Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2152675 C 2005/04/12

(11)(21) 2 152 675

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 1994/01/19
(87) Date publication PCT/PCT Publication Date: 1994/08/04
(45) Date de délivrance/Issue Date: 2005/04/12
(85) Entrée phase nationale/National Entry: 1995/06/26
(86) N° demande PCT/PCT Application No.: US 1994/000737
(87) N° publication PCT/PCT Publication No.: 1994/017229
(30) Priorité/Priority: 1993/01/25 (08/009923) US

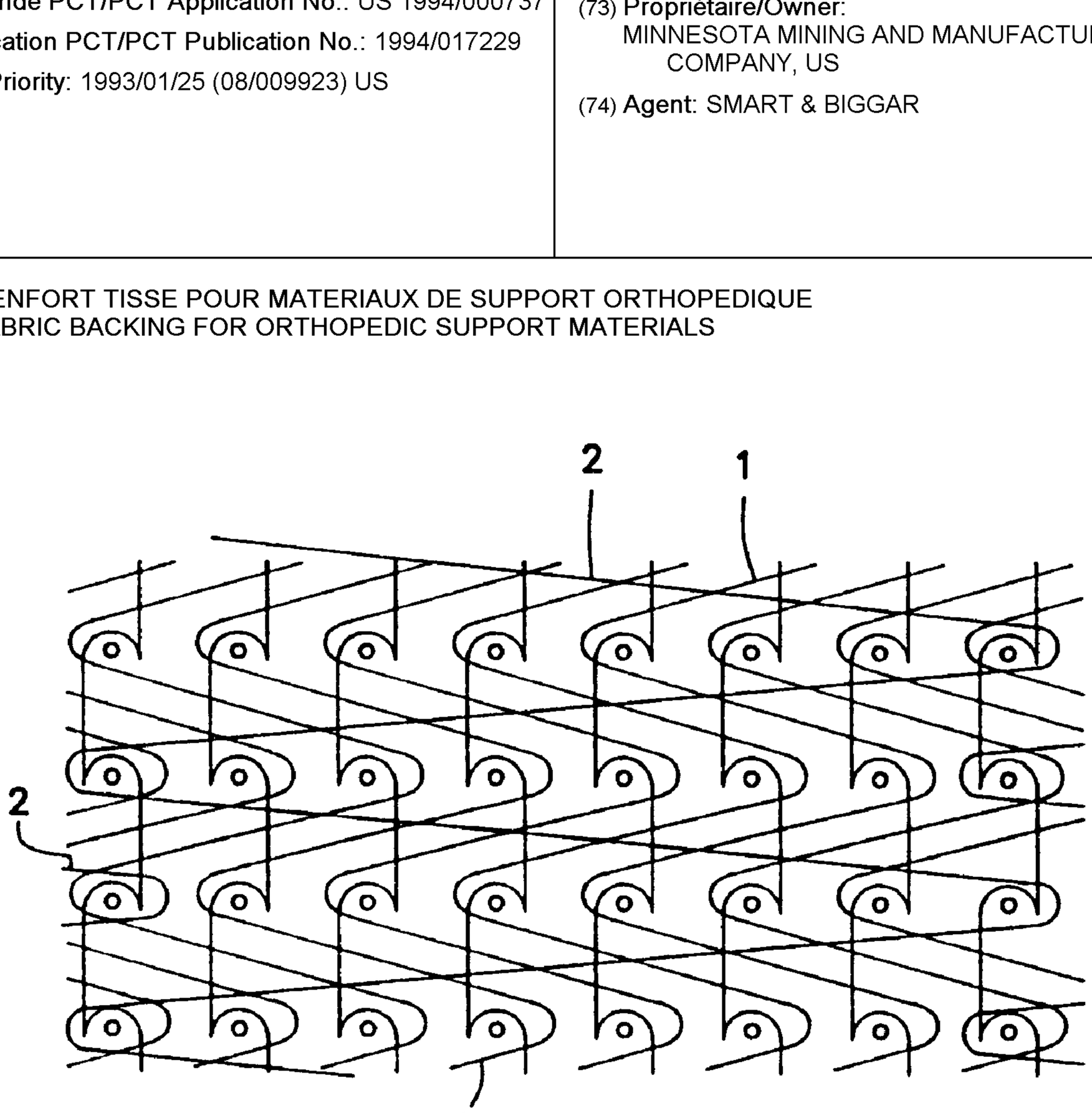
(51) Cl.Int.^{6}/Int.Cl.^{6} D04B 21/00

(72) Inventeurs/Inventors:
SCHOLZ, MATTHEW T., US;
TOCHACEK, MIROSLAV, US;
EDGAR, JASON L., US

(73) Propriétaire/Owner:
MINNESOTA MINING AND MANUFACTURING COMPANY, US

(74) Agent: SMART & BIGGAR

(54) Titre : RENFORT TISSE POUR MATERIAUX DE SUPPORT ORTHOPEDIQUE
(54) Title: FABRIC BACKING FOR ORTHOPEDIC SUPPORT MATERIALS



(57) Abrégé/Abstract:
The present invention provides a unique knit construction having a non-fiberglass microdenier yarn in the fabric of the backing. Preferably, the non-fiberglass microdenier yarn (1)is used in combination with a heat shrinkable yam or a stretch yarn, and alternatively a non-fiberglass yarn for controlling stiffness, i.e., a stiffness-controlling yarn (2). More preferably, the non-fiberglass microdenier yarn is in combination with a stretch yarn and a non-fiberglass stiffness-controlling yarn. Most preferably, the non-fiberglass microdenier yarn (1) is in combination with a heat shrinkable, elastically extensible yarn, and a non-fiberglass stiffness-controlling yarn (2).

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :
D04B 21/00

A1

(11) International Publication Number: WO 94/17229

(43) International Publication Date: 4 August 1994 (04.08.94)

(21) International Application Number: PCT/US94/00737

(22) International Filing Date: 19 January 1994 (19.01.94)

(30) Priority Data:
08/009,923 25 January 1993 (25.01.93) US

(71) Applicant: MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

(72) Inventors: SCHOLZ, Matthew, T.; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). TOCHACEK, Miroslav; P.O. Box 33427, Saint Paul, MN 55133-3427 (US). EDGAR, Jason, L.; P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

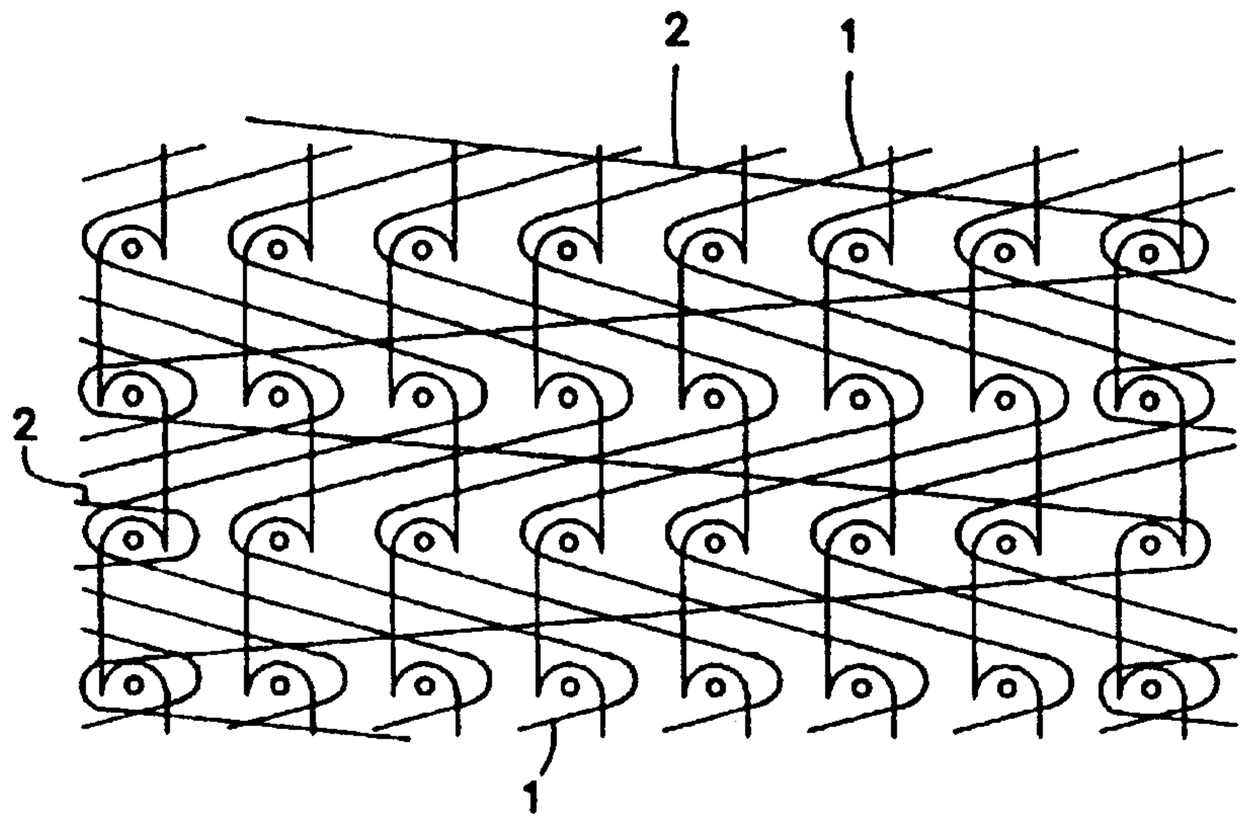
(74) Agents: UBEL, F., Andrew et al.; Office of Intellectual Property Counsel, Minnesota Mining and Manufacturing Company, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).

(81) Designated States: AU, CA, CN, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

2152675

(54) Title: FABRIC BACKING FOR ORTHOPEDIC SUPPORT MATERIALS



(57) Abstract

The present invention provides a unique knit construction having a non-fiberglass microdenier yarn in the fabric of the backing. Preferably, the non-fiberglass microdenier yarn (1)is used in combination with a heat shrinkable yarn or a stretch yarn, and alternatively a non-fiberglass yarn for controlling stiffness, i.e., a stiffness-controlling yarn (2). More preferably, the non-fiberglass microdenier yarn is in combination with a stretch yarn and a non-fiberglass stiffness-controlling yarn. Most preferably, the non-fiberglass microdenier yarn (1) is in combination with a heat shrinkable, elastically extensible yarn, and a non-fiberglass stiffness-controlling yarn (2).

FABRIC BACKING FOR ORTHOPEDIC SUPPORT MATERIALS

Field of the Invention

The present invention relates to knit fabrics. More specifically, the present invention relates to knit fabrics used as backings for orthopedic immobilization devices such as orthopedic casting tapes.

Background of the Invention

Current orthopedic immobilization or support materials, e.g., casting tapes, are composed of a fabric backing and a curable compound such as plaster-of-paris or a synthetic resinous material. The fabric used in the backing serves several important functions. For example, it provides a convenient means of delivering the curable compound. It also helps reinforce the final composite cast. Furthermore, for an orthopedic casting material that incorporates a curable resin, use of a backing material with numerous voids, i.e., a backing with an apertured configuration, ensures adequate porosity. This allows a sufficient amount of curing agent, such as water, to contact the resin and initiate cure. This also ensures that the finished cast is porous, breathable, and comfortable for the patient.

The fabric used in many of the backings of orthopedic casting materials on the market is made of fiberglass. Such fiberglass backing materials generally provide casts with strength superior to casts that use synthetic organic fiber knits, gauze, nonwovens, and other non-fiberglass composite backings. Although fiberglass backing materials provide superior strength, they are of some concern to the medical practitioner during the removal of casts. Because casts are removed using conventional oscillatory cast saws, fiberglass dust is typically generated. Although the dust is generally classified as nonrespirable nuisance dust, and therefore not typically hazardous, many practitioners are concerned about the effect inhalation of such fiberglass dust particles may have on their health. Furthermore, although casts containing

fiberglass generally have improved x-ray transparency compared to that of plaster-of-paris casts, the knit structure is visible, which can interfere with the ability to see fine detail in a fracture.

In developing backing materials for orthopedic casts, conformability of the material is an important consideration. In order to provide a "glove-like" fit, the backing material should conform to the shape of the patient's limb receiving the cast. This can be especially difficult in areas of bony prominences such as the ankle, elbow, heel, and knee areas. The conformability of a material is determined in large part by the longitudinal extensibility, i.e., lengthwise stretch, of the fabric.

Conformable fiberglass backings have been developed, however, special knitting techniques and processing equipment are required. To avoid the need for special techniques and equipment, non-fiberglass backing materials have been developed to replace fiberglass. However, many of the commercially available non-fiberglass backings, such as those containing polyester or polypropylene, also have limited extensibility, and thus limited conformability. Furthermore, the casts made from low modulus organic fibers are significantly weaker than casts made from a fiberglass casting tape. That is, the modulus of elasticity (ratio of the change in stress to the change in strain which occurs when a fiber is mechanically loaded) for many non-fiberglass materials (about 5-100 g per denier), e.g., polyester (about 50-80 grams per denier), is far lower than that for fiberglass (about 200-300 grams per denier) and as such provides a lower modulus, less rigid, cured composite. For this reason, the resin component of the cured composite needs to support a far greater load than it does when fiberglass fabric forms the backing. Thus, greater amounts of resin are generally required with non-fiberglass backings. This is not desirable because large amounts of curable casting compound may result in resin pooling, high exotherm, and reduced cast porosity.

The extensibility, and thereby conformability, of some fiberglass or polyester knit backing materials has been improved by incorporating elastic yarns into the wales of a chain stitch. The use of a backing that incorporates

highly elastic yarns is not necessarily desirable, however, because of the possibility of causing constriction and further injury to the limb if the casting tape is not carefully applied. The constriction results from a relatively high elastic rebound force. Thus, inelastic or only slightly elastic stretch is preferred. A second characteristic that can be a drawback of these backings is the tendency to wrinkle longitudinally when the backing is extended. This results in decreased conformability and a rough surface.

Thus, a need exists for a backing material that is sufficiently conformable to a patient's limb, has low potential for constriction, resists wrinkling during application, and provides a cured cast that exhibits high strength, rigidity, and porosity. Also, a need exists for a backing material that is radiolucent, e.g., transparent to x-rays, in addition to the above-listed characteristics.

Summary of the Invention

The present invention provides backing materials for impregnation with a resin, i.e., resin-impregnated sheets. These resin-impregnated sheets are particularly useful as orthopedic support materials, i.e., medical dressings capable of hardening and immobilizing and/or supporting a body part. Although referred to herein as resin-impregnated "sheets," such hardenable dressings can be used in tape, sheet, film, slab, or tubular form to prepare orthopedic casts, splints, braces, supports, protective shields, orthotics, and the like. Additionally, other constructions in prefabricated shapes can be used. As used herein, the terms "orthopedic support material," "orthopedic immobilization material," and "orthopedic casting material" are used interchangeably to encompass any of these forms of dressings, and "cast" or "support" is used to include any of these orthopedic structures.

Typically, the backing materials of the present invention are used in orthopedic casting tapes, i.e., rolls of fabric impregnated with a curable casting compound. The backing materials of the present invention provide thin casting tapes that are advantageously wrinkle-free during application. Furthermore, they provide superior conformability and moldability without excessive elasticity.

Preferably, the backing materials of the present invention are made from a non-fiberglass-containing fabric. The preferred non-fiberglass backing materials provide superior resin holding capacity compared to other non-fiberglass and fiberglass backing materials. In this way, when coated with resin formulations, the preferred non-fiberglass backing materials of the present invention have the strength and durability of conventional fiberglass casts while remaining radiolucent, e.g., transparent to x-rays.

These and other advantageous characteristics are imparted by the use of a unique knit construction having a non-fiberglass microdenier yarn in the fabric of the backing. Preferably, the non-fiberglass microdenier yarn is used in combination with a stretch yarn, preferably a heat shrinkable yarn. In alternative preferred embodiments, the non-fiberglass microdenier yarn can be used in combination with a non-fiberglass yarn for controlling stiffness, i.e., a stiffness-controlling yarn. More preferably, the non-fiberglass microdenier yarn is in combination with a stretch yarn and a non-fiberglass stiffness-controlling yarn. Most preferably, the non-fiberglass microdenier yarn is in combination with a heat shrinkable, elastically extensible yarn and a non-fiberglass stiffness-controlling yarn. The stiffness-controlling yarn is preferably a monofilament yarn. The monofilament yarn is generally inelastic having a modulus of about 5-100 grams per denier, and preferably about 15-50 grams per denier.

