CHAPTER III
Product Development
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PRODUCT DEVELOPMENT

Constant development and inexhaustible innovations in the product are the price of growth that an industry has to pay particularly when it wants a share in the international markets. This necessitates untiring research and development efforts and a constant monitoring of developments taking place in other parts of the world. The R & D efforts of the synthetic fabric industry can broadly be classified into those related to process and to product improvement and modification. The former are essentially cost-reducing while the latter may occasionally entail additional cost-incurrence.

Product improvement efforts extend to such aspects as blending of cellulosic and natural fabrics, texturing of fabrics, its mercerising, knitting and finishing in order to lend it an attractive. Such efforts may also diversify the end uses of the product. This may also affect the life cycle of the product.

Technological improvements may make for cost-reduction which is essential for a high cost product like Indian synthetics in international markets. Cost reduction, therefore assumes a strategic importance for securing a competitive justice vis-a-vis products from the other countries.

The aforesaid issues form the subject matter of this chapter.
1. **MEANING OF SYNTHETIC FABRICS**

Synthetic fabrics are obtained by knitting or weaving synthetic yarns/fibres together. Obviously before proceeding to discuss various product innovations in synthetic fabrics, it is necessary to understand the nature and chemical composition of synthetic fibres, because most of the properties exhibited by synthetic fabrics are owned by the fibre itself.

Synthetic fibres have been grouped in Chart III.1.

The man-made fibres may be cellulosics or non-cellulosics. Cellulosic fibres are also Natural polymer derivatives and include rayon and acetate, produced from a cellulose base, as well as Cassin fibres produced from protein bases.

The Non-cellulosics are wholly synthetic fibres. In chemistry "Synthesis" means artificial production of compounds from their constituents (as against the extraction from plants, etc.).

The synthesis or the chemical addition of the number of identical molecules each of which consists of a number of identical units called monomers is effected by the process of "Polymerisation". The polymerisation is the chemical addition of monomers. The word "fibre" means a thread like filament. Hence, to sum up, the term "Synthetic Fibre" indicates the thread or filament produced by the chemical addition of identical molecules bearing the properties as exhibited by the fibre obtained.

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1 Concise Oxford Dictionary.
CHART III.1: Showing Classification of Man-Made (Synthetic) Fibres

Man-Made Fibres

Natural Polymer  |  Synthetic Polymer  |  Refractory and Related fibres (carbon, glass metal, metallic oxide, silica)

- Regenerated Protein (Casein vegetable protein)
- Regenerated cellulose
- Cellulose (Cellulose acetates)
- Miscellaneous (alganite, natural rubber)

Polyurethanes  |  Polymides, Polymers  |  Polyvinyl Derivatives  |  Polymerised Hydrocarbons  |  Synthetic Rubbers

- Flurine Substituted (Polytetra fluoroethylene)
- Chlorine-Substituted
- Cyano-Substituted
- Hydroxyl Substituted (Vinyl alcohol)

Mono-Substituted (Vinyl Chloride and derivatives)  |  Di-Substituted (Vinylidene chloride)

Mono-Substituted (Acrylides)  |  Di-Substituted (Vinylidene dinitrile)

Synthetic fibres may be manufactured either by condensation polymerisation\(^3\) (e.g., polyamides and polyester groups), or by addition polymerisation (e.g., polyethylene, acrylic and vinyl groups).\(^*\) Synthetics are also collectively known as non-cellulosic man-made fibres.

Synthetic fabrics are being manufactured by multiple number of countries and are put to diverse uses. Different processes are employed to obtain various varieties of fabrics. Different countries have resorted to product differentiations by using various original brands or trade names for marketing these fabrics.\(^4\) However, Table III.2 elucidates the different varieties obtained by using the same raw material.

**TABLE III.2**

**Showing Synthetic Fabrics Groups, Brand Name and Their Basic Materials**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>NAME</th>
<th>BASIC-MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CELLULOSE</td>
<td>Rayon (viscose Cuprammonium)</td>
<td>Wood and similar pulps, cotton linters</td>
</tr>
<tr>
<td></td>
<td>Secondary acetate</td>
<td>Wood and similar pulps</td>
</tr>
<tr>
<td></td>
<td>Triacetate, Arnel, Triibene, Trilan, Tricel</td>
<td>Wood and similar pulps</td>
</tr>
</tbody>
</table>

(Contd.)


\(^*\) Addition Polymerisation = In which many molecules are simply added together. Condensation Polymerisation = In which monomer molecules combine with the loss of simple molecules, usually water.

4 See Appendix IV.
<table>
<thead>
<tr>
<th>NATURAL PROTEIN</th>
<th>Merinova</th>
<th>Lenital</th>
<th>Fibrolane</th>
<th>Wipelan</th>
<th>Casein from skim milk</th>
<th>Casein from skim milk</th>
<th>Casein from skim milk</th>
<th>Casein from skim milk</th>
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<tbody>
<tr>
<td>SYNTHETICS</td>
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<td></td>
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<td></td>
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<tr>
<td>POLYAMIDE</td>
<td>Nylon 66</td>
<td></td>
<td></td>
<td></td>
<td>Hexamethylene diamine</td>
<td>and adipic acid</td>
<td>Caprolactam</td>
<td>Sebacic Acid</td>
</tr>
<tr>
<td></td>
<td>Nylon 6</td>
<td>(Perlon)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Nylon 11</td>
<td>(Rilsan)</td>
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<td></td>
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<tr>
<td>POLYESTER</td>
<td>Terylene</td>
<td></td>
<td></td>
<td></td>
<td>Terephthalic acid,</td>
<td>Ethylene-glycol</td>
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<tr>
<td>POLYACRYLIC</td>
<td>Orlon,</td>
<td>Acrilan,</td>
<td>Courtelle,</td>
<td>Zefran</td>
<td>Acrylonitrile</td>
<td></td>
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<tr>
<td></td>
<td>Courtyard</td>
<td></td>
<td></td>
<td></td>
<td>Acrylonitrile</td>
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<tr>
<td></td>
<td>Dralon</td>
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<td></td>
<td></td>
<td>Acrylonitrile</td>
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<tr>
<td>VINYLIDENE-</td>
<td>Dravan,</td>
<td></td>
<td></td>
<td></td>
<td>Vinylidene, dimitrite</td>
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<tr>
<td>CYANIDE</td>
<td>Travis</td>
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<td>POLYETHYLENE</td>
<td>Courlene,</td>
<td>Drylene</td>
<td>Wysene,</td>
<td>Rescon</td>
<td>Ethylene from Petroleum</td>
<td>Ethylene from Petroleum</td>
<td>Ethylene from Petroleum</td>
<td>Ethylene from Petroleum</td>
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<tr>
<td>(OR POLYTHENE)</td>
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<tr>
<td>POLYVINYL-</td>
<td>Avisco,</td>
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<td></td>
<td></td>
<td>Vinyl chloride and</td>
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<tr>
<td>ACETATE</td>
<td>Vinyon</td>
<td></td>
<td></td>
<td></td>
<td>acetate</td>
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<td>POLYVINYL-</td>
<td>Mowell,</td>
<td>Vinylon</td>
<td>Kanabian,</td>
<td>Manyro</td>
<td>Polyvinyl Acetate</td>
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<tr>
<td>ALCOHOL</td>
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<td></td>
<td>Woolen,</td>
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<td>Mikron</td>
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<tr>
<td>POLYVINYL-</td>
<td>Rhovyl,</td>
<td></td>
<td></td>
<td></td>
<td>Vinyl Chloride</td>
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<tr>
<td>CHLORIDE</td>
<td>Movil</td>
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<td></td>
<td>Teviren</td>
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<tr>
<td>POLYVINYLIDENE-</td>
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<td></td>
<td></td>
<td>Polyvinylidene chloride</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CHLORIDE</td>
<td>Velon,</td>
<td></td>
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<td></td>
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<tr>
<td>POLYPROPYLENE</td>
<td>Meraklen</td>
<td></td>
<td></td>
<td></td>
<td>Propylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(OLE FINE)</td>
<td>Hostalen,</td>
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<td></td>
<td>Ulstren</td>
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(Contd.)
During the last 45 years in the world and 28 years in India, synthetic fabrics industry has grown from strength to strength. Not only that its productive capacity and output have been increased substantially but the industry has achieved wide diversification in its range of products. It produces a large variety of woven-plain, dobby and Jacquard - Fabrics, knitted fabrics, embroidered and non-woven fabrics.5

2. PROPERTIES

Apart from specific individual properties, there are some of common properties in synthetic fabric's group. All are immune to microbiological and insect attack. Though not fire proof in the same way as asbestos, several of them are flame-proof, i.e., they will disintegrate in a flame but will not burn themselves, and therefore they offer little risk. Most of the fibres are resistant to light and air, especially the

acrylics, as well as to water, acids and alkanies. They
generally have a high tenacity and elasticity and are highly
resistant to abrasion; they are crease-resisting, shrink-proof
and by reason of their low absorbency, are quick drying. The
extent of these properties in any of the fibres determines its
specific end-uses. The principal outlets, both in blends and pure
form, are in apparel industry, in household enduses (blankets,
carpets, curtains), and in industrial uses (ropes, nets,
belting canvas, etc.).

