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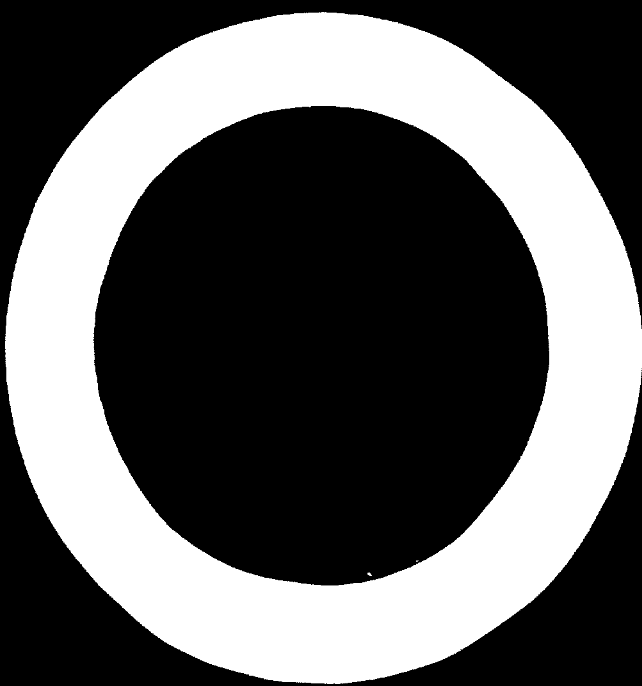
TRAINING FOR INDUSTRY SERIES NO. 3

THE ŁÓDŹ TEXTILE SEMINARS

5. Non-conventional methods of fabric production

UNITED NATIONS



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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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FOREWORD

This publication is the fifth of a series devoted to textile engineering and closely related fields. It is part of the Training for Industry Series published by the United Nations Industrial Development Organization (UNIDO).

Rapid world-wide increases in population and industrialization are reflected in the textile and allied industries. In any ranking of human needs, fibres and textiles for clothing and industrial purposes are second only to foodstuffs. The continuing quantitative and qualitative changes in textile production require the broadest and most complete dissemination of information in this important area.

The purpose of the present series is to make available to the developing countries the most recent scientific and technical information in order to help them to establish textile industries or to improve the effectiveness and economic viability of existing textile industries that are still in the earlier stages of economic development.

At the suggestion of UNIDO, with the support of the authorities of the Polish People's Republic, a post-graduate in-plant training course in textile industries was held in Łódź from May through September 1967. The course was repeated from May through October 1968, and its content was modified and up-dated on the basis of experience and new information. It was repeated again in 1969 and it is planned to continue this programme, up-dating its subject matter and improving its usefulness to the textile industries of the developing countries. It is on these courses that the present series is based.

The courses were organized by the Textile Research Institute in Łódź with the object of training a group of already highly qualified specialists in all branches of industry relating to textiles. Under normal conditions, such training would require work in mills and in research and development over a period of several years.

The courses give the participants an opportunity to become acquainted and to do actual work in conjunction with some of Poland's leading research centres and industrial enterprises, and to discuss with experts problems connected with techniques, technology, economics, organization and research in the field of textiles. In organizing the courses, the Textile Research Institute endeavours to co-ordinate the content of theoretical lectures, technical discussions and practical studies in laboratories and mills, covering all the fundamental problems of textile industries.

The main object of the seminars is to adapt the broad range of problems presented by Polish specialists to the direct needs of the developing countries. Lectures by the research workers of the Institute formed the core of the programme. The lectures do not review or repeat the basic problems usually studied at technical colleges and high schools in the course of normal vocational training; rather, they deal with subjects most often of concern to the management and technical staff of a textile enterprise.

The lectures, as presented in this series, have been grouped in eight parts: textile fibres; spinning; knitting; weaving and associated processes; non-conventional methods of fabric production; textile finishing; testing and quality control; and plant and power engineering.

It is hoped that the experience gained from these courses, as presented in this series, will contribute to the improvement of textile industries everywhere, and particularly in the developing countries.

The views and opinions expressed in this publication are those of the individual authors and do not necessarily reflect the views of the secretariat of UNIDO.

CONTENTS

EXPLANATORY NOTES

References are indicated in parenthesis in the text, by name of author and year of publication. The full references are listed, alphabetically by author, at the end of each article.

References to "tons" indicate metric tons and to "dollars" ($), United States dollars, unless otherwise stated.

The following abbreviations have been used:

cpi means "courses per inch".
Denier (den) is the weight in grams of 9,000 metres of yarn.
gg is "gauge".
kcal is kilocalorie.
Metric count (Nm) is the number of kilometres of yarn per kilogram.
A nanometer (nm) is 10^{-6} mm.
rev/min is revolutions per minute.
Tex is the weight in grams of 1,000 metres of yarn; millitex (mtex) is 0.001 tex.
wpi is "wales per inch".
Worsted count is the number of 560-yard lengths per pound of yarn.

BONDED NON-WOVEN FABRICS

by

W. Jędrzejewski

In the last few years there has been a very intensive development of new textile production techniques. With some of them it is possible to produce textiles with new structures that permit the use of chemical and natural raw materials with very much poorer properties, such as spinnability, than are required in the conventional techniques.

This does not mean that the wearing properties of products made by these new techniques are inferior. Indeed, for many purposes they have better basic wearing features than conventional products. Also, the degree of exploitation of the raw material in certain non-woven fabric assortments is generally higher than in woven fabrics or in felts. For these reasons and because of the very much greater productivity of these new techniques at lower prime production costs, there is a sound basis for a rapid development of non-woven fabrics. Indeed, the rate of development in countries with well-developed chemical and machinery industries is roughly 15 to 30 per cent of the production of each previous year.

General description of non-woven fabrics

Non-woven fabrics are textile products obtained from masses of loose, suitably constituted raw materials by being bonded, needled or stitched together. They can be bonded by using powders. yarn fibres or thermoplastic foils which, at sufficiently high temperatures, bind the basic fibres together, forming products that in many cases can replace cotton of artificial fibres fabrics. The systematics of such fabrics are shown in figure 1.

Some non-woven fabrics are produced by depositing on the fibre mass (fleece) liquid (dispersive) bonding agents such as natural or synthetic latexes or methacryiate resins, by padding, spraying or intermediate depositing (that is, by using yarn previously immersed in a liquid bonding agent). In the production of other non-woven fabrics, during the penetration of the fleece, the needles, which have suitably shaped notches on their surfaces or apices, draw the fibres into the basic fibre layer and bind them there. When thermoplastic fibres are inserted into the needled fleece, a suitably high temperature is applied, causing these fibres to shrink

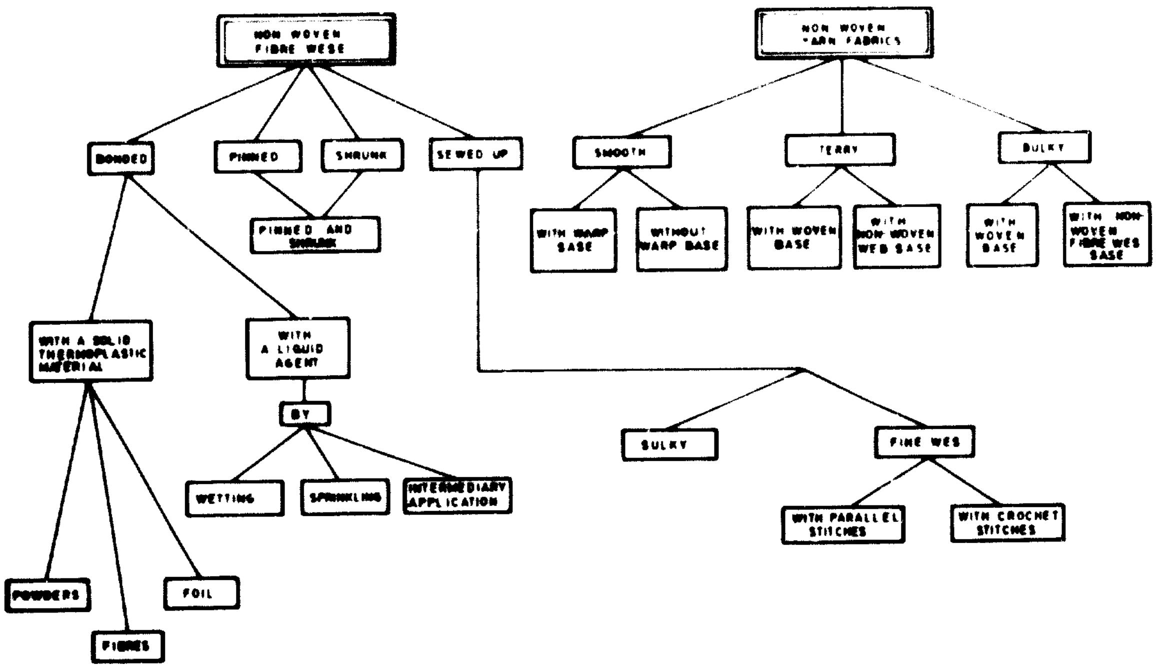


Figure 1. Systematics of non-woven fabrics

and the structure of the product to condense. Fabrics made in this way include the so-called synthetic felts.

Still other kinds of non-woven fabrics are produced by stitching suitably arranged fleece with yarn guided by an appropriate system of knitting needles. Should only part of the fibres be stitched, the rest will form a loose so-called "hair fleece" (artificial fur).

Non-woven fabrics of the Malimo-Malipol type (Eastern Germany) constitute a separate group of products, namely, that obtained by suitable sewing or stitching (depending upon the system used) of a body of yarns. With a flat formation of yarns, fabrics with woven or knitted appearance are obtained. However, when the yarn is sewn into a looped form, a product is obtained that resembles a terry fabric. If the loops are combed out, the product obtained is called a fleece product and resembles fluffy cloth or flannel. All of these technologies, depending on the raw material used and as a result of the changes in the technical parameters, make it possible to obtain many new textile products of various appearance and wearing properties.

Reasons for the development of non-woven fabrics

The new textile products known as non-woven fabrics continue to appear on the textile market in ever greater amounts and varieties. The reasons for this rapid development are primarily economic; the most important of these are:

(a) Great simplicity of the production cycle, which often has been reduced to a single continuously running aggregate;

(b) Possibility of fuller use of textile raw materials, including some with low spinning values;

(c) Very great output of the aggregates used for their production;

(d) Comparatively small capital outlay necessary to start production; and

(e) Satisfactory quality of these fabrics, which not only find various new uses but sometimes meet wearing requirements better than do woven fabrics.

However, the basic factor in the development of the production of non-woven fabrics is the high output and labour economy of the equipment used in these new technologies.

Output of machinery and labour

In the production of interlining fabrics by the bonding technique, an output is achieved that is 20 to 30 times greater than that of the most modern looms, such as the Swiss Sulzer or Swedish Kovo (pneumatic) types. At the same time, production per operative is higher by 100 to 350 per cent.

Production cycle

In the production of woven fabrics, the time from the introduction of the raw material to the completion of the finished goods is in the range of 3 to 6 weeks. The corresponding time for non-woven fabrics is only 10 to 20 minutes. Furthermore, with present methods of spinning and weaving, it takes almost 12 minutes to produce a square metre of average raw cotton fabric, but less than a minute is needed to produce the same area of an average raw bonded non-woven fabric of a similar kind.

Raw material consumption

It is well known that raw material consumption is very important in the economics of textile production, because of the great influence of this factor in the determination of prime production costs. To a great extent, the raw material consumption is determined by technological losses. Because of the smaller number of technological change-overs, these losses are smaller in the production of non-woven fabrics than of woven ones. When it is considered the fibre content of bonded products is lower (part of the fibre is replaced by the bonding agent), the fibre raw material consumption in the production of non-woven fabrics is about 20 to 30 per cent less than that required to produce a corresponding woven fabric. The increased possibility of using cheap raw materials and artificial and synthetic waste raw materials is also significant.

Machines

The variety, cost and space required for machinery to produce non-woven fabrics are all much lower than for equipment needed to produce woven fabrics. For example, if typical interlining fabrics of the combed linen type with a weight of 229 g/m^2 were made by a non-woven method rather than by weaving, the following conventional spinning and weaving machines would be eliminated: 2 linen combers, 1 spreader, 1 twister, 3 drawing frames, 1 roving frame, 6 spinning frames, 1 weft winder, 1 warp winder, 1 warping machine, 60 looms (width 72 cm), 1 sizing machine with drier, or altogether about 80 machines taking up approximately 600 m^2, using about 100 kW of electrical power and requiring approximately 80 operatives.

The machinery for producing non-woven fabrics is either in the preparatory (carding) department or in an aggregate that includes equipment for feeding, web formation, bonding-agent padding, drying, vulcanizing and reeling. Eight workers are needed to operate these machines, and the electrical energy requirement is about 70 kW. The combined floor space for the carding department and the aggregate (for example, one of the American Proctor and Schwartz type) is about 150 m^2. The production area is, therefore, only a fraction of that needed if conventional techniques such as weaving were used.

Capital investment

The size of the capital investment (that is, the cost of preparation for production) for the same production output for the products compared above (interlining fabrics) for non-woven fabrics is only about one-eighth as great as would be needed with spinning and weaving. The smaller part played by the basic investments (machines and buildings) in the total costs means a decrease in depreciation charges, which in consequence lowers the price of the products. Such a comparison is still more striking when needled-and-shrunk non-woven fabrics are substituted for conventional woollen felts produced by felting and fulling.