This combination of yarns is used in a unique knit structure that has the heat shrinkable yarn or stretch yarn in the wales of the chain stitch, the microdenier yarn in the weft in-lay, and the stiffness-controlling yarn, preferably monofilament yarn, also in the weft as a weft insertion. Although this combination of yarns is advantageously used in the backing fabric of an orthopedic support material, it can be used in any application where a highly conformable and moldable fabric is desired.

The fabric is prepared by a warp knitting and heat shrinking process followed by a process by which the fabric is calendared flat to reduce thickness. That is, once the yarns are knitted into the desired configuration, the fabric thickness is reduced by passing it through a hot pressurized set of

calendar rollers to iron the fabric. In certain embodiments, the knit structure is further annealed in a heating cycle to set the stiffness-controlling yarn in a new three-dimensional configuration.

According to one aspect of the present invention, there is provided a resin-coated sheet material comprising: (a) a knit fabric comprising a non-fiberglass microdenier yarn of no greater than about 1.5 denier; and (b) a curable resin coated on the fabric.

According to another aspect of the present invention, there is provided a resin-coated sheet material comprising: (a) a knit fabric comprising a non-fiberglass stiffness-controlling yarn having a modulus of greater than about 5 grams per denier; and (b) a curable resin coated on the fabric.

According to still another aspect of the present invention, there is provided a resin-coated sheet material comprising: (a) a knit fabric comprising an organic-filament yarn, wherein the fabric has been calendared; and (b) a curable resin coated on the fabric.

According to yet another aspect of the present invention, there is provided a warp knit fabric comprising: (a) a chain stitch of a stretch yarn; (b) a weft in-lay of a non-fiberglass microdenier yarn of no greater than about 1.5 denier; (c) a weft insertion of a non-fiberglass stiffness-controlling yarn having a modulus of greater than about 5 grams per denier.

According to another aspect of the present invention, there is provided a resin-coated sheet material comprising: (a) an extensible knit fabric comprising different non fiberglass yarn components; and (b) a curable resin coated on the fabric, wherein one of the yarn components is a non-fiberglass micro-

denier yarn of up to 1.65 dtex (1.5 denier), and wherein the knit fabric has an extensibility of 15-100% measured 1 minute after applying a load of 0.26 N per mm.

According to a further aspect of the present invention, there is provided a method of making the warp knit fabric as described herein, the method comprising the steps of: (a) knitting the stretch yarn, microdenier yarn, and stiffness-controlling yarn with a three-bar warp knitting machine; (b) shrinking the fabric; and (c) calendaring the fabric to reduce the thickness of the fabric.

According to yet a further aspect of the present invention, there is provided a method of preparing an orthopedic support material comprising impregnating a water-curable resin in a flexible substrate comprising a fabric incorporating a stretch yarn, a microdenier yarn, and a stiffness-controlling yarn.

Brief Description of the Drawings

Fig. 1a is a schematic of a chain stitch in a three bar warp knit construction.

Fig. 1b is a schematic of a weft in-lay in a three bar warp knit construction.

Fig. 1c is a schematic of a weft insertion in a three bar warp knit construction.

Fig. 1d is a schematic of a three bar warp knit construction of a preferred fabric of the present invention.

Fig. 2 is a schematic of an alternative embodiment of a fabric having a long weft insertion using 3 individually inserted yarns along the width of the fabric.

Fig. 3 is a schematic of an alternative embodiment of a fabric having a long weft insertion using 6 individually inserted yarns along the width of the fabric.

Fig. 4a is a detailed view of a schematic of a long weft insertion showing the insertion of two yarns laid by adjacent tubular lapping guide elements under the same knitting needle forming one vertical wale of chain stitch.

Fig. 4b is a detailed view of a schematic of a long weft insertion showing an alternative insertion of two yarns laid into two adjacent wales of chain stitch.

Fig. 5 is a schematic of a hand testing fixture with a piece of fabric in position for testing.

Fig. 6 is a graph of the hand testing results (in grams per 8.2 cm width of sample material) for fiberglass containing fabric (SC+), fabric made from polyester microdenier yarn (PE), and fabric made from polyester microdenier yarn and nylon monofilament yarn (PE + mono).

Fig. 7 is a schematic of a preferred process of the present invention for making a fabric out of a heat shrinkable yarn, a microdenier yarn, and a monofilament yarn.

Detailed Description of the Invention

The present invention provides a resin-impregnated sheet material, preferably for use as a backing component of an orthopedic immobilization material such as a casting tape. The backing component acts as a reservoir for a curable casting compound, e.g., a resinous material, during storage and end-use application of the casting tape. That is, the fabric used to form the backing of an orthopedic support material, such as a casting tape, is impregnated with a curable resin such that the resin is thoroughly intermingled with the fabric fibers and within the spaces created by the network of fibers. Upon cure, the resin polymerizes and cures to a thermoset state, i.e., a crosslinked state, to create a rigid structure.

As a result of the fabric used in the backings of the present invention in combination with the preferred resin systems, the backings provide highly extensible orthopedic support materials, e.g., casting tapes, having an extensibility, strength, and durability equivalent to, or superior to, that of conventional fiberglass products. Furthermore, the backing fabrics, i.e., backing materials, of the present invention advantageously provide superior conformability and moldability, without excessive elasticity. Certain preferred fabrics of the present invention also provide increased resin holding capacity relative to conventional fiberglass and non-fiberglass products.

In general, the backing materials of the present invention are constructed from fabrics that are relatively flexible and stretchable to facilitate fitting the orthopedic support material around contoured portions of the body, such as the heel, knee, or elbow. The fabrics of the present invention have an extensibility in the lengthwise direction of about 15-100% after heat shrinking and calendaring (processing steps discussed below), and preferably about 40-60%, when measured one minute after applying a load of 1.50 lb/in (2.6 newtons/cm) width. These extensibility values are all understood to be taken

after calendaring, if a calendaring step is employed. More preferably, the extensibility is about 45-55% after calendaring under this same load. Although above about 55% extensibility some advantage is realized, the greatest advantage is realized in the range of about 45% to about 55% because above 55% the conformability is not significantly increased as compared to the increase in tape thickness, backing density increase, and cost.

The fabrics used in the orthopedic support materials of the present invention must have certain ideal textural characteristics, such as surface area, porosity, and thickness. Such textural characteristics effect the amount of resin the backing can hold and the rate and extent to which the curing agent, e.g., water, comes in contact with the bulk of the curable resin impregnated in the fabric. For example, if the curing agent is only capable of contacting the surface of the resin, the major portion of the resin would remain fluid for an extended period resulting in a very long set time and a weak cast. This situation can be avoided if the resin layer is kept thin. A thin resin layer, however, is typically balanced against the amount of resin applied to the fabric to attain sufficient rigidity and formation of sufficiently strong bonding between layers of tape. A thin resin layer can be achieved at appropriate resin loadings if the fabric is sufficiently thin and has a relatively high surface-to-volume ratio in a porous structure.

The thickness of the fabric is not only optimized in view of the resin loading and resin layer thickness, but also in view of the number of layers in a cast. That is, the thickness of the fabric is balanced against the resin load, resin layer thickness, and number of layers of tape in a cast. Typically, a cast consists of about 4-12 layers of overlapping wraps of tape, preferably about 4-5 layers in nonweight-bearing uses and 8-12 layers in weight-bearing areas such as the heel. Thus, a sufficient amount of curable resin is applied in these few layers to achieve the desired ultimate cast strength and rigidity. The appropriate amount of curable resin can be impregnated into the backing of the present invention using fabrics having a thickness of about 0.05-0.15 cm. Preferably, the fabrics are thin, i.e., having a thickness of less than about 0.13 cm. More preferably, the fabrics of the present invention have a

thickness of about 0.076-0.10 cm measured using an Ames Gauge Co. (Waltham, MA) 202 thickness gauge with a 2.54 cm diameter contact.

The fabrics of the present invention are apertured, i.e., mesh fabrics. That is, the fabrics have openings that facilitate the impregnation of the curable resin and the penetration of the curing agent, e.g., water, into the fabric. These openings are also advantageous because they allow for air circulation and moisture evaporation through the finished cast. Preferably, the fabrics of the present invention have about 6-70 openings per square centimeter. More preferably, there are about 19-39 openings per square centimeter. An opening is defined as the mesh equivalent of the knit. The number of openings is obtained by multiplying the number of wales per cm (chain stitches along the lengthwise direction of fabric) by the number of courses (i.e., rows that run in the cross direction of fabric).

In one embodiment, these and other advantageous characteristics are imparted to the fabric in part through the use of a unique knit construction having a non-fiberglass microdenier yarn in the fabric of the backing. Preferably, the non-fiberglass microdenier yarn is used in combination with a stretch yarn, preferably a heat shrinkable yarn. In alternative preferred embodiments, the non-fiberglass microdenier yarn can be used in combination with a non-fiberglass stiffness-controlling yarn. More preferably, the non-fiberglass microdenier yarn is in combination with a stretch yarn and a non-fiberglass stiffness-controlling yarn. Most preferably, the non-fiberglass microdenier yarn is in combination with a heat shrinkable, highly extensible yarn, and a non-fiberglass stiffness-controlling yarn. Thus, the most preferred fabrics of the present invention do not contain fiberglass yarns. In another alternative embodiment a non-fiberglass stiffness-controlling yarn is used in a conventional resin coated knit fabric to reduce wrinkling of the fabric during application.

This preferred combination of yarns is used in a unique knit structure. The preferred fabric is prepared by a three-bar warp knitting process. A front bar executes a chain stitch with a stretch yarn, preferably a heat shrinkable yarn. A back bar lays in a microdenier yarn, and the middle bar lays in a

stiffness-controlling yarn, preferably a monofilament yarn. A back and middle bars can lay in yarns over any number of needles. This is generally only controlled by the limits of the knitting machine. Generally, the stiffness-controlling yarn is laid in under more needles than the microdenier yarn, and is therefore referred to as a weft insertion. Furthermore, the in-lay yarns can be overlapping or nonoverlapping. That is, each in-lay yarn can be inserted with or without overlapping of other in-lay and/or insertion yarns, i.e., other stiffness-controlling yarns or microdenier yarns. As used herein, an "overlapping" configuration is one in which multiple yarns pass through a single loop of the wale stitch.

Referring to Figs. 1a-d, the knit structure is preferably a three bar warp knit construction. The first lapping bar puts the stretch yarn, preferably the heat shrinkable yarn, in the wales of a chain stitch (Fig. 1a). The lapping order for each yarn is /1-0/0-1/. The second lapping bar puts the microdenier yarn in as a weft in-lay (Fig. 1b). The lapping order for each yarn is preferably /0-0/3-3/. The third lapping bar puts the stiffness-controlling yarn, preferably monofilament yarn, also in the weft, i.e., as a weft insertion (Fig. 1c). The lapping order for each yarn is preferably /7-7/0-0/. A preferred composite three bar warp knit construction is represented by the schematic of Fig. 1d. In this composite, the weft in-lay yarn(s) (1), i.e., the microdenier yarn in this preferred embodiment, and the weft insertion yarn(s) (2), i.e., the stiffness-controlling yarn in this preferred embodiment, are laid in from opposite directions.

As stated above, a basic function of the backing in an orthopedic immobilization material, such as a casting tape, is delivery of the curable casting compound, e.g., resin. The amount of curable casting compound delivered must be sufficient such that adequate layer to layer lamination is achieved, but should not be too great so as to result in resin "pooling" to the bottom of the roll under the force of gravity. Because the modulus of elasticity, i.e., modulus, for non-fiberglass fabrics such as polyester is far lower than that for fiberglass, polyester backings provide little support to the

cured composite. Thus, the non-fiberglass backing needs to hold a greater amount of resin per unit area in order to achieve fiberglass-like strength.

The fabrics of the present invention are capable of holding a sufficiently large amount of resin while not detrimentally effecting the porosity and conformability of the casting material. In addition, preferred fabrics containing microdenier yarns are expected to provide clearer and more vivid printed fabrics than can be obtained with conventional casting tapes. This is believed to be due to the higher surface area of the microdenier yarn.

An alternative method of increasing the ability of the knit fabrics of the invention to hold resin is by texturizing. The texturized fabrics may be obtained by texturizing them into the fabric after knitting or by texturizing the fabric before knitting. Preferably the yarn is texturized before the fabric is knit. Various methods of texturizing are known to those skilled in the art and are described, e.g. in Introductory Textile Science, Fifth Edition (1956) by M.L. Joseph (Holt, Rinehart and Winston, New York). These methods include steam or air jet treatment, various twisting techniques such as the false twist method, gear crimping, the stuffer box method, the knife edge method, draw texturizing and the like. Preferably air jet treatment is used.

Non-fiberglass yarns formed from very small diameter fibers or filaments, i.e., no greater than about 1.5 denier, are used in the present invention. These yarns are referred to herein as non-fiberglass "microdenier" yarns. Herein, microdenier yarns are those having a diameter of no greater than about 1.5 denier, which is a slightly larger diameter than is used in the generally accepted definition of microdenier yarns. Preferably, the non-fiberglass microdenier yarns used in the present invention are formed from fibers or filaments having a diameter of no greater than about 1.0 denier. These yarns contribute to a fabric that is very conformable and moldable with an extremely soft "hand," i.e., flexibility. Fabrics made from entirely these yarns produce an almost silk-like feel with excellent drapeability. Such a fabric is useable as a backing in an orthopedic support material.

The microdenier yarns can be made of any organic staple fiber or continuous filament of synthetic or natural origin. Suitable staple fibers and

filaments for use in the microdenier yarn include, but are not limited to, polyester, polyamide, polyaramid, polyolefin, rayon, halogenated polyolefin, copolymers such as polyether esters, polyamide esters, as well as polymer blends. Preferably, the microdenier yarns are made of rayon and polyester, which are available from several manufacturers, including BASF Fibers (Williamsburg, VA), DuPont (New York, NY), and Dixie Yarns (Charlotte, NC). Rayon and polyester microdenier yarns are commercially available in both staple and continuous filament form, as well as in partially oriented yarn filaments and fully oriented staple yarns.

More preferably, the microdenier yarns are made of polyester fibers or filaments. Generally, this is because polyester yarns are relatively inexpensive, currently available, and regarded as relatively safe and environmentally friendly. Furthermore, polyester yarns do not require drying prior to coating with a water curable resin due to a low affinity for atmospheric moisture, and they have a high affinity for most resins. One particularly preferred yarn is an 18/2 polyester spun yarn with a filament diameter of 1.2 denier, which is available from Dixie Yarns (Charlotte, NC).

The microdenier yarns used in the present invention can be made of a combination of two or more types of the above-listed fibers or filaments. The filaments or staple fibers can be partially oriented and/or texturized for stretch, if desired. Furthermore, if desired dyed microdenier yarns can be used.

Microdenier yarns can be combined with yarns made from fibers or filaments of larger diameter. These larger diameter yarns can be of either synthetic, natural, or inorganic origin. That is, the microdenier yarns can be combined with larger polyester, polyamide, polyacrylonitrile, polyurethane, polyolefin, rayon, cotton, carbon, ceramic, boron, and/or fiberglass yarns. For example, these microdenier yarns could be knit in as the in-lay, i.e., as a weft partial in-lay, with fiberglass yarn in the wale, i.e., chain stitch. If fiberglass yarns are used, typically only about 40-70% of the total weight of the fabric results from the fiberglass component.

The microdenier yarn is preferably made into a warp knit configuration. In a backing fabric having only microdenier yarns, both the weft and the wale are composed of microdenier yarns. Example 1 illustrates one such embodiment. Such a knit can have about 3.9-9.8 wales/cm and about 2.0-9.8 stitches/cm. In general, the number of stitches/cm in fabrics of the present invention can vary depending upon the yarns used and the gauge of the needle bed. Preferably, the fabrics have about 1.2-9.8 stitches/cm, more preferably about 1.6-5.9 stitches/cm, and most preferably about 2.0-3.9 stitches/cm.

