. In acoustical applications, fibre glass presents to advancing sound waves a myriad of small anechoic chambers which reflect the sound inward from many diverse surfaces until it becomes blotted out. In filtration, fibre glass attracts particles in an air or a liquid stream, preventing their passage and affecting their separation from the stream.

These and many other applications for fibre glass and similar materials are possible because of certain basic technological characteristics briefly described as follows.

Chemical Composition

As discussed, glass melting is possible because of mutual solution at high temperature of a specific, limited group of materials known as glass-forming oxides. Such factors as ease of melting, rapid rate of bubble release from the melt, long working range, and facility of fibreization are important.

In the room-temperature condition for end-use application, the fibre composition should possess good chemical durability and resistance to water attack because of the much larger surface area exposed. It should also accept binder properly, should have a high mechanical strength and lack of friability.

Important test parameters for evaluating and controlling glass compositions are liquidus temperature (point of initial crystal formation out of the melt upon cooling), softening point (temperature at which glass, a thermoplastic, softens and flows under its own weight), density (weight per unit volume determined after controlled thermal history or annealing), rate of flow at the fibre forming temperature (a viscosity test), and seed count (either entrained or dissolved gases being released or incomplete melting). Naturally, chemical analysis by any of several reliable methods is essential for control of both raw glass batch materials and finished melted glass. Periodically it is also advisable to evaluate the finished glass for its chemical durability. This is done by measuring weight loss after exposure of fibres of a known, closely controlled filament diameter to water and to acids and bases of a predetermined normality.

Table 1 : Formulation for Insulation-Type Glasses

	Formula for typical mineral or slag wool	**Typical fibre glass insulation compostion**	**Typical high-temperature fibre compostion**
SiO2	50	63	50
Al2O3	10	]	]
Fe2O3	1	6	40
CaO	25	7	6
MgO	14	3	4
Na2O	-	14	-
K2O	-	1	-

B2O3	-	6	-
F2	-	0.7	-

Fibre Diameter

This is the important basic factor as regards specific performance for fibre glass and associated materials, since almost all major end-use behaviour is determined by fibre diameter. Generally product cost increases proportionately with the necessity to create finer filament diameters. The finer-fibreed products will do most of the things that those with coarser fibres will do plus more. Hence end-use requirements should be carefully assessed-if only cold cuts are required, it is not necessary to pay for prime-grade steak.

Table 2 : Filament Diameter Conversion Chart

INCHES

	Min.	**Max.**
AAAAA	.000002	.000008
AAAA	.000008	.00002
AAA	.00002	.00003
AA	.00003	.00006
A	.00006	.00010
B	.00010[t/d]	.00015
C	.00015	.00020
D	.00020	.00025
E	.00025	.00030
F	.00030	.00035
G	.00035	.00040
H	.00040	.00045
J	.00045	.00050
K	.00050	.00055
L	.00055	.00060
M	.00060	.00065
N	.00065	.00070
P	.00070	.00075
Q	.00075	.00080

R	.00080	.00085
S	.00085	.00090
T	.00090	.00095
U	.00095	.00100

MICRONS

Min.	**Max.**
.05	.20
.20	.50
.51	.76
.76	1.52
1.52	2.54
2.54	3.81
3.81	5.08
5.08	6.35
6.35	7.62
7.62	8.89
8.89	10.12
10.12	11.43
11.43	12.70
12.70	13.97
13.97	15.24
15.24	16.51
16.51	17.78
17.78	19.05
19.05	20.32
20.32	21.59
21.59	22.86

22.86	24.13
24.13	25.40

1 Micron equals .00003937 inches (39.37 millionths of an inch)

Filament diameters and ranges applicable to all fibre glass production are presented in Table 2.

In quality control of fibre sizes for a blown fibre glass production operation, diameters are measured by resistance to air flow using a testing device developed by the Sheffield Micronaire Division of Bendix Corporation. Originally intended for evaluating cotton, this device may be recalibrated for glass fibres. Small standard cyclinders containing a weighed mass of fibres of known diameter and range are used to set or produce one specific air flow rate in the test unit. Following, a weighed portion of an unknown fibre sample is loosely packed into a likesized test cylinder, inserted, and its resistance to air flow measured. The mean fibre diameter of the test sample is smaller or greater than the control standard depending upon whether the sample offers, respectively, more or less resistance to the flow of air.

One difficulty with this measuring system is that the extremes, or degree of fibre diameter distribution under and over the nominal value (3-limits) can not be accurately determined. Nevertheless the method has provided the industry with a good, practical, and duplicatable control of fibre diameter.

Diameters down to 1m may also be measured optically at 1,000 diameters using an accurate projection microscope with calibrated screen. This system is more laborious, required excellent equipment and precise operator technique, but provides extremely accurate results.