Production costs

From the above data it can be concluded that the production of bonded non-woven fabrics of a comparable assortment is very much more economical than that of conventional fabrics. The prime costs of products made by this new technology are 20 to 50 per cent lower. The direct production costs of bonded non-woven fabrics are compared with production costs with conventional methods in table 1.

TABLE 1. PRODUCTION COSTS OF NON-WOVEN FABRICS[a]
(comparative mean in per cent)

Factor	*Woven fabrics*	*Non-woven fabrics*
Raw material	54	88
Basic wages	12	1
Department costs	22	9
All factory costs	12	2
Total costs	100	100

[a]Compiled from data obtained in Poland.

Basic production methods and wearing properties of bonded non-woven fabrics

At present there are many methods for the production of bonded non-woven fabrics that differ only in the type of forming machines (carding machines and pneumatic equipment) and the type of bonding agent used. In general, however, these techniques are characterized by high productivity (up to 300 metres per hour and, in the paper system, which is described later, up to 100 running metres per hour). Examples of four basic production methods are considered below, and typical wearing qualities of the non-woven fabrics obtained by them are discussed.

Intermediate bonding method

This process generally utilizes reclaimed fibres with great variation in length. They are first run through a double carding machine, and the web is then crossed on an apparatus of the Blammair type. The laps are fed from this machine onto a feeding lattice in two layers. Threads of waste yarn are passed through a comb to regulate their distribution, immersed in a suitably prepared liquid bonding agent and led between the two layers from spools located on the creel. The two layers, with the coated yarn between them, are pressed together by rollers to form a sheet of fabric.

Non-woven fabrics produced by this method can range in thickness from 3 to 10 mm. Depending on the thickness, yarns of different thickness may be used. The distance between bonding stitches depends on the average length of the fibres and the end-use of the product. This method permits the use of any kind of reclaimed fibres, even those with very poor spinning qualities.

As bonding solutions, natural rubber (latex) or synthetic resins with a high degree of final elasticity can be used.

Non-woven fabrics obtained by this method have many uses, such as materials for wadding, thermal and acoustic insulation, linings and upholstery. Depending on the end-uses of the fabrics, reclaimed fibres of various types and with different degrees of fibrillation may be used. These fabrics weigh between 250 and 600 g/m^2, of which 15 to 20 per cent is the weight of the padded bonding yarn.

Curling and bonding method

Non-woven fabrics of this type are produced on Fehrer (Austria) machines. As raw materials, natural or synthetic (for example, the Polish polyamide Stilon) bristles, coconut fibres, or sisal or long-fibre cow hair are used. They are given a preparatory cleaning to separate out the short (less than 200 mm) fibres, which reduce the fluffiness of the products. After cleaning, the fibres are twisted into so-called "pigtails" and steamed to fix the twist. They are then untwisted, and the curled raw material is fed into the basic machine, which forms a web and sprays both sides of it with bonding agents such as suitably prepared natural latex. After drying and cutting into suitable lengths, several sheets of the product, each about 30 mm thick, are pressed together and vulcanized at about 130° C to yield a final product 1 mm thick.

The finished product is light (up to 0.03 g/cm^3) and thick and has very good elastic recovery, which makes it an excellent upholstery material for pre-formed shapes, such as seats for automobiles and aircraft.

Direct-bonding method

The so-called direct-bonding method of producing flat non-woven fabrics has very favourable prospects, not only because of its low cost but because of the good wearing qualities of articles produced in this way.

Depending upon the end-uses of the fabrics, viscose fibres, either alone or in blends with synthetic fibres, are used. To obtain fabrics with a woven appearance, relatively thick chemical fibres (416 to 555 mtex) are used. By increasing the proportion of polyamide fibres, some parameters, such as resistance to abrasion and tearing and elastic recovery, may be increased slightly.

Decrease in the thickness of the component fibres lowers the porosity of the resultant fabric, which in turn reduces its air permeability, giving it a handle similar to that of paper. On the other hand, if the thickness of the fibres, and especially of chemical fibres, is increased, the optimal proportion of the bonding agent (about 30 to 40 per cent) decreases slightly because of the increased porosity of the fabric (that is, the smaller number of so-called fibre-point links). The tensile strength of the fabric is also decreased, as shown in figure 2.

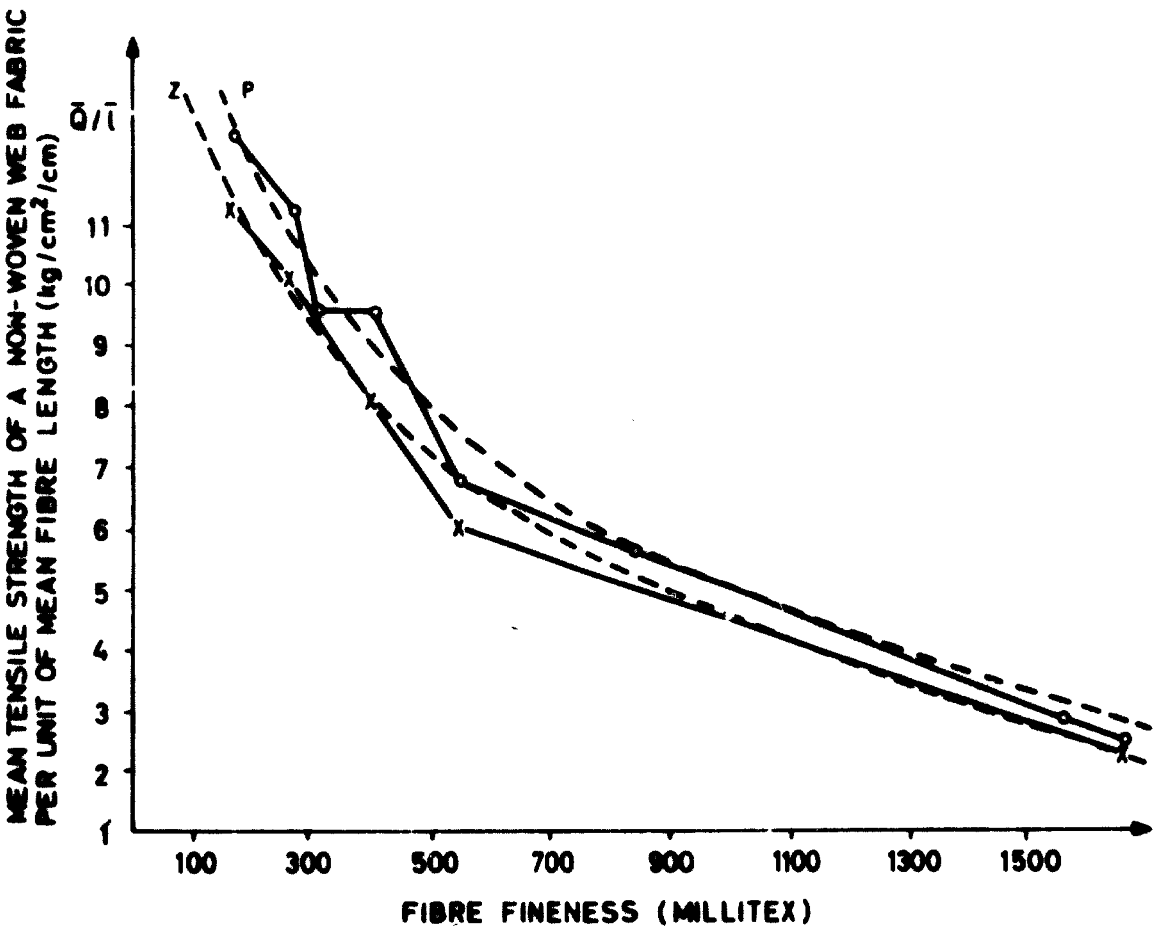


Figure 2. Mean tensile strength of a non-woven fabric prepared pneumatically (o) and by carding it (x), plotted against fibre fineness

The process begins with the proper selection of the raw material blend components, special attention being given to fibre length, thickness and weight. After being mixed three times, the raw material is fed into a machine aggregate in which the web is formed by pneumatic equipment or a wool-carding machine. The bonding agent is a synthetic latex and is applied by padding or by a foam-suction technique.

In Poland, non-woven fabrics of this kind are produced on an American (Proctor and Schwartz) aggregate and on a Polish aggregate equipped with pneumatic devices for fleece formation. The operation of the latter aggregate is shown in figure 3. The products of this aggregate include various tailoring trimmings, cotton cloth, haircloth, paddings, coverings, and the like. The wearing properties of non-woven interlinings made by this method are compared with those made from conventional woven cotton fabrics in table 2.

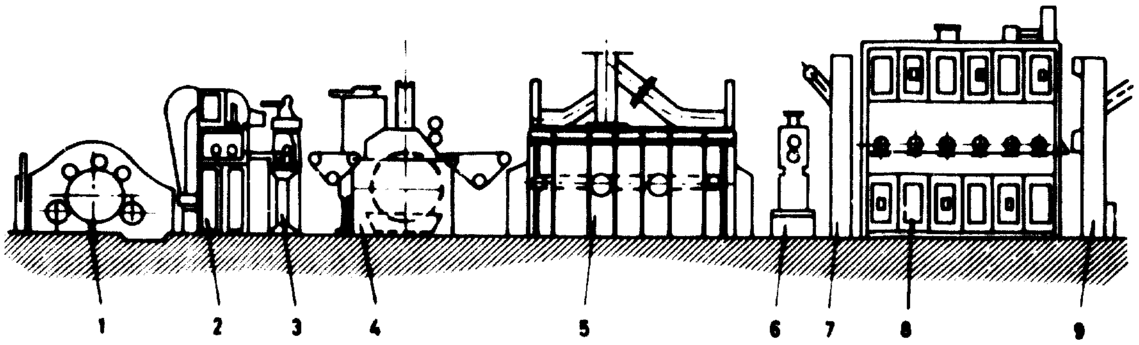


Figure 3. *Polish production unit for bonded non-woven fabrics: (1) carding drum of the CR-34 set, (2) pneumatic forming unit, (3) disc cutter, (4) wetting drum, (5) air-jet dryer, (6) Peralta device, (7) compensator, (8) perforated-drum dryer, (9) winding unit*

TABLE 2. COMPARISON OF THE CHARACTERISTICS OF INTERLINING FABRICS MADE BY DIRECT BONDING WITH THOSE MADE FROM WOVEN COTTON FABRICS

Characteristics	*Viscose non-woven fabrics*	*Woven cotton fabrics*
Weight (g/m²)	100	180
Latex depositing (per cent)	33	—
Thickness (mm)	0.63	0.88
Air permeability (litres/min/m)	400	680
Medium shrinkage (per cent)	0.6	2.3
Abrasive resistance cycles	600	380
Bending stiffness (cm)	7	1.5
Medium tensile strength (kg)	12	29
Medium elongation (per cent)	14	13
Crease resistance before washing	135	55
Crease after being washed three times	120	38

Wet-forming "paper" method

The "paper" system of production of non-woven fabrics has an especially high output. This technique makes use of the adhesive properties of fibryds, that is, certain synthetic compounds in a state between isomorphic and fibrous, that are present in fibrous polymers. At this time, in the United States, for example, fibryds are prepared on the basis of polyesters, polyamides and acrylics. Exact analysis of the formation of these fabrics and of the fibryds shows that the optimum structure of a product is achieved with 70 per cent fibres and 30 per cent fibryds.

The properties of these non-woven fabrics permit their use in the production of maps that can be unfolded and refolded many times without tearing, in the production of bank-notes which not only last much longer but are more difficult to forge and can be washed and in the production of handkerchiefs, table-cloths and napkins that are cheaper than others because their cut edges do not fray and need not be hemmed. Such napkins can be printed on an ordinary printing press. Some end-products of non-woven fabrics of this kind are certain interlining fabrics, curtains, upholstery materials, book bindings and cinema screens.

Depending on the end-use of the fabric, polyester, polyacrylonitrile or polyamide fibres can be employed. These fibres are from 6 to 11 mm in length and 155 to 555 mtex (most often about 300 mtex) in fineness.

Bonding agents used in the production of bonded non-woven fabrics

The bonding agents constitute a very important part of the whole problem of the production of non-woven articles by bonding. A product obtained by this method (that is, a bonded non-woven fabric) is composed of two elements: a textile raw material and a bonding agent that binds the loose fibres into a fabric. The part played by the bonding substance in the ready article is quite significant and constitutes about 40 per cent of the total dry mass. Consequently, the quality of bonded non-woven fabrics depends, to a large degree, on the properties of the bonding agent. Any change in the bonding agent will cause a change in the structural properties on which the wearing properties and the appearance of tne ready non-woven fabric depend.

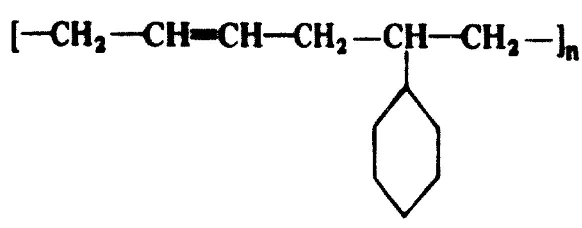
In general, it can be said that the bonding agents used in the production of these non-woven fabrics should have high mechanical strength, good adhesion and suitable elasticity and stability. From the standpoint of utilization, they should be very resistant to the action of light and air, to washing in soap solutions and to cleaning with organic solvents.