Because most microdenier yarns currently on the market are not texturized for stretch, they are inelastic yarns with very little stretch. If used in the wale, i.e., chain stitch, running along the length of the fabric, they limit conformability by limiting the extensibility of the fabric. If texturized microdenier yarns, i.e., stretchable microdenier yarns, are used in combination with nontexturized microdenier yarns, the texturized microdenier yarns are used in the wale, i.e., chain stitch, and the nontexturized microdenier yarns are used in the weft.

Fabric containing microdenier yarns can be made extensible by a number of methods, however. For example, extensibility may be imparted by microcreping as described in U.S. Patent No. 5,405,643. The microcreping of said invention requires mechanical compacting or crimping of a suitable fabric, generally a naturally occurring organic fiber or preferably a synthetic organic fiber. The fibers may be knits, wovens or nonwovens, e.g., spun laced or hydroentangled nonwovens. The process requires mechanical compacting or crimping followed by annealing.

Alternatively, stretch yarns, such as elastic stretch yarns or thermoplastic stretch yarns, can be used along the length of the fabric, preferably in the wale, to impart extensibility. Elastic stretch yarns, such as Lycra, Spandex, polyurethanes, and natural rubber, could be used as described in U.S. Patent No. 4,668,563 (Buese) and placed in the knit as an in-lay, preferably across one needle. Thermoplastic stretch yarns, such as

polyesters and polyamides, could also be used as described in U.S. Patent No. 4,940,047 (Richter et al.).

In one embodiment, an elastic stretch yarn is knitted into the fabric under tension to provide some degree of compaction as the knit relaxes off the knitting machine. Desirable elastic stretch yarns are those of low denier, i.e., no greater than about 500 denier, preferably less than 300 denier. Such low denier elastic stretch yarns do not have as much rebound as higher denier stretch yarns. Furthermore, these yarns are characterized as having elasticity modulus of 0.02 to 0.25 grams per denier and an elongation of 200-700 percent. Suitable stretch yarns include threads of natural rubber and synthetic polyurethane such as Spandex™ and Lycra™. Thus, orthopedic casting materials containing such elastic stretch yarns have lower constriction capacity. When elastic stretch yarns are used in combination with microdenier yarns, highly conformable, highly moldable, highly elastic, composite fabrics with high resin holding capacity result.

Another method by which the conformability of the fabric containing the microdenier yarn can be improved involves using highly texturized, heat shrinkable, extensible, thermoplastic yarns. These elastic properties of these yarns are based on the permanent crimping and torsion of the threads obtained in the texturizing process and are achieved as a result of the thermoplastic properties of the materials. All types of texturized filaments can be used, such as, for example, highly elastic crimped yarns, set yarns, and highly bulk yarns. The use of this type of yarn is preferred over the use of elastic yarns because the degree of elastic rebound force in the fabric is kept very low with heat shrinkable yarns. This minimizes the chance for constriction and further injury to the limb due to too tightly applied casting tapes.

The use of a heat shrinkable yarn in the lengthwise direction, preferably in the wale, of the fabric containing microdenier yarn provides sufficient stretch to the fabric without creating too high an elastic rebound force. The heat shrinkable yarn can be a microdenier yarn texturized to be a heat shrinkable yarn using a process as described in U.S. Patent No. 4,940,047 (Richter et al.). Alternatively, and preferably, the heat shrinkable

yarn is one of a higher denier than that of the microdenier yarn. If a heat shrinkable microdenier yarn is used it is preferably in the wale and the nonshrinkable microdenier yarn is inserted as a weft yarn.

After heat treatment, the heat shrinkable yarn shrinks and compacts the fabric. The resulting fabric can then be stretched generally to its preshrunk length, and in many cases beyond the preshrunk length. Thus, the combination of the microdenier yarn and the heat shrinkable yarn, whether a heat shrinkable microdenier or a yarn of larger denier, provides a fabric with sufficient extensibility in the lengthwise direction such that the fabric has a suitable conformability.

The heat shrinkable yarns used in the present invention are highly texturized and elastically extensible. That is, they exhibit at least about 30%, and preferably at least about 40%, stretch. They are preferably composed of highly crimped, partially oriented filaments that contract when exposed to heat. As a result, the fabric is compacted into a shorter, higher density, and thicker backing. The texturized heat shrinkable yarn is composed of relatively large denier fibers or filaments in order to achieve shrinkage forces sufficient to compact the fabric efficiently and to provide additive rebound forces. Preferably, yarn is prepared from fibers or filaments of greater than about 1.5 denier, more preferably greater than about 2.2 denier, which compact the fabric to the desired extent. The heat shrinkable yarn can be made of fibers or filaments of up to about 6.0 denier.

All types of texturized yarns that shrink upon exposure to heat can be used as the heat shrinkable yarn in the backing of the present invention. This can include highly elastic crimped yarns, set yarns, and highly bulky yarns. Upon shrinkage, the heat shrinkable yarns used in the present invention are highly extensible, i.e., greater than about 40%. This results in a fabric that is highly extensible, i.e., greater than about 45-60%, without the use of highly elastic materials.

Suitable thermoplastic heat shrinkable yarns are made of polyester, polyamide, and polyacrylonitrile fibers or filaments. Preferred heat shrinkable yarns are made of polyester and polyamide fibers or filaments. More

preferably, the heat shrinkable yarns are made of polyester fibers or filaments for the reasons listed above for the microdenier yarns.

The fabric may be heated by using sources such as hot air, steam, infrared (IR) radiation, liquid medium, or by other means as long as the fabric is heated to a high enough temperature to allow the shrinkage to occur, but not so high that the filaments or fibers melt. Steam at 10.3 newtons/cm^2 works well, but requires subsequent drying of the fabric. The preferred method for shrinking polyester heat shrinkable yarn uses hot air at a temperature of about 120-180°C, preferably at a temperature of about 140-160°C. The temperature required generally depends on the source of the heat, the type of heat shrinkable yarn, and the time the fabric is exposed to the heat source, e.g., web speed through a fixed length heating zone. Such a temperature can be readily determined by one of skill in the art.

An example of a preferred heat shrinkable, texturized yarn is Power Stretch yarn produced by Unifi (Greensboro, NC). These yarns are composed of highly crimped partially oriented polyester fibers that contract when exposed to heat. They are available in a variety of plies and deniers. Although 300 denier plied Power Stretch yarn can be used, the preferred yarn is a single 150 denier yarn containing 68 filaments, which has 46% stretch and is available from Dalton Textiles Inc. (Chicago, IL). The 150 denier yarn is preferred because the recovery or rebound force of the fabric is minimized with this yarn. Furthermore, the 150 denier yarn results in a lower fabric density, which allows for a thinner more conformable backing and lowers the total resin usage, thereby reducing the amount of heat generated upon cure.

Once the fabric is heated to allow it to shrink, the fabric density, and thereby thickness, can increase substantially. In some cases the fabric thickness can increase to over 0.140 cm. Preferably, the fabric is kept thin, e.g., less than about 0.13 cm, and more preferably at about 0.076-0.10 cm.

If the fabric is too thick, the thickness can be reduced by passing the fabric through a hot pressurized set of calendar rollers, i.e., two or more rollers wherein one or more can be heated rollers that are turning in opposite directions between which fabric is passed under low tension, thereby

compressing, or "calendaring," the fabric. This process creates thinner fabrics that result in smoother, less bulky casts. Care should be taken to prevent over "calendaring" the fabric, which could result in dramatic stretch loss, i.e., a undesirable reduction in the extensibility.

It is not desirable to reduce the fabric thickness too dramatically because this can result in significantly less resin holding capacity. Preferably the thickness is not reduced by more than about 70%, more preferably by more than about 50%, and most preferably by more than about 30% of the original thickness of the fabric. In addition, the calendaring process advantageously provides some added stiffness in the cross web direction which reduces the tendency of the fabric to wrinkle during application.

Although it is conceivable to heat shrink and "iron" the fabric in a single step using hot calendar rollers, it is preferable to first heat shrink the fabric and then pass it through the "ironing" step. The ironing, i.e., calendaring, may be accomplished using wet or dry fabric or through the use of added steam. Preferably, the ironing is performed on dry fabric to avoid subsequent drying operations necessary prior to application of a water curable resin. In order to attain maximum extensibility in the finished product, it is desirable to fully heat shrink the fabric prior to the hot calendaring operation. If the fabric is only heat shrunk partially and then "ironed," the fabric may not have a sufficient extensibility. Furthermore, the fabric may not be able to be subsequently heat shrunk to any significant degree.

Although the ironing process helps reduce wrinkling of the fabric during application, it does not eliminate it. Since preferred fabrics of the present invention use relatively low modulus organic yarns (in contrast to fiberglass), wrinkles can form during application. Wrinkles form especially when the tape is wrapped around areas where the anatomy changes shape rapidly or where the tape needs to change direction, e.g., at the heel, elbow, wrist, etc. In order to eliminate, or at least reduce, the amount of wrinkling in lower modulus tapes, the present invention preferably uses an added weft insertion of a yarn for stiffness control.

The stiffness-controlling yarn provides a means of maintaining a flat web in the cross direction during application without decreasing resin holding capacity. It can also contribute to increased extensibility of the fabric. The stiffness-controlling yarn is preferably made of a type of fiber or filament that has low shrinkage properties, i.e., less than about 15% shrinkage, i.e., preferably less than about 5%. Thus, there is little width contraction of the tape during the heat shrinking process when heat shrinkable texturized crimped yarns are used in the wale. If used in combination with nonheat shrinkable yarns, such as elastic stretch yarns, this is not necessarily a requirement.

The stiffness-controlling yarn can be made of any fiber or filament having sufficient stiffness to prevent wrinkling and add dimensional stability. It can be a multifilament or a monofilament yarn. Preferably it is a monofilament yarn, i.e., a yarn made from one filament. As used herein "sufficient stiffness" refers to yarns having a modulus of greater than about 5 grams per denier, preferably greater than about 15 grams per denier, and a denier of at least about 40, preferably at least about 100 denier. Furthermore, these yarns generally exhibit only 100% elastic recovery at percent strains up to about 5 to 10%.

Suitable multifilament yarns are made from filaments of large denier, i.e., greater than about 5 denier per filament, and/or are highly twisted yarns. The stiffness-controlling yarn, whether monofilament or multifilament, is preferably about 40-350 denier, more preferably about 80-200 denier, and most preferably about 160-200 denier.

. Suitable filaments for use in the monofilament yarn include, but are not limited to, polyester, polyamide such as nylon, polyolefin, halogenated polyolefin, polyacrylate, polyurea, polyacrylonitrile, as well as copolymers, polymer blends, and extruded yarns. Cotton, rayon, jute, hemp, and the like can be used if made into a highly twisted multifilament yarn. Yarns of round, multilobal, or other cross-sectional configurations are useful. Preferably, the monofilament yarn is made of nylon or polyester. More preferably, the monofilament yarn is made of nylon. Most preferably, the nylon

monofilament yarn is of about 80-200 denier and has less than about 5% shrinkage.

The stiffness-controlling yarn can be used to advantage as an added weft insertion in backings that do not comprise microdenier yarns. This is particularly desirable in knit fabrics that tend to drape and wrinkle more easily than conventional fiberglass backings. Likewise, the use of a monofilament yarn can also be used to advantage as an added weft insertion in fiberglass backings. This is particularly desirable in nonheat-set fiberglass backings that tend to drape and wrinkle more easily than conventional fiberglass backings. The use of a monofilament yarn in combination with fine filament fiberglass yarns, such as ECDE and ECC yarns or even finer yarns, is also particularly desirable.

The stiffness-controlling yarn can be laid in across 1-9 cm, depending on the type of knitting machine used, continuously or discontinuously across the width of the tape, and in any number of configurations. In a weft insertion, the stiffer yarn is inserted by the separate system of tubular yarn guides by reciprocal movement in the cross direction to the fabric. This is generally done under more needles in every stitch than the conventional system containing spun yarn or multifilament microdenier fiber yarns which creates the base knit structure in combination with the chain stitch. The long weft insertion is perpendicular to the chain stitch wale direction and is locked inside the base knit structure together with the yarn of the base short weft in-lay system. It is preferably positioned to ensure a nonwrinkling fabric while allowing for cross web and bias extensibility. For example, each stitch can include a single end, i.e., a yarn made of one strand, of monofilament or multiple ends depending on the number of ends of monofilament yarn employed and the number of needles over which they cross.

The stiffness-controlling yarn can be inserted in one or more segments of various lengths with or without overlapping of other weft yarns, i.e., other stiffness-controlling yarns or microdenier yarns. The preferred configuration is one in which there is no overlapping of the weft insertion yarns.
Preferably, the stiffness-controlling yarn is inserted across 3-25 needles.

More preferably, the stiffness-controlling yarn is laid in across 7 needles in a 6 gauge knit (6 needles/cm) without overlapping. Most preferably, the stiffness-controlling yarn is not laid in across the outermost needles but is inset at least one needle from the edge, more preferably at least two needles from the edge. This is to reduce the chances that loops of the stiffness-controlling yarn will "stick out" from the edge of the fabric (e.g., as a result of an optional compaction of the fabric). It has been observed that cured fabrics having protruding loops of stiffness-controlling yarns can feel sharp or rough to the touch. Insetting these yarns eliminates this problem.

Referring to Fig. 2, three individually inserted stiffness-controlling yarns (1, 2, and 3) can be laid in using a lapping guide system for long weft insertions. As shown, each yarn is laid under 21 knitting needles. In this way, the three yarns (1, 2, and 3) cover a typical bandage width (61 needles). In this embodiment, each two adjacent yarns are inserted in an alternate manner around one needle. That is, weft yarn (1) is laid around the first needle (10) and the twenty-first needle (11); weft yarn (2) is laid around the twenty-first needle (11) and the forty-first needle (12); and weft yarn (3) is laid around the forty-first needle (12) and the sixty-first needle (13). As a result, these long weft insertion yarns are interlocked across the fabric width. More preferably, weft yarn (1) is laid around the second needle (not shown) and the twenty-first needle (11); weft yarn (2) is laid around the twenty-first needle (11) and the forty-first needle (12); and weft yarn (3) is laid around the forty-first needle (12) and the sixtieth needle (not shown). If a bandage width is larger, additional weft yarns could be used.

Alternatively, for the same bandage width, more yarns can be used resulting in shorter segments. This is represented by the schematic of Fig. 3 wherein each of 6 yarns are laid in across 11 needles for a total fabric width equivalent to the fabric represented in Fig. 2. Using the principles of long weft insertion for making the fabrics represented by Figs. 2 and 3, the length of cross web direction segments can be changed. For example, 10 weft insertion yarns can be used across the width of the fabric. In this embodiment, the first weft yarn would be inserted under the first and seventh

needles, the second weft yarn would be inserted under the seventh and thirteenth needles, the third weft yarn would be inserted under the thirteenth and nineteenth needles, etc. More preferably, the first weft yarn would be inserted under the second and eighth needles (i.e., inset from the first needle), the second weft yarn would be inserted under the eighth and fourteenth needles, etc.

Figs. 4a and 4b provide further detailed views of the fabric at the location where adjacent weft insertion yarns overlap. Fig. 4a is a detailed view of a schematic of a long weft insertion showing the insertion of two yarns laid by adjacent tubular lapping guide elements under the same knitting needle joining one vertical wale of chain stitch. This is the manner in which the adjacent weft insertion yarns are oriented in the fabric represented by Figs. 2 and 3. Fig. 4b is a detailed view of a schematic of a long weft insertion showing an alternative insertion of two yarns laid into two adjacent wales of chain stitch. Alternating insertion of two adjacent weft yarns, as shown in Fig. 4a, i.e., one from the left and then one from the right in a subsequent stitch in reverse order into the same wale, allows for balance in the cross-directional tension of these yarns. Furthermore, this prevents the pulling of two adjacent wales of chain stitch apart, which could occur with the fabric represented by the schematic of Fig. 4b, wherein, two weft yarns are inserted into two adjacent wales of chain stitch.