3. PROPERTIES OF SPECIFIC SYNTHETICS

The various synthetic fabrics exhibit various properties
depending upon the fibre from which they have been made.

A. Polyamides (Nylon)

There are two types of polyamide fibres, Nylon 66, derived
from adipic acid and Nylon 6, from caprolactam. In addition,
small quantities of Nylon 11 (Rilsan), made from sebacic acid
(a product of castor oil), are manufactured for specialised
end uses. Nylon displays a high degree of mechanical resistance,
has a low degree of water absorption, does not burn easily, and
has characteristics of light weight, strength and elasticity.
Such qualities make it suitable for numerous industrial end-uses,

6 Industrial Fibres - A Review, Commonwealth Economic
Committee, Intelligence Branch, op. cit., 1964-65,
1975.
in addition to its original outlet as an apparel fibre. Polyamide fibres are produced in all the main industrial countries under various trade names. The United States, U.K., Canada, Australia, France and Switzerland, have concentrated on the production of "Nylon 66" polymer fabrics, while Japan, West-Germany, Netherlands, Italy and the Sino-Soviet group have developed "Nylon 6" to a greater extent. The latter fibre is, however, now being manufactured also in U.K. and U.S.A. Some "Nylon 66" is made in West Germany and Netherlands. A small quantity of "Nylon 11" is manufactured in France, Italy and Brazil.

B. Acrylic Fabrics

Acrylic fabrics made from acrylic fibres (Acrilan, Courtelle, Orlon, etc.) are produced mainly from acrylonitrile, a liquid derivative of oil refining and coal carbonisation process. Acrylic fibre, which is normally made in staple form, is crimped before cutting, a characteristic which makes it the most like the non-celluloses.

They are the most wool-like of the synthetic fabrics and are being increasingly used on the worsted side of the wool industry. With their warm light feel, their ability to retain shape and resist deterioration by the action of sunlight, oils and chemicals, the acrylics are employed for many types of

7 See Appendix IV.
apparel wear. Acrylic fabrics are resistant to the vagaries of weather and insect damage, they possess great dimensional stability and are very strong, hard wearing and readily washable. From the apparel manufacturer's point of view an important consideration is that they are non-irritant and have good resistance to creasing. The main uses of acrylic fibres is therefore in the apparel textile market, where it is strongly established, due partly to their inherent qualities, versatility and cheapness in comparison to polyamides and polyester. Acrylic fabrics are produced in all the main industrial countries, but particularly in U.S.A., Japan, Western Germany and U.K.

C. Polyester Fabrics

Polyester fabrics produced from polyester fibres are derived from petroleum chemicals and are marketed under such trade names as Terylene in the United Kingdom, and Dacron, Potrel and Kodel in the U.S.A. Like the acrylics they are used in the apparel field, for curtain nets, and for filling pillows and quilts, while in the industrial field they are used in the production of ropes, sail cloth, conveyor belts, etc. Its properties of lightness in weight, crease and shrink resistance and good wearing qualities make the fibre particularly attractive to the apparel manufacturers, and its strength and its high resistance to abrasion recommend it for certain industrial uses.
The outstanding characteristics of the polyester fabrics are resilience, when wet or dry, shape retention, durability and ease of care. They are resistant to damage by sunlight and weather and like most other synthetic fabrics are not affected by moth, mildew and bacteria.

D. Other Synthetic Fabrics

The other non-cellulosics may be divided into three broad groups. The first consists of fabrics whose output, though not large compared to the nylon, etc., is nevertheless well established in certain countries. Such fabrics include vinylon, produced mainly in Japan, and the olefin fibre fabrics, mainly polypropylene and polyurethane or spandex fabrics, produced so far mainly in U.S.A. and western Europe. The second group consists of those fabrics whose output is sizable, but which are retained for certain highly specialised end-uses, such as the protein fibre fabrics, Fibrolane, Caslen and Merimova. Finally there is a category of fabrics still at the development stage and are produced in pilot plant quantities.

Since it was first commercially produced by the Italian firm Montecatini, under the name of Meraklon, the polypropylenes have assumed increasing importance due to their qualities of great strength, light weight and low water absorption. The I.C.I. acquired selling and production rights of this fabric. The fabric is marketed under the name Ulstron,
and is becoming registered as being particularly suited for the fishing industry.

Toyo Rayon Co. of Japan while continuing to extend its fibre interests is reported to have developed a fluorocarbon fibre known as Toyoflon made from polytetrafluoroethylene. Production is, as yet, only on a very small scale indeed but the new fibre is being used for filter cloths, non-lubricated bearings.

4. END USES OF SYNTHETIC FABRICS

As mentioned earlier, the synthetic fabrics are put to diverse uses on account of multiple and versatile properties. Although apparel uses still constitute the principal outlets for synthetic fabrics, nevertheless their employment in the household and industrial fields is growing rapidly, despite their relative high prices. In U.S.A., where this development is most marked, apparel end-uses are estimated to have accounted for 42 per cent of overall consumption, industrial outlets for 32 per cent and household uses for 26 per cent. Similar estimates for the U.K. and the E.E.C. countries put the proportions at 81 per cent, 7 per cent and 12 per cent respectively. 8

A. Apparel Uses

Although some countries do not publish statistics on the

<table>
<thead>
<tr>
<th></th>
<th>MELT DYED</th>
<th>ACID DYABLE</th>
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<tbody>
<tr>
<td></td>
<td>Medium Tenacity</td>
<td>Lower Tenacity</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Floor Covering</td>
<td></td>
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<tr>
<td>tufted</td>
<td>P-A-M-D</td>
<td></td>
</tr>
<tr>
<td>Woven</td>
<td>A-N-M</td>
<td></td>
</tr>
<tr>
<td>Needle punch</td>
<td>P-N-M-D</td>
<td>P-M-D</td>
</tr>
<tr>
<td>Wall Covering</td>
<td>P-D</td>
<td>P-D</td>
</tr>
<tr>
<td>Upholstery</td>
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<td>Blanks</td>
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<tr>
<td>Bed Spreads</td>
<td>P</td>
<td>P</td>
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<tr>
<td>Velour</td>
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<td></td>
</tr>
<tr>
<td>Mattresses Pads</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Knitwear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underwear</td>
<td>P-C-H</td>
<td>P-C-H</td>
</tr>
<tr>
<td>Outerwear</td>
<td>H-M</td>
<td>P-M</td>
</tr>
<tr>
<td>Silver Backing</td>
<td>P(1)</td>
<td>P</td>
</tr>
<tr>
<td>Socks</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Work Clothing</td>
<td>P-H</td>
<td>P</td>
</tr>
<tr>
<td>Industrial End-Uses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legends:**
- **P** = Pure
- **C** = In blends with cotton
- **W** = In blends with wool
- **A** = In blends with acrylic fibre
- **V** = In blends with vinyl fibre
- **H** = In blends with high modulus fibre
- **M** = In blends with mass dyed polypropylene fibre having different deniers
- **D** = In blends with dyestable polypropylene fibre having different deniers
- **WV** = In blends with wool and vinyl fibre

**Sources:** Compiled by the present writer from various sources.
consumption of different synthetic fabrics, it is estimated that almost 75 per cent of the consumption of Nylon goes into the apparel industry. Of this about 45 per cent is used in the manufacture of knitted fabrics and the remaining 30 per cent is consumed in the form of woven apparel materials. In knitted form, ladies stockings and socks are the most important outlets, although ladies nightwear of brushed locknit fabric is also important and men's shirts made from warp knitted material have become increasingly popular. In the woven form, light-weight trouserings and gloves have sizeable markets, while there is also trade in light-weight rain-wear and overalls. Over two-thirds of the nylon used is in yarn form and the knitting industry is an expanding market for this fibre.

A recent major development for nylon has been in the field of stretch yarn fabrics; these yarns have penetrated not only into knitting trade but into woven fabrics as well, while their importance has also been quite marked in the weft knit jersey fabrics made from knitted yarns designed for everyday wear. At the present time it is estimated that around 95 per cent of all woven's slacks sold are stretch slacks. In woven fabrics, where bulked stretch nylon yarns are used in conjunction with other fibres, a marked expansion is likely over the next few years. Production of ordinary nylon fabrics for bulking is now giving way to the production of special bulked nylon yarns and fabrics for particular uses. A recent development

9 Ibid., p. 114.
has been the use of nylon staple for increasing abrasion resistance, particularly in rayon suiting and blends of Tricel and rayon.

