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SYNTHETIC FIBERS - 1965

by

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J. H. Dillon

The growth of the synthetic fiber industry has been spectacular since 1945 when nylon became a major raw material of the textile industry. The viscose rayon and acetate rayon industries had their major growth in the period 1920-45. The consumption of rayon and acetate has increased more slowly in recent years, while the true synthetics, which we shall call "synthesized" fibers, have been rapidly assuming a very important position in the textile economy. From the viewpoint of the chemist, then, it may be said that this is the "age of synthetic fibers."

Synthetic or "man-made" fibers may be classified into two broad groups--inorganic and organic. The only commercially important inorganic fiber is that made by extruding molten glass. The organic synthetic fibers may be further broken down into (1) regenerated fibers such as viscose rayon, (2) derivative fibers such as acetate rayon, and (3) the truly synthetic or "synthesized" fibers, which include the polyamides, polyacrylics, polyesters, etc. Another important class of organic fibers, chemically modified natural fibers such as chlorinated wool and cross-linked cotton, might be included under group (2) above but will be omitted from this discussion.

Most synthetic fibers are produced in both continuous filament and staple form. Some are supplied in the form of tow, which is later broken or cut into staple by the yarn manufacturer. In general, the continuous filament and staple forms of a given syntheti fiber composition will have quite different physical propeı.ies, and the chemical properties, such as rate and extent of dye absorption, will also differ because of the higher state of orientation of the filament form. The cross-sectional shape of a synthetic fiber depends greatly upon the method of spinning employed--melt, wet, or solvent spinning--as well as on the shape of the hole in the spinneret. Some synthetics are supplied with several different cross-sectional shapes for specific end-use applications. Only those synthetic fibers which are in commercial production or show special long-range promise will be discussed, using the system of classification outlined above.

INORGANIC FIBERS

Glass. Glass fiber is supplied in both continuous filament and staple forms, and ranks high in production among the synthetic fibers; it is well-suited for electrical and thermal insulation, fire-proof curtains, chemical filter fabrics, and plastic laminates. Glass single filament strength is very high, about 15 grams per denier, but this is not realized in conventional glass filament yarns which exhibit a tenacity of 6-7 grams per denier and ultimate elongations of 3-4 percent. Such yarns tend to be brittle in bending and poor in dynamic fatigue properties. Recent development of yarn impregnants that provide interfiber isolation and glass-rubber adhesion have greatly reduced these limitations and, indeed, glass filament yarns are finding increasing use in industrial fabrics and tire cord. Low denier glass fiber yarns are also being used effectively in bedspreads and drapery fabrics. Glass fibers are dyed by the exterior application of pigments, either to the fabric or to the yarns. Because of its outstanding strength, wet and dry, high melting point, nonflammability, dimensional stability, outstanding electrical resistance, and excellent resistance to chemicals, mildew, heat, moisture, and sunlight, the glass fiber has a very bright future.

Other Inorganic Fibers. A number of inorganic fibers have been produced in experimental quantities, principally for high temperature applications in missile and space technology. Base materials employed for these specialty fibers include quartz, graphite, ceramics and metal alloys. Metallic fibers are made by successive drawing through tungsten or diamond dies to a final diameter as small as 0.0005 inch.

REGENERATED ORGANIC TYPES

Viscose Rayon. The viscose process for regenerated cellulose fibers is accomplished by the following major steps: (1) digestion of wood pulp or cotton linters cellulose in NaOH to form alkali cellulose; (2) aging of alkali cellulose to reduce cellulose D.P. to optimum value for spinning; (3) formation of cellulose xanthate by reaction with CS_2; (4) dissolving xanthate in dilute NaOH; (5) "ripening," filtering, and deaerating xanthate spinning solution; (6) extrusion of xanthate through multiorifice spinneret into regenerating bath (acid solution of metal salts), stretching the filament yarn or tow to produce the desired orientation; and (7) washing, desulfurizing, and drying the yarn or tow. The result is a regenerated cellulose fiber which may be supplied as a continuous filament yarn, or as a tow which may be cut or broken into staple fibers of any desired length. Viscose rayon cellulose differs from native cellulose essentially in that the D.P. is considerably lower, the crystallinity is lower, and the unit cell is slightly altered. The morphology of the native fiber is, of course, completely lost in the viscose process.