By adjusting the denier of the stiffness-controlling yarn, the number of stiffness-controlling yarns per stitch, and the number of needles each stiffness-controlling yarn crosses, the cross web stability and extensibility can be tailored. For example, higher denier monofilaments or multiple lower denier monofilaments that overlap will result in a backing with higher cross web stiffness. Similarly, the higher the number of needles crossed, the stiffer the backing in the cross web direction. This is balanced with the cross web extensibility desired. For nonoverlapping stiffness controlling insertions, the fewer number of needles traversed, the less cross web stability, but the greater the cross web extensibility.

The short weft in-lay system contains generally the same number of yarns per unit width as the number of needles, e.g., 6 ends per centimeter width in a 6 gauge knit, and can be laid in across the desired number of needles. Preferably, the short weft in-lay is laid in under 3 or 4 needles so every end is locked under 3 or 4 wales of chain stitch and provides the cross web integrity of the backing.

Using the known warp knit structure of base chain stitch, a weft in-lay, and an independent weft insertion, the preferred fabric of the invention includes the microdenier fiber yarn in the shorter weft in-lay system and the stiffness-controlling yarn in the long weft insertion system, with the heat shrinkable yarn in the core chain stitch forming system. This preferred configuration provides significant advantage, particularly when used in orthopedic support materials. That is, for example, the fabric of the present invention has advantageous extensibility, conformability, flexibility, cross web stability, resin loading capacity, etc.

The cross web stability can be determined by measuring the "hand," i.e., flexibility, of a fabric on a Handlometer. As used herein, "hand" refers to the combination of resistance due to the surface friction and flexibility of a fabric. Fig. 5 represents a typical "hand" testing apparatus, as for example a Model #211-300 Twing-Albert Handle-O-Meter. This apparatus measures the flexibility and the resistance due to surface friction of a sample of fabric by detecting the resistance a blade, i.e., a load cell fixture (1), encounters when forcing a sheet of fabric (2) into a slot (3) with parallel edges having a slot width of 0.64 cm.

Fig. 6 illustrates the hand of standard Scotchcast Plus® fiberglass fabric (3M Company, St. Paul, MN) compared to a polyester (PE) fabric without the monofilament yarn (Example 3) and a fabric containing a single 180 denier low shrink nylon monofilament per stitch with each monofilament laid in across 21 needles in a 6 gauge knit (Example 4). Fig. 3 indicates that the cross web "hand" can be increased using the monofilament yarn to a point where the fabric does not wrinkle; however, the "hand" is not increased to a level as high as that of the fiberglass fabric. Thus, a fabric containing the

monofilament yarn has improved conformability relative to a conventional fiberglass fabric. As a result, with a combination of a microdenier weft and an added monofilament weft, a fabric with high resin holding capacity and a soft "hand" that does not wrinkle during application is possible.

As produced, the monofilament is relatively stiff and prefers to remain in a straight orientation. Nevertheless, once it is incorporated into the knit it is forced to zig zag through the knit as it is laid in across the needles. The tendency of the monofilament yarn to return to a straight condition actually puts forces on the knit which will reduce the extensibility and especially the rebound, i.e., the amount of stretch gained on consecutive stretching and relaxing. In order to reverse this tendency, the monofilament is annealed in the "as knit" orientation. In this condition, the monofilament will act as a "spring" and tend to draw the knit back in after it is stretched. After annealing, the preferred orientation is the knitted condition. Since the annealing is done after fully heat shrinking the fabric the preferred orientation is the fully shrunk condition. Therefore, the monofilament after annealing offers a restoring force which will actually increase the rebound.

The fabrics of the present invention can be coated with any curable resin system with which the yarns of the fabric do not substantially react. Preferably the resin is water curable. Water-curable resins include polyurethanes, cyanoacrylate esters, isocyanate functional prepolymers of the type described in U.S. Pat No. 4,667,661. Other resin systems which can be used are described in U.S. Pat. Nos. 4,574,793, 4,502,479, 4,433,680, 4,427,002, 4,411,262, 3,932,526, 3,908,644 and 3,630,194. Preferably, the resin is that described in European Published Application 0407056.

Generally, a preferred resin is coated onto the fabric as a polyisocyanate prepolymer formed by the reaction of an isocyanate and a polyol. The isocyanate preferably is of a low volatility, such as diphenyl-methane diisocyanate (MDI), rather than a more volatile material, such as toluene diisocyanate (TDI). Suitable isocyanates include 2,4-toluene diisocyanate, 2,6-toluene diisocyanate, mixtures of these isomers, 4,4'-diphenylmethane diisocyanate, 2,4'diphenylmethane diisocyanate, mixtures of

these isomers together with possible small quantities of 2,2'-diphenylmethane diisocyanate (typical of commercially available diphenyl-methane diisocyanate), and aromatic polyisocyanates and their mixtures such as are derived from phosgenation of the condensation product of aniline and formaldehyde. Typical polyols for use in the prepolymer system include polypropylene ether glycols (available from Arco under the trade name Arcol® PPG and from BASF Wyandotte under the trade name Pluracol®), polytetramethylene ether glycols (Terethane® from DuPont), polycaprolactone diols (Niax® PCP series of polyols from Union Carbide), and polyester polyols (hydroxy terminated polyesters obtained from esterification of dicarboxylic acids and diols such as the Rucoflex® polyols available from Ruco division, Hooker Chemicals Co.). By using high molecular weight polyols, the rigidity of the cured resin can be reduced.

An example of a resin useful in the casting material of the invention uses an isocyanate known as Isonate® 2143L available from the Dow Chemical Company (a mixture containing about 73% of MDI) and a polypropylene oxide polyol from Arco as Arcol® PPG725. To prolong the shelf life of the material, it is preferred to include from 0.01 to 1.0 percent by weight of benzoyl chloride or another suitable stabilizer.

The reactivity of the resin once it is exposed to the water curing agent can be controlled by the use of a proper catalyst. The reactivity must not be so great that: (1) a hard film quickly forms on the resin surface preventing further penetration of the water into the bulk of the resin; or (2) the cast becomes rigid before the application and shaping is complete. Good results have been achieved using 4-[2-[1-methyl-2-(4-morpholinyl)ethoxy]ethyl]-morpholine (MEMPE) prepared as described in U.S. Patent No. 4,871,845 at a concentration of about 0.05 to about 5 percent by weight.

Foaming of the resin should be minimized since it reduces the porosity of the cast and its overall strength. Foaming occurs because carbon dioxide is released when reacts with isocyanate groups. One way to minimize foaming is to reduce the concentration of isocyanate groups in the prepolymer. However, to have reactivity, workability, and ultimate strength, an adequate

concentration of isocyanate groups is necessary. Although foaming is less at low resin contents, adequate resin content is required for desirable cast characteristics such as strength and resistance to peeling. The most satisfactory method of minimizing foaming is to add a foam suppressor such as silicone Antifoam A (Dow Corning), Antifoam 1400 silicone fluid (Dow Corning) to the resin. It is especially preferred to use a silicone liquid such as Dow Corning Antifoam 1400 at a concentration of about 0.05 to 1.0 percent by weight.

Most preferably, the resin systems used with the fabrics of the present invention are those containing high aspect ratio fillers. Such fillers can be organic or inorganic. Preferably they are generally inorganic microfibers such as whiskers (highly crystalline small single crystal fibers) or somewhat less perfect crystalline fibers such as boron fibers, potassium titanate, calcium sulfate, asbestos and calcium metasilicate. They are dispersed in about 3-25% by weight of resin amounts to obtain a resin viscosity of about 0.005-0.1 Pa s to provide a cured cast with improved strength and/or durability. Such fillers are described in U.S. Patent No. 5,354,259.

The resin is coated or impregnated into the fabric. The amount of resin used is best described on a filler-free basis, i.e., in terms of the amount of fluid organic resin excluding added fillers. This is because the addition of filler can vary over a wide concentration range, which effects the resin holding capacity of the composite as a whole because the filler itself holds resin and can increase the resin holding capacity. The resin is applied in an amount of about 2-8 grams filler-free resin per gram fabric. The preferred coating weight for a polyester knit of the present invention is about 3.5-4.5 grams filler-free resin per gram fabric, and more preferably about 3.5 grams.

The preparation of the orthopedic casting materials of the present invention generally involves coating the curable resin onto the fabric by standard techniques. Manual or mechanical manipulation of the resin (such as by a nip roller or wiper blade) into the fabric is usually not necessary. However, some manipulation of the resin into the fabric may sometimes be

desirable to achieve proper impregnation. Care should be given not to stretch the fabric during resin coating, however, so as to preserve the stretchability of the material for its later application around the desired body part. The material is converted to 10-12 foot lengths and wound on a polyethylene core under low tension to preserve stretch. The roll is sealed in an aluminum foil pouch for storage.

Orthopedic casting materials prepared in accordance with the present invention are applied to humans or other animals in the same fashion as other known orthopedic casting materials. First, the body member or part to be immobilized is preferably covered with a conventional cast padding and/or stockinet to protect the body part. Generally, this is a protective sleeve of an air-permeable fabric such that air may pass through the sleeve and the cast to the surface of the skin. Preferably, this sleeve does not appreciably absorb water and permits the escape of perspiration. An example of such a substrate is a knitted or woven crystalline polypropylene material.

Next, the curable resin is typically activated by dipping the orthopedic casting material in water or other aqueous solution. Excess water may then be squeezed out of the orthopedic casting material. The material is wrapped or otherwise positioned around the body part so as to properly conform thereto. Preferably, the material is then molded and smoothed to form the best fit possible and to properly secure the body part in the desired position. Although often not necessary, if desired, the orthopedic casting materials can be held in place during cure by wrapping an elastic bandage or other securing means around the curing orthopedic casting material. When curing is complete, the body part is properly immobilized within the orthopedic cast or splint which is formed.

Preferred Embodiment:

A preferred fabric for use in the casting tape backing of the present invention is a three bar knit of the following construction:

Composition	Component	Wt% in knit
a. Front Bar = polyester heat shrinkable yarn	Chain	30-70%
b. Back Bar = polyester microdenier fiber	Weft	30-70%
c. Middle Bar = monofilament	Weft	3-20%

More preferably, the knit is a 6 gauge knit composed of the following construction:

Composition	Component	Wt% in knit
a. Front Bar = 1/150/68 polyester heat shrinkable yarn	Chain	38.1
b. Back Bar = 18/2 spun polyester microdenier fiber	Weft	56.5
c. Middle Bar = 180 denier nylon monofilament (Shakespear SN-40-1)	Weft	5.3

The fabric made from this particularly preferred composition is heat shrunk by passing the fabric under a source of heat, such as a forced hot air gun, at an appropriate temperature (about 150°C). The heat causes the fabric to shrink under essentially no tension. The fabric was annealed at 175°C. The fabric is then preferably passed through a heated calendar (at a temperature of about 80°C) at 6.9 N/cm^2 and 3.4 m/min to bring the fabric thickness down to about 0.081 cm. Processed in this way, i.e., with full heat shrinkage followed by calendaring, a 9 cm wide sample of this particularly preferred knit has approximately 50-60% stretch under a 2.3 kg load.

A flow chart of the preferred process is shown in Fig. 7. In sum this involves knitting the material on a Raschelina RB crochet type warp knitting machine (see Example 1) wherein the front bar creates a chain stitch of the

heat shrinkable yarn, the middle bar lays in the stiffness-controlling yarn in the weft insertion, and the back bar lays in the microdenier yarn as the weft in-lay. The knit fabric is then heat shrunk to the desired percent stretch or extensibility, and then exposed to calendaring to the desired thickness.

The resin-impregnated sheet material of Example 10 is representative of this preferred fabric. Example 10 also describes a particularly preferred resin composition.

Extensibility (Stretch) Test

To perform this test, either an Instron type or a simple stretch table can be used. A stretch table typically has a pair of 15.25 cm wide clamps spaced exactly 25.4 cm apart. One clamp is stationary and the second clamp is movable on essentially frictionless linear roller bearings. Attached to the movable clamp is a cord that passes over a pulley and is secured to the appropriate weight. A stationary board is positioned on the base of the table with a measuring tape to indicate the lineal extension once the fabric is stretched under to force of the applied weight.

When using a more sophisticated testing machine such as an Instron 1122, the machine is set up with the fabric clamps spaced exactly 25.4 cm apart. The fabric is placed in the fixtures and tested at a temperature of about 23-25°C. The humidity is controlled at about 50 $\pm$ 5% relative humidity. This test is applicable to both resin-coated and uncoated fabrics.

Typically, a piece of unstretched fabric is cut to approximately 30.5 cm. Markings are made on the fabric exactly 2.54 cm apart. If the fabric is coated with a curable resin this operation should be done in an inert atmosphere and the samples sealed until tested. For all samples, it is important to not stretch the samples prior to testing. The fabric is secured in the test fixture under a very slight amount of tension (e.g., 0.01 cN/cm of bandage width) to ensure that the fabric is essentially wrinkle free. The length of the unstretched bandage is 2.54 cm since the clamps are separated by this distance. If the 2.54 cm markings applied do not line up exactly with the clamp, the fabric may have been stretched and should be discarded. In the

case of a vertical test set up where the weight of the bandage (especially if resin coated) is sufficient to result in extension of the fabric, the bandage should be secured in the clamps at exactly these marks.

A weight is then attached to the clamp. Unless otherwise indicated, the weight should be 268 gm/cm width of tape. The sample is then extended by slowly and gently extending the fabric until the full weight is released. In cases where an Instron is used, the sample is extended at a rate of 12.7 cm/min until the proper load has been reached. If the fabric continues to stretch under the applied load the percentage stretch is taken one minute after applying the load. The percentage stretch is recorded as the amount of lineal extension divided by the original sample length and this value multiplied by 100. Note that testing of moisture curable resin-coated fabrics must be performed rapidly in order to avoid having cure of the resin effect the results.

The invention has been described with reference to various specific and preferred embodiments and will be further described by reference to the following detailed examples. It is understood, however, that there are many extensions, variations, and modifications on the basic theme of the present invention beyond that shown in the examples and detailed description, which are within the spirit and scope of the present invention.

Examples

Example 1: Casting Tape Backing Made of Microdenier Fabric

Fabric

Yarn:	Micromattique Polyester (Dupont made, texturized by Unify Inc., Greensboro, NC) single yarn, 150 denier, 200 filament (1/150/200)
Equipment:	Raschelina RB crochet type warp knitting machine from the J. Muller Co. (360 mm knitted capacity, narrow width)
Knit Pattern:	7.5 wales/cm 7.9 stitches/cm 59 openings/cm^2 8.9 cm

Fabric Weight: 0.08 g/cm
Fabric Density: 0.0124 g/cm^2
Thickness: 0.071 cm

This warp knit microdenier fabric was extremely soft and flexible.

Resin Composition

The fabric was coated with 74 g per 3.66 m of fabric with a filled polyurethane prepolymer resin with the following composition:

Chemical	Manufacturer	Wt%	Equiv. Weight
Isonate 2143L	Dow Chemical	54.63	144.23
p-toluenesulfonyl chloride	Aldrich Chemical	0.05	
Antifoam 1400	Dow Corning	0.18	
BHT	Aldrich Chemical	0.48	
MEMPE catalyst	3M Company	1.25	
Pluronic F108	BASF	4.0	7250
Arcol™ PPG-2025 polyol	Arco Chemical	25.11	1016.7
Niax E-562 polymer polyol	Union Carbide	8.5	1781
Arcol™ LG-650 polyol	Arco Chemical	5.91	86.1

The resin had an NCO/OH ratio of 3.84 and an NCO equivalent weight of 357 g/equivalent. The resin was prepared by addition of the components listed above in 5 minute intervals in the order listed. This was done using a 1 gallon glass mason jar equipped with mechanical stirrer, teflon impeller, and a thermocouple. The resin was heated using a heating mantle until the reaction temperature reached 65-71°C and held at that temperature for 1-1.5 hours. After this time, Nyad G Wollastokup 10012 (available from NYCO, Willsboro, NY) filler was added to make the composition 20% by weight filler. The resin was sealed and allowed to cool on a rotating roller at

about 7 revolutions per minute (rpm) overnight. This resin composition was used to coat the fabric. Two coating weights were used. On a filler-free basis, the coating weights were 2.1 grams and 2.33 grams resin per gram fabric (2.6 and 2.9 g/g, including filler, respectively). The resin was applied manually by spreading it over the surface of the fabric and kneading it in until a uniform coating was achieved. The rolls were sealed in an aluminum foil laminate package until evaluation.

