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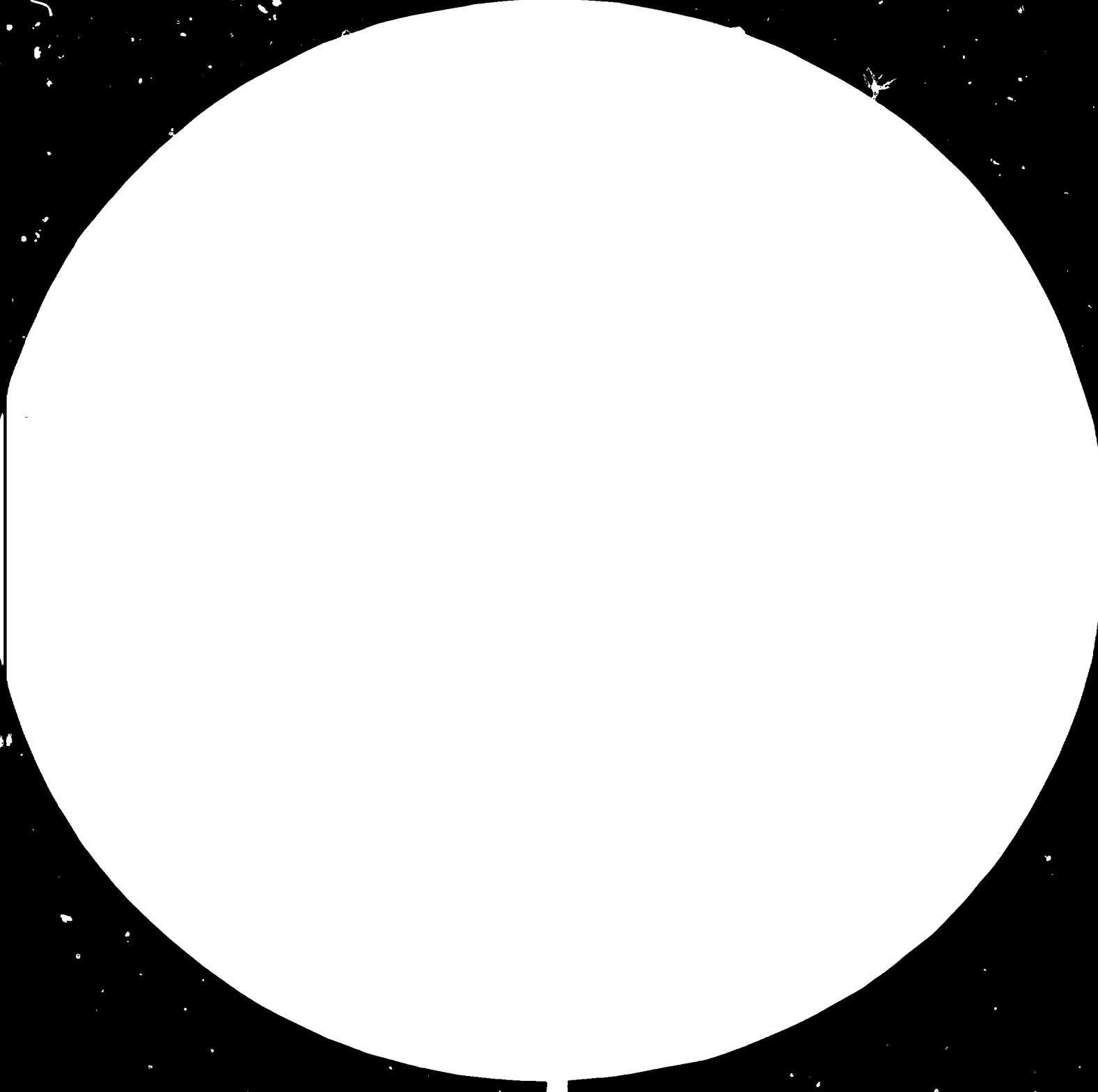
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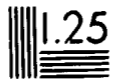
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Physical Methods of Fiber Modification

Prof. Dipl. Ing. Wilhelm Herzog

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Physical Methods of Fiber Modification

By Prof. Dipl. Ing. Wilhelm Herzog

Reviewing the development of synthetic fibers, we note an initial stage during which the efforts were directed at finding fiber-forming polymers.

The synthetic fibers made from them were made to resemble natural fibers and were to have as wide a field of application as possible.

During the second phase of development the field of application for synthetic fibers was expanded through variation and modification and adopted ever more closely to the specific requirements. The use of completely new technological methods, such as texturizing, gave rise to novel textile materials. Thus the synthetic fibers born during this second phase are frequently termed fibers of the second generation.

Under the general heading of physical methods of fiber modification I should now like to report on some of these methods and will be dealing with the following subjects:

- Modification of the structure of the fiber material
- Modification of fiber shape (special cross-sections)
- Conjugated (bi-component) fibers and
- Texturization

Modification of the structure of the fiber material

Synthetic fibers consist of long-chained macromolecules, linked to identical basic molecules by chemical bonds.

Depending on the chemical structure of the basic molecules and the type of linkage making up the macromolecules, these basic molecules are formed into linear chain molecules or into branched or cross-linked macromolecules.

Each fiber consists of many such macromolecules. In addition to the strong chemical bonds acting in the interior of the macromolecules, intramolecular forces - considerably weaker - also exert an effect. The effectiveness of these intermolecular forces depends on the position of the macromolecules in relation to each other.

Fig. 1

If one or more macromolecules are parallel to each other over a certain distance - compared to cross-positioned molecules which are linked only at one point - their linkage becomes stronger due to the summation of several forces.

Fig. 2

In the molten mass or in solution the fibers assume a random disoriented position that is altered constantly because of the temperature changes.

Fig. 3

When the molten mass solidifies or the solution is precipitated, the macromolecules generally take on a random position; however, there are areas in which for certain distances parallel positions are set up.

These crystalline areas in the fiber, quantified by the degree of crystallinity, affect their hygroscopic qualities, dyeability and wet strength.

The orientation of the macromolecules, particularly in the crystalline areas - with respect to the longitudinal axis of the fiber - primarily affects the mechanical properties, tensile characteristics and strength. The application of suitable measures during and after spinning permits purposive changes in the structure of the fiber material, i.e. in the degree of orientation and crystallinity.

Synthetic fibers made by melt spinning have only a low degree of orientation of the macromolecules during the spinning of the fiber. Only the subsequent drawing process provides the desired properties through correct orientation. If this drawing operation is carried out at temperatures exceeding that at which the product turns glassy, this will increase the degree of crystallinity.

The stronger intermolecular links resulting from this operation increase resilience and strength of the fiber.

Fig. 4 demonstrates the effect of drawing the tensile strength and extensibility of polyester fibers. Generally, dyeability decreases with increasing orientation and thermal shrinkage is on the rise. Subsequent heat treatment - depending on the temperature and on the fibers being permitted to shrink freely - causes a decrease in orientation and a rise in crystallinity. The thermal fixation of a fiber for the purpose of limiting shrinkage is the consequence of the interplay between disorientation and the crystallization due to the heat treatment.

Based on the findings on the effect of the structure of fiber materials, chemical and physical modifications were attempted in order to obtain fibers with specific properties,

I should now like to report on some of these modifications.

Modal fibers - modified viscose fibers

The traditional types of regenerated cellulose fibers have a relatively low tensile stiffness in the decisive initial range of the tensile strength-extension behavior; this holds true for the air-dried state and particularly when wet. It implies that even little traction will result in a comparatively high degree of deformation which is only partly restored through elasticity. This type of the conventional cellulose synthetic fibers has inadequate stability of form when wearing and washing textiles made from these fibers - a fact that can only be remedied in some cases by a suitable finish. It was the high degree of longitudinal instability in particular that made textiles made of pure cellulose synthetic fibers unsuitable for washable clothing. Thus it was the goal of modification to obtain a fiber with a high wet modulus. By means of a new spinning technique plus a changed composition of the precipitation bath, a high drawing-out rate and a slow coagulation of the fiber it was possible to improve the orientation of the fiber and thus achieve the desired qualities.

Fig. 5 shows the data for a high wet modulus fiber compared to the traditional viscose material.

You will note that the purpose of modifying the structure of the fiber material was fully achieved. Today modal fibers have become a major interest. Perhaps one day they will take the place of cotton.

Low-pill" - polyester fibers

The advantage of these positive properties, however, is accompanied by the adverse effect of the propensity towards pilling in textiles made of polyester fiber. You know that the term "pilling" refers to the formation of small knots of fibers on the surface of the fabric which severely impair the appearance of the clothes. Pilling is due to abrasion and rubbing during use, causing individual fibers to migrate from the yarn and forming these little knots. In textiles made of natural fibers these pills generally disappear quickly due to abrasion; this is not the case with polyester fibers which have great strength and a particular stiffness. Thus ways to overcome this pilling action were sought.