In the production of bonded non-woven fabrics by the padding method, the bonding agents are used as aqueous emulsions or dispersions of synthetic polymers. The following four kinds of binding factors are the most often used. They differ in the chemical groups that decide their character:

(a) Butadiene-acrylonitrile copolymer (butadiene-acrylonitrile latex)

$$[-CH_2-CH{=}CH-CH_2-\underset{\displaystyle CN}{\underset{|}{CH}}-CH_2-]_n$$

(b) **Butadiene-styrene copolymer (butadiene-styrene latex)**

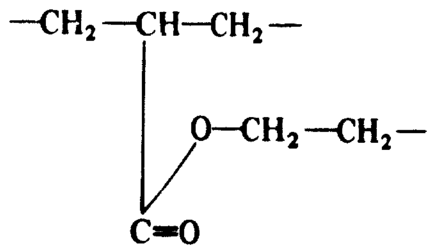


Both of these compounds are widely used as bonding agents in the production of non-woven fabrics because of the good properties they give to the final product. Among these properties are good elasticity, resistance to organic solvents and oils and sufficient mechanical strength. Butadiene-acrylonitrile latexes are used primarily to

make non-woven fabrics for the garment industry and in articles that require resistance to chemical cleaning. Where resistance to solvents is not required, butadiene-styrene latexes with a low free styrene content in the copolymer can be used. The quantity of free styrene should not exceed 0.03 per cent.

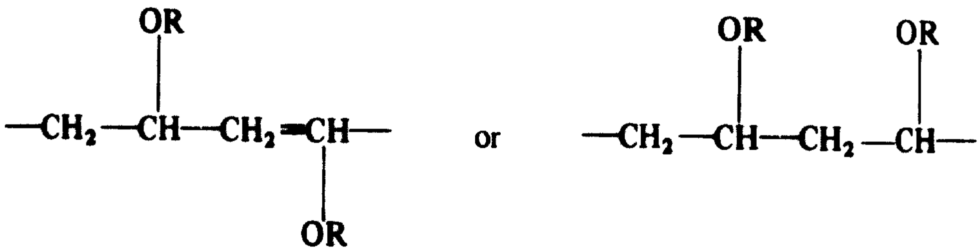
Urea and melamine formaldehyde resins can be added to the latexes, to increase the strength and resistance to solvents of the finished articles.

(c) Thermoreactive polyacrylates (acrylate resins) with the characteristic group



Acrylate resins, like latexes, are used in the production of non-woven fabrics with high elasticity, mechanical strength and resistance to organic solvents.

(d) Derivatives of polyvinyl acetate with the acetate groups in different places



An aqueous dispersion of polyvinyl acetate can be used with the addition of a softening agent such as dibutyl phthalate or octyl phthalate. The amount of softening agent can be regulated. Depending on the percentage of the softening agent in the dispersion, non-woven fabrics with different degrees of rigidity can be obtained.

The characteristics of bonding agents of this type permit the production of such articles as padding for coats, insoles for shoes of various kinds, non-woven fabrics for automobiles, wallpaper and sprayed fluffy non-woven fabrics intended for quilts, padding for protective clothing, and the like.

Non-woven fabrics obtained with the use of an aqueous dispersion of polyvinyl acetate as the bonding agent have good resistance to water and some organic solvents.

It should be noted that non-woven fabrics may be finished by dyeing the fibres and latex, by printing, by coating, and so on.

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STITCHED PRODUCTS

by

W. Jędrzejewski

Stitched non-woven fabrics

Stitched flat non-woven fabrics

Taking into consideration the average length of the raw material and depending on the size of the needle pitch (that is, the distance between the stitches) a suitably prepared fibre blend is mixed accurately on a blending and carding machine and is next carded, usually on a double carding machine.

The carding complex produces about 60 per cent fibre parallelization with a lengthwise trend and therefore must be equipped with appliances for laying the web crosswise. This is done on Blammair appliances (intermittent running layers) or on continuous running feeders that lay the web more or less at right angles to the direction of the processed material.

The central element of the stitching machine is fed with fleece of a density appropriate for the intended use, that is, from 150 to 500 g/m^2. The stitching machine is composed of three parts: the first constitutes the creel with yarn cones for stitching the fleece (Eastern German Maliwatt types) or wrap roller (Polish Arachne type and WP–180). The second part is the basic stitching set, and the third is either a folding machine for the stitched fleece or a reeling machine and a cutter.

The web is supplied to the stitching set either in the form of laps or continuously and is stitched with yarn by means of a system of knitting needles. These are compound needles driven by an eccentric ring system that produces a high number of displacements. The construction of the drive (which operates at about 1,300 rev/min) makes it possible to obtain from 80 to 120 running metres of the product per hour, depending on the type of machine and the stitch density. The stitching machine operates as shown in figure 1. Unreeled fleece (1) from the warp beam passes by means of a conveyor to the stitching zone (2) in which the basic needles (4) pierce the fleece layer and bodkins drop the yarn onto them (5). On the return of the needle, the space under its hook is closed by the closing guides (6), moving in the grooves of the needles (3). These needles can also stitch with a zigzag link of the tricot type. The strength of fleece stitched in this way is much greater, especially crossways, than the strength obtained by parallel chain stitching. With this method, the arrangement of the cross fibres is very important, since the cross-strength of non-woven fibres is in this case a function of the strength resulting

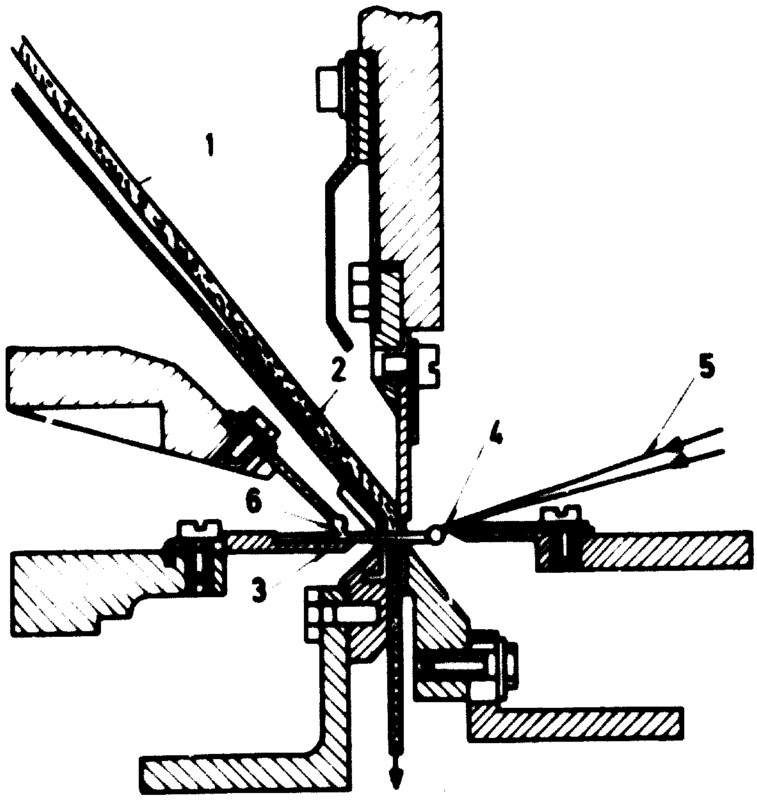

Figure 1. Schematic diagram of the operation of a stitching machine for non-woven fabrics (see text)

from the abrasive force of the moving fibres. The strength of the product across its width depends upon its thickness and the friction coefficient of the fibres.

Tests carried out on the production of non-wovens from fibres of various mean lengths have shown that, at a given density (200 g/m^2) of non-woven fabrics stitched by chain binding, the greatest increase in strength is obtained when the distance between the stitches is 1.5 to 3 times shorter than the fibre length.

With higher densities, the pressure of the stitching yarn on the fibres is greater, which produces correspondingly greater increases in the strength of non-wovens. With a greater number of fibres in the fleece section, the stitching yarn compresses the fibres, as may be seen in the transformation of yarn into web. Later, when the non-wovens are ripped, the friction is great and the fibres not only slip out of the stitch but also break. However, with too-great web densities, such as over 500 g/m^2, the strains are also too great, and the number of breaks in the stitching yarn increases.

Fabrics obtained by stitching together non-woven layers of fibre (web), depending on the composition of the raw material and type of stitching, are commonly used as padding and, after suitable finishing, for children's and women's clothing and as technical insulation material. When covered with rubber or polyvinyl chloride, these stitched non-woven fabrics are used as heat-insulating covers, for sleeping bags, floor coverings and the like. Non-wovens produced by layering and bonding, for example, with latex, are used in the production of soles for footwear.

In order to achieve optimal wear parameters of non-woven stitched fabrics, the four following quantities should be taken into consideration: *(a)* technical properties of fibres (kind, length, thickness), *(b)* type of binding and needle pitch, *(c)* density of the web intended for stitching and *(d)* intended use of the product. Depending on the end-use, various kinds of reclaimed fibres, cotton, partly woollen noils, artificial fibres and, very seldom, synthetic fibres are used. The process consists in stitching with knitting yarn, fibres doffed from small carding machines.

A typical non-woven fabric intended for clothing has the following composition.

The fleece consists of *(a)* 25 per cent of viscose fibre-type wool fibre (416 mtex/60), *(b)* 30 per cent of various reclaimed fibres and *(c)* 45 per cent waste woollen yarn. The stitching yarn is a single-filament yarn with continuous 1-tex polyamide fibres. The weight of the stitching yarn equals about 18 per cent of the weight of the web. The final weight of the non-woven fabric is 350 g/m^2.

The wearing properties that are characteristic of this assortment of stitched non-woven fabrics are the following:

Average bursting resistance (kg/cm)	10
Elongation (per cent)	50
Resistance to abrasion (rev/min)	1,600

Depending on the production assortment, the prime costs of the production of stitched non-woven fabrics are 15 to 25 per cent lower than those of corresponding conventional fabrics. This difference in costs is expected to increase when a continuous production line for stitched non-woven fabrics has been developed.

Stitched and fluffy non-woven fabrics

Stitched and fluffy non-woven fabrics are produced on suitably adapted knitting machines. One of these is the Wildman Jacquard machine (United States) intended for the production of so-called artificial furs that have a long and hairy nap. Several different raw materials may be used.

The technological process consists in the sewing of fibres removed from the collectors of small carding machines, using knitting yarn. The fibres are fixed in the knitted fabric, usually for one third of the fibre length. After suitable finishing operations, the products obtained by this process are used for artificial furs, coats, carpet runners, and the like.

Depending on the intended use, various types of fibres are used, especially wool and synthetic fibres. Synthetic fibres in uniform blends are usually from 155 to 1,666 mtex in fineness and from 38 to 76 mm in length.

Fibre blends are often used in two thicknesses and lengths in various percentages to obtain a double-layered hair nap (imitation furs). In such blends there is usually a much smaller proportion of long and thick fibres (10 to 30 per cent). For example, such compositions are used: 80 per cent polyacrylonitrile fibres of 155 mtex fineness and a length of 50 mm, and 20 per cent polyacrylonitrile fibres of a fineness of 1,666 mtex and a length of 65 mm. Cotton or synthetic yarns are used for binding.

At present, polacrylonitrile fibres (Anilana) are used in Poland in the production on non-woven furlike fabrics, and polyester and polyamide fibres will also be used in the future. The weight of the card sliver ranges from 10 to 20 grams per running metre. Cotton yarn (54/2 Nm) is used for stitching, although the use of a continuous yarn, such as one of viscose, is foreseen.

Stitched and bonded fabrics made from yarns

This category of textile fabrics includes products made by stitching or sewing together woven or non-woven yarn systems, called "soles", with a bonded yarn. Four basic methods for producing these fabrics may be distinguished: *(a)* the Malimo technology (Eastern Germany) for smooth stitched fabrics, *(b)* the Malipol technology (Eastern Germany) for fluffy stitched fabrics, *(c)* the tufting technology for fluffy stitched fabrics and *(d)* the Uwutan technology (Czechoslovakia) for flat bonded fabrics. Each of these methods is discussed below.

The Malimo technology

This technology is characterized by stitching the warp and weft system together on the Malimo machine (Kemter, 1961; Textima, n.d.; Jędrzejewski, 1962). The basic element is a stitching unit consisting of a multi-needle system plus additional guiding needles which feed, respectively, the basic warp yarn and the stitching yarn.

The weft is laid in strips of, for example, 70 or 120 threads, in the case of a set with an operating width of 1,600 mm. This yarn system is then stitched. The practical output of machines of 700 mm width is about 90 running metres per hour, and that of machines of 1,600 mm is about 60 running metres per hour.

The Malimo machine is used primarily to produce articles such as flannel, because soft yarn with a slight twist can easily be raised into a thick nap. Products of this kind are used as towels, diapers for babies, bodices, insoles for leather and rubber footwear, and the like. Very light (loose) articles can be produced by removing the basic warp. These are used for bags for fruit or vegetables or for the so-called bitumen bandages used in pipeline construction for protection against corrosion.

The raw materials most often used in the production of consumers' articles are cotton and viscose yarns. Viscose and polyamide yarns are used in goods for technical purposes.