As regards the consumption of polyester fibre (Terylene) about one half is in woven apparel wear; and also worsted weaving continues to be an important market particularly in men's trousers and suits. The fibre is blended, primarily with wool, while clothes of Terylene and cotton, flax, silk or viscose rayon are produced in much smaller quantities. Terylene/cotton fabrics for rainwear and casual wear are becoming increasingly important. In the fabrics the polyester imparts crease and abrasion-resistance qualities and, possessing a high melting point, it may be heat-set in fabric form into permanent pleats. Ties, shirting and sports wear constitute smaller though significant outlets for the fibre in woven apparel wear. Knitted apparel accounts for a much smaller proportions (as in U.K.) in Terylene consumption than in case of nylon (about 10 per cent as opposed to nylon's 45 per cent); its main end-use is in socks and underwear. Crimplene, a new bulked form of Terylene, is being increasingly used for jersey dresses and knitted outer wear. I.C.I. Fibres Ltd. (U.K.), has now developed a low pilling variant of Terylene which in wool blends gives fabrics a softer, bulkier handle with improved draping qualities, and should open up new fields for Terylene/wool fabrics. Uptill now Terylene staple has been
largely confined to woven fabrics of tight construction and smooth finish and was used on only a relatively small scale for woolen fabrics. Terylene spun voiles using short staple fibre to give a soft light fabric are now being manufactured, while stretch fabrics are also being developed. A further development which has gained ground over the past years is in Terylene/Vinca blends which are used for shirts, raincoats and men's slacks. Here minimum of 67 per cent Terylene is required compared with 55 per cent for woolen and worsted blends.

The acrylic fibre fabrics (in the U.K., Acrilan and Courtelle) are produced in both tow and staple form and are used either alone or in blends with both man-made and natural fibres. Alone they can be woven or knitted into a wide variety of fabrics and garments, e.g., jersey fabrics, blankets, carpets, underwear, high bulk knitted outwear and fur-type (pile) fabrics. In blended form they appear, for example with wool in suits, trousers and skirts as well as dress fabrics; with cotton in shirts, blouses, pyjamas, and dress fabrics. Fleecy fabrics — woven, knitted or tufted — are proving successful in acrylic fibres, being used either as the main body of the garment or as the warm, soft lining to rainwear, while similar soft fleecy materials are used as boot and shoe linings, etc. Various types of acrylic fibre fabrics including jersey materials are frequently laminated with foam, although
fabric to fabric bonding is by no means confined to the acrylics. Double laminated fabrics with coloured acetate backing have found acceptance for men's unlined overcoats.

Apart from the elastomericas, referred above, few synthetic fibres are of significant importance in the apparel trade at the present time. Owing to the difficulty in dyeing the fibre, polypropylene has made little impact yet in this field, although there have been some reports from the U.S. of its use in hosiery and in admixtures with acrylic for use in sweaters. In the U.K., polypropylene staple, produced by I.C.I., is being spun in the wollen and worsted systems to produce a yarn with increased strength and abrasion resistance, which could be used in light-weight suitings. Shoe laces and corset laces are now well established in polypropylene and development work is in progress on blends with cotton for work wear.

**B. Household Uses**

The synthetic fabrics find an expanding market in various household end-uses, particularly in carpets, blankets and curtain materials. Bri-nylon is now established as a major name in the carpet industry especially in commonwealth and EFTA countries. Increasing qualities are being made with an all-nylon pile. Nylon staple generally from 15 to 20 per cent in addition to other fibres is used in a carpet pile, where it can add extra strength and durability to the carpet. Other household uses for nylon comprise of sheets, bed spreads,
blankets, table cloths, upholstery fabrics and knitted stretch
loose covers.

In many developed countries acrylic fibre and fabrics are
of growing importance in the tufting industry. The use of
Acrylic is confined to carpets in which the fibre forms the
complete carpet pile. Courtelle, however, is usually blended
with other man-made fibres such as Evlan or Nylon, but it is
also blended with wool. Sales of acrylic fabrics is growing
in the manufacture of traditional woven blankets, but woven
cellular blankets have been introduced to run parallel with the
already established blankets made on lace machinery. Tufted
blankets are also being marketed on a small scale. Fillings for
quilted garment linings and bed spreads are another growing
outlet for these fibres, while various types of acrylic fabrics,
including jersey materials, are laminated with foam. Acrylics
are also used for loose weave curtains, where ease of cleaning
and soft handle are important. The modacrylic fabrics, verel
in U.S. and Teklan in U.K., have a silk-like handle
with the added advantages of being strong, hardwearing and
flame proof. The modacrylics made their first commercial
appearance in children's nightwears, but they are also suitable
for many household textiles, including curtain nets. At present
Teklan is being produced only as continuous yarn fabric in a
range of multi-filament deniers.

10 Ibid., p.116.
Among household end-uses, polyester fabric (Terylene) is important to the curtain net manufacturer, where its ability to withstand sunlight is a major asset.

Mention has already been made of polypropylene fabric and yarns which are marketed under the trade name of Ulstron filaments and yarns were in industrial ropes, cordage, etc., but more recently staple fibre has found its way into blankets. Outlets at present being developed by I.C.I. include carpets, upholstery fabrics, simulated fur and pile fabrics and various types of prospective clothing.

C. Industrial Uses

Due to their greater strength compared with the natural fabrics, the synthetics are finding an increasing market in the industrial field; two outstanding industrial uses are in tyre-cord and in ropes, twines and nets. However, the introduction of coated nylon fabrics has opened up some completely new uses for textiles by making possible the development of such products as airhouses, Dragones (bulk oil carriers, etc.) and collapsable tanks. Among nylon's many other industrial uses are car safety belts, fire hoses, filter cloths and protective clothing. Nylon reinforced conveyor belting developed has besides the obvious advantages of greater strength, impact resistance, and durability giving longer life and lower costs, it offers other attractions such as increased

11 Ibid.
toughing angles with resulting greater carrying capacity.

Due to flat-spotting after long periods of standing, nylon tyre cord is not used generally in the original equipment tyre market and its main outlet is for replacement tyres.

For many industrial uses, polyester fibre and fabrics can be employed in place of nylon, but its extreme resistance to light, heat, weathering and insect damage, coupled with a resistance to stretching even under great pressure, a high wet and dry strength and low moisture absorption, making it of particular value in such products as ropes, nets, belting, webbings, protective clothing, etc. As mentioned earlier, polyester tyre cord is beginning to compete with Nylon (in U.S.) and offers most of the advantages of that fabric, plus the fact that it is not subject to flat-spotting.

The newer polypropylene fibres, marketed in U.K. under the trade names of Ulstron (I.C.I.) and Courlene (Courtaulds) are particularly suited for nets, and ropes in the fishing industry where strength, rot-proof properties, knotting, smoothness and cleanliness are important. Another use is in the outer braiding covering vacuum cleaner hoses, which a rapidly expanding field has been opened up in the production of fabrics for deck-chairs, garden furniture and awnings.

Polyethylene fibres and fabrics are being used extensively as trawl net materials in Europe and Japan. In United Kingdom I.C.I. have developed a new synthetic staple fibre,
similar to sisal, which can be processed on conventional equipment used for natural hard fibres. Known as Type R polypropylene staple (Table III.4 shows its other uses too), it is already crimped for easier processing, and can be used on its own or in blends with sisal fibre for the manufacture of fabrics. At present only ropes are made from this fibre but a much wider range of products is expected to be produced.

In U.S. the market for polypropylene is wider, including outdoor furniture, webbing, car-seat covers, ropes, brushes, luggage and shoe fabrics.

**TABLE III.4**

Showing Industrial End-uses for Polypropylene staple

<table>
<thead>
<tr>
<th>Characteristics Utilised</th>
</tr>
</thead>
</table>

A. Light Weight Non-Woven Fabrics

(15-40 gr/sq. m) Dry-laid (except as noted)
- Diapers (outer layer)
- Sanitary towel (outer layer)
- Tea bags (wet laid process)
- Wiping clothes
- Hospital uses
- Surgical bandages
- Filters and battery separators

(1) (2) (5) (6) (9) (8)

B. Medium and Heavy Weight Non-Woven Fabrics

(50-1.200 gr/sq.m) Dry-laid or needle-punched

(Contd.)
TABLE III.4 (Contd.)