One was to anchor the yarns or threads within the entire structure of the fabric so that they would come loose with use. However, this leads to a considerable restriction in the use of polyester fibers. Therefore, attempts were made to reduce the bending abrasion resistance of the fiber by physical and later by chemical modification. The physical method that was successful involved a shortening of the macromolecular chain.

Fig. 6 shows a diagram published by Hoechst A.G. on the relationship between bending abrasion resistance and breaking strength on the one hand and molecular weight on the other. The curves for normal polyester fibers and those for low-pill polyester fibers due to physical and chemical modification are presented.

Fig. 7 presents the pilling curves for a fabric and knit goods made of these fibers.

High-shrinkage fibers

High-shrinkage fibers are used for the production of high bulk yarns that have been made from polyacrylnitril fibers; they are used almost exclusively for knitted goods. Since voluminous yarns are also in demand for ladies' and men's clothes, the manufacturers of polyester fibers have now also developed high-shrinkage fibers.

In the case of polyacrylnitril fibers, the problem of producing high shrinkage in the fiber may be solved by better orientation. With polyester fibers this is not sufficient if flock or yarn dyeing is required. For this reason, chemically modified polyester fibers have been developed in addition to the usual high-shrinkage fibers obtained by physical modification and a high degree of orientation. Whereas in the physically modified polyester fibers shrinkage is effected generally at temperatures up to 100°C , shrinkage only sets in at temperatures above 100°C in the case of the copolyester fiber.

Fig. 8 shows shrinkage related to temperature of two TREVIRA high-shrinkage fibers.

With the chemically modified type TREVIRA 550 dyeing may be done at boiling temperatures without causing shrinkage, a process that does not set in before finishing takes place, i.e. fixation with hot air at a temperature of 185°C .

Physically modified polyester high-shrinkage fibers are used for industrial purposes.

We know, for example, of their application in non-woven fabrics used as a base for synthetic leather. The non-woven fabric is rendered firm through a great deal of needle

punching, then shrunk, completely split and finally a layer of water-vapor-permeable polyurethane is added. As far as clothing is concerned, the most widespread use of polyacrylnitril contraction fibers is in the field of high bulk yarns. The new chemically modified high-shrinkage polyester fibers may also be used for high pile yarns in weaving and knitting.

About 30 % high-shrinkage fibers are spun together with 70 % fibers with normal shrinkage.

Fibers with special cross sections

Among the physical modifications there are also fibers with special cross sections. This is particularly the case with melt-spun fibers such as polyamide, polyester and polypropylene materials.

Since it has become possible to achieve a wide variety of cross sections through special spinning nozzles, the effect of these new cross sections has been investigated.

Fig. 9 shows several shapes of these modified cross sections. Investigations have revealed that fibers with a 5-pointed star or H-profile have somewhat less of a tendency to pill because of their lower resistance to bending and higher degree of abrasion.

The touch of the fabrics made from fibers with modified cross sections is also affected. However, the most important effect of the cross-sectional shape is the lustre of the fiber.

Lustre is primarily a matter of light reflection.

If light travelling along its path hits another medium, depending on the characteristics of this medium, light may be absorbed, diffracted in passing through it, or reflected;

reflection is diffuse from coarse surfaces and directional from polished planes. Thus, for lustre the relationship between light absorption, diffraction and reflection is of significance.

With chemical fibers the transparency of the fiber, its surface structure, cross section and longitudinal structure determine lustre.

By adding delustering agents or color pigments, transparency, and thus lustre, are reduced.

Fig. 10

Fibers with round cross sections reflect light evenly in all directions, imparting a certain glitter. Fibers with such profiles were also used in carpets. However, it was found that dirt lodges in the indentations of the fiber, impairing the glitter and causing an early noticeable soiling of the carpet. Thus DuPont has put a fiber on the market under the trade name of ANTRON which combines a round cross section with a rather hollow internal structure.

Fig. 11

The hollow spaces have internal reflecting surfaces whereas on the outside the fiber is smooth without indentations. Thus this fiber has very good anti-soil properties.

Conjugated (bi-component) fibers

Synthetic fibers consisting of two firmly linked but separable polymer materials are termed bi-component (conjugated) fibers; these polymer materials are either placed in layers next to each other, are intertwined or the conjugated fiber consists of a mixture with homogeneous distribution (matrix/fibril system). The two polymers used may have a differing chemical and/or physical structure, e.g. the conjugated fiber may consist of a homopolymer and a modified copolymer, or of two different polymers.

Fig. 12

According to their structure, we differentiate between the following types of conjugated fibers:

S/S (side-by-side) types with a bilateral structure, with polymer components of differing shrinkage properties spun next to each other.

C/C (centric-cover-core) types with generally centric core and cover structure, i.e. the polymer components are spun around each other.

M/F (matrix-fibril) types with a matrix-fibril structure.

The most widely used conjugated fibers are the S/S types.

These fibers may be considered to imitate wool with its bilateral structure. The spindle cell layer or the cortex of the crimped wool hair consists of two elements differing in their chemical reactions and physical stability, the paracortex and the orthocortex. This structure of the wool hair is the reason for its high degree of permanent and regenerable crimp.

The two polymer materials used for the S/S types must comply with different requirements. One of these states that sufficient adhesion must be generated on the interface to prevent a separation of the layers. S/S types are made in order to impart to the fiber an intensive three-dimensional crimp that is to be as permanent as possible and at the same time reversible. For this reason the two polymers used must differ in their shrinking properties at higher temperatures; this shrinkage is to take place during the thermal after-treatment. Usually, for the layer with the higher degree of shrinkage a low-crystalline copolymer is used. The type of crimp may be controlled not only through the relative difference in shrinking height but also through shares of the different polymer and the shape of the cross section.

Fig. 12 shows the cross section of an S/S type produced by Monsanto from polyamide 6 and polyurethane elastomer as components.

Fig. 13 shows the untreated fiber.

Fig. 14 the fiber crimped by heat after-treatment.

Generally, conjugated S/S type fibers are applied in the same fields as texturized yarns. In many instances they are also included in the classification of texturized yarns.

Their principal field of application is high bulk acrylic yarns (staple fibers) for knitted goods and stretch polyamide yarns (filament) for hosiery. The C/C type fibers have been developed due to considerations that differ entirely from those involved in the S/S types.

In almost all instances the core of the C/C fibers has a carrying function and consists of a high-strength material. The cover may, for example, serve to impart certain surface properties to the fiber, as is the case with a fiber consisting of a core of polyamide and a cover of polytetrafluorethylene, imparting special sliding qualities to the fiber.

A cover of polyethylene placed over a polyamide core protects the fiber against aggressive chemicals.

C/C fibers consisting of a core with a higher melting point and a cover with a lower one (e.g. polyamide 6,6 and polyamide 6) have become particularly important.

Such fibers are used for the production of non-woven fabrics in which bonding is carried out by melting at the intersections of the fibers. This bonding takes place at a temperature at which the cover but not the core will melt. These non-woven textiles have an advantage over those bonded with chemical binders in that they feel more like fabric, are softer and have a greater bulk while maintaining good strength. These non-woven textiles are used for floor covering and upholstery purposes.

Well-known brands of C/C fibers are:

Colback manufactured by "Enka Glanzstoff", made of polyester and polyamide 6; Heterofil by ICI Fibres Ltd., made of polyamide 6.6 and polyamide 6.

Conjugated fibers of the M/F type are spun of different kinds or incompatible polymer components; there is no close blending of the two components.

A dense multitude of the finest short fibrils of one polymer is embedded in a continuous matrix made of the other.

When the fiber is drawn the fibrils are drawn out until they have a diameter of 0.1μ or less.

The best-known application of this type are polyamide fibers with inclusions of up to 40 % polyester used for tire cord. While the polyamide provides good adhesion to rubber, the polyester component prevents the well-known flatspotting phenomenon that occurs in tires made exclusively with polyamide cord.

Other types of application for M/F conjugated fibers are now being developed.

Texturizing

During the last ten years texturized yarns have become so important that, for example, today much more texturized than smooth yarn is used for clothing.

In pile carpets too the texturized filament yarn today has a dominating position as far as the pile is concerned. I believe that a good fund of knowledge exists about texturized yarns and therefore I should rather like to discuss developmental tendencies in texturizing.

Depending on the application, the goals set for the texturizing of filament yarns differ widely.