Viscose rayon is hydrophilic (13% moisture absorption at 65% R.H., 70°F). Consequently, it may be dyed without difficulty by several methods and presents no problems as regards generation of static electricity and body comfort. The traditional "regular tenacity" viscose does not have very impressive physical properties - tenacity 1.5-2.6 grams per denier "dry"* and 0.7 to 1.8 grams per denier wet. The corresponding ultimate elongations are 15-30% dry and 20-40% wet. It swells greatly in water and has been noted for its unfortunate progressive shrinkage during consecutive launderings. In spite of these deficiencies, it has long maintained the top position among man-made fibers.

The metamorphosis of viscose rayon began with its introduction into tire cord in continuous filament form. The severe demands of this application led to the development of "high tenacity" filament rayon (3-6 grams per denier) now often referred to as "Tyrex." This was achieved by a combination of increased fiber orientation and higher skin to core ratio. It was not long after this development that high tenacity viscose rayon almost completely replaced cotton in tire cord. Rayon is still the top fiber in this field, once the greatest single market for cotton, and competes quite effectively against the aggressive encroachment of nylon. An even more recent development is the high wet-modulus rayons ("Avril," "Zantrel," "Lirelle," etc.) in which the micro-crystalline structure has been modified to give a marked increase in stiffness at low strains, both wet and dry. These fibers also exhibit increased tenacity and somewhat lower swelling in water. But the secret in achieving greatly reduced progressive laundering shrinkage, approaching cotton in this respect, is their high wet modulus. The acceptance of these new rayons has been spectacular and the future of regenerated cellulose as an apparel fiber, not long ago a subject of despair, has brightened considerably. Another interesting development is a molecularly cross-linked viscose rayon, "Loral," which yields improved fabric stability in laundering, and also has greatly reduced swelling and somewhat better wrinkle recovery properties. In general, it may be expected that viscose rayon will continue to be an important fiber, probably losing some markets to its hydrophobic competitors but seizing others from "king cotton."

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*The term "dry" refers to the standard testing condition--65% R.H., 70°F.

Cuprammonium Rayon. This regenerated cellulose fiber, sometimes referred to as "Cupra" or "Bemberg rayon," is produced by dissolving cellulose in cupric ammonium hydroxide and spinning into a water bath, followed by "hardening" in acid. The fibers thus produced resemble viscose rayon very closely in chemical properties, but they are circular in cross-section and very fine filaments may be produced. Cuprammonium rayon occupies a relatively minor position with respect to rayon made by the viscose process, but it is still produced in quantity and finds application in knitted and woven wearing apparel, upholstery, and decorative fabrics. The cuprammonium process is said to be more costly than the viscose process, but the unique morphology of the filaments which can thus be made, plus the possibility of producing a regenerated cellulose fiber of high D.P., suggests that there is a future for this fiber.

Saponified Acetate Rayon. Perhaps this fiber, marketed under the name "Fortisan," should be included among the cellulose derivatives, since it begins its life as a cellulose acetate fiber. However, after deacetylation under tension, it ends up as regenerated cellulose. It is one of the strongest cellulosic fibers known, having a dry tenacity of 7 grams per denier, which is reduced very little with increasing humidity (6 grams per denier wet). It finds application in yarns requiring high dimensional stability. Unfortunately, it has been found to be lacking in fatigue qualities, but it has been successful in nonrigid airship fabrics. In common with other highly oriented regenerated celluloses, saponified acetate presents difficulties in dyeing and is expensive to produce. It is supplied only in continuous filament yarn.

Regenerated Protein Fibers. Considerable research effort has been expended in attempts to develop good fibers from regenerated proteins. The unquestioned fiber qualities of silk and wool plus the availabilities of many proteins existing in agricultural waste products have made this field attractive. Thus far, no regenerated protein fiber with properties approaching those of wool or silk has been announced. Experimental fibers have been spun from solutions of proteins derived from chicken feathers, egg albumin, casein, and other agricultural by-products. Fibers have also been spun from solutions of silk and wool, but the results have always been discouraging in that the resulting fibers have been very deficient in wet strength.