Dry Ring Strength Test

Rolls of these fabrics were tested for 24-hour dry ring strength with the following results:

Coating weight	24 hr Dry (lbs)	Mean strength
2.1 g filler-free resin/g fabric	86.1, 112.2, 125.4	7.7 kg/cm width
2.33 g filler-free resin/g fabric	101.1, 144.8, 132.4	9.0 kg/cm width

In this test, the "dry strength" of cured cylindrical ring samples of the resin-coated materials was determined. Each cylindrical ring was made of 6 layers of the resin-coated material. Each cylindrical ring had an inner diameter of 5.1 cm. The width of each ring formed was the same as the width of the resin-coated material employed.

Each cylindrical ring was formed by taking a roll of the resin-coated material from its storage pouch and immersing the roll completely in deionized water having a temperature of about 27°C for about 30 seconds. The roll of resin-coated material was then removed from the water and the material was wrapped around a 5.1 cm mandrel, covered with a thin layer of stockinet such as 3M Synthetic Stockinet MS02, to form 6 complete uniform layers using a controlled wrapping tension of about 45 grams per centimeter width of the material. Each cylinder was completely wound within 30 seconds after its removal from the water.

After 30 minutes from the initial immersion in water, the cured cylinder was removed from the mandrel, and allowed to cure for 48 hours in a controlled atmosphere of 34°C ± 2°C and 55% ± 5% relative humidity. After this time, each cylinder was placed in an Instron instrument fixture for testing.

Once in the instrument fixture, compression loads were applied to the cylindrical ring sample along its exterior and parallel to its axis. Each cylinder was crushed at a speed of about 5 cm/min. The maximum or peak force which was applied while crushing the cylinder was then recorded as the ring strength, which in this particular instance is the "dry strength" (expressed in terms of force per unit length of cylinder). For each material, at least three samples were tested and the average peak force applied was then calculated.

The above-listed dry strength test results indicate that the materials made of microdenier yarns only are quite strong. The dry strength approaches the strength of commercially available fiberglass casting tapes, which are typically 88-105 newtons/cm width.

Porosity Test

The 6 layer rings as made were then tested for porosity by sealing about 25 ml of deionized water in a glass beaker in the middle of a cylindrical ring with a petri dish glued to the top of the ring and one glued to the bottom of the ring. Weight loss of this set-up was recorded over time under ambient conditions. The fabrics were comparable in porosity to fabric used in 3M's Scotchcast Plus® orthopedic casting tape. The results are shown below as an average of two samples:

Day No.	Total Weight Loss (g/sq cm) Microfiber polyester		Total Weight Loss (g/sq cm) Scotchcast Plus®
	2.1 g/g	2/3 g/g	
1	.013	.013	.013
4	.032	.034	.031
6	.044	.046	.043
11	.070	.070	.069
13	.082	.081	.079
18	.103	.100	.098
20	.113	.109	.107
25	.128	.123	.122
29	.141	.136	.134
36	.167	.157	.156
43	.189	.175	.175

The linear regression equations for the three products were determined and the slope of the line taken as the rate of water loss. These were: 0.0169 $g/cm^2/day$ for the sample containing 2.1 grams resin per gram fabric; 0.0155 $g/cm^2/day$ for the sample containing 2.3 grams resin per gram fabric; and 0.0156 $g/cm^2/day$ for the sample containing 3M's Scotchcast Plus® orthopedic casting tape. This shows that the moisture vapor porosity of these microdenier fabric backings is equal to, or better than, that of the fabric in the fiberglass backing of Scotchcast Plus®.

Example 2: Resin Holding Capacity of Microdenier Fabric

In order to illustrate the higher resin holding capacity of polyester yarns as the filament diameter is reduced, both an 18/2 spun yarn, which has a filament diameter of 1.2 denier, and the 1/150/200 yarn, which has a filament diameter of 0.75 denier were tested. The yarns were tested for the

absorbency/holding capacity of Isonate®2143L carbodiimide modified 4,4'-diphenylmethanediisocyanate (available from Dow Chemical, Midland, MI) by the following technique.

A sample of 21.6 cm of yarn was weighed. The yarn was immersed in Isonate® 2143L for 30 seconds. It was then removed and gently placed on a Premiere® paper towel (available from Scott Paper Co., Philadelphia, PA) for 30 seconds to absorb excess resin remaining on the outside of the yarn. The sample was then weighed. The results obtained were as follows:

Yarn	Filament Diameter (denier)	Initial Wt. (grams)	Final Wt. (grams)	% Increase
1/150/200 PE	0.75	.0042 .0041	0.0249 0.0235	493 473 mean 483
18/2	1.2	.0071 .0074	0.0227 0.0233	220 215 mean 217

This data indicates that the fine 18/2 yarn cannot hold as much resin as the 1/150/200 yarn, even though the 18/2 yarn is greater in mass. Furthermore, the 1/150/200 yarn (0.75 μm filament diameter) can hold over twice as much resin on a percentage basis.

Example 3: Varying the Number of Stitches per Unit Length in Fabric Containing Microdenier Yarn and Heat Shrinkable Yarn

A series of 4 knits were made using the same type of input yarns but varying the output speed of the take-up roller in order to vary the number of stitches/cm. The knit was a basic 2 bar knit with the weft yarn laid under 4 needles with 6 needles/cm (6 gauge). The knitting machine used was that used in Example 1. The chain stitch was a 2/150/34 Power Stretch yarn produced by Unifi (Greensboro, NC). This yarn is a 2 ply yarn where each yarn is composed of 34 filaments and is 150 denier, making the overall yarn

300 denier. The weft in-lay yarn was the microdenier yarn used in Example 1 (1/150/200).

The tape was rolled up off the knitting machine under essentially no tension. The knits were then heat shrunk by passing the fabric around a pair of 6 inch (15 cm) diameter heated (350°F, 176°C) calendar rolls at a speed of 20 ft/minute (6.1 meters/minute) with the rolls held apart. The tapes were then passed through a heated calendar in a nip position to "iron" the fabric flat and to decrease the thickness. The following 4 knits were produced in this manner:

Property	Knit #1	Knit #2	Knit #3	Knit #4
Stitches/inch on machine	12	8.5	5.0	7.0
Stitch/inch relaxed	15	9.5	5.8	7.87
Width-working (mm)	100	100	100	100
Relaxed width before winder (mm)	85	86	100	90
Finished Heat Set:				
Width (mm)	83	83	100	90
Stitch density/inch	16	13	10	12.5
Useable % stretch	29	43	65	40
Thickness before calendar (inch)	0.049	0.047	0.045	0.054
Thickness after calendar (inch)	0.039	0.037	0.039	0.038

The thickness was measured using an Ames Model 2 thickness gauge (Ames Gauge Company, Waltham, MA) equipped with a 2.5 cm diameter contact comparator, by placing the foot down gently onto the fabric. For each sample, the heated calendar significantly reduced the tape thickness. Varying the number of stitches per inch produced fabrics of significantly different fabric density, percent stretch, and conformability.

Example 4: Knit Fabric Containing Microdenier Yarn, Heat Shrinkable Yarn, and Monofilament Yarn

A knitted backing suitable for use in orthopedic casting was produced according to Example 3, sample Knit #3, except that a 180 denier nylon monofilament SN-40-1 (available from Shakespear Monofilament, Columbia, SC) was used as a weft in-lay. Each of three monofilament yarns were laid in across 21 needles in a substantially nonoverlapping configuration to completely fill the width of the fabric (note that two adjacent monofilaments do not overlap each other but are being alternately laid around one common needle, as illustrated in Fig. 5). The fabric was heat shrunk and calendared in an in-line process. The shrinking was accomplished using hot air regulated at 150°C and subsequently calendared using a pair of silicone elastomer-covered 7.6 cm diameter rollers under a force of 390 newtons. The fabric had an extensibility of approximately 45%, a width of 8.9 cm, and a thickness of 0.12 cm.

The fabric was coated with the following resin system:

Chemical	Manufacturer	Wt %	Equiv. Wt.
Isonate 2143L	Dow Chemical	57.7	144.7
p-toluenesulfonyl chloride	Aldrich Chemical	0.05	
Antifoam 1400	Dow Corning	0.18	
BHT	Aldrich Chemical	0.48	
MEMPE catalyst	3M Company	1.25	
Pluronic F108	BASF	4.0	7250
Arcol™ PPG-2025 polyol	Arco Chemical	20.92	1019.3
Niax E-562 polymer polyol	Union Carbide	9.85	1729
Arcol™ LG-650 polyol	Arco Chemical	5.75	86.1

The NCO/OH ratio of this resin was 4.26 and the NCO equivalent weight was 328 g/equivalent. The resin was prepared as described in Example 1 except that 15% by weight Nyad G Wollastokup 10012 was used

as a reinforcing filler. This resin was coated on the fabric at 3.5 grams per gram fabric (2.8 grams filler-free resin per gram fabric).

The tape produced handled well. That is, the final knit was found to be very easy to work with when wrapped dry around artificial legs after dipping in water at ambient temperature and squeezing three times. No wrinkles formed during this operation. The dry strength was measured to be 19 kg/cm by the method described in Example 1. The ring delamination was measured to be 15.2 newtons/cm by the Delamination Test outlined below. Typical values for commercially available fiberglass orthopedic casting tape are 88-105 newtons/cm dry strength with a ring delamination of 8.8 newtons/cm.

Delamination Test

This test measures the force necessary to delaminate a cured cylindrical ring of a resin-coated material. Each cylindrical ring includes 6 layers of the resin-coated material having an inner diameter of 5.1 cm. The width of the ring formed was the same as the width of the resin-coated material employed. The final calculation of the delamination strength is given in terms of newtons per centimeter of tape width.

Each cylindrical ring was formed by taking a roll of the resin-coated material from its storage pouch and immersing the roll completely in deionized water having a temperature of about 27°C for about 30 seconds. The roll of resin-coated material was then removed from the water and the material was wrapped around a 5.1 cm mandrel covered with a thin stockinet (such as 3M Synthetic Stockinet MS02) to form 6 complete uniform layers using a controlled wrapping tension of about 45 grams per centimeter width of the material. A free tail of about 15.24 cm was kept and the balance of the roll was cut off. Each cylinder was completely wound within 30 seconds after its removal from the water.

After 15 to 20 minutes from the initial immersion in water, the cured cylinder was removed from the mandrel, and after 30 minutes from the initial immersion in water its delamination strength was determined. This was done by placing the free tail of the cylindrical sample in the jaws of the testing

machine, namely, an Instron Model 1122 machine, and by placing a spindle through the hollow core of the cylinder so that the cylinder was allowed to rotate freely about the axis of the spindle. The Instron machine was then activated to pull on the free tail of the sample at a speed of about 127 cm/min. The average force required to delaminate the wrapped layers over the first 33 centimeters of the cylinder was then recorded in terms of force per unit width of sample (newtons/cm). For each material, at least 5 samples were tested, and the average delamination force was then calculated and reported as the "delamination strength."

Example 5: Knit Fabric Containing Microdenier Yarn, Monofilament Yarn, and Smaller Diameter Filament Stretch Yarns

A knit fabric similar to that of Example 4 was made using a 2/150/100 stretch polyester yarn in the wale in place of the 2/150/34 Power Stretch yarn, and except that the fabric was not calendared. This stretch yarn has a filament diameter of 1.5 denier/filament as opposed to 4.4 denier/filament for the 2/150/34 yarn. The final product had only 15% stretch and a thickness of 0.069 cm, as opposed to the 0.12 cm thickness of the heat shrunk fabric of Example 4. This indicates that the larger the filament diameter of the shrink/stretch yarn, the greater force is generated to shrink the knit, thereby resulting in a thinner fabric.

Example 6: Single End 2.2 Denier/Filament Stretch Yarn

A knit similar to that of Example 4 was made with a 1/150/68 polyester stretch yarn in the wale in place of the 2/150/34 Power Stretch yarn. This stretch yarn has a filament diameter of 2.2 denier/filament as opposed to 4.4 denier/filament for the 2/150/34 yarn. In addition, the 1/150/200 microdenier weft yarn was replaced with an 18/2 spun polyester yarn produced by Dixie Yarns. The final product had a 45% stretch and a thickness of 0.091 cm. Other knit properties include: relaxed stitch density = 2.5 stitches/cm; relative weights of fabric components (chain component: 38.1% by weight; weft component: 56.5% by weight; monofilament: 5.3% by weight); shrunk

stitch density = 3.4 stitches/cm; and width = 92 mm. This experiment indicates that a lower basis weight fabric can be produced with a high degree of stretch yarn with a filament size of 2.2 denier.

Example 7: Effect of Shrinking Fully Prior to Calendaring

A knit similar to that of Example 6 was made but this time the knit was not fully heat shrunk prior to calendaring and "ironing" the fabric. After the operation, the fabric had only 13-20% stretch under a 2.3 kg load and a thickness of 0.081 cm. This is markedly less than the 45% stretch observed in Example 6. The fabric was exposed to hot air once again but the fabric could not be shrunk to any significant degree. Therefore, it is important to fully shrink the fabric to the desired extensibility prior to the calendaring operation if a high percent shrinkage is desired.

Example 8: Monofilament In-Lay Variation

Three knits were prepared using the following yarns:

Chain Stitch - 1/150/68 polyester stretch yarn (Dalton Textiles, Oak Brook, IL);

Weft In-Lay Yarn - 18/2 spun polyester microdenier yarn (Dalton Textiles); and

Weft Insertion Yarn - 180 denier nylon monofilament (Shakespear Monofilament, SN-40-1)

The knit was produced using a 6 gauge needle bed (6 needles/cm). The 18/2 spun polyester microdenier yarn was laid across 3 needles. The total knit was produced using 61 needles. The monofilament was laid in across varying numbers of needles in three separate knits. This is shown below:

		Cross Web % Stretch	
Monofilament Weft Insertion	Number of Monofilaments Per Knit Width	1 lb/in Load	1.5 lb/in Load
21 needles	3	4.79	20.4
13	5	8.87	32.9
7	10	18.77	63.4

The knits were heat shrunk off the knitter using a Leister hot air gun set at 150°C. The knits were tested for extensibility in the width or cross web direction on an Instron 1122 (average of 2 samples). The extensibility was taken as the percent stretch under a load of 0.175 N/mm and 0.262 N/mm when stretched at a rate of 5 inches per minute. Clearly the % stretch in the cross web direction increases substantially as the number of monofilaments increases. The knits were coated with the resin of Example 4 and converted into 3.20 meter rolls under minimal tension. In all cases the knit still draped and molded without wrinkling. This indicates that the extensibility in the width direction can be tailored while maintaining a flat and wrinkle free web.

Example 9: Annealing the Monofilament for Rebound Improvement

A fabric containing a monofilament was annealed to impart a restoring force that increases rebound by placing a sample of the knits disclosed in Example 8 in an oven at 175°C for 15 minutes. A monofilament was extracted and found to retain the as-knitted shape very well. It should be noted that a monofilament removed from the non-annealed control was not completely straight due to some annealing which occurred during the heat shrink operation. This indicates that the heat shrinking and annealing could be accomplished in a single step if the temperature and duration at that temperature was sufficient. Furthermore, a monofilament with an annealing temperature somewhat lower than the heat shrink temperature may be

preferred. Note that by varying the denier of the monofilament the amount of restoring force can be adjusted.