In high-elastic yarns (HE) a high degree of elastic stretch is desired. Such yarns are used for highly elastic fabrics such as ski trousers, bathing suits, girdles, etc. In set yarns the attempt is made to interfere with the parallel position of the filaments and thus to achieve - because of diffuse light reflection - a character similar to staple fiber yarns. Slight extensibility and, depending on application, a higher or lesser degree of bulk is required.

In texturized yarns for carpets, the paramount goal is a high bulk intended to make the pile cover adequately.

Twisted yarns are a special category. A smooth yarn with a strong tendency towards twisting is used and processed with S and Z twist; the result is elastic fabrics.

Today, the thermoplastic materials polyamide, polyester, polypropylene and acetate are almost the only ones used for texturizing.

Outside of the texturized carpet yarns, the false twist method predominates in texturization. The economic development of the false twist method is proceeding in the direction of ever increasing spool weights and, in the case of set yarns, of continuous set machines. In Milan this year machines were shown that have a spindle speed of more than 1 million r.p.m.

Of great current interest is the problem of combining the texturizing process with drawing and spinning.

Fig. 15 shows the traditional method with separate operations for spinning, drawing and texturizing. Spinning and drawing is done by the manufacturer of the chemical fiber and the texturizing by a company outside of the synthetic fiber industry. Spinning speeds run 1000 to 1500 meters per minute, the initial speed of the drawing frame is 500 to 1000 m/min.

Fig. 16 demonstrates a method that is still undergoing development. Here spinning and drawing are carried out

continuously, with an initial speed of 2000 to 4000 m/min. Texturizing is carried out separately.

Fig. 17 shows the draft-texturizing process combining drawing with texturizing. The synthetic fiber industry, (particularly in the U.S.A.) is already applying this method on a large scale. We differentiate between the simultaneous and the sequential systems. In the sequential method drawing is carried out before entering the twisting device in a special drawing frame. In the simultaneous method drawing is carried out in the texturizing zone itself. Both methods are in use in the synthetic fiber industry. Compared to the traditional texturizing methods, the yarns produced by the combined draft-texturizing system dye more evenly.

The basic product for draft-texturizing method is undrawn material that is to be drawn 3.2 to 3.7 times or pre-oriented material that still needs to be drawn 1.5 to 2.6 times.

Undrawn material is unstable and must be processed within a few days. It is very sensitive to thermal influences and is not suitable for commercial use; this is why the combined draft-texturizing operation is carried out within the synthetic fiber industry and thus we speak of "producer texturizing".

It may be expected that during the next five years draft-texturizing will be the method of choice; friction texturizing will render feasible spindle speeds of more than 1 million r.p.m. and texturizing speeds of 450 to 600 m/min.

Looking into the more distant future, even today developmental work is being performed in order to arrive at a fully integrated method in which spinning, drawing and texturizing will all be performed in a single operation.

Among the large number of other texturizing methods, the compression chamber crimping method appears to be significant

since this is utilized primarily for the production of texturized carpet yarns.

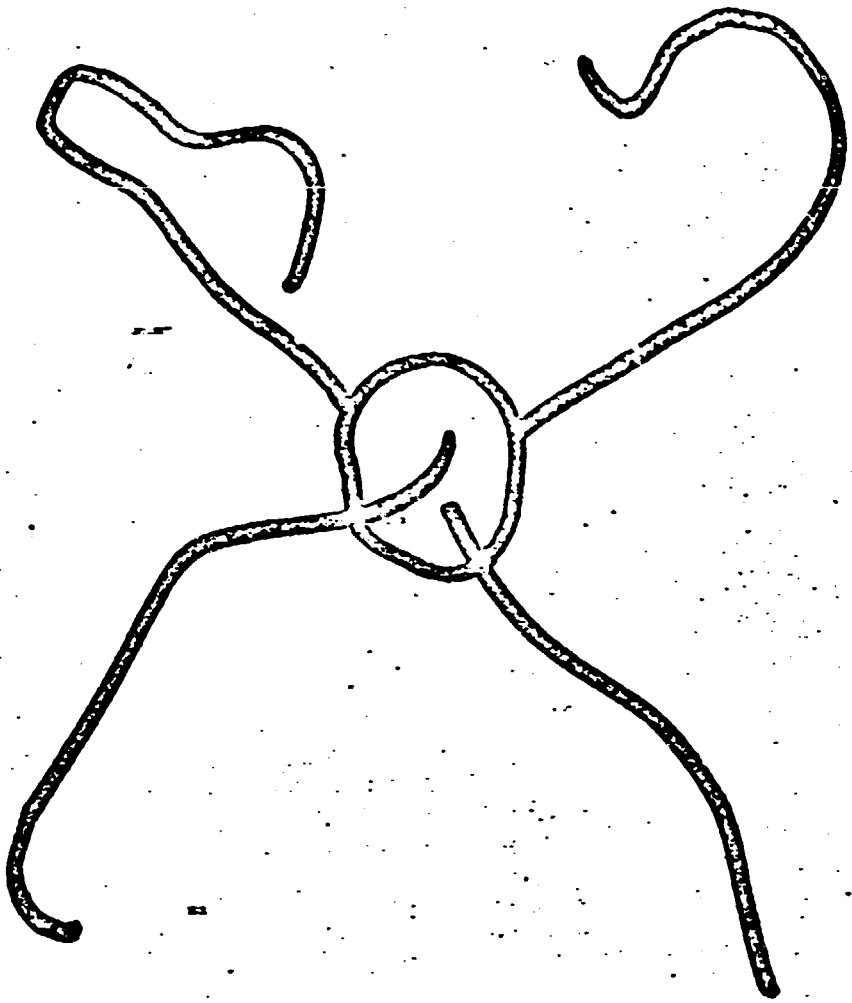
In addition, I should like to mention the blow method (or TASLAN technique) and the steam blowing technique, used by DuPont; both these methods are used to produce carpet yarns.

In the production of twist yarns the so-called twist compression method is used. In this technique special fixtures are used on the drawing machinery to fix the twist which is generated before the yarn enters the ring traveller. The yarn thus is not crimped but rather has a twisting tendency. The yarns are produced with an S and an Z twist and used in two systems to produce ladies' hosiery. The combination of S and Z twisted yarns results in an opposite direction warp of the mesh and thus a high degree of longitudinal elasticity for the stocking.

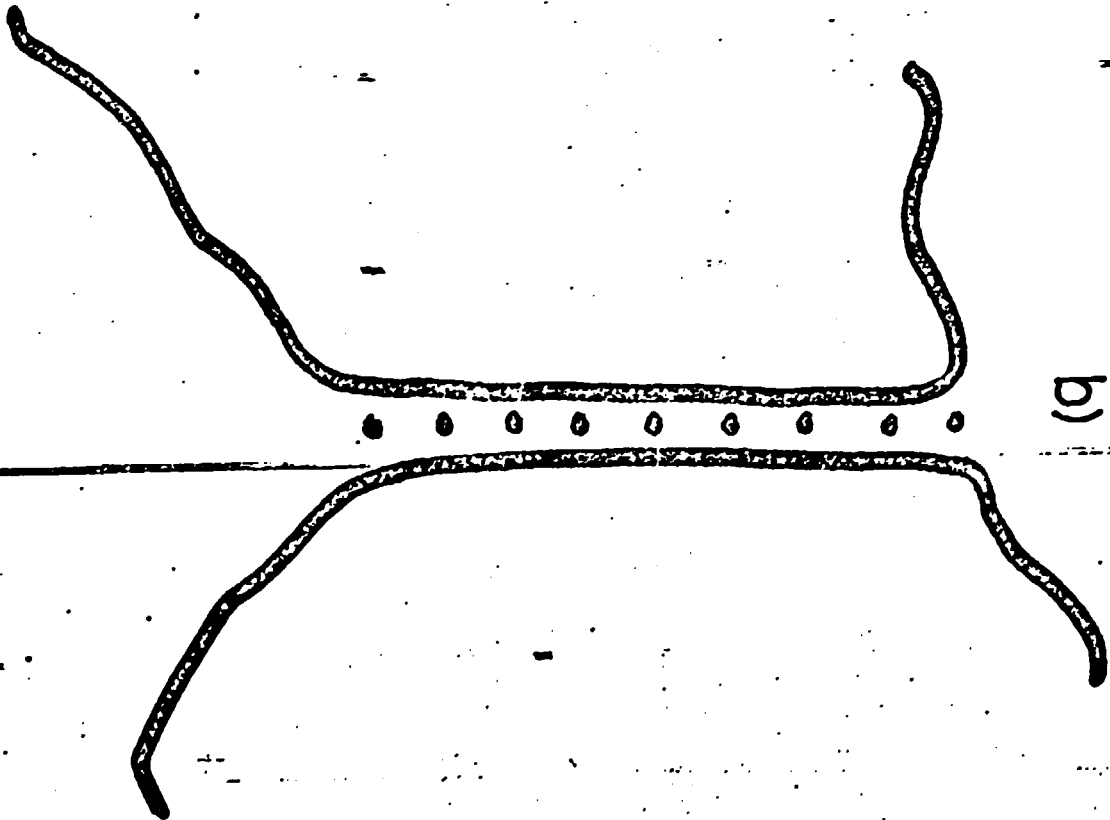
Other texturizing methods, such as the Carruthers technique, the edge drawing method, the knit-de-knit system and the cog wheel method are only of very limited significance.