- Wiping cloths
  (1) (2) (5) (6) (8) (9)
- Filters
  (1) (2) (6) (8) (5) (9) (4)
- Felts for soil protection
  (roads, canal and river)
  (banks, beaches, etc.)
  (9) (5) (7) (3)
- Substrate for synthetic leather
  (4)

C. Reinforcement

- Reinforced cement products
  (2) (3)
- Reinforced paper

Characteristics which make polypropylene fibre suitable for industrial end-uses:

1. Thermobonding
2. Chemical resistance
3. Mechanical resistance
4. Thermal shrinkage
5. Insensitivity to water
6. Atoxic properties
7. Abrasion resistance
8. Mould resistance
9. Cover/price

D. Foam Backs

For some years foam backing has moved from the experimental to the commercial stage. The foam, made from polyurethane, polyether or polyester, has a cellular, sponge-like structure and is resistant to bacteria, insect damage and chemical attack. Quite simply, foam laminating of textiles means the fusion by heat, or bonding of fabrics to foam. Its main uses at present are in outerwear (coats, jackets and rainwear).
blankets, upholstery, curtains and carpets. The use of the foam fabrics imparts insulation and dimensional stability to the product and, due to its light weight, leads to a fabric with the same insulating capabilities as a thicker and heavier conventional material.

Only synthetic fibres rather than wool or other natural fibres, are used in the combination, except in knit wear where blends of wool and synthetics are used. The properties of the foam have restricted its use in apparel wear, mainly to bring the inner layer of outerwear garments, since it is unsuitable as a face material due to its unpleasant "feel". However, as already mentioned, it has an outlet in various household end-uses: blankets, bedspreads and lightweight, sound absorbing curtains.

Many fabrics which deserve to be mentioned in this summary of end-uses may have been omitted, as the range of uses that any one of them is capable of fulfilling may be incomplete.
5. IMPACT OF ENDUSES ON PRODUCT LIFE SPAN

Theodore Levitt emphasises that the extension of enduses has a considerable impact on the extension of various stages in life cycle of a product. Further the nylon's booming sales life was repeatedly and systematically extended and stretched can serve as proof for it and other varieties of synthetic fabrics. The first nylon enduses were mainly military uses, namely for parachutes, thread, and rope. Nylon then entered the circular knit market and dominated the women's hosiery business. After some years, the steady rising growth and profit curves began to flatten out and the threat of obsolescence was imminent. Therefore, before they flattened very noticeably, Du Pont of U.S.A. developed measures for revitalising the sales and profits, to avoid the flattening effect of the operation of the products life cycle, Du Pont took certain action, among which two of them interest us and they were:

1. Developing more varied usage of the product among current users — expansion of end uses.

2. Finding new uses for the basic material — Product Development Aspect.

In order to develop more "varied usage" of the product among

---

13 Ibid., p. 89.
current users, Du Pont began to promote the "fashion smartness" of tinted hose and later of patterned and highly textured hosiery, thereby making hosiery a simple ingredient of fashion. The 'new uses' for the basic material were from varied types of hosiery to new uses as rugs, tyres, bearing, and so forth. If such product innovations, designed to create new uses for nylon after the original military, miscellaneous and circular knit uses had not been introduced, nylon consumption would have reached a saturation level. Appropriate action however resulted in consumption actually exceeding 500 million pounds in 1962-63. Now in the proceeding lines we discuss the various product innovations that have taken place in various varieties in the recent years, as a result of which the synthetic fabrics are having sustained increased demands for various new uses in various fields.

6. PRODUCT DEVELOPMENT

A product being the sum of the physical and psychological satisfaction, it provides to the buyer. Constant researches


have been going on for the development of new synthetic fibre fabrics. A product can also said to be the sum of the intrinsic characteristics of the product, its material and construction, and its ability to perform, its packaging and brand.17 Hence in the process of altering the properties of the product, new products have been developed.

Product development encompasses the technical aspect of the product research, engineering and design.18 Stanton believes, any change, however, minor it may be creates in effect another product. Among other things synthetic fabric product development involves:

1. What are the new uses of the fabric?
2. Is the quality of the fabric right for the intended uses?

In a developing country like India the development of new products are always backed by a strong need for it either for being a composite part of foreign trade consignements of synthetic fabrics or for its home markets to catch with the developments going on in other developed economies.

To carry the job of product development constant researches are going on both in the Research and Development cells of the

individual enterprises and in national institutions such as Council of Scientific and Industrial Research (CSIR), Bombay Textile Research Association (BTRA), National Chemical Laboratory (NCL), Silk and Art Silk Mills Research Association (SASMIRA), and others.

7. **RECENT DEVELOPMENTS IN SYNTHETICS**

The first truly synthetic fibre was discovered about forty years ago by Wallace Carothers and was commercialised in 1939.\textsuperscript{19} In the following decades the research effort on fibres proceeded in two directions:

1. Process and equipment development for producing Nylon on a commercial scale; and

2. A broad but intensive search for developing synthetic fibres beyond Nylon.

Nylon was a profitable product and many wanted to find other new products. Du Pont International alone discovered several thousand different chemical structures seeking improved fibre characteristics, similar activity was going on in several other laboratories round the world especially in Japan, West Germany, France, Canada and U.K. This research led to commercialisation of Acrylics, polyester and polyolefin fibre fabrics in 1950. Each of these fibre classes filled a market need, each reached large volume sales and each achieved profitability at a reasonably early stage.

\textsuperscript{19} "Man Made Fibre Industry", *Times of India Directory and Year Book*, Loc. Cit., p. 376.
It became apparent in the late 1950s, however, that available synthetic fabrics and natural fabrics covered major market needs and that research expenditures and plant investment aimed at establishing fibres and pay poor dividends. Research emphasis changed and in the late 1950s and 1960s it emphasised:

1. Technical modification of existing fibres commonly referred to as a second generation fibre.

2. Modification of speciality fibres which usually are high cost, low volume products, that meet the specific needs of well-defined markets.

Second generation fibre fabrics are illustrated by modified dyeability products in Nylon and Polyester, by bi-component acrylics to provide aesthetics more like wool and by non-round cross section fibres to introduce new lustre and fabric aesthetics. Among the special fibres are man-made Elastomerics, fibres with resistance to very high temperatures (Thermoplastic property) and chloro and fluoro fabrics. In the latter half of 1960s spun bonded and sophisticated non-woven products began to appear.

We have approached the end of 1970s and some trends and new development can be identified that will have important effects on the synthetic fabrics and textile industry. This will be discussed under the following headings:

1. New fibre and fabric technology, namely:
   (a) New Products, and
   (b) Second Generation Fibres.
NEWLY DEVELOPED ARACHNE NONWOVEN BY CZECHOSLOVAKIA.
2. Industry optimisation; and
3. Raw-material supplies.

Among these areas, the greatest amount of research and development effort is directed on second generation fibres and on industry optimisation since these are the places that must affect short range earnings.

A. New Fibre Technology

Two new fibre developments stand out in this decade, they are: (1) Spun-bonded or sophisticated producer non-wovens,
(2) The new high performance aromatic fibres exemplified by the Polyamide first known as "Fibre B" and new trade marketed "KEVLAR" aramid fibre.

Spun-bonded products are produced by spinning fibre directly into a non-woven structure in the fibre producer's plant. These products not being new were introduced in small quantities nearly ten years ago. Development of this class of product is very active and it becomes more evident that spun-bondeds may become a major factor in the Textile business, especially in areas where aesthetic demands are not great.

Most fibre producers have spun-bonded products along in development standing above 10 MM sq. Meters per year production level and are still growing. Sales of spun-bondeds in 1973 were well over 100 M.M. lbs. Properties of the products, span a wide gamut from highly opaque, smooth, stiff paper like
sheets to softer, more fabric like materials, to coarse and extremely tough products. Uses vary from "one use" applica-
tions such as hospital garments and operation room drapers to carpet backing and soil stabilisation in construction of roads. Scientists in a number of industrial laboratories have learned how to combine polymer type character of bonding, fibre shape and configuration and sheet weight to tailor make a wide range of products for diverse uses, and at lower cost to the consumer than the existing products.

The growth will probably continue to be concentrated in carpet backing for tufted carpets, road construction, packaging, interliners and graphics, but, longer-term, the diverse properties available will broaden market opportunity.

Of special interest in recent developments are two products "CAMBRELLE" and "Spun-laced fabrics" which appear to provide aesthetics suitable for some fabric like uses such as table coverings and draperies.

"Cambrelle" is a Nylon/Polypropylene bicomponent fibre in which bonding is achieved by calendering the fabric at temperatures that soften the polypropylene. "Spun laced" fabrics are based on polyester and have no fibre bonding but


* Calendering = It is a process carried out in a machine in which the fabric is smoothed, glazed, etc., by pressing the fabric between revolving cylinders. This machine is used for impregnating fabric with rubber, as in the manufacture of automobile tires.
gain integrity by tangling of fibres. It is expected to achieve further major advances of this type which yield performance and aesthetics to meet the needs of the consumer at low cost leading to the sales.

"KEVLAR" aramid fibre (or "Fibre B") is considered to be the biggest technical breakthrough in fibres since Nylon. Like Nylon the "Kevlar" established a completely new level of fibre strength and physical properties over existing fibres. It took many years of research to improve the fibre's fine structure of Nylon to yield Tire yarn strength: increases from 8 to 9 and finally to 10 grams per denier. Now "Kevlar" aramid fibre has emerged with a strength of more than twice that of the best commercial Nylon.