Fibers based on casein have been produced in the United States and other countries and have had some success, particularly in the bristle field. The only regenerated protein fiber that ever enjoyed commercial textile application in the United States is "Vicara," based on zein, the corn protein. Its counterpart in

England was "Ardil," based on peanut protein. Both were recognized as valuable fibers for blending purposes but were much weaker than wool, both in the dry and wet states. Production of both "Vicara" and "Ardil" has been discontinued. At present writing, only two regenerated protein fibers are in commercial production, "Merinova" in Italy and "Fibrolane" in England.

Alginate Rayon. Alginate rayon is a specialty fiber based on alginic acid derived from seaweed. It is produced on a limited scale in England. It can be converted to the various salts--barium, beryllium, zinc, aluminum, chromium, calcium, iron, or sodium alginate--either in the early stages of fiber manufacture or later in fabric form. Fibers with a dry tenacity of 2 grams per denier can be produced, but the extensibility is very low for the high-tenacity types. Certain of the alginate rayons are alkali-resistant, for example, the beryllium and chromium salts. Others are soluble in dilute alkali, for example, calcium alginate rayon. Such soluble fibers may be treated with a dilute alkaline solution which dissolves the alginate fibers and leaves a desired open structure. The metallic alginate fibers are resistant to flame because of the high metal content.

DERIVATIVE TYPES

Cellulose Nitrate Fibers. The first commercial synthetic fiber was formed of cellulose nitrate, and regenerated cellulose fibers have been produced with the nitrate as the starting material. Dangers from fire and explosion with cellulose nitrate fibers have been mainly responsible for the disappearance of this fiber.

Cellulose Acetate Rayon. Acetate rayon ranks third in American consumption of synthetic fibers. The cellulose acetate is prepared in the following major steps: (1) acetylation of wood pulp or cotton linters cellulose by soaking in glacial acetic acid; (2) formation of cellulose triacetate by reaction with acetic anhydride in presence of acid catalyst; (3) hydrolysis of triacetate in acetic acid; (4) precipitation of resulting "secondary acetate" in water; and (5) washing and drying of the flakes. The "secondary acetate" has a degree of substitution of about 2.3, as compared to 3.0 for theoretically complete substitution. It is dissolved in acetone to form the spinning solution which is extruded from a spineret, downward into a warm air column where rapid evaporation of the solvent takes place and the fibers are oriented under gravity. Both continuous filament and staple fibers are produced.

Acetate may be considered the ancestor of the newer hydrophobic fibers, for it is thermoplastic and has a "livelier" handle than its cousin, viscose. Acetate is on the borderline between the hydrophilic and the hydrophobic fibers, absorbing only about 6% moisture under standard conditions. It is not particularly strong. The "regular" variety has a dry tenacity of 1.3 to 1.5 grams per denier and a wet tenacity ranging from 0.8 to 1.2 grams per denier. Its ultimate extension may be as high as 50% dry and 40% wet. Acetate is somewhat "wool-like" in mechanical behavior and yields better wrinkle recovery than untreated viscose in equivalent fabrics. It cannot be dyed by ordinary methods; in fact, an entirely new type of dyestuff, the so-called dispersed dye, had to be developed for acetate. It is subject to atmospheric fading and shade changes, and this has led to the "dope-dyeing" technique where the colorant is incorporated into the spinning bath. Acetate suffers from several minor ailments--it is soluble in acetone, creates static in processing, and has a low softening point. It has many compensating good properties, however, and because it can be produced at low cost, will continue to be an important apparel fiber. It should also be noted that vast quantities of staple acetate are used in cigarette filters.