The advantages of texturized yarns, their adaptability to certain types of utilization assure an even wider application in the future and thus an increase in production.

FIG. 1



a)



b)



FIG. 2



FIG. 3

FIG. 4

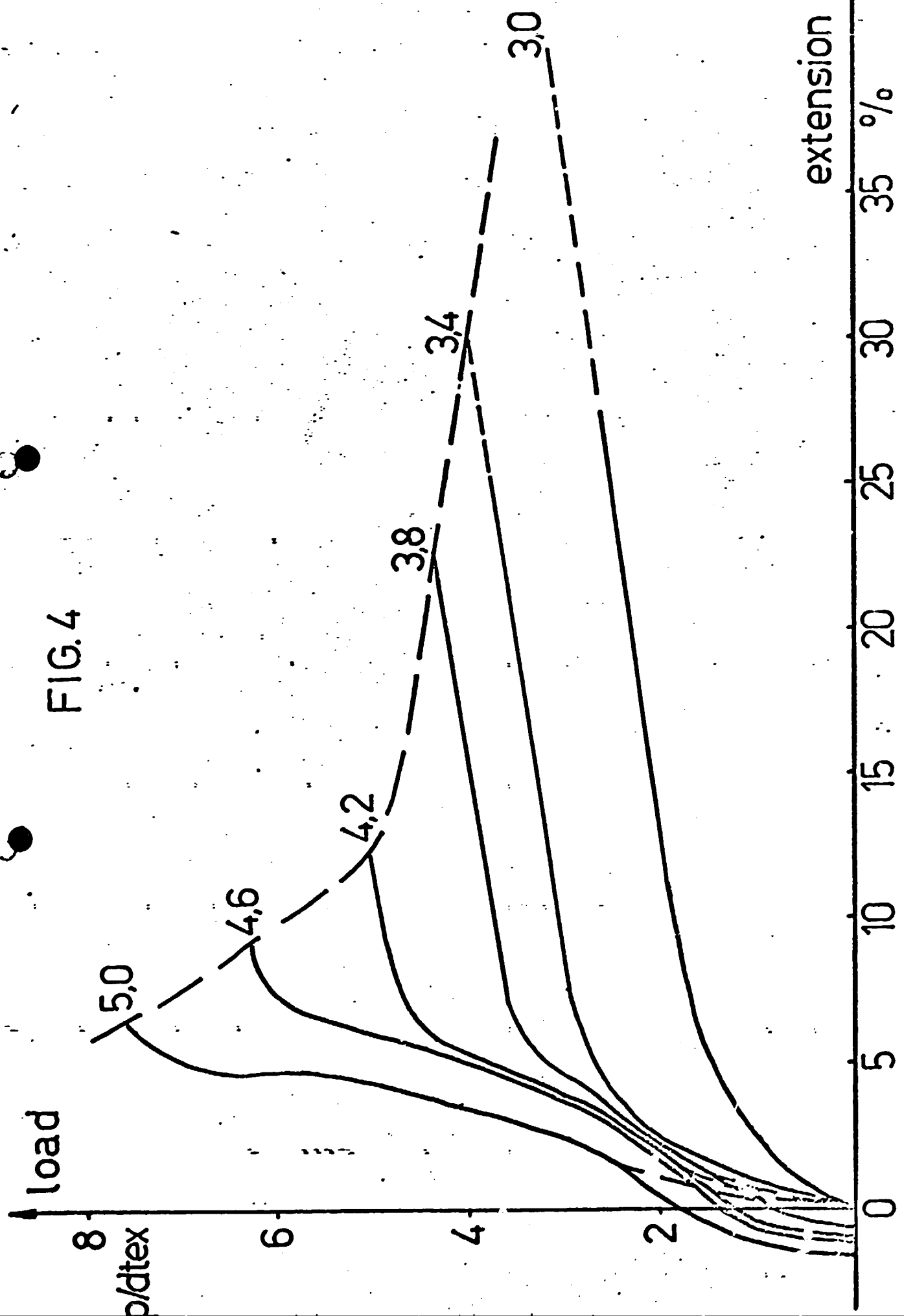


FIG.5

DATES OF STRUCTURE AND CHARACTERISTICS
OF A MODAL-FIBRE IN COMPARISON TO A
CLASSIC CELLULOSIC-SYNTHETIC FIBRE

	<i>DP</i>	<i>CrI</i>	<i>fr</i>	<i>tensile strenght</i> <i>in p/tex</i>		<i>extension</i> <i>in%</i>		<i>wet-modul</i> <i>in p/tex</i>
				<i>cond.</i>	<i>wet</i>	<i>cond.</i>	<i>wet</i>	
<i>CLASSIC VISCOSE-FIBRE</i>	290	0,79	0,312	19,8	10,5	27	29	34
<i>MODAL-FIBRE</i>	360	0,70	0,458	37,4	25,2	14	16	112

DP average grade of polymerisation

CrI crystalline index

fr factor for orientation

FIG.6

abrasion resistance
against breaking

breaking stress

rotations

p/dtex

5000

5

4000

4

3000

3

2000

2

1000

1

10 000

15 000

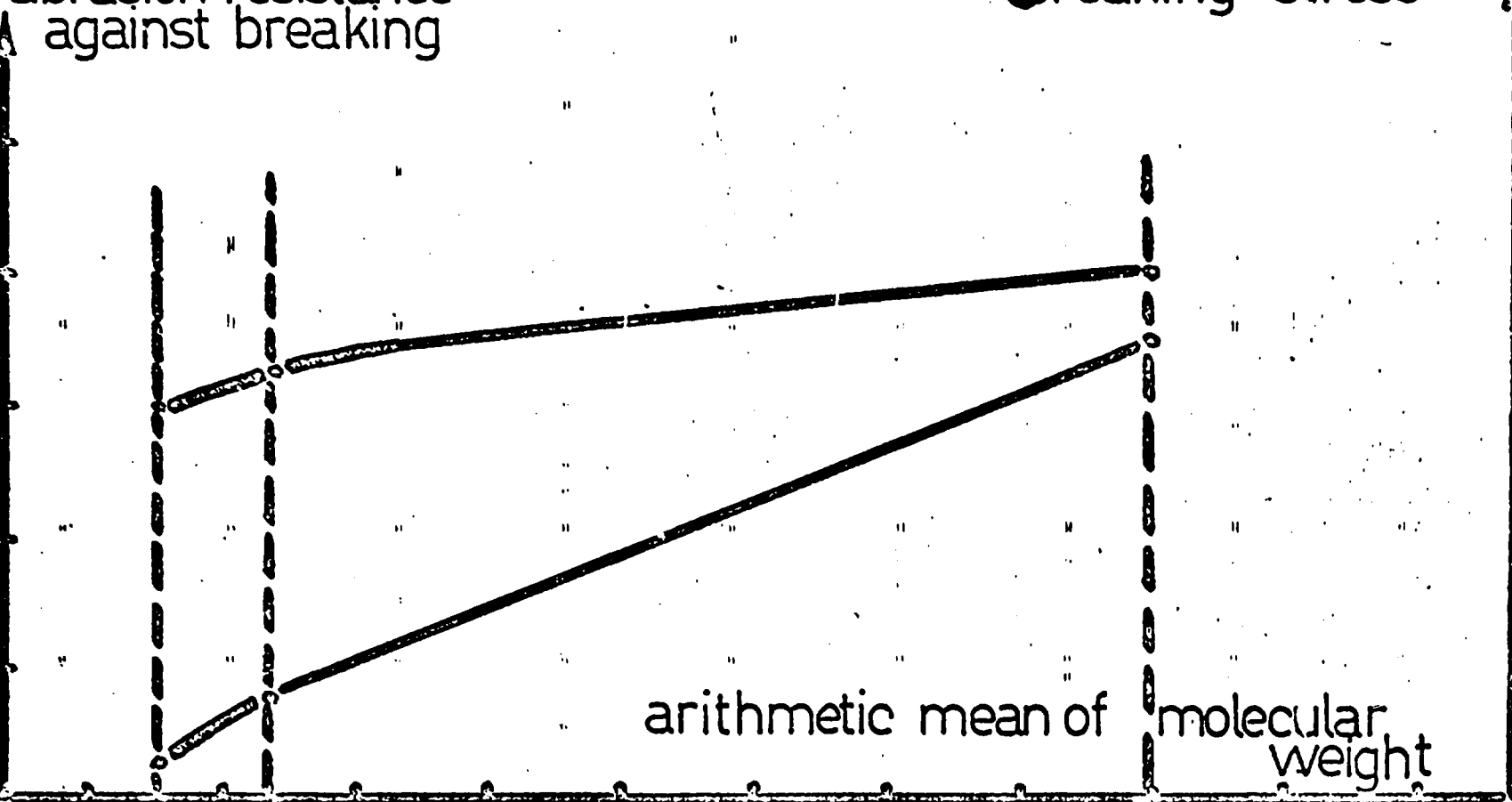
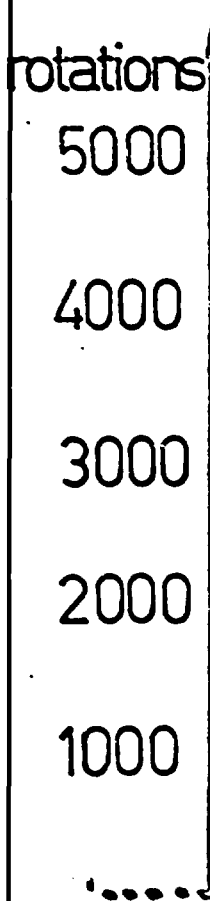
20 000