Table III. 5 shows the properties of "Kevlar" yarn.

TABLE III. 5

Comparing KEVLAR Yarn Properties with that of Nylon and Polyester

<table>
<thead>
<tr>
<th>Property</th>
<th>KEVLAR</th>
<th>NYLON</th>
<th>POLYESTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenacity gpd</td>
<td>21</td>
<td>9.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Modulus gpd at 20°C</td>
<td>450</td>
<td>55.0</td>
<td>110.0</td>
</tr>
<tr>
<td>Modulus gpd at 200°C</td>
<td>300</td>
<td>20.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

The extra ordinary fibre strength in Kevlar was achieved by developing a new physical structure or manner of arranging stiff polymer chains in a fibre through molecular orientation. Wholly aromatic polyamides have been produced previously. For example, "Nomex" is a wholly aromatic polyamide but strength and modulus were not outstanding.

These properties are expected to make "Kevlar" useful in a number of markets, the largest of which is tyre cord. On account of high modulus of steel wire, it has shown rapid growth as a tyre cord as radial tyre constructions have progressively taken over the tyre market. "Kevlar" now provides an organic synthetic fibre which promises to compete effectively with steel both in tyre performance and tyre economics.

The price of Kevlar is high (Rs. 25 per lb), because the raw material is expensive and the mechanical complexities involved in producing this unusual fibre. However, broad development experience with tyre manufacturers indicates that at this price, the value in use of "Kevlar" compares favourably with steel in many tyre constructions, because one pound of Kevlar replaces about 4 to 5 pounds of steel wire.

3. Other uses of "KEVLAR" and "KEVLAR FAMILY"

Many uses of Kevlar are visualised in other markets where high strength, high modulus or stability to high temperature is important. These include precision "V" belts, sewing thread
for tough industrial uses and cables.

Another member of the Kevlar family is "Kevlar 49" which is used as a fibre reinforcement for plastics. A comparison of the properties of "Kevlar 49" with the most widely used of all fibre reinforcement, namely E-glass fibre, shows that "Kevlar 49" combines with almost twice the tensile strength* and modulus of glass, with a 40 per cent lower density. The specific tensile strength is in fact higher than is now available from any known material and the specific modulus exceeds all materials except the expensive space age materials "boron" and "graphite". These properties make "Kevlar 49" especially useful as a high strength, high stiffness, weight saving replacement for glass in reinforced plastics for the aircraft, marine and sports goods markets, and as a replacement for steel in electro-mechanical and wire rope uses. Lockheed Air Craft in the knitted state has adopted it for components of the L-1011 Air Bus and most of other airframe manufacturers in the U.S.A. and Europe use it.

Additional advantage of "Kevlar 49" over glass in dielectric properties and corrosion resistance have led to development of "Kevlar 49" reinforced electric circuit boards and chemical hardware. This development of synthetic fibre, with a completely new level of properties, through consistent researches

* Capable of being stretched so as to find the load the thread will support without breaking.
gives rebirth to many fibres and also new fibres are synthesised.

8. AN EVALUATION OF OTHER NEW PRODUCTS
(PENUMACEL, TOYOFLON, ULSTRON, Lycra and Spanzelle).

A completely different type of new product (fibre) with the genetic name "Penumacel" is based on polyester polymer and is spun as a closed cell foam. This collapse of thin walled cells in the foam is avoided by inflating the cells during manufacture with a "Freon" fluoro carbon gas of large molecular size which cannot escape from the closed cell. The fibre has a very low density less than 2 per cent that of polyester.21

Although fibre properties would allow use in blended fabrics or as loose filling material, it has been found that these fibres are especially useful when bonded together for cushioning uses. As such they serve well in products that require firm support such as carpet underlay mattresses, auto seats and furniture. A roll of "Penumacel" 72 inches by 26 inches in size (underlay for carpeting) which weighs only 60 pounds is easily carried by one man.

When load is exerted on the cushion, the small air molecules escape through the wall and the cells partially collapse, so that the cushion conforms to the load but the "Freon" gas still provides support. When the load is removed, air is forced back into the cells by osmotic pressure and when pressure equilibrium is established the fibre is reinflated to

21 Ibid.
its original size and shape. Thus recovery of the cushion is dependent not on the recovery force of the thin polymer wall of the fibre but upon the re-equilibrium of gas pressure in the cells. This is a unique approach to cushioning and one that appears to be very useful. How far will it penetrate the market is not clear but substantial growth appears assured.

Toyo Rayon Company of Japan is reported to have developed a fluorocarbon fibre known as "Toyoflon" made from polytetrafluoroethylene. Yet production is on a very small scale but the new fibre is being used for filter cloths, non-lubricated bearings, etc. The Nippon Carbon Company is understood to have derived a fibre from carbonated polyacrylonitrile, marketed under the name of "Carbolan", and is suitable for industrial uses such as filters, insulators, and anti-static materials.

It has also been reported that Japan has produced a fibre by co-polymerising polyvinyl chloride and polyvinyl alcohol. It is to be marketed under the name "Superenvilon", and is said to have similar handle to the acrylics, and a dyability higher than that of most non-cellulosics. The new fibre is claimed to be suitable for underwear, sweaters and other garments.

Polypropylene, in the form of "ulstron" filament yarn, is at present widely used in the manufacture of fish nets and ropes, while staple fibre is finding increasing use in filter cloths and overalls. Ulstrom staple in blankets/is its first non-industrial use, also its modifications for household textiles,
carpets, etc., are in experimental stage.

Polyurethane fibre "Lycra" was produced by Du Pont in U.S.A. under the generic term "Spandex", this elastomeric fibre is sold usually in blends with other synthetics and its main advantages are light weight, strength and the elasticity it imparts to mixture fabrics. In U.S. sales of Du Pont's spandex, first produced commercially in 1962, has found way in domestic and export markets. The Firestone Synthetic Fibres Company has developed "Spanselle", a multifilament polyurethane elastomer in sizes ranging from 60 to 420 denier.  

9. BLENDED FABRICS

The synthetic fibres in order to capture greater share of market stepped into the market for cotton in the form of combination with various cotton and other cellulosics, giving rise to the development of blends. A set of Terylene or Nylon fabrics have been produced with same cotton contents ranging from 50 to 80 per cent. However, synthetics encroached into woollen's market too to form blends with it, as a result Tere-wool is one of the most prominent varieties. No doubt, the blended fabrics have certain advantages in respect of their use, softening, texturing and attractiveness. They are helpful ultimately in the marketing aspect of synthetic. The pure

100% synthetic fabrics have certain disadvantages such as they are sticky and cause much perspiration as they are less porous in nature. However, the bio-chemists have found that the synthetic fabrics when constantly used cause irritation of the epidermal layer of skin which ultimately peels up this layer. Hence from the point of view of the survival and growth of its market, the synthetic fabrics had to capture the greater part of market in the form of blended fabrics with cotton and wool. Hence consistent demand round the year is experienced.

A. Advantages and Future of Blending

In the proceeding lines discussion is devoted towards fibre and yarn blends and mixtures from a variety of standpoints including economic, natural fibre extension, fabric performance improvement, fabric design and styling, aesthetic and comfort factors and altered concepts in dyeing and finishing.

The first question we look for in textile products are the following main requirements:

(a) Protection from the elements  
(b) Durability  
(c) Aesthetic, colour, style, design and hand  
(d) Cleanability  
(e) Stability  
(f) Comfort  
(g) Property retention  
(h) Ease of care  
(i) Colour fastness  
(j) Price

The order of importance differs in various parts of world and there are certainly other factors too that require consideration.
By using a staple fibre yarn and filaments in 100% form of a variety of generic materials we can obtain a number of the required properties. Strength without comfort, colour and design with low abrasion resistance, price without performance—all these are available from the fibres and yarns which have been available for many years. This unending search for the all-purpose fibre led to the idea that by combining or blending the best properties of all fibres and the millenium attained.

B. Natural Fibre Blending - Cotton Replacement by Rayon

The blending of natural fibres, particularly cotton, has been carried out for a long time with the purpose of improving the quality and performance of yarns and fabrics. Many areas of world produce cotton of only poor quality in terms of strength, staple length and impurities and it is standard practice to import cotton of such a quality as to provide additive values to the domestic material.

While this procedure is technically feasible it is done at the cost of importation and, furthermore, one can never know from the season to season just what the cost is going to be.

Cotton availability and price suggest that world cotton production has reached its peak. This, combined with facts of rapidly growing population and need for more food growing land indicates that the cost of high grade cotton will continue to increase to the point that there will one day be insufficient
cotton to support and improve the lower grades, as has been
the long time custom.

Cotton blends with synthetics require high grade cotton
the price of which in western world is higher than that of
synthetics.