Binders

Raw glass fibre in any form, blown bulk or continuous, is brash and easily fragmentized. This is because self-abrasion induced by any kind of motion or rubbing action causes surface defects. These in turn reduce flexural, tensile, and other mechanical strength parameters. The adage is also true with fibres as with other forms of glass that glass is only as strong as its surface.

Consequently, a family of various types of "binders" for mineral and glass wool products has been developed. Applied from 5 to 25 wt% depending upon application, binders are based mostly upon phenol-formaldehyde resins for bonding; they also are formulated to include melamine resins, silicone compounds for water repellency, soluble or emulsified oils for lubrication, wetting agents for control of surface tension, and extenders or stabilizers.

The phenol-formaldehyde resins used are of the strong-base resole (one-step) type, and are water-soluble with a specified dilutability or tolerance of up to 25 volumes of water. Fire-retardant additives are usually reacted in the resin formulation. The resins must be refrigerated prior to use but have fairly long-term (24 hr) stability in the mixed-binder state. The phenolics cure (polymerize) on the glass by chemical action induced by heat (350 to 500Ã¸F in the wool; up to 700Ã¸ F ambient in the curing ovens). Resin age, pH, percent solids, and degree of cleanliness are important factors in cure.

In the binder formulations used, the end results justify the care and difficulties required in handling. When sprayed on immediately after fibreization or attenuation, the resin accumulates in droplets around the fibres, reaching fibre juctures or simply flattening out along the fibre. Hence both protection against abrasion and resiliency for the final product are provided. The deposition and flattening-out of resin droplets along fibre surfaces, and also accumulations at junctures of two or more fibres are clearly visible in the SEM photomicrograph.

Raw phenolic resins may be tested for cure temperature and time on a standard cure plate. Degree of cure of resin applied to glass wool products may be evaluated by colour (light or pinkish tan-probable undercure, unless artificially coloured; dark tan to brown-good cure), by acetone extration, water absorption, or degree of thickness recovery of the product after prolonged compression. Silicone are evaluated by surface

(wetting) angle, and the other ingradients by specific quality and performance tests called out in their manufacturer's specifications.

The amount of binder present is a valuable control parameter and is determined by ignition at 1050Ã¸ F of a dry, cured resin-glass sample and then calculating the percent weight loss.

Thickness and Density

These two parameters are so closely interrelated that, in the manufacturing process, a change in one invariably produces a compensating modification in the other. If a machine is producing at 1 in. thickness and 1 lb/cu ft density, and the thickness is doubled to 2 in., the density per inch of thickness would be halved. Hence, the quantity of fibre input to the machine must be doubled to maintain the product at 1 lb density. Since a near-uniform fibre production rate is desirable, the required gain in the fibre input per unit area is accomplished by halving the machine speed, thereby permitting twice as much fibre to accumulate.

In the manufacture of wool fibre, thickness is usually controlled by raising or lowering a set of "flights" or flat semented elements on a chain drive which contact and compress the top surface. These move at the same speed as the bottom or collecting open-mesh converyor. The flights are also constructed of an expanded metal or other openmesh material to permit passage of heated air in the forced-draft curing oven.

Ultimate or specified thickness values of glass fibre and associated wool products are determined by the Gustin-Bacon "measurematic" null-balance device. In this unit the pressure of only a 3g weight (to depress the few protruding surface fibre) is exerted by a plate which contacts the top of the test sample.

Thicknesses vary in fibre glass end products from "in. to as much as 8 in.

The accompanying density in blown fibre glass wool products is determined solely by weight of a sample 1 sq ft in area. Density may be made to vary from 1/2 lb to as much as 7 lb/cu ft in some board products. The upper limit on the flexibile roll goods is approximately 2 1/2 lb/cu ft.

Hence it can be seen that many combinations of wool thickness and density are possible. Most product applications are based upon the best combination of the two to fulfill requirements of thermal, acoustical, or other serice with performance balanced against cost. The close and necessary relationship between thickness and density will become more evident in the ensuing descriptions of individual products and their performance. (Fibre glass product density should not be confused with glass density mentioned earlier. Glass density refers to the fector of increase of the solid glass substance over the weight of an equivalent volume of water taken as unity.)

Percent Shot

As indicated, some of the processes generate a larger percentage of glassy beads or "shot" than others. The shot is often mobile, that is, not attached or adhered to adjoining fibres. Hence it may be removed by mechancial manipulation of a sample and weighed as a quality determination.

Percent Recovery

The degree of recovery in insulation or wool products relates directly to the thickness which the manufacturer guarantees in his finished product specifications. The specifications for the product you want to purchase must be met under any and all conditions.