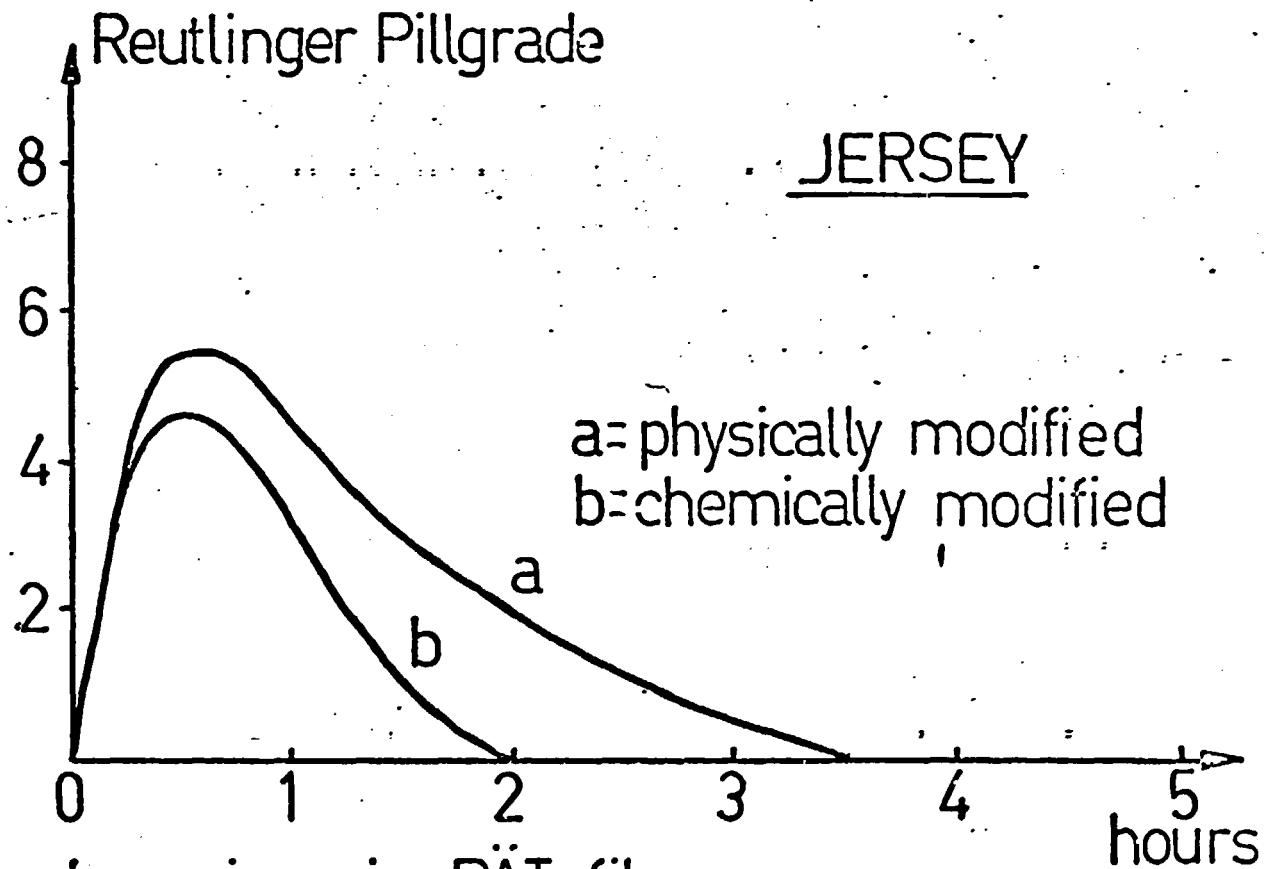
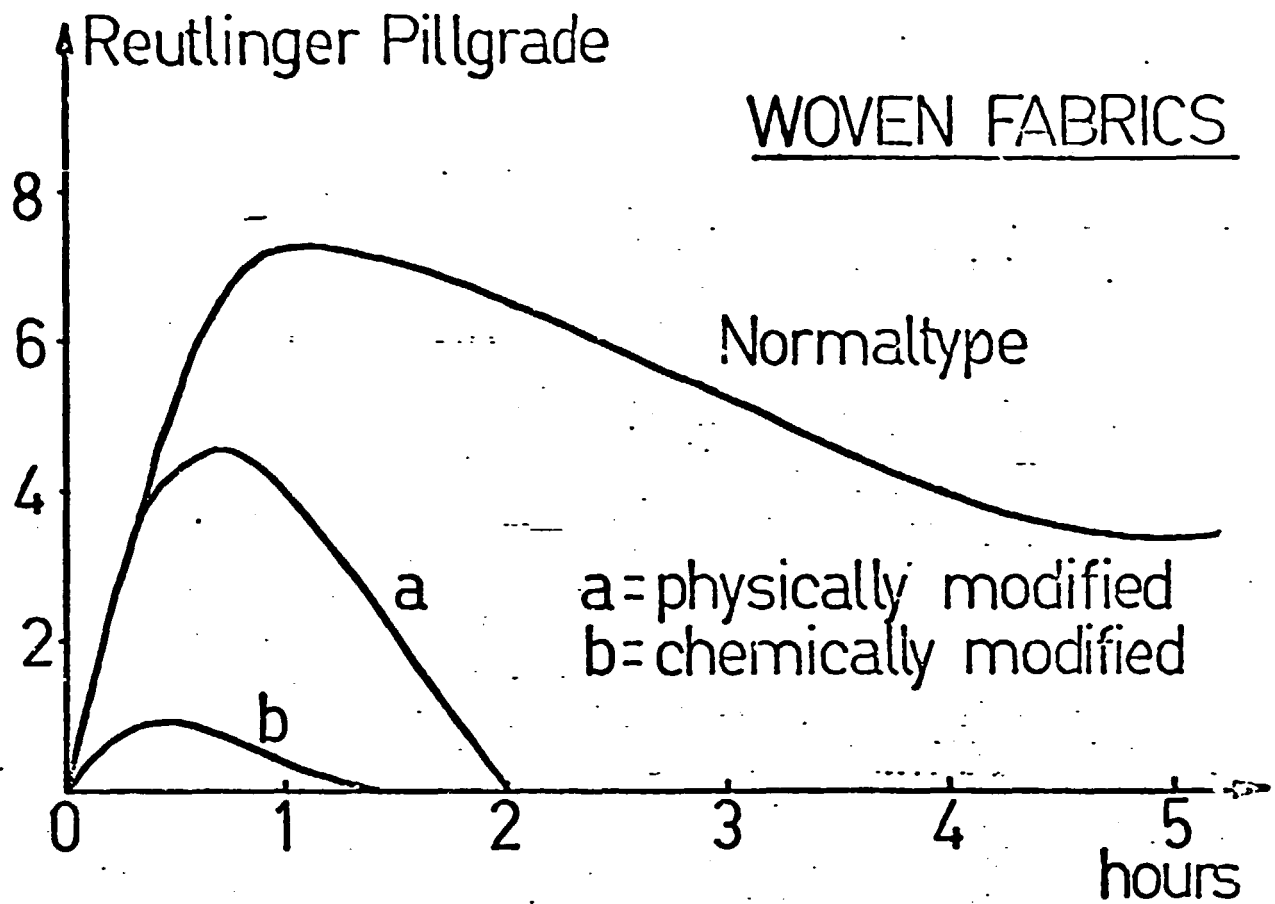
physically modified
chemically modified

normal

arithmetic mean of
molecular
weight

abrasion resistance against breaking and breaking stress
of PAT-fibres with different molecular weight