A typical Malimo product is one intended for flannels that has the following technological characteristics:

Yarn:
- waste yarn weft (6 Nm)
- stitching cotton (20/2 Nm)
- basic viscose (6 Nm)

Number of stitching needles – 10 to 25

Number of warp threads in a carriage – 15

Density arrangement of yarns:
- sewing – 40 per 10 cm
- weft – 50 per 10 cm
- basic – 50 per 10 cm

Density of stitching – 40 per 10 cm

Weight of product – 480 g/m^2

Yarn content (per cent)
- basic – 25
- stitching – 38
- weft – 37

Bursting strength (kilograms per centimetre)
on the warp about 11
on the weft about 6

In use, towels made by the Malimo process have been found to have excellent moisture-absorptive properties that are attributable, in part, to the low degree of twist of their component yarns. The characteristics of Malimo towels with those of woven ones are compared in table 1.

TABLE 1. COMPARISON OF THE CHARACTERISTICS OF TOWELS MADE BY THE MALIMO PROCESS WITH THOSE OF WOVEN TOWELS

Characteristics	*Malimo*	*Woven fabrics*
Raw material	Cotton and waste yarn	Cotton
Weight (g/m^2)	334	413
Resistance to bursting, average (kg/5 cm)	25	33
Resistance to abrasion (rev)	3,100	2,800
Shrinkage (per cent)	4.1	5.7
Thickness (mm)	1.5	4.0

The advantages of Malimo products have created a great demand for them and this market, together with the relatively low capital investment required, has aroused much interest in the Malimo technology.

The Malipol technology

With this method, to woven or non-woven products are added stitched loops, thus obtaining fabrics very much like one-sided terrys. In textiles intended for clothing, such as coats, yarn blended of wool and chemical fibres is most often used as the loop yarn. After teaseling, the loops are usually sheared, after which the goods are suitably finished.

Although Malipol fabrics are usually of a solid colour, some effects may be achieved by the use of blended-fibre yarns, by twisting together yarns of different colours, or by colour-strip warping of the sewing yarn.

These fabrics are crush-resistant, have good drapability and resemble fabrics constructed entirely of wool. Indeed, Malipol technology permits the production of good-quality fabrics with good saving of wool. The characteristics of coat fabrics made in this way are compared with those of woven coat fabrics in table 2.

Tufting technology

Tufted fabrics can also be produced by a process slightly different from the Malipol technology. The difference is that, in the so-called one-headed tufter, the product is made by sewing loops into the basic fabric with a special guide needle. The length of the loops is regulated by a special looper-gripper. The height of the loop depends on the height of the sinker.

TABLE 2. COMPARISON OF THE CHARACTERISTICS OF COAT FABRICS MADE BY THE MALIPOL PROCESS WITH THOSE OF WOVEN COAT FABRICS

Characteristics	*Malipol coat fabrics*	*Woven coat fabrics*
Raw material (per cent)	Viscose —60 Wool —40	Wool —58 Viscose —42
Weight (g/m²)	634	736
Resistance to creasing, average (degrees)	98	112
Shrinkage, average (per cent)	2.2	3.5
Resistance to bursting, average (kg/5 cm)	45	62
Resistance to tearing, average (kg/5 cm)	7.4	7.0
Resistance to abrasion (rev)	6,850	5,520
Heat insulating ability (kcal/m²/hour)	128	132
Permeability to air (litres/100 mm/min)	268	243
Thickness (mm)	3.26	3.25

Cut carpets also can be produced by this technique; a suitably shaped sinker forms the loop and then cuts it. Later in the production process, bonding, drying and baking take place, and finally the loops are sheared to the required length on a multi-knife rolling machine.

In the automatic tufting process, the tufter may have several hundred or even more than a thousand needles where large product widths (approximately 5 metres) are concerned.

Certain surface or colour effects can be achieved in these products in various ways. The simplest of these are twisting together varicoloured yarns or printing. The basic fabric is usually of linen or hemp and of a yarn count and thickness selected to permit the sewing yarn to be twined round the weft of the fabric.

In the production of carpets, a typical 3.5/3 Nm yarn is used that is made of the following raw material: *(a)* 60 per cent polyamide fibres (Polan), 40 per cent woollen-type viscose fibres; *(b)* 40 per cent polyamide fibres (Polan), 60 per cent woollen-type viscose fibres; *(c)* 100 per cent woollen-type viscose fibres. Typical fibre thicknesses used are: polyamide fibres, 555 to 1,666 mtex and viscose fibres, 416 to 1,666 mtex. Typical fibre lengths used are: polyamide fibres, 105 to 150 mm and viscose fibres, 60 to 140 mm. The average weight of per square metre of product before bonding is about 1,500 g/m² and after bonding about 2,200 g/m².

The Uwutan technology

This production process, which is used in Czechoslovakia (a similar one is in use in the United States), consists of a free arrangement of yarn over the unrolling roller

(Vyskumny Ustav Pletarsky, 1963). The unrolled yarn is immersed in the bonding agent and then dried and vulcanized. The output of so-called net products by this process is 2.5 running metres per hour.

Both the yarn and the binding agent may be dyed, and it is also possible to print the fabric, which is used for decoration, packing and technical material.

The typical raw material used in this technology is a continuous viscose yarn of a thickness appropriate to the intended use of the product.

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THERMOPLASTIC AND NEEDLED-AND-SHRUNK FABRICS

by

H. Mrożewska

Non-woven fabrics bonded with thermoplastic elements

Thermoplastic fabrics constitute a considerable part of the general group of non-woven fabrics. The production of these textiles is characterized by high output, low production costs and the possibility of using reclaimed raw materials and others with low spinning qualities. Because of their special properties, thermoplastic fabrics are very widely used.

A whole series of production methods can be distinguished in the technology of production of non-woven fabrics from thermoplastic raw materials. Thermoplastic fabrics can be produced by binding the fleece with thermoplastic fibres, powders, foils or yarns. The first three of these methods are most often used.

Both flat and fluffy articles can be produced by binding the fleece with fibres. Flat fabrics are obtained by compressing fleece that contains thermoplastic fibres and by using special presses such as calenders and cylinder presses (Krčma *et al.*, 1962; Mrożewska, 1962).

Fluffy fabrics are obtained by shrinking web containing certain thermoplastic fibres in special heaters, free of any pressure. The web is formed on conventional cards and machines for crossing fleece or on pneumatic machines. The pressed or shrunk fleece, as a ready product, is either wound into rolls or cut into slabs.

Because of the specificity of the process of producing thermoplastic fabrics, the same general principles are always followed. Nevertheless, there are variations in the individual machines and machine aggregates used by individual producers in various countries.

Figure 1 is a technological diagram of a set of machines in a universal aggregate for the production of non-woven fabrics from thermoplastic raw materials. The output of the aggregate is in the range of 2 to 10 running metres per minute. The temperatures used range from 80° to 250°C, with the possibility of grading them as the fleece moves through the heater. The operating width of the aggregate is 1,800 mm (Mrożewska, 1962).

For the production of thermoplastic fabrics with fibres as the bonding agent, any fibres may be used that soften, become sticky and shrink at suitable temperatures. Polyvinyl chloride, polyethylene, polypropylene and softened acetate fibres are used. These fibres soften and shrink at temperatures from 120° to 170°C.

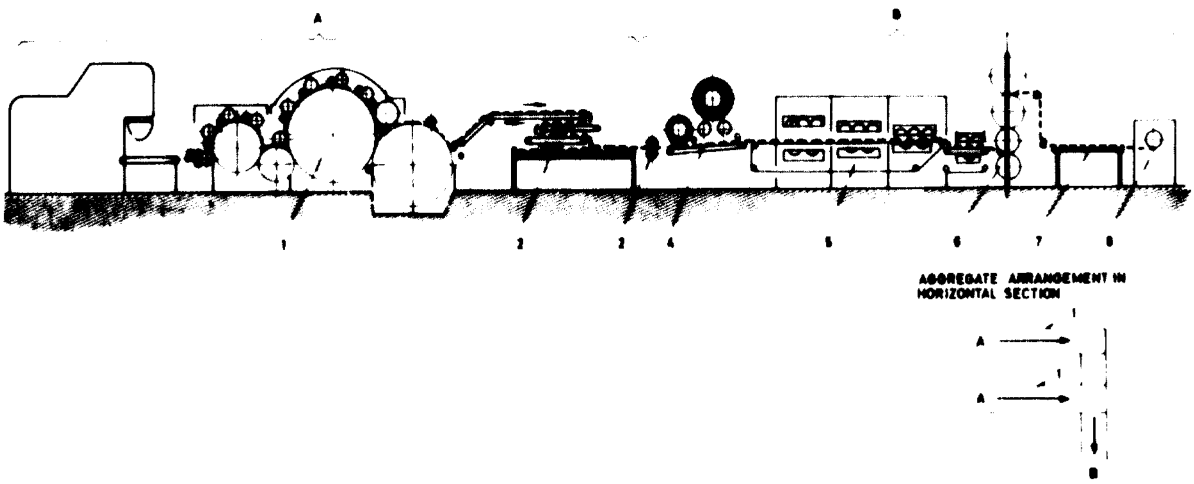

Figure 1. Technological diagram of a set of machines in a universal aggregate for the production of non-woven fabrics from thermoplastic raw materials (type IW–IV): (1) preliminary carding set, CR–34, (2) fleece-forming machine, (3) double-disc cutters for fleece, (4) appliance for introducing foil, (5) radiation heater, (6) calender, (7) bench for cutting non-woven fabric, (8) winding machine

The most important parameters with regard to the strength of non-woven flat fabrics are: *(a)* the proportion of thermoplastic fibre in the blend (table 1), the *(b)* proportion of softening agent (figure 2) and *(c)* the pressure and temperature of the press.

The most important parameters with regard to the degree of density of non-woven fluffy fabrics, which is the primary feature, are: *(a)* the proportion of thermoplastic fibre, *(b)* fibre length and *(c)* the heating temperature. The optimal proportion of thermoplastic fibres for both flat and fluffy non-woven fabrics (table 1, figure 3) is in the range of 30 to 50 per cent.

TABLE 1. RESISTANCE PROPERTIES OF THERMOPLASTIC NON-WOVEN FABRICS WITH VARIOUS POLYVINYL CHLORIDE FIBRE CONTENTS IN THE BLEND[a]

Polyvinyl chloride content (per cent)	*Weight of non-woven fabrics (g/m²)*	*Resistance to bursting (kg/5 mm)*		*Lengthening (per cent)*		*Resistance to creasing (degrees)*	
		Length-ways	*Broad-ways*	*Length-ways*	*Broad-ways*	*Length-ways*	*Broad-ways*
10	150	3.1	0.25	22.5	—	91	97
20	150	3.4	0.43	24.5	14.6	99	69
30	150	8.4	1.8	41.5	11.7	83	70
40	150	15.0	4.5	23.5	10.0	47	53
50	150	23.3	5.2	14.5	7.5	48	51

[a] Non-woven fabrics made from polyvinyl chloride fibres 3.3 den/60 mm and viscose fibres 3 den/45 mm applying pressing temperature 160°C, pressing time 1.5 min, pressing pressure 21 kg/cm².

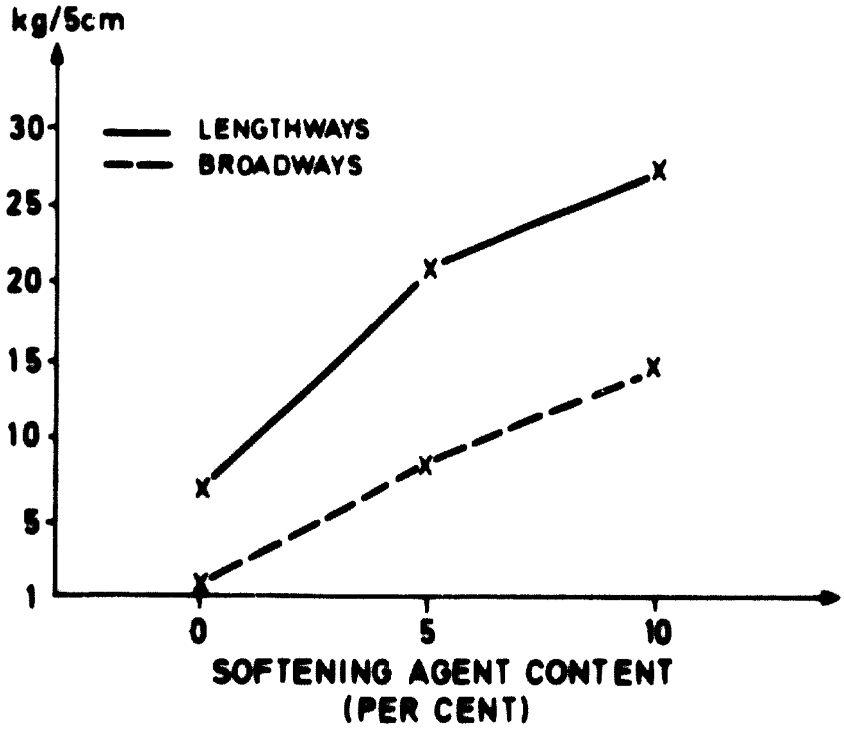

Figure 2. Relationship of the softening agent content to the stretching resistance of Termonina