Cellulose Triacetate Fibers. A cellulose triacetate fiber was announced in October 1954 under the name "Arnel." This fiber is, of course, considerably more hydrophobic than conventional cellulose acetate rayon and has a much higher softening temperature. Thus, it has the wet dimensional stability of the other hydrophobic fibers, such as the polyamides, acrylics, and polyesters, but is much cheaper to produce. It is colored with acetate dyes. Triacetate is superior to ordinary acetate in that fabrics made from it are fast to machine washing, can be permanently pleated and can be ironed at higher temperatures. Its level of wash and wear performance is quite satisfactory, although somewhat below that of the polyesters. Both the filament and staple varieties of triacetate have enjoyed considerable success, but so, also, has ordinary acetate in recent years.

SYNTHESIZED FIBERS

Polyamides. The first synthesized fiber to meet with commercial success was nylon 66, formed by condensation polymerization of the salt resulting from the reaction of hexamethylene diamine with adipic acid. It is melt-spun into continuous filament yarn or tow and oriented by cold drawing. Highly oriented nylon 66 has a tenacity of 6-9 grams per denier, a high extensibility, and an unusually low modulus at low strains. Its resilience characteristics are good, although the time for recovery from large strains is rather high. It has a reasonably high melting point of about 264°C and a good resistance to alkalies. It is degraded by acids. It absorbs about 4% moisture at 65% R.H., 70°F.

The great strength and ability to absorb energy possessed by nylon 66 have made it useful in many industrial and military applications where it is employed in continuous filament form. The continuous filament finds its greatest application in women's hosiery yarns, where it has replaced silk, but it is also used in satins, taffetas, marquisettes, and women's lingerie fabrics. The staple form of nylon 66 is made with lower orientation and thus has a somewhat lower tenacity. It can be crimped by several methods and is blended with other fibers on the woolen, worsted, and cotton systems of spinning. Blended in an amount of only 30% in a woolen hosiery yarn, it imparts an amazing resistance to wear and reduces felting shrinkage greatly. It is also used in suiting materials, but does not appear to have quite the potential of some of the other hydrophobic fibers for inducing wrinkle-resistance and crease-retention. Neither does it have the bulking power of some of the other fibers, in spite of its low specific gravity (1.14), for it has the circular cross-section characteristic of a melt-spun fiber. The shape of the cross-section can be varied, however, by recently devised techniques. The dyeing of nylon 66 offered some problems initially, but these have been solved and it can be dyed either with ionic or nonionic dyestuffs. It offers problems in soil retention, flammability, static electrification, wicking, and pilling. On the whole, however, it is a remarkably good and versatile fiber that deserves its position as the foremost of the synthesized fibers in American consumption.

Another very important polyamide fiber, nylon 6, had its early development in Europe under the trade name "Perlon L." This isomer of nylon 66 is made by the conversion of amino caprolactam to amino-caproic acid which polymerizes to nylon 6. Nylon 6 is said to be somewhat cheaper to produce than is nylon 66. It has a lower melting point - about 223°C - but in other physical and chemical properties is very similar to nylon 66. Nylon 6 is produced in quantity by a number of American and European firms. It has been successful in many applications ranging from apparel to tire cord.

Several other nylons are under development or in use. Examples are nylon 4, nylon 7 (Russian "Enant"), nylon 11 (French "Rilsan"), and nylon 610. Nylon, the first synthesized fiber, now ranks second to viscose rayon in production of man-made fibers and its use continues to increase in many products throughout the world.

Acrylics. Several synthesized fibers based principally upon acrylonitrile are now in quantity production. American acrylic fibers are marketed under the trade names, "Orlon," "Acrilan," "Creslan," and "Zefran." They are formed either by "dry spinning" (extrusion of the polymer in solution into a heated chamber in which the solvent evaporates) or by "wet spinning" (extrusion of the polymer solution into a coagulating bath). Various solvents have been used, prominent among them being dimethyl formamide. The earliest form of "Orlon" was essentially polyacrylonitrile, but because of dyeing and other difficulties, it now consists of a copolymer in which acrylonitrile is the major constituent (85% or higher). This is also true for the other acrylics and great secrecy surrounds the nature of the minor constituents. It is known, however, that vinyl pyridine and methyl methacrylate have been employed. "Zefran" differs from the other acrylics in that it is referred to as a "nitrile alloy" polymer. It has a somewhat higher tenacity - 3.5 to 4.2 grams per denier compared to 2.0 to 3.0 grams per denier for the staple forms of the other acrylics and has different dyeing characteristics. Only "Creslan" is currently furnished in continuous filament form, as well as in staple. "Orlon" fibers have the "dog-bone" cross-section characteristic of "dry-spinning," whereas the other acrylic fibers are circular in cross-section, indicating that they are "wet spun."