Lowviscosic PÄT-fibres
Random-Tumble-Pilling-Tester

Pill-curves of unsheared and coloured PÄT-articles

FIG. 7

FIG.8

TREVIRA 540

TREVIRA 550

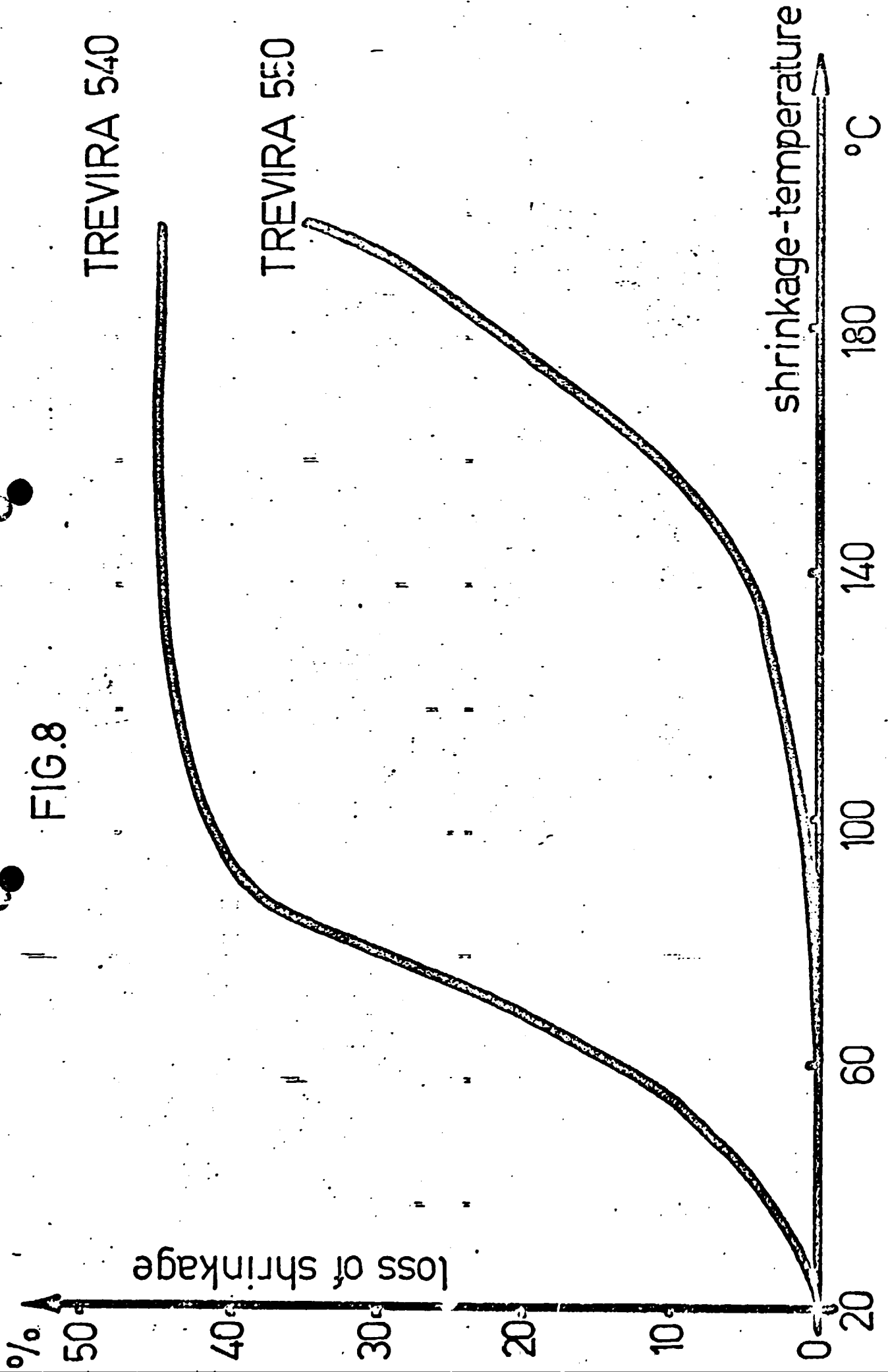


FIG. 9

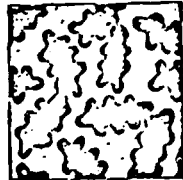
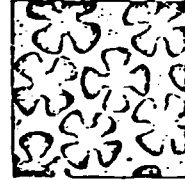
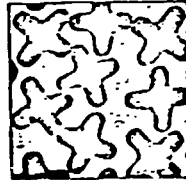
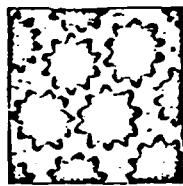
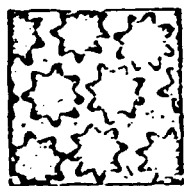
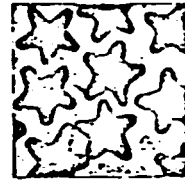
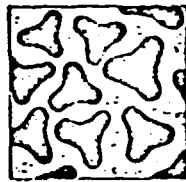
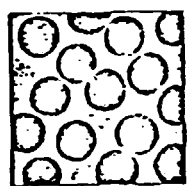
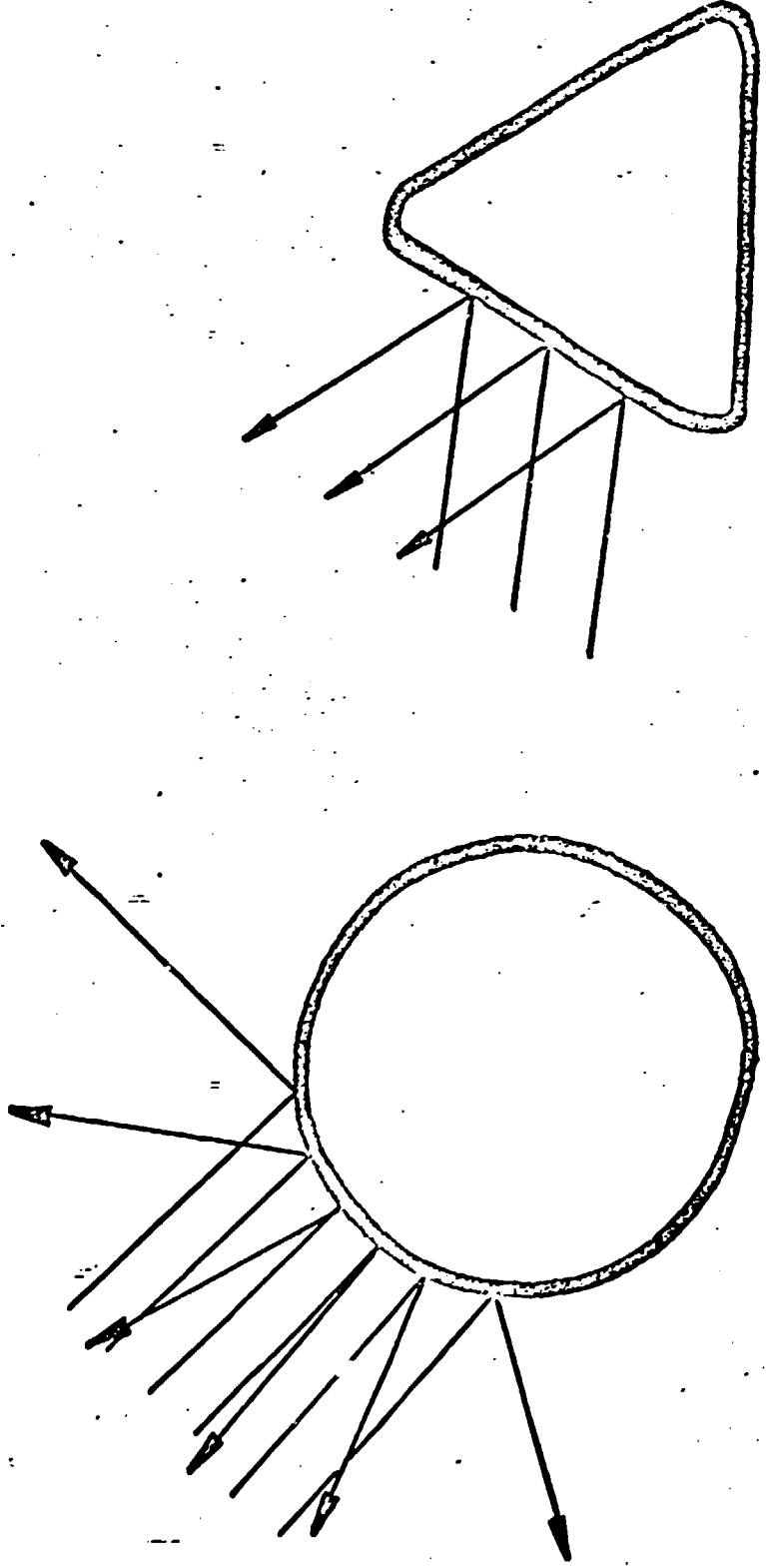