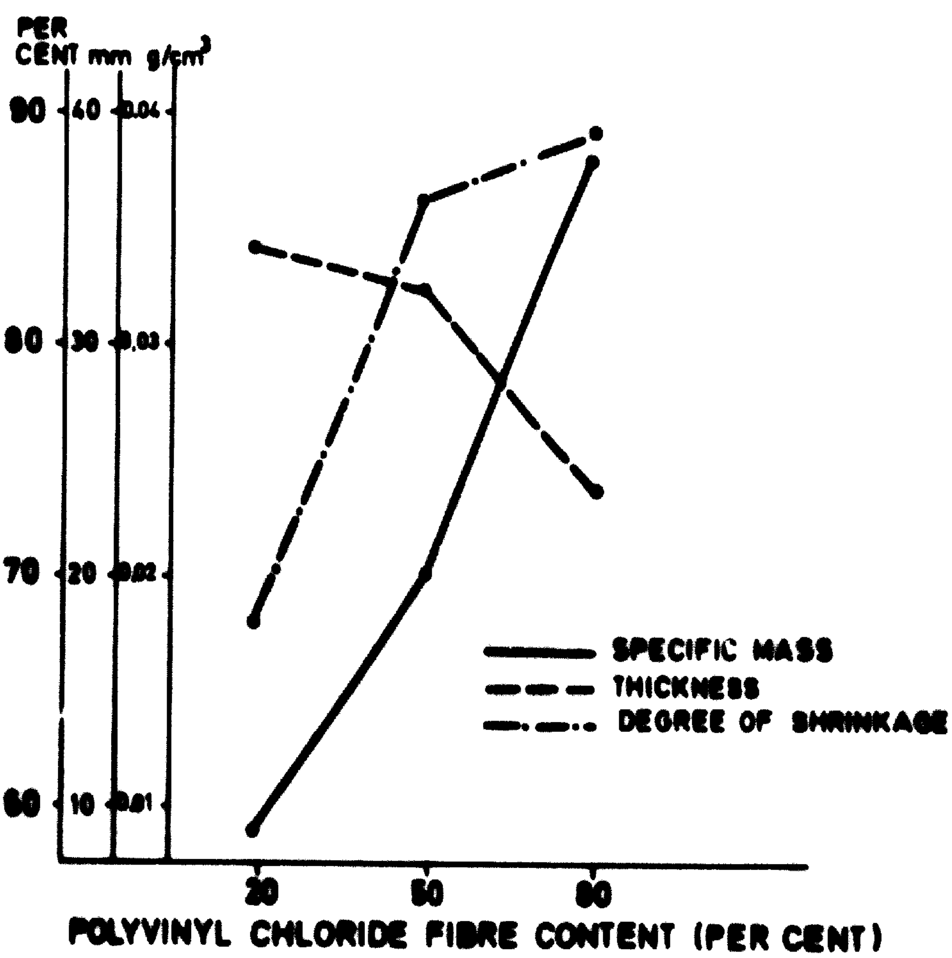

Figure 3. Relationship of the specific mass, thickness and degree of surface shrinkage of non-woven fabrics on the polyvinyl chloride fibre content in a blend with polyester fibre (Elana).

The results of investigations, presented in figure 3, were achieved by using polyvinyl chloride fibre blends of 3.75 den/60 mm and polyester fibre noils. The weight of the fleece after shrinking amounted to 100 g/m^2.

It was also found that, to achieve the highest degree of density in fluffy fabrics, bonding fibres (about 80 mm long) and short filling fibres (about 25 mm long) should be used. The other parameters that have been mentioned are regulated during the production process. Depending on the end-use of the non-woven fabrics, various blends of thermoplastic and filling fibres are used. While any chemical or natural fibres can be used as filling fibres, reclaimed fibres are used most often.

The group of flat thermoplastic fabrics called Termonina, produced in Poland, has been used in the footwear industry as stiffening filling inserts and for the

TABLE 2. WEARING TESTS FOR FOOTWEAR TERMONINA

Characteristics		*Termonina* 120	*Termonina* 240	*Termonina* 500
Weight (g/m^2)		115.70	232.60	491.60
Thickness at a load of 5 kg/cm^2 (mm)		0.51	0.66	0.93
Resistance to stretching (kg)	lengthways	9.20	19.80	78.40
	broadways	2.90	5.70	21.20
Lengthening (per cent)	lengthways	5.50	9.00	11.00
	broadways	6.00	7.50	6.00
Abrasion resistance (number of revolutions)		260 ± 90	1,238 ± 230	2,565 ± 1,025
Shrinkage after wetting (per cent)	lengthways	1.60	1.20	1.80
	broadways	1.20	0.80	1.00
Hygroscopicity (per cent)		7.60	16.80	5.60
Permeability to air at the pressure of a 10-mm column of water on a surface of 100 cm^2 (litres/min)		182.50	86.00	7.00
Limiting number of bends with "0" load	lengthways	43,400	—	3,308
	broadways	87,800	—	7,029
Limit of flexibility (kg)	lengthways	2.50	—	12.50
	broadways	0.80	—	3.60
Length of bends (cm)	lengthways	4.8 ± 0.21	7.5 ± 0.25	14.50
	broadways	3.7 ± 0.50	4.9 ± 0.25	12.50
Bending rigidity (g/cm)	lengthways	1.280	9.274	149.87
	broadways	0.586	2.607	96.02
	total	0.866	5.109	119.90

filtration of liquids and air. These fabrics are produced at a temperature of 130° to 140°C and under suitable pressure. The basic binding fibres are polyvinyl chloride fibres in proportions from 30 to 60 per cent. The filling fibres of footwear Termonina are reclaimed cellulose fibres, and filtration Termonina for liquids are thin polyacrylonitrile fibres (2 den).

The production of non-woven fabrics by bonding with thermoplastic agents is done on typical textile machinery that has been adapted and fitted with new appliances.

Footwear Termoninas are made with the weights of 120, 240 and 500 g/m^2 and are used instead of cotton fabrics for interlinings and for strengthening edges and toe-caps. They are characterized by good wearing properties, such as high rigidity, which eliminates the need for the additional impregnation that is necessary with woven fabrics; very little shrinkage after wetting (about 1 to 1.4 per cent), which prevents the deformation of footwear when damp; high bursting strength and abrasion resistance; and excellent hygienic properties (table 2).

Filtration Termoninas are used in anti-dust masks and as air filters in the automotive industry. They are also used for liquid filtration, as of galvanizing solutions (table 3).

The technological aspect of the production of Termonina is characterized by its simplicity and short production cycle, which eliminates the spinning, weaving and finishing that are parts of the production of conventional cotton fabrics. The shortening of the production cycle permits economies of production area, electrical

TABLE 3. WEARING TEST FOR FILTRATION TERMONINA FOR GALVANIZING SOLUTIONS

Characteristics		*Filtration Termonina 90*
Weight (g/m^2)		89.80
Thickness at a load of 5 kg/cm^2 (mm)		0.28
Weight density (g/cm^3)		0.32
Resistance to stretching (kg)	lengthways	14.50
	broadways	4.10
Lengthening (per cent)	lengthways	26.0
	broadways	19.0
Permeability to air at the pressure of a 10-mm column of water on a surface of 100 cm^2 (litres/min)		113.0
De-dusting ability		
from medium crystal precipitates (tin bicarbonate suspension)		Separates
from small crystal precipitates (barium sulphate suspension)		Separates with slight cloudiness
Flow time of 100 ml water on a Herzberg apparatus (seconds)		54.0

energy, labour and machinery, which lower the prime costs by about 35 per cent as compared with cotton fabric production. Furthermore, Termoninas for footwear elements can be made from 75 to 100 per cent reclaimed fibres with poor spinning properties. Flat thermoplastic non-woven fabrics are also produced in France, the United Kingdom and elsewhere (Dilles, 1962a).

Shrunk thermoplastic non-woven fabrics are characterized by bulkiness; their weight is about 0.02 g/cm². These non-woven fabrics are used mainly in acoustic and thermal insulation, filtration and for padding material. They are most often produced with weights from 300 to 1,000 g/m².

Because of their low strength, these non-woven fabrics cannot be used to bear mechanical loads. They are produced in France by Rhovyl and also in Eastern Germany and in Poland.

Flat thermoplastic non-woven fabrics are also produced by bonding the fleece with thermoplastic powders. In this method, a thermoplastic powder is deposited by a special appliance on the fleece, which is then pressed at a suitable temperature. Various kinds of powder-depositing appliances and other components of aggregates for producing powder-bonded non-woven fabrics are used in different countries.

The usual bonding powders are polyvinyl chloride, copolyvinyl chloride, polyethylene and polyamide, in proportion of 30 to 50 per cent (by weight) of the fleece. The significant technological parameter is the molecular size of the powder, which fluctuates in the range of 40 to 600 microns (Krčma *et al.*, 1962; Tugov and Reutov, 1962).

Various chemical and natural fibres, usually reclaimed waste, can be used to form the fleece. Ready non-woven fabrics bonded by powders are produced in weights ranging from 80 to 150 g/m² when intended for stiffening elements in the footwear industry, insulating materials in the electrotechnical industry, interlining fabrics for garments and the like. The production of non-woven fabrics of this type has been begun in Western Europe and elsewhere by various firms.

Similar non-woven fabrics used for stiffening and filling in the garment industry, in leather goods and footwear are produced by surface bonding of the fleece with thermoplastic foil, usually a polyvinyl chloride foil in solid net form Non-woven fabrics produced in this way have weights from 300 to 1,200 g/m². The solid or net foil is introduced between two fleeces (figure 1, appliance 4), and the layer system is then heated and pressed in a calender (Krčma *et al.*, 1962).

For fleece-foil point-line bonding, a polyvinyl chloride foil layer is applied to each side of the fleece, where it is welded into various patterns (lines, squares, triangles, circles etc.) on an electrical-capacitance welding machine with a high generator output (12 to 50 kW). In this method, foils of a thickness of 0.15 mm are used. The fleece, which weighs from 50 to 300 g/m², consists of approximately 80 per cent thermoplastic polyvinyl chloride fibres and 20 per cent chemical fibres, such as polyesters and polyamides, that can become adhesive. During welding with high-frequency currents, high temperatures are formed within the foil and fleece, and the foil and fleece are point-line bonded under the pressure of the electrodes. Non-woven fabrics welded with polyvinyl chloride foils in this way are used for covering the interiors of aircraft and automobiles and also in leather goods. They possess good acoustic insulation properties (Dilles, 1962b; Mrożewska, 1964).

Bonding with yarns is done by leading thermoplastic fibre yarn, either from one yarn system between two fleeces, or from two yarn systems to the two surfaces of the fleece and pressing in a calender at a suitable temperature.

The production of non-woven fabrics of this kind (Sasheen) has been started by the American firm Minnesota Mining and Manufacturing Co. In this process, a continuous thermoplastic cellulose acetate yarn with a thickness of 150 den is bonded to both sides of a thin fleece by rollers heated to 160°C. The product is characterized by a soft handle and good thermal insulation and is used for padding, insulating linings and non-woven fancy fabrics (dressing-gowns, jacket fabrics), and the like (Jędrzejewski, 1959).

Thermoplastic non-woven fabrics can also be produced by applying combinations of the methods mentioned above.

Needled-and-shrunk non-woven fabrics

Felt-like products can be made by the needling process from fleece composed entirely of synthetic fibres.

The needling process was first applied in 1900 in the production of paddings, rugs, carpet underlays, and the like. Coarse vegetable fibres such as coconut fibres, jute and ramie were used for the production of these articles, obtaining products with weak bonds. In the last few years, the needling process has become important in the production of felt-like products made from fine fibres. These needled non-woven fabrics can be produced either with or without reinforcement with yarn or a woven, knitted or net fabric.

In order to increase the density of needled felt-like non-woven fabrics, the fleece can be condensed further by the application of heat to synthetic fibres that can be shrunk in this way.

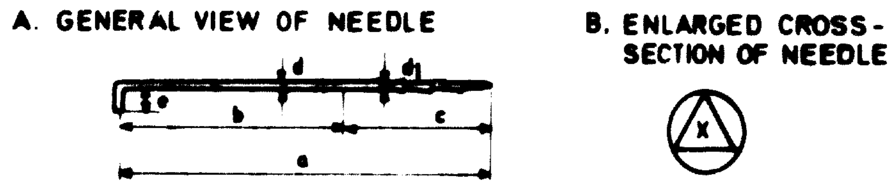

Figure 4. Diagram of a stitching needle with multi-directional notches: (a) total length of needle, (b) length of stem, (c) operating part of needle, (d) diameter of stem, (d_1) thickness of operating part, (e) length of base

The needling process consists in the drawing of fibres through the fleece by the use of special needles (figure 4) with multi-directional notches. This process is carried out on special machines that are produced by several firms in various countries.

The needling machines produced by Bywater (United Kingdom), Fehrer (Austria) and Hunter (United States) operate at from 250 to 900 vibrations per minute and have operating widths from 2.2 to 11.4 m (Zehle, 1962). Machines operating at 700 to 900 vibrations per minute are used at this time to produce felt-like non-woven fabrics from fine synthetic fibres.