Also, long ago spinners recognised the problems of
cotton blending, and presumably as a means of working round
their problem vis-a-vis cotton imports, substituted "old"
viscose rayon for the long staple cotton and this practice
prevails even today. The "old" rayon staple did obviate
the need for cotton importations.

However, "old" rayon staple is extremely weak when wet and
possesses only low abrasion resistance and by its use one
problem was solved but others developed.

The development in Europe and U.S.A. of high performance
rayons with strength and abrasion resistance of the same
order as cotton, both wet and dry, provided an infinitely improved
result in cotton blending. Studies in India show an increase
in tenacity and abrasion resistance in fabrics about 25% higher
than that of 100% cotton in complete contradiction from
the "old rayon".

Recent developments indicate that rayon staples with a
high, chemically induced crimp supply a level of bulk and
other physical properties equal to that of the highest grade
cottons.
New rayon blended fabrics can be dyed in a range of bright colour and, when resin finished, meet all the wash and wear, ease of care standards and, because of ability to absorb moisture, are as comfortable as 100% cotton in hot, humid weather.

Such a fabric blend meets the requirements as listed, though in terms of durability alone other blends possess greater durability. From the standpoint of extending domestic cotton crops and eliminating the need for imports these new rayon staples provide an outstanding possibility. Only the high wet modulus rayons are capable of yielding this high level of chemical crimp which is not feasible via the polynosic route.

C. Cellulosic/Polyester Blends

The most common fibre blend today is that of polyester and cotton, though increasingly rayon is replacing cotton.

Polyester staple is a strong abrasion resistant fibre with excellent properties in terms of resisting creases, shedding wrinkles and with good hot wet properties that yield excellent results as a wash and wear material.

Its adverse properties are that it is moisture resistant, prone to produce static electricity, is very difficult and expensive to dye and its aesthetic properties are quite poor.

By blending polyester with cellulosics, most of the negative properties of polyester are diminished in the fabric
and the cellulosics benefit from the strength and abrasion resistance of the polyester.

Firstly came the finding, which ran counter to the theory, that low percentages of polyester in a cellulosic blend do not provide additive strength. It is only at the 50% level that the value of polyester begins to manifest itself but at a 35% level, for instance, the fabric properties are lower than those of 100% cotton.\(^\text{23}\)

At the 75% level polyester in blends with 25% cellulosic, the fabrics are about as strong as 100% polyester but, by then, the low moisture absorption began to present problems as do the factors of dry creasing.

As a result of several years of marketing trial and error the polyester fibre producers evolved their philosophy that 65% of polyester and 35% of cellulosic was the ideal blend.

The textile industry on the other hand favoured the 50/50 blend, firstly on the basis that the performance of such a blend was more than adequate and, furthermore, at that time the price of cellulosics was lower than that of polyester.

In spite of these findings, which were duplicated in Europe, the blend of 35% polyester and 65% cellulose is still being made because consumers around the world now believe that the presence of polyester confers miraculous

properties.

Another problem inherent in the earlier work in polyester/cellulosic blending was that of pilling, which is the development of small balls of 'fuzz' and 'fluff' at points of continued abrasive wear. This is due to the fact that, under conditions of abrasive wear, the polyester does not break off as do wool, cotton and rayon but become self entangled and presents an unsightly appearance.

Another problem with polyester blends is that of oil and grease retention which even vigorous washing cannot remove. Latest finishes improve this fault at extra cost.

Most manufacturers now make a non-pilling polyester of lower tenacity similar to that of cotton and high wet modules (H.W.M.) rayon and this totally eliminates the problem in conjunction with good finishing procedures.

Polyester/cellulosic fabrics are expensive to dye and require extremely high temperatures with consequent high utilization of energy and expensive equipment or chemical assistants which are expensive.

Polyester staple is sold today with two types of dyeing systems namely, disperse and cationic and consequently a blend of these two types of polyester in conjunction with cellulosics give the capability of dyeing three different colours in one dyebath. This type of blending gives the possibility of producing yarn dyed effects in piece dyed
fabrics under the engineered condition of weaving.

Polyester/cotton blended fabrics have entered into every end use market which at one time was exclusively in 100% cotton and forecasts are that, within a relatively short time, the blended fabrics will replace 100% cotton entirely in the U.S.A., Western Europe and Japan and the reason for this projection is that polyester/cellulosic blends meet virtually all the prerequisites listed at the beginning. As to whether this projection is good for hot countries is more doubtful and especially where there is no ready access to cheap polyester.

Although comfort is very subjective thing, there are many consumers who believe that even 50/50 blends of polyester, and cellulosics leave much to be desired in this regard but the initial cost, plus the extra cost of processing through dyeing and finishing make these blended fabrics more expensive than blends in, say, cotton and rayon.

Although the big blended fabric volume is in polyester/cotton there is a sharply growing tendency to substitute rayon for cotton and this tendency will grow as the cotton shortage increases. The combining of polyester and rayon offers many advantages especially when the newer high wet modules rayons are used.

In the first place one starts the blending with two engineered fibres not subject to the wide variations inherent in each cotton shipment. The respective staple lengths are cut to
effect the best union with each other and hence to obtain the best yarn and fabric properties.

Because of rayons uniformity the need for combing is eliminated and, whereas it is normal to have 10% waste when cotton is used, this is reduced to 2% in the case of H.W.M. rayon.

The final product is noticeably improved over the cotton blend in terms of appearance free from the characteristic short term streaks, endemic to polyester cotton blends.

New polyester/cellulosic blends, well finished with fibre reactive resins, have set new standards for performance in terms of strength, abrasion resistance, easy care properties, including wash and wear.

Polyester staple manufacturers have also produced a high shrinking product which, when blended with other fibres and under normal processing conditions in dyeing, shrinks to a predetermined extent. Such a material when blended with normal polyester, wool or the cellulosics gives interesting new possibilities in fabric development to form densely constructed fabrics and interesting surface effects.

Thus, it is obvious that polyester staple which, in itself, is not attractive from an aesthetic standpoint and is deficient in comfort factor, can be blended with cotton and rayon to produce 'all-purpose fabric' and this blend may continue to be so until something better comes along except in hot and humid climates where rayon/cotton blends are more acceptable to the
consumer or where the cost of polyester is too high for mass production fabrics.

D. Nylon Staple In Blends

Before the full development of polyester, it seemed as though nylon might be a preferred blending fibre. Its aesthetic properties are extremely poor, yielding a very harsh hand and touch. It was conceived that a relatively small percentage of tough nylon would strengthen other less strong fibres such as cotton, rayon, and wool. Also, it was found that small percentage merely served to weaken the blend and a high enough percentage to add strength and wear resistance destroyed the aesthetic properties.

The problem was partially solved by the "Du pont" development of a highly stretched nylon which, when blended with other fibres, immediately participated in strength addition at low percentages. But this nylon shrank in hot water and returned to a state of high elongation without contributing its strength to a cotton fabric until high percentages were used.

The advent of polyester staple put an end to this which nevertheless, remains in some areas of the world as a spinning aid in weak fibres.

E. Blended Acrylics

Because of acrylic's capability of being bulked and the luxurious touch that can be developed, were originally conceived
of as a 'synthetic wool'. Their hot wet properties leave much to be desired and their aesthetic properties can easily be lost without care and attention to their fundamentals.

Acrylics in their early days were blended with wool as a lower priced extender and, while quite satisfactory in heavy weight fabrics, in hot climates the results were disastrous in tropical suitings where a combination of heat and moisture altered the total character of the fabrics.

Acrylics in blends with rayon are commonly used to give wool-like finishes in women’s dress goods and the difference in the ways of accepting dyestuffs makes possible two colour piece dye effects.

Acrylics are frequently self-blended by first stretch breaking a tow on a Turbo convertor and then taking, say 35% of the fibre and steam relaxing it before blending with the other 65% of fibre. Yarns made into sweaters and the like develop a high bulk as a result of the interaction of shrinking and staple fibres.

A similar result can be obtained on acrylic fibres by blending co-polymer whereby, at the point of extrusion, different setting temperatures of the two polymers cause a bulking or yarn distortion which gives a high bulk effect. Whether acrylic blends have any worthwhile future except, in static uses as drapes, curtains and furniture lines is a moot point.
F. Triple Blending or Three Way Blends

As discussed earlier, the blending of two staple fibres on the basis that this form of blending is commercially important, nevertheless the blending of three fibres is quite common practice.

Three fibres are blended for the purpose of attaining the best physical qualities of each in the final fabric and this three way blending is used more for reasons of styling, colouration and fabric design.

As mentioned earlier, there exist polyesters with cationic and disperse dyeability and these blended with rayon can yield three separate and distinct colour. Now this presents a real challenge to fabric development, people possessing Jacquard equipment and box looms because results can be obtained in a piece dyeing operation that compare with those obtained by raw stock or yarn dyeing procedures.