FIG. 10



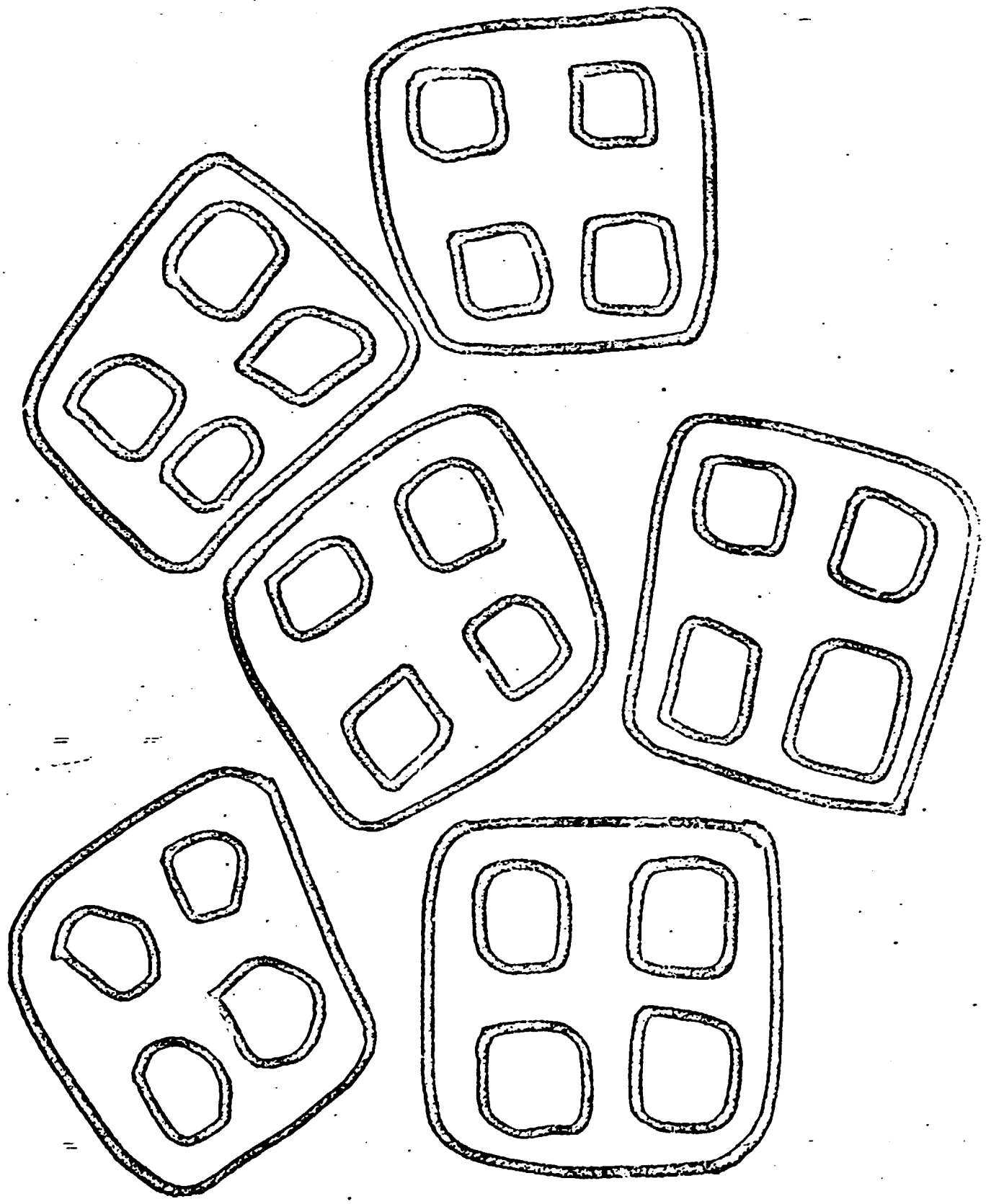


FIG. 11

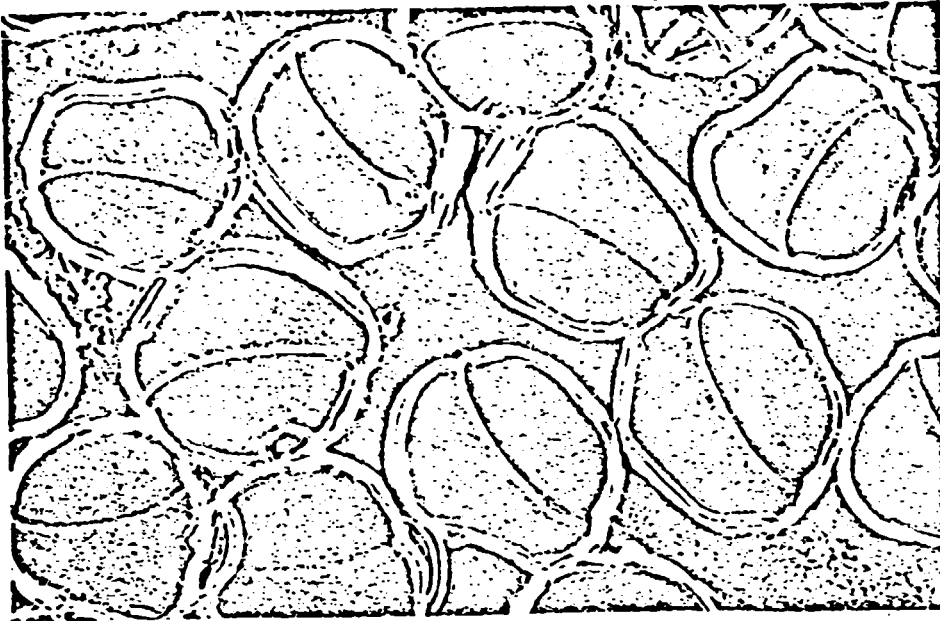


FIG. 12

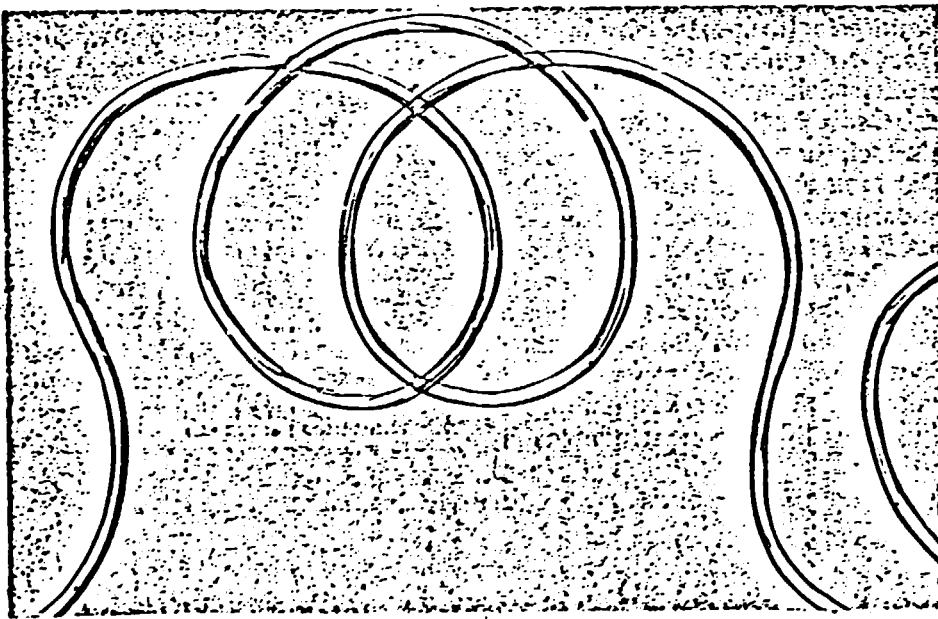


FIG. 13

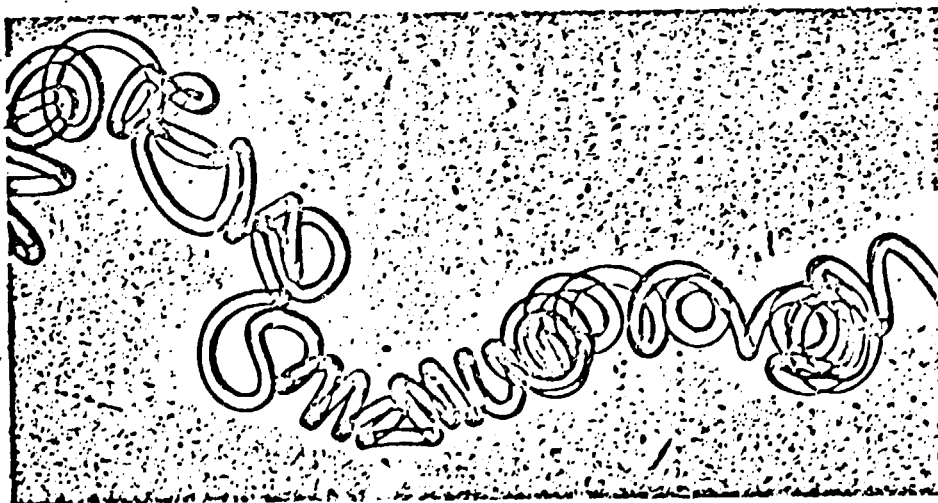