Example 10: Preferred Casting Tape Backing

A knitted backing suitable for use in orthopedic casting was produced using the following components:

Composition	Component
Front Bar = polyester (Dalton Textiles, Oak Brook, IL) 1/150/68 heat shrinkable yarn	Chain
Back Bar = spun polyester (Dalton Textiles, Oak Brook, IL) 18/2 microdenier yarn	Weft in-lay
Middle Bar = 180 denier nylon monofilament (Shakespear Monofilament, Columbia, SC) (Shakespear SN-40-1)	Weft insertion

The knit was constructed using a total of 61 needles in a metric 6 gauge needle bed on a Raschelina RB crochet type warp knitting machine from the J. Müller of America, Inc. The basic knit construction was made with the chain on the front bar and the weft in-lay under 3 needles on the back bar. The middle bar was used to inlay a total of 10 monofilament weft insertion yarns each passing over 7 needles. The weft insertion yarns were mutually interlocked across the bandage width being alternatively laid around one common needle, e.g., weft insertion yarn No. 1 was laid around needles No. 1 and 7, weft insertion yarn No. 2 around needles No. 7 and 13, etc. The fabric made from this particularly preferred composition was heat shrunk by passing the fabric under a forced hot air gun set to a temperature of 150°C. The heat caused the fabric to shrink as the web was wound up on the core under essentially no tension. The fabric was then heated in loose roll form at 175°C for 20 minutes to anneal the monofilament yarn in the shrunk condition. After cooling, the fabric was passed through a heated calendar roll

(79°C) to bring the fabric thickness down to about 0.038-0.040 inches (0.97 mm - 1.02 mm). Processed in this way, i.e., with full heat shrinkage followed by calendaring, a fabric with with following properties was produced:

Property	Measured Result
Width (cm)	9.5
Basis weight (g/sq m)	150
Thickness (mm)	0.97-1.02
Stitches/cm	3.54
Wales/cm	6.29
Openings/sq cm	22.3
Extensibility (%) length	46.3*
Extensibility (%) width	63.4*

* Note that the lengthwise extensibility was measured under a load of 5 lb (22.2 N) and the widthwise extensibility was measured under a load of 1.5 lb/in (2.63 N/cm).

Resin Composition

The fabric described above was coated with the following resin composition:

Chemical	Manufacturer	Wt %	Equiv. Weight
Isonate 2143L	Dow Chemical	56.8	144.3
p-toluenesulfonyl chloride	Aldrich Chemical	0.05	
Antifoam 1400	Dow Corning	0.18	
BHT	Aldrich Chemical	0.48	
MEMPE catalyst	3M Company	1.15	
Pluronic F108	BASF	5.0	7250
Arcol™ PPG-2025 polyol	Arco Chemical	22.2	1016.7
Niax E-562 polymer polyol*	Union Carbide	8.5	1781
Arcol™ LG-650	Arco Chemical	5.6	86.1

* Formerly available from Union Carbide, now available from Arco Chemical Company as Poly 24-32.

The resin had an NCO/OH ratio of 4.25 and an NCO equivalent weight of 332.3 g/equivalent. The resin was prepared by addition of the components listed above in 5 minute intervals in the order listed. This was done using a 1 gallon glass mason jar equipped with a mechanical stirrer, teflon impeller, and a thermocouple. The resin was heated using a heating mantle until the reaction temperature reached 65-71°C and held at that temperature for about 1-1.5 hours. After this time, Nyad G Wollastokup 10012 (available from Nyco, Willsboro, NY) filler was added to make the composition 20% by weight filler. The reaction vessel was sealed and allowed to cool on a rotating roller at about 7 revolutions per minute (rpm) overnight. This filled resin composition was coated on the above described fabric at a coating weight of 3.5 g filled resin/g fabric (2.8 g/g fabric on a filler free basis). The coating was performed under minimal tension to avoid stretching the fabric by spreading the resin directly on one surface. The coated fabric was converted into 3.35 m rolls wrapped around a 1.2 cm diameter polyethylene core. The converting operation was also done under minimal tension to avoid stretching the fabric. The rolls were then placed into aluminum foil laminate pouches until later evaluation.

The material was evaluated by removing the roll from the pouch, dipping under 23-25°C water with three squeezes, followed by a final squeeze to remove excess water and wrapping on a forearm. The material was found to be very conformable and easy to work with without wrinkling. The cast became very strong in a short amount of time (less than 20-30 minutes) and had a very pleasing appearance. Note that when the tape was immersed in water it quickly became very slippery. The roll unwound easily and did not stick to the gloves of the applier. Molding was easy due to the non-tacky nature of the resin. The cast was rubbed over its entire length without sticking to the gloves and the layers bound well to each other. The final cured cast had a much smoother finish than typical fiberglass casting

materials. The cast could also be drawn on and decorated with felt tipped marker much more easily than fiberglass casting materials and the artwork was much more legible.

Example 11: Preferred Casting Tape Backing

A knitted backing suitable for use in orthopedic casting was produced using the following components:

Composition	Component
Front Bar = polyester (Dalton Textiles, Oak Brook, IL) 1/150/68 heat shrinkable yarn	Chain
Back Bar = spun polyester (Dalton Textiles, Oak Brook, IL) 18/2 microdenier yarn	Weft in-lay
Middle Bar = 180 denier nylon monofilament (Shakespear Monofilament, Columbia, SC) (Shakespear SN-40-1)	Weft insertion

The knit was constructed using a total of 45 needles in a metric 4 gauge needle bed on a Raschelina RB crochet type warp knitting machine from the J. Müller of America, Inc. The basic knit construction was made with the chain on the front bar and the weft in-lay under 3 needles on the back bar. The middle bar was used to inlay a total of 5 monofilament weft insertion yarns each passing over 9 needles. The weft insertion yarns were mutually interlocked across the bandage width being alternatively laid around one common needle, e.g., weft insertion yarn No. 1 was laid around needles No. 3 and 11, weft insertion yarn No. 2 around needles No. 11 and 19, etc. Notably, needles Nos. 1, 2, 44 and 45 did not have a weft insertion yarn pass around them. The fabric made from this particularly preferred composition was heat shrunk by passing the fabric under a forced hot air gun set to a temperature of 150°C. The heat caused the fabric to shrink as the web was wound up on the core under essentially no tension. The fabric was then heated in loose roll form at 175°C for 20 minutes to anneal the monofilament

yarn in the shrunk condition. After cooling, the fabric was passed through a heated calendar roll (79°C) to bring the fabric thickness down to about 0.81 mm - 1.02 mm.

After calendaring, the fabric was microcreped, as herein described. The microcreping process is a mechanical way to impart functional qualities to web structures. In one embodiment of the process (the "Micrex" process), an untreated web (e.g., a fabric), supported by a main roll, is introduced into a converging passage, firmly gripped, and conveyed into the main treatment cavity where the microcreping process takes place. By adjustment of controls, varying amounts of residual compaction and crepe cross-section can be attained, depending upon the desired result and the characteristics of the material being treated. The treated web passes through a secondary passage between rigid and/or flexible retarders which control the uniformity and degree of compaction. Compaction is retained in the fabric by annealing the fibers in the compacted state. By "annealing" is meant the maintenance of the fiber at a specified temperature for a specific length of time and then cooling the fiber. This treatment removes internal stresses resulting from the previous microcreping operation effectively "setting" the fabric structure in a new preferred orientation. This can be done using dry heat (e.g., hot roll, infrared irradiation, convection oven, etc.) or steam. The choice of annealing method depends upon such factors as fabric weight, fiber type and process speed. One simple method to apply heat to the fabric is to pass the fabric over a heated roll. Alternatively, steam heat is preferred for some fabrics. Two commercial microcreping processes are believed to be capable of treating fabrics of the present invention. One such process, discussed above, is commercialized by the Micrex Corporation of Walpole, Massachusetts (the "Micrex" process). A second such process is commercialized by the Tubular Textile Machinery Corporation of Lexington, North Carolina (the "TTM" process). The TTM process is similar in principle to the Micrex process - although certain details are different. In the TTM process, the fabric is passed into the compacting zone over a feed roll and under a shoe. The fabric is then compacted or microcreped by contacting a lower compacting shoe and

a retarding roll. Nevertheless, in both processes the fabric is subjected to a compaction force due to frictional retarders.

In the present example the fabric was microcreped on a Micrex compactor having a 193 cm wide open width and equipped with a bladeless set up, i.e., no rigid retarder was used. The surface of the flexible frictional retarder was equipped with 600 grit wet or dry sand paper (available from 3M). The main roll was heated to a temperature of 135°C and the dry fabric was passed through at a speed of approximately 4.87 meters per minute. The take-up roll was set at a speed 60% slower, i.e., 2.93 meters per minute, in order to ensure 40% compaction. Processed in this way, i.e., with full heat shrinkage followed by calendaring and microcreping, a fabric with the following properties was produced:

Property	Measured Result
Width (cm)	9.9
Basis weight (g/sq cm)	.014
Thickness (mm)	0.91
Stitches/cm	4.7
Wales/cm	4.7
Openings/sq cm	22
Extensibility (%) length	70*
Extensibility (%) width	12*

* Note that the lengthwise extensibility was measured under a load of 22.2 N and the widthwise extensibility was measured under a load of 0.175 N/mm.

Resin Composition

The fabric described above was coated with resin and tested as described in Example 10. The material was found to be very conformable and easy to work with without wrinkling. The cast became very strong in a short amount of time (less than 20-30 minutes) and had a very pleasing appearance. Note that when the tape was immersed in water it quickly became very

slippery. The roll unwound easily and did not stick to the gloves of the applier. Molding was easy due to the non-tacky nature of the resin. The cast was rubbed over its entire length without sticking to the gloves and the layers bound well to each other. The final cured cast had a much smoother finish than typical fiberglass casting materials. The cast could also be drawn on and decorated with felt tipped marker much more easily than fiberglass casting materials and the artwork was much more legible. Notably, by not passing a weft insertion yarn around either needles No. 1, 2, 44 or 45 the weft insertion yarns did not extend past the edge of the fabric after microcreping. This avoids undesirable roughness at the edge of the fabric (which roughness is especially undesirable after the resin is cured) and also avoids exposure of a "loop" of the weft insertion yarn at the edge.

Example 12: Casting Tape Backing

A knitted backing suitable for use in orthopedic casting was produced using the following components:

Composition	Component
Front Bar = polyester (Dalton Textiles, Oak Brook, IL) 2/150/34 heat shrinkable yarn	Chain
Back Bar = spun polyester (Dalton Textiles, Oak Brook, IL) 1/150/100 heat shrinkable yarn	Weft in-lay
Middle Bar = 180 denier nylon monofilament (Shakespear Monofilament, Columbia, SC) (Shakespear SN-40-1)	Weft insertion

The knit was constructed using a total of 61 needles in a metric 6 gauge needle bed on a Raschelina RB crochet type warp knitting machine from the J. Müller of America, Inc. The basic knit construction was made with the chain on the front bar and the weft in-lay under 4 needles on the back bar. The middle bar was used to inlay a total of 3 monofilament weft insertion yarns

each passing over 21 needles. The weft insertion yarns were mutually interlocked across the bandage width being alternatively laid around one common needle, e.g., weft insertion yarn No. 1 was laid around needles No. 1 and 21, weft insertion yarn No. 2 around needles No. 21 and 41, etc. The fabric made from this composition was heat shrunk by passing the fabric under a forced hot air gun set to a temperature of 150°C. The heat caused the fabric to shrink as the web was wound up on the core under essentially no tension. The fabric was then heated in loose roll form at 175°C for 20 minutes to anneal the monofilament yarn in the shrunk condition. After cooling, the fabric was passed through a heated calendar roll (79°C) to bring the fabric thickness down to about 1.17 mm. Processed in this way, i.e., with full heat shrinkage followed by calendaring, a fabric with the following properties was produced:

Property	Measured Result
Width (cm)	8.9
Basis weight (g/sq cm)	0.017
Thickness (mm)	1.17
Stitches/cm	2.5
Wales/cm	6.7
Openings/sq cm	16.7
Extensibility (%) length	15*
Extensibility (%) width	20*

* Note that the lengthwise extensibility was measured under a load of 22.2 N and the widthwise extensibility was measured under a load of 0.175 N/mm.

Resin Composition

The fabric described above was coated with resin and tested as described in Example 10. The material was found to be very conformable and easy to work with without wrinkling. The cast became very strong in a short amount of time (less than 20-30 minutes) and had a very pleasing appearance. Note

that when the tape was immersed in water it quickly became very slippery. The roll unwound easily and did not stick to the gloves of the applier. Molding was easy due to the non-tacky nature of the resin. The cast was rubbed over its entire length without sticking to the gloves and the layers bound well to each other. The final cured cast had a much smoother finish than typical fiberglass casting materials. The cast could also be drawn on and decorated with felt tipped marker much more easily than fiberglass casting materials and the artwork was much more legible.

This example illustrates that a resin coated knit fabric comprising a non-fiberglass stiffness-controlling yarn having a modulus of greater than about 5 grams per denier is capable of being applied (e.g., wrapped around a limb) without wrinkling.

The foregoing detailed description and examples have been given for clarity of understanding only. No unnecessary limitations are to be understood therefrom. The invention is not limited to the exact details shown and described, for variations obvious to one skilled in the art will be included within the invention defined by the claims.

60557-5016

CLAIMS:

1. A resin-coated sheet material comprising:

(a) an extensible knit fabric comprising different non fiberglass yarn components; and

(b) a curable resin coated on the fabric,

wherein one of the yarn components is a non-fiberglass micro-denier yarn of up to 1.65 dtex (1.5 denier), and wherein the knit fabric has an extensibility of 15-100% measured 1 minute after applying a load of 0.26 N per mm.

2. The resin-coated sheet material of claim 1, wherein the knit fabric has an extensibility of 40-60% measured 1 minute after applying a load of 0.26 N per mm.

3. The resin-coated sheet material of claim 1 or 2, wherein the knit fabric is a warp knit fabric having a chain stitch, a weft in-lay, and a weft insertion.

4. The resin-coated sheet material of any one of claims 1 to 3, wherein the micro-denier yarn is positioned in the fabric as a weft in-lay.

5. The resin-coated sheet material of any one of claims 1 to 4, wherein the micro-denier yarn is a polyester yarn.

6. The resin-coated sheet material of any one of claims 1 to 5, further comprising a stretch yarn.

7. The resin-coated sheet material of claim 6 wherein the stretch yarn is positioned in the chain stitch.

8. The resin-coated sheet material of claim 7 wherein the stretch yarn is an elastic stretch yarn of no greater then 550 dtex (500 denier).

9. The resin-coated sheet material of claim 7 wherein the stretch yarn is a heat shrinkable, thermoplastic micro-denier yarn having at least 30% stretch.

10. The resin-coated sheet material of any one of claims 1 to 9, wherein the fabric includes a non-fiberglass stiffness-controlling yarn having a modulus of greater than 4.55 g/tex (5 grams per denier) comprising an inelastic monofilament yarn.

11. The resin-coated sheet material of claim 10 wherein the monofilament yarn is selected from the group consisting of a polyester monofilament yarn and nylon monofilament yarn.

12. The resin-coated sheet material of claim 10 or 11, wherein the stiffness-controlling yarn is capable of less than 15% shrinkage.

13. The resin-coated sheet material of any one of claims 10 to 12, wherein the stiffness-controlling yarn is capable of being annealed in an as knit orientation.

14. The resin-coated sheet material of any one of claims 9 to 13, wherein the stretch yarn is positioned in the wales of a chain stitch.

15. The resin-coated sheet material of any one of claims 1 to 14, wherein the resin is water-curable.

16. The resin-coated sheet material of any one of claims 1 to 15, wherein the curable resin comprises an isocyanate-terminated prepolymer.

17. The resin-coated sheet material of any one of claims 1 to 16, wherein the fabric has been calendared.

18. The resin-coated sheet material of any one of claims 10 to 17, wherein the fabric includes the stiffness-controlling yarn as a weft insert.

19. The resin-coated sheet material of any one of claims 1 to 18, wherein the micro-denier yarn is not greater than 1.10 dtex (1.0 denier).

20. A method of making a resin-coated sheet material according to claim 17, 18 or 19, the method comprising the steps of:

(a) knitting a stretch yarn, a micro-denier yarn, and a stiffness-controlling yarn with a three-bar warp knitting machine to form a fabric;

(b) shrinking the fabric;

(c) calendaring the fabric to reduce the thickness of the fabric; and

(d) coating a curable resin on the fabric.

21. The method of claim 20 wherein the step of shrinking the fabric is carried out with hot air at a temperature of 120-180°C.

22. The method of claim 20 or 21 wherein the step of shrinking the fabric is carried out fully before the step of calendaring the fabric.

23. The method of any one of claims 20 to 22, further comprising a step of annealing the fabric to set the shape of the stiffness-controlling yarn in its knitted orientation.

24. Use of a resin-coated sheet material according to any one of claims 1 to 19, for preparing an orthopedic support material.