This type of result is not confined to polyester/rayons for whenever the basic dyeing capabilities require a different class of dyestuffs, then this type of work can be carried out. However, when differing generics accept the same type of dyestuff, then control of colour is much more difficult.

While some of this three way blending is carried out for the purpose of piece dyeing multi-coloured effects, other/three way blending is done to obtain different appearances in fabrics in terms of surface effects or even for the sake of a
commercial advantage in being able to mention the name of the most prestigious fibre. For example, addition of 5% of silk noils to a blend of cotton and rayon enables the fabric vendor to claim that the ultimate garment is part silk.

Similarly flax and linen are added in minor percentages to polyester/cellulosic blends to give the over-all appearance of the natural product but with the superior performance of the synthetic fibres. This three way multi-coloured piece dyeing calls for superior skills on the part of dyer and a very precise knowledge of the reactivity of one group of dyes with another.

G. Impact of Blends on Dyeing

The first truly synthetic fibre fabric did not create too much difficulty for the dyer, once their properties were understood and when the disperse dyestuffs were developed for acetate. Existing conventional equipment was adequate to deal with the colouring and colour applications.

The advent of polyester presented completely new problems in that elevated temperature close to the boil in conjunction with expensive dyeing assistants were required or still further elevated temperatures that could only be obtained under pressure.

Most recently polyesters have been developed which will dye close to the boil and without dyeing assistants but polyester requires more energy to colour with higher cost
dyestuffs than the cellulosics or nylon.

Acrylics, too, require high temperatures for efficient utilisation of dyestuff and, once it is decided to blend any fibre with acrylics or polyester, full attention is given to the dyeing requirements.

The developments in blends have all led to an increased dyehouse cost, except for cotton/rayon blends (cellulosics), in terms of the use of more expensive dyestuffs and more sophisticated dyeing equipment.

H. Finishing of Blends

Over past few years the finishing of the blended fabrics has become more complicated in the endeavour to improve the deficiencies inherent in the constituent fibre. came the

First/fibre reactive resin finishing that made cellulosics the equal of the synthetics in terms of easy care and wash and wear performance, albeit at the cost of abrasion resistance. Then it was blended with polyester and abrasion problem was overcome.

Then it was found that polyester and grease had a strong attraction that ordinary washing could not remove and it became necessary to apply soil release finishes along with the resins to facilitate the removal of grease-born soil in washing.

Now there are finishes that one applies to polyester
that permit moisture transfer - not absorption - but wicking from the body. This was to improve the comfort factor of polyester which may be more psychological than real.

In addition there are the water repelling finishes - chiefly silicones - that must also be compatible with the other constituents of the finishing system.

Further is the question of fire retardancy finishes for polyester which have been developed that render polyester/cellulosic blends less hazardous to flame in critical end uses.

Blended fabrics have complicated the job of the dyer and finisher.

10. Workwear Innovation

A set of workwear shirting fabrics from polyester/cotton contents (from 50 to 100%) have been woven and an equivalent range will also be produced in cotton/Nylon blends.

A U.K. firm has developed a technique offering a new standard of comfort in weatherproof cotton workwear. Jeltek Ltd. of Hounslow (U.K.); see a high future for the new workwear range, which is made up in pure cotton coated with polyurethane and perforated with tiny pin-holes. The "microvent" process, resulting from several years of research, allows perspiration to penetrate outwards and evaporate from

the surface of the garment. At the same time the technique prevents outside moisture from penetrating inwards, making the garments totally weatherproof.

11. Non-Flammable and Fire Retardant Fibres

Non-flammable, heat-resistant synthetic fibres are another area of broad research interest. Use of these fibres is limited to protective clothing and industrial fibres. This technology should not be confused with the large efforts aimed at flame retardant fabrics for general apparel use where emphasis is on non-burning. For prospective clothing the garment must not burn and in addition, must protect the wearer from flames and intense heat.

"NOMEX" the best known example, has become established in markets for military uniforms, fire-fighting equipment and industrial uses, but its demand is low. In past years (1971-74) several new fibres of this class have appeared, namely "KERMEL" and "ENKATHERM" in Europe; "CONEX" in Japan; and PBI and HT-4 in U.S.A. PBI and HT-4 fibres are under intense testing by the American Military,25 because they both show significant advantage over "NOMEX" in the very drastic use conditions which are of interest to the military. The objective is to give personnel a few more seconds to escape from burning aircraft or from the searing fibres that are fed by large quantities to jet fuel. These two new fibres

promise a major advance in protection.

The greatest short term profits are realised from research and development effort aimed at second generation fibres. Much cannot be said about the details of the results of this work. But briefly three general areas of research where broad advances are likely to be made can be discussed. They are

(1) Flame and fire retardants
(2) Aesthetics fibres, and
(3) Mercerising processes

Several flame retardant mod-acrylic and polyester fibres have been introduced in commercial use in U.S.A., Japan and Europe. These fibres meet current regulations, so long as fabric construction and fibre content are properly controlled.

12. Static Control

For many years researches are directed to eliminate static generation in the synthetics. Several anti-static nylon yarns have been commercialised in recent years and other improved versions are well along in development. The most recent announcement have concerned introduction of highly conductive fibres which are introduced into yarns at very low concentration. High conductivity in organic fibres such as polyester or Nylon can be achieved by imbending carbon in the fibre.

13. New Aesthetics, Lusture, Texture, etc.

This is the area of greatest activity for second generation
fibres today. Fibre cross section, crump, mixed shrinkage, new texturing procedure, new colouration effects are all being pursued to provide new fabric products. This will continue as one of the most active and most rewarding areas of fabric research and development because it is these characteristics that are seen by the consumer and recognised as a new product. Strong efforts throughout the world are aimed at obtaining silk-like aesthetics from polyester and acrylic filament yarns.

Also at achieving new styling potential in apparel and carpets, considerable activity is reported on developing moisture absorbing fibre and fabrics, especially in Japan.

14. Development in Mercerising*

One major fully continuous trial has been carried out at Umist, Belgium, to investigate the effects of presteaming the fabric temperature of the alkali and the general operating procedures. The success of this trial can be quickly applied in a second trial. One curious effect which may explain some of the earlier failures is the greatly reduced pick-up of alkali from the hot mercerising liquor.

The evaluation of this work is being allowed by the need to bleach and cross link all fabric samples in order to check up the efficiency of the mercerisation step. A dyeing

* Treating of threads so that they are able to take dyes and become glossy like silk.
text has been developed by one collaborator in Struttygart, U.S.A., and was examined involving laborious procedures.

15. Knitting

The knitting industry in the past has not developed much in India. It has been more or less like a cottage industry and the developments taken place in the advanced countries in knitting technology have not yet found their way into India. This is largely because of the paucity of synthetic filament yarns, and the consequent banning of import of warp knitting machines by the Government. But with the recent use of spun yarns on warp knitting machines and increased production of synthetic filament yarns within the country, the knitting industry in India is likely to grow faster in future. Even in the conventional fields, such as underwear, socks, etc., the growth potential of the knitting industry is very high and yet none of the laboratories are undertaking any research.²⁶

The utilisation of warp knitting machinery besides for synthetics continues for cotton and other yarns also. Notable results were obtained with an East German machine designed essentially for continuous filament synthetic yarns. The fault rate at high speed was low even though fine gauge cotton yarns were being knitted.

The prograde programme is being seriously developed by the shortage of yarn, but the first order has been placed for a prograde machine by an Italian manufacturer.27

16. **Draw Texturing**

In draw texturing two processing steps are combined into one. As it is known that Nylon and Polyester fibre are produced by melt spinning a polymer and then stretching or drawing the fibre characteristics. Combining this drawing step with texturing promises to lead to improved process efficiency and to higher quality products. Several recent developments have provided yarn with spun aesthetics directly from the fibre producers process. A fascinating example is "Nandel" (trade name) yarn, the unique structure of which is that a bundle of parallel fibres are held together by a few wrapping fibres.28

The spun-bonded as already discussed in this chapter in which one or more conventional process steps are eliminated to provide lower costs and new products for the consumer. The ingenuity of scientific research is aimed at progressing in this direction.

17. **Finishing**

With increasing use of synthetic fabrics as a single fabric or in blends, textile industry undertakes developments in the

27 Raymond Craig, "Developments in Man Made Fibres", Loc. Cit.
28 Ibid.
conventional equipments of fabric finishing. The term "finishing" as applied to textiles can be taken broadly to embrace the processes such as dyeing and printing, because they transform a somewhat lifeless article into one possessed of charm and appeal. Fabrics look good because of the outstanding fastness properties of the finishes to light, abrasion, washing, and to conditions of normal wear. Special technology developed for finishing of textured fibre fabrics involves higher heat setting temperatures and dyes with good sublimation fastness.