The acrylic fibers are quite hydrophobic with water absorption ranging from 1.5 to 2.5% under standard conditions. They are of low specific gravity (1.16 - 1.18) and possess unusual bulking power, either alone or blended with other fibers. They are relatively free of pilling and thus are suitable for knitted or loosely woven fabrics. "Orlon Sayelle," a special bicomponent acrylic fiber with permanent crimp, behaves very much like wool and is excellent for bulky sweaters. Indeed its bicomponent structure is patterned after the natural bilateral symmetry of the wool fiber cortex. The acrylics have also found large markets in blankets and carpets. At this writing, all of the acrylic fibers are in short supply and it may be necessary to increase still further the capacity for producing the basic raw material, acrylonitrile.

Modacrylics. The generic term "modacrylic" has been adopted by the U. S. Federal Trade Commission to describe a fiber composed of a substance in which less than 85%, but at least 35%, by weight of the material is acrylonitrile. Only two modacrylic fiber types are produced in the United States, "Dynel," which is a 40/60 copolymer of acrylonitrile/vinyl chloride and "Verel," which is composed of acrylonitrile and vinylidene chloride. "Dynel," the older of these fibers, is characterized by rather low tenacity, very low water absorption (0.4% under standard conditions), and low softening temperature. Verel is less hydrophobic, absorbing

3.0% water under standard conditions and has a somewhat higher softening temperature. Both fibers are unusual in that they do not support combustion and have excellent chemical resistance. They are very difficult to dye. The modacrylics have found volume only in the limited areas of work clothing, carpeting, synthetic furs, fire-resistant drapery fabrics, and in crease-retaining fabrics for men's and boys' slacks.

Polyvinyls. A great number of polyvinyl halide fibers have been developed in the United States, Europe, and Japan. Many of these have been based wholly upon polyvinyl chloride. Only a few of these vinyl halide fibers have survived the pilot plant stage for they are inherently low in strength and dimensional stability and have very low softening temperatures. They are useful for plastic molding purposes and have limited industrial application because of their chemical resistance and nonflammability. Vinyl halide fibers now commercially available include the French "Rhovyl" and the German "PeCe" polyvinyl chloride fibers. Vinyon HH, an 86/14 vinyl chloride/vinyl acetate copolymer, is the only commercial survivor of the vinyl halide fibers in the United States.

A very different picture is presented by the polyvinyl alcohol fibers which were developed in Japan. Insolubility of the polyvinyl alcohol fiber is achieved by reaction with formaldehyde. Fibers with a tenacity of 4.5 grams per denier and quite good abrasion resistance can be made. The ultimate elongation is rather low (10 to 20%) and the wet softening temperature is about 104°C. The dry melting point lies between 210° and 232°C. The fiber can be dyed to excellent fastness with vat dyes. It is poor in resilience and thus fabrics made from it wrinkle badly. Its chief virtues are low cost and high strength. The fiber is produced in Japan on a commercial basis and is marketed under the names vinylon and "Kuralon." It is available in staple and continuous filament form in the United States, but after extensive development studies by one American firm, it was found economically unfeasible to produce in this country.

Polyvinylidenes. Several fibers based primarily on vinylidene chloride, but generally containing a minor component such as vinyl chloride to permit chemical and physical processing, are produced in sizable quantities. For example, saran, "Velon," and "Rovanna" are made in the United States. These melt-spun fibers are extremely hydrophobic, chemically resistant, and moderately strong (2.5 grams per denier in highly oriented form). They are supplied both in continuous filament and staple form. Their major application has been in rather coarse monofilament form for weaving seat coverings for public vehicles, nonstaining window screens, etc. They have shown considerable promise as carpet fibers. They offer difficult problems in dyeing and are generally supplied in dope-dyed form.