SMART & BIGGAR

OTTAWA, CANADA

PATENT AGENTS

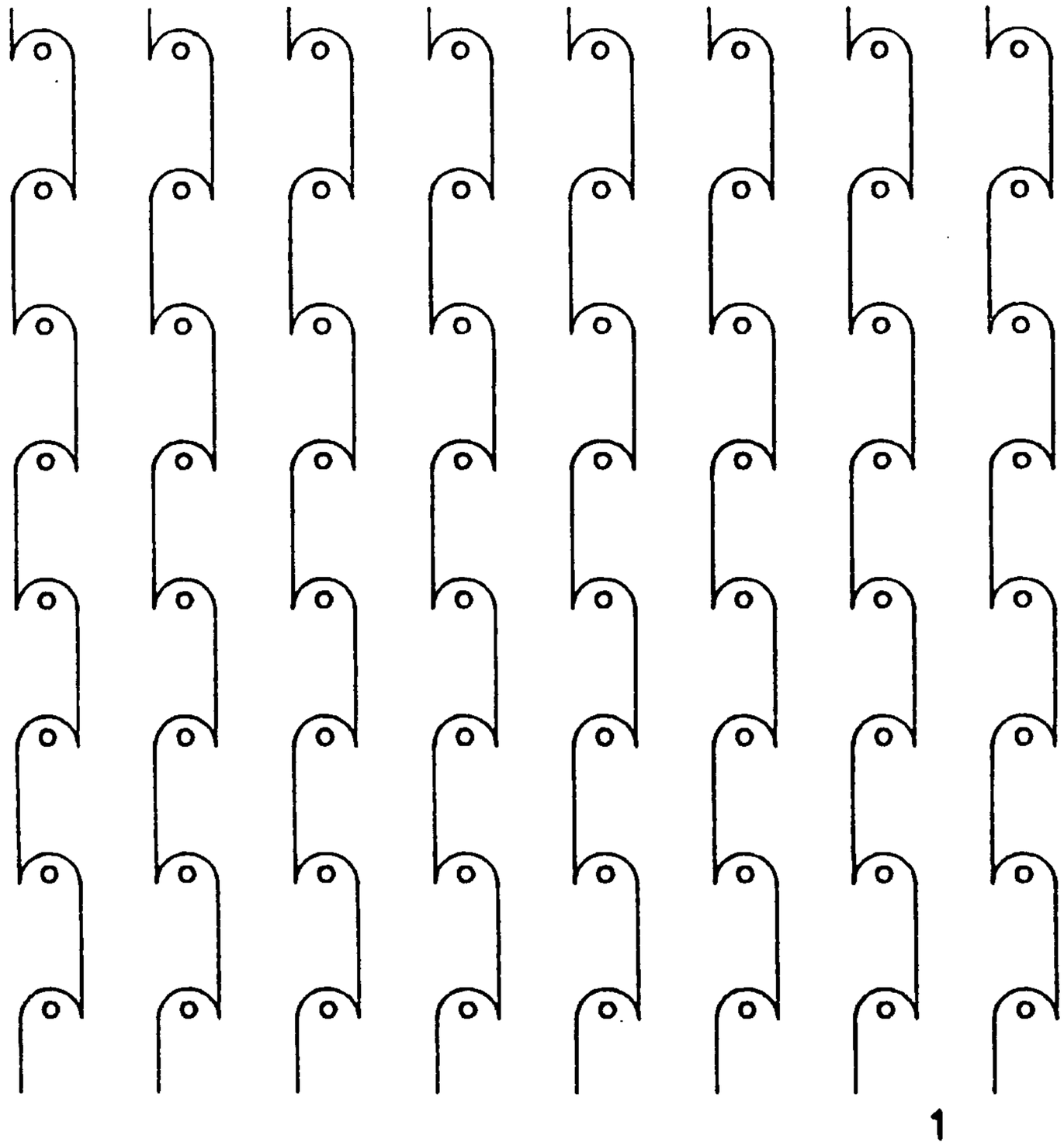


FIG. 1A

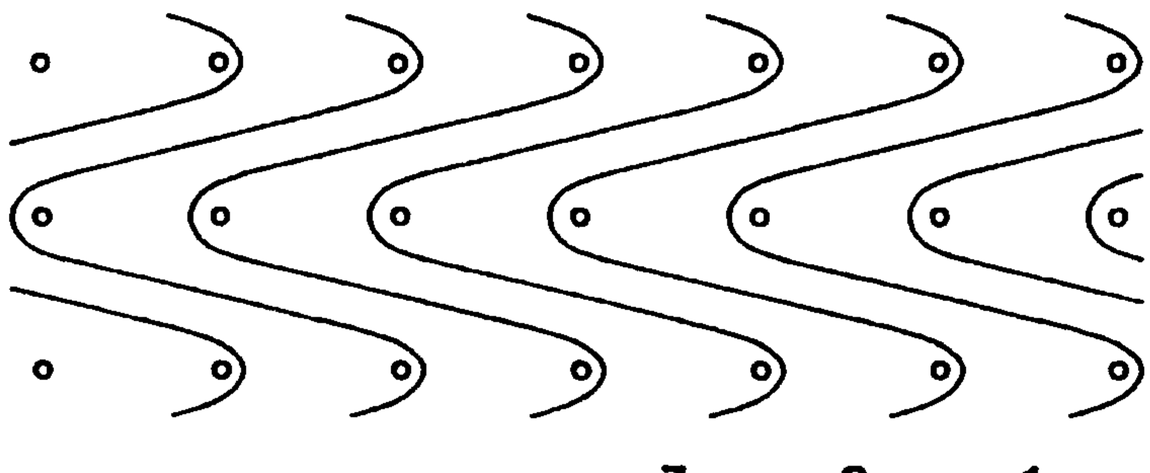


FIG. 1B

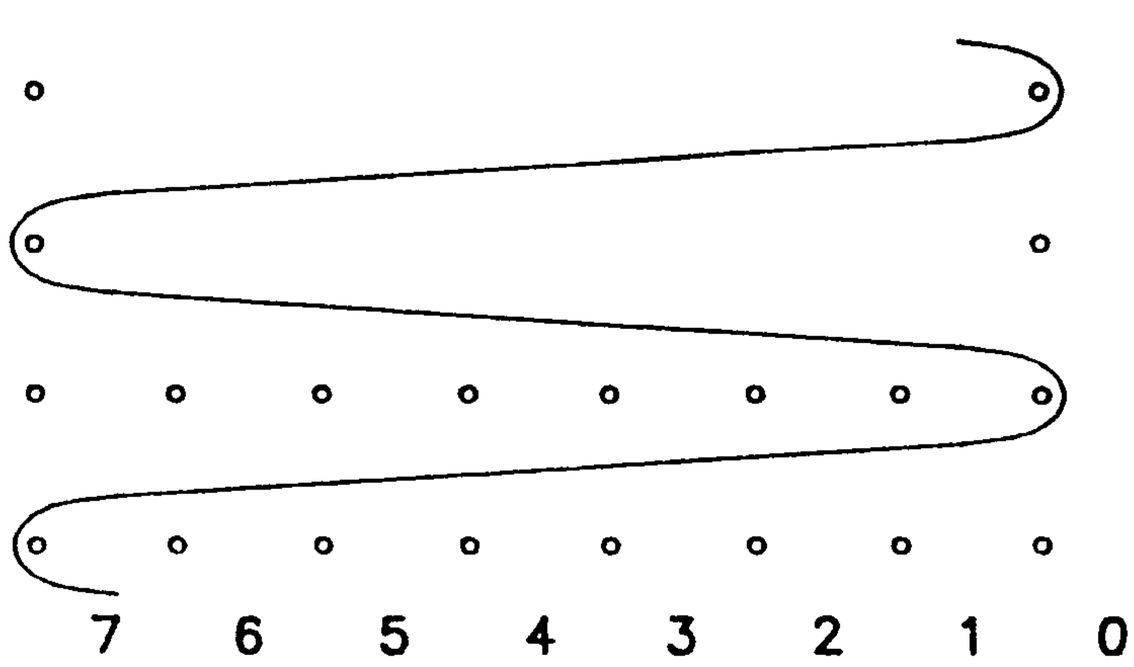


FIG. 1C

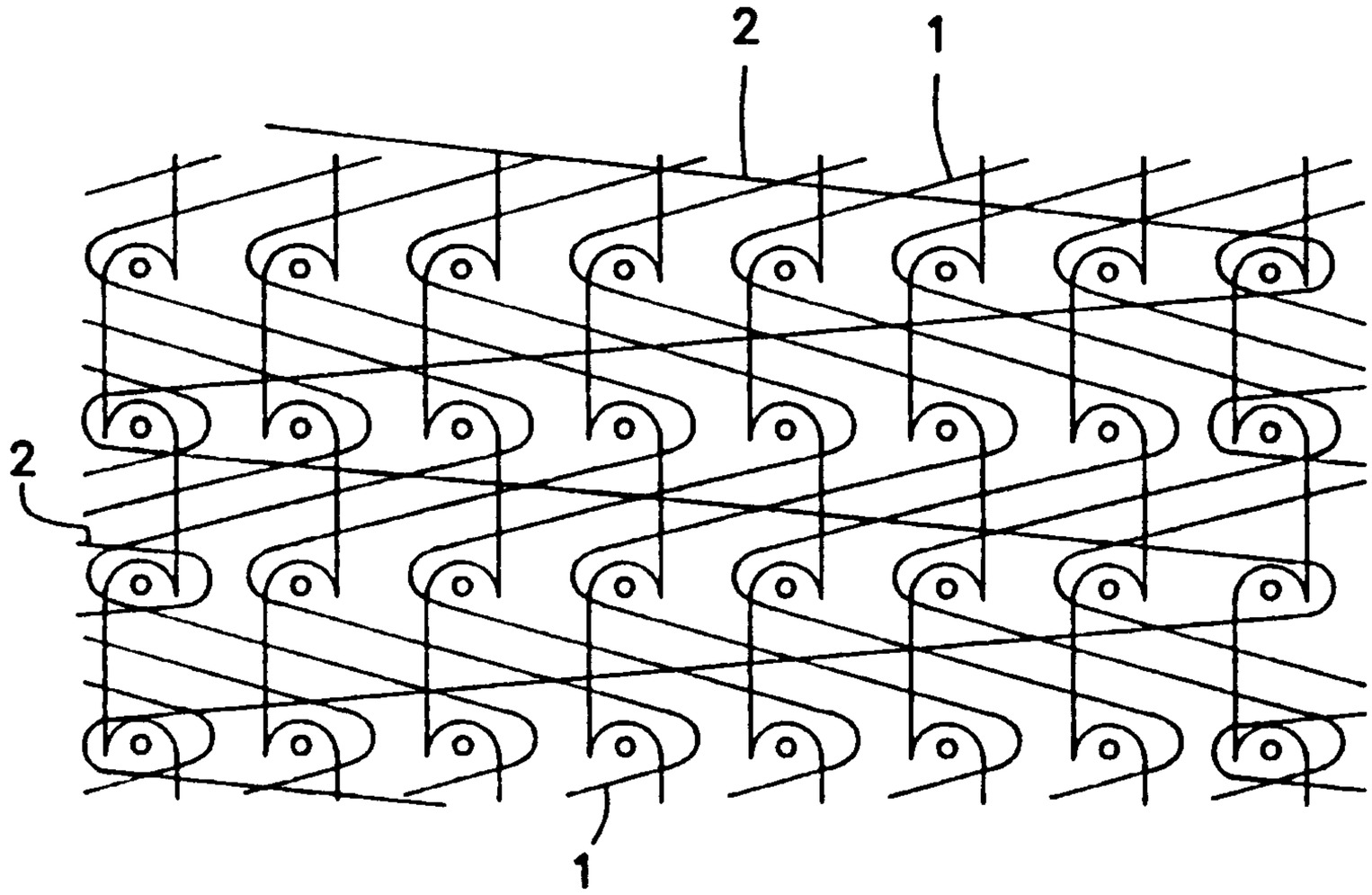


FIG. 1D

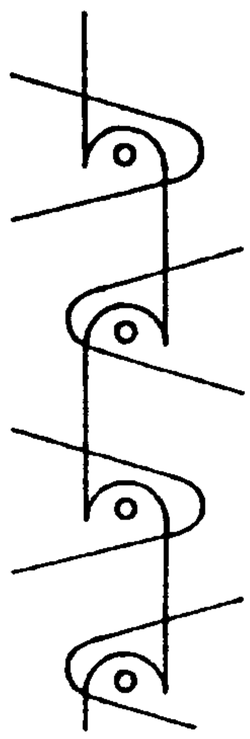


FIG. 4A

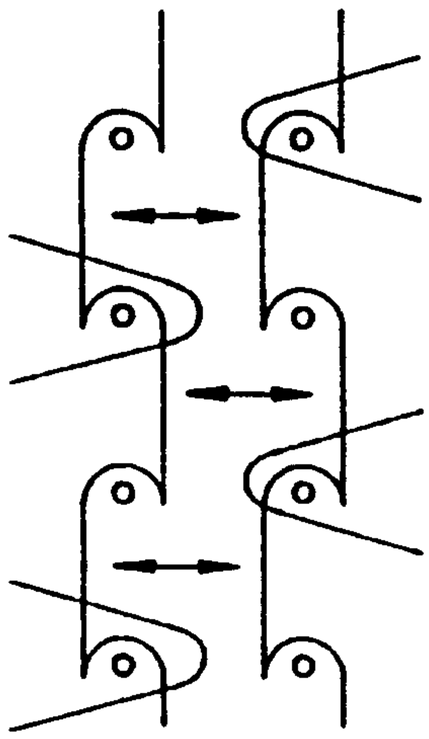


FIG. 4B

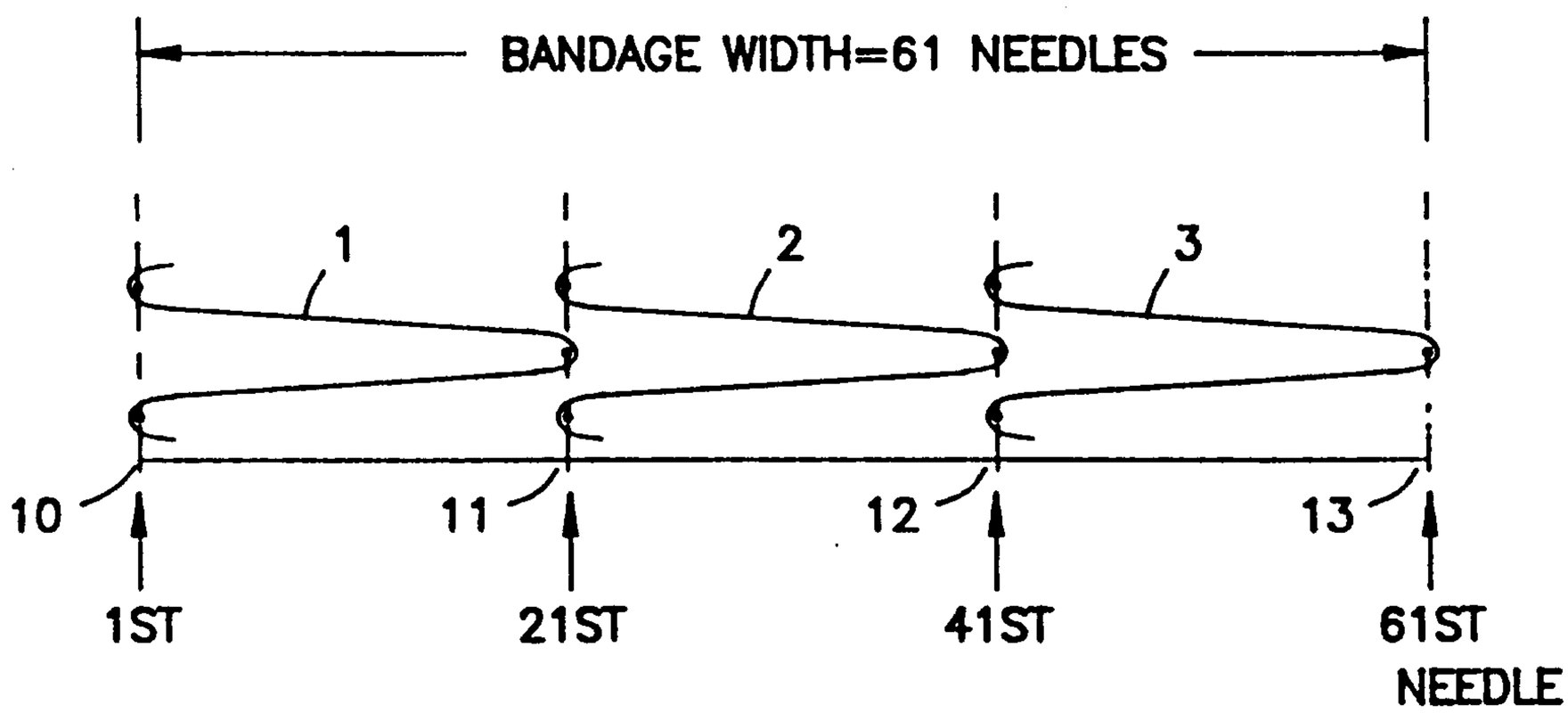