Machines with double needling fields, that is, ones in which the needles act simultaneously from above and below the fleece, are widely used to produce felt-like fabrics with bilaterally closed surfaces. One such machine, the Bywater type 2 head Multi-Punch machine, is illustrated in figure 5. It is characterized by a large number (9,360) of needles, has an operating width of 2,286 mm, performs 205 needlings, each 108.2 mm deep, per square centimetre, has an output range from 1.2 to

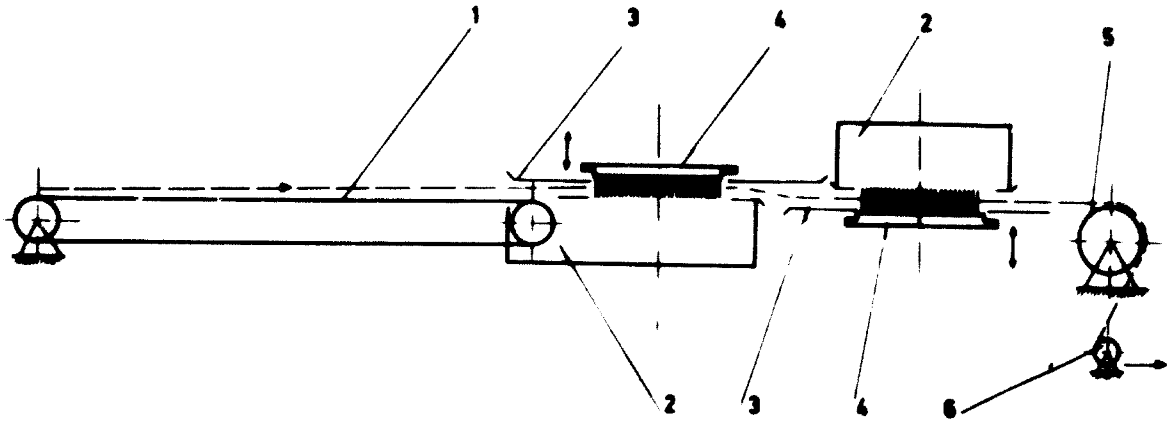

Figure 5. Technological diagram of the Bywater needling machine (type 2 Head Multi-Punch machine): (1) feeding lattice, (2) regulating plates, (3) holding plates, (4) needling board, (5) receiving roller and (6) tightening roller

30 running metres per minute, and the main shaft operates at 600 rev/min. Fabrics of weights from 25 to 3,000 g/m^2 can be produced on these machines.

Recently, a needling process called Fiberwoven for the production of non-woven fabrics mainly intended for blankets and plaids has been developed in the United States by the Chatham Manufacturing Co. The machines for this process have been built by Hunter (United States) since 1964.

The principle of this new Fiberwoven system is that the needles act bilaterally on the fleece at an acute angle in relation to the intermediate product (figure 6). The

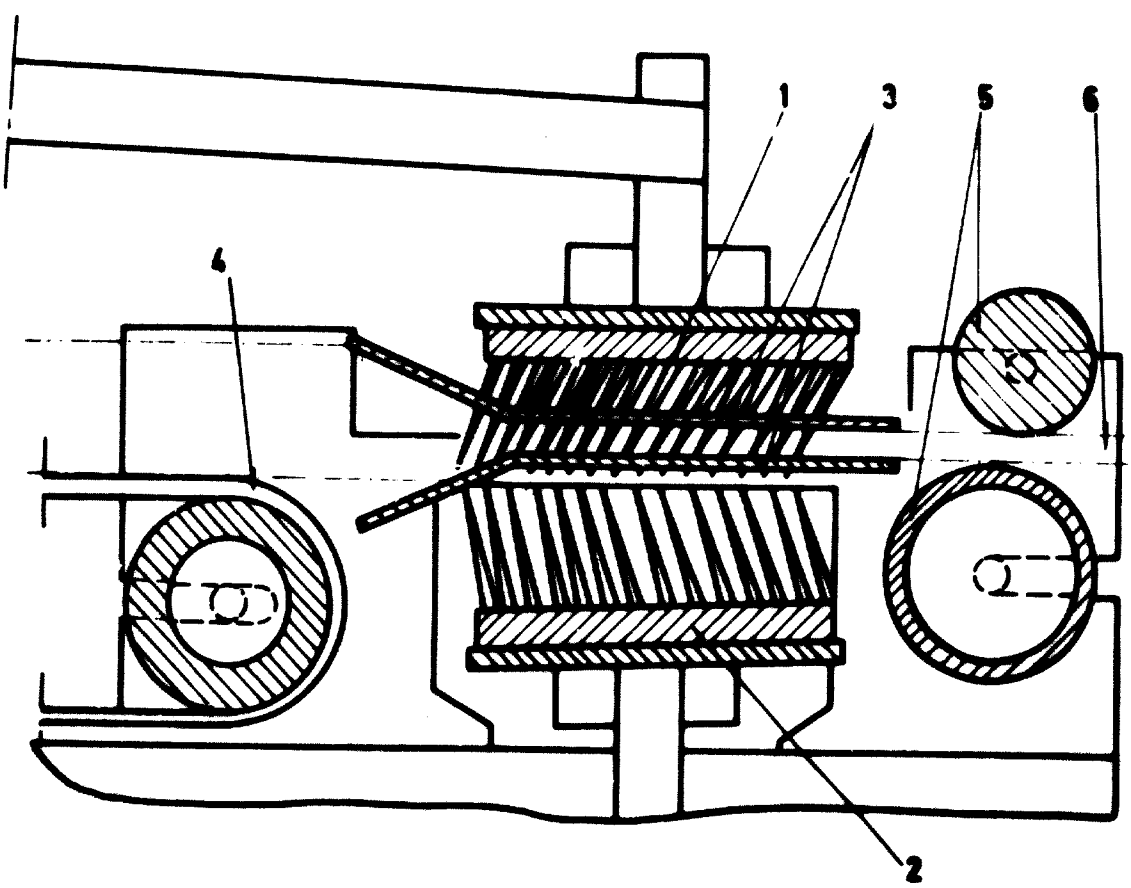

Figure 6. Simplified technological diagram of a pair of needling plates of a needling machine used in the Fiberwoven system: (1) upper needling plate, (2) lower needling plate, (3) holding plate, (4) feeding lattice, (5) receiving rollers, (6) needled product

paths of the needles cross inside the product, thus binding the fibres better throughout its whole section and giving the finished product very good strength properties (Anon. 1964a, 1964b and 1964c).

The production of needled felt-like non-woven fabrics that are given additional density by shrinking has been initiated in many countries according to various patents and with the use of many different thermoplastic synthetic fibres. For example, in France polyvinyl chloride fibres are mostly used, and in the United Kingdom, modified polyester and polypropylene fibres (Fröhlich, 1957).

Depending on the technological and construction solutions concerning aggregates for the production of needled-and-shrunk non-woven fabrics, various sources of heat are used, among them hot baths, steam, hot air, radiant heating and dielectric heating. Chemical compounds that soften the thermoplastic fibres are also used, especially in wet heating processes.

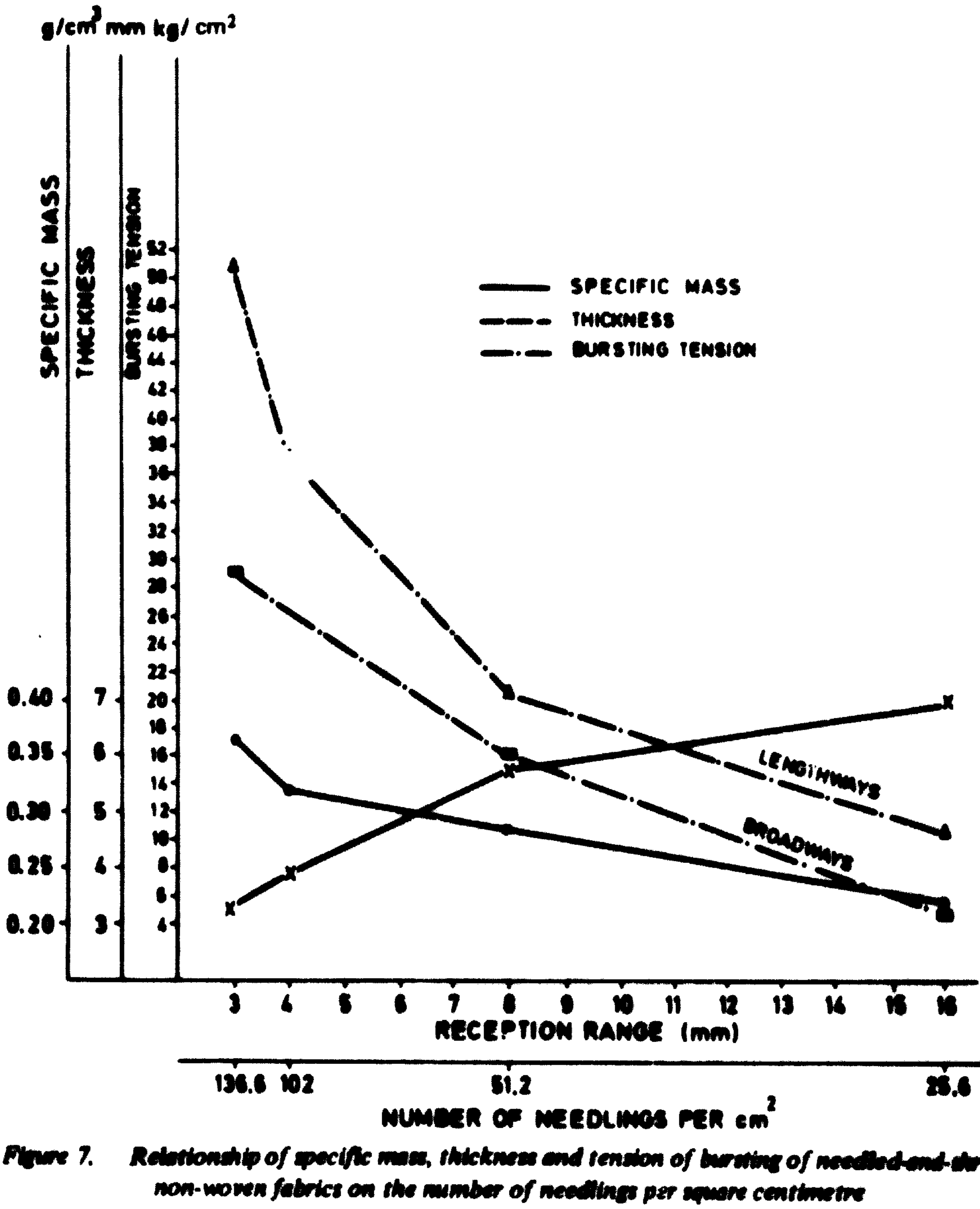

Figure 7. Relationship of specific mass, thickness and tension of bursting of needled-and-shrunk non-woven fabrics on the number of needlings per square centimetre

The main parameters of the needling process, which differ according to the type of raw material, fleece thickness and end-use of the product include: the type of needle, needle gauge, number of needlings per square centimetre, depth of needling and the distance between the regulating plate and the holding plate. The construction of the needling machine permits changes in all of these parameters.

In the production of needled-and-shrunk non-woven fabrics on an optimal type of needling machine, the two basic parameters, which determine the physico-mechanical properties of the non-woven fabrics, are the number of needlings per square centimetre (figure 7) and the thermoplastic fibre content of the blend (figure 8). The second of these determines the degree of condensation of the non-woven fibres in the shrinking process. The shrinking process is carried out at a suitable temperature, depending on the kind of thermoplastic fibres applied. Polyvinyl chloride fibres are shrunk at temperatures from 120° to 140°.

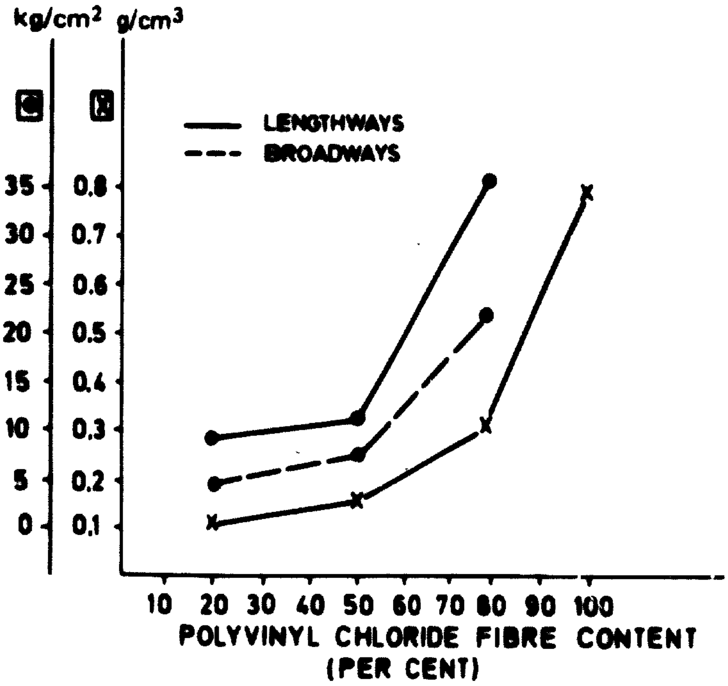

Figure 8. Relationship of specific mass and tension of bursting of needled-and-shrunk non-woven fabrics on the polyvinyl chloride fibre content in the blend

Needled-and-shrunk felt-like non-woven fabrics (the so-called needled thermo-felts) made from 50 to 80 per cent polyvinyl chloride and polyacrylonitrile fibres have the same mechanical properties as conventional woollen felts (table 4).

As compared with woollen felts, needled thermofelts are characterized by resistance to chemical action and biological deterioration, in combustibility and in the possibility of achieving much higher weights. (To obtain weight densities greater than 0.46 g/cm³ with wool felts, an additional size impregnation is required.) The introduction of the needled thermofelt technology has eliminated the need for wool in the felt industry.

Needled-and-shrunk non-woven fabrics and needled non-woven fabrics made from fine fibres are used mainly as technical, sealing, washer, filtration and paper felts, printing washers, plaids and non-woven fabrics for garments.