Number of new finishing processes other than dyeing and printing are being developed for application to synthetic textile materials. Antistatic finishes have been developed to overcome static elasticity in synthetic fibre pile carpet and impart soil resistant and bacteriostatic properties. Customers look fabrics material with easy care properties along with its aesthetic look in virtually every piece they buy. Special finishes have been, therefore, developed for cellulosic fabrics to produce improvements in dimensional stability, appearance and crease retention. In addition, there are finishing processes such as those covering water-repellency and other functional attributes. 29

Different fibre blends and the development of more sophisticated wet processing methods have, however, complicated

the modern finishing techniques for many fabrics. But a number of newly developed finishes are imparting improved fabric properties without interfering with the other processes.

With large investments in machinery and application of great skills in operation, there is a significant change in finishing technology. Rapid progress of automation cannot only be observed in batch processing techniques such as high temperature beam dyeing machines or tensionless jiggers, but also in the continuous methods of scouring and bleaching and solvent dyeing and finishing.

A. Functional Role of Finishing

Both synthetic and natural fibres require a number of chemical processes in order to produce a host of functional properties demanded for their end-uses. For some years, some of these properties have been produced by a series of sequential separate finishing operations.

Despite the inherent strength property and anti-microbial resistance of synthetic fabrics, deposition of finishing agents is necessary to produce certain functional properties, such as flame resistance, antistatic effect and wrinkle recovery. Frequently undesirable changes accompany these fibre modifications. For example polyester is blended with cotton for improved strength in durable press fabrics with introduction of new problems of soil retention, frosting and pilling. All the time these changes are being made, in a field as fundamental
as textiles, we are compelled to consider the economic factors, of original cost, of care and length of life of the textile as well as aesthetics, which adds to the enjoyment of using the textiles without well-being of its users. In the last category, should be included fabrics or their finishes with non-allergenic characteristics, flame-resistant properties and, for certain uses, fabrics which are anti-microbial. This leads to combining of many functional effects in one fabric.

Every textile may not have a complete range of the possible characteristics, but there are many which are obviously desirable. The big buildings now a days have large glass areas which are usually enclosed with draperies which should be flame-resistant, light fast and spot and stain resistant, as should be the carpets and upholstery. And if the building is hospital, these fabrics should have also anti-microbial characteristics. In the home, the anti-microbial and anti-fungal treatment of fabrics is again important in the areas of the kitchen, bathroom and nursery, especially now, since these rooms are being carpeted rather than having washable floors. There are serious soil release problems which need to be answered; these are associated with oily stains on the synthetics usually recommended for kitchen or outdoor carpets.

For a combination of functional effects, there are several routes that may be taken, e.g., use of a series of treatments, which lead to a multi-functional finish by a judicious combination of several finishing agents.
However, because of differences in the ionic character of the reactants, and catalysts needed in the mixture, or because of differences in reaction rates of the various ingredients, many potentially desirable multi-functional finishes are not practicable.

During the finishing process frequently, chemical finishes are applied at the stentering stages. For this purpose a padding mangle forms part of the stenter range. The finish, for example, a resin treatment, is applied on the mangle and the cloth passes forward to be dried. It is sometimes convenient to provide the stenter with high temperature heating enclosures following the drying sections. The facility is employed for the "Curing" of finishes or for heat-setting treatments.  

Unlike cellulose-fibre fabrics, which when dried at a particular dimension tend to retain that dimension when dry, fabrics of synthetic fibres do not usually, possess this property. For this reason, synthetic fibre fabrics are commonly "heat-set", that is, they are subjected to a temperature approaching the softening point of the fibre while it is held at the required dimensions during passage through the stenter.

"Calendering" is another process which consists in passing a fabric between the two heavy rotating rollers - called "bowls" - under pressure. Its primary function is to smoothen

30 Ibid.
the fabric and close its interstices, so in some way it may be regarded as similar to domestic ironing, even in that the calendering action is facilitated if the fabric is a little damp and the bowls warm. According to the conditions of calendering, a wide range of fabric effects may be obtained.

During these finishing treatments the fabric construction becomes distorted in one way or another, and, in general, goods would not be acceptable if presented in this form. Therefore, mechanical finishing is, imparted to rectify irregularities introduced during earlier processes and to give the fabric a desirable handle, attractive surface, and other refinements.

B. World Trends in Finishing

Salient features of the recent trends tend to treat large batches at a time. This is not only economical but also essential as the woven and knitted goods are available in great widths which are economically more viable. Continuous methods of processing are favoured in all processing preparation, dyeing or finishing for longer runs and high degree of standardisation. Modern continuous and semi-continuous bleaching ranges are increasing so also "open width scouring" at the expense of rope washing. This is to eliminate creasing and weft distortion. It also offers more efficient high speed washing with better utilisation of heat, water and a reduced volume of effluent. In dyeing machines the trends are towards complete automation in batch dyeing, package dyeing and beam dyeing, for high
Temperature design of pressure, jiggers and winches. The jet dyeing system with minimum of tension have found a great favour. Spray dyeing and processing have wider application in finishing. Gentle handling of fabrics at all stages particularly for knits is being widely applied. Fully instrumented high speed drying and setting is done on the stenter that can handle even delicate fabrics under precise conditions of dimensional control. This ensures a high degree of uniformity of temperature across the width of the cloth. The instrumentation of colour matching and colour measurement of dyeing machinery has enabled better shade uniformity. Solvent processing has been used in recent years, enabling similar other air water emulsion processing. Solvent dyeing now used for acetate fabrics and certain acrylics is heading to develop commercial methods of dyeing polyester/cotton blended fabrics. Application of permanent press, easy-care and soil-resistant finishes by solvent techniques are fast developing. The development of antistatic and anti soil agents are making their application to synthetic fibre easier.

In recent years, flameproofing is being considerably improved. The utilisation of phosphorus chemically reacted with or deposited within cellulosic fibres represents the most significant contribution to the field of durable flame retardancy for these fibres. From direct phosphorylation, the technology has developed to employing multicomponent systems for combination effects. Because of the limited efforts
expanding in this field in the past and with the potential of huge legislated markets projected for the future, reactive flame retardants are literally in their infancy. New phosphorus compounds, novel phosphorus nitrogen combinations and revolutionary finishing techniques not used before are the efforts of several laboratories currently researching the field. The study of "actinic degradation" of textiles, particularly of cellulosic materials, is comparatively recent including finishing of textiles for specific end-uses to improve their resistance to sunlight. Many impurities in fibres or dyes and finishing agents applied from some other points of view, have an effect of "photosensitising" the degradation of different fibres. To minimise this photosensitisation, a proper selection of dyes and finishing agents is essential. In addition to this, to protect the fibres in their presence, different types of compounds which can be employed in combination, which could deactivate the sensitisers by acting as screeners, light scatters or utilise the solar energy themselves. The material that have been studied as light degradation inhibitors for cellulosic fibres can be grouped as ultra-violet absorbers, antioxidants, chemical modification of cellulosic substrate, mineral dyeing, pigment application, metal coatings, dyes, polymers or reactant finishes.

18. Water Free Dyeing

A method to dye fabrics under a gasified dyeing formulae which does not require water has recently been developed by the
Ashikaga Textile Industrial Experimental Station (Tochigi Pref), Japan. It is said that the method if put into practical use, would become the first of its kind in the world.

Under conventional method water used in dyeing causes pollution problems, but under the method developed, the dye is gasified through heating before dyeing of the fabrics. Gasification is carried out by placing the dye in a drum called the dyeing chamber and exposing it to a temperature ranging between 150 - 190°C. When the dye is gasified, the fabric is sent into the chamber automatically for dyeing. The gas which remains after the dyeing operation can be turned into powder when cooled and utilised again. So far the researches have succeeded only in "dyeing synthetic fabrics" into a single colour.

19. Product Planning in Indian Synthetic Textile Industry

Product planning has a very low status both in principle and practice in the synthetic textile industry in India. The prime reason being the production-oriented philosophy, due in turn to the tendency of top management to employ technical personnel. Managers with technical backgrounds tend to pay more attention to the technical problems as these are the things they understand best. Consequently many mills are

32 Ibid.
dominate by the economies of scale and achievement of efficiencies in production to the extent of pushing innovations and customer satisfaction efforts into the background. This attitude is further compounded by the absence of marketing departments and the rare use of marketing research in the industry. Thus, the requirements of production are uppermost in the minds of those shaping company policies.

There are various factors responsible for such unsound product planning:

(a) belief that growth of an industry is assured by an expanding and more affluent population. This is taken as a guarantee against product obsolescence.

(b) belief that there is no competitive substitute for the currently dominating products such as polyester-cotton blends for men’s wear and Nylons for Women’s wear.

(c) Too much pre-occupation with mass production and the advantages of decreasing unit costs with increase in the volume of production.

As a result some products do not conform to change in consumer needs and tastes. Hence new product decisions are forecasted.

The textile industry may adopt a consumer oriented approach leading to a renewed product planning procedure. A system which incorporates requirements of the international market and the restraints of the company has to be evolved.