FIG. 14

FIG. 15

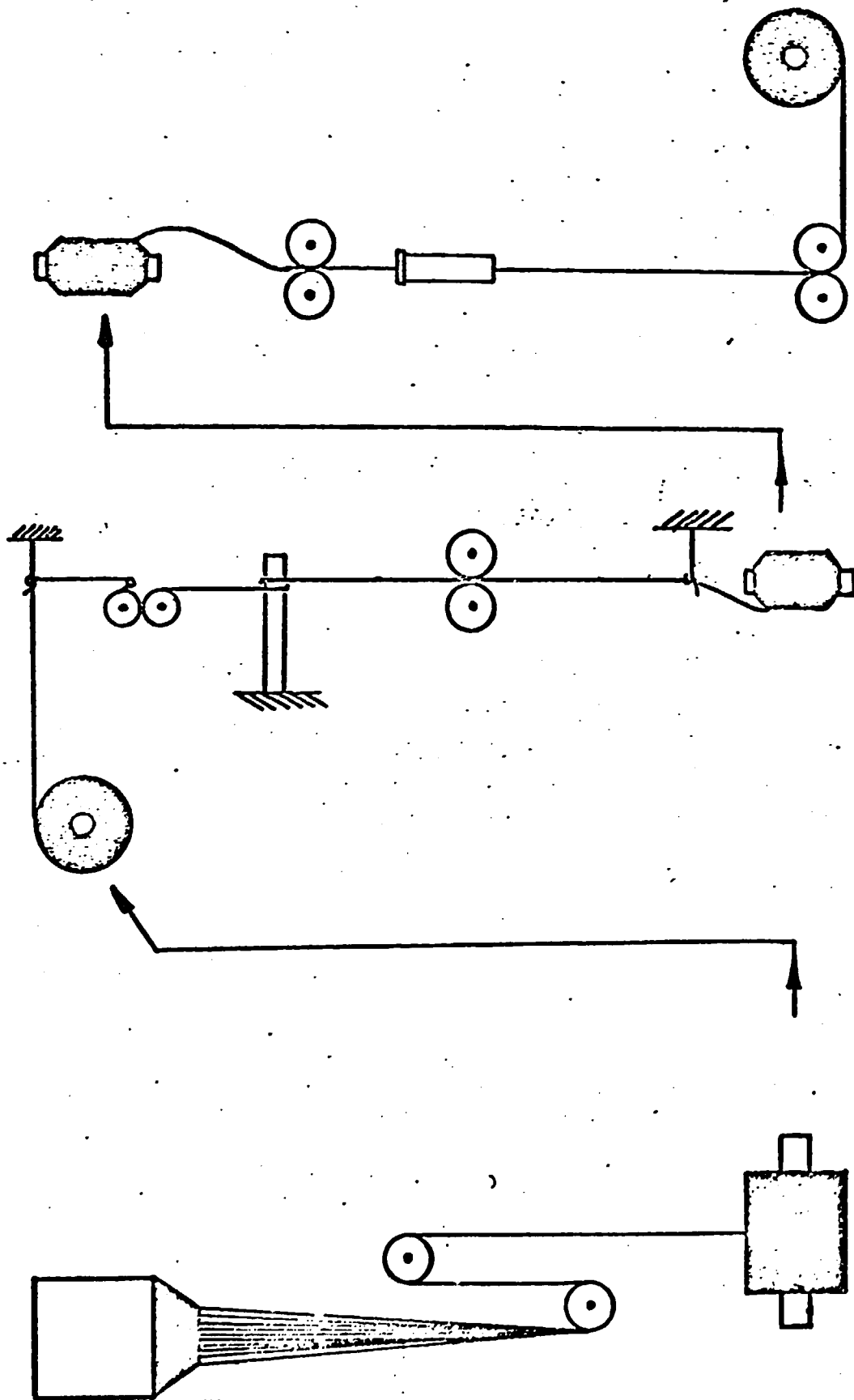


FIG. 16

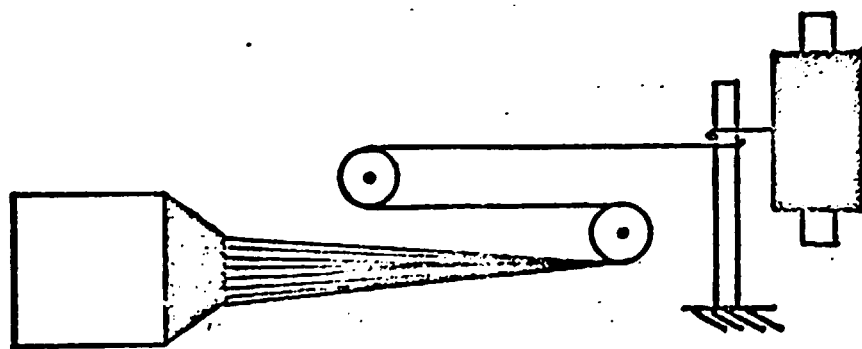
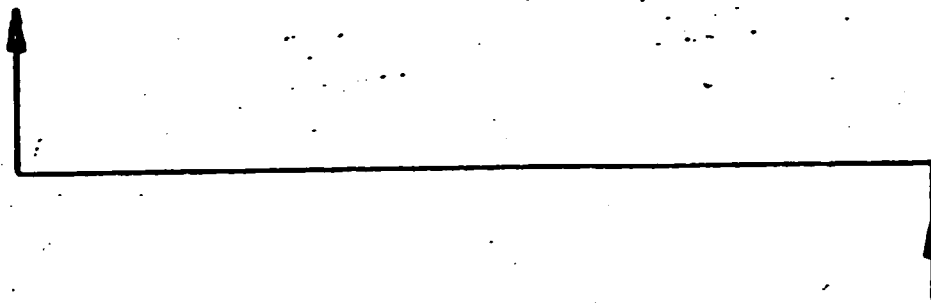
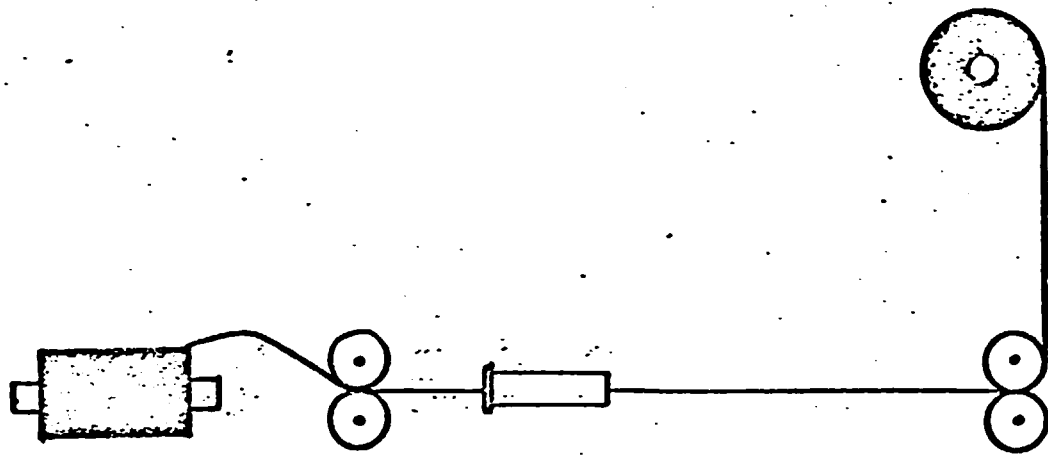


FIG. 17