TABLE 4. COMPARISON OF RESISTANCE PROPERTIES OF NEEDLED THERMOFELTS AND CONVENTIONAL WOOLLEN FELTS

Characteristics	*Needled thermofelts*		*Woollen felts*
Composition of raw material	50% polyvinyl chloride 3.75 den/60 mm; 50% polyacrylonitrile fibres 4.5 den/2.5 mm	80% polyvinyl chloride 2.8 den/90 mm; 20% polyester-woollen noils	50% wool 64s 50% wool noils 64s
Specific mass (g/cm^3)	0.365	0.542	0.36
Weight per square metre (g)	1,236.9	926.8	1,224
Thickness (mm)	3.39	1.71	3.4
Bursting tension (kg/cm^2) lengthways	51.4	51.46	28.0
broadways	29.0	46.1	44.0
Lengthening (per cent) lengthways	148.0	90.0	130.0
broadways	91.0	80.0	90.0

The production processes for needled and needled-and-shrunk non-woven fabrics are characterized by large outputs and low production costs in comparison with the conventional methods of fabric production by weaving and felting. For example, the production of needled blankets by the Fiberwoven method is characterized by a twentyfold greater output than is possible with weaving. Also, the prime production costs for needled thermofelts are only about half as great as those for woollen felts.

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THE TECHNOLOGY OF LAMINATING TEXTILE PRODUCTS

by

T. Mordaka

The finishing of non-woven, woven and knitted fabrics intended for laminating

A textile laminate ("foamback") is formed by permanently bonding a fabric (non-woven, woven or knitted) to a sheet of polyurethane foam material. It is of fundamental importance in the finishing of fabrics that are to be laminated that every operation be performed without tension so that shrinkage by either the wet or steam method will be maximized. Because of the slighter filling of fabrics intended for laminating, they should be waterproofed if they are to be used as outerwear such as coats. Waterproofing can be carried out either before or after lamination. Should the fabric be waterproofed before lamination, silicone resins cannot be used, because products that have been treated with these resins do not bond permanently with polyurethane foam when either the bonding method or the welding method is used. In this case, other available preparations should be used for waterproofing. Where the facilities of textile plants that produce laminates permit, the finished products can be waterproofed.

Woollen fabrics intended for laminating should be well clipped on the reverse side so as to remove protruding and weakly fixed fibres and to improve the conditions for bonding the fabrics with the foam.

Before cotton or woollen fabrics of a width of 140 cm or more are laminated, they must be wound on paper rollers.

Technologies for laminating textile products

Because of their properties, polyurethane materials occupy a special place in the large family of plastics. Prominent among the physico-chemical characteristics of these materials are their weak solubility in conventional organic solvents, resistance to elevated temperatures, high adhesiveness to practically all materials and the fact that they may be given any degree of elasticity. Polyester and polyether materials also can be used in the production of valuable foams.

Polyurethane foams were first bonded to textiles to produce garment linings. The resulting products were characterized by good thermal insulation, lightness, resistance to creasing and encouraged further investigations on the use of polyurethane foam, mainly in outerwear and on the improvement of methods for binding the foam to the textile.

At present, there are three known and applied industrial methods of laminating, that is, of bonding the foam with textile products: *(a)* sewing or stitching, *(b)* bonding with an adhesive, and *(c)* welding with high-frequency electrical currents or by slightly melting the foam by means of a flame.

The easiest way to attach the foam to the textile is by sewing or stitching. However, this method has certain drawbacks, among the more important being that the outside surface of the product has a poor appearance.

The electrical-welding method and the so-called flame method consist in melting the foam slightly and joining the softened portion layer to the fabric without additional bonding agents. All polyester foams and certain types of polyether foams can be joined by these methods.

The method most generally used by most laminate manufacturers is the bonding of the polyurethane foam with the textile product by using liquid bonding agents or thermoplastic powders. The liquids are either solvents or dispersion agents. Bonding agents intended for laminating must have excellent bonding strength and great elasticity of the bonding membrane and be resistant to solvents.

Polyurethane materials are the bonding solvents used in the production of laminates. They have two components; one consisting of di- or tri-isocyanates and the other of polyester resins that contain a free hydrogen oxide group within the molecule. During hardening, the isocyanate groups react with the hydrogen oxide groups to form urethane bonds. The isocyanate in this case plays the role of a "netting" agent. The bonding agent must be prepared (that is, the components must be mixed) immediately before the bonding process. This is because the hardening reaction begins as soon as the components are mixed and, after a relatively short time, the mixture is useless. As a solvent for the preparation of the proper bonding mixture, ethyl acetate, acetone or trichloroethylene may be used.

Aqueous dispersions of acrylate resins are the dispersion agents used in the production of laminates. Since they contain no organic solvents, there is no danger of fire when they are used. Usually, the application of bonding agents based on aqueous dispersions requires a condenser to bring the consistency of the adhesive mixture to a state that will allow it to be absorbed into both the foam and the fabric. Should the agent require thinning, this can be done by the addition and thorough mixing of a suitable amount of cold water. Bonding agents of this kind cannot be mixed with cation-active substances.

Among the agents used to bond polyurethane foam to textiles are powdered thermoplastic substances in the form of the copolymer of polyvinyl chloride and polyvinyl acetate or polyethylene. These powdered thermoplastic substances are melted by infra-red radiation, and the bond between the foam and the fabric is fixed by calendering and cooling.

Laminating with adhesives

The lamination of textile products can be done by spreading a layer of adhesive directly onto the foam or by the formation of an intermediate film of adhesive on a special conveyor that transfers it mechanically onto the fabric or foam. The conveyor must be made of a material that has almost no affinity for polyurethane adhesives. The sequence of operations is as follows.

The adhesive, in the form of a thin film, is deposited by a blade onto a cotton conveyor coated with silicone rubber. After passing through a drying chamber, the bonding film is transferred to the foam by a roller that presses the foam against the conveyor that holds the adhesive film, and the foam next passes to a second set of rollers that bonds it to the fabric under lesser pressure. The product is then suitably fixed and dried in a drum heated from the inside with steam.

Lamination of textile products by direct bonding is done in a slightly different way. The adhesive is deposited directly onto the foam by rollers. After a short transfer, the foam, with its coating of adhesive, is bonded to the textile product and, after passing through a drying chamber, the laminate is run between rollers which, by their pressure, cause the foam to become bonded permanently to the textile product.

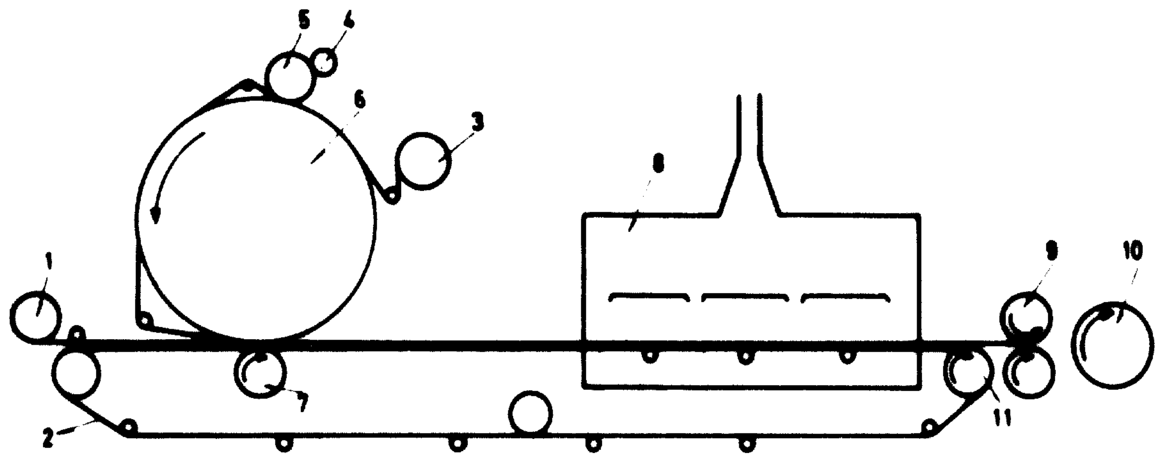

Figure 1. Equipment for laminating textile fibres directly (see text)

Many different systems for the lamination of textiles by direct bonding have been developed. One of them is diagrammed in figure 1; the sequence of operations of this method is as follows. The beam of fabric (1) to be laminated is put on a conveyor (2) by unrolling. The polyurethane foam is unrolled from the beam (3) and is introduced between the intermediate drum (6) and the rotating roller (5), which deposits the adhesive on the foam. The roller (4) serves to regulate the thickness of the layer and the amount of adhesive deposited. Next, passing over the surface of the drum (6) and the widening roller, the foam passes between the drum (6) and the roller beneath it (7), where the foam, coated with a layer of adhesive, undergoes preliminary bonding to the fabric fed by the conveyor (2) from the beam (1). The pressure of the roller (7) on the drum (6) is regulated so as to permit the setting of the roller (7) at any distance from the drum, depending on the thickness of the foam and fabric and the required pressure. The conveyor (2) carries the preliminary bonded laminate to the drying chamber (8), where the solvent contained in the glue is evaporated away. After leaving the drying chamber, the laminate leaves the conveyor belt and is introduced between two pressing rollers (9). Between these (usually pneumatically pressed) rollers, the final bonding takes place and the laminate is taken up onto the roller (10).

When the laminating process has been completed, the finished product should be seasoned for about 30 hours. This time is essential for the complete cross-linking of the adhesive and the achievement of a permanent bond between the foam and the textile. The output of an aggregate of this kind of appliance is from 5 to 15 running metres per minute. The average consumption of adhesive in the wet state ranges from 70 to 110 g/m^2.

Laminating by slight melting of the polyurethane foam

The polyurethane plastics are included within the thermoplastic group, the characteristic feature of which is that they always soften during heating and harden on cooling. As noted earlier, there are two known industrial methods for laminating textile products by slightly melting the polyurethane foam: the electrical-welding method and the flame method.

The welding method, also called the seam-welding method, consists in melting the seam of the foam slightly with an electrical current and binding it to the textile. The laminate obtained in this way has a surface with a structure that is similar to that of laminates obtained by simply stitching the foam to the fabric. For this reason, its usefulness (for example, in outer garments) is limited. The productivity of the welding method is relatively low (4 running metres per minute). However, this method makes it possible to obtain a bilateral laminate in a single transfer, that is, to obtain a laminate in a fabric-foam-fabric array.

Laminates produced by the welding method are used primarily in the furniture, automobile and footwear industries. The practical production output of equipment for laminating textile products by welding is about 1,200 running metres per 8-hour shift.

The second method based on the same principle, that is, physical changes in the foam under the influence of heat, is the flame laminating method. This method differs from the previous one in that the foam is melted slightly across its entire surface and the laminate obtained is smooth. The foam is slightly melted by a gas flame from a gas burner that extends across the whole operating width of the machine. The height and width of the flame can be regulated, and the burner can be supplied with piped gas or with a mixture of propane and butane from bottles. The appliances for flame laminating are equipped with electromagnetic switches to cut off the gas supply to the burner if the machine stops. During this process, the foam loses from 0.3 to 0.8 mm in thickness, depending on the kind of fabric to be laminated. When laminating thick (heavy) fabrics, the melting of the foam should be greater than for laminating light fabrics in order to achieve better bond strength. The parameters must therefore be calculated for each kind of fabric to be laminated.

The laminates obtained by the flame method are characterized by good wearing properties and above all by softness and drapability. However, the bond strength is less than in laminates obtained by the use of adhesives. The advantage of the flame method is its high output, which amounts to 30 running metres per minute.

In the building of industrial machines for the flame technology, the greatest experience has been had by firms in the United States. Laminating aggregates built in Europe (Denmark, the Netherlands and Norway) are based on American construction solutions. For example, the American Foam Co. builds equipment of this kind in Denmark. These machines can be used for laminating polyester and polyether foams with all kinds of textile products, and also with plastic foils.

The equipment comprises three basic complexes: *(a)* for feeding the foam, *(b)* for melting the foam and *(c)* for winding the finished laminate. The foam is wound on a roller that turns freely on ball bearings. The foam is unwound by tension and is led by a guide roller and a system of adjusted laminating bars to the second complex, where the foam is slightly melted. This complex comprises a burner, a cooling roller, pressing rollers, pumps for the cooling liquid and an air blower. The slight melting of the foam and the pressure of the fabric onto the layer of foam takes place on the cooling roller. The foam is slightly melted from above, and it meets the fabric under the pressing roller where permanent bonding takes place. The laminate is cooled and then passed to the third complex, which consists of equipment for winding the ready laminate onto a roller that is driven by a friction clutch and equipment for unwinding the fabric intended for laminating.

The technical data of this machine aggregate are as follows: maximum operating width, 200 cm; gas requirements, 2 to 4 kg/hour; laminating speed, 10 to 40 m/min.

The flame method of lamination is well suited for use with certain woven, non-woven and knitted fabrics. Thin products, particularly, show better results in wear tests when made in this way.

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THE STRUCTURE AND VARIETY OF TEXTILE PRODUCTS LAMINATED WITH POLYURETHANE FOAM

by

H. Górski

The properties of polyurethane foam give laminated textile products made from them many characteristic features, most importantly high heat protection, lightness and dimensional stability. These features of polyurethane laminates indicate their usefulness in clothing. The high elasticity, elastic recovery and the sound-absorbence of this material facilitate the production of a wide variety of laminated products for use in furnishing living quarters and offices and for products with special uses, such as sound-proofing materials.

Laminates used for clothing

Clothing made from foam laminates is generally intended for wear during the autumn, winter and spring. They are made from woollen-type and cotton-type fabrics and of knitted fabrics of various raw material compositions. A polyurethane foam with a thickness of 1.5 to 2 mm and a specific weight of 30 kg/m^3 is used for laminating.