Another fiber of this group, consisting principally of polyvinylidene cyanide, was developed in the United States and marketed under the trade name "Darvan." It is classified as a "nytril" fiber by the Federal Trade Commission. It was found to have outstanding properties as a blending fiber for wool and cotton. It was extremely difficult to dye, however, and was taken over by another American fiber producer in 1960 and modified considerably to improve its dyeing behavior. It is no longer made in the United States but has been marketed in Germany under the trade name "Travis."

Polyesters. The first of this important class of fibers, "Terylene," was developed in England in 1941. The U.S. patent rights were purchased by an American firm in 1946 and the polyester fiber "Dacron" was introduced to the American market. It is composed of polyethylene terephthalate which can be formed by direct esterification of ethylene glycol or by catalyzed ester exchange between ethylene glycol and dimethyl terephthalate. The fiber is melt-spun, but unlike nylon, it is drawn at an elevated temperature. The melting point is 264°C and the moisture absorption under standard conditions is about 0.4%. It is furnished in filament, tow, and staple forms. The tenacity of the staple fiber, wet or dry, ranges from 2.2 to 4.0 grams per denier. Tenacities up to 9.5 grams per denier are attained in the continuous filament variety. The outstanding characteristic of the polyesters is high resilience under wet conditions. Blended with wool, polyesters confer excellent wrinkle-recovery and crease-retention behavior upon worsted fabrics. Blended with cotton, polyesters yield fabrics with the so-called "wash-wear" or "minimum care" behavior that have achieved wide consumer acceptance. Unlike the all-cotton wash-wear fabrics, polyester-cotton blends do not exhibit lowered strength and abrasion resistance; instead, the polyester component improves fabric behavior in these respects. The early problems of pilling, static electrification, and dyeing, characteristic of hydrophobic fibers, have been largely solved and it may be said that introduction of the polyesters was the beginning of a renaissance in apparel. The continuous filament polyester yarns have also been very successful, particularly in industrial applications. Early experience with polyesters in tire cords indicates that these fibers may eventually offer a challenge to nylon in this important market.

With this spectacular success of Dacron, it was natural to expect other polyesters to appear. Three others are now manufactured in this country, "Kodel," "Fortrel," and "Vycron." All of them are enjoying good acceptance by textile manufacturers and consumers. While there are subtle differences among these various polyesters, they are quite similar in constitution and performance.

Polyolefins. The first of the olefin polymers, low density polyethylene, was not successful in fibers. Fibers were weak, impossible to dye, very low melting, and poor in sunlight resistance. With the advent of low pressure polymerization and the resulting linear, high density polyethylene, the fiber potential of polyethylene increased. Nevertheless, its use as a fiber has been extremely limited. It is available only in continuous monofilament form. It can be obtained in numerous pigmented colors and with either low or high thermal shrinkage values. Its low softening temperature and "waxy hand" make it unsuitable for apparel. Its unusual chemical resistance and low cost, however, have brought it into limited and very specialized fiber usage.

Polypropylene was hardly more promising as a fiber than polyethylene until the discovery of stereospecific catalysts by Natta and Ziegler. Professor Natta was the first to demonstrate the possibility of making isotactic polypropylene fibers with much higher melting temperature and strength. Primarily because of the very low cost of propylene, about 4 cents per pound, the chemical industry became very interested in its potential as a base for films and fibers. Enormous investments in facilities for producing isotactic polypropylene fiber and/or film have since been made in the United States. It will require several years and skillful research to induce dyeability in this very hydrophobic fiber before these hugh investments can be justified. Nevertheless, several American firms are supplying polypropylene fiber in monofilament, multifilament, staple, and tow forms. Providing that satisfactory dyeing and stabilizing techniques are developed, the fiber appears to offer apparel fabrics of desirable, wool-like hand. Polypropylene monofilaments are being used in rope, cordage, webbing, and auto seat covers. Its low specific gravity (0.90) offers advantages in several marine applications and, combined with low monomer cost per pound, makes its use attractive in fabrics where the number of yards per dollar is the significant cost factor. Tenacities of the commercial fiber are 4.5 to 8.0 grams per denier for the multifilament; 3.0 to 6.0 grams per denier for the staple and tow varities. The "recovery" properties are quite good at room temperature. It must be noted, however, that properties decay with increasing temperatures and that isotactic polypropylene melts at 165°C and shrinks about 4% at 100°C. The future of polypropylene as a textile fiber seems to hinge upon two factors: (1) whether the good mechanical properties inherent in its isotactic structure can be preserved in the course of modifying that isotactic structure to achieve dyeability, and (2) how much of a limitation will be its low softening and melting temperatures.