BANDAGE WIDTH=61 NEEDLES
1
2
3
10
11
12
13
1ST
21ST
41ST
61ST
NEEDLE

FIG. 2

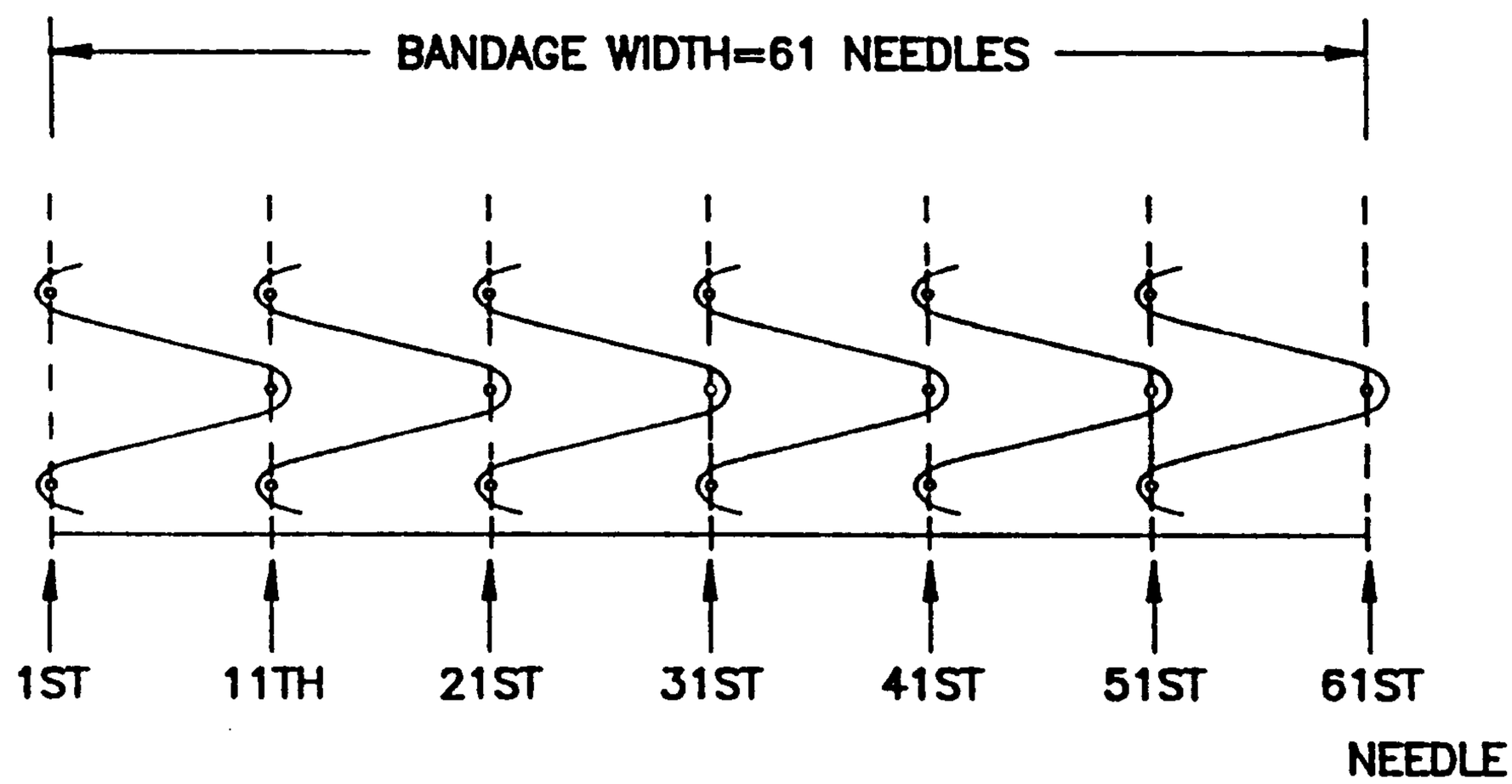

BANDAGE WIDTH=61 NEEDLES
1ST
11TH
21ST
31ST
41ST
51ST
61ST
NEEDLE

FIG. 3

2152675

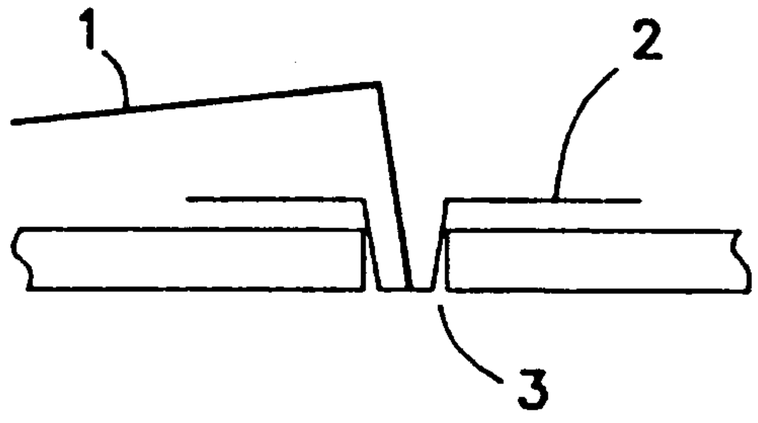


FIG. 5

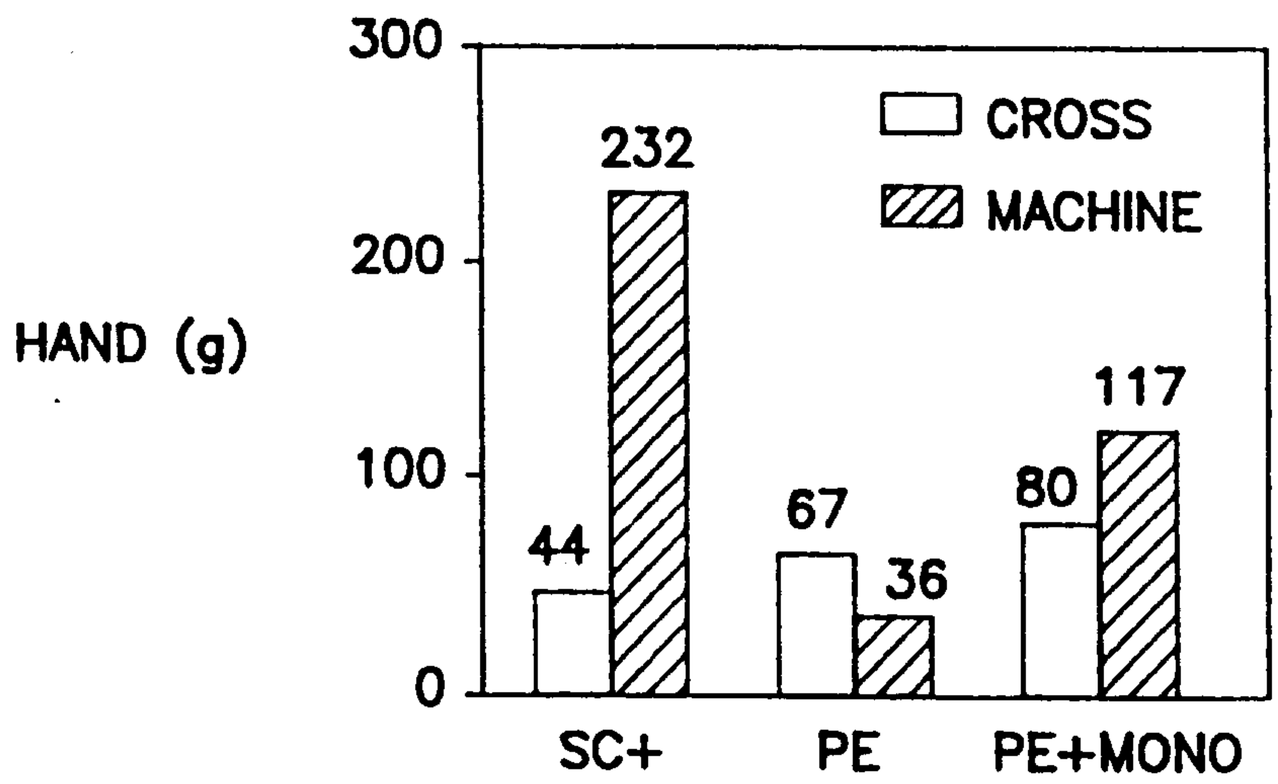


FIG. 6

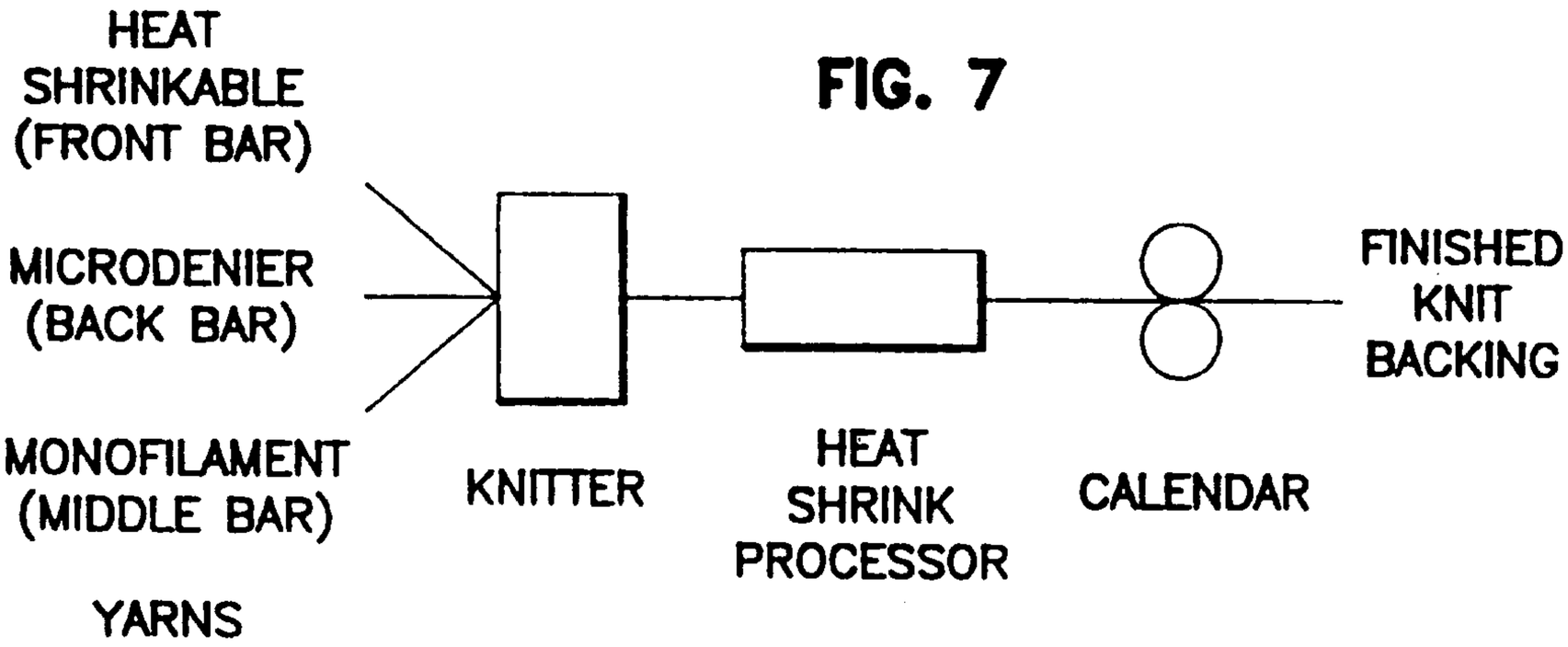
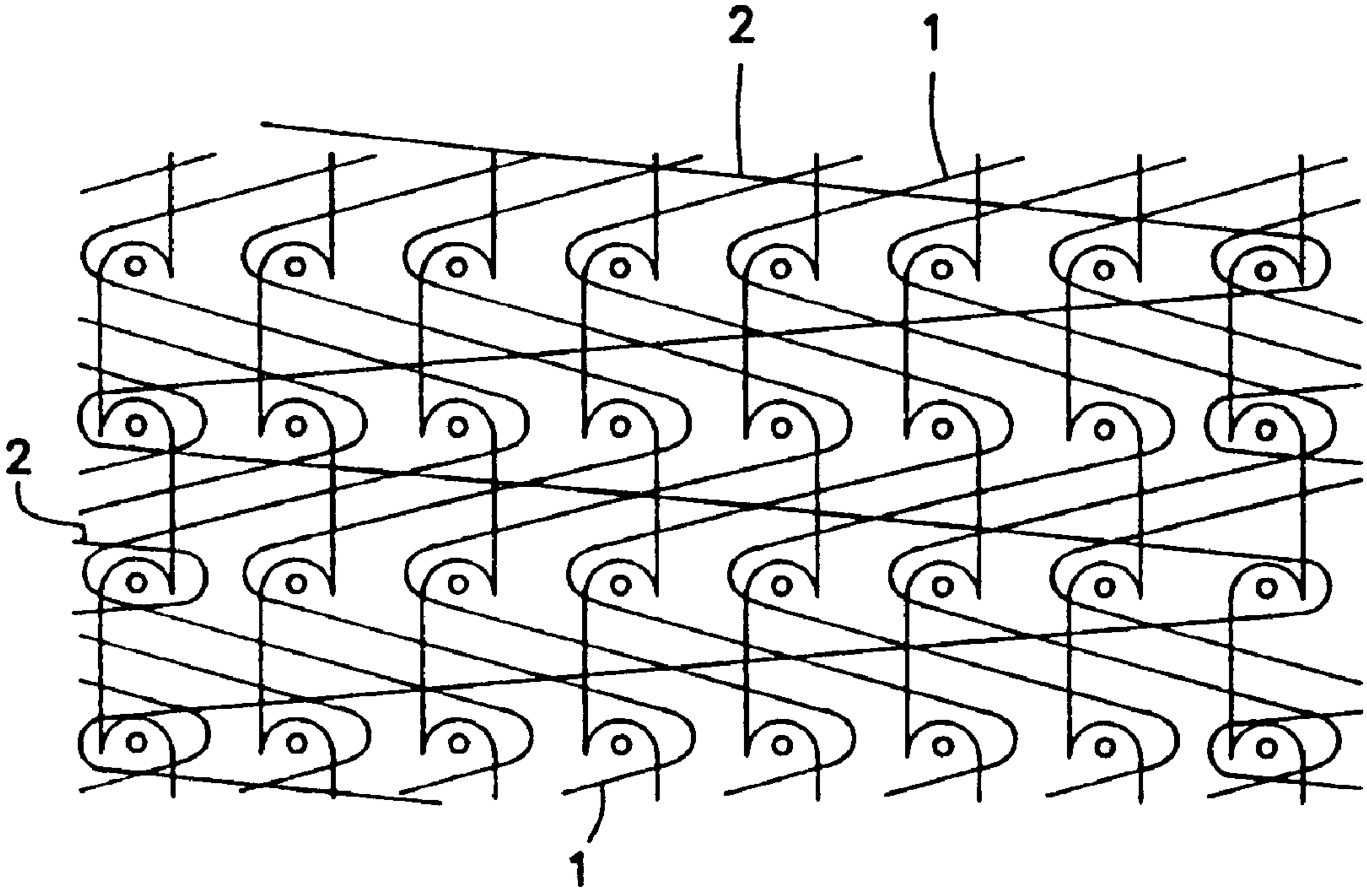


FIG. 7


2
1
2
1