Clothing laminates made from woollen-type fabrics

Of all fabrics of the woollen type, coat fabrics are almost the only ones that are laminated. The structure of these laminated woollen fabrics, however, is different from that of conventional coat fabrics. Because of the low breaking strength of foams, fabrics laminated with them must be constructed in such a way that they can withstand all outside forces that act on them. After laminating, the durability of the products is raised, but only slightly. Consequently, polyamide and polyester synthetic fibres and wool are best suited for use in coat fabrics that are to be laminated. However, improving the strength of a fabric by modifying its structure sometimes leads to negative results because of other features of the laminates. For example, the numbers of twists and fillings of the fabric that are regarded as optimal in conventional fabrics cannot be used for laminates, because such fabrics must be soft, light, permeable to air and have good adhesion to the foam.

The yarn twist factor should be low, because this positively affects the adhesion of the foam to the fabric, making it softer and more fluffy. Short weft and warp

TABLE 1. TECHNICAL REQUIREMENTS FOR FABRICS OF THE WOOLLEN TYPE INTENDED FOR LAMINATING

Characteristics		*Men's coats*		*Ladies', youths' and children's coats*			
Fibre composition of blend		50 % polyester fibres 50 % wool fibres		50 % polyester fibres 50 % viscose fibres		30 % polyester fibres 70 % viscose fibres	
Yarn thickness (Nm)	warp	12/1	10/1	8/1	12/1	10/1	8/1
	weft	12/1	10/1	8/1	12/1	10/1	8/1
Fabric width (cm)		← 144 →					
Number of threads per 10 cm	warp	150—160	130—140	110—120	145—155	120—130	105—115
	weft	130—140	115—125	90—100	125—135	110—120	85—95
Weight (g/m^2)		380	400	420	360	380	400
Weave		Linen and cross-binding with short weaves		Linen, cross-binding with short weaves			
Finish		Waterproofed, depositing of finish 2—2.5% ; fluffing or half-raised					
Minimum tensile strength	warp	← 30 →					
	weft	← 30 →					
Maximum shrinkage after wetting (per cent)	warp	← 4 →					
	weft	← 4 →					
Fat content (per cent)		← up to 1 →					

interlacing raises the bursting strength of the fabric, at the same time permitting its weight to be reduced. If a fabric is made with less raw material, the yarn used must be coarser to secure proper density. The structure of the fabric should not be such that the foam is visible through it. A high shrinkage of the fabric is also inadmissible, because this can affect the appearance of the surface of the laminate adversely and cause deformations of garments made from them.

The most important feature of the conventional coat fabrics is their heat-insulating property. In order to achieve this, it is necessary to select a suitable raw material (generally wool) and structure (high weight and thickness) of the fabric. The foam component of laminated fabrics provides the heat-insulating feature, so that lightness and heat insulation are combined. This makes it possible to produce very much lighter and thinner coat fabrics than was formerly possible. However, in order to ensure that the fabrics will have sufficient resistance to abrasion, which determines the durability of laminated garments, they must have suitable yarn filling. In addition, the three following characteristics are required of fabrics intended for laminating with the use of adhesives: *(a)* softness and good draping features, *(b)* small fat content, so as to avoid difficulties in achieving the required strength of the bond between fabric and foam and *(c)* a well-sheared reverse side.

The technical requirements for coat fabrics of the woollen type intended for laminating are presented in table 1.

Clothing laminates made from cotton-type fabrics

Fabrics of this type are used mainly for spring and autumn coats, heavy and light jackets, waistcoats and ladies' suits. These fabrics can be made from cotton, from blends of cotton and viscose rayon and from viscose fibres blended with polyester fibres so as to strengthen these fabrics and increase their resistance to abrasion. Fabrics of this type, and primarily those intended for spring-autumn coats and jackets, can gradually replace a wide assortment of articles presently made of wool. The filling of cotton fabrics intended for laminating must be less than in conventional fabrics because, when a fabric with too much filling is used, a laminate of too great stiffness and susceptibility to creasing results. Thus, fabrics with a poplin structure are of no use for laminating. Fabrics with various other weaves can be used, but care must be taken that the filling of the fabric does not exceed the following limits: weave 1/1, warp filling 55 to 60 per cent, weft about 45 per cent; weave 2/2, warp filling about 70 per cent, weft about 55 per cent. Many fabrics of this kind must be waterproofed because of their intended use, and this may require changing the structure of the fabric, even to the disadvantage of the draping features or resistance to creasing. The technical requirements for fabrics of the cotton type intended for laminating are presented in table 2.

Clothing laminates made from knitted fabrics

The assortment of laminated knitted garment fabrics includes materials for ladies' and youths' coats, heavy and light jackets for men, ladies' suits, waistcoats, dressing-gowns and children's clothes. The wide variety of end-uses of knitted fabric laminates shows the necessity of using many different textile raw materials. From the point of view of the strength of the laminate, the use of synthetic polyamide, polyester and polyacrylonitrile fibres and of wool fibres is most advisable.

TABLE 2. TECHNICAL REQUIREMENTS FOR COTTON - TYPE FABRICS INTENDED FOR LAMINATING

Characteristics		*Men's, ladies', youths' and children's coats*		*Men's, ladies', youths' jerkins and light jackets*	
Blend composition		75 % viscose fibres, 25 % polyester fibres			
Yarn thickness (Nm)	warp	36/2	40/2	40/2	
	weft	20/1		20/1	24/1
Number of threads per 10 cm (orientational)	warp	210—235		215—240	
	weft	200—225		205—230	
Weight (g/m²)		230—250		200—220	
Weave		←— Any short weave —→			
Finish		*Waterproofing* Finishing variants: (a) smooth (singeing, clipping) (b) fluffing (c) light raising			
Minimum tensile strength (kg)	warp	←— 40 —→			
	weft	←— 40 —→			
Maximum shrinkage after wetting (per cent)	warp	←— 4 —→			
	weft	←— 4 —→			
Fabric width (cm)		←— 144 —→			

In connexion with the need to reduce the weight of the knitted fabric, which is done by decreasing its density and by using finer yarn, it is most advisable to use constructions that guarantee good filling of the knitted fabric. Knitted fabrics that are insufficiently filled do not become covered completely with the foam, and this significantly lowers the aesthetic qualities of the laminate. Moreover, an increased number of joinings in the knitted fabric gives additional places of contact with the foam, allowing better adhesion. The weight of knitted fabrics intended for laminating is about 30 to 40 per cent lower than that of corresponding conventional knitted fabrics.

By decreasing the density of knitted fabrics intended for laminating, their susceptibility to excessive shrinkage is increased. In order to avoid the deformation of garments made from laminated knitted fabrics, 6 per cent is considered as the maximum admissible indicator of shrinkage before laminating. The shrinkage of a laminate is less than that of a knitted fabric by 1 or 2 per cent.

The wearing qualities of laminates made from knitted fabrics are good, and in some cases even better than those made from woven fabrics. Consequently, the prospects for the development of this branch of the production of laminates are great.

The technical requirements for knitted fabrics intended for laminating are presented in table 3.

Quality requirements for foam-backed garments

The usefulness of garments made from laminated fabrics depends upon the characteristics of both the textile fabric and the foam and upon the durability of their bonding.

Laminates intended for use in coats should have 2 mm of foam. For other garments, foam of a thickness of 1.5 mm is sufficient.

Table 4 shows the basic requirements for garment laminates, taking into consideration their technological indicators (bond durability), wear indicators (shrinkage, crease-resistance, permeability to water) and quality indicators (permissible disappearance of the foam). The water-permeability indicator concerns only waterproofed articles.

Laminated textile products used in furnishing living quarters

Carpets and rugs laminated with polyurethane foam have high elastic recovery, good adhesion to floors and increased sound-proofing qualities. For laminating carpets and rugs, a polyurethane foam with a specific weight of 45 to 60 kg/m^3 may be used, but polyether foam has better elastic recovery after squeezing. The thickness of the foam layer is usually 6 mm. Laminated carpets wear better than conventional ones. Laminated underlays can be used under ordinary carpets.

Decorative fabrics laminated with polyurethane foam intended for curtains have excellent sound-proofing qualities. For this reason, curtains of this kind can be used, for example, to protect rooms in hotels, schools, hospitals and apartments from street noises. The ability of polyurethane foam to deaden sounds makes it useful for lining automobile bodies.

TABLE 3. TECHNICAL REQUIREMENTS FOR KNITTED FABRICS INTENDED FOR LAMINATING

Characteristics	*Men's, ladies', youths' and children's coats, jerkins and light jackets*	*Men's, ladies' and children's coats, jerkins and light jackets*	*Sports wear, jerkins, and wind-cheaters*	*Dressing-gowns*	*Blouses and dressing-gowns*
Blend composition: (Anilana-polyacrylonitrile fibres, Merona, Argona-viscose fibres, Polana, Stilon-polyamide fibres)	75 % cotton, 25 % viscose fibres 100 % Anilana 75 % Anilana, 25 % Merona 50 % Anilana, 50 % Merona	30 % wool, 20 % polana, 50 % Argona 100 % Anilana 75 % Anilana, 25 % Argona 50 % Anilana, 50 % Argona	100 % Stilon	100 % viscose silk	50 % Stilon, 50 % viscose silk
			20 den, 40 den	60 den	Stilon 20 den, 40 den viscose silk 60 den
Knitted fabric width	← 128 →				
Number of threads per 10 cm line	64—68	60—65	120—130	90—95	120—130
column	45—48	50—55	80—90	60—65	80—90
Weight (g/m²)	170—200	180—200	70—80	110—120	90—100
Weave	with design	smooth	only slightly stretchable		
Type of machine	Raschel	Suprema	warp		
Number of needle sheaths	30	20	26		
Kind of finish	(a) smooth (b) fluffed (c) slightly raised, clipped		water-proofed	printed	(a) single coloured (b) printed
Shrinkage after wetting (per cent) in the direction of line	← 6 →				
column	← 6 →				

TABLE 4. QUALITY REQUIREMENTS FOR GARMENT LAMINATES

Characteristics	*Kind of laminate*	
	Woven fabric	*Knitted fabric*
Thickness of foam (mm)		
coats	2.0	2.0
other garment articles	1.5	1.5
Joining strength (g/5 cm)	500.0	400.0
Shrinkage (per cent)	4.0	4.0
Crease-resistance according to a 5-step scale, after 15 minutes (degrees)	3.0	3.0
Permeability to water — rain test (ml)	0	0
Permissible disappearance of thickness of 1.5 mm foam during laminating (mm)		
for quality I	0.50	0.50
for quality II	0.70	0.70
for quality III	0.85	0.85
Permissible disappearance of thickness of 2 mm foam during laminating (mm)		
for quality I	0.60	0.60
for quality II	0.80	0.80
for quality III	0.95	0.95

Furniture fabrics may be laminated with polyurethane foam to improve their elastic properties, which in effect decreases their permanent deformation in use. The textile component of these laminates should be lighter than conventional fabrics used for this purpose because, if the fabric is too heavy, the thin layer of foam (2 to 3 mm) does not improve its elasticity.

The maintenance of laminated garments

Polyether foams are not very resistant to the action of solvents used in chemical cleaning, thus articles laminated with this foam should only be washed. However, articles laminated with polyester foam can be either washed or chemically cleaned, depending upon the properties of the fabric layer.

Washing

Laminated articles can be washed with all detergents normally used for delicate articles. Detergents, including ionic ones, should be used in the proportion of

5 g/litre. Synthetic detergents should be used in amounts depending on their concentration. The optimal washing temperature is 40°C.

Laminated articles with a woven fabric or knitted fabric of natural or artificial cellulose fibres on the outer surface should be washed by hand, by squeezing (laminates of knitted fabrics) or with the use of a soft brush (laminates of knitted fabrics and woven fabrics). They should next be rinsed two or three times in warm, soft water and once again in unsoftened cold water.

Laminated articles whose outer surface is a woven or knitted fabric made entirely or partially of synthetic fibres should be washed mechanically with a large ratio of detergent solution to the weight of the dry article. For rotary washers it should be 50 : 1, and the optimal washing time is 5 minutes. Laminates of this kind can also be washed by hand, by squeezing or with a soft brush. Rinsing is done in the same way as for laminates made from woven or knitted fabrics of cellulose fibres.

Laminated articles should be centrifuged in a not-overloaded centrifuge at 1,500 rev/min or squeezed without twisting and dried while hanging or spread out in a temperature of 20° to 60°C.

Laminated articles are ironed in steam presses or with an iron under a protective piece of linen at a temperature range between 150° and 160°C.

Chemical cleaning

Laminated fabrics with high susceptibility to shrinkage and articles heavily soiled with grease should be cleaned chemically. Perchloroethylene or white spirit with an added chemical cleaning agent should be used.

The articles should be cleaned in a clean, cold (20° to 25°C) solvent that is filtered during cleaning. The duration of each operation depends on the kind of fibre used in the outer surface of the laminate and on the capacity and nature of the cleaning appliances.

In the case of laminates made from woven or knitted fabrics composed of synthetic fibres, the cleaning time is half that used normally for conventional woollen articles. The optimal centrifuging time is 3 to 5 minutes at 400 rev/min. Drying is done in the chemical cleaning equipment. The drying time should be between 10 and 16 minutes at a temperature up to 60°C. Ironing is done in exactly the same way as after washing, as described above.

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