An austere condition exits in manufacture and packaging of either flat or roll-type insulation products. Unfortunately, they are usually compressed to conserve shipping space.

It would be most disconcerting to allow a 3 in. construction space for insulation, and when the material arrived for installation, find that it filled only a portion of the alloted space. In such an instance, naturally, the thermal efficiency and resistance to heat flow would be different than that originally designed for the building. Therefore, the industry sets and maintains rigid standards for recovery of the products to specified values.

The percent thickness recovery is influenced by the following : the original flight setting (usually original production thicknesses are slightly over specification); thickness itself (greater thicknesses generally have

lower percent recovery); density (lower density-lower recovery); tightness of compression, rollup, etc., in packaging for shipment; type, age, formulation, and degree of cure of the bonding resin; and degree of relative humidity in the storage area (packaged insulation should be sealed inside non-moisture-transferring memebranes).

Other Properties

Other functions of fibre glass and related mineral wool products such as resistance to heat transmission (thermal insulation), acoustical or sound absorption, propensity as a filtration medium, and others will be detailed in the ensuing discussions of specific product applications and performances.

BUILDING INSULATION

Thermal Insulation-Homes

Insulation of homes against heat loss (winter) and heat gain (summer) probably represents the largest single usage for fibre glass and mineral wool products. Many different areas of the home may be thermally protected: ceilings, side walls, perimeters of slabs, floors, etc. Not only are many different types of available insulating materials used, but the way various components perform in combination must be taken into consideration in analyzing for the complete insualted structure, either in retrofitting or new construction. An understanding of the way insulation performs should start with consideration of the basic units of heat and related definitions.

MANUFACTURING PROCESSES

1. GENERAL

The manufacturing process can be broadly divided into two parts: polymerisation and spinning. Polymerisation process includes copolymer composition, catalyst system, polymerisation reaction and monomer recovery. Spinning includes solution/dope preparation, spring techniques and finishing operations including after treatment, cutting and baling. A general process for acrylic fibre production is given in Figure 1. In the preparation of acrylic and modacrylic fibres, both polymerisation and spinning help to determine the ultimate properties of the fibre. The polymerisation process, determines the composition and molecular weight of the polymer and thus sets the limits on the final properties of the fibre as well as on the spinning process.

2. FACTORS RESPONSIBLE FOR POLYMERISATION

I. Co-polymer Composition: Acrylic fibre manufacture requires acrylonitrile polymer with specific composition. All acrylic fibres contain acrylonitrile (90-94%) and a neutral comonomer. Ionic comonomers are used mainly to improve dyeability of acrylic fibres.

II. Neutral comonomers: Methyl acrylate and vinyl acetate, are used to increase the solubility of the polymer in the spinning solvent and to improve the rate of diffusion of dyes into the fibre.

III. Ionic Componomers: Properties modifying monomers such as ionic monomers sodium styrene sulphonate (SSS), sodium methallyl sulphonate (SMS) to provide supplemental dyesites and to impart differential water sensitivity between elements in bicomponent fibres or halogen containing monomers such as vinyl chloride, vinyl bromide and vinylidene chloride to impart flame resistance.

IV. Molecular Weight: The molecular weight of the polymer is vital since it determines the solution properties of the polymer and rheological properties of the dope, i.e. polymer solution. The molecular weight of the polymer must be low enough so that the polymer is readily soluble in spinning solvents, yet high enough to give dope of moderately high viscosity. Polymers with a very high molecular weight fraction may form insoluble microgels in the spinning solution. Fibre dyeability is dependent on molecular weight distribution of the polymer, since most acrylic fibres derive their dyeability from sulphonate and sulphate initiator fragments, at the polymer chain ends, the dyesite content of the fibre is inversely related to number average molecular weight of the polymer and is sensitive to the fraction of low molecular weight polymer.

V. Catalyst Preparation: The catalysts used are normally solids (ferrous compounds) and are brought in to solution before feeding to the polymerization reactor. The preparation involves weighting of solids, charging of required quantity of de-mineralised water and agitation in a dissolver. After ensuring the correct concentration the various solutions are transferred to storage tanks from where they are metered to a polymerisation reactor at a predetermined rate.

VI. Process Parameters: Properties of the polymer, i.e. molecular weight and dye sites vary, depending on the following parameters:

- Water/monometer ratio
- SO2/persulphate ratio
- Reaction temperature
- Dwell time
- pH of the reactor slurry
- Amount of fe2+ with respect to monomer weight
- Addition of chain-stopper agent
- Agitator's rpm

These parameters are closely monitored and controlled to obtain the desired degree of polymerisation.

ERROR: Infinite table loop

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