Polyurethanes. A number of commercially unimportant polyurethane fibers were developed as early as 1937. One such product, "Perlon U," was produced by the reaction of 1,4 butanediol and hexmethylene diisocyanate. The fibers, prepared by melt spinning, melt at 178°C as compared to 264°C for its nylon 66 cousin. Recently, however, the polyurethane fibers with elastomeric properties have come into prominence and bid fair to revolutionize older concepts of garment manufacture and performance. Indeed, the long reign of the rubber elastomers in foundation garments and in the stretch portions of other textile items appears to be challenged by these new, dyeable polyurethane polymers, classified by the Federal Trade Commission as "spandex" fibers.

The first of the spandex fibers was "Lycra" which is a polyurethane, or it might be considered to be a substituted polyamide. It has an ultimate extension of about 600% and a reasonably good tenacity of 0.6 to 0.8 grams per denier. Obviously, the evaluation of elastomeric fibers depends importantly upon elastic reversibility and time constants of elastic recovery. Suffice it to say that "Lycra" fibers show 98% recovery after 600 cycles of straining to some unspecified maximum. "Lycra" is furnished in both staple and monofilament form. Only monofilament is supplied by its closest competitor "Vyrene." Other spandex fibers, "Spandelle" and "Glospan" are supplied as multifilament yarns. "Lycra" is superior to rubber in its resistance to sunlight, abrasion, oxidation, oils, and chemicals; it has a far superior flex life; can be dyed in a full range of colors, and is offered in much finer fiber diameters. "Vyrene" meets most of these specifications but is less easily dyed and is more subject to embrittlement and degradation when subjected to prolonged heating.

Introduction of the spandex fibers has brought with it entirely new concepts of fiber performance and new ideas of fabric engineering. It is unlikely that the public will soon be clothed in skin-tight ski pants, but the judicious use of spandex fibers will undoubtedly yield a wide range of more comfortable, attractive garments.

Fluorocarbons. Only one fiber has thus far been developed which fits this Federal Trade Commission category. This is "Teflon," based on polytetrafluoroethylene. Teflon deserves special mention because of its unusual resistance to chemicals and heat. The monofilament melts at about 288°C. Its most outstanding characteristic is its low coefficient of friction - it is the slipperiest material known. It is furnished as monofilament, staple, tow, and flock. It is undoubtedly the most expensive fiber that is commercially available. Its applications thus far have been for pump packings, bearings, gaskets, artificial arteries, and electrical insulation.

General. The foregoing summary includes the principal classes of synthetic fibers now in use. Each class is supplied in many special types which could hardly be enumerated in this brief article. It must also be recognized that there are many variations within each class; for example , consider the fibers employing the principle of bi-componency ("Orlon Sayelle" and "Cantrece" nylon) and the various bulking and stretch treatments ("Agilon," "Ban-lon," "Fluflon," "Helanca," "Taslan," "Tycora," etc.). There are several special types of synthetic fibers that have been omitted from this discussion; for example , the polystyrene fibers with outstanding electrical properties, the high temperature fiber "HT-1," the polycarbonate fibers, and the aromatic polyamide fibers. The possibilities of fibers based on the so-called "ladder polymers' have also been omitted; such fibers may invade realms of high temperature never before considered appropriate for organic materials. One thing is certain, the field of synthetic fibers is dynamic. There appears to be no limit to the potential of present man-made fiber types and others yet to come.

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